HP 4062C/PC Semiconductor Parametric Test System
HP 4062UX Semiconductor Process Control System

System Operation

HEWLETT
PACKARD

HP Part No. 04062-90321
Printed in Japan February 1995

Edition 2
E0295

Product Warranty

This Hewlett-Packard system product is warranted against defects in material and workmanship for a period of three months from date of installation. During the warranty period, HP will, at its option, either repair or replace products which prove to be defective.

Warranty service of this product will be performed at Buyer's facility at no charge within HP service travel areas. Outside HP service travel areas, warranty service will be performed at Buyer's facility only upon HP's prior agreement and Buyer shall pay HP's round trip travel expenses. In all other cases, products must be returned to a service facility designated by HP.

For products returned to HP for warranty service, Buyer shall prepay shipping charges to HP and HP shall pay shipping charges to return the product to Buyer. However, Buyer shall pay all shipping charges, duties, and taxes for products returned to HP from another country.

HP warrants that its software and firmware designated by HP for use with an instrument will execute its programming instructions when properly installed on that instrument. HP does not warrant that the operation of the instrument, or software, or firmware will be uninterrupted or error free.

Limitation of Warranty

The foregoing warranty shall not apply to defects resulting from improper or inadequate maintenance by Buyer, Buyer-supplied software or interfacing, unauthorized modifications or misuse, operation outside of the environment specifications for the products, or improper site preparation or maintenance.

No other warranty is expressed or implied. Hewlett-Packard specifically disclaims the implied warranties or merchantability and fitness for a particular purpose.

Exclusive Remedies

The remedies provided herein are Buyer's sole and exclusive remedies. Hewlett-Packard shall not be liable for any direct, indirect, special, incidental, or consequential damages, whether based on contract, tort, or any other legal theory.

Assistance

Product maintenance agreements and other customer assistance agreements are available for Hewlett-Packard products.

Certification

Hewlett-Packard Company certifies that this product met its published specifications at the time of shipment from the factory. HP further certifies that its calibration measurements are traceable to the National Institute of Standards and Technology (NIST), to the extent allowed by the Institute's calibration facility, and to the calibration facilities of other International Standards Organization members.

Printing History

New editions are complete revisions of the manual. Update packages, which are issued between editions, contain additional and replacement pages to be merged into the manual by the customer. The dates on the title page change only when a new edition is published. No information is incorporated into a reprinting unless it appears as a prior update; the edition does not change when an update is incorporated.

The software revision code printed before the date indicates the version level of the software product at the time the manual or update was issued. Many product updates and fixes do not require manual changes and, conversely, manual corrections may be done without accompanying product changes. Therefore, do not expect a one to one correspondence between product updates and manual updates.

To make this manual compatible to a previous software revision, refer to Appendix F in this manual.

Edition 1	Rev. C.05.60 and X.05.60, January 1990
Update 1	HP IMA Operation, April 1990
Update 2	Rev. C.06.00 and X.06.00, May 1991
Update 3	Rev. C.06.20 and X.06.20, and P.06.20, November 1991
Edition 2	Rev. C.06.30 and X.06.30, and P.06.30, February 1995

Safety Summary

The following general safety precautions must be observed during all phases of operation, service, and repair of this instrument. Failure to comply with these precautions or with specific warnings elsewhere in this manual may impair the protections provided by the equipment. In addition, it violates safety standards of design, manufacture, and intended use of the instrument. Hewlett-Packard Company assumes no liability for customer's failure to comply with these requirements.

Note

HP 4062F complies with INSTALLATION CATEGORY II (CAT 2) for mains input and INSTALLATION CATEGORY I (CAT 1) for measurement input terminals, and POLLUTION DEGREE 2 defined in IEC 1010-1.
HP 4062F is INDOOR USE product.

GROUND THE INSTRUMENT

To minimize shock hazard, the instrument chassis and cabinet must be connected to an electrical ground. The power terminal and the power cable must meet International Electrotechnical Commission (IEC) safety standards.

DO NOT OPERATE IN AN EXPLOSIVE ATMOSPHERE

Do not operate the instrument in the presence of flammable gases or fumes. Operation of any electrical instrument in such an environment constitutes a definite safety hazard.

KEEP AWAY FROM LIVE CIRCUITS

Operation personnel must not remove instrument covers. Component replacement and internal adjustments must be made by qualified maintenance personnel. Do not replace components with power cable connected. Under certain conditions, dangerous voltages may exist even with the power cable removed. To avoid injuries, always disconnect power and discharge circuits before touching them.

DO NOT SERVICE OR ADJUST ALONE

Do not attempt internal service or adjustment unless another person, capable of rendering first aid and resuscitation, is present.

DO NOT SUBSTITUTE PARTS OR MODIFY INSTRUMENT

Because of the danger of introducing additional hazards, do not install substitute parts or perform any unauthorized modification to the instrument. Return the instrument to a Hewlett-Packard Sales and Service Office for services and repair to ensure that safety features are maintained.

DANGEROUS PROCEDURE WARNINGS

Warnings, such as example below, precede potentially dangerous procedures throughout this manual. Instructions contained in the warnings must be followed.

Warning

Dangerous voltages, capable of causing death, are present in this instrument. Use extreme caution when handling, testing, and adjusting.

Safety Symbols

The general definitions of safety symbols used on equipment or in manuals are listed below.

⚠	Instruction manual symbol: the product will be marked with this symbol when it is necessary for the user to refer to the instruction manual in order to protect against damage to the instrument.
⚡	Indicates dangerous voltage (terminals fed from the interior by voltage exceeding 1000 volts must be so marked).
⏚	Indicates earth (ground) terminal.
⊥	Frame or chassis terminal. A connection to the frame (chassis) of the equipment which normally includes all exposed metal structures.
∿	Alternating current.
⎓	Direct current.
|	ON (Supply).
○	OFF (Supply).
WARNING	The warning sign denotes a hazard. It calls attention to a procedure, practice, condition or the like, which, if not correctly performed or adhered to, could result in injury or death to personnel.
CAUTION	The caution sign denotes a hazard. It calls attention to an operating procedure, practice, condition or the like, which, if not correctly performed or adhered to, could result in damage to or destruction of part or all of the product.

Preface

Purpose

This manual is intended to impart an in-depth understanding of the system software, and contains the information you'll need to program your HP 4062C/UX/PC to perform measurements.

Audience

This manual is intended for system programmers of the HP 4062C/UX/PC.

Contents

Chapter 1, General Information, describes the hardware and software of the HP 4062C/UX/PC, the power-on procedure, START program, and instructions on how to connect test samples.

Chapter 2, VFP Operation, explains the Virtual Front Panel (VFP), and covers VFP Control mode operation.

Chapter 3, Measurement Programming, explains Test Instruction Set (TIS) software, and its subprograms and how to use them (including program examples).

Chapter 4, Program Debugging, describes how to use the measurement program debugging capabilities of HP 4062C/UX/PC.

Chapter 5, Prober Control, provides specific wafer prober control information for using HP-IB compatible wafer probers.

Chapter 6, Wafer Probing and Data Logging, describes wafer probing and data logging software and explains how to use it.

Chapter 7, Statistical Graphics, covers Basic Statistics and Data Manipulation and Statistical Graphics software for analyzing statistical data and graphically displaying analysis results.

Chapter 8, HP IMA Operation, covers the operation of the Interactive Measurement and Analysis (HP IMA) software.

Appendix A, Error Messages, lists all the HP 4062C/UX/PC error messages.

Appendix B, BSDM and Statistical Graphics, describes BSDM programs.

Appendix C, System Software Enhancements, provides several easy-to-implement system software enhancements.

Appendix D, PARA and XYGRAPH Programming Hints, contains hints on how to modify PARA and XYGRAPH.

Appendix E, Unsupported Wafer Prober, provides information about using unsupported wafer probers with HP 4062C/UX/PC.

Appendix F, Manual Backdates, describes how to make this manual compatible with previous revisions of the system software.

Contents

1. General Information

Introduction 1-1
Description 1-2
HP Software Copyrights 1-2
Hardware Configuration 1-3
Switching Matrix Subsystem (SMS) 1-5
Switching Matrix Controller (SWC) 1-5
Switching Matrix (SWM) 1-5
Handle 1-5
Output Enabled Indicator 1-5
FIXTURE CLOSED DETECT Switch, WAFER PROBER SENSE Switch 1-6
DC Subsystem (DCS) 1-6
Capacitance Measurement Subsystem (CMS) 1-6
Your System Controller 1-7
System Software Specifics 1-8
Test Instruction Set (TIS) 1-8
XYGRAPH 1-8
PARA 1-8
Virtual Front Panel (VFP) 1-8
Probing Pattern Generator (PPG) 1-9
The Probing Control Library 1-9
The File Creation Library 1-9
Statistical Graphics 1-9
Wafer Mapping 1-10
Diagnostics (DIAG) 1-10
Offline Debugging (HP 4062UX only) 1-10
System Software Specifics of HP 4062UX 1-11
Operating Environment 1-11
System Software Contents 1-11
System Software Specifics of HP 4062C 1-13
Operating Environment 1-13
System Software Contents 1-13
System Software Specifics of HP 4062PC 1-15
Operating Environment 1-15
System Software Contents 1-15
System Administration (HP 4062UX only) 1-17
Test Session Specifics 1-17
Resource Management 1-18
Locking 1-18
Spooling 1-21
Turning Your HP 4062C/UX/PC On 1-22

Entering Your Codeword . . . 1-23
The START Program . . . 1-24
When to Execute START . . . 1-24
PreSTART Execution Conditions . . . 1-25
Executing the START Program of the HP 4062UX . . . 1-27
Copyright Message Page . . . 1-28
Execution Mode Selection Page . . . 1-29
Configuration Display Page . . . 1-31
Supposed Configuration Modification Page . . . 1-33
Executing the START Program of HP 4062C . . . 1-35
Executing the START Program of HP 4062PC . . . 1-38
Softkeys . . . 1-41
Connecting Test Samples . . . 1-42

2. VFP Operation
Introduction . . . 2-1
Entering and Leaving VFP Control . . . 2-6
Standalone Monitor Page Description (HP 4062UX only) . . . 2-8
VFP Control Page Descriptions . . . 2-11
VFP Control Page 1: DCS and CMU Measurements, and Pin-Port Connections . . . 2-12
VFP Control Page 2: SWM Pin-port Cross Point Conditions . . . 2-16
Controlling the SWM . . . 2-18
SWM Control—Page 1 . . . 2-18
SWM Control—Page 2 . . . 2-19
Controlling the DCS . . . 2-21
Setting Up the SMUs . . . 2-21
V Source Mode (VS) Setup . . . 2-21
I Source Mode (IS) Setup . . . 2-22
Setting Up the VS/VMU . . . 2-24
VS Setup . . . 2-24
Setting SMU and VM Integration Time . . . 2-25
Controlling the CMU . . . 2-26
DCS and CMU On/Off Status . . . 2-28
Setting the On/Off Status . . . 2-28
Setting On/Off selectively . . . 2-28
Setting On/Off for all DCS units and the CMU simultaneously . . . 2-29
DCS and CMU Measure/Not Measure Status . . . 2-30
Setting the Measure/Not Measure Status . . . 2-30
Executing Measurements . . . 2-31
EXEC Mode Displays . . . 2-32
Measurement Results . . . 2-32
DCS Port Status . . . 2-32
Manually Swept Measurements . . . 2-32
Error-Compensated Capacitance Measurements . . . 2-34
Obtaining a Display Hard Copy . . . 2-36

3. Measurement Programming
Introduction . . . 3-1
Before Programming . . . 3-2
Run the START program . . . 3-2
Measurement Program Flow . . . 3-3
Storing Measurement Programs . . . 3-5
Initializing Your System . . . 3-6
Parameter Measurements Using PARA . . . 3-7
Resistance Measurements . . . 3-7
Transistor Measurements . . . 3-9
Short Channel FET Measurements . . . 3-11
Connecting Pins and Ports . . . 3-13
General I-V Measurements . . . 3-15
XYGRAPH Subprograms . . . 3-19
Sweep, Pulsed, and Pulsed Sweep I-V Measurements . . . 3-22
Capacitance Measurements Using CMU . . . 3-28
Capacitance Measurement Using CMU84 . . . 3-38
Feedback Measurements . . . 3-44
Timing Control Subprograms . . . 3-52
Locking the System Resources (HP 4062UX only) . . . 3-53
High Speed Measurement Programming Hints . . . 3-54
Using DCS Program Memory Functions . . . 3-56
Storing DCS Control Commands in the DCS Program Memory . . . 3-58
Triggering Program Memory Segments and Getting Data . . . 3-60
Triggering program memory segments . . . 3-60
Getting the Measured Data . . . 3-61
Controlling the SWM . . . 3-63
Programming Example . . . 3-64
Optimizing the DCS Program . . . 3-66
Storing Sweep Measurement Commands . . . 3-68
Overlay Programming with COM4062 . . . 3-70
Example of Overlay Programming . . . 3-72

4. Program Debugging
Introduction . . . 4-1
VFP Monitor Mode . . . 4-2
Port Status . . . 4-4
Standalone VFP (HP 4062UX only) . . . 4-9
Starting Standalone VFP . . . 4-9
VFP Monitor Mode Operation . . . 4-9
VFP Control Mode Operation . . . 4-10
Offline Debugging (HP 4062UX only) . . . 4-11
START Program . . . 4-11
System Software Support Levels . . . 4-11
Offline Data Simulation . . . 4-12
Constant Data Simulation . . . 4-13
File Data Simulation . . . 4-13
Example . . . 4-16
Detecting Errors . . . 4-17
Determining Execution Mode . . . 4-18
Instrument Locking in Offline Mode . . . 4-18

Using VFP in Offline Debugging 4-18
Individual Parametric Test Sessions (HP 4062UX only) 4-19
Description 4-19
Creating and Destroying Test Sessions 4-19

5. Prober Control
Introduction 5-1
Electroglas 1034X 5-2
Prober Settings 5-2
START Program Execution 5-2
Prober Auto and Manual Modes 5-3
TIS Prober Control Subprograms 5-5
Setting the System Index and Probing Origin 5-5
Moving the X-Y Positioner 5-6
Raising and Lowering the Chuck 5-7
Loading and Unloading Wafers 5-7
Sample Programs 5-8
Electroglas 2001X 5-13
Prober Settings 5-13
START Program Execution 5-14
Prober Remote and Local Modes 5-15
TIS Prober Control Subprograms 5-16
Setting the System Index and Probing Origin 5-16
Moving the X-Y Stage 5-17
Raising and Lowering the Chuck 5-18
Inker Trigger 5-18
Loading and Unloading Wafers 5-18
Checking Prober Status 5-18
Sample Programs 5-19
TSK A-PM-3000A/6000A/7000A 5-24
Prober Settings 5-24
START Program Execution 5-24
Prober Remote and Local Modes 5-25
TIS Prober Control Subprograms 5-26
Setting the System Index and Probing Origin 5-26
Moving the X-Y Stage 5-27
Raising and Lowering the Chuck 5-27
Inker Trigger 5-28
Loading and Unloading Wafers 5-28
Checking Prober Status 5-28
Prober Processor Halt 5-28
Sample Programs 5-29

6. Wafer Probing and Data Logging

Introduction 6-1
Wafer Measurement Software Requirements 6-2
Probing Pattern Generator (PPG) 6-4
PPG Setup Pages 6-4
Required Parameters 6-4
Loading and Executing PPG 6-6
Printing a Display Hardcopy (HP 4062UX only) 6-7
Wafer Parameter Setting Page 6-9
Alphanumeric Chip Selection Page 6-13
Graphics Chip Selection Page 6-16
Fixed Pattern Module Selection Page 6-19
Flexible Pattern Module Selection Page 6-21
Outputting the Probing Pattern Data 6-23
Entering the PPG DISPLAY Function 6-23
Starting the PPG DISPLAY Function 6-23
Moving into the PPG DISPLAY Function 6-23
Specifying the Probing Pattern Data File 6-24
Outputting to the CRT 6-24
Outputting to the Printer 6-24
Changing the Printer Configuration 6-24
Example: Printing to HP-UX Spool Printer (for HP 4062UX) 6-25
Example: Printing to SRM Spool Printer (for HP 4062C/UX/PC) 6-25
Example: Printing to MS-DOS Parallel Printer (for HP 4062PC) 6-25
PPG Example 6-26
Probing Control Library (PCL) 6-30
PCL Programming 6-30
Primary Prober Control Programming 6-31
Confirming the present probing position 6-34
“Free” probing 6-37
Probing control using the X- and Y-chip coordinates 6-38
File Creation Library (FCL) 6-41
FCL Programming 6-42
Creating Data Files for Wafer Maps 6-44
Creating Data Files for Statistical Graphics 6-48
Creating DOS Data Files 6-51
WAFER MAP 6-52
Loading and Executing the WAFER MAP Program 6-52
Printing a Display Hardcopy (HP 4062UX only) 6-54
Entering Measurement and Probing Pattern Data Files 6-56
Setting Up and Displaying Wafer Maps 6-56
Additional WAFER MAP Information 6-60
Data File Format 6-60
Increasing Data Set Size 6-60
User-Defined Data Files 6-63
Wafer Mapping Without “WAFER MAP” 6-64
Converting a BDAT Data File to a DOS File 6-67
Using the FCONV Utility Program 6-67
Format of a DOS Data File 6-69

7. Statistical Graphics
Introduction 7-1
Description 7-2
Entering Data 7-5
Using BSDM 7-6
Using Statistical Graphics 7-13
Creating Data Files for Control Charts 7-20
Using User-Defined Transformations 7-23

8. HP IMA Operation
How to Start HP IMA with an HP 4062C/UX/PC 8-1
SWM Panel 8-3
How to Open the SWM Panel from the HP IMA Softpanel 8-3
How to Open the SWM Panel from a Measurement Program 8-4
How to Operate the SWM Panel 8-5
Connecting Measurement Pins to Ports 8-7
Disconnecting Measurement Pins from Ports 8-7
Error Messages 8-8
How to program using the AIS of HP IMA with TIS 8-9
Sample Program 1 8-10
Sample Program 2 8-14
Sample Program 3 8-15
AIS Measure and Panel Instructions 8-20

A. Error Messages
Introduction A-1
Error Messages Listings A-1
START Errors A-2
TIS Errors A-8
PGMLIB Errors A-16
VFP Errors A-17
PPG Errors A-19
Diagnostics (DIAG) Errors A-22
BASIC or BASIC/UX Language System Errors A-25

B. BSDM and Statistical Graphics
Basic Statistics and Data Manipulation B-1
General Information B-1
Description B-1
Special Considerations B-3
Data Matrix Configuration B-3
Scratch Data Sets B-3
Data File Configuration B-3
Parser B-4
Incorrect Responses B-4
Hardware Requirements B-5
Getting Started B-5
Start B-5
Object of Program B-5
Special Considerations B-6
Terminology B-6

Data on Mass Storage B-6
Keyboard Entry B-7
Missing Values B-8
Graphics Input B-8
"Other" Input B-8
Edit B-9
Object of Program B-9
Special Considerations B-9
Order of Corrections B-9
Subfiles B-9
Correcting Data Value(s) B-9
Correcting Observation(s) B-10
Adding Observation(s) B-10
Deleting Observation(s) B-10
Deleting Subfile(s) B-10
Deleting Variable(s) B-10
Exceeding Program Limitations B-10
Methods and Formulas B-10
Transform B-10
Object of Program B-10
Special Considerations B-11
Missing Values (Algebraic Transformations) B-11
User-Defined (Algebraic Transformations) B-11
Declaring Missing Values B-12
Create Rank Variables B-12
Creating Variables by Subfile B-12
Creating Variables by Sequence Number B-12
Creating Standardized Score Variables B-13
Creating Lag Variables B-13
Creating Uniform Random Number Variables B-13
Recode B-14
Object of Program B-14
Special Considerations B-14
Coding Schemes B-14
Brackets B-14
Observations That Do Not Fall in an Interval B-14
Sort B-15
Object of Program B-15
Special Considerations B-15
Subfile Structure Options B-15
What Happens B-15
Subfiles B-16
Object of Program B-16
Special Considerations B-16
Use of Subfiles B-16
Change Names B-16
Object of Program B-16
Store Data B-16
Object of Program B-16
Special Considerations B-16
Use of Program B-16

Protecting Existing Data B-16
List B-17
Object of Program B-17
Join B-17
Object of Program B-17
Special Considerations B-17
Adding Observations B-17
Adding Variables B-17
Subfiles B-17
Printer Is B-18
Object of Program B-18
Special Considerations B-18
Select and Scan B-18
Object of Program B-18
Special Considerations B-18
One Variable B-18
Variable A OR Variable B B-18
Variable A AND Variable B B-19
Variable A = Variable B B-19
Basic Statistics B-19
Object of Program B-19
Special Considerations B-19
Parser on Statistics Options B-19
Data Type B-19
Hard-Copy Output B-19
Additional Order Statistics B-19
Methods and Formulas B-19
Tukey's Middlemeans B-20
Go To Advanced Stat B-20
Objective B-20
Return To BSDM B-20
Objective B-20
Backup B-20
Objective B-20
Statistical Graphics B-22
General Information B-22
Object of Program B-22
Special Considerations B-22
Common Plotting Characteristics B-23
Restart B-23
Plot B-23
X-axis B-23
Y-axis B-24
Labels B-24
Symbols B-24
Dump Graphics On CRT B-24
Select Plotter B-24
Select Pen Color B-24
Overlay B-24
Store B-24
Load B-24

Return B-24
Time Plot B-25
Object of Program B-25
Special Considerations B-25
Special Plotting Characteristics B-25
X-axis B-25
Overlay B-25
References B-25
Histogram B-25
Object of Program B-25
Special Considerations B-25
Special Plotting Characteristics B-26
Cell Limits B-26
Normal Curve Overlay B-26
Methods and Formulae B-26
References B-27
Scattergram B-28
Object of Program B-28
Special Considerations B-28
Changes Necessary For Larger Data Sets B-29
Statistics Library Data Formats B-29
Method 1: Numeric Data Only B-29
Method 2: Numeric Data and Descriptive Data B-30

C. System Software Enhancements
Software Organization (HP 4062C/PC) C-1
The START Program C-1
For HP 4062UX C-1
For HP 4062C/PC C-2
Softkeys C-5
Subprogram Library File C-6

D. PARA and XYGRAPH Programming Hints
PARA Functions and Subprograms D-2
FNR2t D-3
FNR4d D-6
FNR4t D-10
Set_tr D-13
FNBvcbo D-14
FNBvces D-17
FNHfe D-19
FNHfe1 . . . . D-24
FNVth1 . . . . D-26
FNVth2 . . . . D-28
FNVth2m D-30
FNVth3 . . . . D-34
FNVth4 . . . . D-39
FNVth5 . . . . D-41
FNIds D-43
Setmultitr D-45
FNDelta_l, FNDelta_w D-46

XYGRAPH (Lingraph, Cvgraph, Loggraph) D-51

E. Unsupported Wafer Prober
Introduction E-1
Creating Prober Control Subprograms E-1
Modifying the SYSCONFIG file and START Program E-1
SYSCONFIG file E-1
START Program E-2

F. Manual Backdates

Index

Figures

1-1. HP 4062C/UX/PC System 1-1
1-2. Standard System Configuration (48-pin SWM System) 1-4
1-3. Standard System Configuration (96-pin SWM System) 1-4
1-4. System Software Directory Structure (HP 4062UX) 1-11
1-5. System Software Directory Structure (HP 4062C) 1-14
1-6. System Software Directory Structure (HP 4062PC) 1-16
1-7. Typical Multiple Test Sessions and Processes System Operation 1-18
1-8. Implicit and Explicit Locking Concepts 1-19
1-8. Front Panel Feature 1-22
1-9. Copyright Message Page 1-28
1-10. Execution Mode Selection Page 1-29
1-11. Configuration Display Page 1-31
1-12. Supposed Configuration Modification page 1-33
1-13. System START Page 1-35
1-14. HP 4062C Configuration Page 1-36
1-15. System START Page 1-38
1-16. HP 4062PC Configuration Page 1-39
1-17. System Softkeys 1-41
1-18. Measurement Pins 1-42
1-19. Test Fixture Adapter (for 48-pin SWMs) 1-44
1-20. Test Fixture Adapter (for 96-pin SWMs) 1-45
2-1. Example VFP Page 2-1
2-2. VFP Monitor Page 2-8
2-3. VFP Control Page 1 2-12
2-4. VFP Control Page 2 2-16
2-5. SWM Control—Page 1 2-18
2-6. SWM Control—Page 2 2-19
2-7. SMU VS Setup Sequence 2-21
2-8. SMU IS Setup Sequence 2-23
2-9. VS/VMU VS and VM Setup Sequence 2-24
2-10. CMU Measurement Items 2-26
2-11. VFP Control Page 1—EXEC Mode 2-31
2-12. Capacitance Measurement Items 2-34
3-1. Typical Measurement Program Flow 3-3
3-2. Sample Program: FNR2t Resistance Measurement 3-7
3-3. Two-Terminal Resistance Measurement Circuit 3-8
3-4. Sample Program: FNVth4 Threshold Voltage Measurement 3-9
3-5. Threshold Voltage Measurement Circuit 3-10
3-6. Sample Program: Lateral Diffusion Measurement 3-11
3-7. Lateral Diffusion Measurement Circuit 3-12
3-8. Sample Program: Using The Connect Subprogram 3-13
3-9. Sample Program: Voltage Output Using Force_v 3-16

3-10. Sample Program: Current Measurement Using Measure_i 3-17
3-11. Sample Program: Current Measurement Using Force_meas 3-18
3-12. Sample Program: Graphics Output Using Lingraph 3-20
3-13. Sample XYGRAPH 3-21
3-14. DCS Staircase Sweep Measurement Output 3-23
3-15. DCS Pulsed Bias Spot Measurement Output 3-23
3-16. Pulsed Bias Measurement Sweep Output 3-24
3-17. DCS Pulsed Sweep Measurement Output 3-24
3-18. Sample Program: Swept I-V Measurement 3-25
3-19. Sample Program: Swept Multichannel I-V Measurement 3-26
3-20. Sample Program: Real-time Swept I-V Measurement 3-27
3-21. C-V Sweep Measurement Output 3-29
3-22. C-t Measurement Sequence 3-29
3-23. Pin Assignments for Capacitance Measurements Using CMU 3-31
3-24. Sample Program: Capacitance Measurement Using CMU 3-32
3-25. MOS Capacitor Characteristic C-V Curve Measured by CMU 3-33
3-26. Sample Program: Swept C-V Measurement Using CMU 3-34
3-27. Sample Program: Swept C-t Measurement 3-36
3-28. MOS Capacitor Characteristic C-t Curve 3-37
3-29. Pin Assignments for Capacitance Measurements Using CMU84 3-39
3-30. Sample Program: Capacitance Measurement Using CMU84 3-40
3-31. MOS Capacitor Characteristic C-V Curve Measured by CMU84 3-41
3-32. Sample Program: Swept C-V Measurement Using CMU84 3-42
3-33. Analog Search Measurement Waveforms 3-45
3-34. Sample Program: Feedback Measurement Using Set_bsearch 3-46
3-35. Sample Program: Breakdown Voltage Measurement 3-47
3-36. Sample Program: Threshold Voltage Measurement 3-48
3-37. Sample Program: Threshold Voltage Measurement Using Set_asearch . . . 3-50
3-38. Sample Program: DCS Program Memory Function 3-64
3-39. Overlay Programming with COM4062 3-70
4-1. Sample Program: Using VFP Subprograms 4-3
4-2. Sample Program: Collector I-V Characteristics Measurement 4-5
4-3. Collector I-V Curve (generated by Sample Program: Collector I-V Characteristics Measurement) 4-6
4-4. Sample Program: Collector I-V Characteristics Measurement Using Port_status 4-7
4-5. Collector I-V Curve (generated by Sample Program: Collector I-V Characteristics Measurement Using Port_status) 4-8
4-6. Standalone VFP Monitor Page 4-9
4-7. Simulation File Data Record Syntax 4-14
5-1. HP 4062UX START Display (1034X Probers) 5-3
5-2. HP 4062C/PC START Display (1034X Probers) 5-3
5-3. Moving the X-Y Positioner (1034X Probers) 5-6
5-4. Sample Program: Probing Selected Chips (1034X Probers) 5-9
5-5. Sample Program: Probing All Chips (1034X Probers) 5-11
5-6. HP 4062UX START Display (2001X Probers) 5-14
5-7. HP 4062C/PC START Display (2001X Probers) 5-14
5-8. Moving the X-Y Stage (2001X Probers) 5-17
5-9. Sample Program: Probing Selected Chips (2001X Probers) 5-20
5-10. Sample Program: Probing All Chips (2001X Probers) 5-22
5-11. HP 4062UX START Display (TSK Probers) 5-25

5-12. HP 4062C/PC START Display (TSK Probers) 5-25
5-13. Moving the X-Y Stage (TSK Probers) 5-27
5-14. Sample Program: Probing Selected Chips (TSK Probers) 5-30
5-15. Sample Program: Probing All Chips (TSK Probers) 5-32
6-1. Wafer Measurement Data Flow and Software Requirements 6-2
6-2. Wafer Measurement Program Required Parameters 6-5
6-3. Wafer parameter Setting Page 6-9
6-4. Alphanumeric Chip Selection Page 6-13
6-5. Graphics Chip Selection Page 6-16
6-6. Fixed Pattern Module Selection Page 6-19
6-7. Flexible Pattern Module Selection Page 6-21
6-8. PPG Wafer Setup, Example 1 6-26
6-9. PPG Wafer Setup, Example 2 6-28
6-10. Sample Program: Prober Control, Example 1 6-31
6-11. Sample Program: Prober Control, Example 2 6-33
6-12. Sample Program: Using Wpos_number 6-35
6-13. Sample Program: "Free" Probing Control 6-37
6-14. Sample Program: Probing Control Using X- and Y-Chip Coordinates . . . 6-39
6-15. FCL Subprograms 6-42
6-16. Test Module Connections 6-44
6-17. Sample Program: Data Logging for Wafer Mapping 6-45
6-18. Sample Program: Creating a Data File for Statistical Graphics 6-48
6-19. Creating a Data File for Statistical Graphics Using & Wbuild_file 6-49
6-20. Sample Wafer Map 6-52
6-21. Wafer Map Setup Page 6-57
6-22. Example Wafer Map 6-57
6-23. Wafer Map Setup Page Explanation 6-58
6-24. Sample Program: Creating More Than One Data File 6-62
6-25. Sample Program: Sample_map Program Listing 6-65
6-26. FCONV Page 6-68
6-27. Format of DOS Data File 6-69
7-1. Example Control Chart 7-3
7-2. Example Histogram 7-3
7-3. Example Scattergram 7-4
7-4. BSDM and Statistical Graphics Flow 7-7
7-5. Sample Program: Creating a Data File for Control Charts 7-21
8-1. HP IMA Selection Menu Page 8-2
8-2. SWM Panel Example 8-4
8-3. Sample Program 1: Collector Characteristics Measurement 8-10
8-4. Collector Characteristics Measurement Circuit 8-11
8-5. UNIT DEFINITION Page for Collector Characteristics Measurement . . . 8-11
8-6. SOURCE SET UP Page for Collector Characteristics Measurement 8-12
8-7. DISPLAY MODE SET UP Page for Collector Characteristics Measurement 8-12
8-8. Collector Characteristics Example 8-13
8-9. Sample Program 2: Collector Characteristics Measurement Using SWM Panel 8-14
8-10. Sample Program 3: Vth Measurement 8-17
8-11. Vth Measurement Circuit 8-17
8-12. UNIT DEFINITION Page for Vth Measurement 8-18
8-13. SOURCE SET UP Page for Vth Measurement 8-18
8-14. DISPLAY MODE SET UP Page for Vth Measurement 8-19
8-15. Vth Example 8-19

C-1. START Program Enhancements of HP 4062UX C-2
C-2. START Program Enhancements of HP 4062C C-4

Tables

2-1. DCS and CMU Off Status 2-28
2-2. Port Status Items 2-32
3-1. COM Declaration Subprograms for Programmatic Linking 3-71
4-1. System Software Support Levels 4-11
4-2. Offline Data Simulation Modes 4-12
8-1. Definition for UNIT ID 8-5
F-1. Manual Backdating by Software Revision F-1

1

General Information

Introduction

This chapter covers the HP 4062C/PC Semiconductor Parametric Test System and HP 4062UX Semiconductor Process Control System, and other basic information. Figure 1-1 shows a typical HP 4062C/UX/PC.

If you haven't read the Preface at the beginning of this manual, please do so before continuing. The Preface contains descriptions of the contents of each the chapters in this manual.

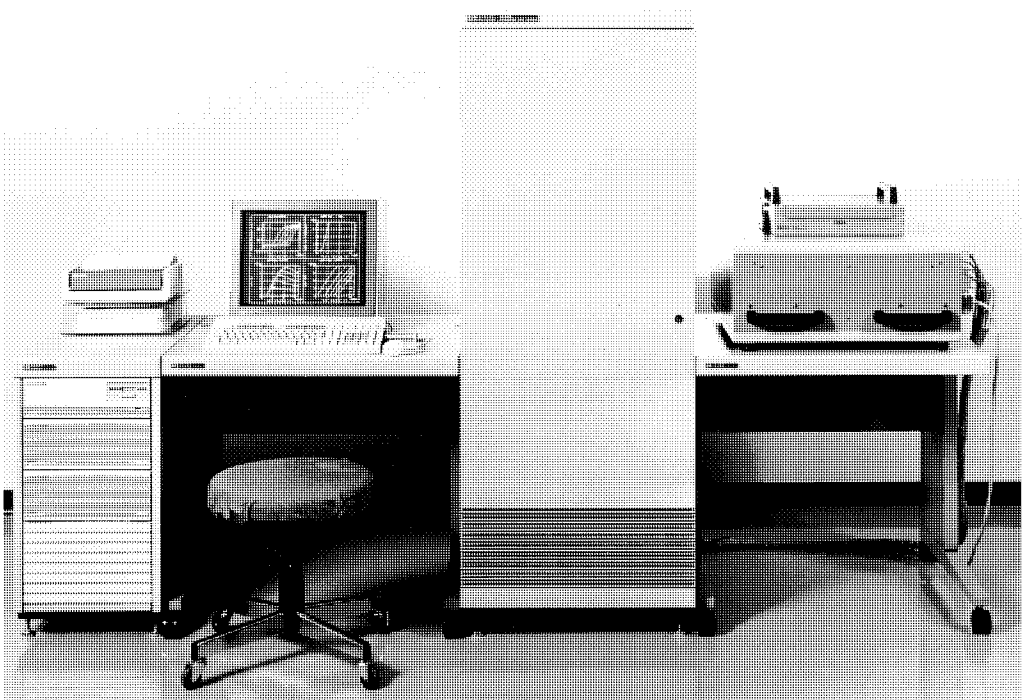


Figure 1-1. HP 4062C/UX/PC System

Note Computer tables are not furnished, but can be ordered separately from HP Sales Offices.

Description

The HP 4062C/UX/PC is a high performance computer-controlled system for measuring discrete, packaged, and wafer-state semiconductor device parameters.

HP Software Copyrights

Hewlett-Packard software (including software updates), the logical pattern implemented in firmware, and printed documentation are all copyrighted materials, protected under law. Unless HP specifically grants a customer the right to reproduce copyrighted materials, these may not be copied except for archive purposes, to replace a defective copy, or for program error verification purposes.

The acquisition of any HP 4062C/UX/PC software or software/firmware product grants the customer a license to use the software product originally purchased with one HP 4062C/UX/PC with no time limit. No title to, or ownership of, the software is transferred to the customer.

Hardware Configuration

The standard HP 4062C/UX/PC consists of three basic subsystems, totaling four separate instruments (not including the system controller). All subsystems are controlled via the Hewlett-Packard Interface Bus (HP-IB) by an HP 9000 Series 300 Computer (system controller). The system controller is equipped with BASIC for HP 4062C/PC or BASIC/UX running under the HP-UX operating system for HP 4062UX.

Throughout the HP 4062C/UX/PC documentation, the following abbreviations are used to identify the HP 4062C/UX/PC's subsystems and instruments.

- SMS: Switching Matrix Subsystem:

  The SMS consists of the following two instruments:

  SWC: HP 4084B Switching Matrix Controller
  SWM: HP 4085B 48-pin or HP 4089A 96-pin Switching Matrix

- DCS: DC Measurement Subsystem: HP 4142B Modular DC Source/Monitor

- CMS: Capacitance Measurement Subsystem:

  The CMS consists of the one of the following instruments:

  CMU: HP 4280A 1 MHz C Meter/C-V Plotter
  CMU84: HP 4284A Precision LCR Meter
  LCR: HP 4274A Multi-Frequency LCR Meter

Figure 1-2 shows the basic configuration for an HP 4062C/UX/PC equipped with a 48-pin SWM, including the system controller. Figure 1-3 shows the basic configuration for an HP 4062C/UX/PC equipped with a 96-pin SWM, including the system controller.

Note

In addition, the HP 4062C requires a VFP Timer Board. When the CMU84 or LCR exists in the HP 4062C, it is connected to the HP-IB interface with a select code of 7.

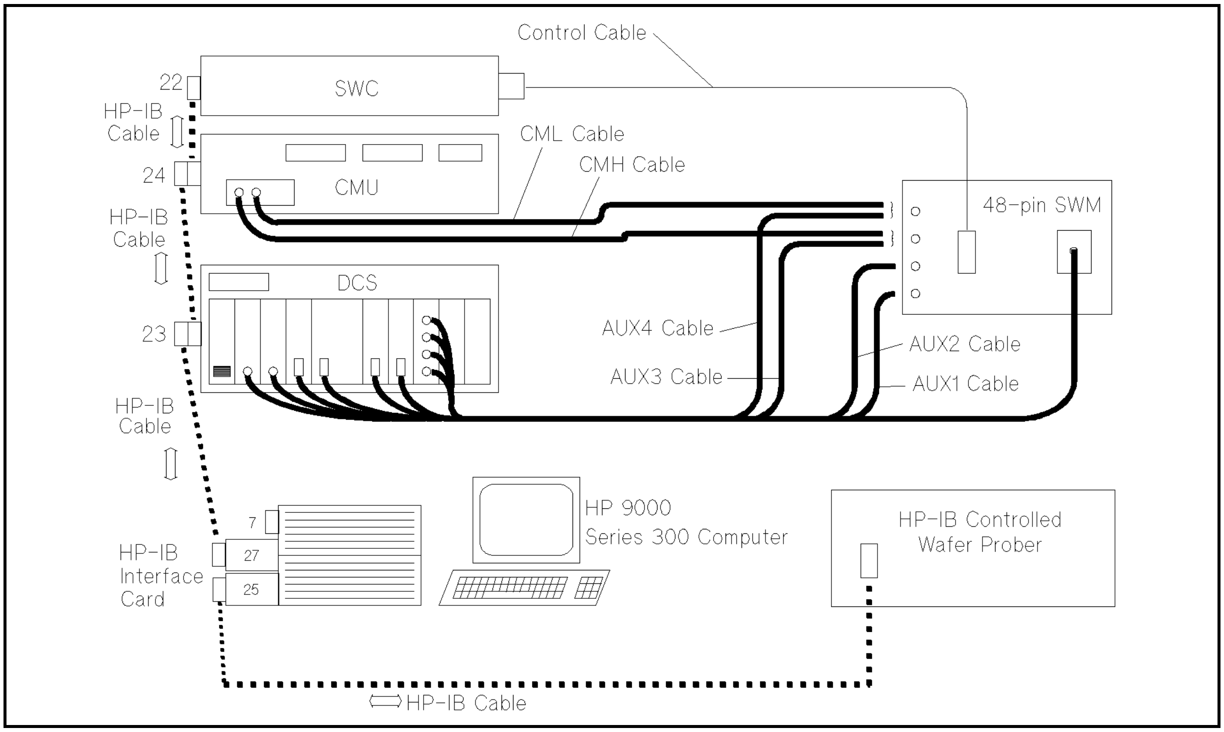


Figure 1-2. Standard System Configuration (48-pin SWM System)

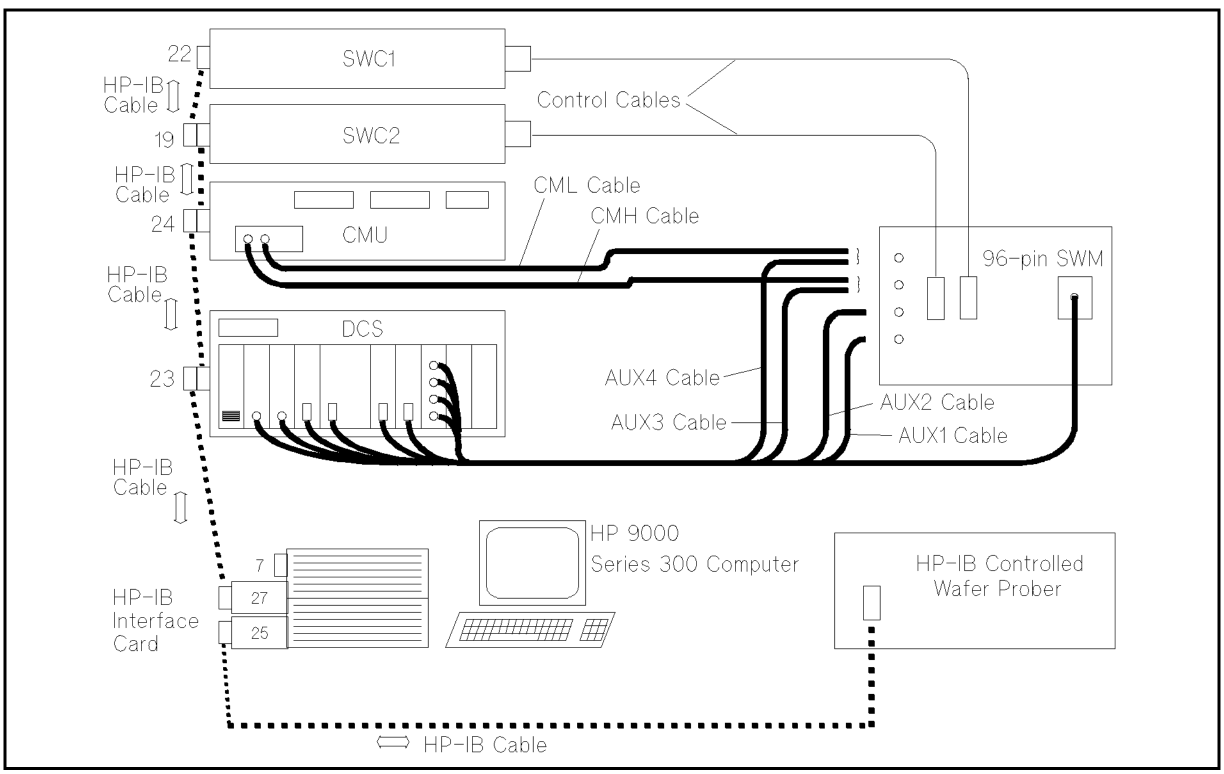


Figure 1-3. Standard System Configuration (96-pin SWM System)

Each subsystem and instrument is briefly described as follows. For more detailed information, see the *System Information* manual.

Switching Matrix Subsystem (SMS)

Your SMS's configuration depends on your SWM (48- or 96-pin), as follows:

If your SWM is a 48-pin SWM, your SMS includes the HP 4085B SWM and one HP 4084B SWC.

If your SWM is the 96-pin SWM, your SMS includes the HP 4089A or HP 4089A SWM and two HP 4084B SWCs. One SWC controls measurement pins 1–48, and the other SWC controls measurement pins 49–96.

Switching Matrix Controller (SWC)

The SWC provides relay control signals and dc power for the SWM.

Switching Matrix (SWM)

The SWM determines connection configurations between its measurement pins (measurement terminals) and the HP 4062C/UX/PC's measurement subsystems and instruments.

You can install the SWM on a wafer prober, or you can connect any of the furnished test fixtures to the SWM. The SWM's switching relays enable programmable electronic switching to provide virtually any connection configuration between measurement subsystems and the SWM's measurement pins. When using a wafer prober, this capability lets you perform a variety of parametric measurements through the SWM with only one probing to a wafer.

To minimize leakage current, which affects low current measurements, the measurement signal lines inside the SWM are fully guarded. Also, to minimize the effects of residual resistance, you can implement a Kelvin connection at any SWM measurement pin.

All SWM switching relays are mounted on removable boards, called pin boards, to make it easy to replace a defective relay.

If your system has a port expander on the HP 4089B SWM (Option 340 for both the HP 4062C/PC and the HP 4062UX), you can use additional ports as auxiliary (AUX) ports. This option increases the number of AUX ports from 4 to 12. For more information on the port expander, see the *System Information*.

Handle

Warning **Keep hands clear of the SWM, hinge, and wafer prober when lowering the SWM into position on your wafer prober.**

Output Enabled Indicator

Warning **Potentially hazardous voltages may be present at the measurement pins when the output enabled lamp on the SWM is lit.**

FIXTURE CLOSED DETECT Switch, WAFER PROBER SENSE Switch

Warning

If either the FIXTURE CLOSED DETECT switch or WAFER PROBER SENSE switch is closed, dangerous dc voltage exceeding ±42 V may be present at the measurement pins. Severe electric shock will result if the measurement pins are touched.

DC Subsystem (DCS)

The DCS handles dc measurement chores via the HP-IB. The DCS's configuration depends on the combination of plug-in modules ordered.

Two types of DCS programmable Source/Monitor Unit (SMU) plug-in modules are available. The HP 41420A 200 V/1 A SMU and the HP 41421B 100 V/100 mA SMU make a wide range of high resolution I-V measurements possible. You can program each SMU to operate as a voltage source/current monitor (V source mode) or as a current source/voltage monitor (I source mode).

SMUs connected to SWM ports 2, 3, and 4 can be used to implement Kelvin connections, and all SMUs have a driven guard terminal. Because SMUs require no adjustments, are separate plug-in modules, and are identical—except for the HP 41420A 200 V/1 A SMU—the DCS is easy to maintain and repair.

Other available DCS plug-in modules are the HP 41424A Voltage Source/Voltage Monitor Unit (VS/VMU), which provides two voltage sources (VS1 and 2) and two voltage monitors (VM1 and 2) and the HP 41425A Analog Feedback Unit (AFU).

Warning

HP 41423A 1000 V High Voltage Unit (HVU) or HP 41422A 10 A High Current Unit (HCU) are plug-in modules of the HP 4142B DCS and can be installed in the DCS. However, the SWM is not guaranteed for voltage that exceeds ±200 V or current that exceeds ±1 A. If you force high voltage or current to the devices under test (DUTs) through the SWM, the SWM would not only be damaged but you might also get an electrical shock. Do not operate the HP 4062C/UX/PC system if an HVU or HCU is installed in the DCS.

Capacitance Measurement Subsystem (CMS)

The CMU provides high speed capacitance and conductance measurements at 1 MHz.
The CMU's internal dc bias source and timer let you perform accurate C-V, G-V, and C-t measurements.

The CMU84 provides capacitance and conductance measurements from 1 kHz to 1 MHz. The CMU84's internal dc bias source lets you perform accurate C-V and G-V measurements.

The LCR provides capacitance measurements from 100 Hz to 100 kHz.

Your System Controller

The HP 4062C/UX's system controller is an HP 9000 Series 300 Computer. The HP 4062PC's system controller is an IBM PC-AT compatible computer with a measurement coprocessor. This manual assumes that you have operating and programming experience for the HP 9000 Series 300 or IBM PC-AT compatible computer.

If this is not the case, refer to the following manuals to thoroughly familiarize yourself with your system controller so you can make the most efficient use of this manual.

- For operating the HP 4062UX:

  A Beginners Guide to HP-UX
  Introducing UNIX System V
  Using the BASIC/UX System
  BASIC/UX Programming Techniques Manual

- For operating the HP 4062C:

  Using the BASIC System
  Series 300 BASIC Programming Techniques Manual

- For operating the HP 4062PC:

  Documentation supplied with MS-DOS
  Installing and Using HP BASIC in the MS-DOS Environment
  Programming with HP BASIC

System Software Specifics

The System Software provides high level operation for the HP 4062C/UX/PC. The system software contains instrument control software, automatic wafer prober control software and utility software.

Test Instruction Set (TIS)

The Test Instruction Set (TIS) is a powerful software tool designed to facilitate measurement programming. A measurement program is quickly and easily written using TIS and HP 9000 Series 300 BASIC or BASIC/UX. Measurement programs that include TIS are documents that are easier to maintain than programs written solely in BASIC or BASIC/UX. TIS can be thought of as a library of pre-compiled subprograms and user-defined functions.

Refer to Chapter 3 for details, and to the *Programming Reference* for complete TIS syntax and other rules governing the use of TIS.

XYGRAPH

The XYGRAPH file is a set of utility subprograms that let you plot a variety of graphs. XYGRAPH simplifies the scaling, labeling, and plotting of graph axes, and provides an optional grid pattern. XYGRAPH subprograms are written in BASIC or BASIC/UX, you can easily modify and enhance them, should the need arise.

Refer to Chapter 3 for sample programs that include XYGRAPH subprograms, and *Programming Reference* for complete XYGRAPH syntax and other rules governing the use of XYGRAPH.

PARA

The Parameter (PARA) file consists of a series of utility subprograms that make it possible to obtain complex dc semiconductor parameter measurement results with a minimum of time and effort. PARA subprograms are written in BASIC or BASIC/UX, so they can be modified to suit user requirements.

Refer to Chapter 3 for sample programs that include PARA subprograms, and to the *Programming Reference* for complete PARA syntax and other rules governing the use of PARA.

Virtual Front Panel (VFP)

The Virtual Front Panel (VFP) makes it possible to manipulate and monitor system operations directly from the system controller's keyboard and display, without the need for separate measurement programming. This feature lets you control the system as if it were a single, stand-alone instrument, with a system controller for a front panel.

Refer to Chapter 2 for details.

Probing Pattern Generator (PPG)

Probing Pattern Generator is an interactive program that lets you establish the desired probing pattern for wafer measurements. When using PPG, you are instructed to input the various parameters that are required to create a probing pattern through prompts displayed on the screen of the controller.

Store the generated probing pattern into a probing pattern data file, which is also created by PPG. You can edit this data file anytime.

The probing pattern data file is used by the Probing Control Library (PCL) and by WAFER MAP. The subprograms for wafer prober control using TIS are not always easy to use. It is necessary to consider the shape of the wafer, the probing sequence, etc., when writing a program with TIS subprograms since wafer prober control has only primary control functions. PCL, however, makes programming easy because it uses the data file created by PPG. Therefore, you do not have to consider factors such as the shape of the wafer when writing test programs.

Refer to Chapter 6 for details.

The Probing Control Library

Probing Control Library (PCL) is a set of subprograms that are used to control an automatic wafer prober. These subprograms are used with the probing pattern data file created by PPG. The probing control library is stored in the WAFER program file. PCL consists of subprograms that provide functions such as getting a probing pattern data file, designating an initial probing position, specifying a chip and test module to be probed, and reporting the present probing position. PCL subprograms are used in the same way as TIS subprograms, and make it easy to control the prober.

Refer to Chapter 6 for details.

The File Creation Library

The file creation library (FCL) is a set of subprograms used to create data files for wafer maps and statistical graphics. FCL created data files are compatible with Basic Statics and Data Manipulation (BSDM).

Refer to Chapter 6 for details.

Statistical Graphics

The system software includes the Basic Statistics and Data Manipulation (BSDM) programs. BSDM performs various data manipulation operations and basic statics calculations, and stores processed data. The interactive Statistical Graphics utilities can then create trend charts, histograms, and scattergrams.

Refer to Chapter 7 for details.

Wafer Mapping

WAFER MAP is a software utility that facilitates the creation of wafer maps. WAFER MAP uses the measurement data file created by FCL and the probing pattern data file created by PPG. This program makes it possible to create wafer maps with a minimum of effort. It is also possible to generate wafer maps using a computer that is not connected to the HP 4062C/UX/PC because the WAFER MAP program does not access the system instruments.

Refer to Chapter 6 for details.

Diagnostics (DIAG)

DIAG is used to verify normal system operation and also used as an aid when troubleshooting the HP 4062C/UX/PC.

Refer to the *System Information* manual for details on the contents and use of DIAG.

Offline Debugging (HP 4062UX only)

The HP 4062UX has both offline and online debugging modes. The offline debugging mode executes the measurement program with simulated TIS drivers. These drivers do not access the instrument hardware.

You can check parameters in TIS commands and determine how to process measurement data. Simulated data are generated from the TIS commands automatically from a measurement data file created beforehand.

Offline debugging is useful in a multi-tasking system like the HP 4062UX, which can execute other test programs simultaneously.

Refer to Chapter 4 for details.

System Software Specifics of HP 4062UX

Operating Environment

The HP 4062UX system uses HP-UX and BASIC/UX as its operating environment.

System Software Contents

Figure 1-4 shows the directory structure of the HP 4062UX's system software. For the 4062TISC fileset (Option 320), see the *Programming Guide for C Library* manual.

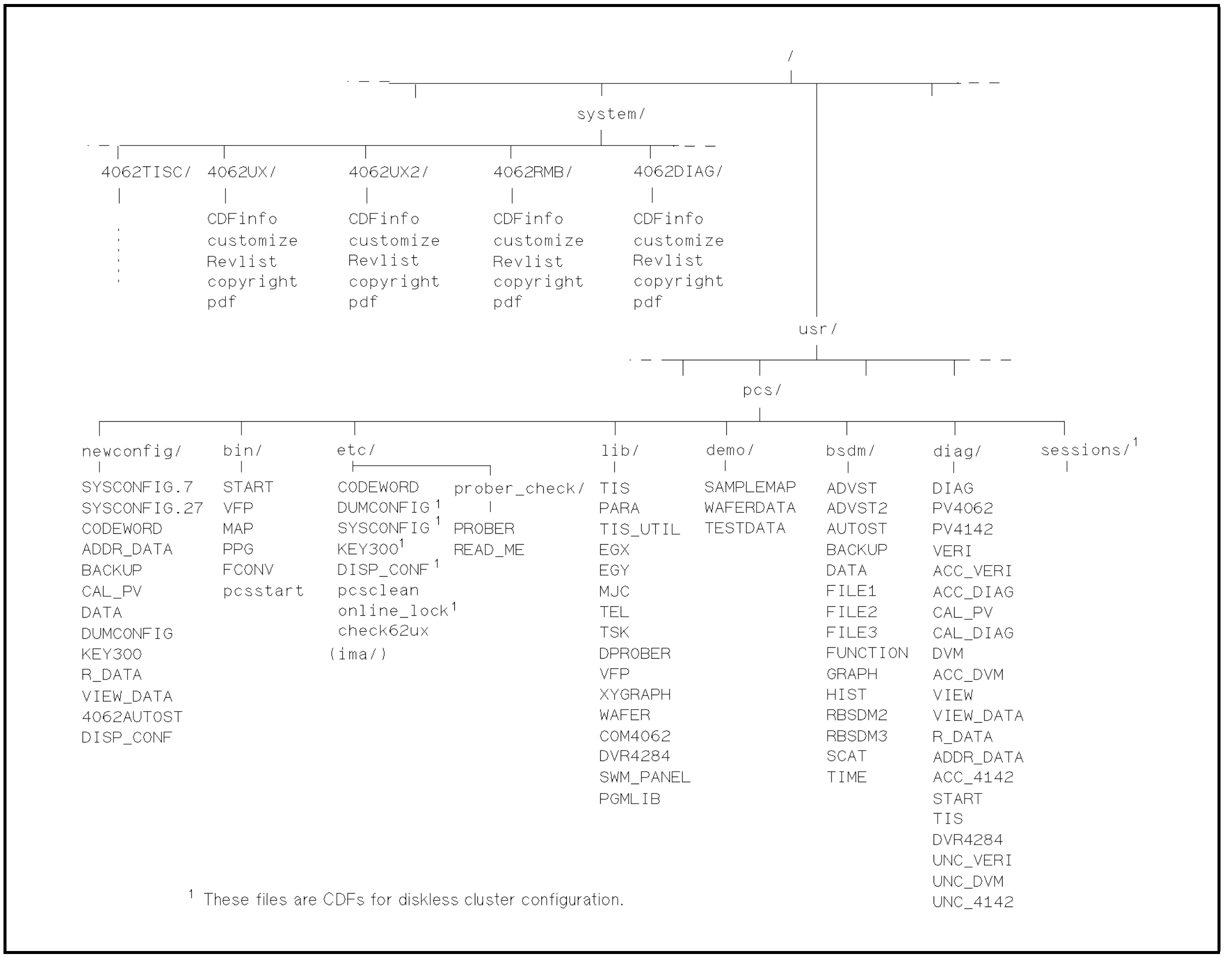


Figure 1-4. System Software Directory Structure (HP 4062UX)

- /usr/pcs/bin directory

  Contains ordinarily executable files.

- /usr/pcs/etc directory

  Contains miscellaneous system related files.

  - /usr/pcs/etc/ima directory

    Contains the Interactive Measurement and Analysis (IMA) software files, if the system is equipped with the IMA support option.

- /usr/pcs/lib directory

  Contains library files.

- /usr/pcs/demo directory

  Contains sample data and a program for a wafer map.

- /usr/pcs/bsdm directory

  Contains all statistic library files.

- /usr/pcs/diag directory

  Contains all files required to execute system diagnostics or performance verification.

- /usr/pcs/sessions directory

  Contains session key files, which are allocated by each test session and are used to make a shared memory key value.

- /usr/pcs/newconfig directory

  Contains copies of all system software files that you may modify. When the system software is updated, the copies in this directory are updated for these files. This is to save your modifications of the files and to let you update the file depending on the situation.

- /system/4062UX, /system/4062UX2, /system/4062RMB, /system/4062DIAG, and /system/4062TISC directory

  Contains files to customize the system software and a file that includes the revision number for each system software file. These files are HP-UX files.

Several directories contain HP-UX executable files. These files are represented in lowercase characters as shown in Figure 1-4.

System Software Specifics of HP 4062C

Operating Environment

The HP 4062C system software operates under the BASIC Language System environment, and requires the following BIN files.

Driver BIN Files:	CRTA, CRTB, HPIB, GPIO, CS80 or SCSI
Language Extension BIN Files:	KBD, CLOCK, ERR, IO, MAT, GRAPH, GRAPHX, EDIT, CRTX, MS

If you plan to use an external disk drive other than the CS80, other BIN files may be required (instead of CS80). Refer to the *BASIC User's Guide* .

System Software Contents

The HP 4062C's system software is provided on 9 mini-flexible disks as follows:

SYSTEM SOFTWARE (1) Disk:	REVID, START, SYSCONFIG, KEY200, KEY300, CODEWORD, DIAG, READ_ME, PROBER, and INSTALL
SYSTEM SOFTWARE (2) Disk:	REVID, TIS, EGX, EGY, TEL, TSK, MJC, PARA, TIS_UTIL, XYGRAPH, WAFER, DPROBER, DVR4284, and COM4062
SYSTEM SOFTWARE (3) Disk:	REVID, AUTOST, FILE1, FILE2, FILE3, FUNCTION, RBSDM2, RBSDM3, ADVST, ADVST2, GRAPH, SCAT, TIME, HIST, DATA, BACKUP, and FCONV
SYSTEM SOFTWARE (4) Disk:	REVID, VFP, MAP, PPG, DISP_CONF, SAMPLEMAP, WAFERDATA, TESTDATA, SWM_PANEL, and PGMLIB
SYSTEM SOFTWARE (5) Disk:	REVID, VIEW, VIEW_DATA, UNC_VERI, UNC_DVM, and UNC_4142
PERFORMANCE VERIFICATION (PV4062 #1)	REVID, PV4062, START, TIS, KEY200, KEY300, CODEWORD, and SYSCONFIG
PERFORMANCE VERIFICATION (PV4062 #2)	REVID, VERI, DVR4284, TIMER, SYSCON27, SYSCON27A, ACC_VERI (ACC_DATA for revision 6.0 or earlier), CAL_PV (CAL_DATA for revision 6.0 or earlier), ACC_DIAG (ACC_DATAD for revision 6.0 or earlier), and CAL_DIAG (CAL_DATAD for revision 6.0 or earlier)
PERFORMANCE VERIFICATION (PV4062 #3)	REVID, DVM, ACC_DVM (DVM_ACC for revision 6.0 or earlier), and CAL_PV (CAL_DATA for revision 6.0 or earlier)
PERFORMANCE VERIFICATION (PV4142)	REVID, PV4142, ACC_4142, ADDR_DATA, R_DATA, VIEW, VIEW_DATA, UNC_VERI, UNC_DVM, and UNC_4142 (For revision 6.0 or earlier, PV4142 #1 and #2 disks are supplied.)

HP strongly recommends that you install the system software on a hard disk drive. Figure 1-5 shows the recommended directory structure of the HP 4062C's system software, when it is installed on an HFS formatted disk drive.

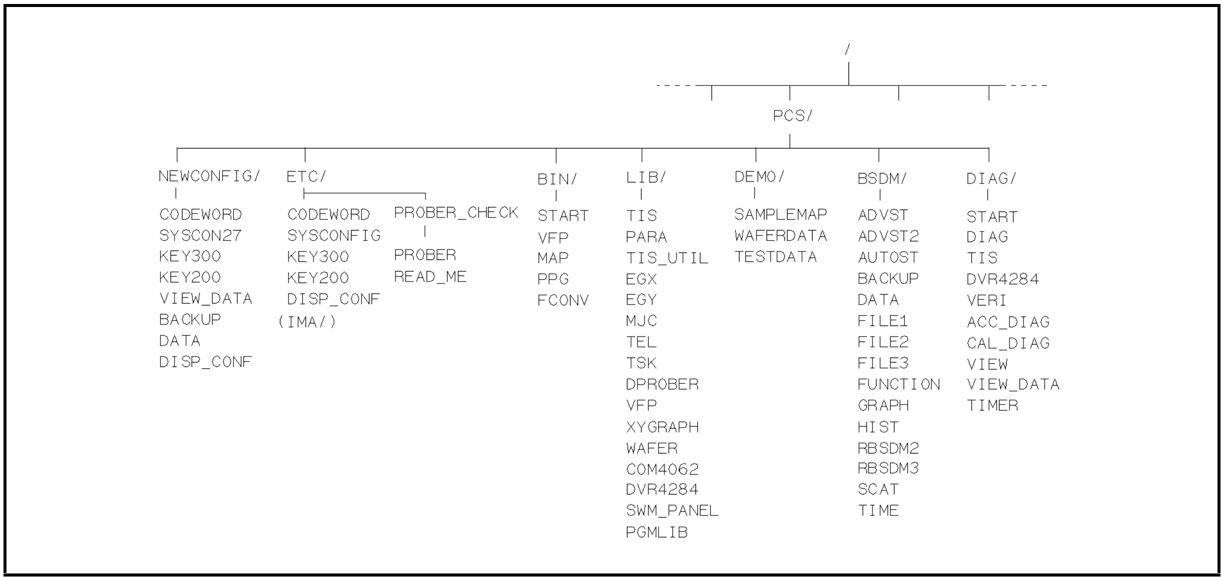


Figure 1-5. System Software Directory Structure (HP 4062C)

- /PCS/BIN directory

  Contains executable files.

- /PCS/ETC directory

  Contains miscellaneous system related files.

  - /PCS/ETC/IMA directory

    Contains the Interactive Measurement and Analysis (IMA) software files, if the system is equipped with the IMA support option.

- /PCS/LIB directory

  Contains library files.

- /PCS/DEMO directory

  Contains sample data and a program for a wafer map.

- /PCS/BSDM directory

  Contains all statistic library files.

- /PCS/DIAG directory

  Contains all files required to execute system diagnostics or performance verification.

- /PCS/NEWCONFIG directory

  Contains the copies of all system software files that you may modify. When the system software is updated, only the copies in this directory are updated for these files. This is to keep your modifications on the files and to let you update files, depending on the situation.

System Software Specifics of HP 4062PC

Operating Environment

The HP 4062PC system software operates under the BASIC Language Processor system on the MS-DOS system, and requires the following BIN files.

Driver BIN Files:	HPIB, GPIO, CRTB, DFS (CRTB and DFS are included in the BASIC core.)
Language Extension BIN Files:	CRTX, KBD, CLOCK, ERR, IO, MAT, GRAPH, GRAPHX, EDIT, MS

System Software Contents

The HP 4062PC's system software is provided on 6 flexible disks (5.25 or 3.5 inches) as follows:

SYSTEM SOFTWARE (1) Disk:	REVID, START, SYSCONFI, KEY200, KEY300, CODEWORD, DIAG, VERI, ACC_DIAG, CAL_DIAG, VIEW_DAT, UNC_VERI, UNC_DVM, UNC_4142, INSTALL, READ_ME, PROBER, and BLP62.CON
SYSTEM SOFTWARE (2) Disk:	REVID, TIS, EGX, EGY, TEL, TSK, MJC, PARA, TIS_UTIL, XYGRAPH, WAFER, PGMLIB, DPROBER, DVR4284, COM4062, VFP, and SWM_PANE
SYSTEM SOFTWARE (3) Disk:	REVID, AUTOST, FILE1, FILE2, FILE3, FUNCTION, RBSDM2, RBSDM3, ADVST, ADVST2, GRAPH, SCAT, TIME, HIST, DATA, BACKUP, MAP, PPG, SAMPLEMA, WAFERDAT, TESTDATA, and FCONV
PERFORMANCE VERIFICATION (PV4062 #1)	REVID, PV4062, START, TIS, KEY200, KEY300, SYSCONFI, SYSCON_A, VERI, DVM, DVR4284, ACC_DVM, CAL_PV, and ACC_VERI
PERFORMANCE VERIFICATION (PV4062 #2)	REVID, DVM, ACC_DVM, and CAL_PV
PERFORMANCE VERIFICATION (PV4142)	REVID, VIEW, VIEW_DATA, UNC_VERI, UNC_DVM, UNC_4142, PV4142, ACC_4142, ADDR_DAT, and R_DATA

HP strongly recommends that you install the system software on a hard disk drive. Figure 1-6 shows the recommended directory structure of the HP 4062PC's system software, when it is installed on a DFS (DOS file system).

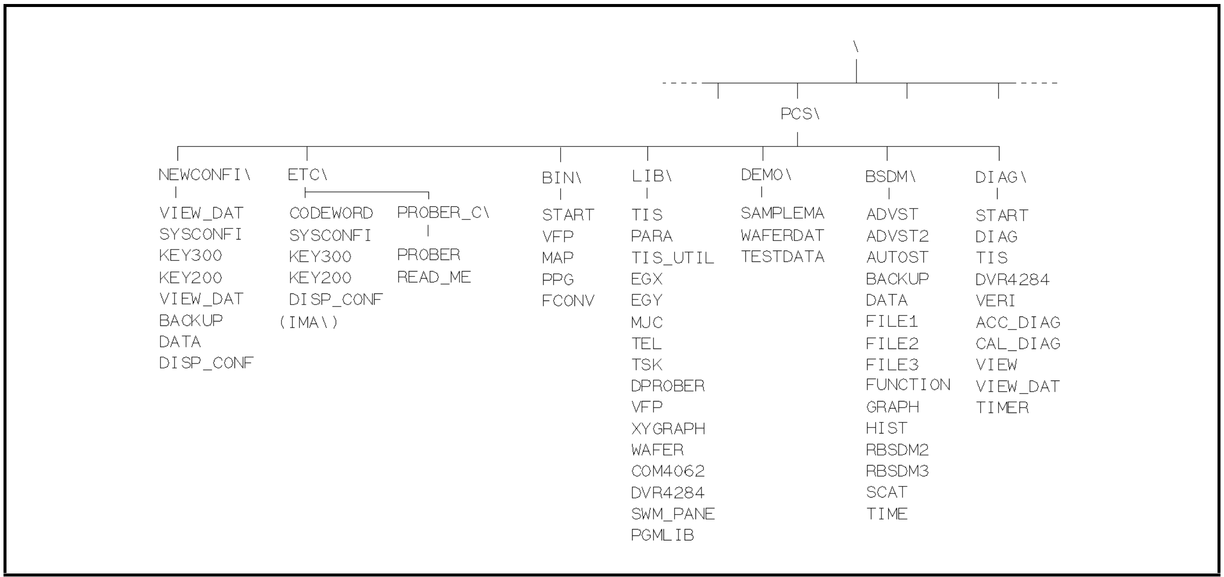


Figure 1-6. System Software Directory Structure (HP 4062PC)

- \PCS\BIN directory

  Contains executable files.

- \PCS\ETC directory

  Contains miscellaneous system related files.

  - \PCS\ETC\IMA directory

    Contains the Interactive Measurement and Analysis (IMA) software files, if the system is equipped with the HP IMA support option.

- \PCS\LIB directory

  Contains library files.

- \PCS\DEMO directory

  Contains sample data and a program for a wafer map.

- \PCS\BSDM directory

  Contains all statistic library files.

- \PCS\DIAG directory

  Contains all files required to execute system diagnostics or performance verification.

- \PCS\NEWCONFI directory

  Contains the copies of all system software files that you may modify. When the system software is updated, only the copies in this directory are updated for these files. This is to keep your modifications on the files and to let you update files, depending on the situation.

System Administration (HP 4062UX only)

Test Session Specifics

During normal system operation, several test sessions usually run concurrently, with multiple processes executing within each test session. Test sessions have their own attributes and all processes within each test session share these attributes independently from other test sessions. Each test session has the following attributes:

- Test Session Name

  Test session names distinguish each test session and are arbitrary strings limited to 14 characters.

- Online and Offline Mode

  Test session online or offline status, stored in the TIS global data area, applies to all processes within your test session.

- Instruments Settings

  Instrument settings are stored in the TIS global data area. These settings are maintained and are referred to by TIS subprograms. For offline mode test sessions, TIS maintains and refers to instrument settings as if the instruments are actually present.

- System Configuration

  Your system configuration is stored in the TIS global data area. Each offline test session can have its own system configuration.

- Locking Status (Explicit and Implicit)

  Refer to "Locking" for complete details on locking.

Figure 1-7 shows an example of typical multiple test session system operation, with multiple processes taking place within the test sessions.

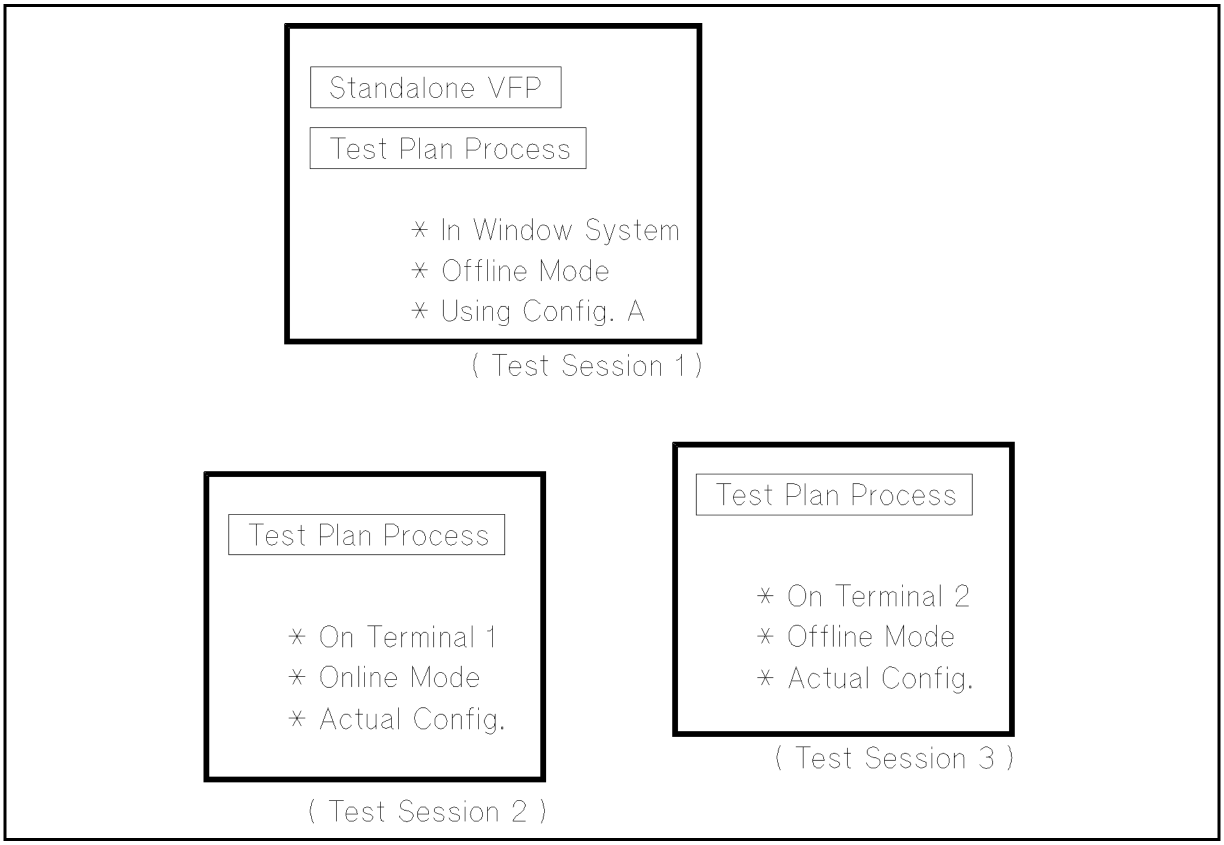


Figure 1-7. Typical Multiple Test Sessions and Processes System Operation

As Figure 1-7 shows, three independent test sessions are executing concurrently.

Test session 1 executes in the offline mode from the window environment using its own system configuration. In this test session, a measurement program is being debugged using the VFP (two processes).

Test session 2 executes in the online mode from terminal 1 using the actual system configuration.

Test session 3 executes in the offline mode from terminal 2, also using the actual system configuration.

Resource Management

The HP 4062UX software provides two resource management methods: locking and spooling.

Locking

The HP 4062UX's locking function "locks," or exclusively controls, and "unlocks," or releases control of, the system's resources—system instruments or wafer prober, or both—specified in a single TIS control subprogram (*implicit* locking) or entire measurement program sequences (*explicit* locking).

Implicit and explicit locking are described in this section. Determine the locking method you will use by taking into consideration the tradeoffs between test execution speed and system flexibility. Figure 1-8 shows the basic concepts of implicit and explicit locking.

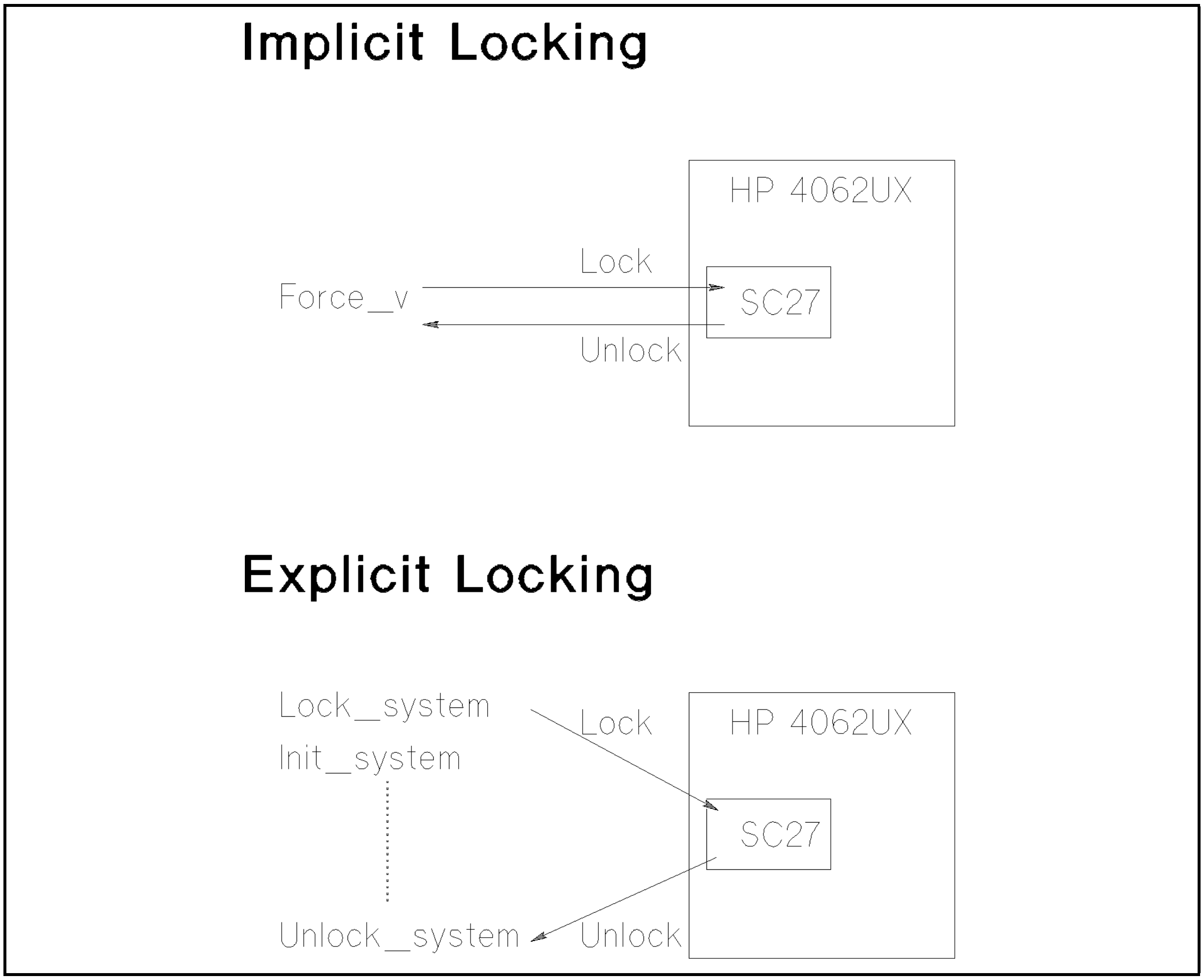


Figure 1-8. Implicit and Explicit Locking Concepts

- Implicit Locking

  Implicit locking locks the system resources to a TIS control subprogram until the subprogram executes, at which time the TIS control subprogram unlocks the system resources. For example, in Figure 1-8, the system resources that are connected to an HP-IB interface with a select code of 27 (SC27) implicitly lock to Force_v when Force_v begins, then unlocks when Force_v executes.

  The system resources can implicitly lock to TIS control subprograms from other processes, but implicitly lock to only one TIS control subprogram at a time.

  If the system resources are implicitly locked to a TIS control subprogram, succeeding TIS control subprograms will queue until the system resources are unlocked.

  If the system resources are explicitly locked (see below) to another process, however, TIS control subprograms that attempt to implicitly lock the system resources fail, and an error is reported.

- Explicit Locking

  Explicit locking exclusively locks and unlocks the system resources to and from a process via the Lock_system and Unlock_system TIS subprograms. For example, in Figure 1-8, the system resources that are connected to an HP-IB interface with a select code of 27 (SC27) explicitly lock to the process during the succeeding measurement program(s) at Lock_system, then unlock when the program sequence completes and Unlock_system executes.

Explicitly locked system resources also unlock if you exit BASIC/UX. If the system resources are explicitly locked to a process, TIS control subprograms that attempt implicit locking are ignored.

Explicit locking helps to optimize program execution speed by eliminating frequent locking and unlocking operations.

Note also, that explicit locking is a *process* function instead of a *program* function. If the system resources are explicitly locked and you scratch a program or load another program, the system resources remain locked to the process until Unlock_system executes or until you exit BASIC/UX.

Note

Implicitly locked system resources unlock if a TIS subprogram terminates because of an error, or if a measurement program terminates as the result of an BASIC/UX Reset. Explicitly locked system resources remain locked in the event of an error. Implicitly or explicitly locked system resources unlock if you terminate a BASIC/UX process by any method.

- START Program

The START program lets you select explicit locking before you run START. If you select explicit locking at START, the system resources are explicitly locked to this test session and to the online mode BASIC/UX process initiated when you run START. All subsequent measurement programs run from this process are run in explicit locking mode (Lock_system and Unlock_system TIS subprograms not required).

All other test sessions and processes generated after explicit locking START is run can execute in offline mode only until you execute Unlock_system for the explicitly locked test session.

The following modes can be set at system START:

Online Mode:

Lets you run a measurement program while accessing the system resources, and locks the system resources to this test session.

Online Debug Mode:

Lets you run a measurement program while accessing the system resources, but does not lock the system resources to this test session. You can lock the system resources to the test session by using the Lock_system and Unlock_system TIS subprograms.

Offline Mode:

Lets you run a measurement program without accessing the system resources.

- Locking the Wafer Prober

Because your wafer prober is controlled by BASIC/UX subprograms, the wafer prober is locked using an I/O interface locking function of BASIC/UX.

Spooling

Spooling is used for printers and plotters. HP-UX serves the printer/plotter spooler facility, and BASIC/UX is extended to support the spooler. All HP 4062UX programs that use a printer or plotter can also use the spooler, depending on your requirements.

Turning Your HP 4062C/UX/PC On

The basic procedure for turning your HP 4062C/UX/PC on consists of turning on the system components, allowing the system to warm-up, and running the system diagnostics program (described in *System Information*) to initialize your HP 4062C/UX/PC and confirm correct system operation. The procedure for turning on your system is as follows:

1. Open the cabinet's front door, and turn on the cabinet-mounted components and the cabinet, including your wafer prober (if used). Refer to Figure 1-8 for the locations of the LINE ON/OFF switch of the cabinet-mounted components and the SYSTEM ON/OFF switch of the cabinet.

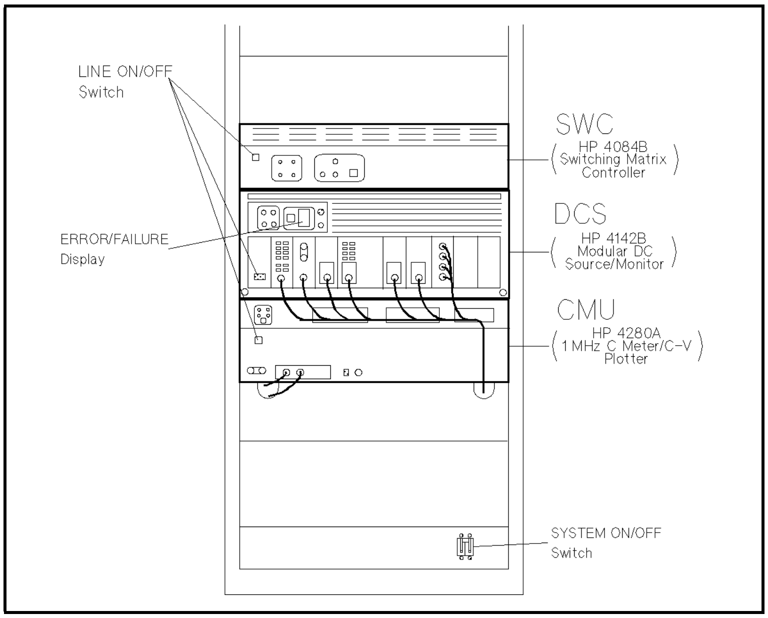


Figure 1-8. Front Panel Feature

   If a character other than 0 is displayed on the DCS's front panel ERROR/FAILURE display after the DCS's LOCAL/SELF-TEST lamp goes out, ensure that the system is thoroughly warmed up, and recycle the DCS's power. If, once again, a character other than 0 is displayed after the DCS's self-test, refer to the *System Information* for details.

2. Allow the system to warm-up for a minimum of 40 minutes.

3. Turn on your system controller and its peripherals. Refer to *Using the BASIC System* to load BASIC for an HP 4062C, *Using the BASIC/UX System* to start up, log in, and log out the BASIC/UX for an HP 4062UX, and *Installing and Using HP BASIC in MS-DOS Environment* to start BASIC for an HP 4062PC.

Caution When using the HP 4062UX, turning off your computer or an online mass storage device improperly or at the wrong time may corrupt the file system. Consult your system administrator if you want to turn off your computer.

4. Run the system diagnostics program as described in the *System Information* manual.

If your HP 4062C/UX/PC must be used immediately after you turn it on, or in environments where the ambient temperature undergoes moderate to extreme changes, the Long_cal or

Short_cal subprogram must be executed for every 3° C transition. Long_cal and Short_cal are included in the Test Instruction Set (TIS) described in Chapter 3.

Entering Your Codeword

Before you can use your HP 4062C/UX system software, you must enter your codeword into the CODEWORD file. To obtain your special codeword, read the *HP 4062C* or the *HP 4062UX System Software Right-To-Use Certificate* included with your system.

You must not change any codeword in the CODEWORD file for your HP 4062PC. The codeword in the CODEWORD file identifies the HP 4062PC.

The procedure for entering your codeword is as follows:

1. If you are not in a BASIC or BASIC/UX environment, load BASIC or BASIC/UX.
2. Load the CODEWORD file using the GET command.
   - For HP 4062UX:

     `GET "/usr/pcs/etc/CODEWORD"` (Return)
   - For HP 4062C with the recommended directory structure:

     `GET "/PCS/ETC/CODEWORD"` (Return)
   - For HP 4062C with the flexible disks:

     Insert the SYSTEM SOFTWARE (1) disk into the disk drive.

     `GET "CODEWORD"` (Return)
3. Select the `EDIT` softkey.
4. Add your special codeword as follows.

```
10 ! Please add your CODEWORD to this file.
20 ! RE-SAVE "CODEWORD"
30 ! #1234567890123456                      Example of CODEWORD
40 ! #3274563239487593                      Your codeword
```

5. Save this ASCII file.
   - For HP 4062UX:

     `RE-SAVE "/usr/pcs/etc/CODEWORD"` (Return)
   - For HP 4062C with the recommended directory structure:

     `RE-SAVE "/PCS/ETC/CODEWORD"` (Return)
   - For HP 4062C with the flexible disks:

     `RE-SAVE "CODEWORD"` (Return)

The START Program

The START program functions as follows:

- Generates the parametric test session.
- Determines the execution mode (online, online debug, or offline; for HP 4062UX only).
- Verifies your system configuration.
- Initializes the individual system components.
- Checks the measurement cable connections.
- Measures the residual impedances of the system's measurement cabling and stores the measurement values for error compensation purposes.
- Declares the COM blocks accessed by other system software files.

When you execute START, the program compares the codeword you entered in the CODEWORD file with the codeword generated by the ID Module. If these codewords are different, START displays an error message, and aborts.

When to Execute START

You must execute START before you can use any other system software. You must also execute START after any of the following operations:

- When you turn your HP 4062C/UX/PC on.
- If you turn a system instrument off or on after you've executed START.
- If you rearrange system cabling after you've executed START.
- If you change the DCS's plug-in module configuration after you've executed START.
- If you execute a SCRATCH A or SCRATCH C command after you've executed START (HP 4062C/PC only).
- If you execute a SCRATCH A command after you've executed START (HP 4062UX with a wafer prober).
- If you change the configuration of the SWM's pin boards after you've executed START.
- If you execute a program (other than MAP) before you've linked TIS.
- If you execute any of the Statistical Graphics programs.
- If you want to change the execution mode (HP 4062UX only).

Note

When you use a HP 4062C/PC, START declares the COM blocks for both the TIS and a wafer prober. When you use HP 4062UX, START declares the COM blocks for a wafer prober only.

If the COM blocks declared during START are lost, the following symptoms may occur:

- The VFP display may appear without a frame, and VFP will not operate properly (HP 4062C only).
- `ERROR 145 IN 10 May not build COM at this time`

  may be displayed.
- `TIS ERROR 20 Device not present.`

  `ERROR 449 IN 10`

  may be displayed.

If any of these symptoms occur, execute START before proceeding. For more detailed information on COM blocks, refer to the *BASIC Programming Techniques* when using the HP 4062C/PC or the *BASIC/UX Programming Techniques* when using the HP 4062UX.

Note

When the COM blocks created by START are destroyed and when the START program is executed repeatedly, the SCRATCH C statement must be executed to clear the COM block area. Executing the START program again after the destruction of the declared COM blocks increases the COM block area and decreases the available memory area for the BASIC program. The TIS CSUBs may also be slower to search the common variables.

PreSTART Execution Conditions

Before you can execute START, a number of HP 4062C/UX/PC conditions must be established, as listed below. Note that most, or all, of these conditions are established at system installation, and should not be changed.

To ensure correct START program execution, be sure the following conditions are satisfied:

- The ID Module must be installed in your system controller and your system's CODEWORD must be entered into the CODEWORD file. See "Entering Your Codeword".
- Be sure the HP-IB addresses of the rack-mounted system components are set as follows:

SWC (HP 4084B Switching Matrix Controller):	22
DCS (HP 4142B Modular DC Source/Monitor):	23
CMU (HP 4280A 1 MHz C Meter/C-V Plotter):	24
CMU84 (HP 4284A Precision LCR Meter):	17
LCR (HP 4274A Multi-Frequency LCR Meter):	17

  If your system is equipped with the HP 4089A/B 96-pin SWM, be sure the second SWC's HP-IB address is set to 19.
- The SWC(s), DCS, and CMU must be connected to an HP-IB Interface. Be sure the HP-IB Interface is set as follows:

Select Code:	27 for HP 4062C/UX, 7 for HP 4062PC
HP-IB Address (on the HP-IB Interface):	21
System Controller:	ON
Interrupt Level:	3

- Your automatic wafer prober (if you're using one) is connected to a second HP-IB Interface. Be sure the interface is set as follows:

Select Code:	25
HP-IB Address (on the HP-IB Interface):	21
System Controller :	ON
Interrupt Level:	3

If you don't want to use a second HP-IB Interface, you must modify the SYSCONFIG file. Refer to the *HP 4062C/UX/PC Installation Manual* for details.

For details on wafer prober use, refer to Chapter 5.

- The LCR is connected to the system controller's internal HP-IB interface (select code 7).
- The SWC(s) and SWM must be interconnected with the Control Cable(s).
- The DCS and SWM must be interconnected using the Interconnection Cable Assembly. The DCS's VSs and VMs can be connected to any of the SWM's AUX ports using the AUX cables.
- If using the CMU, the CMU and SWM must be interconnected using the Test Lead Assembly, CMH Cable, and CML Cable.
- If using the CMU84, the CMU84 and SWM must be interconnected using the Test Leads, BNC-T adapters, BNC f-to-f adapters, and BNC-T adapters.
- A BNC shorting cap must be connected to the CMU's front panel INT BIAS-REMOTE ON/OFF connector.
- The CMU's INT BIAS limit switch must be set to ± 100 V.
- A BNC shorting cap must be connected to the CMU's rear panel EXT BIAS-SLOW connector.
- The Test Fixture Adapter must be installed on the SWM. If the Test Fixture Adapter is not available, you'll need to press and hold the WAFER PROBER SENSE switch during START program execution.

  Do *not* use the Relay Test Adapter when you execute START.
- (For HP 4062C only) Be sure the VFP Timer Board, which is installed in the system controller, is set as follows:

Select Code:	26
Interrupt Level:	3

- The DCS must *not* include an HP 41422A High Current Unit or an HP 41423A High Voltage Unit.

Executing the START Program of the HP 4062UX

The START program provides four different display pages. The following explanations describe each START page.

- Copyright Message page:

  Displays the copyright message and system software revision number. This page appears only when the START program is about to create a parametric test session.

- Execution Mode Selection page:

  Displays the parametric test session's ID (Test Session Name) and lets you change the execution mode.

- Configuration Display page:

  Displays the system's configuration.

- Supposed Configuration Modification page:

  Lets you modify the system configuration for offline mode operation.

When you're ready to execute the START program, perform the following procedure:

1. Load START using the BASIC/UX LOAD command.

   `LOAD "/usr/pcs/bin/START"` (Return)

2. Select the `RUN` softkey.

3. When you execute the START program for the first time in your test session, the Copyright Message page is displayed.

   If you have already executed the START program, the Execution Mode Selection page is displayed.

Note

If the DCS includes an HP 41422A High Current Unit or an HP 41423A High Voltage Unit, a warning message is displayed and the START execution is aborted. Remove the HP 41422A or HP 41423A and execute the START program again.

Copyright Message Page

When you execute the START program for the first time in your test session, the Copyright Message page as shown in Figure 1-9 is displayed.

```
---------------------------------------------------
  4062UX System START Program  (revision X.06.20)
---------------------------------------------------


(c)  Copyright 1983, 1985, 1987, 1988, 1989, 1990, 1991,
Hewlett-Packard Company.   All rights reserved.   Copying
or reproducing the 4062UX's software by any means, except
for archival purposes,  without the prior written consent
of Hewlett-Packard Company is prohibited.









Press Continue.

 Continue
```

Figure 1-9. Copyright Message Page

Softkey:

`Continue` :

Proceeds to the Execution Mode Selection page.

Execution Mode Selection Page

The Execution Mode Selection page, as shown in Figure 1-10, lets you select the desired execution mode.

If another test session is in the online or online debug mode, the following warning message is displayed and the Execution mode is fixed to the offline mode and cannot be altered.

```
Warning: The system instruments are now used in other session.

         You may continue with OFF LINE mode only.
```

Note

If the system instrument configuration data file SYSCONFIG is absent, the following warning message is displayed and the Execution mode is fixed to the offline mode and cannot be altered:

```
Warning: /usr/pcs/etc/SYSCONFIG file not configured.

         You may continue with OFF LINE mode only.
```

Refer to the *HP 4062C/UX/PC Installation Manual* for details on the SYSCONFIG file.

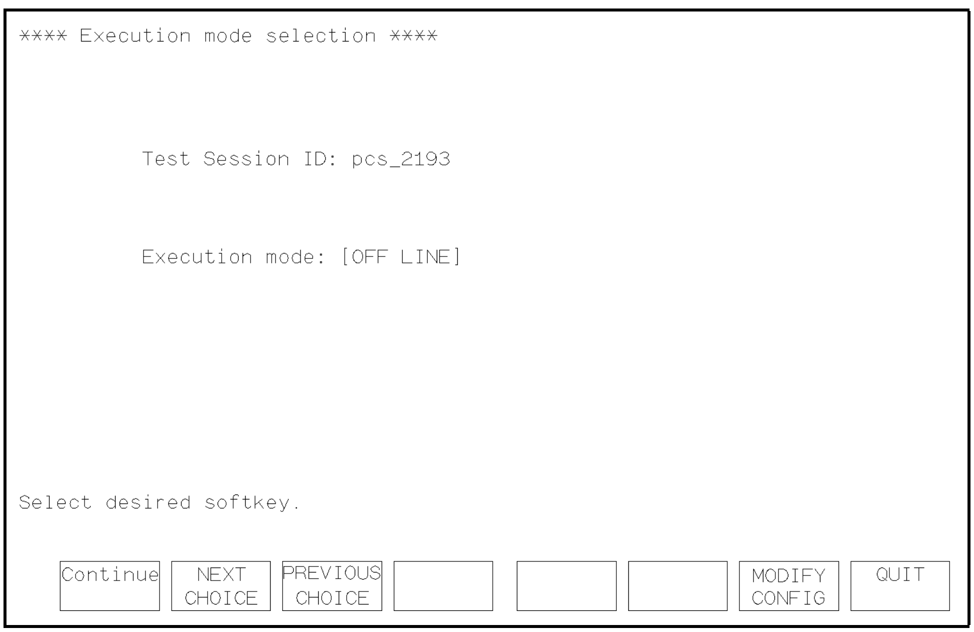


Figure 1-10. Execution Mode Selection Page

- Test Session ID:

  Displays the ID of your test session.

- Execution mode:

  Displays the present execution mode. You can alter the execution mode by using the `NEXT CHOICE` and `PREVIOUS CHOICE` softkeys.

Softkeys:

`Continue`:

Confirms the execution mode, makes the test session, and proceeds to the Configuration Display page.

`NEXT CHOICE`, `PREVIOUS CHOICE`:

Alters the execution mode. These softkeys are not displayed if another process is in the online or online debug mode.

`MODIFY CONFIG`:

Initiates the "supposed" configuration modification page for offline mode operation. This softkey is displayed only when the present execution mode is offline.

`QUIT`:

The first time you exit the START program, exits the START program and creates a new test session. Anytime after the first time you exit the program, exits without changing the execution mode of the test session.

Configuration Display Page

After your system is initialized, the START program displays your system's Configuration Display page as shown in Figure 1-11.

```
**************** SYSTEM CONFIGURATION ****************|**** AVAILABLE PINS *****
4084B/4089A SWITCHING MATRIX:             Present      |  01 02 03 04 05 06 07 08
4142B DC SOURCE/MONITOR (Rev. 3.00)       Present      |  09 10 11 12 13 14 15 16
4280A 1MHz C METER/C-V PLOTTER:           Present      |  17 18 19 20 21 22 23 24
4284A 20Hz-1MHz LCR METER (Opt. 001/006): Not present  |  25 26 27 28 29 30 31 32
ELECTROGLAS 2001X WAFER PROBER:           Present      |  33 34 35 36 37 38 39 40
***************** DCS CONFIGURATION ******************|  41 42 43 44 45 46 47 48
SLOT1: 41421B (SMU1)       SLOT5: 41421B (SMU4)        |
SLOT2:                     SLOT6: 41424A (AUX1/2)      |  49 50 51 52 53 54 55 56
SLOT3: 41420A (SMU2)       SLOT7:                      |  57 58 59 60 61 62 63 64
SLOT4: 41421B (SMU3)       SLOT8: 41425A               |  65 66 67 68 69 70 71 72
************ AUXILIARY PORT CONFIGURATION ************|  73 74 75 76 77 78 79 80
AUX1: VS1                  AUX3: CMH                   |  81 82 83 84 85 86 87 88
AUX2: VS2                  AUX4: CML                   |  89 90 91 92 93 94 95 96

        Session ID: pcs_125
    Execution mode: ON LINE

System date & time: 1 Nov 1988  00:00:00

Select desired softkey.

   EDIT   Continue  RUN  SCRATCH  LOAD " "  RE-STORE " "  Delete TIS  Link TIS
```

Figure 1-11. Configuration Display Page

`**************** SYSTEM CONFIGURATION ****************`

This section shows which system components are correctly set (`Present`) for system operation. If an instrument is displayed as `Not present`, make sure the instrument is turned on, check the instrument's HP-IB address setting and HP-IB cable connections, and execute the START program again. The system controller conducts a serial poll of the individual system components on the HP-IB during START.

If a port expander (Option 340) is equipped with the SWM, the "`(Opt. 340`" is shown after the `SWITCHING MATRIX`.

`4142B DC SOURCE MONITOR` description shows the firmware ROM revision number. If the number is under 3.00, you can force up to 20 V to search port when you perform analog search measurement.

`4284A 20Hz-1MHz LCR METER` description shows if Option 001 Power Amplifier/DC Bias and Option 006 2 m/4 m Cable Length Operation exist. If option 001 does not exist, you can not perform C-V measurement. If option 006 does not exist, the measurement accuracy is not specified.

`****************** DCS CONFIGURATION *****************`

This section shows each DCS slot number, the model number of the plug-in module installed in each slot, and the SWM port (in parentheses) to which each module is connected. If an SWM port is not displayed, that module is not connected to the SWM. Note that the HP 41420A SMU occupies 2 DCS slots and the START program "sees" only the higher of the 2 slots where the SMU is installed (in this example, slot 3). Vacant slots are left blank (slot 7). If you reconfigure any DCS plug-in modules after you've executed START, you *must* execute START again.

`************ AUXILIARY PORT CONFIGURATION ************`

This section shows the configuration of the SWM's AUX ports. If the AUX ports are connected incorrectly, `Nothing Connected` is displayed. If you reconfigure any AUX port cables after you've executed START, you *must* execute START again.

If your SWM is an HP 4089B with Option 340 (adds a port expander), the AUXILIARY PORT CONFIGURATION block may vary. For instance, it may be displayed as follows:

```
AUX11:VS1  12:     13:VM1   AUX31:CMH84 32:     33:     |
AUX21:VS2  22:     23:VM2   AUX41:CML84 42:     43:     |
```

A blank field means either no instrument or an unsupported instrument is connected.

`******************* AVAILABLE PINS *******************`

This section lists the available measurement pins (pin boards) installed in the SWM. Pin boards not present at system START are not listed (are not displayed).

- Session ID:

  Indicates the session ID for your test session.

- Execution mode:

  Indicates your execution mode.

Supposed Configuration Modification Page

The Supposed Configuration Modification page, as shown in Figure 1-12, lets you modify the system configuration for offline mode operation.

If you run START in the online mode before you run START in the offline mode, the online mode configuration is displayed as this page:

```
**************** SYSTEM CONFIGURATION **************** |**** AVAILABLE PINS *****
4084B/4089A SWITCHING MATRIX:           Present        | 01 02 03 04 05 06 07 08
4142B DC SOURCE/MONITOR (Rev. 3.00):    Present        | 09 10 11 12 13 14 15 16
4280A 1MHz C METER/C-V PLOTTER:         Present        | 17 18 19 20 21 22 23 24
4284A 20Hz-1MHz LCR METER (Opt. 001/006): Not present  | 25 26 27 28 29 30 31 32
WAFER PROBER:                           Not Present    | 33 34 35 36 37 38 39 40
***************** DCS CONFIGURATION ****************** | 41 42 43 44 45 46 47 48
SLOT1: 41421B (SMU1)        SLOT5: 41421B (SMU4)       |
SLOT2:                      SLOT6: 41424A (AUX1/2)     | 49 50 51 52 53 54 55 56
SLOT3: 41420A (SMU2)        SLOT7:                     | 57 58 59 60 61 62 63 64
SLOT4: 41421B (SMU3)        SLOT8: 41425A              | 65 66 67 68 69 70 71 72
************ AUXILIARY PORT CONFIGURATION ************ | 73 74 75 76 77 78 79 80
AUX1: VS1                   AUX3: CMH                  | 81 82 83 84 85 86 87 88
AUX2: VS2                   AUX4: CML                  | 89 90 91 92 93 94 95 96




Select desired softkey.

 Continue   NEXT    PREVIOUS  DEFAULT    LOAD   RE-STORE  CHANGE   QUIT
           CHOICE    CHOICE   CONFIG    CONFIG   CONFIG    MODE
```

Figure 1-12. Supposed Configuration Modification page

`**************** SYSTEM CONFIGURATION ****************`

This section shows which system components are set (Present) for system operation.

`****************** DCS CONFIGURATION *****************`

This section shows each DCS slot number, the model number of the plug-in module installed in each slot, and the SWM port (in parentheses) to which each module is connected. Note that the HP 41420A SMU occupies 2 DCS slots and the START program "sees" only the higher of the 2 slots where the SMU is installed (in this example, slot 3). Vacant slots are left blank (slot 7).

`************ AUXILIARY PORT CONFIGURATION ************`

This section shows the configuration of the SWM's AUX ports. If the AUX ports are connected incorrectly, "Nothing Connected" is displayed.

`******************* AVAILABLE PINS *******************`

This section lists the available measurement pins (pin boards) installed in the SWM.

Softkeys:

`Continue` :

Confirms the system configuration for offline mode operation, makes a test session, and proceeds to the Configuration Display page.

NEXT CHOICE , PREVIOUS CHOICE :

Alters the contents where the field pointer is positioned. The available choices are as follows:

- DCS CONFIGURATION:

  HP 41420A SMU (200 V/1 A)
  HP 41421B SMU (100 V/100 mA)
  HP 41424A VS/VMU
  HP 41425A AFU

  To change the DCS configuration, change the SWM port field (SMU, VS/VMU, and AFU) first.

- AUX PORT CONFIGURATION:

  VS
  VM
  CMH or CMH84
  CML or CML84

- AVAILABLE PINS:

  12, 24, 36, or 48 pins for 48-pin SWMs
  24, 36, 48, 64, 72, 84, or 96 pins for 96-pin SWMs

Note Even if the SWM is specified as the HP 4089A 96-pin SWM at the SYSTEM CONFIGURATION section, you can select the 48-pin SWM's pin configuration.

DEFAULT CONFIG :

Replaces the contents of the default configuration file (/usr/pcs/etc/DUMCONFIG) with the displayed configuration.

LOAD CONFIG :

Loads the configuration information from the file stored by the RE-STORE CONFIG softkey. When you select this softkey, a message prompting you to enter a file name is displayed.

RE-STORE CONFIG :

Stores the contents of the displayed configuration into a file. When you select this softkey, a message prompting you to enter a file name is displayed. File names can be up to 14 characters.

CHANGE MODE :

Returns you to the Execution Mode Selection page.

QUIT :

The first time you exit the START program, exits the START program and creates a new test session. Anytime after the first time you exit the program, exits without changing the execution mode of the test session.

Executing the START Program of HP 4062C

When you're ready to execute the START program, perform the following procedure:

1. Load START using the BASIC LOAD command.

   - For HP 4062C with the recommended directory structure:

     Load START using the BASIC LOAD command.

     `LOAD "/PCS/BIN/START"` (Return)

   - For HP 4062C with the flexible disks:

     a. Insert SYSTEM SOFTWARE (1) disk into the disk drive.

     b. Load START using the BASIC LOAD command.

        `LOAD "START"` (Return)

        Do not remove the (1) disk until the START program is finished because the remaining the (1) disk files "CODEWORD", "SYSCONFIG", and "KEY300" are loaded while START is executing.

2. Select the `RUN` softkey.

The START program's initial display page, shown in Figure 1-13, is displayed. The revision number (in parentheses) indicates the START program version you received. If your revision number is different, the contents of this display may vary.

```
--------------------------------------------------------
  4062C System START Program  (revision C.06.20)
--------------------------------------------------------


(c)  Copyright 1983, 1985, 1987, 1988, 1989, 1990, 1991,
Hewlett-Packard Company.   All rights reserved.   Copying
or reproducing the 4062C's software by any means,  except
for archival purposes,  without the prior written consent
of Hewlett-Packard Company is prohibited.







System initialization in prograss...
```

Figure 1-13. System START Page

After your system is initialized, the START program displays your HP 4062C's configuration page, similar to the display shown in Figure 1-14. Descriptions of the various sections of the HP 4062C's configuration page are provided after Figure 1-14.

```
**************** SYSTEM CONFIGURATION **************** |**** AVAILABLE PINS *****
16321A VFP TIMER BOARD:                     Present     | 01 02 03 04 05 06 07 08
4084B/4089A SWITCHING MATRIX:               Present     | 09 10 11 12 13 14 15 16
4142B DC SOURCE/MONITOR (Rev. 3.00):        Present     | 17 18 19 20 21 22 23 24
4280A 1MHz C METER/C-V PLOTTER:             Present     | 25 26 27 28 29 30 31 32
4284A 20Hz-1MHz LCR METER (Opt. 001/006): Not present  | 33 34 35 36 37 38 39 40
ELECTROGLAS 2001X WAFER PROBER:             Present     | 41 42 43 44 45 46 47 48
***************** DCS CONFIGURATION ***************** |
SLOT1: 41421B (SMU1)        SLOT5: 41421B (SMU4)        | 49 50 51 52 53 54 55 56
SLOT2:                      SLOT6: 41424A (AUX1/2)      | 57 58 59 60 61 62 63 64
SLOT3: 41420A (SMU2)        SLOT7:                      | 65 66 67 68 69 70 71 72
SLOT4: 41421B (SMU3)        SLOT8: 41425A               | 73 74 75 76 77 78 79 80
************ AUXILIARY PORT CONFIGURATION ************ | 81 82 83 84 85 86 87 88
AUX1: VS1                   AUX3: CMH                   | 89 90 91 92 93 94 95 96
AUX2: VS2                   AUX4: CML


System date & time: 1 Nov 1989  00:00:00

New system data ?
```

Figure 1-14. HP 4062C Configuration Page

`**************** SYSTEM CONFIGURATION ****************`

This section shows which system components are correctly set (`Present`) for system operation. If an instrument is displayed as `Not present`, make sure the instrument is turned on, check the instrument's HP-IB address setting and HP-IB cable connections, and execute the START program again. The system controller conducts a serial poll of the individual system components on the HP-IB during START.

If a port expander (Option 340) is equipped with an SWM, the "`(Opt. 340)`" is shown after the `SWITCHING MATRIX`.

`4142B DC SOURCE MONITOR` description shows the firmware ROM revision number. If the number is under 3.00, you can force up to 20 V to search port when you perform analog search measurement.

`4284A 20Hz-1MHz LCR METER` description shows if Option 001 Power Amplifier/DC Bias and Option 006 2 m/4 m Cable Length Operation exist. If option 001 does not exist, you can not perform C-V measurement. If option 006 does not exist, the measurement accuracy is not specified.

`****************** DCS CONFIGURATION *****************`

This section shows each DCS slot number, the model number of the plug-in module installed in each slot, and the SWM port (in parentheses) to which each module is connected. If an SWM port is not displayed, that module is not connected to the SWM. Note that the HP 41420A SMU occupies 2 DCS slots and the START program "sees" only the higher of the 2 slots where the SMU is installed (in this example, slot 3). Vacant slots are left blank (slot 7). If you reconfigure any DCS plug-in modules after you've executed START, you *must* execute START again.

`************ AUXILIARY PORT CONFIGURATION ************`

This section shows the configuration of the SWM's AUX ports. If the AUX ports are connected incorrectly, `Nothing Connected` is displayed. If you reconfigure any AUX port cables after you've executed START, you *must* execute START again.

If your SWM is an HP 4089B with Option 340 (adds a port expander), the AUXILIARY PORT CONFIGURATION block may vary. For instance, it may be displayed as follows:

```
  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
AUX11:VS1  12:     13:VM1   AUX31:CMH84 32:     33:     |
AUX21:VS2  22:     23:VM2   AUX41:CML84 42:     43:     |
  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
```

A blank field means either no instrument or an unsupported instrument is connected.

`****************** AVAILABLE PINS ******************`

This section lists the available measurement pins (pin boards) installed in the SWM. Pin boards not present at system START are not listed (are not displayed).

If you don't need to update system date and time, press Return.

Executing the START Program of HP 4062PC

When you're ready to execute the START program, perform the following procedure:

1. Load START program using the BASIC LOAD command.

   - For HP 4062PC with the recommended directory structure:

     Load START program using the BASIC LOAD command.

     `LOAD "\PCS\BIN\START:DOS,C"` Return

   - For HP 4062PC with the flexible disks:

     a. Insert SYSTEM SOFTWARE (1) disk into the disk drive.

     b. Load START program using the BASIC LOAD command.

        `LOAD "START"` Return

        Do not remove the (1) disk until the START program is finished because the remaining the (1) disk files "CODEWORD," "SYSCONFIG," and "KEY300" are loaded while START is executing.

2. Select the **RUN** softkey.

The START program's initial display page, shown in Figure 1-15, is displayed. The revision number (in parentheses) indicates the START program version you received. If your revision number is different, the contents of this display may vary.

```
---------------------------------------------------------
  4062PC System START Program  (revision P.06.20)
---------------------------------------------------------



(c)  Copyright 1983, 1985, 1987, 1988, 1989, 1990, 1991,
Hewlett-Packard Company.   All rights reserved.   Copying
or reproducing the 4062PC's software by any means, except
for archival purposes,  without the prior written consent
of Hewlett-Packard Company is prohibited.









System initialization in prograss...
```

Figure 1-15. System START Page

After your system is initialized, the START program displays your HP 4062PC's configuration page, similar to the display shown in Figure 1-16. Descriptions of the various sections of the HP 4062PC's configuration page are provided after Figure 1-16

```
**************** SYSTEM CONFIGURATION ****************|**** AVAILABLE PINS *****
                                                       | 01 02 03 04 05 06 07 08
4084B/4089A SWITCHING MATRIX:             Present      | 09 10 11 12 13 14 15 16
4142B DC SOURCE/MONITOR (Rev. 3.00):      Present      | 17 18 19 20 21 22 23 24
4280A 1MHz C METER/C-V PLOTTER:           Present      | 25 26 27 28 29 30 31 32
4284A 20Hz-1MHz LCR METER (Opt. 001/006): Not present  | 33 34 35 36 37 38 39 40
ELECTROGLAS 2001X WAFER PROBER:           Present      | 41 42 43 44 45 46 47 48
***************** DCS CONFIGURATION *****************  |
SLOT1: 41421B (SMU1)       SLOT5: 41421B (SMU4)        | 49 50 51 52 53 54 55 56
SLOT2:                     SLOT6: 41424A (AUX1/2)      | 57 58 59 60 61 62 63 64
SLOT3: 41420A (SMU2)       SLOT7:                      | 65 66 67 68 69 70 71 72
SLOT4: 41421B (SMU3)       SLOT8: 41425A               | 73 74 75 76 77 78 79 80
************ AUXILIARY PORT CONFIGURATION ************  | 81 82 83 84 85 86 87 88
AUX1: VS1                  AUX3: CMH84                 | 89 90 91 92 93 94 95 96
AUX2: VS2                  AUX4: CML84


System date & time: 1 Nov 1989  00:00:00

New system data ?
```

Figure 1-16. HP 4062PC Configuration Page

`**************** SYSTEM CONFIGURATION ****************`

This section shows which system components are correctly set (`Present`) for system operation. If an instrument is displayed as `Not present`, make sure the instrument is turned on, check the instrument's HP-IB address setting and HP-IB cable connections, and execute the START program again. The system controller conducts a serial poll of the individual system components on the HP-IB during START.

If a port expander (Option 340) is equipped with an SWM, the "`(Opt. 340)`" is shown after the `SWITCHING MATRIX`.

`4142B DC SOURCE MONITOR` description shows the firmware ROM revision number. If the number is under 3.00, you can force up to 20 V to search port when you perform analog search measurement.

`4284A 20Hz-1MHz LCR METER` description shows if Option 001 Power Amplifier/DC Bias and Option 006 2 m/4 m Cable Length Operation exist. If option 001 does not exist, you can not perform C-V measurement. If option 006 does not exist, the measurement accuracy is not specified.

`****************** DCS CONFIGURATION *****************`

This section shows each DCS slot number, the model number of the plug-in module installed in each slot, and the SWM port (in parentheses) to which each module is connected. If an SWM port is not displayed, that module is not connected to the SWM. Note that the HP 41420A SMU occupies 2 DCS slots and the START program *sees* only the higher of the 2 slots where the SMU is installed (in this example, slot 3). Vacant slots are left blank (slot 7). If you reconfigure any DCS plug-in modules after you've executed START, you *must* execute START again.

`************ AUXILIARY PORT CONFIGURATION ************`

This section shows the configuration of the SWM's AUX ports. If the AUX ports are connected incorrectly, `Nothing Connected` is displayed. If you reconfigure any AUX port cables after you've executed START, you *must* execute START again.

If your SWM is an HP 4089B with Option 340 (adds a port expander), the AUXILIARY PORT CONFIGURATION block may vary. For instance, it may be displayed as follows:

```
  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
AUX11:VS1  12:     13:VM1   AUX31:CMH84 32:     33:     |
AUX21:VS2  22:     23:VM2   AUX41:CML84 42:     43:     |
  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
```

A blank field means either no instrument or an unsupported instrument is connected.

`****************** AVAILABLE PINS ******************`

This section lists the available measurement pins (pin boards) installed in the SWM. Pin boards not present at system START are not listed (are not displayed).

If you don't need to update system date and time, press Return.

Softkeys

During system START, the START program automatically loads the KEY300 softkey file. Figure 1-17 shows the softkeys available after START executes.

Refer to Appendix C for changing softkeys.

						User 1	Caps Command
EDIT	Continue	RUN	SCRATCH	LOAD ""	RE-STORE ""	Delete TIS	Link TIS
						User 2	Caps Command
RENumber	Continue	RUN	MOVELINES , TO	COPYLINES , TO	FIND ""	Delete TIS	Link TIS
						User 3	Caps Command
Init_ System	Prober_ reset	Unlink & Store	SYSTEM$("MSI")	Vfp_ control	Link VFP	Delete AIS/TIS	Link AIS/TIS

Figure 1-17. System Softkeys

Connecting Test Samples

Measurements are performed at the SWM's measurement pins by an HP personality board mounted on a wafer prober, or by one of the test fixtures installed on the SWM.

The SWM's measurement pins are arranged in three concentric circles. The outermost pins are pin board guard pins; the center pins are force pins; and the innermost pins are sense pins. Figure 1-18 shows how measurement pins are configured, and describes each measurement pin.

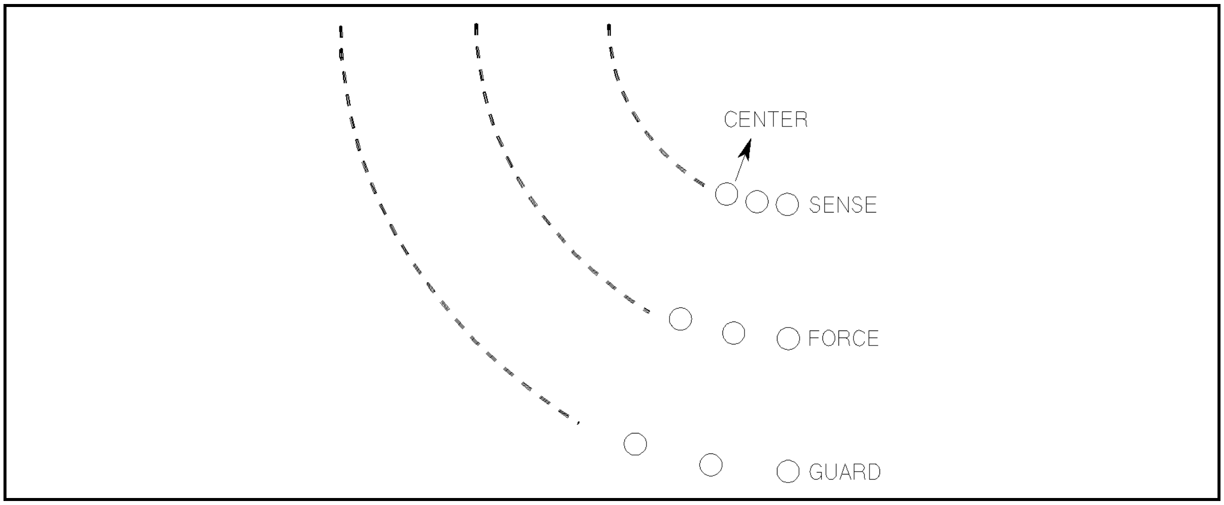


Figure 1-18. Measurement Pins

SENSE: Sense pins function as the input terminals for Kelvin connections implemented by the SMU2, SMU3, or SMU4 ports. Refer to the *System Information* for more information on Kelvin connections.

Sense pins connected by the SMU1 or AUX1-4 ports are open-terminated, and thus, have no function.

FORCE: Force pins function as the output terminals for Kelvin connections implemented by the SMU2, SMU3, or SMU4 ports.

Force pins function as the input/output terminals for subsystem components connected by the SMU1 or AUX1–4 ports.

Note that force pins act as guard pins when the GSMU is connected by SMU1, or when the GCMU is connected by CML or CMH.

GSMU and GCMU are virtual ports: therefore, they have no actual SWM connectors. GSMU connects to the guard of SMU1, and GCMU connects to the guard of CML or CMH.

GUARD: Guard pins function as guard terminals for the SMU, CMH, and CML ports.

A blank pin assignment sheet is included at the end of this chapter. Fill in the sheet before you enter your program, then use the sheet as a quick reference during programming. Additional copies of the pin assignment sheet can be made as necessary.

If your system includes a wafer prober, refer to the prober manual for instructions on how to connect test samples.

If you're measuring discrete components, packaged devices, or materials, use one of the test fixtures for your HP 4062C/UX/PC.

Figure 1-19 and Figure 1-20 and describe the system's HP 16066A and HP 16370A Test Fixture Adapters, respectively. For complete information on these and other system accessories, refer to each accessory's operating note.

Warning

TO PREVENT INJURY WHEN INSTALLING OR REMOVING THE TEST FIXTURE ADAPTER, BE SURE TO CLOSE THE TEST FIXTURE ADAPTER'S LID.

Caution

Do not touch measurement pins or fixture contacts with bare hands. Oil, perspiration, and dirt prevent good contact and degrade measurement accuracy.

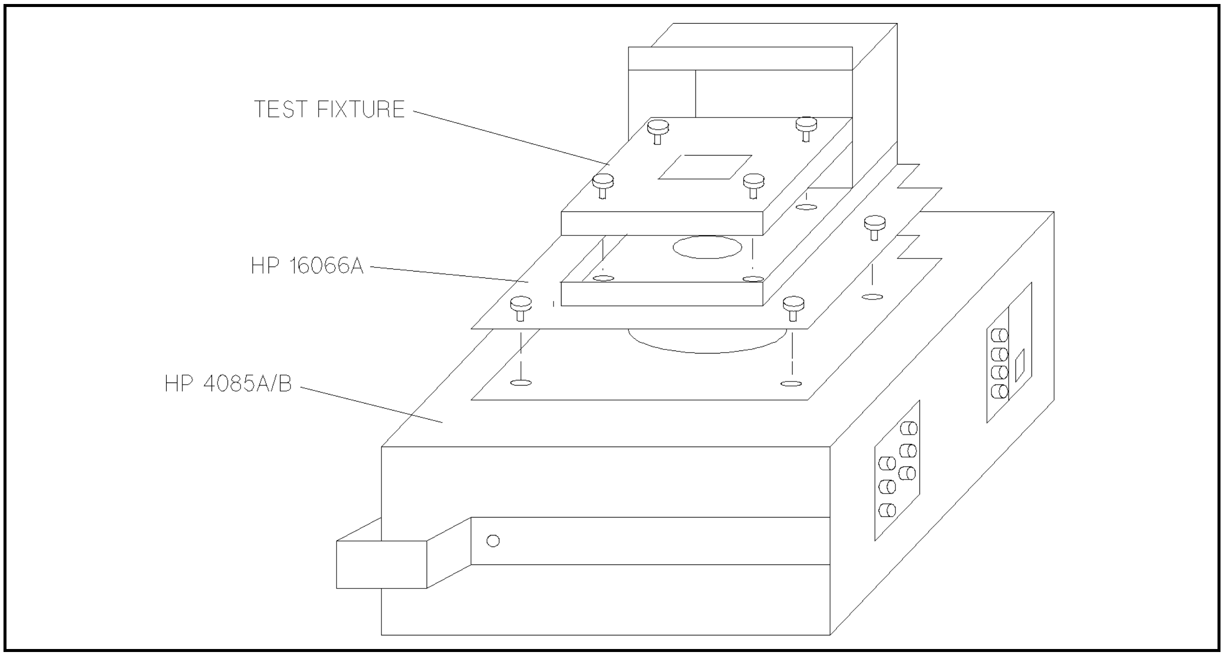


Figure 1-19. Test Fixture Adapter (for 48-pin SWMs)

The HP 16066A installs onto the 48-pin SWM and is for adapting the following test fixtures to the SWM's measurement pins.

HP 16067A Low Leakage Fixture (24-pin DIP)

HP 16068A Low Leakage Fixture (48-pin DIP)

HP 16069A Universal Low Leakage Fixture

HP 16070A General Purpose DIP Fixture

HP 16071A Universal Fixture

The HP 16066A is equipped with a light-tight, electrostatic shielding cover to ensure stable, accurate low current measurements. The procedure for mounting the HP 16066A and for installing test fixtures is as follows:

1. Place the HP 16066A on the SWM as shown.
2. Tighten the four thumb screws.
3. Raise the lid on the HP 16066A and insert the desired test fixture into the adapter so that the model number printed on the test fixture is toward the front of the HP 16066A.
4. Tighten the fixture's four thumb screws.

To enable the SWM for measurements, the HP 16066A's lid must be closed. When closed, the SWM's OUTPUT ENABLED lamp will light.

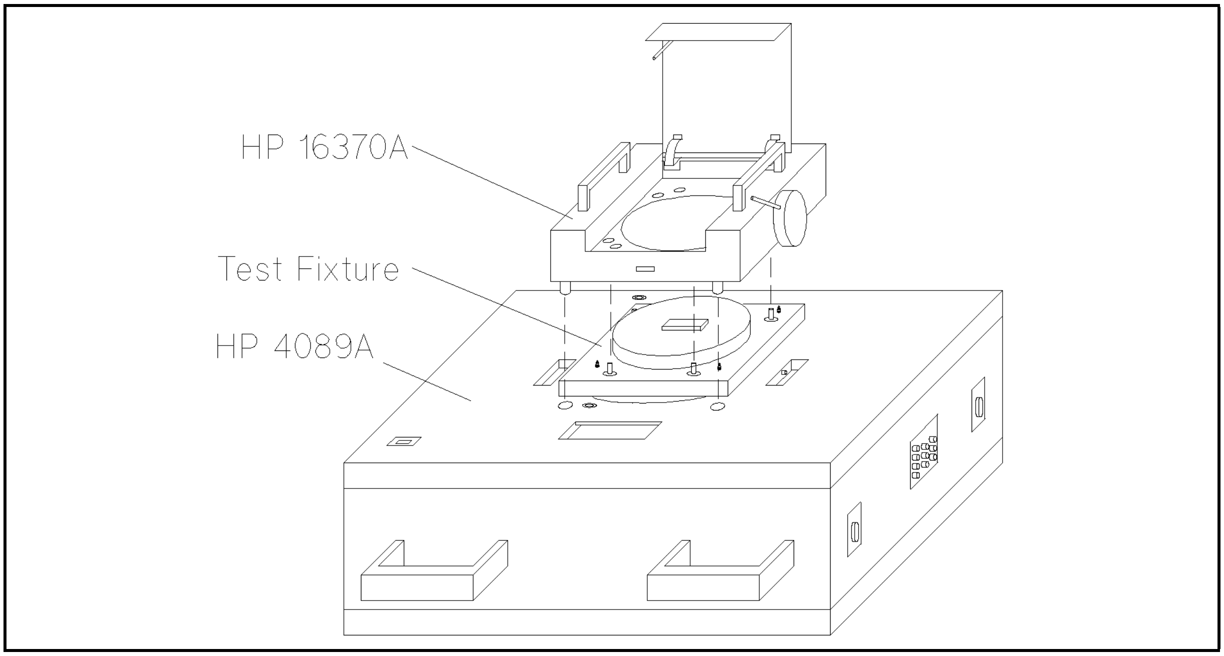


Figure 1-20. Test Fixture Adapter (for 96-pin SWMs)

The HP 16370A mounts directly onto the 96-pin SWM and is for adapting the following test fixtures to the SWM's measurement pins.

HP 16371A Low Leakage Fixture (24-pin DIP)

HP 16372A Low Leakage Fixture (48-pin DIP)

HP 16373A Low Leakage Fixture (64-pin DIP)

HP 16374A Universal Purpose DIP Fixture

HP 16375A General Purpose DIP Fixture

HP 16376A/B Universal Fixture

HP 16378A Cable Extension Fixture

The HP 16370A is equipped with a light-tight, electrostatic shielding cover to ensure stable, accurate low current measurements. The procedure for mounting the HP 16370A and for installing test fixtures is as follows:

1. Turn the HP 16370A and the test fixture upside down.
2. Position the test fixture in the HP 16370A adapter and push the test fixture's black push-to-lock fasteners to lock the test fixture into the test fixture adopter.
3. Turn the HP 16370A adapter over again (topside up).
4. Position the HP 16370A (with the test fixture installed) on the SWM.
5. Push the HP 16370A's right and left side levers down to secure the test fixture adapter on the SWM.

To enable the SWM for measurements, the HP 16370A's lid must be closed. When closed, the SWM's OUTPUT ENABLED lamp will light.

Pin Assignment Sheet

Pin	Description	Pin	Description	Pin	Description	Pin	Description
1		25		49		73	
2		26		50		74	
3		27		51		75	
4		28		52		76	
5		29		53		77	
6		30		54		78	
7		31		55		79	
8		32		56		80	
9		33		57		81	
10		34		58		82	
11		35		59		83	
12		36		60		84	
13		37		61		85	
14		38		62		86	
15		39		63		87	
16		40		64		88	
17		41		65		89	
18		42		66		90	
19		43		67		91	
20		44		68		92	
21		45		69		93	
22		46		70		94	
23		47		71		95	
24		48		72		96	

Memo:

2

VFP Operation

Introduction

The HP 4062C/UX/PC's Virtual Front Panel (VFP) function makes it possible for you to manipulate and monitor system operations from your system controller, without the need for separate measurement programming. In other words, you can control your HP 4062C/UX/PC as if it were a single, standalone instrument, using your system controller as a "front panel." Figure 2-1 shows one of the VFP pages.

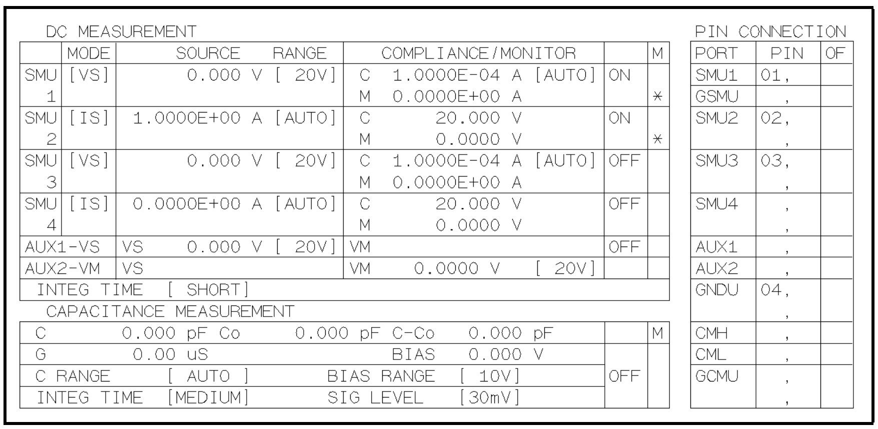


Figure 2-1. Example VFP Page

The system instruments you can control and monitor using the VFP standalone control mode are as follows:

- The DCS's SMUs connected to the SWM's SMU ports.
- The DCS's VS/VMU VSs and VMs, which can be connected to the SWM's AUX1, AUX2, AUX3, and AUX4 ports.
- The CMU's CMH and CML can be connected to the SWM's AUX3 and AUX4 ports.

Note

You *cannot* control and monitor the CMU84 and the LCR using the VFP standalone control mode.

Note

The VFP does *not* support the port expander. No relays in the port expander can be controlled with the VFP. If the port expander is installed on your SWM, the AUX11, AUX21, AUX31, and AUX41 ports are recognized as AUX1, AUX2, AUX3, and AUX4, respectively.

VFP provides two operation modes, Standalone and Monitor.

- VFP Monitor Mode:

  The VFP's monitor mode lets you monitor measurement results while a measurement program is executing by displaying and periodically updating measurement results on the VFP display—similar to the front panel display of an instrument measuring in REMOTE via HP-IB control. For information concerning VFP monitor mode operation, refer to "VFP Monitor Mode" in Chapter 4.

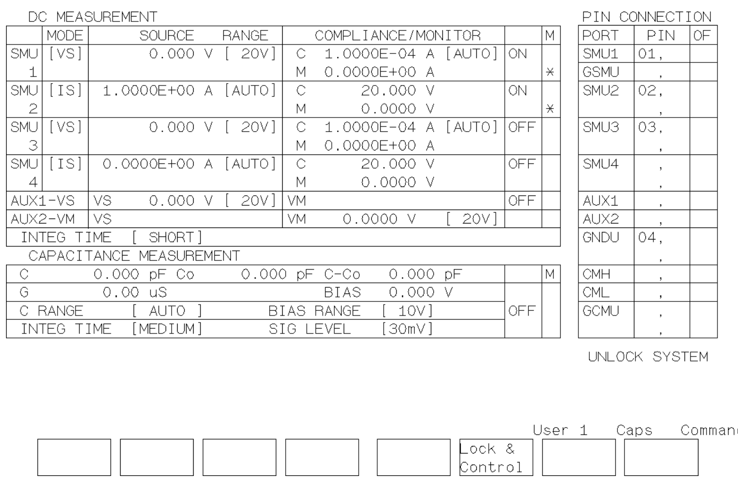
- VFP Standalone Mode:

  For HP 4062UX, VFP standalone mode provides two operation modes, Standalone Monitor and Standalone Control, which you can easily switch between.

  For HP 4062C/PC, VFP standalone mode provides Standalone Control mode only.

  1. Standalone Monitor Mode (HP 4062UX only):

     The VFP's standalone monitor mode lets you monitor measurement results while another process is accessing the test session by displaying and periodically updating measurement results on the VFP display—similar to the front panel display of an instrument measuring in REMOTE via HP-IB control.



     This mode is particularly well suited to the debugging of new test plans. Using multitasking in windows, VFP makes it possible to display real time instrument status in one window, while another process executes a test plan in another window.

2. Standalone Control Mode:

The VFP's standalone control mode lets you establish measurement parameter settings and perform measurements from your system controller's keyboard (independently of a measurement program), and to monitor measurement results on the VFP display. You can also change any settings previously established by one of your measurement programs.

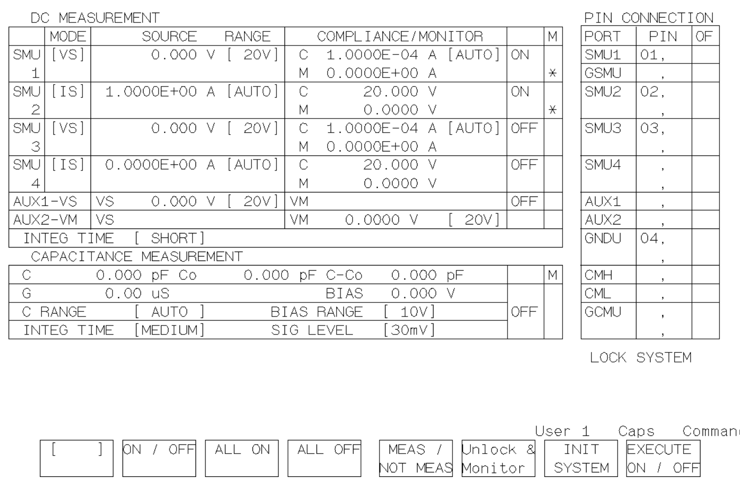
This mode is particularly well suited to new device development and evaluation, because measurement programming is not required.

The VFP's standalone control mode provides three display pages—four if your HP 4062C/UX/PC is equipped with the 96-pin SWM—and each page has a different purpose in relation to system control. Each page, therefore, provides different control functions and capabilities. This section describes each VFP control page.

a. DCS and CMU Measurements, and Pin-port Connections: Page 1

This page shows DCS and CMU measurement information, and SWM pin-port connection control information.

On this page you can establish DCS and CMU measurement parameters and observe measurement results, and you can connect and disconnect SWM ports and measurement pins.



b. SWM Pin-Port Cross Point Conditions: Page 2

This page shows the established SWM measurement pin to SWM port cross point configuration. If your HP 4062C/UX/PC is equipped with the 96-pin SWM, this page consists of two displays: display 1 for pins 1 through 48, and display 2 for pins 49 through 96.

On this page you can connect and disconnect SWM cross points and observe cross point connections.

```
 PIN-PORT CROSS POINT CONDITIONS   PIN NUMBER
         00000 00001 11111 11112 22222 22223 33333 33334 44444 444
         12345 67890 12345 67890 12345 67890 12345 67890 12345 678
                                                                    # = INVALID
   SMU1  @++++ +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++      RELAY
   GSMU  +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++       ASSIGN
   SMU2  +@+++ +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++  @ = CONNECTED
 P SMU3  ++@++ +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++
 O SMU4  +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++
 R
 T AUX1  +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++
   AUX2  +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++
 N
 A GNDU  +++@+ +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++
 M
 E CMH   +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++
   CML   +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++
   GCMU  +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++

                                                             LOCK SYSTEM

                                                        User 1   Caps   Command
 CONNECT  DIS-     CLEAR
          CONNECT  ALL
```

c. Relay Assignments: Page 3

This page shows the Make (on) and Break (off) status of all pin board relays. If your HP 4062C/UX/PC is equipped with the 96-pin SWM, this page consists of two displays: display 1 for pins 1 through 48, and display 2 for pins 49 through 96.

On this page you can set the Make or Break status of relays on the pin boards installed in your SWM. Note, however, that this page is for use by service personnel only, and is *not* for making measurements.

```
 RELAY ASSIGNMENTS             PIN NUMBER
         00000 00001 11111 11112 22222 22223 33333 33334 44444 444
         12345 67890 12345 67890 12345 67890 12345 67890 12345 678
    K 10 @++++ +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++
    K 20 +@+++ +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++  @ = MAKE
 R  K 30 ++@++ +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++
 E  K 40 +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++
 L  K 50 +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++
 A  K 60 +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++
 Y  K 70 +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++
    K 80 +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++
 N  K 90 +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++
 U  K 11 @++++ +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++
 M  K 21 +@@@+ +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++
 B  K 81 +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++
 E  K 12 @++++ +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++
 R  K 82 +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++
    K 92 +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++++ +++

                                                             LOCK SYSTEM

                                                        User 1   Caps   Command
 MAKE     BREAK    CLEAR
                   ALL
```

d. Input Relay Assignments: Page 4

This page is displayed when the SWM is the 96-pin SWM only. This page shows the Make (on) or Break (off) status of all input relays.

On this page you can set the Make or Break status of relays on the input relay boards installed in your SWM. Note, however, that this page is for use by service personnel only, and is *not* for making measurements.

INPUT RELAY CONTROL PAGE

R E L A Y   N U M B E R

	K10	K20	K30	K40	K50	K60	K70	K80	K90	K11	K21 (K31)	K41	K81	K91
BLOCK 1	@	@	+	+	@	@	@	@	@	+	@	@	+	+
BLOCK 2	+	+	@	@	+	+	+	+	+	@	@	@	@	@

@ : MAKE   + : BREAK   - : CONTROLLER NOT EXISTS

CAUTION ! This page is for service personnel only.
If incorrect input relay conditions are set on this page, incorrect measurement execution will result.

LOCK SYSTEM

User 1   Caps   Command

MAKE | BREAK | CLEAR ALL

Entering and Leaving VFP Control

Because the VFP's control mode accesses the COM blocks generated by the START program, you must execute START before you enter VFP control. For complete START program details, refer to "The START Program" in Chapter 1.

You can enter VFP control directly after system START or after you have executed a measurement program, and there's only one accepted method for leaving VFP control. The procedures for entering and leaving VFP control are described as follows:

- Entering VFP:
  - Entering VFP control after START:
    - For HP 4062UX:
      1. Load VFP using LOAD command.

         `LOAD "/usr/pcs/bin/VFP"` (Return)
      2. Select the `RUN` softkey.
    - For HP 4062C/PC with the recommended directory structure:
      1. Load VFP using LOAD command.

         `LOAD "/PCS/BIN/VFP"` (Return) *for HP 4062C/PC*

         `LOAD "\PCS\BIN\VFP"` (Return) *for HP 4062PC*
      2. Select the `Link TIS` softkey, then the `RUN` softkey.
    - For HP 4062C with the flexible disks:
      1. Insert SYSTEM SOFTWARE (4) disk into the disk drive.
      2. Load VFP using LOAD command.

         `LOAD "VFP"` (Return)
      3. Remove SYSTEM SOFTWARE (4) disk and insert SYSTEM SOFTWARE (2) disk.
      4. Select the `Link TIS` softkey, then the `RUN` softkey.
    - For HP 4062PC with the flexible disks:
      1. Insert SYSTEM SOFTWARE (2) disk into the disk drive.
      2. Load VFP using LOAD command.

         `LOAD "VFP"` (Return)
      3. Select the `Link TIS` softkey, then the `RUN` softkey.
  - Entering VFP control after a measurement program:
    - For HP 4062UX and HP 4062C/PC with the recommended directory structure:
      1. Select the `Link VFP` softkey.
      2. Select the `Vfp_control` softkey (Return)
    - For HP 4062C with the flexible disks:
      1. Insert SYSTEM SOFTWARE (4) disk into the disk drive.
      2. Select the `Link VFP` softkey.
      3. Select the `Vfp_control` softkey.

- For HP 4062PC with the flexible disks:
  1. Insert SYSTEM SOFTWARE (2) disk into the disk drive.
  2. Select the `Link VFP` softkey.
  3. Select the `Vfp_control` softkey.

- Leaving VFP:

  Press Stop. When using HP terminal keyboards, press Break.

  Or select the `EXIT VFP` softkey in the VFP standalone monitor page.

After you enter the VFP:

- For HP 4062C/PC:

  The VFP Control page 1 is displayed.

- For HP 4062UX:

  The Standalone Monitor page is displayed. To enter the Control pages, select the `Lock & Control` softkey from the Standalone Monitor page.

Note

If you use the HP 4062UX when a test session has been locked by another process, you cannot enter the standalone control mode. When you enter the standalone control mode, the test session is locked to your process, so other processes cannot access the test session until you exit the standalone control mode.

Standalone Monitor Page Description (HP 4062UX only)

Figure 2-2 shows the VFP monitor page. Page item descriptions follow the figure.

This page—shown in Figure 2-2—shows DCS and CMU measurement information, and SWM pin-port connection control information. This page lets you monitor how the system resources are set.

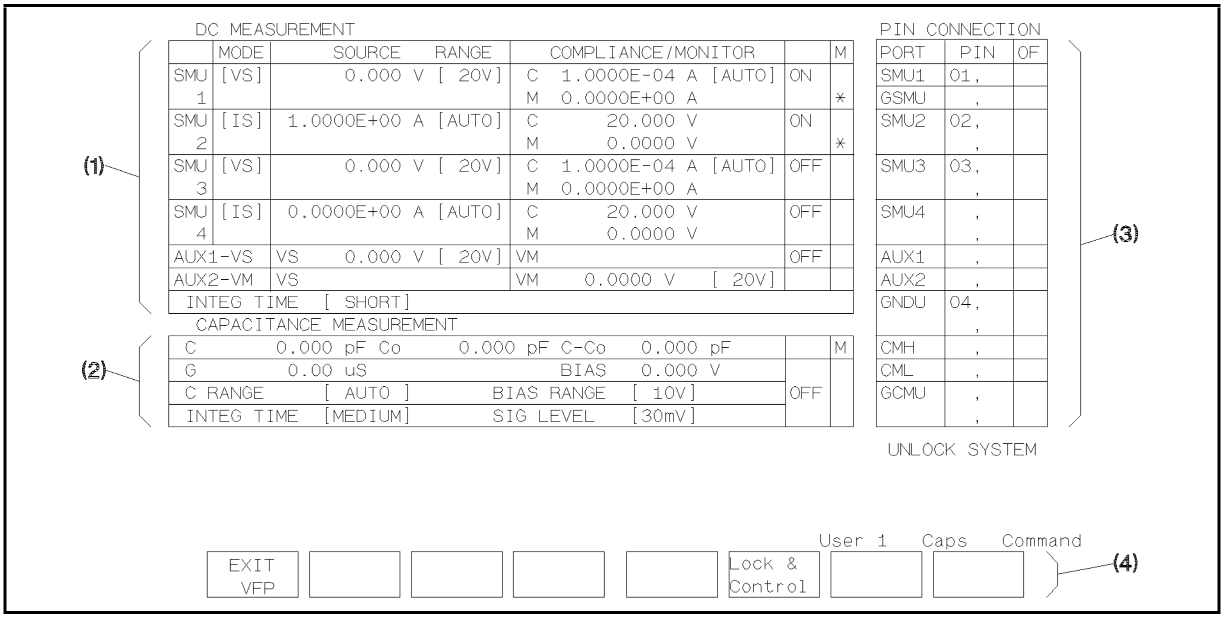


Figure 2-2. VFP Monitor Page

The following descriptions are keyed to the parenthesized items in Figure 2-2.

(1) DC MEASUREMENT

- MODE Column:

  This column shows whether an SMU is set to function as a voltage source `VS` (V source mode) or as a current source `IS` (I source mode).

- SOURCE Column:

  This column is for setting source parameters. When an SMU is set to `VS`, this column shows the output voltage and range. When an SMU is set to `IS`, this column shows the output current and range.

- COMPLIANCE / MONITOR Column:

  This column is for setting compliance parameters and for monitoring voltage or current. In this column, `C` means compliance and `M` means monitor. When an SMU is set to `VS`, this column shows the current compliance and measurement values. When an SMU is set to `IS`, this column shows the voltage compliance and measurement values.

- On/Off Column (unlabeled):

  This column shows the On/Off status of the DCS's output units.

- M (Measure/Not Measure) Column:

This column shows the Measure/Not Measure status of the DCS's measurement units and the CMU. An asterisk (*) in this column means the unit in the corresponding row is set to Measure.

- AUX1 and AUX2 Rows:

  VM and VS Connection: The first (left) section shows whether one of the DCS's VMs or VSs is connected to the SWM's AUX1 or AUX2 ports. As Figure 2-2 shows, a VM is connected to AUX1 and a VS is connected to AUX2.

  VS Output: The second (center) section shows the VS's output voltage value and the output range set.

  VM Measurement: The third (right) section shows the VM's voltage measurement value and measurement range set.

- INTEG TIME Row:

  This row shows SMU and VM integration time (INTEG TIME).

(2) CAPACITANCE MEASUREMENT

- C Row:

  This row shows the capacitance measurement value C, capacitance zero-offset value Co, and error-compensated capacitance value C-Co.

- G and BIAS Row:

  This row shows the conductance measurement value G and the internal dc bias source's output voltage.

- C RANGE and BIAS RANGE Row:

  This row shows the capacitance measurement and dc bias ranges.

- INTEG TIME and SIG LEVEL Row:

  This row shows the CMU's integration time and test signal level.

- On/Off Column (unlabeled):

  This column shows the CMU's ON/OFF status.

- M (Measure/Not Measure) Column:

  This column shows the CMU's Measure/Not Measure status of the DCS's measurement units and the CMU. An asterisk (*) in this column means the CMU is set to Measure.

(3) PIN CONNECTION

- PORT Column:

  This column shows the SWM's 9 measurement and 2 guard ports.

- PIN Column:

  This column shows the number of the measurement pin connected to the corresponding SWM port. If more than 1 pin is connected to a port, pin numbers are displayed in ascending order.

- OF (Overflow) Column:

An asterisk (*) is displayed in this column if there are more measurement pins connected to a port than can be displayed in the PIN column.

(4) Softkeys

`Lock & Control` :

Sets the standalone control mode. If the test session is locked to another processes, you cannot enter the standalone control mode.

`EXIT VFP` :

Exits the VFP program.

VFP Control Page Descriptions

When you invoke the standalone VFP, the default mode is the standalone monitor mode. To enter the standalone control mode, select the `Lock & Control` softkey from the standalone monitor page.

Note If you use the HP 4062UX when a test session is locked to another process, you cannot enter the standalone control mode. When you enter the standalone control mode, the test session is locked to this process, so other processes cannot access the test session until you exit the standalone control mode.

The following explanations describe the functions of each VFP control page and tells what you can do on each page. Detailed page control procedures are given later in this chapter.

VFP Control Page 1: DCS and CMU Measurements, and Pin-Port Connections

Figure 2-3 shows the VFP control page 1 of the HP 4062UX. The VFP control page 1 of the HP 4062C/PC is similar to the HP 4062UX page, except the HP 4062UX has `LOCK SYSTEM` displayed at the lower right of the screen and an `Unlock & Monitor` softkey is available.

Page item descriptions follow the figure.

This page—shown in Figure 2-3—shows DCS and CMU measurement information, and SWM pin-port connection control information.

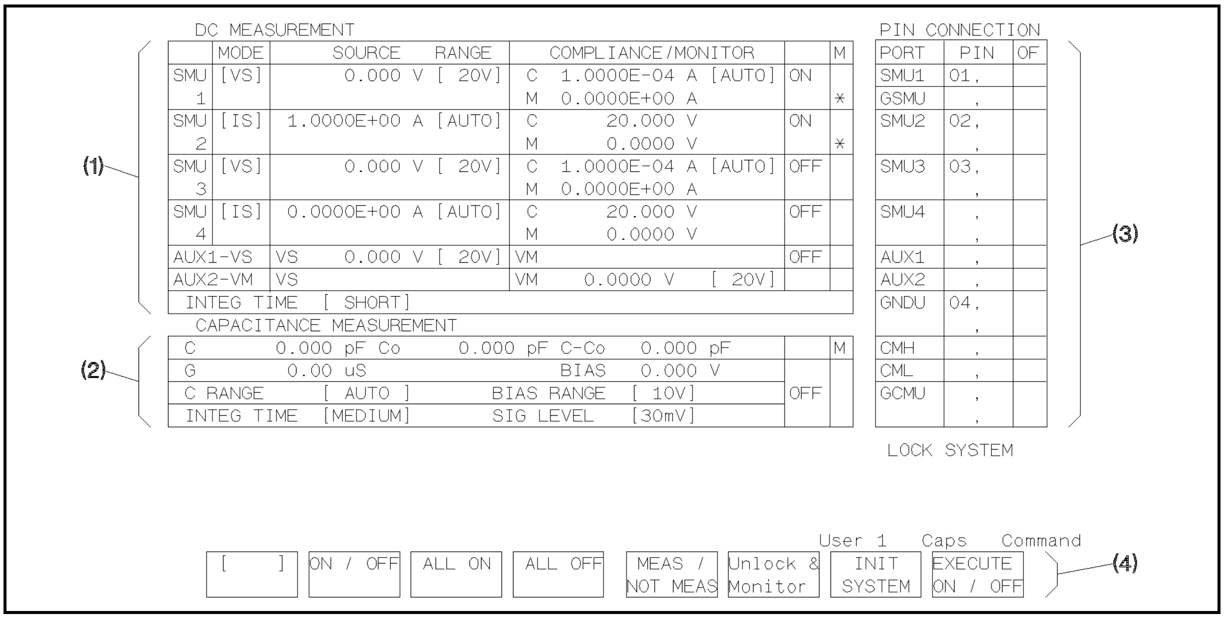


Figure 2-3. VFP Control Page 1

The following descriptions are keyed to the parenthesized items in Figure 2-3.

(1) DC MEASUREMENT

- MODE Column:

  This column shows whether an SMU is set to function as a voltage source `VS` (V source mode) or as a current source `IS` (I source mode).

- SOURCE Column:

  This column is for setting source parameters. When an SMU is set to `VS`, this column shows the output voltage and range. When an SMU is set to `IS`, this column shows the output current and range.

- COMPLIANCE / MONITOR Column:

  This column is for setting compliance parameters and for monitoring voltage or current. In this column, `C` means compliance and `M` means monitor. When an SMU is set to [`VS`], this column shows the current compliance and measurement values. When an SMU is set to [`IS`], this column shows the voltage compliance and measurement values.

- On/Off Column (unlabeled):

This column shows the On/Off status of the DCS's output units. See "DCS and CMU On/Off Status" for details.

- M (Measure/Not Measure) Column:

  This column shows the Measure/Not Measure status of the DCS's measurement units and the CMU. An asterisk (*) in this column means the unit in the corresponding row is set to Measure. See "DCS and CMU Measure/Not Measure Status" for details.

- AUX1 and AUX2 Rows:

  VM and VS Connection: The first (left) section shows whether one of the DCS's VMs or VSs is connected to the SWM's AUX1 or AUX2 ports. As Figure 2-3 shows, a VM is connected to AUX1 and a VS is connected to AUX2.

  VS Output: The second (center) section shows the VS's output voltage value and the output range set.

  VM Measurement: The third (right) section shows the VM's voltage measurement value and measurement range set.

  To perform differential voltage measurements, connect the 2 VMs of the DCS's VS/VMU to the SWM's AUX1 and AUX2 ports. Before you execute the VFP program, you must set the VMs to the differential voltage measurement mode by using the Set_vm subprogram.

  To set VMs to the grounded voltage measurement mode from the differential voltage mode on VFP control page 1, select the `Init_system` softkey.

- INTEG TIME Row:

  This row shows SMU and VM integration time (INTEG TIME).

(2) CAPACITANCE MEASUREMENT

- C Row:

  This row shows the capacitance measurement value C, capacitance zero-offset value Co, and error-compensated capacitance value C-Co.

- G and BIAS Row:

  This row shows the conductance measurement value G and the internal dc bias source's output voltage.

- C RANGE and BIAS RANGE Row:

  This row shows the capacitance measurement and dc bias ranges.

- INTEG TIME and SIG LEVEL Row:

  This row shows the CMU's integration time and test signal level.

- On/Off Column (unlabeled):

  This column shows the CMU's ON/OFF status. See "DCS and CMU On/Off Status" for details.

- M (Measure/Not Measure) Column:

This column shows the CMU's Measure/Not Measure status of the DCS's measurement units and the CMU. An asterisk (*) in this column means the CMU is set to Measure. See "DCS and CMU Measure/Not Measure Status" for details.

(3) PIN CONNECTION

- PORT Column:

  This column shows the SWM's 9 measurement and 2 guard ports.

- PIN Column:

  This column shows the number of the measurement pin connected to the corresponding SWM port. If more than 1 pin is connected to a port, pin numbers are displayed in ascending order. Refer to "SWM Control—Page 1" for details on how to connect and disconnect measurement pins and ports on this page.

- OF (Overflow) Column:

  An asterisk (*) is displayed in this column if there are more measurement pins connected to a port than can be displayed in the PIN column.

(4) Softkeys

`[     ]` :

Changes the setting of a DCS or CMU item in brackets (`[     ]`) when the cursor is positioned at a bracketed item.

`ON / OFF` :

Changes the On/Off status (toggles between On and Off) of the CMU and a selected DCS output unit. Place the cursor anywhere in the row of a DCS output unit to change its status.

`ALL ON` :

Sets the CMU and all DCS output units to On.

`ALL OFF` :

Sets the CMU and all DCS output units to Off.

`MEAS / NOT MEAS` :

Changes the Measure/Not Measure status (toggles between Measure and Not Measure) of the CMU and a selected DCS measurement unit. Place the cursor anywhere in the row of a DCS measurement unit to change its status.

`Unlock & Monitor` : (HP 4062UX only)

Sets the standalone Monitor Mode.

`INIT SYSTEM` :

Initializes your HP 4062C/UX/PC. See the *System Information* for details. The On/Off and Measure/Not Measure statuses, conditions unique to the VFP, are set to Off and Not Measure when you select the `INIT SYSTEM` softkey.

`EXECUTE ON / OFF` :

Changes the VFP's EXEC (execute) On/Off status (toggles between EXEC On and Off). Measurements execute repeatedly when EXEC is set to On.

To display the following softkey, press Menu.

C --> Co :

Sets the capacitance measurement value C as the capacitance zero-offset value Co.

Press Next or Prev to display VFP control pages.

To exit VFP control, press Stop. To exit VFP control when using HP terminal keyboards, press Break.

VFP Control Page 2: SWM Pin-port Cross Point Conditions

Figure 2-4 shows the VFP control page 2 of the HP 4062UX. The VFP control page 2 of the HP 4062C/PC is similar to the HP 4062UX page, except `LOCK SYSTEM` is displayed at the lower right of the HP 4062UX screen.

Page item descriptions follow the figure.

This page—shown in Figure 2-4—shows the established SWM measurement pin to SWM port cross point configuration.

If your HP 4062C/UX/PC is equipped with the 96-pin SWM, this page consists of two displays: display 1 for pins 1 through 48, and display 2 for pins 49 through 96. To change the displays, press (Next) or (Prev).

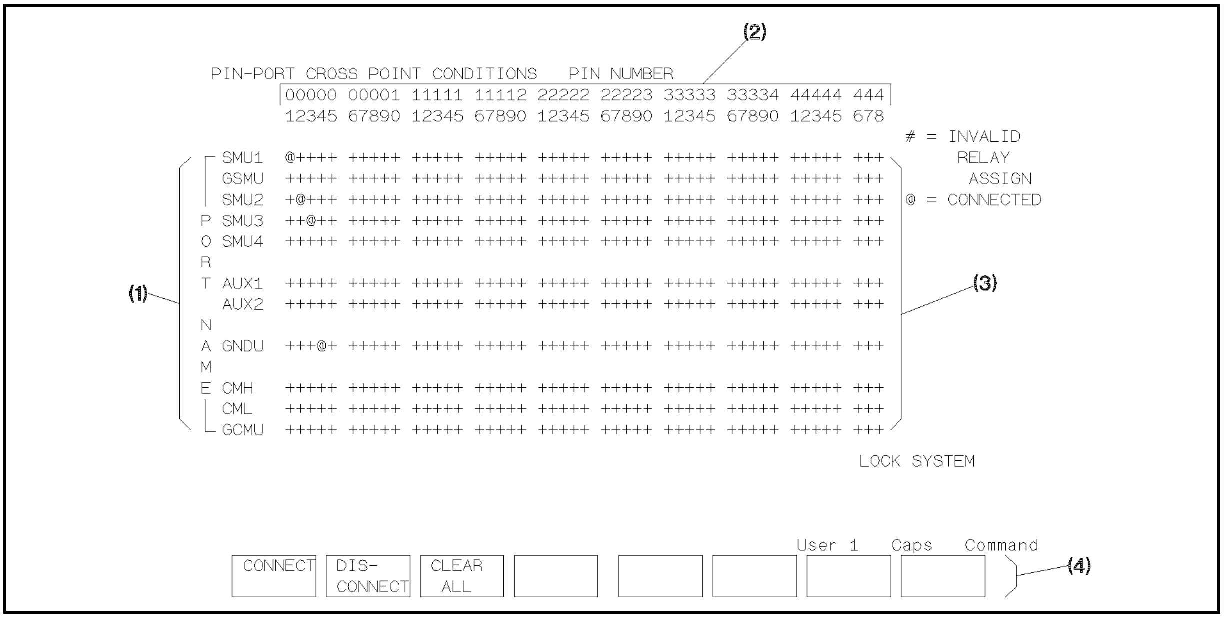


Figure 2-4. VFP Control Page 2

The following descriptions are keyed to the parenthesized items in Figure 2-4.

(1) PORT NAME

Lists the SWM's 9 measurement and 2 guard ports.

(2) PIN NUMBER

Lists the pin numbers (locations) of pin boards installed in the SWM that you can control. Only the pin numbers of installed pin boards are displayed. If a pin board's relays are *not* set correctly to allow a correct pin-port connection, a " `#` " symbol is displayed in that pin number's column.

(3) Cross Point Conditions

Shows which measurement pin is connected to which port. The " `@` " symbol indicates a pin-port cross point connection; the " `+` " symbol indicates no connection. The " `-` " symbol indicates an empty pin board location.

(4) Softkeys

`CONNECT` :

Connects a pin to a port at the cursor's location.

`DISCONNECT` :

Disconnects a pin from a port at the cursor's location.

`CLEAR ALL` :

Clears all pin-port cross point connections.

Press (Next) or (Prev) to display additional VFP control pages.

To exit VFP, press (Stop). To exit VFP control while using HP terminal keyboards, press (Break).

Controlling the SWM

This section provides detailed SWM control information, including procedures for setting specific items. You can connect and disconnect SWM measurement pins and ports for making measurements under VFP control from control pages 1 and 2 only. Although control page 3 and 4 allow control of individual pin board relays, this page is for servicing your HP 4062C/UX/PC only, and is *not* for measurements.

SWM Control—Page 1

On this page, you can connect and disconnect measurement pins and ports from the PIN CONNECTION portion of VFP control page 1, shown in Figure 2-5, as described in the following paragraphs.

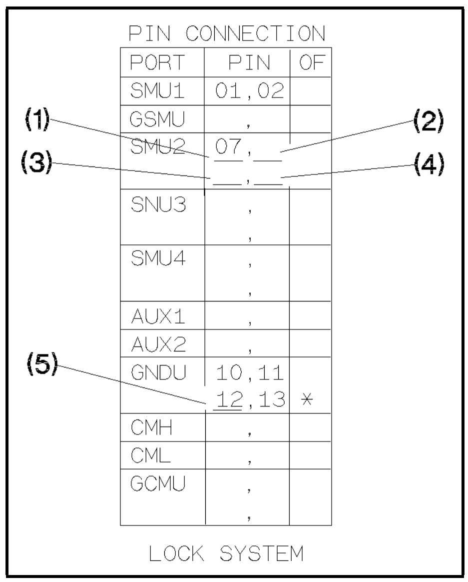


Figure 2-5. SWM Control—Page 1

- Connecting measurement pins to ports

  Position the cursor in the PIN column next to the desired port, type in the pin number you wish to connect, and press (Return).

  For example, to connect pin 7 to SMU2 as shown in Figure 2-5, perform the following procedure:

  1. Position the cursor anywhere in the SMU2 row, (1) through (4).
  2. Enter 07 or 7 (Return).

  Pin number 07 is displayed at (1), no matter where you position the cursor in the SMU2 row.

  Note, however, that you can only connect pins to ports that are physically connected to your HP 4062C/UX/PC.

- Disconnecting measurement pins from ports

  Move the cursor to the pin number you wish to disconnect, and press (Clear line) (Return).

For example, to disconnect pin 12 from the GNDU as shown in Figure 2-5, perform the following procedure:

1. Position the cursor at (5).
2. Press (Clear line) (Return). Pressing the Space Bar twice (and (Return)) will also disconnect the pin.

If more measurement pins than can be displayed are connected to a port, an asterisk (*) is displayed in the OF (overflow) column, as in this example.

When you disconnect a pin, the lowest-numbered pin of the undisplayed (OF) pins is displayed.

Note, however, that you can only disconnect undisplayed (OF) pins on VFP control page 2.

SWM Control—Page 2

On this page, you can connect and disconnect individual cross points, and you can disconnect all cross points. Also, you must use this page to disconnect undisplayed pins (OF) on page 1. Figure 2-6 shows SWM control page 2.

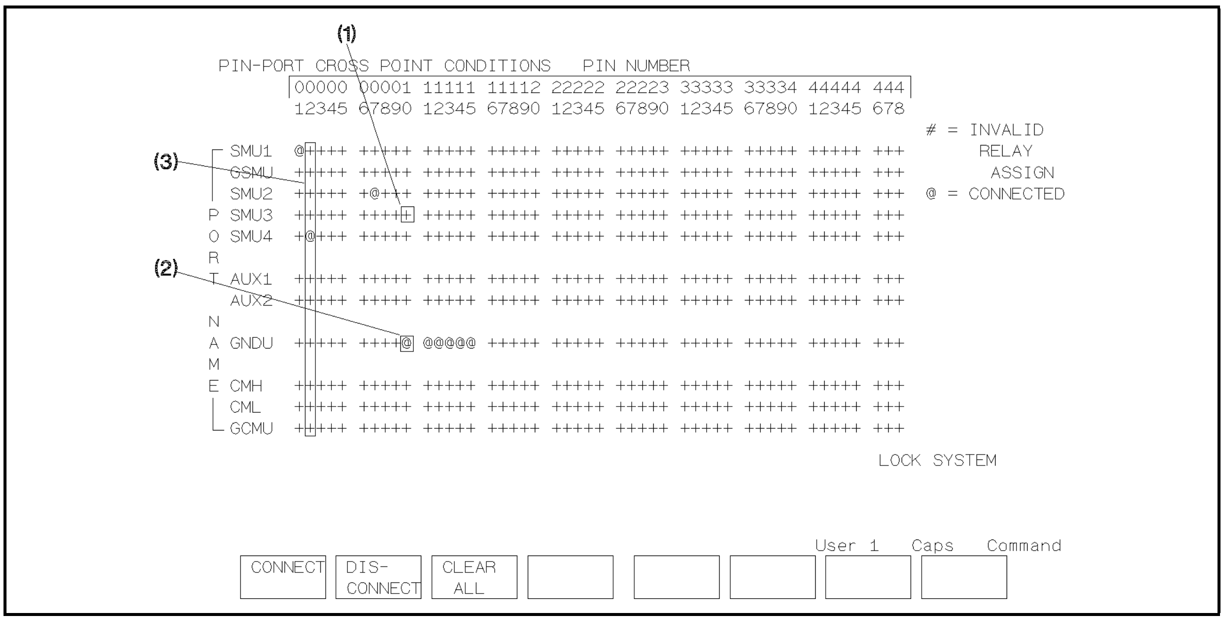


Figure 2-6. SWM Control—Page 2

- Connecting cross points

Position the cursor at the desired cross point (port row and pin number column) and select the `CONNECT` softkey. The " `@` " symbol is displayed at connected cross points.

For example, to connect pin 10 (connected to the GNDU in Figure 2-6) to SMU3, perform the following procedure:

1. Position the cursor at (1).
2. Select the `CONNECT` softkey.

The " `@` " symbol is displayed at (1), and the " `+` " symbol is displayed at (2).

- Disconnecting individual cross points

  Position the cursor anywhere in the pin number column of the pin you wish to disconnect and select the `DISCONNECT` softkey. When disconnecting cross points, you need not position the cursor at the exact cross point.

  For example, to disconnect pin 2 from SMU4, as shown in Figure 2-6, perform the following procedure:

  1. Position the cursor anywhere in the pin 2 column (3).
  2. Select the `DISCONNECT` softkey.

  The " @ " symbol displayed at the cross point connection is displayed as the " + " symbol.

- Disconnecting all cross points

  To disconnect all cross points, select the `CLEAR ALL` softkey.

Controlling the DCS

This section provides detailed DCS control information, including procedures for setting specific items. On VFP control page 1, you can control SMU and VS/VMU (VS and VM) settings.

Setting Up the SMUs

You can set the DCS's SMUs to function as voltage sources/current monitors (V source mode—VS) or as current sources/voltage monitors (I source mode—IS).

V Source Mode (VS) Setup

Figure 2-7 shows the SMU1 row of the DC MEASUREMENT portion of VFP control page 1, with SMU1 set to VS. In this figure, the numbers in parentheses show the items you can change from this page.

In the following explanations, VS means voltage source, M means measurement, and C means compliance.

The procedures following Figure 2-7 for setting VS items are keyed to the numbers in parentheses in the figure. When setting up an SMU as a VS, set up each item in the sequence given ((1), (2), etc.).

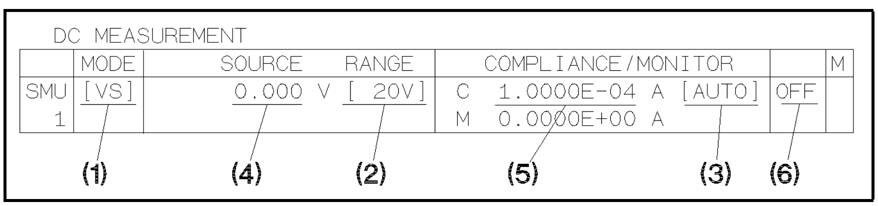


Figure 2-7. SMU VS Setup Sequence

(1) MODE

1. Position the cursor at (1).
2. Select the [ ] softkey to set SMU1 to `VS`.
3. Press (Return).

When you set an SMU to VS, the SMU is automatically set as follows:

VS (output) Value:	0 V
VS RANGE:	20 V
Compliance (C) Value:	100 μA
M Range:	AUTO
ON/OFF Status:	OFF

(2) SOURCE RANGE

To change an SMU's VS range, the SMU's ON/OFF status must be set to OFF.

1. Position the cursor at (2).
2. Select the [ ] softkey until the desired VS range is displayed. (2, 20, 40, 100, or 200[1] V.)

3. Press Return.

Each time you change the VS range, even if you return to the initial setting, you must press Return.

1 The 200 V range is available for HP 41420A SMUs only.

(3) MONITOR RANGE

1. Position the cursor at (3).
2. Select the [ ] softkey until the desired Monitor range is displayed.
3. Press Return.

Each time you change the Monitor range, even if you return to the initial setting, you must press Return.

Refer to the *System Information* for Monitor range details.

(4) VS VALUE

1. Position the cursor at (4).
2. Press Clear line to clear any previously set value.
3. Enter the desired VS value.
4. Press Return.

When you press Return, the VS value entered is checked against the set VS range (2). If the VS value exceeds the VS range, an error message is displayed.

(5) Compliance (C) VALUE

To change an SMU's C Value, the SMU's On/Off status must be set to Off.

1. Position the cursor at (5).
2. Press Clear line to clear any previously set value.
3. Enter the desired C value.
4. Press Return.

When you press Return, the C value entered is checked against the set SMU VS range (2). If the C value exceeds the maximum C value for the selected VS range, an error message is displayed.

(6) Setting the On/Off Status

Refer to "Setting the On/Off Status" procedure to set the On/Off status.

If you omitted VS setup step (4) or (5), or entered these items in the incorrect sequence, an error message is displayed and the cursor returns to the incorrectly set parameter.

I Source Mode (IS) Setup

Figure 2-8 shows the SMU1 row of the DC MEASUREMENT portion of VFP control page 1, with SMU1 set to IS. In this figure, the numbers in parentheses show the items you can change from this page.

In the following explanations, IS means current source, M means measurement, and C means compliance.

The procedures following Figure 2-8 for setting up IS items are keyed to the numbers in parentheses in the figure. When setting up an SMU as an IS, set up each item in the sequence given ((1), (2), etc.).

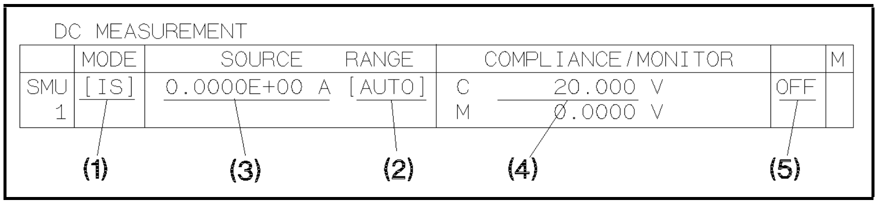


Figure 2-8. SMU IS Setup Sequence

(1) MODE

1. Position the cursor at (1).
2. Select the `[ ]` softkey to set SMU1 to `IS`.
3. Press (Return).

   When you set an SMU to IS, the SMU is automatically set as follows:

IS (output) Value:	0 mA
IS Range:	AUTO
Compliance (C) Value:	20 V
On/Off Status:	Off

(2) IS RANGE

1. Position the cursor at (2).
2. Select the `[ ]` softkey until the desired range is displayed. (`E-0A` [1] through `E-8A` , and `AUTO`).
3. Press (Return).

Each time you change the IS range, even if you return to the initial setting, you must press (Return).

[1] The `E-0A` range is available for HP 41420A SMUs only.

(3) IS VALUE

1. Position the cursor at (3).
2. Press (Clear line) to clear any previously set value.
3. Enter the desired IS value.
4. Press (Return).

(4) Compliance (C) VALUE

To change an SMU's C value, the SMU's On/Off status must be set to Off.

1. Position the cursor at (4).
2. Press (Clear line) to clear any previously set value.
3. Enter the desired C value.

4. Press (Return).

When you press (Return), the C value entered is checked against the set IS value (3). If the C value exceeds the maximum C value for the IS range, an error message is displayed.

(5) Setting the On/Off Status

Refer to "Setting the On/Off Status" for the procedure for setting the On/Off status.

Setting Up the VS/VMU

Figure 2-9 shows the AUX1 and AUX2 rows of the DC MEASUREMENT portion of VFP control page 1, with the SWM's AUX1 port connected to VS1, and the AUX2 port to VM2. In this figure, the numbers in parentheses show the items you can change from this page.

The procedures following Figure 2-9 for changing VS/VMU VS and VM items are keyed to the numbers in parentheses in the figure.

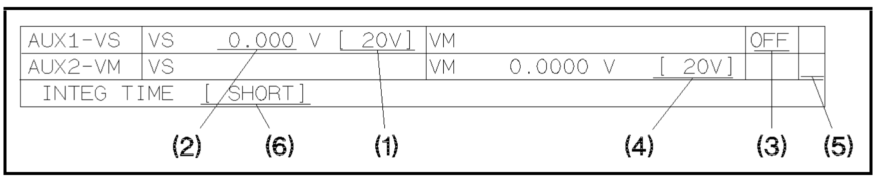


Figure 2-9. VS/VMU VS and VM Setup Sequence

VS Setup

(1) VS RANGE

To change the VS range, the VS's On/Off status must be set to Off.

1. Position the cursor at (1).
2. Select the `[ ]` softkey until the desired range is displayed (`[ 20V ]` or `[ 40V ]`).
3. Press (Return).

Each time you change the VS range, even if you return to the initial setting, you must press (Return).

(2) VS VALUE

1. Position the cursor at (2).
2. Press (Clear line) to clear any previously set value.
3. Enter the desired VS value.
4. Press (Return).

When you press (Return), the VS value entered is checked against the VS range (1). If the VS value exceeds the VS range, an error message is displayed.

(3) Setting the On/Off Status

Refer to "Setting the On/Off Status" for the procedure for setting the On/Off status.

(4) VM RANGE

1. Position the cursor at (4).
2. Select the [ ] softkey until the desired VM range is displayed.[1]
3. Press Return.

Each time you change the VM range, even if you return to the initial setting, you must press Return.

[1] VM ranges for the grounded measurement mode: AUTO, 2 V, 20 V, or 40 V. VM ranges for the differential measurement mode: 0.2 V or 2 V.

(5) Setting the Measure/Not Measure status

Refer to "Setting the Measure/Not Measure Status" for the procedure for setting the Measure/Not Measure status.

Setting SMU and VM Integration Time

To set SMU or VM integration time (INTEG TIME)—item (6) in Figure 2-9—perform the following procedure:

(6) INTEG TIME

1. Position the cursor at (6).
2. Select the [ ] softkey to display the desired INTEG TIME. (SHORT, MEDIUM, or LONG)
3. Press Return.

Each time you change INTEG TIME, even if you return to the initial setting, you must press Return.

Controlling the CMU

This section provides detailed CMU measurement set up information, including procedures for setting specific items. On VFP control page 1, you can control all CMU measurement settings.

Figure 2-10 shows the CAPACITANCE MEASUREMENT portion of VFP control page 1. In this figure, the numbers in parentheses show the items you can change from this page. The procedures following Figure 2-10 for setting CMU items are keyed to the numbers in parentheses in the figure.

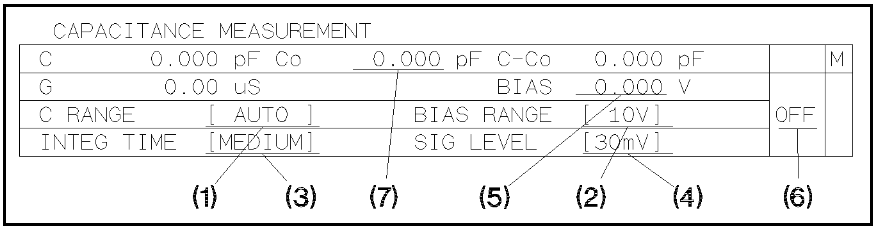


Figure 2-10. CMU Measurement Items

(1) C RANGE

1. Position the cursor at (1).
2. Select the [ ] softkey to display the desired C range (AUTO, 10, 100, or 1000 pF).
3. Press Return.

Each time you change the C range, even if you return to the initial setting, you must press Return.

(2) BIAS RANGE

To change the dc bias range, the CMU's On/Off status must be set to Off.

1. Position the cursor at (2).
2. Select the [ ] softkey to display the desired dc bias range (1, 10, or 100 V).
3. Press Return.

Each time you change the dc bias range, even if you return to the initial setting, you must press Return.

(3) INTEG TIME

1. Position the cursor at (3).
2. Select the [ ] softkey to display the desired integration time (SHORT, MEDIUM, or LONG).
3. Press Return.

Each time you change the integration time, even if you return to the initial setting, you must press Return.

(4) SIG LEVEL

1. Position the cursor at (4).
2. Select the [ ] softkey to display the desired signal level (10 or 30 mVrms).
3. Press Return.

Each time you change the signal level, even if you return to the initial setting, you must press Return.

(5) BIAS

1. Position the cursor at (5).
2. Press Clear line to clear any previously set value.
3. Enter the desired dc bias output voltage.
4. Press Return.

When you press Return, the dc bias output voltage (BIAS) entered is checked against the bias range (2). If the bias you set exceeds the bias range limits, an error message is displayed.

(6) Setting the On/Off Status

Refer to "Setting the On/Off Status" for the procedure for setting the On/Off status.

When you set the CMU's On/Off status to On, the dc bias output voltage (BIAS) entered is checked against the bias range (2). If the bias you set exceeds the bias range limits, an error message is displayed.

(7) Co

1. Position the cursor at (7).
2. Press Clear line to clear any previously set value.
3. Enter the desired capacitance zero-offset (Co) value.
4. Press Return.

Refer to "Error-Compensated Capacitance Measurements" for more on capacitance zero-offset.

DCS and CMU On/Off Status

On VFP control page 1, you can set the On/Off status of the DCS's SMUs and VSs, and the CMU's internal dc bias source. On and Off are described as follows, and "Setting the On/Off Status" describes how to set the On/Off status.

- On status:

  When you set an SMU or VS to On, it is set to the conditions displayed in the corresponding SMU or VS row of the DC MEASUREMENT portion of control page 1.

  When you set the CMU to On, its internal dc bias source is set to the conditions displayed in the CAPACITANCE MEASUREMENT portion of control page 1.

- Off status:

  When you set an SMU, VS, or the CMU's internal dc bias source to Off, it is set as listed in Table 2-1, regardless of the conditions displayed on control page 1. The Off status is similar to Zero Output, which is briefly discussed in the *System Information* manual.

Table 2-1. DCS and CMU Off Status

Subsystem	Source Unit	Setting
DCS	SMU Mode	V Source
	Output Voltage	0 V
	Voltage Range	20 V
	Current Compliance	100 μA
	VS Output Voltage	0 V
	Voltage Range	20 V
CMU	DC Bias Output Voltage	0 V
	DC Bias Range	10 V

The Off status is automatically set if you perform any of the following operations:

If you initialize your HP 4062C/UX/PC (select the `INIT SYSTEM` softkey), all DCS units and the CMU are set to Off.

If you control the SWM, all units connected to the SWM are set to Off.

If you change an SMU's mode setting, the SMU changed is set to Off.

Setting the On/Off Status

On VFP control page 1 (Figure 2-3), you can set the On/Off status for DCS units and the CMU selectively, or for all DCS units and the CMU simultaneously, as follows.

Setting On/Off selectively

The `ON / OFF` softkey toggles between On and Off for this operation.

- SMUs:

  Position the cursor anywhere in the row of the SMU you wish to set to On or Off, and select the `ON / OFF` softkey.

- VSs:

  Position the cursor anywhere in the AUX row of the VS you wish to set to On or Off, and select the `ON / OFF` softkey.

- CMU:

  Position the cursor anywhere in the CAPACITANCE MEASUREMENT portion of control page 1, and select the `ON / OFF` softkey.

Setting On/Off for all DCS units and the CMU simultaneously

To set all DCS units and the CMU to On or Off, select the `ALL ON` or `ALL OFF` softkey, regardless of the cursor's position.

DCS and CMU Measure/Not Measure Status

On VFP control page 1, you can set the Measure/Not Measure status of the DCS's measurement units and the CMU. Measure and Not Measure are described as follows, and "Setting the Measure/Not Measure Status" describes how to set the Measure/Not Measure status.

- Measure status:

  The Measure status enables measurements in VFP. To perform measurements, you must enable the selected DCS measurement unit(s) or CMU, or both, by setting the Measure/Not Measure status to Measure.

  If a DCS unit or the CMU is set to Measure, an asterisk (*) is displayed in the M (Measure) column for the selected DCS measurement unit(s) and/or the CMU.

- Not Measure status:

  The Not Measure status disables measurements in VFP. To disable measurements, set the selected DCS measurement unit(s) or CMU, or both, to Not Measure.

To minimize overall measurement time, set only the measurement units you need for your measurement to Measure.

Setting the Measure/Not Measure Status

The `MEAS / NOT MEAS` softkey toggles between Measure and Not Measure. Positioning the cursor for setting the Measure/Not Measure status is the same as that for "Setting On/Off selectively".

All DCS measurement units and the CMU are set to Not Measure after the START program and after you initialize your HP 4062C/UX/PC (selecting the `INIT SYSTEM` softkey).

Executing Measurements

To perform measurements from the VFP standalone control mode, enable the EXEC mode by selecting the `EXECUTE ON / OFF` softkey, which toggles between EXEC On and Off. Measurements execute repeatedly when the EXEC mode is enabled.

When you enable the EXEC mode, an inverse-video E appears below the PIN CONNECTION portion of control page 1, as shown in Figure 2-11 (6).

To disable the EXEC mode, select the `EXECUTE ON / OFF` softkey again (the inverse-video E no longer appears).

Only units whose Measure/Not Measure status is set to Measure—units with an asterisk (*) displayed in the M column—perform measurements when you enable the EXEC mode.

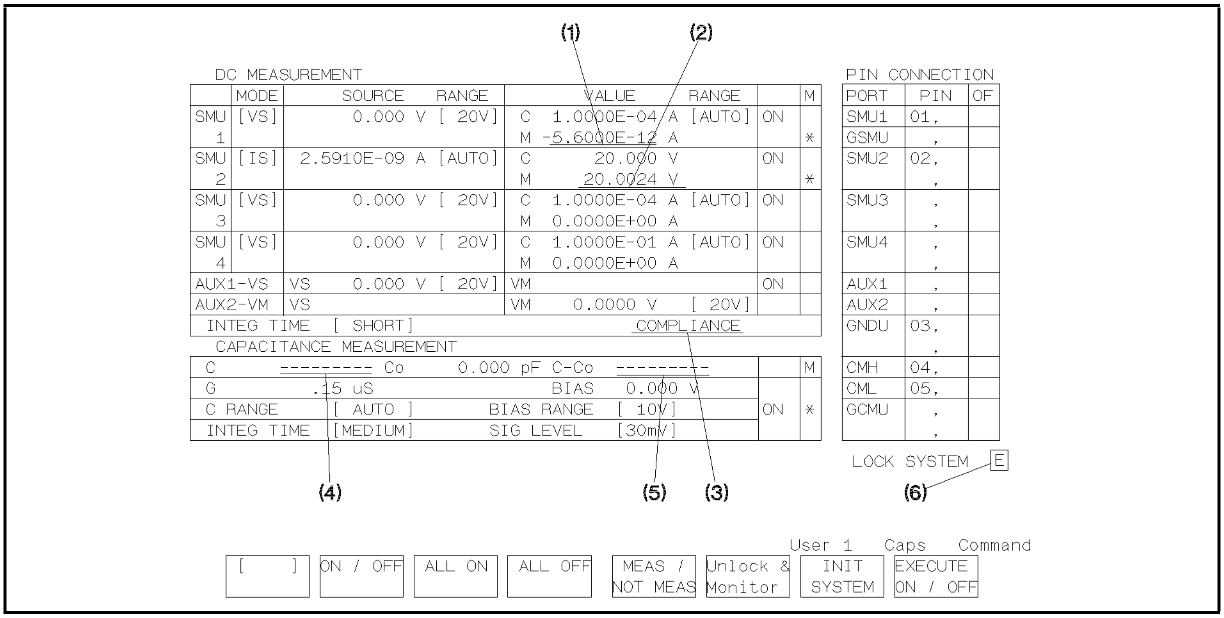


Figure 2-11. VFP Control Page 1—EXEC Mode

When the EXEC mode is enabled, you can use only the following softkey and keyboard keys:

The `EXECUTE ON / OFF` softkey to disable the EXEC mode.

The cursor control keys or the rotary knob to manually sweep voltage or current (see "Manually Swept Measurements").

The (Shift) (Reset/Break) keys to stop program execution.

EXEC Mode Displays

When you enable the EXEC mode, VFP control page 1 displays measurement results and the DCS's port status as described in the following paragraphs.

Measurement Results

Measurements execute repeatedly when you enable the EXEC mode, and displayed measurement results are refreshed (for units set to Measure) after each measurement executes.

As Figure 2-11 shows, DCS measurement results are displayed at (1) and (2), and CMU measurement results are displayed at (4) and (5).

If an overflow occurs during CMU measurements,—is displayed at (4) and (5).

DCS Port Status

During DCS measurements, if saturation or oscillation occurs, or if an SMU reaches compliance, the status of the DCS port where the condition occurs is displayed at (3) of Figure 2-11.

Table 2-2 lists the DCS port status items and provides a brief description of each.

Table 2-2. Port Status Items

Item	Description
blank	All units are working properly.
Saturation	The A/D converter connected to an SMU or VM is saturated.
Oscillation	An SMU or VS is oscillating.
Compliance	An SMU has reached compliance.

The priority in which DCS port status items are displayed is in the order listed in Table 2-2. For example, if saturation and oscillation occur at the same time, saturation is displayed.

Manually Swept Measurements

You can manually sweep DCS output voltage and current, and CMU dc bias voltage, by using the cursor control keys or the rotary knob. To do so, perform the following procedure:

1. Set the desired unit's Measure/Not Measure status to Measure by selecting the `MEAS / NOT MEAS` softkey.
2. Set up the measurement unit as required.
3. Position the cursor at the (output) value of the measurement unit.
4. Enable the EXEC mode to start measurements by selecting the `EXECUTE ON / OFF` softkey.
5. Press the cursor control key or rotate the rotary knob clockwise to increase output value. Conversely, press the cursor control key or rotate the rotary knob counterclockwise to decrease output value.

When you're finished making measurements, select the `EXECUTE ON / OFF` softkey to disable the EXEC mode.

Error-Compensated Capacitance Measurements

If you are making capacitance measurements using test fixtures, be sure to take into account the inherent stray capacitance of the test fixtures and cables. This capacitance zero-offset value must be eliminated to obtain accurate measurement results, and VFP control provides this capability.

This section describes the VFP control capacitance measurement items, and provides the procedure for performing error-compensated capacitance measurements when using the HP 4062C/UX/PC's test fixtures.

If you are using a wafer prober to perform wafer capacitance measurements, be sure to take into account the stray capacitance of your prober's cables and probe card.

Figure 2-12 shows the CAPACITANCE MEASUREMENT portion of VFP control page 1. The descriptions following the figure are keyed to the numbers in parentheses in the figure.

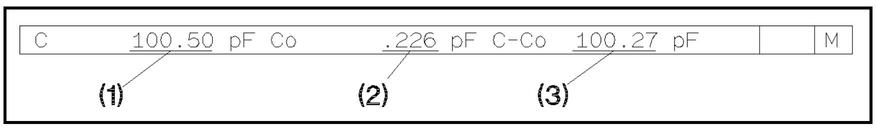


Figure 2-12. Capacitance Measurement Items

(1) Capacitance Measurement Value: C

This C measurement value is error-compensated for the residual impedances of the cables and the switching matrix. This value is the same as that obtained by the TIS Measure_cmu statement, but different from the raw data displayed on the CMU's front panel.

(2) Capacitance Zero-Offset Value: Co

Displays the capacitance zero-offset value Co setting. Co is the stray capacitance of the cables and the test fixture used.

(3) Corrected Capacitance Value: C-Co

Displays the true capacitance of the test device by subtracting the capacitance zero-offset value Co from the capacitance measurement value C.

To make an error-compensated capacitance measurement, perform the following procedure:

1. Install the test fixture adapter on the SWM and install the required test fixture in the test fixture adapter.
2. Close the test fixture adapter's shielding cover.
3. Connect the desired measurement port and pin(s) to the test fixture from the SWM display of VFP control page 1 before you install your test device in the fixture.
4. Set up the CMU as required (refer to "Controlling the CMU").
5. Select the `EXECUTE ON / OFF` softkey to enable the EXEC mode.
6. The stray capacitance measurement value is displayed at (1). Select the `EXECUTE ON / OFF` softkey again to stop measurements.

7. Press Shift and Menu to display the **C --> Co** softkey and select the **C --> Co** softkey to enter the stray capacitance measurement value (1) as the Co value (2).

8. Insert your test device into the test fixture and perform a measurement. The error-compensated capacitance value is displayed at (3).

Obtaining a Display Hard Copy

To obtain a hard copy of the system controller's display from VFP control, press (Shift) (Alpha) (Dump Alpha) or (Shift) (Graph) (Dump Graphics). The display is output to the printer specified by the DUMP DEVICE IS statement.

Default setting for the DUMP DEVICE IS statement is 701. If the HP-IB address of your printer is not 1, be sure to specify the DUMP DEVICE IS statement before you enter VFP control.

3

Measurement Programming

Introduction

This chapter provides Test Instruction Set (TIS) programming fundamentals, briefly explains TIS subprograms and their use, includes many programming examples, and describes VFP monitor mode operation.

HP 4062C/UX/PC's TIS software is a powerful tool that facilitates measurement programming. You can quickly and easily write measurement programs using TIS and HP 9000 Series 300 BASIC or BASIC/UX. Also, measurement programs that include TIS subprograms are much easier to document and maintain than programs written solely in BASIC or BASIC/UX.

In effect, TIS is a library of precompiled subprograms and user-defined functions. Because TIS subprograms are compiled, they execute much faster than comparable BASIC or BASIC/UX subprograms and functions. (See "CSUB" in the *BASIC* or *BASIC/UX Language Reference* for more details.)

In addition, you can use the utility subprograms PARA, XYGRAPH, DVR4284 and TIS_UTIL in conjunction with TIS subprograms to facilitate

1. the measurement of some of the more common dc semiconductor parameters,
2. the graphing of measurement results, and
3. the calculation of optimum parameters for analog search measurements.

Refer to the *Programming Reference* for complete TIS, PARA, XYGRAPH, DVR4284, and TIS_UTIL subprogram syntax and details.

Note

This chapter assumes that you have HP 9000 Series 300 Computer operating and programming experience. If this is not the case, refer to the following manuals to thoroughly familiarize yourself with your system controller so you can make the most efficient use of this chapter.

- For operating the HP 4062UX:

  A Beginners Guide to HP-UX
  Introducing UNIX System V
  Using the BASIC/UX System
  BASIC/UX Programming Techniques

- For operating the HP 4062C/PC:

  Using the BASIC System
  BASIC Programming Techniques

Before Programming

Before you begin measurement programming with TIS, you'll need to establish COM blocks for the system software, as described in this section.

Run the START program

Run the system software's START program to initialize your HP 4062C/UX/PC and create the COM blocks for TIS. Refer to Chapter 1 for details on how to execute START.

Note

For HP 4062UX, this chapter is written assuming online or online debug mode operation.

When the START program is finished, "START" end is displayed. After START, you can use the following key strokes to enter the edit mode to input measurement programs:

`SCRATCH` softkey (Return)

`EDIT` softkey (Return)

Note

Do *not* execute a SCRATCH A or SCRATCH C command at this time. Doing so destroys the COM blocks created by the START program.

Measurement Program Flow

Figure 3-1 shows the normal flow of a typical measurement program.

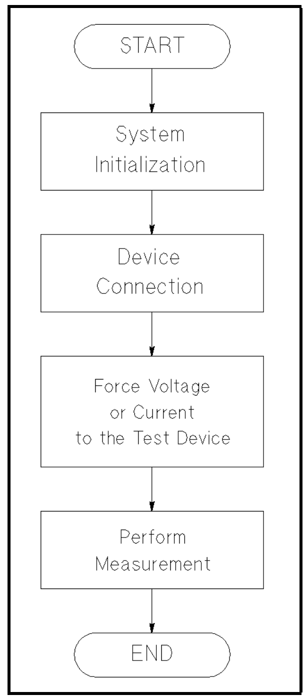
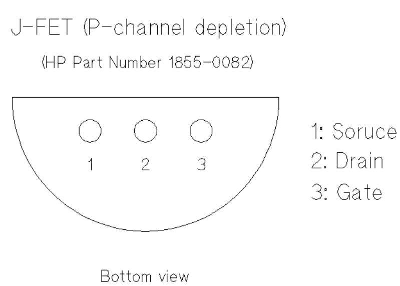


Figure 3-1. Typical Measurement Program Flow

The practical HP 4062C/UX/PC operation examples provided throughout the remainder of this chapter demonstrate TIS programming by performing measurements in accordance with this program flow.

Unless otherwise noted, the test device used for these examples is the following J-FET:



Be sure to link TIS and PARA before you execute a measurement program. To link TIS and the other required subprograms to your measurement program, perform the following procedure:

- For HP 4062UX:
  1. Select the `Link TIS` softkey.
  2. Type in `LOADSUB FROM "/usr/pcs/lib/`*subprogram*`"` (Return).
- For HP 4062C/PC with the recommended directory structure:
  1. Select the `Link TIS` softkey.
  2. Type in:

     `LOADSUB FROM "/PCS/LIB/`*subprogram*`"` (Return). *for HP 4062C/PC*
     `LOADSUB FROM "\PCS\LIB\`*subprogram*`"` (Return). *for HP 4062PC*
- For HP 4062C/PC with the flexible disks:
  1. Insert SYSTEM SOFTWARE (2) disk into your disk drive.
  2. Select the `Link TIS` softkey.
  3. Insert the SYSTEM SOFTWARE disk that contains the required subprogram into your disk drive.
  4. Type in `LOADSUB FROM "`*subprogram*`"` (Return).

If you execute a measurement program before you link TIS, you'll destroy the COM blocks created by the START program, and the following error message is displayed:

```
ERROR 7 IN 110 Undefined function or sub
```

Linking TIS at this point displays the following error message:

```
ERROR 145 IN 170 May not build COM at this time
```

If this occurs, run the START program again.

Storing Measurement Programs

You can store measurement programs that include TIS and other subprograms (PARA, VFP, and so on) just as you would BASIC or BASIC/UX programs. Note, however, that TIS and its related subprograms are large files. Measurement programs linked to TIS often exceed 100 kilobytes (KB), even if your program's measurement portion is only, for example, 1 KB.

To economize on disk space unlink TIS and other subprograms from your measurement programs before you store the programs by selecting the `Unlink & Store` softkey.

The `Unlink & Store` softkey deletes (unlinks) TIS—and subprograms linked *after* TIS—from your measurement program, and displays the typing aid `"RE-STORE "_"`. Simply type in the measurement program's file name at this prompt, press Return, and only the measurement portion of your program is stored.

If you link subprograms to your measurement program *before* you link TIS, however, the `Unlink & Store` softkey unlinks only TIS. That is, any subprograms you linked before TIS are still included with your measurement program when you select `Unlink & Store`.

To store subprograms other than TIS with your measurement program, therefore, be sure to link them before you link TIS.

If you select `Unlink & Store` and TIS is not linked, the following error message is displayed:

```
ERROR 133 DELSUB of nonexist or busy sub
```

In this instance, however, ignore this message.

Note

Use only the STORE and RE-STORE commands to store your TIS measurement programs. The SAVE command is invalid for storing measurement programs.

Initializing Your System

For initializing the system, TIS provides the following subprogram.

- Init_system

Init_system initialize all system instruments, except the wafer prober, and establishes the same system control settings as the START program. For more information on the initial control setting, see *System Information* .

Parameter Measurements Using PARA

For information on PARA subprograms, refer to Appendix D.

Resistance Measurements

For resistance measurements, PARA provides the following subprograms:

- FNR2t

  FNR2t is for two-terminal resistance measurements.

- FNR4t
- FNR4d

  FNR4t and FNR4d are for four-terminal pair (Kelvin connection) resistance measurements.

Figure 3-2 provides an example program for measuring sheet resistance using the PARA subprogram FNR2t. Figure 3-3 shows the measurement circuit used.

```
10   !
20   !  Sample Program
30   !    Requirements: TIS, PARA
40   !
50   INTEGER High,Low
60   High=1
70   Low=2
80   Itest=1.E-3
90   Compliance=30
100  !
110  Init_system
120  R=FNR2t(High,Low,Itest,Compliance)
130  PRINT "RESISTANCE=";R;"(ohm)"
140  !
150  END
160  !
```

Figure 3-2. Sample Program: FNR2t Resistance Measurement

line 30:	Shows the subprograms (TIS and PARA) that must be linked to the measurement program.
line 50:	Declares variables as type integer.
line 110:	Initializes the system.
line 120:	Performs a two-terminal resistance measurement.
line 130:	Prints measurement results.

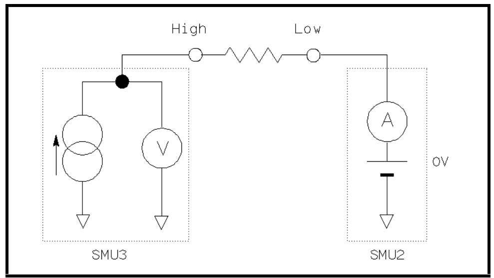


Figure 3-3. Two-Terminal Resistance Measurement Circuit

Transistor Measurements

For transistor dc parameter measurements, PARA provides the following subprograms:

- Set_tr
- FNBvcbo
- FNBvces
- FNHfe
- FNHfe1
- FNVIds
- FNVth1
- FNVth2
- FNVth2m
- FNVth3
- FNVth4
- FNVth5

  Set_tr connects the specified measurement pins to a transistor and passes these pin numbers to the specified function (FN) subprograms. You must specify Set_tr in your measurement program before any FN subprograms can execute.

Figure 3-4 provides an example program that performs a threshold voltage measurement using the PARA subprogram FNVth4. Figure 3-5 shows the measurement circuit used.

```
10   !
20   !  Sample Program
30   !    Requirements: TIS,PARA
40   !
50   INTEGER Source,Drain,Gate
60   Source=1
70   Drain=2
80   Gate=3
90   Id=-1.E-7
100  Vds=-2
110  Vgmin=.5
120  Vgmax=2
130  !
140  Init_system
150  Set_tr(Source,Gate,Drain)
160  Vth=FNVth4(Id,Vds,Vgmin,Vgmax)
170  PRINT "Vth=";Vth
180  !
190  END
200  !
```

Figure 3-4. Sample Program: FNVth4 Threshold Voltage Measurement

line 50: Declares the variables as type integer.

line 140: Initializes the system.

line 150: Connects the specified measurement pins to the test device (transistor) and passes these pin numbers to FNVth4 via the COM blocks.

line 160: Measures the transistor's threshold voltage.

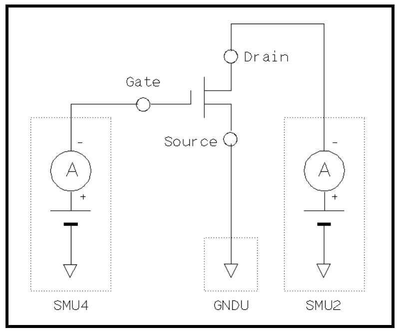


Figure 3-5. Threshold Voltage Measurement Circuit

Short Channel FET Measurements

For short channel multiple FET parameter measurements, PARA provides the following subprograms:

- Setmultitr
- FNDelta_l
- FNDelta_w

  Setmultitr subprogram connects the specified measurement pins to a multiple FET and passes these pin numbers to the FNDelta_l or FNDelta_w subprogram. You must specify Setmultitr in your multiple-FET measurement program before FNDelta_l or FNDelta_w can execute.

Figure 3-6 provides an example program that performs a short channel FET measurement using the PARA subprogram FNDelta_l. The test device used in this example is a MOSFET. Figure 3-7 shows the measurement circuit used.

```
10   !
20   !  Sample Program
30   !    Requirements: TIS, PARA
40   !
50   INTEGER Source,Gate,Substrate,Drain_1,Drain_2,Drain_3
60   Source=1
70   Gate=2
80   Substrate=3
90   Drain_1=4
100  Drain_2=5
110  Drain_3=6
120  D1_length=3
130  D2_length=4
140  D3_length=5
150  Vds=.05
160  Vgs=3
170  !
180  Init_system
190  Setmultitr(Source,Gate,Substrate,Drain_1,Drain_2,Drain_3)
200  Deltal=FNDelta_l(Vds,Vgs,D1_length,D2_length,D3_length)
210  PRINT "Delta L=";Deltal;"um"
220  !
230  END
240  !
```

Figure 3-6. Sample Program: Lateral Diffusion Measurement

lines 50 through 160:	Declare variables as type integer and assign constants.
line 190:	Connects the specified measurement pins to the test device and passes these pin numbers to the FNDelta_l subprogram via the COM blocks.
line 200:	Measures and calculates lateral diffusion ΔL.

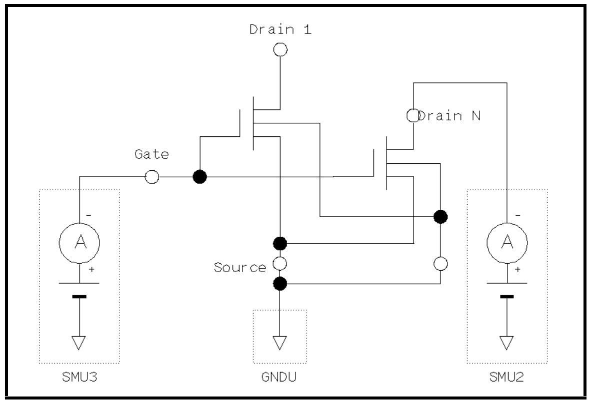


Figure 3-7. Lateral Diffusion Measurement Circuit

Connecting Pins and Ports

For connecting measurement pins to ports, TIS provides the following subprograms:

- Connect
- Connect_th

  You can connect up to 12 measurement pins per port with a single Connect subprogram, without clearing previous SWM settings.

  Be sure, however, that you do *not* connect the same pin to more than one port at a time.

  If the same pin number appears in two or more Connect subprograms that specify different ports, only the port specified in the most recently defined Connect subprogram is connected to the measurement pin.

Figure 3-8 provides an example program of how to use the Connect subprogram.

```
10   !
20   !  Sample Program
30   !    Requirements: TIS,VFP
40   !
50   INTEGER Source,Drain,Gate
60   Source=1
70   Drain=2
80   Gate=3
90   !
100  Init_system
110  Connect(FNSmu(1),Drain)
120  Connect(FNSmu(2),Gate)
130  Connect(FNGnd,Source)
140  !
150  Vfp_frame
160  !
170  END
180  !
```

Figure 3-8. Sample Program: Using The Connect Subprogram

lines 110 through 130:	Connect the specified pins and measurement ports.
line 150:	Displays VFP page (for monitoring purposes only).

Figure 3-8 also links the VFP subprogram (see line 30) for using the VFP in the monitor mode. When line 150 executes, VFP page is displayed, as shown in the following illustration.

DC MEASUREMENT

	MODE	SOURCE RANGE	COMPLIANCE/MONITOR		M
SMU 1	[VS]	0.000 V [20V]	C 1.0000E-04 A [AUTO] M 0.0000E+00 A	OFF	
SMU 2	[VS]	0.000 V [20V]	C 1.0000E-01 A [AUTO] M 0.0000E+00 A	OFF	
SMU 3	[VS]	0.000 V [20V]	C 1.0000E-04 A [AUTO] M 0.0000E+00 A	OFF	
SMU 4	[VS]	0.000 V [20V]	C 1.0000E-01 A [AUTO] M 0.0000E+00 A	OFF	
AUX1-VS	VS	0.000 V [20V]	VM	OFF	
AUX2-VM	VS		VM 0.0000 V [20V]		
INTEG TIME [SHORT]					

CAPACITANCE MEASUREMENT

C 0.000 pF	Co 0.000 pF	C-Co 0.000 pF		M
G 0.00 uS		BIAS 0.000 V	OFF	
C RANGE [AUTO]		BIAS RANGE [10V]		
INTEG TIME [MEDIUM]		SIG LEVEL [30mV]		

PIN CONNECTION

PORT	PIN	OF
SMU1	02,	
GSMU	,	
SMU2	03, ,	
SNU3	, ,	
SMU4	, ,	
AUX1	,	
AUX2	,	
GNDU	01, ,	
CMH	,	
CML	,	
GCMU	, ,	

On this page, you can verify pin-to-port connections by observing the PIN CONNECTION area of the display, as well as observing measurement results on the remaining VFP page areas.

General I-V Measurements

For general I-V measurement controls, TIS provides the following subprograms:

- Force_v

  Sets the output dc voltage of the specified SMU or VS.

  One advantage of the Force_v subprogram is that you can specify the source you wish to use by specifying the source's port address or any measurement pin connected to the source.

  Figure 3-9 provides an example program of how to use Force_v.

- Force_i

  Sets the specified SMU's output dc current. You can specify the SMU you wish to use in the same manner as described for Force_v.

- Set_smu

  Sets the measurement integration time and filter mode for SMUs, VSs, and VMs.

- Set_vm

  Sets VMs to grounded or differential measurement mode.

- Measure_v

  Performs dc voltage measurements using a specified SMU or VM.

  You can specify the desired measurement unit (SMU or VM) by specifying the unit's port address or any measurement pin connected to the unit.

- Measure_i

  Performs dc current measurements using a specified SMU or VS.

  You can specify the desired measurement unit (SMU or VS) by specifying the unit's port address or any measurement pin connected to the unit.

  Figure 3-10 provides an example program of how to use Measure_i.

- Force_meas

  Controls voltage or current output and measurement.

  Figure 3-11 provides an example program of how to use Force_meas.

```
10   !
20   !  Sample Program
30   !    Requirements: TIS,VFP
40   !
50   INTEGER Source,Drain,Gate
60   Source=1
70   Drain=2
80   Gate=3
90   !
100  Init_system
110  Connect(FNSmu(1),Drain)
120  Connect(FNSmu(2),Gate)
130  Connect(FNGnd,Source)
140  !
150  Vfp_frame
160  PAUSE
170  !
180  Vd=-5
190  Vg=.4
200  Compliance=1.E-2
210  !
220  Force_v(Gate,Vg)
230  Force_v(Drain,Vd,Vd,Compliance)
240  !
250  Vfp_monitor
260  !
270  END
280  !
```

Figure 3-9. Sample Program: Voltage Output Using Force_v

This program is the same as Figure 3-8, with the addition of lines 160 through 250. The functions of the new program lines are as follows:

line 160: Temporarily suspends (pauses) program execution.

lines 220 and 230: Output voltage to the test device.

line 250: Refreshes the VFP monitor display.

Figure 3-10 provides an example program that performs a current measurement using the Measure_i subprogram.

```
10   !
20   !  Sample Program
30   !    Requirements: TIS
40   !
50   INTEGER Source,Drain,Gate,Integ_time
60   Source=1
70   Drain=2
80   Gate=3
90   Vstart=0
100  Vstop=-4
110  Vstep=-.1
120  Compliance=1.E-2
130  Vg=.4
140  Integ_time=2
150  !
160  Init_system
170  Set_smu(Integ_time)
180  Connect(FNSmu(1),Drain)
190  Connect(FNSmu(2),Gate)
200  Connect(FNGnd,Source)
210  Force_v(Gate,Vg)
220  !
230  FOR Vd=Vstart TO Vstop STEP Vstep
240    Force_v(Drain,Vd,Vstop,Compliance)
250    Measure_i(Drain,Id)
260    PRINT "Vd=",Vd;"V","Id=",Id*1000;"mA"
270  NEXT Vd
280  !
290  Disable_port
300  Connect
310  !
320  END
330  !
```

Figure 3-10. Sample Program: Current Measurement Using Measure_i

line 170:	Sets SMU (or VM) measurement integration time.
lines 230 through 270:	Decrement (see lines 90, 100) the drain voltage, measure the drain current at each step V, and print both.

Figure 3-11 provides an example program that performs a current measurement using Force_meas.

```
10   !
20   !  Sample Program
30   !    Requirements: TIS
40   !
50   INTEGER Source,Drain,Gate,Integ_time
60   Source=1
70   Drain=2
80   Gate=3
90   Vstart=0
100  Vstop=-4
110  Vstep=-.1
120  Compliance=1.E-2
130  Vg=.4
140  Integ_time=2
150  !
160  Init_system
170  Set_smu(Integ_time)
180  Connect(FNSmu(1),Drain)
190  Connect(FNSmu(2),Gate)
200  Connect(FNGnd,Source)
210  Force_v(Gate,Vg)
220  !
230  FOR Vd=Vstart TO Vstop STEP Vstep
240    Force_meas(Drain,Drain,1,Vd,Id,Vstop,0,Compliance)
250    PRINT "Vd=";Vd;"V","Id=",Id*1000,"mA"
260  NEXT Vd
270  !
280  Disable_port
290  Connect
300  !
310  END
320  !
```

Figure 3-11. Sample Program: Current Measurement Using Force_meas

lines 230 through 260: Decrement the drain voltage, measure the drain current at each step V, and print both.

XYGRAPH Subprograms

For generating graphics plots of measurement results, TIS provides the following XYGRAPH utility subprograms:

- Lingraph
- Lingraph1
- Loggraph
- Loggraph1
- Cvgraph

When using XYGRAPH subprograms, be sure to link XYGRAPH to your measurement program.

For more information on XYGRAPH, refer to Appendix D.

Figure 3-12 provides an example program that plots the results of the measurement performed in Figure 3-10 using the XYGRAPH subprogram Lingraph.

```
10   !
20   !  Sample Program
30   !    Requirements: TIS,XYGRAPH
40   !
50   OPTION BASE 1
60   DIM Vd(1001),Id(1001)
70   INTEGER Source,Drain,Gate,Point,Integ_time
80   Source=1
90   Drain=2
100  Gate=3
110  Vstart=0
120  Vstop=-10
130  Vstep=-.1
140  Compliance=1.E-2
150  Vg=.4
160  Integ_time=2
170  Point=INT((Vstop-Vstart)/Vstep)+1
180  !
190  Init_system
200  Set_smu(Integ_time)
210  Connect(FNSmu(1),Drain)
220  Connect(FNSmu(2),Gate)
230  Connect(FNGnd,Source)
240  Force_v(Gate,Vg)
250  !
260  FOR I=1 TO Point
270    Vd(I)=Vstart+Vstep*(I-1)
280    Force_meas(Drain,Drain,1,Vd(I),Id(I),Vstop,0,Compliance)
290    PRINT I
300  NEXT I
310  !
320  Lingraph(Vstop,Id(Point)*1000,"DRAIN VOLTAGE (V)","DRAIN CURRENT (mA)"
,"VD-ID CURVE",1)
330  !
340  FOR I=1 TO Point
350    DRAW Vd(I),Id(I)*1000
360  NEXT I
370  !
380  Disable_port
390  Connect
400  !
410  END
420  !
```

Figure 3-12. Sample Program: Graphics Output Using Lingraph

line 320: Draws optimized X- and Y-axes, and a graph name.

lines 340 through 360: Draw the resultant curve from the measurement data.

When Figure 3-12 executes, the X-Y graph shown in Figure 3-13 is displayed.

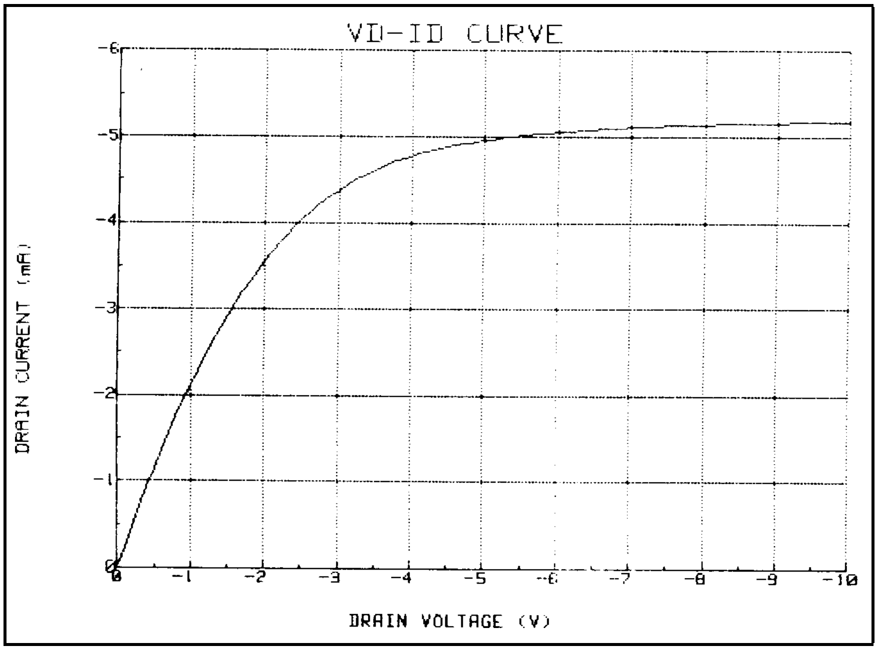


Figure 3-13. Sample XYGRAPH

Sweep, Pulsed, and Pulsed Sweep I-V Measurements

For sweep, pulsed, and pulsed sweep measurements, TIS provides the following subprograms:

- Set_iv
- Set_pbias
- Set_piv

  Set the parameters for swept I-V, pulsed I/V, and pulsed I-V sweep measurements, respectively.

- Sweep_miv

  Performs swept measurements in accordance with the conditions established by Set_iv.

- Sweep_iv

  Performs swept measurements or pulsed measurements in accordance with the conditions established by Set_iv, Set_pbias, and Set_piv.

- Rsweep_miv

  Performs real-time swept measurements in accordance with the conditions established by Set_iv.

- Rsweep_iv

  Performs real-time swept measurements or pulsed measurements in accordance with the conditions established by Set_iv, Set_pbias, and Set_piv.

- Rsweep_stop

  Stops real-time swept measurements established by Rsweep_miv or Rsweep_iv.

- Set_sync

  Sets a synchronous port and its parameters for a synchronous search measurement or a synchronous staircase sweep measurement.

Note

When performing sweep measurements, specify the desired Set subprogram before its corresponding Sweep subprogram. For example, specify Set_iv before Sweep_iv executes.

If you omit Set subprograms or do not specify their parameters, the parameters specified in the most recent Set subprogram will apply.

Refer to Figure 3-18, Figure 3-19, and Figure 3-20 for examples.

- Measure_p

  Performs pulsed voltage or current measurements using a specified SMU or VM. You can specify a measurement unit (SMU or VM) by specifying the unit's address, port address, or any measurement pin connected to the unit.

- Staircase Sweep Measurements

SMU and VS output can be swept in a staircase manner as shown in Figure 3-14.

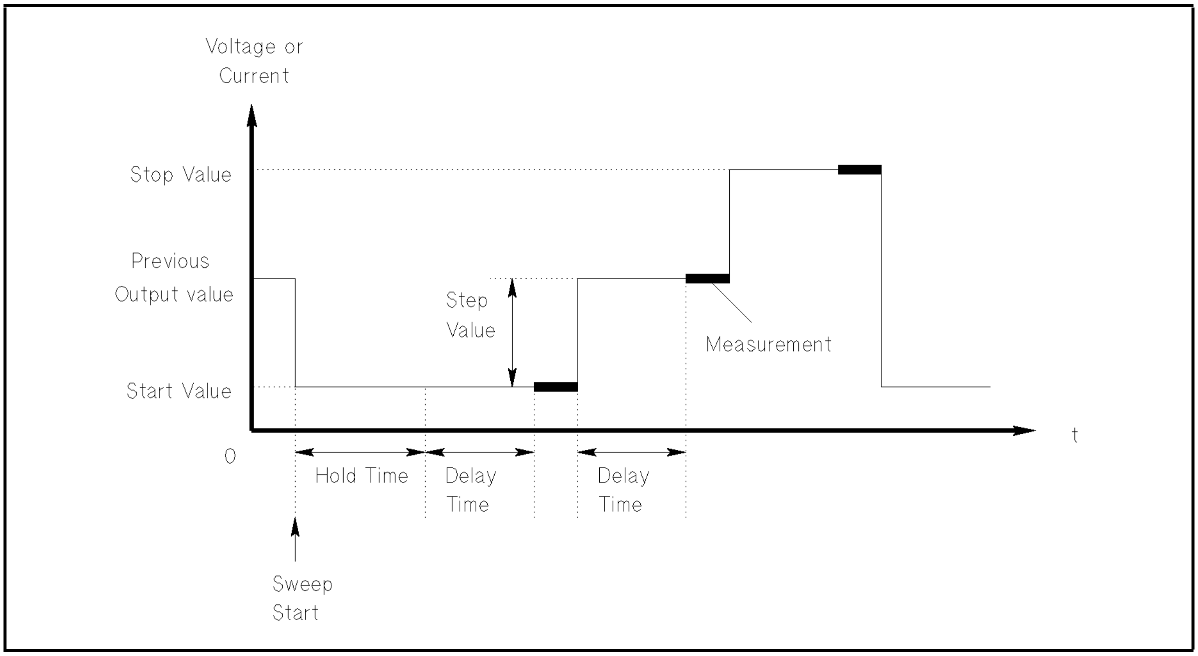


Figure 3-14. DCS Staircase Sweep Measurement Output

- Pulsed Bias Spot Measurements

SMU and VS output can be pulsed as shown in Figure 3-15.

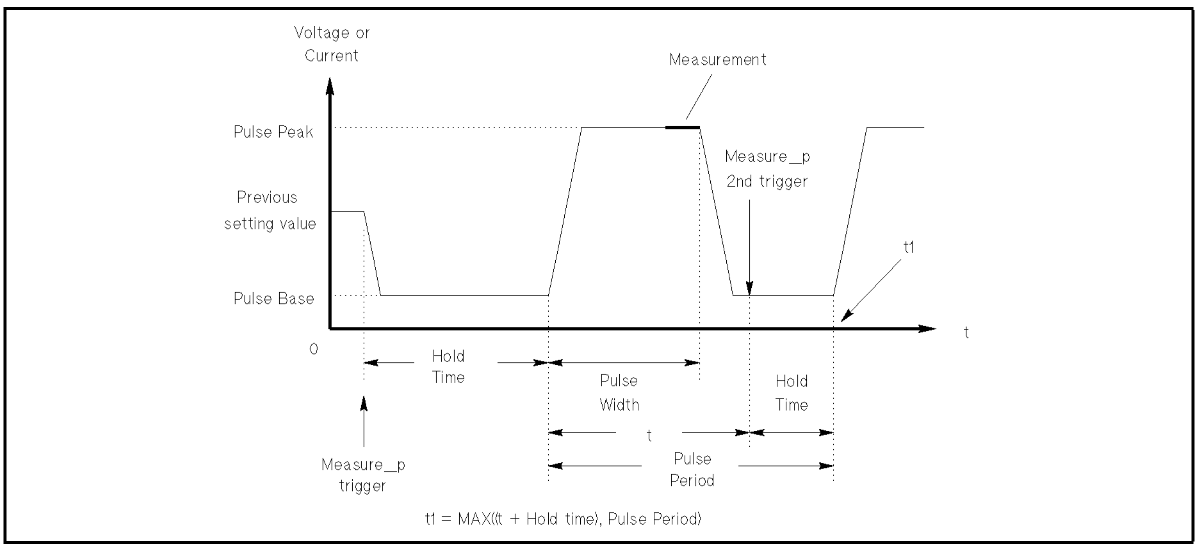


Figure 3-15. DCS Pulsed Bias Spot Measurement Output

- Pulsed Bias Sweep Measurements

SMU and VS output can be swept in a staircase manner with pulsed bias as shown in Figure 3-16.

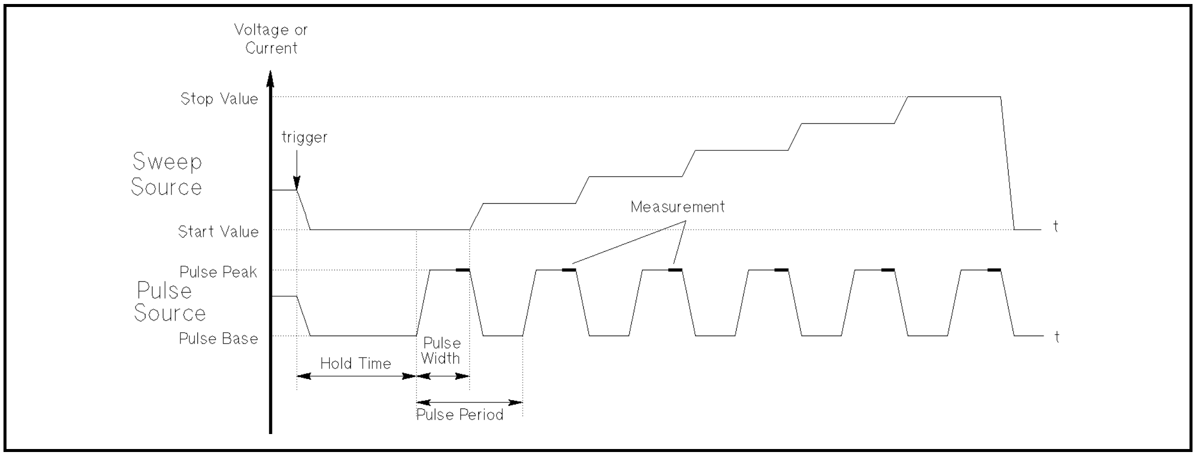


Figure 3-16. Pulsed Bias Measurement Sweep Output

- Pulsed Sweep Measurements

SMU or VS sweep output can be pulsed as shown in Figure 3-17.

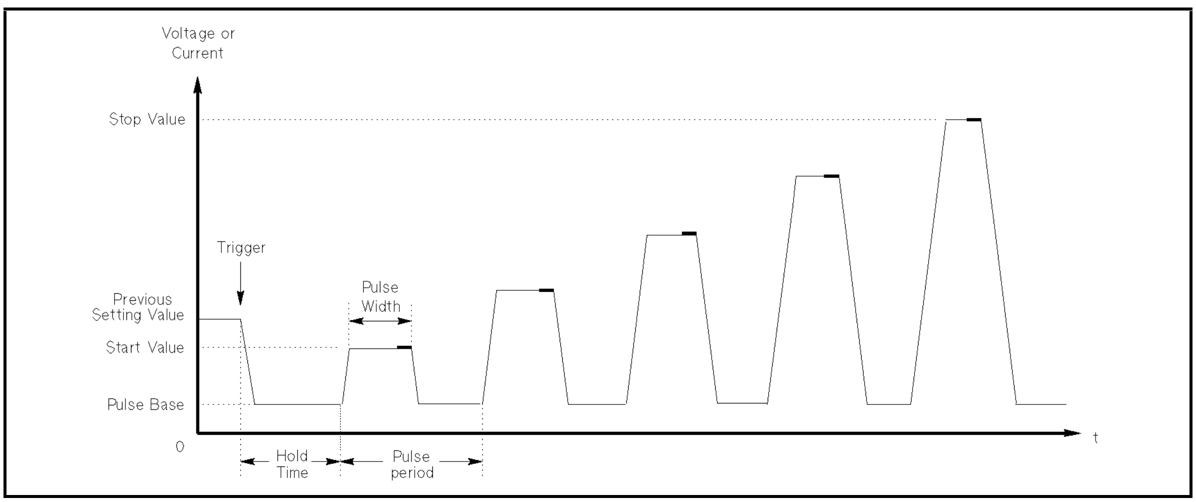


Figure 3-17. DCS Pulsed Sweep Measurement Output

Figure 3-18 provides an example program of a swept I-V measurement.

```
10   !
20   !  Sample Program
30   !    Requirements: TIS,XYGRAPH
40   !
50   OPTION BASE 1
60   DIM Vd(1001),Id(1001)
70   INTEGER Source,Drain,Gate,Point,Integ_time
80   Source=1
90   Drain=2
100  Gate=3
110  Vstart=0
120  Vstop=-10
130  Vstep=-.1
140  Compliance=1.E-2
150  Vg=.4
160  Integ_time=2
170  Point=INT((Vstop-Vstart)/Vstep)+1
180  !
190  Init_system
200  Set_smu(Integ_time)
210  Connect(FNSmu(1),Drain)
220  Connect(FNSmu(2),Gate)
230  Connect(FNGnd,Source)
240  Force_v(Gate,Vg)
250  !
260  Set_iv(Drain,1,0,Vstart,Vstop,Point,0,0,Compliance)
270  Sweep_iv(Drain,2,0,Id(*),Vd(*))
280  !
290  Lingraph(Vstop,Id(Point)*1000,"DRAIN VOLTAGE (V)","DRAIN CURRENT (mA)"
,"VD-ID CURVE",1)
300  !
310  FOR I=1 TO Point
320    DRAW Vd(I),Id(I)*1000
330  NEXT I
340  !
350  Disable_port
360  Connect
370  !
380  END
390  !
```

Figure 3-18. Sample Program: Swept I-V Measurement

line 260: Sets the swept I-V measurement parameters.

line 270: Executes the measurement.

Figure 3-19 provides an example program of a swept multichannel I-V measurement.

```
10   !
20   !  Sample Program
30   !    Requirements: TIS
40   !
50   OPTION BASE 1
60   DIM Vd(1001),Id(1001),Ig(1001),Range(2)
70   INTEGER Source,Drain,Gate,Point,Integ_time,Port(2)
80   Source=1
90   Drain=2
100  Gate=3
110  Port(1)=Drain
120  Port(2)=Gate
130  Vstart=0
140  Vstop=-10
150  Vstep=-.1
160  Compliance=1.E-2
170  Vg=.4
180  Range(1)=Compliance
190  Range(2)=1.E-9
200  Integ_time=2
210  Point=INT((Vstop-Vstart)/Vstep)+1
220  !
230  Init_system
240  Set_smu(Integ_time)
250  Connect(FNSmu(1),Drain)
260  Connect(FNSmu(2),Gate)
270  Connect(FNGnd,Source)
280  Force_v(Gate,Vg)
290  !
300  Set_iv(Drain,1,0,Vstart,Vstop,Point,0,0,Compliance)
310  Sweep_miv(Port(*),Range(*),Id(*),Ig(*),Vd(*))
320  !
330  IMAGE "Vd=",M2D.D,"V",3X,"Id=",M2D.3D,"mA",3X,"Ig=",MD.3DE,"mA"
340  FOR I=1 TO Point
350    PRINT USING 330;Vd(I),Id(I)*1000,Ig(I)*1000
360  NEXT I
370  !
380  Disable_port
390  Connect
400  !
410  END
420  !
```

Figure 3-19. Sample Program: Swept Multichannel I-V Measurement

line 300: Sets the swept I-V measurement parameters.

line 310: Executes the measurement.

Figure 3-20 provides an example program of a real-time swept I-V measurement.

```
10   !
20   !  Sample Program
30   !    Requirements: TIS,XYGRAPH
40   !
50   OPTION BASE 1
60   INTEGER Source,Drain,Gate,Point,Integ_time,Status
70   Source=1
80   Drain=2
90   Gate=3
100  Vstart=0
110  Vstop=-10
120  Vstep=-.1
130  Compliance=1.E-2
140  Vg=.4
150  Integ_time=2
160  Point=INT((Vstop-Vstart)/Vstep)+1
170  !
180  Init_system
190  Set_smu(Integ_time)
200  Connect(FNSmu(1),Drain)
210  Connect(FNSmu(2),Gate)
220  Connect(FNGnd,Source)
230  Force_v(Gate,Vg)
240  !
250  Lingraph(Vstop,Compliance*1000,"DRAIN VOLTAGE (V)","DRAIN CURRENT (mA)
","VD-ID CURVE",1)
260  !
270  Set_iv(Drain,1,0,Vstart,Vstop,Point,0,0,Compliance)
280  !
290  FOR I=1 TO Point
300    Rsweep_iv(Drain,2,0,Id,Status,Vd)
310    DRAW Vd,Id*1000
320  NEXT I
330  !
340  Disable_port
350  Connect
360  !
370  END
380  !
```

Figure 3-20. Sample Program: Real-time Swept I-V Measurement

line 250:	Draws X- and Y-axes, and a graph name.
line 270:	Sets the swept I-V measurement parameters.
line 300:	Executes the real-time swept measurement.
line 310:	Draws the result curve from the measurement data.

Capacitance Measurements Using CMU

For capacitance measurements using CMU, TIS provides the following subprograms and a TIS_UTIL utility subprogram (Conv_mode):

- Set_cmu

  Sets CMU integration time and test signal level.

- Measure_cmu

  Performs capacitance and conductance measurements and returns error-compensated measurement results.

  Note that CMU capacitance measurement results include stray capacitance and do not represent a test device's true capacitance value. To obtain true capacitance values, perform the following procedure.

  1. With *nothing* connected to your test fixture, execute Measure_cmu to obtain the capacitance zero-offset value Co. Note this value.
  2. Connect your test device, execute Measure_cmu, and note the capacitance measurement value C.
  3. Subtract Co from C to obtain the true capacitance value.

- Set_cv
- Set_ct

  Set the parameters for swept C-V and C-t measurements.

- Sweep_cv
- Sweep_ct

  Perform swept measurements in accordance with the conditions established by Set_cv and Set_ct, respectively.

- Force_v

  Sets the internal dc bias source of the CMU.

- Disable_port

  Sets the specified ports, units, or measurement pins to Zero Output status.

- Conv_mode

  Converts the capacitance and conductance measurement values obtained by Measure_cmu to the capacitance and resistance values of a series equivalent circuit, and returns the values.

■ C-V Measurements

To facilitate test device C-V characterization, the CMU's internal dc bias source output can be swept in a staircase manner as shown in Figure 3-21.

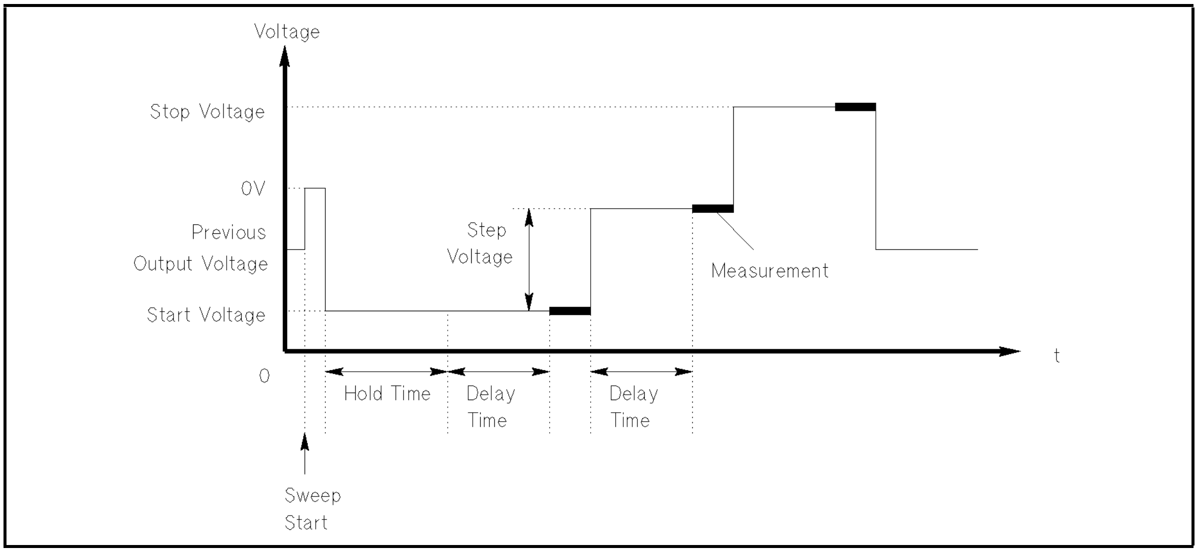


Figure 3-21. C-V Sweep Measurement Output

■ C-t Measurements

The CMU performs C-t measurements by applying a bias pulse to a device under test (DUT), then by measuring capacitance at constant user-specified intervals. Figure 3-22 shows the C-t measurement sequence along with the various measurement parameters.

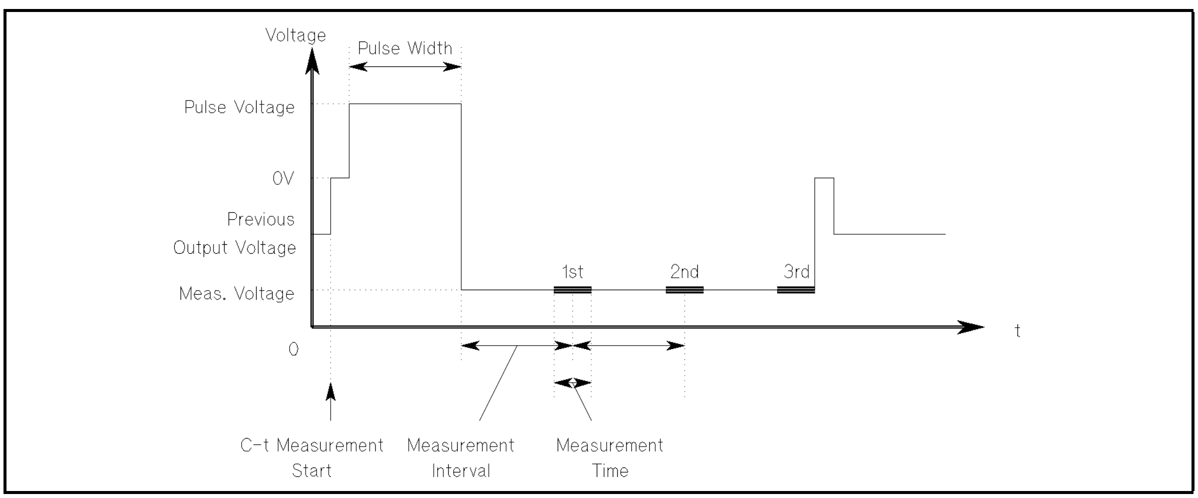
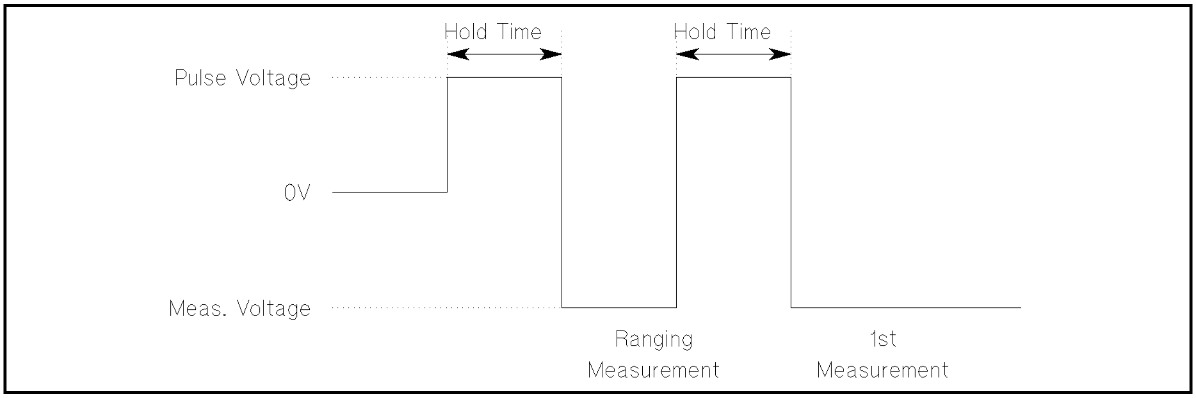


Figure 3-22. C-t Measurement Sequence

If range changing occurs before the 1st measurement completes, the bias pulse is applied again, and measurement is performed as follows:



C-t Measurement Sequence (Continued)

Figure 3-24 provides an example program of a stray capacitance error-compensation. This program also shows how to use the Cvgraph subprogram. The test device used for this example is a MOS capacitor.

To run this program, install the Low Leakage Test Fixture—via the Test Fixture Adapter—on the SWM. With nothing connected to the test fixture, close the test fixture adapter's cover and select the RUN softkey to measure the capacitance offset value. Connect the test device to the fixture following the displayed instructions to obtain the error-compensated capacitance measurement results and a graph of the test device's characteristics.

Figure 3-23 shows the test device's measurement pin assignments, and Figure 3-25 shows an example C-V characteristic curve for the MOS capacitor used in this sample program.

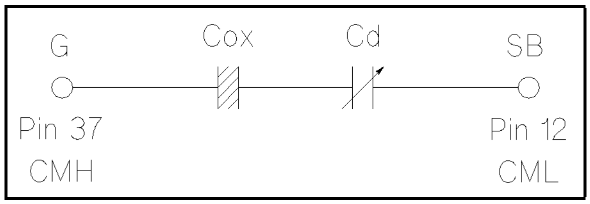


Figure 3-23. Pin Assignments for Capacitance Measurements Using CMU

```
10   !
20   !  Sample Program
30   !    Requirements: TIS,XYGRAPH
40   !
50   OPTION BASE 1
60   DIM Cdata(101),Gdata(101),Vdata(101)
70   INTEGER Gate,Substrate,Point,Integ_time,Sig_level
80   Gate=37
90   Substrate=12
100  Vstart=5
110  Vstop=-5
120  Vstep=-.1
130  Point=INT((Vstop-Vstart)/Vstep)+1
140  Integ_time=2
150  Sig_level=2
160  Hold_time=60
170  !
180  Init_system
190  Set_cmu(Integ_time,Sig_level)
200  Connect(FNCmh,Gate)
210  Connect(FNCml,Substrate)
220  Measure_cmu(Coff)
230  !
240  BEEP
250  DISP "Connect test device to the fixture, close the shielding cover, a
nd press Continue."
260  PAUSE
270  !
280  DISP
290  Force_v(Gate,Vstart,Vstart)
300  WAIT Hold_time
310  !
320  FOR I=1 TO Point
330    Vdata(I)=Vstart+Vstep*(I-1)
340    Force_v(Gate,Vdata(I),Vstart)
350    Measure_cmu(Cdata(I),Gdata(I))
360  NEXT I
370  !
380  MAT Cdata= Cdata-(Coff)
390  MAT Cdata= Cdata*(1.E+12)
400  !
410  Cvgraph(MAX(Vdata(*)),MAX(Cdata(*)),"GATE VOLTAGE (V)","GATE CAPACITAN
CE (pF)","C-V CURVE",1)
420  !
```

Figure 3-24. Sample Program: Capacitance Measurement Using CMU

```
430  MOVE Vdata(1),Cdata(1)
440  FOR I=1 TO Point
450    DRAW Vdata(I),Cdata(I)
460  NEXT I
470  !
480  Disable_port
490  Connect
500  !
510  END
520  !
```

Sample Program: Capacitance Measurement Using CMU (Continued)

lines 50 through 160:	Declare measurement data array variables and assign constants.
lines 180 through 220:	Initialize the system and measure the test fixture's capacitance (with no test device connected) to obtain the capacitance zero-offset value.
lines 290 and 300:	Output the start V and wait the specified hold time.
lines 320 through 360:	Perform a swept C-V measurement.
lines 380 and 390:	Calculate the test device's true capacitance (subtracts zero-offset value from capacitance measurement value) and convert measurement results from Farads to pico Farads.
line 410:	Draws optimized X- and Y-axes, and graph labels.

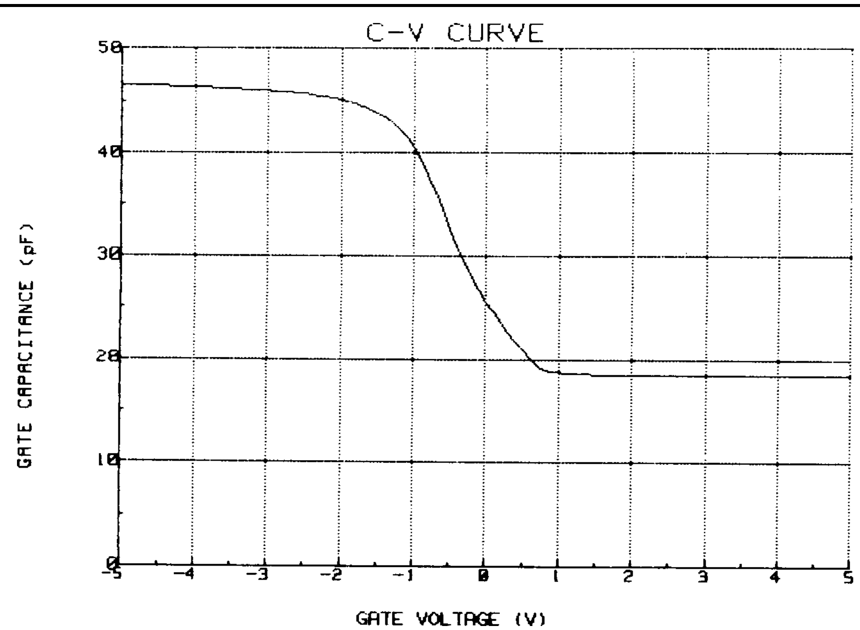


Figure 3-25. MOS Capacitor Characteristic C-V Curve Measured by CMU

Figure 3-26 provides an example program of a swept C-V measurement.

```
10   !
20   !  Sample Program
30   !    Requirements: TIS,XYGRAPH
40   !
50   OPTION BASE 1
60   DIM Cdata(101),Gdata(101),Vdata(101)
70   INTEGER Gate,Substrate,Point,Integ_time,Sig_level
80   Gate=37
90   Substrate=12
100  Vstart=5
110  Vstop=-5
120  Vstep=-.1
130  Point=INT((Vstop-Vstart)/Vstep)+1
140  Integ_time=2
150  Sig_level=2
160  Hold_time=60
170  !
180  Init_system
190  Set_cmu(Integ_time,Sig_level)
200  Connect(FNCmh,Gate)
210  Connect(FNCml,Substrate)
220  Measure_cmu(Coff)
230  !
240  BEEP
250  DISP "Connect test device to the fixture, close the shielding cover, a
nd press Continue."
260  PAUSE
270  !
280  DISP
290  Set_cv(Vstart,Vstop,Point,Hold_time)
300  Sweep_cv(0,Cdata(*),Gdata(*),Vdata(*))
310  !
320  MAT Cdata= Cdata-(Coff)
330  MAT Cdata= Cdata*(1.E+12)
340  !
350  Cvgraph(MAX(Vdata(*)),MAX(Cdata(*)),"GATE VOLTAGE (V)","GATE CAPACITAN
CE (pF)","C-V CURVE",1)
460  !
370  MOVE Vdata(1),Cdata(1)
380  FOR I=1 TO Point
390    DRAW Vdata(I),Cdata(I)
400  NEXT I
410  !
420  Disable_port
430  Connect
```

Figure 3-26. Sample Program: Swept C-V Measurement Using CMU

```
440 !
450 END
460 !
```

Sample Program: Swept C-V Measurement Using CMU (Continued)

line 290:	Sets the swept C-V measurement parameters.
line 300:	Executes the measurement and returns capacitance and conductance measurement values to the array variables.

Figure 3-27 provides an example program of a swept C-t measurement. Figure 3-28 shows an example C-t characteristic curve for the MOS capacitor used in the sample program.

```
10   !
20   !  Sample Program
30   !    Requirements: TIS,XYGRAPH
40   !
50   OPTION BASE 1
60   DIM Cdata(40),Gdata(40),Time(40)
70   INTEGER Gate,Substrate,Point,Integ_time,Sig_level
80   Gate=37
90   Substrate=12
100  Vaccumulation=-5
110  Vdepletion=5
120  Point=40
130  Integ_time=2
140  Sig_level=2
150  Hold_time=1
160  Delay_time=2
170  !
180  Init_system
190  Set_cmu(Integ_time,Sig_level)
200  Connect(FNCmh,Gate)
210  Connect(FNCml,Substrate)
220  Measure_cmu(Coff)
230  !
240  BEEP
250  DISP "Connect test device to the fixture, close the shielding cover, a
nd press Continue."
260  PAUSE
270  !
280  DISP
290  Set_ct(Vaccumulation,Vdepletion,Point,Hold_time,Delay_time)
300  Sweep_ct(1.E-10,Cdata(*),Gdata(*),Time(*))
310  !
320  MAT Cdata= Cdata-(Coff)
330  MAT Cdata= Cdata*(1.E+12)
340  !
350  Lingraph(MAX(Time(*)),MAX(Cdata(*)),"TIME (s)","CAPACITANCE (pF)","C-t
 CURVE",1)
460  !
370  MOVE Time(1),Cdata(1)
380  FOR I=1 TO Point
390    DRAW Time(I),Cdata(I)
400  NEXT I
410  !
420  Disable_port
```

Figure 3-27. Sample Program: Swept C-t Measurement

```
430  Connect
440  !
450  END
460  !
```

Sample Program: Swept C-t Measurement (Continued)

lines 290 and 300:	Perform a C-t measurement.
line 350:	Draws optimized X- and Y-axes, and graph labels.

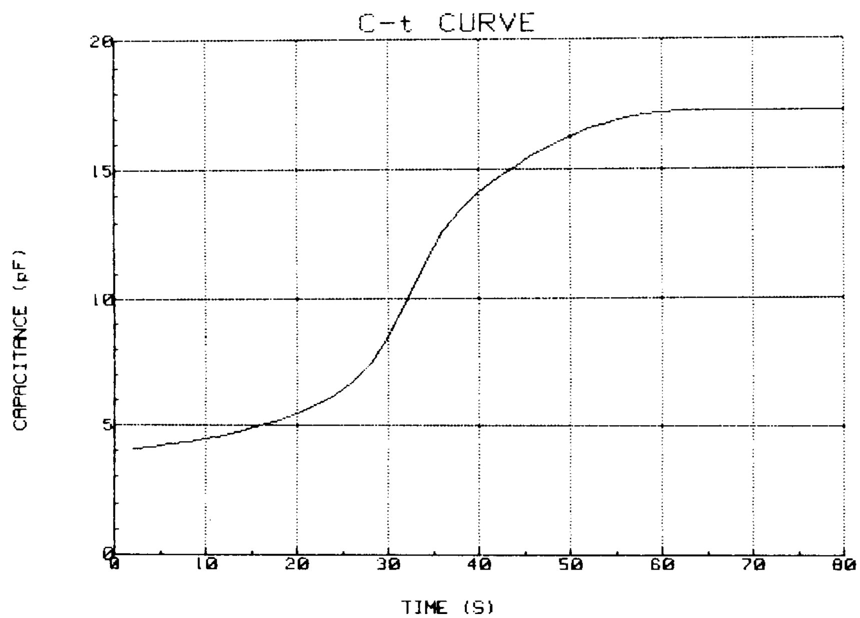


Figure 3-28. MOS Capacitor Characteristic C-t Curve

Capacitance Measurement Using CMU84

For capacitance measurement using CMU84, TIS provides the following subprograms:

Note

TIS subprograms to control the CMU84 are included in the HP 4062 Revision 6.0 or later. Prior to Revision 6.0, however, the DVR4284 provides subprograms to control the CMU84.

Hewlett-Packard recommends that you create test programs using TIS instead of DVR4284. However, test programs using DVR4284 are guaranteed because DVR4284 can also be used with Revision 6.0 or later.

- Set_cmu84 (TIS)

  Sets CMU84 integration time and test signal level.

- Set_freq (TIS) and Frequency84 (DVR4284)

  Set CMU84 measurement frequency.

- Measure_cmu84 (TIS)

  Performs capacitance and conductance measurements and returns error-compensated measurement results.

  Note that CMU84 capacitance measurement results include stray capacitance and do not represent a test device's true capacitance value. To obtain true capacitance values, perform the following procedure:

  1. With *nothing* connected to your test fixture, execute Measure_cmu84 to obtain the capacitance zero-offset value Co. Note this value.
  2. Connect your test device, execute Measure_cmu84, and note the capacitance measurement value C.
  3. Subtract Co from C to obtain the true capacitance value.

- Set_cv84 (TIS)

  Sets the parameters for swept C-V measurements.

- Sweep_cv84 (TIS)

  Performs swept measurements in accordance with the conditions established by Set_cv84.

- Force_v (TIS) and Force_v84 (DVR4284)

  Set the internal dc bias source of the CMU84.

- Disable_port (TIS) and Disable_port84 (DVR4284)

  Set the ports of the CMU84 to Zero Output status.

- Port_status (TIS) and Port_status84 (DVR4284)

  Return the status of the port of the CMU84.

- FNCmu84 (TIS)

  Returns the CMH84 or CML84 terminal address of the CMU84.

- Open_corr84

  Performs the OPEN correction of the CMU84.

- Short_corr84

  Performs the SHORT correction of the CMU84.

Figure 3-30 provides an example program of stray capacitance error-compensation. This program also shows how to use the Cvgraph subprogram. The test device used for this example is a MOS capacitor.

To run this program, install the Low Leakage Test Fixture—via the Test Fixture Adapter—on the SWM. With nothing connected to the test fixture, close the test fixture adapter's cover and select the RUN softkey to measure the capacitance offset value. Connect the test device to the fixture following the displayed instructions to obtain the error-compensated capacitance measurement results and a graph of the test device's characteristics.

Figure 3-29 shows the test device's measurement pin assignments, and Figure 3-31 shows an example C-V characteristic curve for the MOS capacitor used in this sample program.

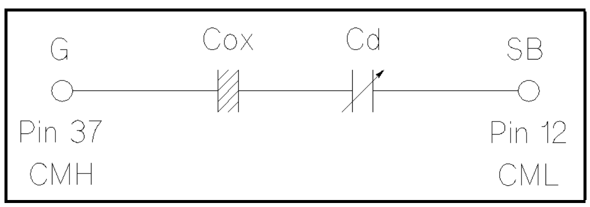


Figure 3-29. Pin Assignments for Capacitance Measurements Using CMU84

```
20   !  Sample Program
30   !    Requirements: TIS,XYGRAPH
40   !
50   OPTION BASE 1
60   DIM Cdata(101),Gdata(101),Vdata(101)
70   INTEGER Gate,Substrate,Point,Integ_time
80   Gate=37
90   Substrate=12
100  Vstart=5
110  Vstop=-5
120  Vstep=-.1
130  Point=INT((Vstop-Vstart)/Vstep)+1
140  Integ_time=2
150  Sig_level=.03
160  Hold_time=60
170  Freq=1.E+5
180  !
190  Init_system
200  Connect(FNCmh,Gate)
210  Connect(FNCml,Substrate)
220  Set_cmu84(Integ_time,Sig_level)
230  Set_freq(FNCmh,Freq)
240  Measure_cmu84(Coff)
250  !
260  BEEP
270  DISP "Connect test device to fixture, close shielding cover, and press
 Continue."
280  PAUSE
290  !
300  DISP
310  Force_v(FNCmh,Vstart)
320  WAIT Hold_time
330  !
340  FOR I=1 TO Point
350    Vdata(I)=Vstart+Vstep*(I-1)
360    Force_v(FNCmh,Vdata(I))
370    Measure_cmu84(Cdata(I),Gdata(I))
380  NEXT I
390  !
400  MAT Cdata= Cdata-(Coff)
410  MAT Cdata= Cdata*(1.E+12)
420  !
430  Cvgraph(MAX(Vdata(*)),MAX(Cdata(*)),"GATE VOLTAGE (V)","GATE CAPACITAN
CE (pF)","C-V CURVE",1)
440  !
450  MOVE Vdata(1),Cdata(1)
460  FOR I=1 TO Point
```

Figure 3-30. Sample Program: Capacitance Measurement Using CMU84

```
470     DRAW Vdata(I),Cdata(I)
480   NEXT I
490   !
500   Disable_port
510   Connect
520   !
530   END
540   !
```

Sample Program: Capacitance Measurement Using CMU84 (Continued)

lines 50 through 160:	Declare measurement data array variables and assign constants.
lines 180 through 220:	Initialize the system and measure the test fixture's capacitance (with no test device connected) to obtain the capacitance zero-offset value.
lines 290 and 300:	Output the start V and wait the specified hold time.
lines 320 through 360:	Perform a swept C-V measurement.
lines 380 and 390:	Calculate the test device's true capacitance (subtracts zero-offset value from capacitance measurement value) and convert measurement results from Farads to pico Farads.
line 410:	Draws optimized X- and Y-axes, and graph labels.

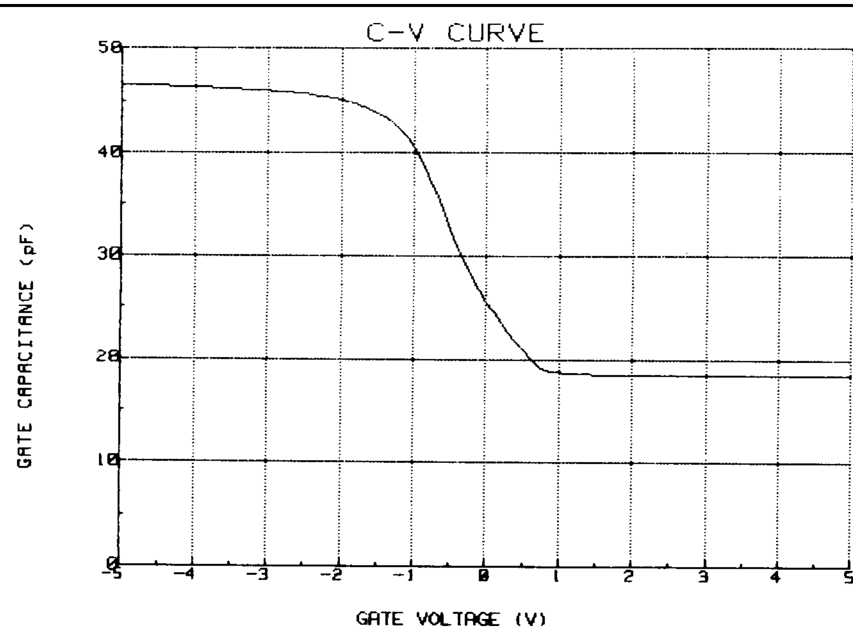


Figure 3-31. MOS Capacitor Characteristic C-V Curve Measured by CMU84

Figure 3-32 provides an example program of a swept C-V measurement.

```
10   !
20   !  Sample Program
30   !    Requirements: TIS,XYGRAPH
40   !
50   OPTION BASE 1
60   DIM Cdata(101),Gdata(101),Vdata(101)
70   INTEGER Gate,Substrate,Point,Integ_time
80   Gate=37
90   Substrate=12
100  Vstart=5
110  Vstop=-5
120  Vstep=-.1
130  Point=INT((Vstop-Vstart)/Vstep)+1
140  Integ_time=2
150  Sig_level=.03
160  Hold_time=60
170  Freq=1.E+5
180  !
190  Init_system
200  Set_cmu84(Integ_time,Sig_level)
210  Set_freq(FNCmh,Freq)
220  Connect(FNCmh,Gate)
230  Connect(FNCml,Substrate)
240  Measure_cmu84(Coff)
250  !
260  BEEP
270  DISP "Connect test device to the fixture, close the shielding cover, a
nd press Continue."
280  PAUSE
290  !
300  DISP
310  Set_cv84(Vstart,Vstop,Point,Hold_time)
320  Sweep_cv84(0,Cdata(*),Gdata(*),Vdata(*))
330  !
340  MAT Cdata= Cdata-(Coff)
350  MAT Cdata= Cdata*(1.E+12)
360  !
370  Cvgraph(MAX(Vdata(*)),MAX(Cdata(*)),"GATE VOLTAGE (V)","GATE CAPACITAN
CE (pF)","C-V CURVE",1)
380  !
390  MOVE Vdata(1),Cdata(1)
400  FOR I=1 TO Point
410    DRAW Vdata(I),Cdata(I)
420  NEXT I
430  !
```

Figure 3-32. Sample Program: Swept C-V Measurement Using CMU84

```
440  Disable_port
450  Connect
460  !
470  END
480  !
```

Sample Program: Sweep C-V Measurement Using CMU84 (Continued)

line 290:	Sets the swept C-V measurement parameters.
line 300:	Executes the measurement and returns capacitance and conductance measurement values to the array variables.

Feedback Measurements

For feedback measurements, TIS provides the following subprograms.

- Set_asearch
- Set_bsearch
- Set_lsearch

  Set the parameters for analog, binary, and linear searches, respectively.

- Set_sync

  Sets the parameters for synchronizing an SMU with the control port (SMU) set by Set_bsearch or Set_lsearch.

- Search

  Initiates feedback measurements in accordance with the conditions set by Set_asearch, Set_bsearch, Set_lsearch, and Set_sync.

Note Set_asearch subprogram requires the AFU.

- Analog Search Measurements

  Analog search measurements are performed by using the DCS's AFU, one search SMU, and one sense SMU, as described in the *System Information* .

  Optimum parameter value settings vary depending on test device characteristics and other parameter settings. To help you set optimum parameter values, use the TIS_UTIL utility subprograms: Para_hfe for h_{FE} measurements, and Para_vth for threshold V measurements.

Figure 3-33 shows analog search measurement waveforms.

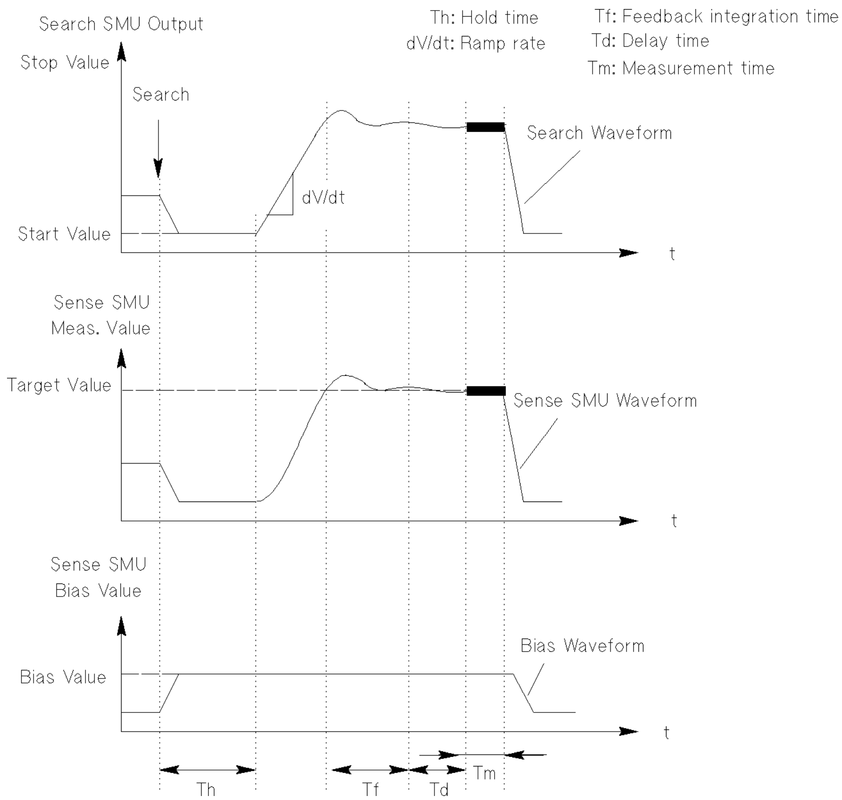


Figure 3-33. Analog Search Measurement Waveforms

Figure 3-34 provides an example program of a threshold voltage measurement using Set_bsearch.

```
10   !
20   !  Sample Program
30   !    Requirements: TIS
40   !
50   INTEGER Source,Drain,Gate
60   Source=1
70   Drain=2
80   Gate=3
90   Vmin=0
100  Vmax=5
110  Goal=-1.E-7
120  Range=-1.E-6
130  Comp=1.E-5
140  H_time=0
150  Accuracy=.1
160  !
170  Init_system
180  Connect(FNGnd,Source)
190  Connect(FNSmu(2),Gate)
200  Connect(FNSmu(1),Drain)
210  !
220  Force_v(Drain,-2,5,1.E-2)
230  Set_bsearch(Gate,Drain,0,Vmin,Vmax,Goal,Range,Comp,H_time,Accuracy)
240  Search(Vth)
250  !
260  PRINT "Vth=";Vth;"V"
270  !
280  Disable_port
290  Connect
300  !
310  END
320  !
```

Figure 3-34. Sample Program: Feedback Measurement Using Set_bsearch

lines 50 through 150:	Declare variables as type INTEGER and assign constants.
lines 180 through 200:	Connect the specified measurement pins to the test device.
line 220:	Outputs voltage to the test device's drain pin.
line 230:	Sets the feedback measurement's binary search parameters.
line 240:	Executes the feedback measurement.
line 260:	Prints measurement results.

Figure 3-35 provides an example program of a breakdown voltage measurement using Set_lsearch.

```
10   !
20   !  Sample Program
30   !    Requirements: TIS
40   !
50   INTEGER Emitter,Base,Collector,Mode,Integ_time
60   Emitter=1
70   Base=2
80   Collector=3
90   Mode=0
100  Start=0
110  Stop=10
120  Step=.1
130  Comp=1.E-2
140  Integ_time=1
150  !
160  Init_system
170  Set_smu(Integ_time)
180  Connect(FNSmu(1),Emitter)
190  Connect(FNGnd,Base)
200  !
210  Set_lsearch(Emitter,Emitter,Mode,Start,Stop,Step,1.E-6,1.E-6,Comp)
220  Search(Vebo)
230  !
240  PRINT "VEBO=";Vebo;"V"
250  !
260  Disable_port
270  Connect
280  !
290  END
300  !
```

Figure 3-35. Sample Program: Breakdown Voltage Measurement

lines 50 through 140:	Declare variables as type integer and assign constants.
lines 180 and 190:	Connect the specified measurement pins to the test device.
line 210:	Sets the feedback measurement's linear search parameters.
line 220:	Performs a feedback measurement.
line 240:	Prints measurement results.

Figure 3-36 provides an example program of a MOSFET threshold voltage measurement using Set_bsearch and Set_sync.

```
10   !
20   !  Sample Program
30   !    Requirements: TIS
40   !
50   INTEGER Source,Drain,Gate,Substrate
60   Source=1
70   Drain=2
80   Gate=3
90   Substrate=4
100  Vmin=0
110  Vmax=3
120  Goal=1.E-7
130  Range=1.E-6
140  Comp=1.E-5
150  H_time=0
160  Accuracy=.1
170  !
180  Init_system
190  Connect(FNGnd,Source)
200  Connect(FNSmu(1),Drain)
210  Connect(FNSmu(2),Gate)
220  Connect(FNSmu(3),Substrate)
230  !
240  Force_v(Drain,2,5,1.E-2)
250  Set_bsearch(Gate,Drain,0,Vmin,Vmax,Goal,Range,Comp,H_time,Accuracy)
260  Set_sync(Substrate,0,-1)
270  Search(Vth)
280  !
290  PRINT "Vth=";Vth;"V"
300  !
310  Disable_port
320  Connect
330  !
340  END
350  !
```

Figure 3-36. Sample Program: Threshold Voltage Measurement

lines 50 through 160:	Declare variables as type integer and assign constants.
lines 190 through 220:	Connect the specified measurement pins to the test device.
line 240:	Outputs voltage to the drain.
line 250:	Sets the feedback measurement's binary search parameters.
line 260:	Sets the parameters to synchronize the substrate voltage with the gate voltage.

line 270:	Performs a feedback measurement.
line 290:	Prints measurement results.

Figure 3-37 provides an example program of a FET threshold voltage measurement using Set_asearch.

```
10   !
20   !  Sample Program
30   !    Requirements: TIS
40   !
50   INTEGER Source,Drain,Gate,Substrate,Status,S_mode,M_mode
60   Source=1
70   Drain=2
80   Gate=3
90   Substrate=4
100  S_mode=1
110  M_mode=3
120  Start=1.5
130  Stop=3
140  Bias=5
150  Goal=1.E-5
160  Ramp=5000
170  Comp_cont=1.E-3
180  Comp_mon=1.E-3
190  H_time=0
200  D_time=0
210  Integ_time=8.E-6
220  !
230  Init_system
240  Connect(FNGnd,Source)
250  Connect(FNSmu(1),Drain)
260  Connect(FNSmu(2),Gate)
270  Connect(FNSmu(3),Substrate)
280  !
290  Force_v(Substrate,0,20,2.0E-2)
300  Set_asearch(Gate,Drain,S_mode,M_mode,Start,Stop,Bias,Goal,Ramp,Comp_co
nt,Comp_mon,H_time,D_time,Integ_time)
310  Search(Vth,Status,Id)
320  !
330  PRINT "Vth=";Vth;"[V]"
340  PRINT "Id=";Id;"[A]"
350  !
360  Disable_port
370  Connect
380  !
390  END
400  !
```

Figure 3-37. Sample Program: Threshold Voltage Measurement Using Set_asearch

lines 50 through 210: Declare variables as type integer and assign constants.

lines 240 through 270: Connect the specified measurement pins to the test device.

line 290:	Outputs voltage to the substrate.
line 300:	Sets the feedback measurement's analog search parameters.
line 310:	Performs a feedback measurement.
lines 330 and 340:	Prints measurement result.

Timing Control Subprograms

TIS provides the following timing control subprograms:

- Prepare
- Execute

As a rule, TIS subprograms included in your measurement program execute in the same order as other BASIC/UX language statements. That is, each program line executes in the sequence in which it occurs in your program.

In many practical applications, however, two or more of the same TIS subprograms require simultaneous execution. For example, when characterizing a FET, you may need to bias both the gate and the drain at the same time, then measure the gate voltage and drain current, also at the same time. To do this, specify two Force_v subprograms, a Measure_v, and a Measure_i subprogram within a single Prepare ... Execute construct. When the Execute subprogram executes, both Force_v subprograms, followed immediately by the two Measure subprograms, execute simultaneously.

Locking the System Resources (HP 4062UX only)

To explicitly (exclusively) lock the system resources to a single process, TIS provides the following subprograms.

- Lock_system
- Unlock_system

Lock_system explicitly locks the system resources to a process until Unlock_system is called or until you exit BASIC/UX. The following example shows Lock_system and Unlock_system usage:

```
:
1000 Lock_system
1010 !
1020 Init_system
:
2000 Unlock_system
:
```

Whenever the system resources are explicitly locked to a process, no other processes can access the system resources. Refer to "Resource Management" in Chapter 1 and to the *Programming Reference* for complete details on locking.

High Speed Measurement Programming Hints

To get the most out of your HP 4062C/UX/PC's high speed measurement capabilities, include the following methods in your measurement programs to maximize efficiency.

- Minimize Range Changes

  The most effective way to reduce measurement time is to minimize range changes, especially current range changes.

  For example, consider the following program lines and assume that your test device has a resistance of 500 kΩ

`Force_v(FNSmu(1),10,10,0.1)`	*I compliance value = 100 mA*
`Measure_i(FNSmu(1),A)`	*I measurement range = Auto range*
	(Auto range is the default measurement range.)

  When Force_v executes, the 100 mA I measurement range is set, as determined by the set I compliance value. When Measure_i executes, however, the I measurement range changes to the 100 μA range, because Auto ranging is set and the I measurement value is only 20 μA. Range changes such as these slow your measurement down.

  To increase measurement speed while maintaining the necessary measurement resolution, minimize the difference between the I compliance value in Force_v and the I measurement range in Measure_i.

  An example of how to do this is as follows. Keep in mind that the closer the two ranges, the less time it takes to change ranges.

  ```
  Force_v(FNSmu(1),10,10,1E-4)
  Measure_i(FNSmu(1),A) or Measure_i(FNSmu(1),A,1E-4)
  ```

  In summary, the Force subprogram's compliance value should be within the measurement range specified in the Measure subprogram. This minimizes range changes, thereby maximizes measurement speed.

- Use Limited Auto Ranging

  Limited Auto ranging allows automatic range changes between the specified range and higher ranges. When the specified compliance value is for various measurement values, you can increase measurement speed by using Limited Auto ranging. Refer to the *System Information* for more information on Limited Auto ranging.

  For example, if measurement values vary from 0 A to 50 μA, but the measurement resolution is greater than 10 pA, use the following subprograms:

  ```
  Force_v(FNSmu(1),10,10,100E-6)  --  I compliance value = 100 μA
  Measure_i(FNSmu(1),A,100E-9)  --  I measurement range = 100 nA
  ```

  Because I range changes are limited to the 100 μA to 100 nA ranges, these subprograms execute faster than those that omit the I range parameter (for example, by specifying Auto ranging in the Measure_i subprogram). The 100 nA measurement range setting is especially effective for increasing measurement speed because the measurement range is fixed and cannot change to the 10 nA or 1 nA ranges, which are inherently slower than other ranges.

- Use Integer Variable or Constants to Assign Port Addresses

  There are four ways to assign port and unit addresses, as follows:

1. Integer variables (SMU1, Base, etc.)
2. Constants (32701, 32702, etc.)
3. Unit address functions (FNUnitsmu(1), FNVs(1), etc.)
4. Port address functions (FNPort(1), FNsmu(1), etc.)

Both 1 and 2 are faster than 3 and 4. This is an effective way to save measurement time in applications like model parameter extractions, which include many Connect subprograms.

- Specify the measurement pins when disconnecting

There are three ways to disconnect measurement pins and ports, as follows:

1. Disconnect specific pins connected to any ports. (Connect(0,P1,P2, ...)
2. Disconnect all pins connected to a port. (Connect(Port1,0))
3. Disconnect all pins from all ports. (Connect)

Of these three ways, 1 is the fastest, independent of the number of parameters.

- Use the Disable_port Statement

You must execute the Disable_port subprogram before changing port settings after a parameter measurement. If you do not execute Disable_port, it takes longer to set ports. Using the parameters in the Disable_port subprogram reduces command execution time.

- Use an Analog Search instead of a Binary or Linear Search

Use an analog search for Vth or h_{FE} measurements. Analog searches are faster than binary and linear searches.

- Use Separate Force and Measure Subprograms

The Force_v, Force_i, Measure_v, and Measure_i subprograms execute faster when specified separately, as opposed to specifying a Force_meas subprogram, which executes a Force and Measure sequentially. Use separate Force and Measure subprograms, therefore, except when you need to specify a hold time with a resolution in ms.

- Don't use Prepare ... Execute constructs

These constructs increase the HP 4062A's measurement speed, but do not increase the HP 4062C/UX/PC's measurement speed. Prepare ... Execute constructs have been retained only to ensure compatibility within the HP 4062 family (HP 4062A, B, C, and UX).

- Use the Voltage Sources (VSs)

Whenever possible, use VSs rather than SMUs to source voltage. Keep in mind, though, that SMUs provide greater current capability and accuracy than VSs.

- Use the program memory function of the DCS

If you measure the same parameters for cassettes, wafers, and chips, you can store the measurement functions in the program memory of the DCS and execute the functions with triggers. This reduces the time it takes to transfer control commands to the DCS, and increases the measurement throughput of several devices. See "Using DCS Program Memory Functions" for more information.

Using DCS Program Memory Functions

This section provides information on how to use the DCS program memory functions. For more about the concept of the DCS program memory function, see the *System Information*.

You can make test programs using TIS to measure device parameters with the HP 4062 system. TIS is a powerful command set that controls the HP 4062 system instruments and measures device parameters. You can also use the HP 4062 system with a wafer prober, and measure the device parameters of each chip on each wafer. If you use the FOR ... NEXT loop and use TIS subprograms, such as Force_i or Measure_v, TIS sends the DCS control commands via the HP-IB. Sending the control commands using this method doesn't take much time, but if you measure device parameters for several chips, the total time can become lengthy.

To solve this problem and to increase test throughput, you can use the *DCS program memory* function. The system controller sends DCS control command sets in the DCS program memory segments before measurements are started. Then the controller sends only a trigger to start a measurement and get measured data. The triggers are sent to the DCS and the measurements are executed until all the chips are measured.

Note that the SWC, CMU, and CMU84 do not have functions to keep instructions in their memory.

To support the DCS program memory function, the PGMLIB file is supplied. The PGMLIB file includes DCS program storing procedures and DCS program storing support procedures. On the other hand, procedures for triggering and getting data are included in the TIS file. The following is a list of all the DCS subprogram names and a brief descriptions of each function:

- DCS program storing procedures (PGMLIB):

`Pgm_start`	Declares the beginning of storing in the DCS program memory.
`Pgm_end`	Declares the end of storing in DCS program memory.
`Pgm_force_v`	Stores the Force_v operation in program memory.
`Pgm_force_i`	Stores the Force_i operation in program memory.
`Pgm_measure_i`	Stores the Measure_i operation in program memory.
`Pgm_measure_v`	Stores the Measure_v operation in program memory.
`Pgm_set_asearch`	Stores the Set_asearch operation in program memory.
`Pgm_search`	Stores the Search operation in program memory.
`Pgm_set_pbias`	Stores the Set_pbias operation in program memory.
`Pgm_measure_p`	Stores the Measure_p operation in program memory.
`Pgm_set_smu`	Stores the Set_smu operation in program memory.
`Pgm_set_vm`	Stores the Set_vm operation in program memory.
`Pgm_ch_sw_on`	Stores the Ch_sw_on operation in program memory.
`Pgm_ch_sw_off`	Stores the Ch_sw_off operation in program memory.
`Pgm_disable_dcs`	Stores the DCS Disable_port operation in program memory.
`Pgm_wait`	Stores a specified waiting time operation in the program memory.

- DCS program storing procedures (PGMLIB):

`FNAddr4142`	Returns the DCS device selector, which consists of a select code and an address bus.
`FNUnit4142`	Returns a DCS unit address from the DCS port address.
`FNChannel4142`	Returns a DCS channel number from a DCS unit address.
`FNRange4142`	Returns a DCS range code from a voltage or current value.
`Readerror4142`	Gets four error codes from the DCS.

- Triggering and getting data procedures (TIS):

`Run_dcs_program`	Triggers a specified program stored in the DCS program memory.
`Readout_dcs`	Gets the measured data and measurement status for the spot, pulsed spot, and search measurements.
`Readsweep_dcs`	Gets the measured data and measurement status for the sweep measurements.

Note

After measurements are executed using the DCS program memory feature, the operation of TIS subprograms that control the DCS are *not* guaranteed because the TIS subprograms keep the settings of the previous execution in the controller's memory. Previous settings of the program memory segment do not remain in the controller's memory. To recover from the execution of the program memory segment, execute the following subprograms to reset the DCS:

`Init_system`
`Disable_port` (with no parameter)
`Long_cal`
`Short_cal`

The DCS control commands for the binary search and linear search cannot be stored in the program memory. The output value of the search unit is determined by the previous measured value of the sense unit, and the output value stored in the program memory cannot be changed.

Also, DCS program storing procedures for sweep measurements are not supplied. The number of times it takes to send the control command sets for sweep measurements are much fewer than for the spot measurements. If you want to store programs for sweep measurements in the program memory, use the OUTPUT statement to send the DCS control commands for sweep measurements. More details on this technique are provided later in this chapter.

Note

Cycling the power of the DCS clears the program memory.

Storing DCS Control Commands in the DCS Program Memory

You can store a set of DCS control commands in program memory. The programs stored in program memory are numbered from 1 to 99; therefore, the DCS can keep up to 99 programs in the program memory.

The program statements that are used to store a set of DCS control commands must begin with the Pgm_start subprogram and end with the Pgm_end subprogram. Pgm_start has one parameter: the program number stored in program memory, which ranges from 1 to 99. If 0 is specified as the parameter for Pgm_start, the DCS control commands are not stored in the program memory, but are executed immediately.

`Pgm_`*xxxxx* subprograms are useful for storing the DCS control commands in the DCS program memory. Replace the *xxxxx* with TIS subprograms that control the DCS, such as `Force_i`. The arguments of the `Pgm_`*xxxxx* statements are similar to the arguments of the corresponding TIS statements.

Use the Readout_dcs statement for measurement execution statements (such as `Measure_i`) that require returned variables. The variable name arguments in which measured data are returned are specified in the Readout_dcs statement.

Note that you must keep the pin board relays in the dry-switching mode after ending a program stored in program memory. The pin board relays establish pin-port connections of the SWM. If the pin-port connections are changed after the stored program is executed, your program must force the SMUs to the zero output status. To do so, you can use the Pgm_disable_dcs statement before the Pgm_end statement. The Pgm_disable_dcs statement sets the DCS units to the zero output status.

Note

TIS statements without the `Pgm_`*xxxxx* statement (such as Force_i), cannot be executed between the Pgm_start and Pgm_end subprograms. If a TIS statement is executed, a mismatched data transfer occurs.

`Pgm_`*xxxxx* subprograms are supplied in the PGMLIB file for spot and search measurements, but are not supplied for sweep measurements. You can store the DCS control commands for sweep measurements by sending the control commands directly to the HP-IB. See "Storing Sweep Measurement Commands" for details on how to store a program for sweep measurements.

For example, the following program lets you store a program that measures a 4-terminal integrated resistor:

```
  .   .   .   .   .   .   .   .
  .   .   .   .   .   .   .   .
1340 Pgm_start(1)
1350  Voltage=1.0
1360  Vrange=2.0
1370  Icomp=1.E-2
1380  Irange=1.E-2
1390  Pgm_force_v(FNSmu(1),Voltage,Vrange,Icomp)
1400  Pgm_force_v(FNSmu(2),Voltage,Vrange,Icomp)
1410  Pgm_force_v(FNSmu(3),Voltage,Vrange,Icomp)
1420  Pgm_force_v(FNSmu(4),Voltage,Vrange,Icomp)
1430  Pgm_measure_i(FNSmu(1),Irange)
1440  Pgm_measure_i(FNSmu(2),Irange)
1450  Pgm_measure_i(FNSmu(3),Irange)
1460  Pgm_measure_i(FNSmu(4),Irange)
1470  Pgm_disable_dcs(FNSmu(1),FNSmu(2),FNSmu(3),FNSmu(4))
1480 Pgm_end
  .   .   .   .   .   .   .   .
  .   .   .   .   .   .   .   .
```

If you store a control command set into program memory that specifies the same segment number as another control command set, the new control command set replaces the existing control command set.

Triggering Program Memory Segments and Getting Data

To execute a program memory segment programmed by Pgm_start ... Pgm_end, use the Run_dcs_program statement. Specify the segment number in the statement. Use the Readout_dcs or Readsweep_dcs statement to get the measured data from the DCS. These statements cannot be executed between the Pgm_start and Pgm_end statements.

The typical control sequence is shown as follows:

1. Control the SWM using the Connect statements and make the desired connections.
2. Trigger the program memory segments in the DCS using the Run_dcs_program statement and execute measurements.
3. Get the measured data using the Readout_dcs statement.
4. Disconnect the connections in the SWM.

Note

Be careful to dry switch the relays in the SWM. Do not make or break the relays when voltage or current is forced to the relays.

The following paragraphs cover how to trigger program memory segments and how to get measured data. A programming example is also shown.

Triggering program memory segments

The Run_dcs_program statement lets you set up eight program segment numbers in the argument. The same segment number can be specified more than once as shown in the following example:

```
  .  .  .  .  .  .  .  .
510  Run_dcs_program(3,3,3,3)
  .  .  .  .  .  .  .  .
```

In the example above, program memory segment 3 is executed consecutively four times. Then the measured values are kept in the DCS buffer memory until the controller reads them from the DCS buffer memory.

Once a program memory segment is executed, you can abort the program using the following procedure:

1. Stop the program by pressing the (Stop) key.
2. Abort the executed program memory segment by typing:

   `CALL Init_system` (Return)

Tip

After executing the Init_system, Long_cal, or Short_cal statement, the first Run_dcs_program statement sets the output switches of all the SMUs and VSs and executes the specified programs stored in the DCS program memory. Later Run_dcs_program statements do nothing to the output switch status until after an Init_system, Long_cal, or Short_cal statement is executed.

Getting the Measured Data

For spot measurements or search measurements, the Readout_dcs statement can be used. The measured data are returned to the specified variable and its status is also returned to the next specified variable. The series of the parameters is as follows:

`Readout_dcs(`*data1* [`,`*st1* [`,`*data2* [`,`*st2* [`,` · · · ·]]]] `)`

Where *datax* is a measured data variable and *stx* is its corresponding measurement status variable. You can specify up to eight pairs of *datax* and *stx*.

For example, use the following statement to get the data obtained by a voltage measurement at an SMU:

```
  .  .  .  .  .  .  .  .  .
630   Readout_dcs(Vmeas,Stat)
  .  .  .  .  .  .  .  .  .
```

You can omit the second parameter, which is a variable of the measurement status.

As another example, after executing the analog search measurement, you can get the search value, sense value, and measurement status as follows:

```
  .  .  .  .  .  .  .  .  .
640   Readout_dcs(Search,Stat,Sense)
  .  .  .  .  .  .  .  .  .
```

The Readsweep_dcs statement can be used for sweep measurements. The measured data is transferred in chronological order and returned to the specified array. The measurement statuses corresponding to the measured data are also returned to the specified array. The series of the parameters is as follows:

`Readsweep_dcs(`*data1*`(*)`[`,`*st1*`(*)`[`,`*data2*`(*)`[`,`*st1*`(*)`[· · ·]]]] `)`

Where *datax* is a measured data array name and *stx* is a status array name in which the measurement status is returned. The element number means the step number of the sweep measurement.

For example, when the staircase sweep measurement is executed to draw a Ic-Vc curve, you can get the Ic for each Vc step as follows:

```
  .  .  .  .  .  .  .  .  .
Readsweep_dcs(Ic(*),Ic_st(*),Vc(*))
  .  .  .  .  .  .  .  .  .
```

For details on the data records, see "Binary Measurement Data Output Format" in the HP 4142B *HP-IB Command Reference Manual*.

You can also execute TIS statements that control the SWM, CMU, and CMU84. For example, a capacitance measurement is available using the Measure_cmu statement during a measurement using the program memory, as follows:

```
  .   .   .   .   .   .   .   .
2030   Run_dcs_program(2)
2040   Measure_cmu(Capacitance)
2050   Readout_dcs(Imeas,Stat)
  .   .   .   .   .   .   .   .
```

The forced value of the DCS can affect capacitance measurements, and the test signal (sine wave) of capacitance measurements can affect I-V measurements. Do not execute I-V measurements and capacitance measurements at the same time.

Controlling the SWM

When you execute the program memory segments, you must dry switch the relays in the SWM. If a voltage or current is forced, making or breaking relays results in poor contact of the relays and you will not get reliable measured data.

To prevent damaging the relays, no voltage or current should be forced when the relays make or break. The following programming notes can keep the relays dry switching and can help prevent the relays from being damaged:

- The Connect statements must be executed before the Run_dcs_program statements.
- The Pgm_disable_dcs statement is executed before the Pgm_end statement, and is executed to set the SMUs or VSs to the zero output status.

The following programming example shows how to connect the proper pins and ports

```
  .   .   .   .   .   .   .   .
  .   .   .   .   .   .   .   .
1350 Pgm_start(4)
  .   .   .   .   .   .   .   .
1380  Pgm_disable_dcs
1390 Pgm_end
  .   .   .   .   .   .   .   .
  .   .   .   .   .   .   .   .
1530  Connect(FNSmu(1),24)
1540  Connect(FNSmu(2),26)
1550  Connect(FNGnd,28)
1560  Run_dcs_program(4)
1570  Readout_dcs(Ic,Ic_st,Ib,Ib_st)
1580  Connect(0,24,26,28)
  .   .   .   .   .   .   .   .
  .   .   .   .   .   .   .   .
```

Programming Example

Figure 3-38 provides an example program measuring sheet resistance and h_{FE} in the chips of a wafer specified in the WAFER1 file. For the Wget, Wstart_number, Wmove_next subprogram, see "Probing Control Library (PCL)" in Chapter 6.

```
10   !
20   !  Sample Program
30   !    Requirement: TIS, PGMLIB, WAFER
40   !
50   INTEGER R1,R2,Tr_c,Tr_b,Tr_e,Chip,St
60   REAL Vr,Ir,Vstart,Vstop,Vce,Ib,Ic
70   R1=4
80   R2=8
90   Tr_b=12
100  Tr_c=16
110  Tr_e=20
120  Vr=1.0
130  Vstart=0
140  Vstop=3
150  Vce=10
160  Ic=1.E-3
170  !
180  !*****************  STORING DCS PROGRAMS  ******************
190  Pgm_start(1)
200   Pgm_force_v(FNSmu(1),Vr,2,1.E-2)
210   Pgm_measure_i(FNSmu(1))
220   Pgm_disable_dcs(FNSmu(1))
230  Pgm_end
240  !
250  Pgm_start(2)
260   Pgm_set_asearch(FNSmu(1),FNSmu(2),1,4,Vstart,Vstop,Vce,Ic,500,1.E-4,Ic*1.15)
270   Pgm_search
280   Pgm_disable_dcs(FNSmu(1),FNSmu(2))
290  Pgm_end
300  !
310  !*****************  STARTING MAIN TEST ROUTINE  *************
320  Init_system
330  Wget("WAFER1")
340  Wstart_number(1,1)
350  FOR Chip=1 TO FNWtotal_chip
360   PRINT "Chip No. = ";Chip
370   Connect(FNGnd,R2)
380   Connect(FNSmu(1),R1)
390   Run_dcs_program(1)
400   Readout_dcs(Ir,St)
410   PRINT "  R   = ";Vr/Ir;" Status = ";St
420   Connect(0,R1,R2)
430   Connect(FNGnd,Tr_e)
440   Connect(FNSmu(1),Tr_b)
450   Connect(FNSmu(2),Tr_c)
460   Run_dcs_program(2)
470   Readout_dcs(Ib,St,Ic)
480   PRINT "  hFE = ";Ic/Ib;" Status = ";St
490   Connect(0,Tr_c,Tr_b,Tr_e)
500   Wmove_next
510  NEXT Chip
520  !
530  END
```

Figure 3-38. Sample Program: DCS Program Memory Function

Line 70 to 110	Define the pin numbers to the terminals of the devices (resistor and transistor).
Line 120	Sets the forced voltage value of the resistor to the `Vr` variable.
Line 130 to 160	Set the start voltage, stop voltage, bias voltage, and target current of the analog search measurement.
Line 190 to 290	Store into program segment 1 the DCS control commands that measure current when voltage is forced to the terminals of the resistor.
Line 250 to 290	Store into program segment 2 the DCS control commands that use analog search measurement to measure the h_{FE} of the transistor.
Line 330	Gets the probing pattern data from the WAFER1 file.
Line 340	Sets the starting location of the chip.
Line 350 and 510	Define the loop statements. The statements between line 360 and 500 are executed the number times specified by the FNTotal_chip function.
Line 370 and 380	Connect the SMU1 and GNDU ports to the DUT terminals.
Line 390	Triggers program segment 1 and executes the measurement.
Line 400	Gets the measured data.
Line 410	Calculates the resistance value and prints it.
Line 420	Disconnects the pin-port connections.
Line 430 to 450	Connect the SMU1, SMU2, and GNDU to the transistor terminals.
Line 460	Triggers program segment 2 and executes the analog search measurement.
Line 470	Gets the measured data.
Line 480	Calculates the h_{FE} and prints it.
Line 490	Disconnects the pin-port connections.
Line 500	Moves the probing position to the next chip.

Optimizing the DCS Program

Optimize your program by writing or rewriting the program using the HP-IB control commands of the DCS. It is beneficial to know the HP-IB control commands of the DCS, which are provided in the HP 4142B manuals.

A program using the Pgm_*xxxx* subprograms are not always the most efficient programs. The most efficient program controls the fewest DCS units and changes the least amount of parameters. Note that the HP 4062UX system software cannot optimize your program automatically. You must optimize your program yourself.

For example, the following program is functionally identical to the program shown previously in this chapter that stores an integrated resistor (4 circuit) measurement:

```
  .   .   .   .   .   .   .   .
1340  Pgm_start(1)
1350   ASSIGN @Dcs TO FNAddr4142
1360   OUTPUT @Dcs;"AV-4"
1370   OUTPUT @Dcs;"DV";FNChannel4142(FNUnitsmu(1)),FNRange4142(1),1,0.01
1380   OUTPUT @Dcs;"DV";FNChannel4142(FNUnitsmu(2)),FNRange4142(1),1,0.01
1390   OUTPUT @Dcs;"DV";FNChannel4142(FNUnitsmu(3)),FNRange4142(1),1,0.01
1400   OUTPUT @Dcs;"DV";FNChannel4142(FNUnitsmu(4)),FNRange4142(1),1,0.01
1410   OUTPUT @Dcs;"MM";FNChannel4142(FNUnitsmu(1)),FNChannel4142(FNUnitsmu
(2)),FNChannel4142(FNUnitsmu(3)),FNChannel4142(FNUnitsmu(4))
1420   OUTPUT @Dcs;"XE"
1430   OUTPUT @Dcs;"DZ"
1440   ASSIGN @Dcs TO *
1450  Pgm_end
  .   .   .   .   .   .   .   .
```

The FNAddr4142 function returns the device selector showing the select code and bus address of the DCS. The FNChannel4142 function returns the DCS channel number translated from the specified unit address.

In the above program, the following procedures are stored in program memory segment 1:

1. Integration time of the DCS is set to four periods of the line frequency.
2. Four SMUs are set to force 1.0 V with 10 mA current compliance.
3. The current measurement is executed in the four SMUs.
4. When the measurement is finished, the output voltage for the four SMUs is set to 0 V.

Note

HP-IB control commands must be sent to the DCS between the Pgm_start and Pgm_end statements. If HP-IB control commands of the DCS are sent using the OUTPUT statement outside of the Pgm_start and Pgm_end contexts, a mismatched data transfer occurs.

Note

You must take care of the output switch status of the SMUs or VSs when using the "`CN`" and "`CL`" commands. When the output switch is set to off, forcing voltage or current causes an error. It takes about 100 ms to execute the `CN` or `CL` command.

To increase the measurement speed, use the `CN` and `CL` commands as few times as possible.

Note that you do not need to set the output switch status of the SMUs or VSs when using TIS subprograms, because the TIS subprograms automatically control the output switches.

Storing Sweep Measurement Commands

To store the DCS control commands for sweep measurements, you can send the DCS control commands directly with the OUTPUT statement. The OUTPUT statement must be programmed within the Pgm_start ... Pgm_end context.

Programming with the DCS control commands directly lets you create very useful and diverse test procedures. For details on how to program using DCS control commands (ASCII commands), see the HP 4142B *Operation Manual*.

Note

Even when a sweep measurement program stored in program memory is executed, the total throughput may not increase. The transfer time of a sweep measurement program does not consume a lot of the total measurement time.

The following example illustrates a measurement of the Ic-Vc characteristics of a bipolar transistor. A staircase voltage (Vc) is forced from 0 V to 10 V in 101 steps to the collector terminal, and collector current (Ic) is measured for four base current values (0.5 μA, 1.5 μA, 2.5 μA, and 3.5 μA).

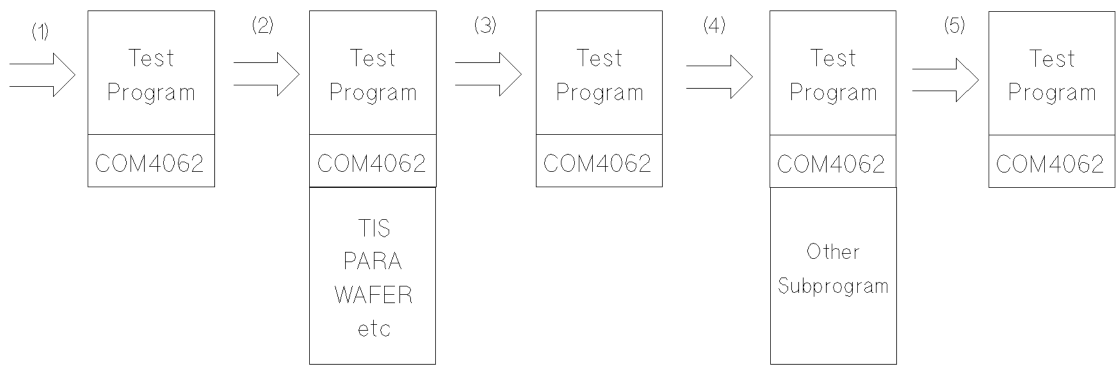
```
 .   .   .   .   .   .   .   .
130   INTEGER B_ch,C_ch,Ic_st(101)
140   REAL Vc,Ic(101)
150   ASSIGN @Dcs TO FNAddr4142
160   B_ch=1
170   C_ch=2
 .   .   .   .   .   .   .   .
250   Pgm_start(4)
260    OUTPUT @Dcs;"WV";C_ch;"1,1,12,0,10,101,0.2"
270    OUTPUT @Dcs;"WT0.01"
280    OUTPUT @Dcs;"MM2";C_ch
290    OUTPUT @Dcs;"DI";B_ch;"1,15,5E-7,10"
300    OUTPUT @Dcs;"XE"
310    OUTPUT @Dcs;"DI";B_ch;"1,15,1.5E-6,10"
320    OUTPUT @Dcs;"XE"
330    OUTPUT @Dcs;"DI";B_ch;"1,15,2.5E-6,10"
340    OUTPUT @Dcs;"XE"
350    OUTPUT @Dcs;"DI";B_ch;"1,15,3.5E-6,10"
360    OUTPUT @Dcs;"XE"
370    OUTPUT @Dcs;"DZ"
380   Pgm_end
 .   .   .   .   .   .   .   .
 .   .   .   .   .   .   .   .
460   Connect(FNGnd,16)       ! Emitter:   Pin 16
470   Connect(FNSmu(2),20)    ! Collector: Pin 20
480   Connect(FNSmu(1),24)    ! Base:      Pin 24
490   Run_dcs_program(4)
500   Connect(0,FNSmu(1),FNSmu(2),FNGnd)
510   Readsweep_dcs(Ic(*),Ic_st(*))
520   Draw_graph(5.E-7,Ic(*),Ic_st(*))
530   Readsweep_dcs(Ic(*),Ic_st(*))
540   Draw_graph(1.5E-6,Ic(*),Ic_st(*))
550   Readsweep_dcs(Ic(*),Ic_st(*))
560   Draw_graph(2.5E-6,Ic(*),Ic_st(*))
570   Readsweep_dcs(Ic(*),Ic_st(*))
580   Draw_graph(3.5E-6,Ic(*),Ic_st(*))
 .   .   .   .   .   .   .   .
```

Line 130 and 140	Declare variables and arrays.
Line 150	Creates an I/O path name (@Dcs) and assigns that name to the DCS.
Line 160 and 170	Store the channel numbers of the DCS in the B_ch and C_ch variables.
Line 240 to 380	Store to program memory the DCS control commands that measure the Ic-Vc characteristics.
Line 250	Sets the output switches of the specified SMUs to on.
Line 260	Sets the staircase sweep source. Start voltage is 0 V and stop voltage is 10 V with 101 steps.
Line 270	Sets the hold time. The measurement takes a specified time for charging or discharging before the first measurement.
Line 280	Sets the measurement mode to the staircase sweep measurement and specifies the measurement SMU.
Line 290	Forces 0.5 μA to the base terminal.
Line 300	Starts the staircase sweep measurement.
Line 310	Forces 1.5 μA to the base terminal.
Line 320	Starts the staircase sweep measurement.
Line 330	Forces 2.5 μA to the base terminal.
Line 340	Starts the staircase sweep measurement.
Line 350	Forces 3.5 μA to the base terminal.
Line 360	Starts the staircase sweep measurement.
Line 460 to 480	Makes the pin-port connections in the SWM.
Line 490	Triggers program 4 stored in the program memory.
Line 500	Disconnects pins and ports.
Line 510	Gets the measured data when base current is 0.5 μA.
Line 520	Calls the subprogram to draw an Ic-Vc curve.
Line 530	Gets the measured data when base current is 1.5 μA.
Line 550	Gets the measured data when base current is 2.5 μA.
Line 570	Gets the measured data when base current is 3.5 μA.

Overlay Programming with COM4062

When the test program is too large to load in the memory area, an overlay programming technique can be used. HP BASIC allows you to delete unnecessary subprograms and to add necessary subprograms to the test program. For example, after executing measurements and getting the measured data into the memory or a file, the test program can delete the measurement subprograms, link the data transfer subprogram, and transfer the measured data to the host computer.

Figure 3-39 shows the concept of the overlay programming for the HP 4062 system. The TIS, PARA, WAFER, and so on, which are provided by the HP 4062C/UX/PC system software, are not necessary when the test program does not execute the measurements and perform the other processing, such as data transferring, data processing, and so force.



(1) Running the program.

(2) Linking the necessary subprograms such as TIS, etc.

(3) Deleting the linked subprograms.

(4) Linking other subprograms.

(5) Deleting the linked subprograms.

Figure 3-39. Overlay Programming with COM4062

To delete subprograms and to link the subprograms from a program file, the DELSUB and LOADSUB statements are used as follows:

- Deleting subprograms:

  `DELSUB` *subprogram/function name* [`TO END`]

  The `TO END` option deletes all the routines between the specified subprogram/function name and the end of program.

- Linking subprograms:

  `LOADSUB ALL FROM "`*file name*`"`

  The *file name* includes the desired subprograms and functions.

TIS, PARA, WAFER, and so on, which are provided by the HP 4062C/UX/PC system software, include several COM statements. HP BASIC checks the COM block definitions during the pre-run. If the new COM statements included in the linked subprograms are executed, an error is reported because the COM block is not declared during the pre-run. The necessary COM statements must be included in the test program.

The COM4062 includes the COM block declarations for the HP 4062 system as the following subprograms:

Hp_com_tis
Hp_com_prober
Hp_com_vfp
Hp_com_para

Note that the COM4062 does not includes the COM declarations for PPG and BSDM because PPG and BSDM are standalone programs.

If the test program includes the COM4062 subprograms for the linked library files such as TIS, WAFER, and so on, the COM blocks of the linked library files are checked during the pre-run. Table 3-1 shows the necessary COM4062 subprograms for the system library file of the HP 4062C/UX/PC system.

Table 3-1. COM Declaration Subprograms for Programmatic Linking

Linked File Name	Necessary COM Declaration Subprograms
START	Hp_com_prober, Hp_com_tis[1]
TIS	Hp_com_prober, Hp_com_tis[1]
VFP	Hp_com_prober, Hp_com_vfp
WAFER	Hp_com_prober
PARA	Hp_com_para
DPROBER	Hp_com_prober
EGX	Hp_com_prober
EGY	Hp_com_prober
TSK	Hp_com_prober
MAP	Hp_com_prober

1 For the HP 4062UX system, only the Hp_com_prober is necessary.

Example of Overlay Programming

The “TESTOVR” is a test program and links the TIS for the measurements, and links the Transfer_data subprogram from the file “TRANS.”

The program in the “TESTOVR”:

```
10   ! RE-STORE "TESTOVR"
20   !
30   ! Overlay Programming Example
40   !
50   ! LOADSUB Hp_com_prober FROM "/PCS/LIB/COM4062"    /usr/pcs/lib/COM4062 for HP 4062UX
60   ! LOADSUB Hp_com_tis FROM "/PCS/LIB/COM4062"       /usr/pcs/lib/COM4062 for HP 4062UX
70   !
80   LOADSUB ALL FROM "/PCS/LIB/TIS"                    /usr/pcs/lib/TIS for HP 4062UX
90   Init_system
100  Measure
110  DELSUB Init_system TO END
120  !
130  LOADSUB ALL FROM "TRANS"
140  Transfer_data
150  DELSUB Transfer_data TO END
160  END
170  !
180  SUB Measure
190  COM /Meas/ REAL Hfe(100),R1(100),R2(100)
200  !
210  SUBEND
```

Note that in the example above, the Hp_com_tis and Hp_com_prober from the COM4062 file must be linked before you run the example because the TIS subprograms are linked at line 80.

Program segment in the file “TRANS”:

```
10   ! RE-STORE "TRANS"
20   END
30   SUB Transfer_data
40   COM /Meas/ REAL Hfe(100),R1(100),R2(100)
50   !
60   SUB END
```

The TESTOVR program links the TIS subprograms and executes the measurements. After measurements, the TIS subprograms are deleted (unlinked). Then the Transfer_data subprogram is linked and executed. Note that the COM block declaration of the Measure subprogram must be identical to that of the Transfer_data subprogram.

4

Program Debugging

Introduction

This chapter describes the following measurement program debugging capabilities.

- VFP Monitor Mode
- Port Status
- Standalone VFP (HP 4062UX only)
- Offline Debugging (HP 4062UX only)
- Individual Parametric Test Sessions (HP 4062UX only)

Note

BASIC or BASIC/UX has its own debugging capabilities as follows:

Using Live Keyboard

Cross References

Single-Stepping a Program

Tracing

Refer to *BASIC* or *BASIC/UX Programming Techniques* for more information.

VFP Monitor Mode

The VFP monitor mode lets you monitor system conditions and measurement results during measurement program execution. These conditions and results are displayed and periodically updated, similar to the front panel display of an instrument measuring in REMOTE via HP-IB control.

Unlike the VFP standalone control mode, where measurement programming is not required, you can only use the VFP monitor mode in conjunction with a measurement program.

The method for using the VFP in the monitor mode is described in the following paragraphs. For information concerning VFP standalone control mode operation, refer to Chapter 2.

Note

Remember that the VFP display is an ALPHA mode display, so the print area of the CRT is used when monitoring the system with the VFP. If any statements specifying the print area of the CRT appear in your measurement program, they may overlay and interfere with the VFP monitor mode display.

To enable the VFP monitor mode from your measurement program, include the Vfp_frame and Vfp_monitor subprograms.

Vfp_frame clears the CRT and displays VFP page 1; and *must* appear in your measurement program before Vfp_monitor executes. Vfp_monitor refreshes the displayed system conditions and measurement results.

Figure 4-1 provides a programming example for enabling the VFP monitor mode from a measurement program.

This program is the same as Figure 3-10, with the addition of lines 170 and 270. The function of these new program lines is as follows:

```
10    !
20    !  Sample Program
30    !    Requirements: TIS,VFP
40    !
50    INTEGER Source,Drain,Gate,Integ_time
60    Source=1
70    Drain=2
80    Gate=3
90    Vstart=0
100   Vstop=-4
110   Vstep=-.1
120   Compliance=1.E-2
130   Vg=.4
140   Integ_time=2
150   !
160   Init_system
170   Vfp_frame
180   Set_smu(Integ_time)
190   Connect(FNSmu(1),Drain)
200   Connect(FNSmu(2),Gate)
210   Connect(FNGnd,Source)
220   Force_v(Gate,Vg)
230   !
240   FOR Vd=Vstart TO Vstop STEP Vstep
250     Force_v(Drain,Vd,Vstop,Compliance)
260     Measure_i(Drain,Id(I))
270     Vfp_monitor
280   NEXT Vd
290   !
300   Disable_port
310   Connect
320   !
330   END
340   !
```

Figure 4-1. Sample Program: Using VFP Subprograms

Line 170: Clears the CRT and displays VFP page 1.

Line 270: Refreshes the VFP monitor display.

Port Status

The Port_status, Rsweep_iv, Rsweep_miv, and Port_status84 subprograms return the status of a specified port when a measurement completes, which is particularly useful for determining the cause of abnormal measurement results.

The port status returned by these subprograms is determined by the most recent measurement subprogram. Executing Port_status does *not* clear the status of a port. The following table shows the statuses returned by the Port_status, Rsweep_iv, Rsweep_miv, and Port_status84 subprograms:

Port Status and its Number

Unit	Returned No.	Conditions
SMU	0	Normal.
	1	Another unit reached compliance or limit.
	2	This unit reached compliance or limit.
	3	This unit is oscillating.
	4	Measurement overflow.
CMU	0	Normal.
	6	Measurement value exceeds the set range.
CMU84	0	Normal.
	1	Analog bridge is unbalanced.
	2	A/D converter is not working.
	3	Signal source is overloaded.
	4	ALC[1] is unable to be regulated.

1 ALC is an acronym of Automatic Level Control.

Note

Port_status returns the last measurement status after Sweep_iv or Sweep_miv is executed.

Figure 4-2 provides an example program that measures variations in collector voltage and collector current in accordance with controlled changes in base current. The graph shown in Figure 4-3 is generated when this program executes.

```
10    !
20    !  Sample Program
30    !    Requirements: TIS,XYGRAPH
40    !
50    INTEGER Emitter,Base,Collector
60    Emitter=1
70    Base=2
80    Collector=3
90    Compliance=1.E-1
100   Vstart=0
110   Vstop=5
120   Vstep=.1
130   !
140   Init_system
150   Connect(FNSmu(1),Collector)
160   Connect(FNSmu(2),Base)
170   Connect(FNGnd,Emitter)
180   !
190   Force_i(Base,5.E-5)
200   Force_v(Collector,Vstop,Vstop,Compliance)
210   Measure_i(Collector,Icmax)
220   !
230   Lingraph(Vstop,Icmax*1000,"COLLECTOR VOLTAGE (V)","COLLECTOR CURRENT
(mA)","I-V CURVE",1)
240   !
250   FOR Ib=1.E-5 TO 5.E-5 STEP 1.E-5
260     Force_i(Base,Ib)
270     FOR Vc=Vstart TO Vstop STEP Vstep
280       Force_v(Collector,Vc,Vstop,Compliance)
290       Measure_i(Collector,Ic)
300       DRAW Vc,Ic*1000
310     NEXT Vc
320     MOVE 0,0
330   NEXT Ib
340   !
350   Disable_port
360   Connect
370   !
380   END
390   !
```

Figure 4-2. Sample Program: Collector I-V Characteristics Measurement

lines 150 through 170:	Connect the specified ports and measurement pins.
lines 190 through 230:	Measure the collector current to obtain the maximum value for the Y-axis, and draw the X-axis, Y-axis, and graph labels.
lines 250 through 330:	Obtain and plot collector I-V characteristics.

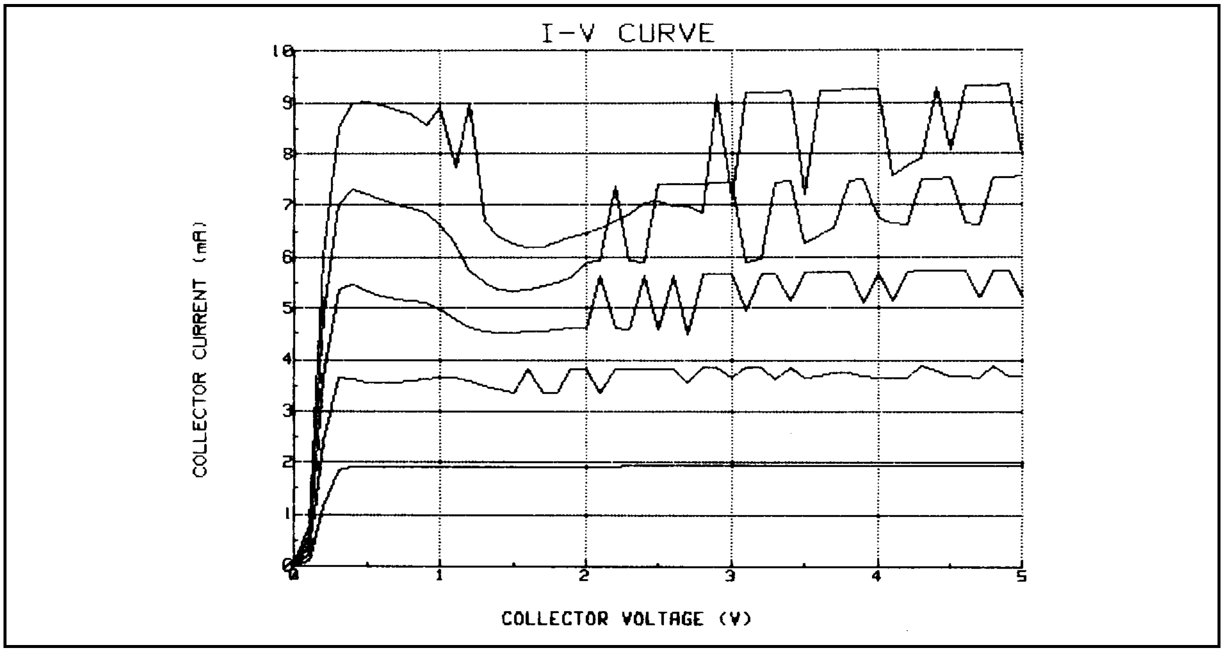


Figure 4-3.
Collector I-V Curve (generated by Sample Program: Collector I-V Characteristics Measurement)

Figure 4-3 shows that an SMU is apparently oscillating. By using the Port_status subprogram, as shown in Figure 4-4, you can confirm SMU oscillation and the particular base current values where oscillation occurs, as shown in Figure 4-5.

```
10    !
20    !  Sample Program
30    !    Requirements: TIS,XYGRAPH
40    !
50    INTEGER Emitter,Base,Collector,Status
60    Emitter=1
70    Base=2
80    Collector=3
90    Compliance=1.E-1
100   Vstart=0
110   Vstop=5
120   Vstep=.1
130   !
140   Init_system
150   Connect(FNSmu(1),Collector)
160   Connect(FNSmu(2),Base)
170   Connect(FNGnd,Emitter)
180   !
190   Force_i(Base,5.E-5)
200   Force_v(Collector,Vstop,Vstop,Compliance)
210   Measure_i(Collector,Icmax)
220   !
230   Lingraph(Vstop,Icmax*1000,"COLLECTOR VOLTAGE (V)","COLLECTOR CURRENT
(mA)","I-V CURVE",1)
240   !
250   FOR Ib=1.E-5 TO 5.E-5 STEP 1.E-5
260     Force_i(Base,Ib)
270     FOR Vc=Vstart TO Vstop STEP Vstep
280       Force_v(Collector,Vc,Vstop,Compliance)
290       Measure_i(Collector,Ic)
300       Port_status(Collector,Status)
310       IF Status=3 THEN
320         LINE TYPE 3
330       ELSE
340         LINE TYPE 1
350       END IF
360       DRAW Vc,Ic*1000
370     NEXT Vc
380     MOVE 0,0
390   NEXT Ib
400   !
410   Disable_port
420   Connect
430   !
440   END
450   !
```

Figure 4-4. Sample Program: Collector I-V Characteristics Measurement Using Port_status

Line 50:	Adds the integer variable required to execute Port_status.
Line 300:	Reads the port status of SMU1, which is connected to the collector.
Lines 310 through 350:	Change the graph's line type to demonstrate SMU oscillation.

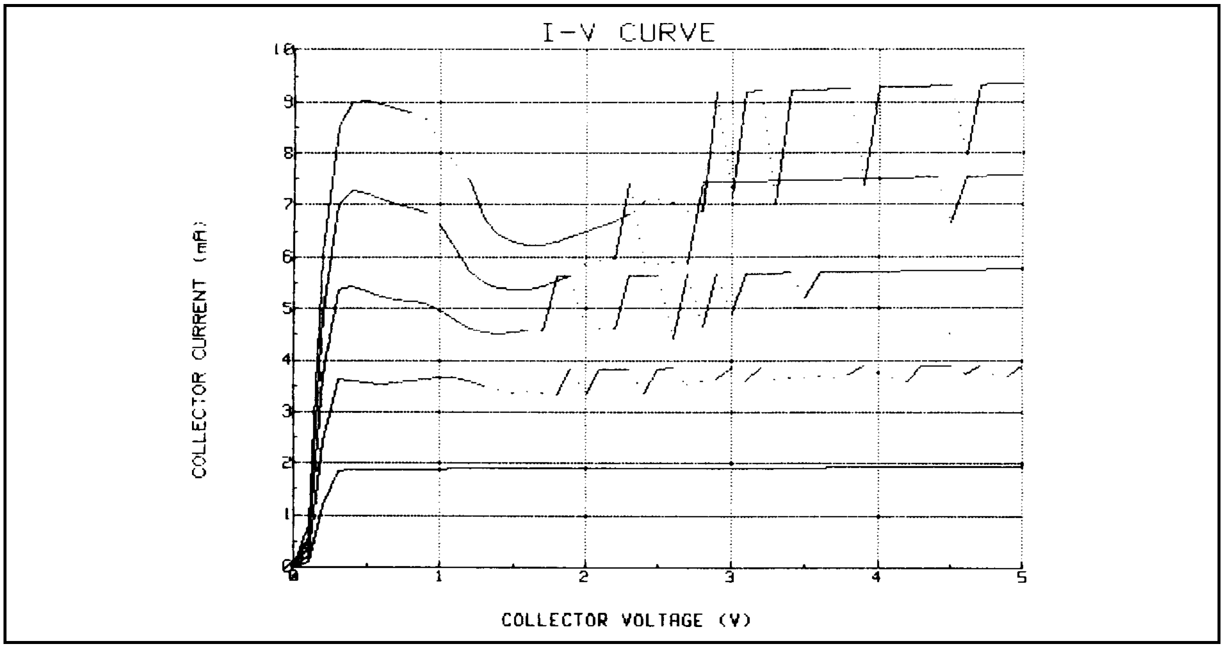


Figure 4-5.
Collector I-V Curve (generated by Sample Program: Collector I-V Characteristics Measurement Using Port_status)

Note

Because of parasitic reactance that may be present at your test device, Port_status may not detect SMU oscillation. To minimize the possibility of oscillation occurring, install ferrite beads on your test device's leads. See *System Information* for more details.

Standalone VFP (HP 4062UX only)

The Standalone VFP lets you monitor system instrument status in one window while another process executes a measurement program in another window. The Standalone VFP also lets you control the system instruments.

Note You cannot monitor or control the CMU84 and the LCR using the Standalone VFP.

Starting Standalone VFP

From the X Window system, start the VFP as follows:

1. Create a new window and load HP BASIC/UX.
2. Load VFP using HP BASIC/UX's LOAD command.

   `LOAD "/usr/pcs/bin/VFP"` (Return)

3. Select the RUN softkey.

The VFP monitor page, similar to that shown in Figure 4-6, is displayed.

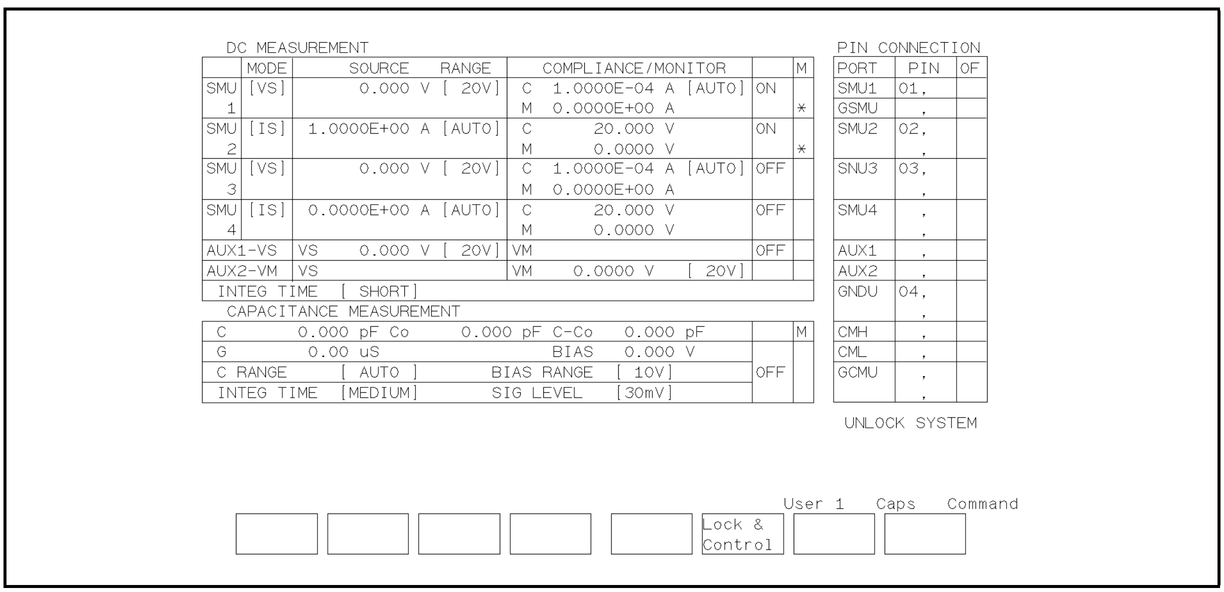


Figure 4-6. Standalone VFP Monitor Page

VFP Monitor Mode Operation

The VFP monitor mode monitors the system instrument statuses of any online or online debug mode test session process executing a measurement program.

After starting up the standalone VFP, the VFP monitor page reports system instrument statuses such as SMU voltage/current settings, SWM relay connection settings, and the measurement values most recently obtained. The VFP monitor page refreshes every 0.5 seconds.

Note that VFP's monitor mode does not access the system instruments, even if operated from the online mode. Thus, the VFP can monitor system instrument status, even if another process has explicitly locked the system instruments.

To exit standalone VFP, select the `EXIT VFP` softkey or press (Stop).

VFP Control Mode Operation

The VFP control mode requires access to the system instruments. You can only use the VFP control mode, therefore, when the system instruments are available (not explicitly locked to another process). The VFP control mode changes the settings of the system instruments.

The VFP control mode is especially efficient in the window environment. For example, you can trace a measurement program in one window (on online debug mode), while you measure using VFP control mode in another window (on online debug mode). In this case, the VFP control mode informs you of the actual status of the ports. For another example, the VFP control mode can patch measurement programs. If some measurement program does not work because an SMU reaches compliance, the VFP control mode notifies you and lets you change the compliance value.

Refer to Chapter 2 for complete details on VFP operation.

Offline Debugging (HP 4062UX only)

Offline debugging (1) maximizes system instrument usage efficiency, (2) detects errors in the earliest measurement program development stages without the need to access the system instruments, and (3) provides a method for developing measurement programs without the need for an actual test device.

START Program

To perform offline debugging, run the START program and select the offline mode from the Execution Mode Selection page.

System instrument configuration for the offline mode is determined on the START program's Supposed Configuration Modification page. The hardware configuration includes:

Switching Matrix Pin Configuration
DCS Module Configuration
DCS and CMS to Switching Matrix Interconnections

The START program reads the supposed system configuration from the DUMCONFIG file in the /usr/pcs/etc directory. The DUMCONFIG file is normally set up by the system administrator to reflect the actual system configuration. The default SWM is listed as the HP 4089A 96-pin SWM, but you can also select the HP 4085B 48-pin SWM's pin configuration.

Refer to Chapter 1 for more details on the START program.

System Software Support Levels

Table 4-1 lists the system software support levels when performing offline debugging.

Table 4-1. System Software Support Levels

Support Level	Software
Supported	TIS[1] , PARA[2] , VFP, START, DVR4284[3] , PGMLIB
Not operational	DPROBER[4] , WAFER[5]
Unsupported	EGX, EGY, TSK, DIAG, PV4062, DVR4274
Not related	TIS_UTIL, XYGRAPH, PPG, MAP, BSDM

1 TIS performs pass parameter checking and returns dummy data

2 The PARA functions may not operate properly in the offline mode because the PARA functions process dummy data returned from TIS subprograms while in this mode.

3 File data simulation mode and constant data simulation mode are supported for the DVR4284 of HP 4062UX Revision 6.0 or later. For the DVR4284 of Revision 5.6, however, only constant data simulation mode is supported.

4 DPROBER is a dummy prober driver.

5 WAFER can be used in conjunction with DPROBER.

Offline Data Simulation

The following TIS measurement subprograms return simulated values during offline operation. To obtain simulated values without performing actual measurements, the system software provides the offline data simulation function.

- Execute
- Force_meas
- Measure_cmu and Measure_cmu84
- Measure_i
- Measure_p
- Measure_v
- Port_status and Port_status84
- Search
- Sweep_ct
- Sweep_cv and Sweep_cv84
- Sweep_iv
- Sweep_miv
- Rsweep_iv
- Rsweep_miv
- Readout_dcs
- Readsweep_dcs

Two offline data simulation modes for specifying data are available: constant data simulation mode and file data simulation mode.

Constant data simulation is best suited for developing measurement algorithms.

File data simulation is best for overall measurement program debugging related to wafer prober control, data logging, measurement sequence coordination, etc., after measurement algorithms are more fully developed.

Combining these two offline data simulation modes make more efficient use of the offline mode debugging function.

The Off_line_data TIS subprogram is included to let you select the method you require for specifying data. Refer to the *Programming Reference* for more detailed information on the Off_line_data TIS subprogram.

Table 4-2 lists the comparisons between the constant data simulation mode and the file data simulation mode.

Table 4-2. Offline Data Simulation Modes

Item	Constant Data Simulation	File Data Simulation
Preparation before using	Not required	Required
If you modify a measurement program	Nothing required	Data file modification required
Conditional TIS calling	Possible	Restricted
Ability to specify measurement values	Restricted	Possible
Data realism	Poor	Good
Test data management	Difficult	Easy

Constant Data Simulation

Constant data simulation is the default data simulation mode when you initiate an offline debugging test session (run the START program) or process. You can also set the constant data simulation mode by calling the Off_line_data TIS subprogram with no parameters. Note that the START program does not affect the offline data simulation mode of other processes in the same test session.

In the constant data simulation mode, TIS measurement subprograms return constant values, such as range values or compliance setting values, in accordance with the measurement parameters passed to the subprograms.

- DC Measurement Subprograms

  Returned values are determined by the subprogram's specified measurement range parameter value. The returned value's polarity is the same as that of the measurements subprogram's output value. Refer to the *Programming Reference* for details on the returned values for each measurement subprogram.

- DC Sweep Measurement Subprograms

  Return a sequence of linear values to the subprogram's measurement value arrays. Linear values returned to the arrays range from 0 to the value specified for the subprogram's measurement range parameter. Refer to the *Programming Reference* for details on the returned values for each measurement subprogram.

- Search Measurement Subprograms

  Returned search values are the average of the Set_asearch, Set_bsearch, or Set_lsearch subprograms' specified start/minimum control and stop/maximum control values. Refer to the *Programming Reference* for details on the returned search value for each measurement subprogram.

- Capacitance Measurement Subprograms

  Returned values are determined by the subprogram's specified measurement range parameter value. Refer to the *Programming Reference* for details on the returned values for each measurement subprogram.

- Port_status

  Returns 0 in the constant data simulation mode.

- Readout_dcs and Readsweep_dcs

  Return 0.1 to the *data* variables or arrays, and return 0 to the *status* variables or arrays.

File Data Simulation

The file data simulation mode is set by calling the Off_line_data TIS subprogram with a specified file name parameter. In this mode, TIS measurement subprograms return measurement values to their respective Off_line_data file name parameter. Refer to the *Programming Reference* for details on returned measurement values for each TIS measurement subprogram.

Offline data simulation files, which are HP-UX ASCII files, contain a sequence of data records that correspond to their respective TIS measurement subprograms. Figure 4-7 shows the general syntax of TIS measurement subprograms and their data records. Parameter items are real numbers. Items are delimited by blank spaces.

The Data_creation TIS subprogram will help you create an entry data file that you can modify to suit your requirements. Refer to the *Programming Reference* for complete details.

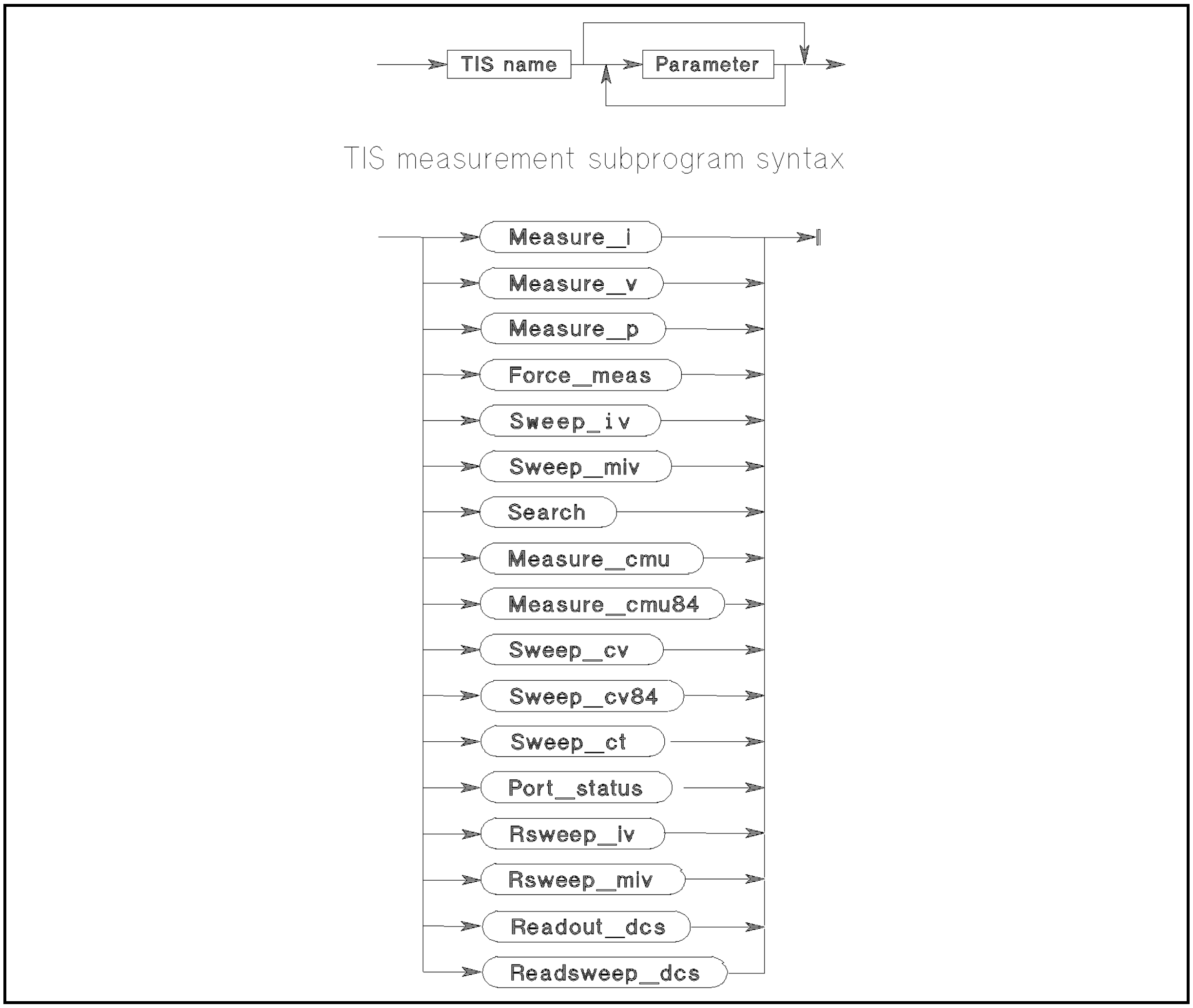


Figure 4-7. Simulation File Data Record Syntax

For TIS sweep subprograms, one or more array data list representing sweep data is included in the data record. Array data lists must be included within square brackets ([ ]). A right bracket ([) indicates the beginning of an array data list, and a left bracket (]) indicates the end of an array data list. Array data lists consist of a number of data lines, each of which represents a list of real numbers corresponding to a TIS measurement subprogram's parameters. A blank space, tab, or comma can be used to delimit each real number, as in the following example:

```
1000 ! Sweep_miv
1010 ! [
1020 !  1.1355 12.537 4.885E-6, 0.0000
1030 !  1.3227 15.831 5.837E-6, 0.1008
1040 !  1.4602 16.992 6.135E-6, 0.1926
1050 !  1.5062 17.032 6.253E-6, 0.3012
1060 ! ]
```

If the number of elements is not enough to fill the corresponding data array, the last element in the list is repeatedly used to fill the rest of the array. Conversely, if the number of elements in the data simulation file exceeds the corresponding array size, extra elements are truncated.

Each line contains an exclamation mark, indicating a standard HP BASIC/UX comment line. If a line also ends with an exclamation mark, the offline data simulation function treats that line as a valid program line.

You can edit data records with the HP BASIC/UX editor, if required.

Example. An example of a data simulation file and its corresponding measurement program is as follows:

Example offline data simulation file named DATA1:

```
1000 ! Measure_v 1.32197
1010 ! Measure_v 1.85224
1020 ! Sweep_iv
1030 ! [
1040 ! -1.00000E-13, 0.00000E+00
1050 !  3.27391E-03, 0.49999E+00
1060 !  5.01159E-03, 1.00001E+00
1070 !  6.21532E-03, 1.50000E+00
1080 !  6.59102E-03, 1.99999E+00
1090 !  6.64221E-03, 2.49999E+00
1100 !  6.64915E-03, 2.99999E+00
1110 !  6.64989E-03, 3.50000E+00
1120 !  6.65023E-03, 4.00001E+00
1130 !  6.65051E-03, 4.50000E+00
1140 !  6.65053E-03, 5.00000E+00
1150 ! ]
```

Example measurement program:

```
  :       :
1040 Off_line_data("DATA1")
1050 !
1060   Connect(FNPort(2),Drain,Gate)
1070   Connect(FNPort(3),Sub)
1080   Connect(FNGnd,Source)
1090 !
1100   Force_v(Sub,Vsub,Vsub,10E-6)
1110   Force_i(Drain,Ids1,Ids2,2.0)
1120   Measure_v(Drain,Vth1,1.8)
1130   Force_i(Drain,Ids2,Ids2,2.0)
1140   Measure_v(Drain,Vth2,1.9)
1150 !
1160   Disable_port(Drain,Gate,Sub)
1170   Connect(FNPort(1),Gate)
1180 !
1190   Force_v(Sub,Vsub,Vsub,10E-6)
1200   Force_v(Gate,Vgs,Vgs,10E-6)
1210   Set_iv(Drain,1,20.0,0.0,5.0,11,0.0,0.0,10E-3)
1220   Sweep_iv(Drain,2,7.0E-3,Ids(*),Vds(*))
1230 !
1240   Disable_port
1250   Connect
1260 !
1270 Off_line_data
  :      :
```

Detecting Errors

Offline test execution can detect most TIS errors, except for error 67, as listed below. Pass parameter checking is performed the same way for both online and offline modes.

Offline test execution can *not* detect errors caused by an SRQ assertion and errors resulting from instrument configuration restrictions.

Error No.	Description
20	Device not present.
21	Invalid port or pin assigned.
22	Improper number of pass parameters specified.
23	Improper size of pass parameters specified.
24	Improper pass parameters' value specified.
25	Between PREPARE ... EXECUTE, a port is measure-assigned twice.
34	Pin board not present.
35	(First pin number) $\geq$ (last pin number)
43	Specified VS not connected. Illegal parameter set.
44	VS output voltage incompatible with set voltage range.
45	SMU compliance incompatible with set source or set range.
46	Illegal sweep power-compliance specified.
47	Start and stop values are not same polarity.
48	VS i_meas : source port must be same as measurement port.
49	Illegal SMU measurement function assigned.
50	Target value incompatible with compliance value.
51	This port must be the same V/I mode as the control variable.
52	Improper search offset value specified.
53	Monitor port must be different form search port.
54	Target value out of range.
55	Illegal search v_range, time, and speed combination specified.
56	SMU output voltage incompatible with set voltage range.
57	Analog Feedback Unit (AFU) not present.
58	Pulse period incompatible with pulse width.
59	Improper DCS sweep, search, and pulse settings.
60	Improper search values (start_value and stop_value) specified.
61	Base_value and peak_value are not same polarity.
62	Specified VM is still set to Differential Voltage Measurement mode.
63	Sync range adjustment error.
64	Cannot specify zero (0) for sweep or bias&sweep.
65	Improper pulse measurement pass parameter specified for set_iv.
66	Improper pulse measurement range specified.
84	CMS output voltage incompatible with set voltage range.

Determining Execution Mode

To determine test session execution mode status, use the Is_on_line TIS subprogram. The Is_on_line subprogram returns the online test session status: 1 is returned if a test session is online; 0 is returned if a test session is not online. Include this TIS subprogram to ensure the isolation between online and offline test sessions. For example, to prevent the storing of simulated data values obtained in an offline process in a true database, use Is_on_line to determine your execution mode.

Instrument Locking in Offline Mode

Implicit locking of the system instruments occurs in the offline mode and is required to ensure exclusive access to the TIS global data area.

Explicit locking is not available in the offline mode, which also means that the Lock_system and Unlock_system TIS subprograms are not supported in the offline mode and are ignored if called.

Because there is no interface between online and offline mode processes, if an online process implicitly or explicitly locks the system instruments, other offline mode test sessions can still execute normally.

Using VFP in Offline Debugging

You can use the VFP in offline mode test sessions, in both the standalone and monitor modes.

For monitor mode operation, the VFP monitors offline measurement program execution the same as for online mode operation.

Standalone mode operation, however, is somewhat restricted during offline operation. You can establish instrument settings and can modify measurement program parameters, but must *not* perform measurements from the offline VFP. This is because it is not possible to obtain valid simulated data for a measurement program during offline VFP standalone mode operation.

Individual Parametric Test Sessions (HP 4062UX only)

Each test session (1) ensures complete independence among multiple users, (2) isolates online and offline test execution, and (3) lets you concurrently run online and offline measurement programs independently from separate test sessions.

Description

Individual test sessions ensure independence among multiple HP 4062UX users, while keeping the system's multitasking capabilities. Each user works within their own test session, and measurement program execution in one session never interferes with operations performed in other test sessions.

Processes within a test session share test system hardware configuration, instrument status, and online or offline execution mode. This information is kept in the system's COM blocks (a shared global data area). The COM blocks are accessible by many processes for specific jobs, especially for debugging. The processes sharing the COM blocks form a test session.

A test session can operate in either the online or offline mode, as established when you first run the START program to generate a test session.

Creating and Destroying Test Sessions

A test session is created when you run the START program and specify a test session name. You must specify the test session name in the shell environment variable named PCS_SESSION_ID. The START program refers to this variable and creates a test session with the name you specified (unless you specified a duplicate name). Logging out automatically destroys a test session.

All measurement program processes during a test session initiate upon the first execution of any TIS subprogram, with the exceptions of run-time error handling procedures and VFP intrinsics.

TIS subprograms obtain the test session name from the shell environment variable PCS_SESSION_ID. While a process is active, it retains this test session name, even if you scratch the HP BASIC/UX program or CSUB library, modify the PCS_SESSION_ID variable, and load the HP BASIC/UX program or CSUB library again.

Note

Adding the following lines to the login shell script files lets you change the test session name using the login shell process ID for constructing test session names:

For /etc/profile:

```
PCS_SESSION_ID=pcs_$$
export PCS_SESSION_ID
```

For /etc/csh.login:

```
setenv PCS_SESSION_ID pcs_$$
```

Also, if you create more than one test session at a single login, change the process ID. This is especially useful when performing online testing in one window while performing offline debugging in another window.

5

Prober Control

Introduction

This chapter provides the information required to control Electroglas 1034X/2001X/2010X/3001X and Tokyo Seimitsu (TSK) A-PM-3000A/6000A/7000A/60A/80A wafer probers using TIS wafer prober control subprograms specific to each wafer prober.

Included for each prober are instructions on prober interface settings, prober manual and auto modes, available prober control TIS subprograms, explanations of how to initiate the various prober functions, and programming examples.

One advantage of using prober control TIS subprograms is that prober control programs are easier to write and can be used to control any wafer prober by simply linking the appropriate version of TIS.

Electroglas 1034X prober control TIS subprograms are provided in EGX files; explanations for controlling this prober begin from "Electroglas 1034X".

Electroglas 2001X/2010X/3001X prober control TIS subprograms are provided in EGY files; explanations for controlling this prober begin from "Electroglas 2001X."

TSK A-PM-3000A/6000A/7000A/60A/80A prober control TIS subprograms are provided in TSK files; explanations for controlling this prober begin from "TSK A-PM-3000A/6000A/7000A".

Caution

TIS prober control subprograms are written in BASIC or BASIC/UX and are unprotected. They can, therefore, be accessed through the computer's EDIT function, making accidental erasure or modification of the subprograms possible. To guard against this possibility, be sure to make backup copies of the system software before you begin using them.

Caution

For the HP 4062PC, the BASIC program in background mode cannot control a wafer prober connected to the PC HP-IB interface card (HP 82335 or HP 82990, select code 25). In background mode, the measurement coprocessor cannot access the HP-IB interface installed in PC slots. You must control the wafer prober in foreground mode only.

Note

Some prober functions described in this chapter depend on the settings of manually operated prober switches. Refer to your prober's manual for details.

This chapter discusses only TIS prober control subprograms. You can use PCL subprograms instead of TIS subprograms, but to do so, you must first create probing data and probing pattern files using the probing pattern generator (PPG). For details on how to use PCL subprograms and the probing pattern generator, refer to Chapter 6.

Electroglas 1034X

The section provides the information you'll need to control the Electroglas 1034X wafer prober using TIS prober control subprograms.

Prober Settings

To control the Electroglas 1034X wafer prober from your HP 4062C/UX/PC, your 1034X must have the following HP-IB capabilities:

Item	Prober Control Command	Data Returned from Prober
Move chuck to specified X-Y coordinates	MOX±xxxxxxY±xxxxx[1]	MC
Chuck up	ZU	MC
Chuck down	ZD	MC
Chuck home	HO	MC
Set the current position as the origin	PRX±xxxxxxY±xxxxx[1]	
Check prober status	?S	SZxx1/0x1/0 [2]

[1] x represents any number between 0 and 9.
[2] x represents any single character. 1/0 represents either 1 or 0.

Your 1034X must be set as follows:

HP-IB Address: 1

SRQ Switch: disabled

START Program Execution

Before you can control your 1034X using TIS (or PCL) subprograms, you must run the START program. When the START program is finished, system configuration information similar to that shown in Figure 5-1 (for HP 4062UX) or Figure 5-2 (for HP 4062C/PC) is displayed.

If a prober name other than 1034X is displayed, or if Not Present is displayed following the prober name, check the interface cable connections, the prober's address setting, and the select code setting of your computer's interface board. Refer to "Prober Settings" for the correct settings.

```
**************** SYSTEM CONFIGURATION **************** **** AVAILABLE PINS *****
4084B/4089A SWITCHING MATRIX:              Present       01 02 03 04 05 06 07 08
4142B DC SOURCE/MONITOR (Rev. 3.00)        Present       09 10 11 12 13 14 15 16
4280A 1MHz C METER/C-V PLOTTER:            Present       17 18 19 20 21 22 23 24
4284A 20Hz-1MHz LCR METER (Opt. 001/006): Not present   25 26 27 28 29 30 31 32
ELECTROGLAS 1034X WAFER PROBER:            Present       33 34 35 36 37 38 39 40
***************** DCS CONFIGURATION ***************** 41 42 43 44 45 46 47 48
SLOT1: 41421B (SMU1)      SLOT5: 41421B (SMU4)
SLOT2:                    SLOT6: 41424A (AUX1/2)         49 50 51 52 53 54 55 56
SLOT3: 41420A (SMU2)      SLOT7: 41425A                  57 58 59 60 61 62 63 64
SLOT4: 41421B (SMU3)      SLOT8:                         65 66 67 68 69 70 71 72
************ AUXILIARY PORT CONFIGURATION ************ 73 74 75 76 77 78 79 80
AUX1: VS1                 AUX3: CMH                      81 82 83 84 85 86 87 88
AUX2: VS2                 AUX4: CML                      89 90 91 92 93 94 95 96

        Session ID: pcs_125
    Execution mode: ON LINE

System date & time: 1 Nov 1989  00:00:00

Select desired softkey.

   Continue   NEXT    PREVIOUS  DEFAULT    LOAD   RE-STORE  CHANGE   QUIT
             CHOICE    CHOICE    CONFIG   CONFIG   CONFIG    MODE
```

Figure 5-1. HP 4062UX START Display (1034X Probers)

```
**************** SYSTEM CONFIGURATION **************** **** AVAILABLE PINS *****
16321A VFP TIMER BOARD:                    Present       01 02 03 04 05 06 07 08
4084B/4089A SWITCHING MATRIX:              Present       09 10 11 12 13 14 15 16
4142B DC SOURCE/MONITOR (Rev. 3.00):       Present       17 18 19 20 21 22 23 24
4280A 1MHz C METER/C-V PLOTTER:            Present       25 26 27 28 29 30 31 32
4284A 20Hz-1MHz LCR METER (Opt. 001/006): Not present   33 34 35 36 37 38 39 40
ELECTROGLAS 1034X WAFER PROBER:            Present       41 42 43 44 45 46 47 48
***************** DCS CONFIGURATION *****************
SLOT1: 41421B (SMU1)      SLOT5: 41421B (SMU4)           49 50 51 52 53 54 55 56
SLOT2:                    SLOT6: 41424A (AUX1/2)         57 58 59 60 61 62 63 64
SLOT3: 41420A (SMU2)      SLOT7:                         65 66 67 68 69 70 71 72
SLOT4: 41421B (SMU3)      SLOT8: 41425A                  73 74 75 76 77 78 79 80
************ AUXILIARY PORT CONFIGURATION ************ 81 82 83 84 85 86 87 88
AUX1: VS1                 AUX3: CMH                      89 90 91 92 93 94 95 96
AUX2: VS2                 AUX4: CML


System date & time: 1 Nov 1989  00:00:00

New system data ?
```

Figure 5-2. HP 4062C/PC START Display (1034X Probers)

Prober Auto and Manual Modes

Before you can control your 1034X using TIS prober control subprograms, you must manually set your prober to the Auto mode by pressing the AUTO key on the prober's Option D interface. There are no HP-IB commands for setting the 1034X to Auto.

When set to Auto, the 1034X's subpanel operations are disabled.

You can determine your prober's Auto or Manual mode status by using TIS's Prober_status subprogram.

Note

If your 1034X is set to Manual mode while a program is running, program execution pauses when the next TIS prober control subprogram executes. To resume program execution, set the 1034X to Auto mode.

TIS Prober Control Subprograms

You can control most of the 1034X's functions by using the TIS prober control subprograms stored in the EGX file. These subprograms are listed as follows:

Pdown
Pup
Pmove
Pimove
Phome
Pscale
Porig
Ppos
Prober_status

You can execute Pscale, Ppos, and Prober_status when your 1034X is set to either the Manual or Auto mode. See the *Programming Reference* for details on the syntax of these subprograms. Sample 1034X control programs are provided in "Sample Programs".

Note

When controlling your 1034X using TIS (or PCL) subprograms, your HP 4062UX may function abnormally if you execute an I/O statement such as ENTER, OUTPUT, or SPOLL.

Setting the System Index and Probing Origin

You must execute the Pscale and Porig subprograms before you can move the prober's X-Y positioner using either the Pimove or Pmove subprogram. To set Pscale and Porig, perform the following procedure:

1. Set your 1034X to Manual and align the wafer.
2. Raise the chuck using the Z DRIVE switch, and probe the initial chip.
3. Set your 1034X to the Auto mode.
4. Set the X- and Y-indexes by executing Pscale.
5. Set the X-Y positioner's present position as the probing origin (stored in TIS variables) by executing Porig.

Do not include Pscale and Porig in a prober control program that contains a Wstart_number or Wstart_xy PCL subprogram, because these PCL subprograms include functions identical to Pscale and Porig. Refer to Chapter 6 for details.

Moving the X-Y Positioner

To move the X-Y positioner, use either the Pmove or Pimove subprogram. Pmove moves the X-Y positioner to the specified X- and Y-coordinates. Pimove, on the other hand, moves the X-Y positioner the specified number of system index units. Figure 5-3 shows the probing sequence that results when the following program is executed. The numbers in parentheses are keyed to the program lines.

```
10   Pscale(5000,5000)
20   Porig
30   Pmove(5,0)
40   Pimove(0,2)
50   Pimove(0,2)
60   Pmove(0,5)
```

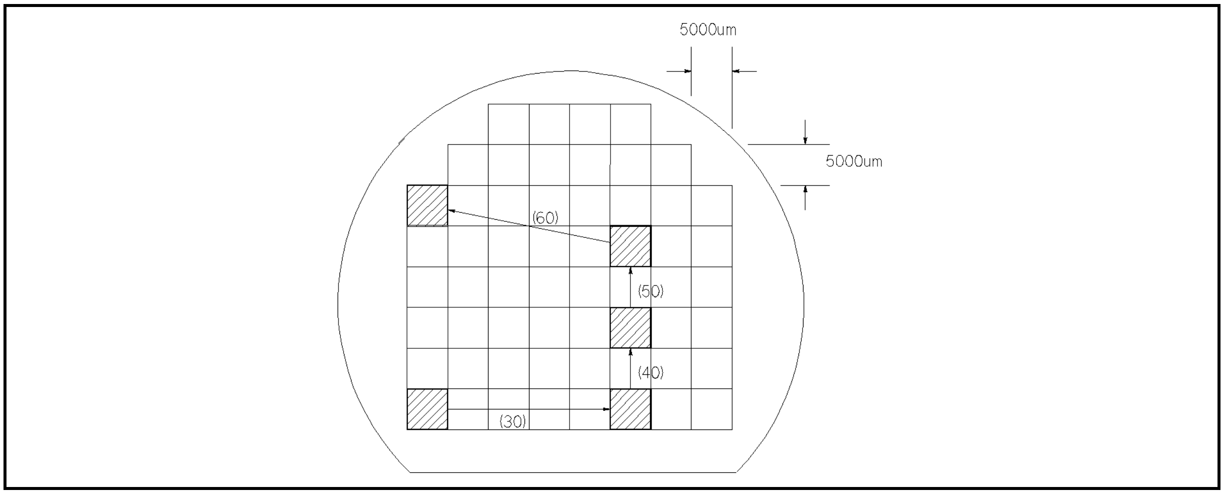


Figure 5-3. Moving the X-Y Positioner (1034X Probers)

The resolution of X-Y positioner movements initiated by Pmove and Pimove statements is determined by the system index units set by Pscale.

Pimove and Pmove initiated movements execute after the TIS variables containing the X- and Y-coordinates of the present probing position are referenced. These variables are updated upon the completion of a movement. You can recall the values stored in these variables by executing the Ppos subprogram.

During program execution, the X-Y positioner can be moved using the joy stick if the 1034X is set to Manual mode. The X- and Y-coordinates stored in the TIS variables before the prober was set to Manual, however, remain unchanged.

Caution Neither TIS nor the wafer prober can detect out-of-range X-Y positioner conditions. Be careful when specifying Pmove or Pimove parameters. Improper parameters may cause the wafer forcer to strike the platen frame.

Raising and Lowering the Chuck

Normally, the chuck lowers automatically before the X-Y positioner is moved, then raises automatically upon completion of a movement. If the chuck is already down when a movement executes, it remains down at the completion of the movement.

To raise and lower the chuck whenever the X-Y positioner is stationary, use the Pup and Pdown subprograms. If Pup and Pdown are used in conjunction with any X-Y positioner movement (independent from program control), check the Prober_status. If the second parameter of the Prober_status subprogram is 1, then the probes are positioned on the wafer.

Loading and Unloading Wafers

To load and unload wafers, use the Phome subprogram. After you execute Phome and the wafer chuck has returned to its home position, set the VACUUM switch on your 1034X to off. When Phome executes, the wafer chuck is lowered, the X-Y positioner moves to the home (wafer loading) position, and the prober is set to Manual mode, at which time you can load or unload a wafer, or perform any manual operations.

Sample Programs

The following sample programs show how to control your Electroglas 1034X wafer prober using TIS prober control subprograms. Figure 5-4 shows an example for sequentially probing selected chips, and Figure 5-5 shows an example for probing all chips in sequential order.

Be sure to link TIS and EGX before you execute a measurement program. To link TIS and EGX to your measurement program, perform the following procedure.

- For HP 4062UX:
  1. Select the `Link TIS` softkey.
  2. Type in `LOADSUB FROM "/usr/pcs/lib/EGX"` (Return)
- For HP 4062C/PC with the recommended directory structure:
  1. Select the `Link TIS` softkey.
  2. Type in:

     `LOADSUB FROM "/PCS/LIB/EGX"` (Return) *for HP 4062C/PC*
     `LOADSUB FROM "\PCS\LIB\EGX"` (Return) *for HP 4062PC*
- For HP 4062C/PC with the flexible disks:
  1. Insert SYSTEM SOFTWARE (2) disk into the current system mass storage.
  2. Select the `Link TIS` softkey.
  3. Type in `LOADSUB FROM "EGX"` (Return)

This program probes the chips whose X-Y coordinates are specified in the DATA statement on line 120.

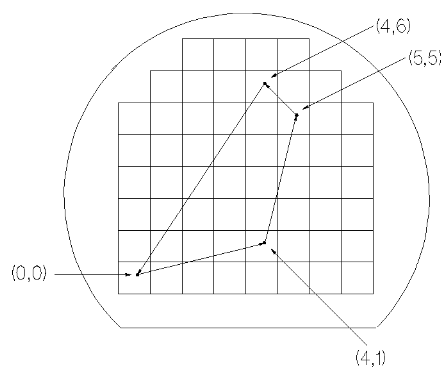
```
10   !
20   !  Sample Program
30   !    Requirements: TIS,EGX
40   !
50   INTEGER Auto,Onwafer
60   !
70   Size_x=5000
80   Size_y=5000
90   !
100  Init_system
110  !
120  DATA 4,1,5,5,4,6,0,0
130  !
140  Pscale(Size_x,Size_y)
150  DISP "Align the wafer then press [AUTO]."
160  REPEAT
170   Prober_status(Auto)
180  UNTIL Auto
190  DISP
200  !
210  X=0
220  Y=0
230  Porig(X,Y)
240  !
250  REPEAT
260    READ X,Y
270    Pmove(X,Y)
280    Prober_status(Auto,Onwafer)
290    IF Onwafer THEN CALL Test
300  UNTIL X=0 AND Y=0
310  Phome
320  END
330  !
340  !
350  SUB Test
360  !
370  SUBEND
380  !
```

Figure 5-4. Sample Program: Probing Selected Chips (1034X Probers)

Lines 70 and 80:	Set the size of each chip.
Line 100:	Initializes the system.
Line 120:	Sets the coordinates of the chips to be probed. The coordinates of the first chip to be probed are (4,1), and those of the second chip, (5,5), etc. A total of three chips are probed.

Line 140:	Sets the index values for X and Y.
Lines 150 through 180:	Repeatedly check prober status until the prober is set to Auto mode, at which time the remainder of the program is executed.
Line 230:	Sets the present position as the probing origin.
Line 260:	Reads the X-Y coordinates of the chip being probed from the DATA statement in line 120.
Lines 270 through 290:	Set the prober on the chip and execute the Test subprogram, if Onwafer is true.
Line 300:	Repeats lines 260 through 290 until the prober returns to 0,0.
Line 310:	Moves the X-Y positioner to the home position and sets the 1034X to Manual mode.
Lines 350 through 370:	Insert the measurement routine here.

The probing pattern that results when this program executes is as follows:



This program probes all chips, starting from the lower left-hand side of the wafer.

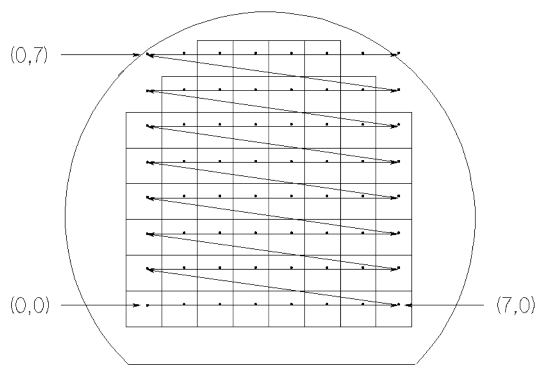
```
10   !
20   ! Sample Program
30   !   Requirements: TIS,EGX
40   !
50   Integer Auto,Onwafer
60   !
70   Size_x=5000
80   Size_y=5000
90   Chip_x=7
100  Chip_y=7
110  !
120  Init_system
130  !
140  Pscale(Size_x,Size_y)
150  DISP "Align the wafer then press [AUTO]."
160  REPEAT
170    Prober_status(Auto)
180  UNTIL Auto
190  DISP
200  !
210  X=0
220  Y=0
230  Porig(X,Y)
240  !
250  FOR Y=0 TO Chip_y
260    FOR X=0 TO Chip_x
270      Pmove(X,Y)
280      Prober_status(Auto,Onwafer)
290      IF Onwafer THEN CALL Test
300    NEXT X
310  NEXT Y
320  Phome
330  END
340  !
350  !
360  SUB Test
370  !
380  SUBEND
390  !
```

Figure 5-5. Sample Program: Probing All Chips (1034X Probers)

Lines 70 and 80:	Set the size of the chips.
Lines 90 and 100:	Set the number of chips for X and Y.
Line 120:	Initializes the system.
Line 140:	Sets the index values for X and Y.

Lines 130 through 160:	Repeatedly check prober status until the prober is set to Auto, at which time the remainder of the program is executed.
Line 230:	Sets the present position as the probing origin.
Lines 250 through 290:	Move the X-Y positioner one index unit and execute the subprogram Test if onwafer is true. These steps are repeated until the coordinates of the chip being probed are equal to Chip_y and Chip_x.
Line 320:	Moves the X-Y positioner to the home position and sets the 1034X to Manual mode.
Lines 360 through 380:	Insert the measurement routine here.

The probing pattern that results when this program executes is as follows.



Electroglas 2001X

The section provides the information you'll need to control the Electroglas 2001X wafer prober using TIS prober control subprograms.

Prober Settings

To control the Electroglas 2001X wafer prober from your HP 4062C/UX/PC, your 2001X must have the following HP-IB capabilities:

Item	Prober Control Command	Data Returned[1] from Prober
Move chuck to specified X-Y coordinates	MMX±xxxxxxY±xxxxxx[2]	MC[3]
Chuck up	ZU	MC[3]
Chuck down	ZD	
Chuck home	LO	MC[3]
Auto Profile	PZ	
Auto Align	AA	MC[3]
Trigger an inker	IKx[4]	
Check prober status	?S	SZU/DW0/1C0/1[5]
Response to AUTOPROBE key		SP[3]

1 Your 2001X must be set to true SRQ line before outputting data.
2 x represents any number between 0 and 9.
3 Must return MF if the command response fails.
4 x represents any ASCII character between 0 and ?.
5 U/D represents either U or D. 0/1 represents either 0 or 1.

Your 2001X must be set as follows.

Set mode display

METRIC/ENGLISH: METRIC
AUTO PROBER PATTERN: EXTERNAL
I/O PROTOCOL: STANDARD

External I/O parameters

I/O PORT: GP-IB
GP-IB ADDRESS: 2

Set option display

AUTO LOAD: ENB
AUTO ALIGN: ENB
AUTO PROFILE: ENB

SRQ switch (A4 SW1-8): ENB (open)

START Program Execution

Before you can control your 2001X using TIS (or PCL) subprograms, you must run the START program. When the START program is finished, system configuration information similar to that shown in Figure 5-6 (for HP 4062UX) or Figure 5-7 (for HP 4062C/PC) is displayed.

If a prober name other than 2001X is displayed, or if Not Present is displayed following the prober name, check the interface cable connections, the prober's address setting, and the select code setting of your computer's interface board. Refer to "Prober Settings" for the correct settings.

```
***************** SYSTEM CONFIGURATION *****************|**** AVAILABLE PINS *****
4084B/4089A SWITCHING MATRIX:             Present       | 01 02 03 04 05 06 07 08
4142B DC SOURCE/MONITOR (Rev. 3.00)       Present       | 09 10 11 12 13 14 15 16
4280A 1MHz C METER/C-V PLOTTER:           Present       | 17 18 19 20 21 22 23 24
4284A 20Hz-1MHz LCR METER (Opt. 001/006): Not present   | 25 26 27 28 29 30 31 32
ELECTROGLAS 2001X WAFER PROBER:           Present       | 33 34 35 36 37 38 39 40
****************** DCS CONFIGURATION ******************| 41 42 43 44 45 46 47 48
SLOT1: 41421B (SMU1)       SLOT5: 41421B (SMU4)         |
SLOT2:                     SLOT6: 41424A (AUX1/2)       | 49 50 51 52 53 54 55 56
SLOT3: 41420A (SMU2)       SLOT7: 41425A                | 57 58 59 60 61 62 63 64
SLOT4: 41421B (SMU3)       SLOT8:                       | 65 66 67 68 69 70 71 72
************ AUXILIARY PORT CONFIGURATION ************  | 73 74 75 76 77 78 79 80
AUX1: VS1                  AUX3: CMH                    | 81 82 83 84 85 86 87 88
AUX2: VS2                  AUX4: CML                    | 89 90 91 92 93 94 95 96

        Session ID: pcs_125
    Execution mode: ON LINE

System date & time: 1 Nov 1989  00:00:00

Select desired softkey.

 Continue | NEXT   | PREVIOUS | DEFAULT | LOAD   | RE-STORE | CHANGE | QUIT
          | CHOICE | CHOICE   | CONFIG  | CONFIG | CONFIG   | MODE   |
```

Figure 5-6. HP 4062UX START Display (2001X Probers)

```
***************** SYSTEM CONFIGURATION *****************|**** AVAILABLE PINS *****
16321A VFP TIMER BOARD:                   Present       | 01 02 03 04 05 06 07 08
4084B/4089A SWITCHING MATRIX:             Present       | 09 10 11 12 13 14 15 16
4142B DC SOURCE/MONITOR (Rev. 3.00):      Present       | 17 18 19 20 21 22 23 24
4280A 1MHz C METER/C-V PLOTTER:           Present       | 25 26 27 28 29 30 31 32
4284A 20Hz-1MHz LCR METER (Opt. 001/006): Not present   | 33 34 35 36 37 38 39 40
ELECTROGLAS 2001X WAFER PROBER:           Present       | 41 42 43 44 45 46 47 48
****************** DCS CONFIGURATION ******************|
SLOT1: 41421B (SMU1)       SLOT5: 41421B (SMU4)         | 49 50 51 52 53 54 55 56
SLOT2:                     SLOT6: 41424A (AUX1/2)       | 57 58 59 60 61 62 63 64
SLOT3: 41420A (SMU2)       SLOT7:                       | 65 66 67 68 69 70 71 72
SLOT4: 41421B (SMU3)       SLOT8: 41425A                | 73 74 75 76 77 78 79 80
************ AUXILIARY PORT CONFIGURATION ************  | 81 82 83 84 85 86 87 88
AUX1: VS1                  AUX3: CMH                    | 89 90 91 92 93 94 95 96
AUX2: VS2                  AUX4: CML



System date & time: 1 Nov 1989  00:00:00

New system data ?
```

Figure 5-7. HP 4062C/PC START Display (2001X Probers)

Prober Remote and Local Modes

Before you can control your 2001X using TIS prober control subprograms, you must set your prober to the Remote mode. There are no HP-IB commands for setting your 2001X to Remote. Your prober's RUN TIME display must display "IDLE" and "ON LINE" before you execute your program.

To control your 2001X using TIS subprograms, perform the following procedure:

1. Turn on the 2001X.
2. Press the cassette switches.
3. Press the switch on the left side of the joystick.
4. Set your prober as described in "Prober Settings".
5. Run the START program.
6. Load, align, and profile a wafer as follows:
   a. Press LOAD on the joystick unit.
   b. Press the FID TARG key on the Monitor Unit.
   c. Use the joystick to set the probing pattern.
   d. Press the PAUSE key.
   e. Press the ALIGN SCAN key.
   f. Use the joystick to move the wafer to the first area.
   g. Press the FIRST key.
7. Load your program and link EGY.
8. Press the AUTOPROBE key on the operator console to lock out the key board (set your 2001X to Remote). The run time display changes from IDLE to PROBE.

Pressing the AUTOPROBE key locks out your 2001X's keyboard and sends a status message telling the controller that prober setup is complete and testing may begin. To determine whether your prober is set to Remote or Local, use the Prober_status subprogram.

Note

To stop program execution, press your system controller's (Stop) key only. Program execution continues if you press the PAUSE key on the prober's operator console.

TIS Prober Control Subprograms

You can control most of the 2001X's functions by using the TIS prober control subprograms stored in the EGY file. These subprograms are listed as follows:

Pdown
Pup
Pmove
Pimove
Phome
Pscale
Porig
Ppos
Pink
Prober_reset
Prober_status

You can execute Pscale, Porig, Ppos, Prober_reset, and Prober_status when your 2001X is set to either the Remote or Local mode. See the *Programming Reference* for details on the syntax of these subprograms. Sample 2001X control programs are provided in "Sample Programs".

Note

When controlling your 2001X using TIS (or PCL) subprograms, your HP 4062C/UX/PC may function abnormally if you execute an I/O statement such as ENTER, OUTPUT, or SPOLL.

Setting the System Index and Probing Origin

You must execute the Pscale and Porig subprograms before you can move the prober's X-Y stage using either the Pimove or Pmove subprogram.

Pscale sets the system index for Pimove and Pmove initiated X-Y stage movements. You can execute Pscale before you set your wafer prober to the Remote mode.

Porig sets the origin for all absolute movements (Pmove) of the prober's X-Y stage by assigning the specified X- and Y-coordinate values to the present probing position, then calculating the origin (0,0) from the system index values specified by Pscale.

If the X- and Y-coordinates specified by Porig are (0,0), or if no coordinates are specified, the present probing position becomes the origin. The present probing position is stored in TIS variables. These variables are updated each time the X-Y stage is moved so that the program always knows the present probing position. You must execute Porig after a new wafer is loaded.

Do not include Pscale and Porig in a prober control program that contains a Wstart_number or Wstart_xy PCL subprogram, because these PCL subprograms include functions identical to Pscale and Porig. Refer to Chapter 6 for details.

Moving the X-Y Stage

To move the X-Y stage, use either the Pmove or Pimove subprogram. Pmove moves the X-Y stage to the specified X- and Y-coordinates. Pimove, on the other hand, moves the X-Y stage the specified number of system index units. Figure 5-8 shows the probing sequence that results when the following program executes. The numbers in parentheses are keyed to the program lines.

```
10   Pscale(5000,5000)
20   Porig
30   Pmove(5,0)
40   Pimove(0,2)
50   Pimove(0,2)
60   Pmove(0,5)
```

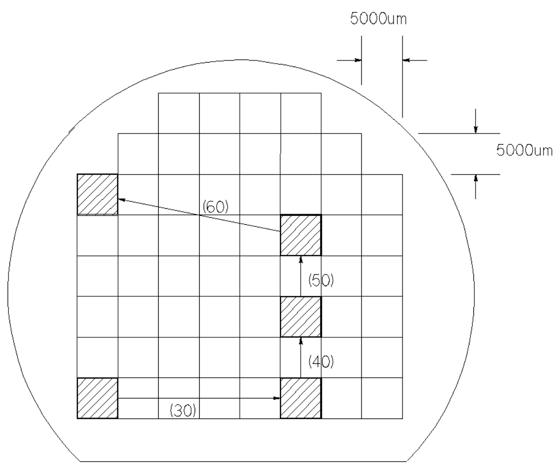


Figure 5-8. Moving the X-Y Stage (2001X Probers)

Pimove and Pmove initiated movements execute after the TIS variables containing the X- and Y-coordinates of the present probing position are referenced. These variables are updated upon the completion of a movement. You can recall the values stored in these variables by executing the Ppos subprogram.

During program execution, you can move the X-Y stage using the joystick if the 2001X is set to PAUSE or IDLE mode. The X- and Y-coordinates stored in the TIS variables before the prober was set to PAUSE or IDLE, however, remain unchanged.

Note

Operator console initiated X-Y stage movements are in the index units set from the operator console.

Raising and Lowering the Chuck

Normally, the chuck lowers automatically before the X-Y stage moves. To raise the chuck when a movement completes, use the Pup subprogram. If the chuck is already down when a movement executes, it remains down at the completion of the movement. You can execute the Pup and Pdown subprograms when the X-Y stage is stationary.

Inker Trigger

To trigger your prober's inker function, use TIS's Pink(n) subprogram, where n is an integer between 0 and 15 that specifies the inker bin code. The actual inkers to be triggered by the inker bin code depend on the preset inker assignment.

Loading and Unloading Wafers

To load and unload wafers, use the Phome subprogram. If the wafer prober is ON LINE, Phome performs the following operations:

1. Unloads the wafer from the X-Y stage.
2. Loads, profiles, and aligns the next wafer.
3. Moves the X-Y stage to the initial probing position.

During this sequence of operations, the wafer prober remains ON LINE. After the X-Y stage is positioned at the initial probing position, the wafer prober is automatically set to the Remote mode.

Before you execute any other prober control subprograms, the program must check the prober status to confirm that the prober is Remote. When the last wafer is unloaded, the prober is not returned to Remote, and this causes TIS error 41. Check this flag and Remote mode status by using the Prober_status subprogram.

If your 2001X is not equipped with a profiler, a program modification is necessary because Phome sends a profiler control command. Refer to the semantics for Phome in the *Programming Reference* .

Checking Prober Status

To check your prober's Remote or Local status, execute the Prober_status subprogram. The syntax of Prober_status is as follows:

```
Prober_status (variable 1, variable 2)
```

If the value returned to variable 1 is 1, the wafer prober is in the Remote mode. Variable 2 indicates whether the present probing position is on the wafer or not, and is altered when Pmove, Pimove, or Pup executes. A 1 is returned to variable 2 when the probe is on the wafer.

Sample Programs

The following sample programs show how to control your Electroglas 2001X wafer prober using TIS prober control subprograms. Figure 5-9 shows an example for sequentially probing selected chips, and Figure 5-10 shows an example for probing all chips in sequential order.

Be sure to link TIS and EGY before you execute a measurement program. To link TIS and EGY to your measurement program, perform the following procedure.

- For HP 4062UX:
  1. Select the `Link TIS` softkey.
  2. Type in `LOADSUB FROM "/usr/pcs/lib/EGY"` (Return)
- For HP 4062C/PC with the recommended directory structure:
  1. Select the `Link TIS` softkey.
  2. Type in:

     `LOADSUB FROM "/PCS/LIB/EGY"` (Return) *for HP 4062C/PC*
     `LOADSUB FROM "\PCS\LIB\EGY"` (Return) *for HP 4062PC*
- For HP 4062C/PC with the flexible disks:
  1. Insert SYSTEM SOFTWARE (2) disk into the current system mass storage.
  2. Select the `Link TIS` softkey.
  3. Type in `LOADSUB FROM "EGY"` (Return)

This program probes the chips whose X-Y coordinates are specified in the DATA statement on line 120.

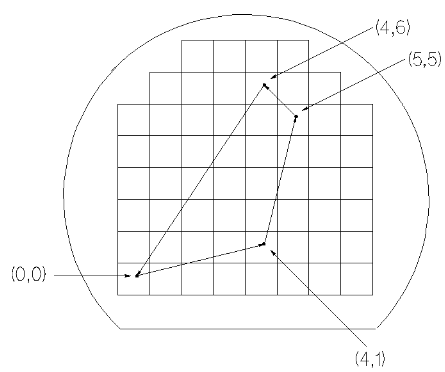
```
10   !
20   !  Sample Program
30   !    Requirements: TIS,EGY
40   !
50   INTEGER Auto,Onwafer
60   !
70   Size_x=5000
80   Size_y=5000
90   !
100  Init_system
110  !
120  DATA 4,1,5,5,4,6,0,0
130  !
140  Pscale(Size_x,Size_y)
150  DISP "Align the wafer then press [AUTO PROBE]."
160  REPEAT
170    Prober_status(Auto)
180  UNTIL Auto
190  DISP
200  !
210  X=0
220  Y=0
230  Porig(X,Y)
240  !
250  REPEAT
260    READ X,Y
270    Pmove(X,Y)
280    Prober_status(Auto,Onwafer)
290    IF Onwafer THEN CALL Test
300  UNTIL X=0 AND Y=0
310  Phome
320  END
330  !
340  !
350  SUB Test
360  !
370  SUBEND
380  !
```

Figure 5-9. Sample Program: Probing Selected Chips (2001X Probers)

Lines 70 and 80:	Set the size of each chip.
Line 100:	Initializes the system.
Line 120:	Sets the coordinates of the chips to be probed. The coordinates of the first chip to be probed are (4,1), and those of the second chip, (5,5), etc. A total of three chips are probed.

Line 140:	Sets the index values for X and Y.
Lines 150 through 180:	Repeatedly check prober status until the prober is set to Remote mode, at which time the remainder of the program is executed.
Line 230:	Sets the present position as the probing origin.
Line 240:	Raises the chuck.
Line 270:	Reads the X-Y coordinates of the chip being probed from the DATA statement in line 120.
Lines 280 through 300:	Set the prober on the chip and execute the Test subprogram if onwafer is true.
Line 310:	Repeats lines 270 through 300 until the probe returns to 0,0.
Line 320:	Moves the X-Y positioner to the home position and sets the 1034X to Local mode.
Lines 360 through 380:	Insert the measurement routine here.

The probing pattern that results when this program is executed is as follows:



This program probes all chips, starting from the lower left-hand side of the wafer, and provides an example for controlling a fully automatic wafer prober.

```
10   !
20   !  Sample Program
30   !    Requirements: TIS,EGY
40   !
50   Integer Rmt,Onwafer,No_wafer
60   !
70   Size_x=5000
80   Size_y=5000
90   Chip_x=7
100  Chip_y=7
110  !
120  Init_system
130  !
140  Pscale(Size_x,Size_y)
150  DISP "Align the wafer then press [AUTO PROBE]."
160  LOOP
170    REPEAT
180      Prober_status(Rmt,Onwafer,Nowafer)
190    UNTIL Rmt
200    DISP
210    !
220    X=0
230    Y=0
240    Porig(X,Y)
250    Pup
260    FOR Y=0 TO Chip_y
270      FOR X=0 TO Chip_x
280        Pmove(X,Y)
290        Prober_status(Rmt,Onwafer)
300        IF Onwafer THEN CALL Test
310      NEXT X
320    NEXT Y
330    Phome
340  END LOOP
350  END
360  !
370  !
380  SUB Test
390  !
400  SUBEND
410  !
```

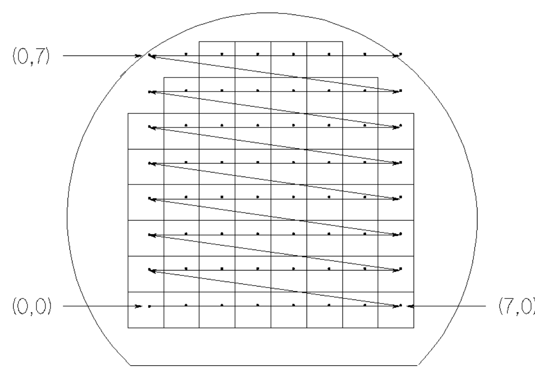
Figure 5-10. Sample Program: Probing All Chips (2001X Probers)

Lines 70 and 80: Sets the size of the chips.

Lines 90 and 100: Sets the number of chips for X and Y.

Line 120:	Initializes the system.
Line 140:	Sets the index values for X and Y.
Lines 150 through 190:	Repeatedly check prober status until the prober is set to Remote at which time the remainder of the program is executed.
Lines 220 through 240:	Sets the current position as the probing origin.
Lines 260 through 290:	Move the X-Y stage one index unit and execute the subprogram Test if OnWafer is true. These steps repeat until the coordinates of the chip being probed are equal to Chip_x, Chip_y.
Line 330:	Unloads the present wafer and loads the next wafer.
Line 340:	Repeats line 170 through 340 until the last wafer is unloaded.
Lines 380 through 400:	Insert the measurement routine here.

The probing pattern that results when this program executes is as follows.



TSK A-PM-3000A/6000A/7000A

The section provides the information you'll need to control Tokyo Seimitsu (TSK) A-PM-3000A/6000A/7000A wafer probers using TIS prober control subprograms.

Prober Settings

To control the TSK wafer prober from your HP 4062C/UX/PC, your prober must have the following HP-IB capabilities:

Item	Prober Control Command	Data Returned from Prober
Move chuck to specified X-Y coordinates	AY±xxxxxxX±xxxxx[1]	65
Chuck up	Z	67 or 73[2]
Chuck down	D	68
CPU halt	T	
Trigger inker	Mx[3]	69
Chuck home	L	70 or 76[4]

[1] x represents any number between 0 and 9.
[2] 73 indicates Edge sensor is ON.
[3] x represents any number between 1 and 4.
[4] 76 (error SRQ) indicates cassette is empty. If 76 is returned, output E0010 (string) for E command from the system controller.

Your TSK must be set as follows:

- HP-IB Address: 5
- Mode Switches:

  3-4 OFF
  3-5 ON
  23-4 ON

START Program Execution

Before you can control your TSK prober using TIS (or PCL) subprograms, you must run the START program. When the START program is finished, system configuration information similar to that shown in Figure 5-11 (for HP 4062UX) or Figure 5-12 (for HP 4062C/PC) is displayed.

If a prober name other than your TSK prober is displayed, or if Not Present is displayed following the prober name, check the interface cable connections, the prober's address setting, and the select code setting of your computer's interface board. Refer to "Prober Settings" for the correct settings.

```
**************** SYSTEM CONFIGURATION **************** |**** AVAILABLE PINS *****
4084B/4089A SWITCHING MATRIX:                 Present  |  01 02 03 04 05 06 07 08
4142B DC SOURCE/MONITOR (Rev. 3.00)           Present  |  09 10 11 12 13 14 15 16
4280A 1MHz C METER/C-V PLOTTER:               Present  |  17 18 19 20 21 22 23 24
4284A 20Hz-1MHz LCR METER (Opt. 001/006): Not present  |  25 26 27 28 29 30 31 32
A-PM-3000A/6000A WAFER PROBER:                Present  |  33 34 35 36 37 38 39 40
**************** DCS CONFIGURATION ****************    |  41 42 43 44 45 46 47 48
SLOT1: 41421B (SMU1)       SLOT5: 41421B (SMU4)        |
SLOT2:                     SLOT6: 41424A (AUX1/2)      |  49 50 51 52 53 54 55 56
SLOT3: 41420A (SMU2)       SLOT7: 41425A               |  57 58 59 60 61 62 63 64
SLOT4: 41421B (SMU3)       SLOT8:                      |  65 66 67 68 69 70 71 72
************ AUXILIARY PORT CONFIGURATION ************  |  73 74 75 76 77 78 79 80
AUX1: VS1                  AUX3: CMH                   |  81 82 83 84 85 86 87 88
AUX2: VS2                  AUX4: CML                   |  89 90 91 92 93 94 95 96

        Session ID: pcs_125
    Execution mode: ON LINE

System date & time: 1 Nov 1989  00:00:00

Select desired softkey.

 Continue  NEXT    PREVIOUS  DEFAULT   LOAD    RE-STORE  CHANGE   QUIT
           CHOICE  CHOICE    CONFIG    CONFIG  CONFIG    MODE
```

Figure 5-11. HP 4062UX START Display (TSK Probers)

```
**************** SYSTEM CONFIGURATION **************** |**** AVAILABLE PINS *****
16321A VFP TIMER BOARD:                       Present  |  01 02 03 04 05 06 07 08
4084B/4089A SWITCHING MATRIX:                 Present  |  09 10 11 12 13 14 15 16
4142B DC SOURCE/MONITOR (Rev. 3.00):          Present  |  17 18 19 20 21 22 23 24
4280A 1MHz C METER/C-V PLOTTER:               Present  |  25 26 27 28 29 30 31 32
4284A 20Hz-1MHz LCR METER (Opt. 001/006): Not present  |  33 34 35 36 37 38 39 40
A-PM-3000A/6000A WAFER PROBER:                Present  |  41 42 43 44 45 46 47 48
**************** DCS CONFIGURATION ****************    |
SLOT1: 41421B (SMU1)       SLOT5: 41421B (SMU4)        |  49 50 51 52 53 54 55 56
SLOT2:                     SLOT6: 41424A (AUX1/2)      |  57 58 59 60 61 62 63 64
SLOT3: 41420A (SMU2)       SLOT7:                      |  65 66 67 68 69 70 71 72
SLOT4: 41421B (SMU3)       SLOT8: 41425A               |  73 74 75 76 77 78 79 80
************ AUXILIARY PORT CONFIGURATION ************  |  81 82 83 84 85 86 87 88
AUX1: VS1                  AUX3: CMH                   |  89 90 91 92 93 94 95 96
AUX2: VS2                  AUX4: CML


System date & time: 1 Nov 1989  00:00:00

New system data ?
```

Figure 5-12. HP 4062C/PC START Display (TSK Probers)

Prober Remote and Local Modes

Before you can control your TSK prober using TIS prober control subprograms, you must set your prober to the Remote mode. To set your TSK prober to Remote, press the DATA IN switch after you align a wafer in GP-IB mode. Use the Prober_status subprogram to confirm your prober's Remote status. TSK probers are set to Local when a Phome or Prober_reset subprogram is executed.

TIS Prober Control Subprograms

You can control most TSK prober functions by using the TIS prober control subprograms stored in the TSK file. These subprograms are listed as follows:

Pdown
Pup
Pmove
Pimove
Phome
Pscale
Porig
Ppos
Pink
Prober_reset
Prober_status

You can execute Pscale, Porig, Ppos, Prober_reset, and Prober_status when your TSK prober is set to either the Remote or Local mode. See the *Programming Reference* for details on the syntax of these subprograms. Sample TSK prober control programs are provided in "Sample Programs".

Note

When controlling your TSK prober using TIS (or PCL) subprograms, your HP 4062C/UX/PC may function abnormally if you execute an I/O statement such as ENTER, OUTPUT, or SPOLL.

Setting the System Index and Probing Origin

You must execute the Pscale and Porig subprograms before you can move the prober's X-Y stage using either the Pimove or Pmove subprogram.

Pscale sets the system index for Pimove and Pmove initiated X-Y stage movements. You can execute Pscale before you set your wafer prober to the Remote mode.

Porig sets the origin for all absolute movements (Pmove) of the prober's X-Y stage by assigning the specified X- and Y-coordinate values to the present probing position, then calculating the origin (0,0) from the system index values specified by Pscale.

If the X- and Y-coordinates specified by Porig are (0,0), or if no coordinates are specified, the present probing position becomes the origin. The present probing position is stored in TIS variables. These variables are updated each time the X-Y stage is moved so that the program always knows the present probing position. You must execute Porig after a new wafer is loaded.

Do not include Pscale and Porig in a prober control program that contains a Wstart_number or Wstart_xy PCL subprogram, because these PCL subprograms include functions identical to Pscale and Porig. Refer to Chapter 6 for details.

Moving the X-Y Stage

To move the X-Y stage, use either the Pmove or Pimove subprogram. Pmove moves the X-Y stage to the specified X- and Y-coordinates. Pimove, on the other hand, moves the X-Y stage the specified number of system index units. Figure 5-13 shows the probing sequence that results when the following program executes. The numbers in parentheses are keyed to the program lines.

```
10   Pscale(5000,5000)
20   Porig
30   Pmove(5,0)
40   Pimove(0,2)
50   Pimove(0,2)
60   Pmove(0,5)
```

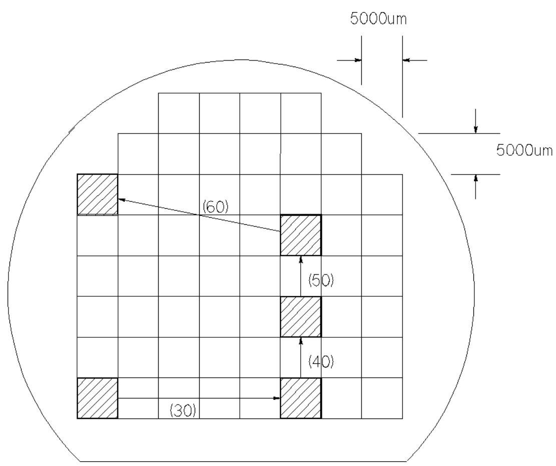


Figure 5-13. Moving the X-Y Stage (TSK Probers)

The resolution of X-Y stage movements initiated by Pmove and Pimove is determined by the system index units set by Pscale.

Pimove and Pmove initiated movements execute after the TIS variables containing the X- and Y-coordinates of the present probing position are referenced. These variables are updated upon the completion of a movement. You can recall the values stored in these variables by executing the Ppos subprogram.

Pmove and Pimove halt your TSK prober's processor to minimize measurement errors caused by system noise. Therefore, the prober's panel controls are disabled.

Raising and Lowering the Chuck

Normally, the chuck lowers automatically before the X-Y stage is moved, then raises automatically at the completion of a movement. If the chuck is already down when a movement executes, it remains down at the completion of a movement. You can execute Pup and Pdown at any time when the X-Y stage is stationary.

The Pup subprogram halts your TSK prober's processor after the chuck is raised to minimize measurement errors caused by noise. Pdown releases the processor from its halt state.

Inker Trigger

To trigger your prober's inker function, use TIS's Pink(n) subprogram, where n is an integer between 1 and 4 that specifies the inker to be triggered. If the processor is halted before Pink executes, the processor is released from its halt condition.

Loading and Unloading Wafers

To load and unload wafers, use the Phome subprogram. If the wafer prober's UNLOAD switch is set to AUTO, Phome performs the following operations:

1. Unloads the wafer from the X-Y stage.
2. Loads and aligns the next wafer.
3. Moves the X-Y stage to the initial probing position.

During this sequence of operations, the wafer prober is released from the Remote mode. After the X-Y stage is positioned at the initial probing position, the wafer prober is automatically set to the Remote mode.

Before you execute any other prober control subprograms, the program must check the prober status to confirm that the prober is Remote. When the last wafer has been unloaded, the prober is not returned to Remote, but sets a flag indicating there are no more wafers in the wafer stack. Check this flag and Remote mode status by using the Prober_status subprogram.

Checking Prober Status

To check your prober's Remote or Local status, execute the Prober_status subprogram. The syntax of Prober_status is as follows:

```
Prober_status (variable 1, variable 2, variable 3)
```

If the value returned to variable 1 is 1, the wafer prober is in the Remote mode.

Variable 2 indicates whether the present probing position is on the wafer or not, and is altered when Pmove, Pimove, or Pup executes. A 1 is returned to variable 2 when the prober is on the wafer.

Variable 3 indicates wafer stack status. After the last wafer is unloaded from the chuck by the Phome subprogram, this variable is set to 1 and the prober is set to the Local mode. Variable 3 is always 0 if your prober is *not* equipped with an automatic wafer loader.

Prober Processor Halt

To reduce the possibility of measurement errors caused by noise generated by your TSK prober, the prober's processor is halted when Pup, Pmove, or Pimove executes. While the processor is halted, the prober's front panel controls are disabled, except for the INITIAL switch. The processor is released from its halt condition when a Pdown, Pink, Phome, or Prober_reset subprogram executes.

Sample Programs

The following sample programs show how to control your TSK prober using TIS prober control subprograms. Figure 5-14 shows an example for sequentially probing selected chips, and Figure 5-15 shows an example for probing all chips in sequential order.

Be sure to link TIS and TSK before you execute a measurement program. To link TIS and TSK to your measurement program, perform the following procedure.

- For HP 4062UX:
  1. Select the `Link TIS` softkey.
  2. Type in `LOADSUB FROM "/usr/pcs/lib/TSK"` (Return)
- For HP 4062C/PC with the recommended directory structure:
  1. Select the `Link TIS` softkey.
  2. Type in:

     `LOADSUB FROM "/PCS/LIB/TSK"` (Return) *for HP 4062C/PC*
     `LOADSUB FROM "\PCS\LIB\TSK"` (Return) *for HP 4062PC*
- For HP 4062C/PC with the flexible disks:
  1. Insert SYSTEM SOFTWARE (2) disk into the current system mass storage.
  2. Select the `Link TIS` softkey.
  3. Type in `LOADSUB FROM "TSK"` (Return)

This program probes three chips whose X-Y coordinates are specified in the DATA statement on line 120.

```
10   !
20   !  Sample Program
30   !    Requirements: TIS,TSK
40   !
50   INTEGER Rmt,Onwafer
60   !
70   Size_x=5000
80   Size_y=5000
90   !
100  Init_system
110  !
120  DATA 4,1,5,5,4,6,0,0
130  !
140  Pscale(Size_x,Size_y)
150  DISP "Align the wafer then press [DATA IN]."
160  REPEAT
170    Prober_status(Rmt)
180  UNTIL Rmt
190  DISP
200  !
210  X=0
220  Y=0
230  Porig(X,Y)
240  !
250  REPEAT
260    READ X,Y
270    Pmove(X,Y)
280    Prober_status(Rmt,Onwafer)
290    IF Onwafer THEN CALL Test
300  UNTIL X=0 AND Y=0
310  Phome
320  END
330  !
340  !
350  SUB Test
360  !
370  SUBEND
380  !
```

Figure 5-14. Sample Program: Probing Selected Chips (TSK Probers)

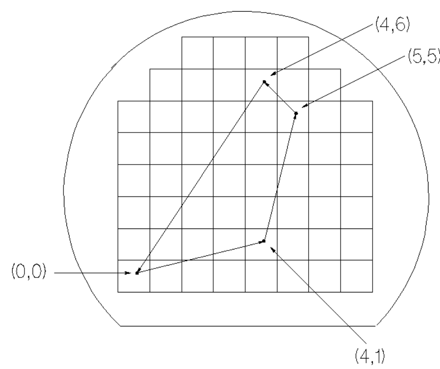
Lines 70 and 80: Sets the size of each chip.

Line 100: Initializes the system.

Line 120: Sets the coordinates of the chips to be probed. The coordinates of the first chip to be probed are (4,1) and those of the second chip, (5,5). A total of three chips are probed.

Line 140:	Sets the index values for X and Y.
Lines 150 through 180:	Repeatedly check prober status until the prober is set to Remote, at which time the remainder of the program is executed.
Line 230:	Sets the present position as the probing origin.
Line 260:	Reads the X-Y coordinates of the chip being probed from the DATA statement in line 120.
Lines 270 through 290:	Set the probe on the chip and execute the Test subprogram if Onwafer is true.
Line 300:	Repeats lines 260 through 290 until the probe returns to 0,0.
Line 310:	Moves the X-Y stage to the wafer loading position and releases the TSK prober from the Remote mode.
Lines 350 through 370:	Insert the measurement routine here.

The probing pattern that results when this program is executed in shown below.



This program probes all chips, starting from the lower left-hand side of the wafer, and provides an example for controlling a fully automatic wafer prober.

```
10   !
20   !  Sample Program
30   !    Requirements: TIS,TSK
40   !
50   Integer Rmt,Onwafer,No_wafer
60   !
70   Size_x=5000
80   Size_y=5000
90   Chip_x=7
100  Chip_y=7
110  !
120  Init_system
130  !
140  Pscale(Size_x,Size_y)
150  DISP "Align the wafer then press [DATA IN]."
160  LOOP
170    REPEAT
180      Prober_status(Rmt,Onwafer,No_wafer)
190    UNTIL Rmt OR No_wafer
200    IF No_wafer THEN STOP
210    DISP
220    !
230    X=0
240    Y=0
250    Porig(X,Y)
260    !
270    FOR Y=0 TO Chip_y
280      FOR X=0 TO Chip_x
290        Pmove(X,Y)
300        Prober_status(Rmt,Onwafer)
310        IF Onwafer THEN CALL Test
320      NEXT X
330    NEXT Y
340    Phome
350  END LOOP
360  END
370  !
380  !
390  SUB Test
400  !
410  SUBEND
420  !
```

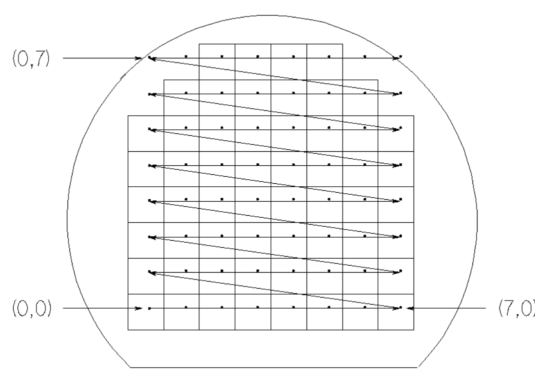
Figure 5-15. Sample Program: Probing All Chips (TSK Probers)

Lines 70 and 80: Set the size of the chips.

Lines 90 and 100: Set the number of chips for X and Y.

Line 120:	Initializes the system.
Line 140:	Sets the index values for X and Y.
Lines 150 through 190:	Repeatedly check prober status until the prober is set to Remote, at which time the remainder of the program is executed.
Line 200:	Discontinues program execution after unloading the last wafer.
Lines 230 through 250:	Set the present position as the probing origin.
Lines 270 through 300:	Move the X-Y stage one index unit and execute the subprogram Test if Onwafer is true. These steps repeat until the coordinates of the chip being probed are equal to Chip_x, Chip_y.
Line 340:	Unloads the present wafer and loads the next wafer.
Line 350:	Repeats lines 170 through 340 until the last wafer is unloaded.
Lines 340 through 360:	Insert the measurement routine here.

The probing pattern that results when this program executes is as follows.



6

Wafer Probing and Data Logging

Introduction

This chapter describes the system's wafer probing and data logging software and provides information on how to effectively use this software for performing wafer measurements with an automatic wafer prober.

Included are descriptions on how to establish the desired probing pattern, control the probing sequence, create measurement data files, file measurement data, and generate wafer maps.

The software described in this chapter consists of four program files: PPG, WAFER, MAP, and FCONV. These files contain the following:

- PPG file:

  The Probing Pattern Generator (PPG) prompts you for probing pattern parameters (such as wafer size, chip size, chip probing sequence, etc.). PPG stores this information in a PPG-created probing pattern data file.

- WAFER file:
  - Probing Control Library (PCL)

    PCL is a set of subprograms for controlling a wafer prober in accordance with probing pattern data stored in a probing pattern data file.

  - File Creation Library (FCL)

    FCL is a set of subprograms that convert measurement results into the format required for wafer mapping and statistical graphics, and stores this data in an FCL-created measurement data file.

- MAP file

  MAP uses the data stored in probing pattern data files and measurement data files to generate wafer maps.

- FCONV file

  FCONV converts the BDAT data file formatted for BS&DM to the DOS text file. The BDAT data files created by the FCL cannot be used by any database and data analysis software except the BS&DM. The data files converted by the FCONV can be loaded into any database and data analysis software because the DOS text file created by the FCONV is one of the ASCII text files in HP-UX and MS-DOS.

Caution

For the HP 4062PC, the PCL in background mode cannot control a wafer prober connected to the PC HP-IB interface card (HP 82335 or HP 82990, select code 25). In background mode, the measurement coprocessor cannot access the HP-IB interface installed in PC slots . You must control the wafer prober in foreground mode only.

Wafer Measurement Software Requirements

Figure 6-1 provides an example of the organization and data flow of a typical wafer measurement. The figure also shows the software required during each measurement phase.

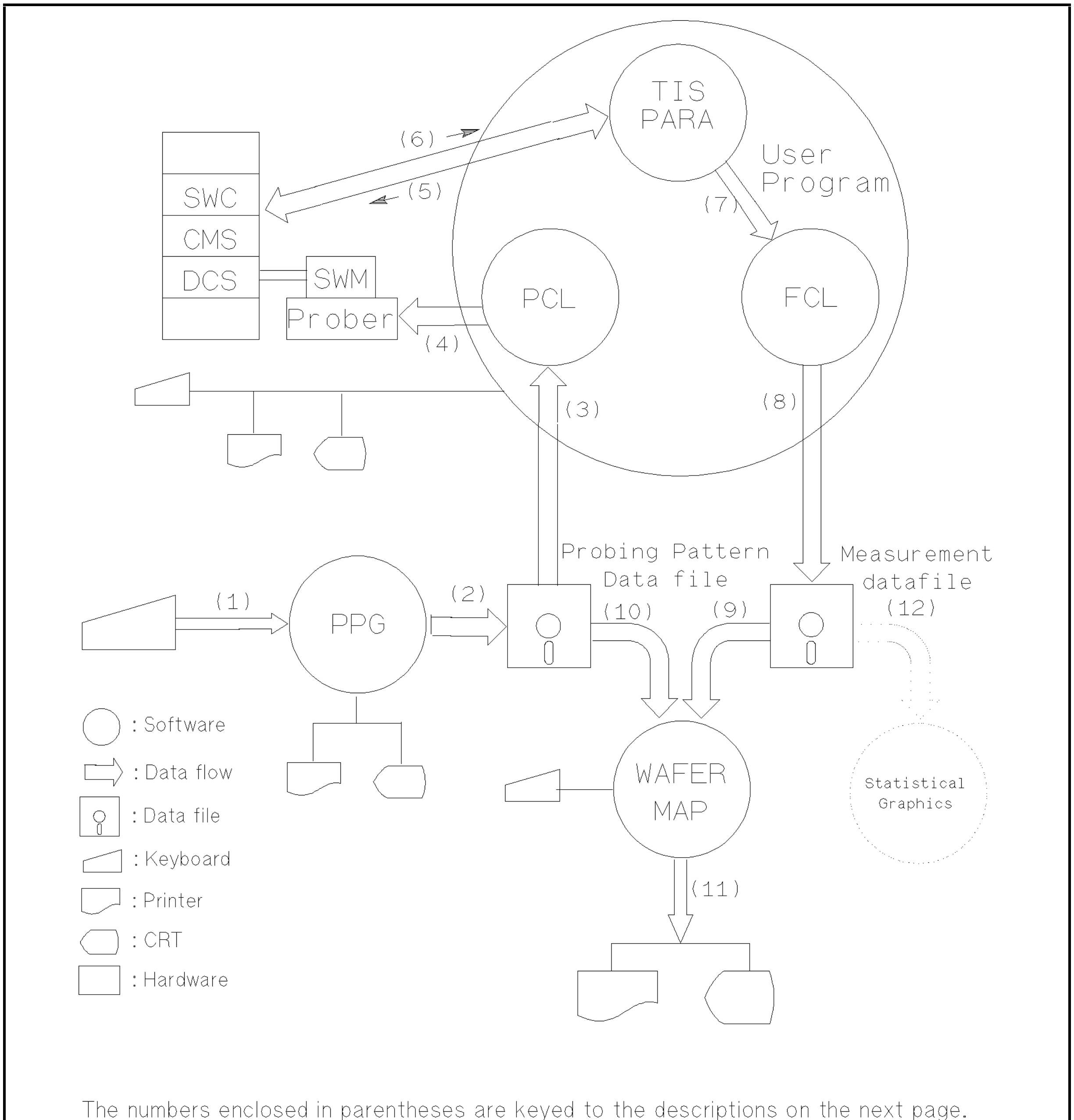


Figure 6-1. Wafer Measurement Data Flow and Software Requirements

- Probing Pattern Generator (PPG)

(1) PPG prompts you to enter the data necessary to create a probing pattern.

(2) PPG creates the probing pattern data file, and stores the data you input into the file. This data file can be updated whenever necessary.

- Probing Control Library (PCL)
  - (3) The PCL subprogram loads the probing pattern data file created in (2).
  - (4) PCL controls the wafer prober in accordance with the probing pattern data.
- TIS, PARA, etc.
  - (5) You can use subprograms, such as TIS and PARA, to facilitate measurement programming.
  - (6) Wafer measurement results are returned to TIS and PARA.
- File Creation Library (FCL)
  - (7) You can use the FCL subprograms to convert the measurement results into the format required for wafer mapping and statistical graphics.
  - (8) FCL creates a measurement data file, and stores the data from (7) into the file.
- WAFER MAP
  - (9) WAFER MAP loads the measurement data file generated in (8).
  - (10) WAFER MAP loads the probing pattern data file generated in (2).
  - (11) WAFER MAP uses the measurement data and probing pattern data to create a wafer map, then displays the map on the CRT or outputs the map to a printer.

Probing Pattern Generator (PPG)

PPG is an interactive program that lets you establish the desired probing pattern for performing wafer measurements. PPG prompts you for the various parameters required to create a probing pattern, then generates the probing pattern and stores it in the specified probing pattern data file. PPG lets you create new data files or edit previously created data files. Probing pattern data files are used by the Probing Control Library (PCL) and by WAFER MAP.

The TIS subprograms for wafer prober control are sometimes difficult to use because these subprograms have only primary control functions, which requires you to consider the shape of the wafer, the probing sequence, and so on, when writing a program. PCL controls the wafer prober according to the probing pattern data file, thus eliminating the need for TIS subprogram control of the wafer prober.

PPG Setup Pages

PPG provides five display pages to simplify wafer setups: a Wafer Parameter Setting page, two Chip Selection pages, and two Module Selection pages. These pages are briefly described as follows:

- Wafer Parameter Setting page:

  The Wafer Parameter Setting page is the first page displayed when you execute the PPG program. This page lets you set the wafer parameters you require: wafer size, chip size, probing sequence, module size, and module number. You can also retrieve or save probing pattern data files from this page.

- Chip Selection pages:

  The Chip Selection pages let you select wafer chips for probing. You can choose an alphanumeric or graphics wafer display for selecting chips by selecting either the `WAFER ALPHA` or `WAFER GRAPH` softkey on the Wafer Parameter Setting page.

- Module Selection pages:

  The Module Selection pages let you select chip modules for probing. On the Wafer Parameter Setting page, you can specify a fixed pattern for probing modules by selecting the `CHIP FIXED` softkey, or you can specify the X-Y coordinates of the modules you wish to probe by selecting the `CHIP FLEX` softkey.

Each PPG operation page lets you interactively select and enter the parameters required to develop the probing pattern you desire. Extensive use of softkey functions simplify operator requirements throughout PPG operation, as described in the remainder of this chapter.

Required Parameters

Figure 6-2 shows an example wafer and briefly describes the wafer parameters established by PPG that are required in the main measurement program and wafer map program.

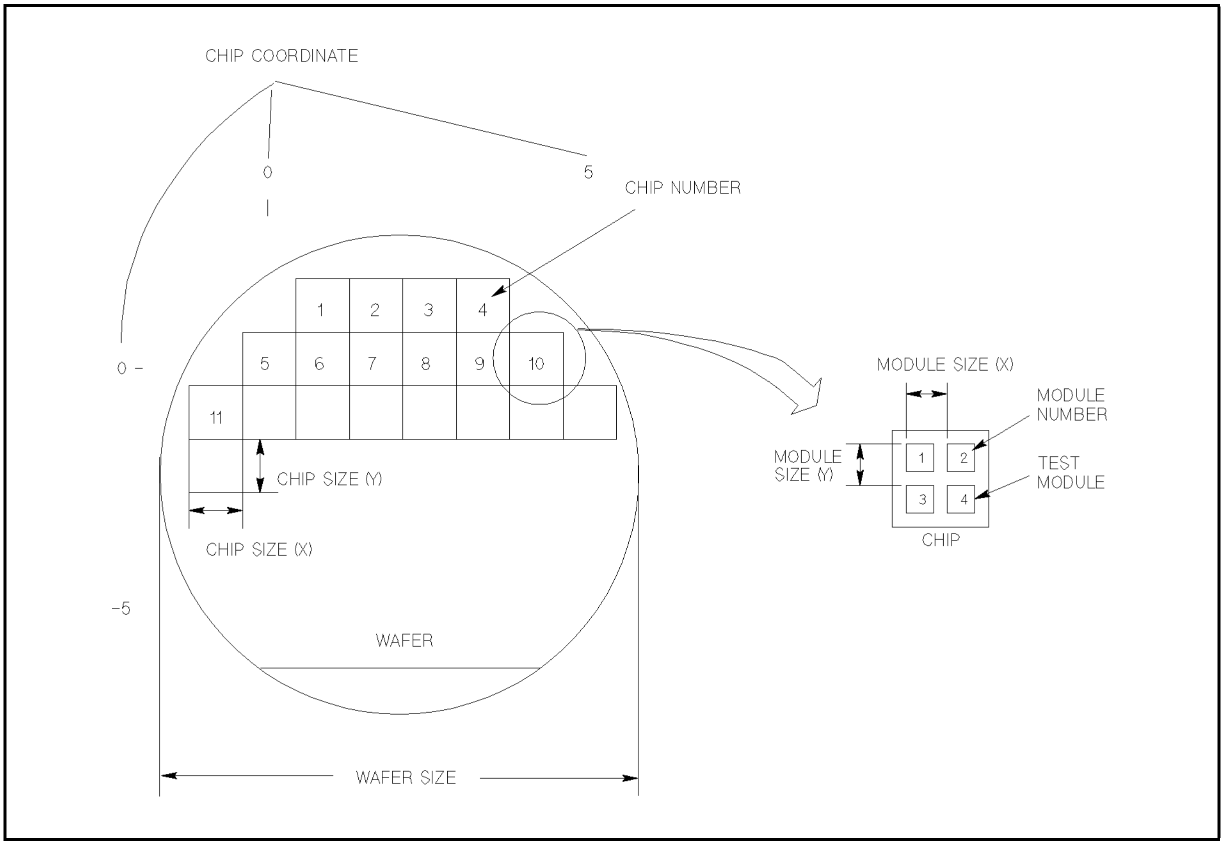


Figure 6-2. Wafer Measurement Program Required Parameters

WAFER SIZE:	The diameter of the wafer in inches.
CHIP SIZE (X-, Y-):	The size of the chip in microns (μm).
CHIP NUMBER:	The chip number is one way to identify wafer chips and to indicate the chip probing sequence.
CHIP COORDINATES (X-, Y-):	The chip coordinates are another way to identify wafer chips. Any chip can be specified as the origin of an X-Y graph.
MODULE SIZE (X-, Y-):	The size of the module in microns (μm). Test modules are the smallest chip element that can be probed.
MODULE NUMBER:	The module number is used to identify test modules and to indicate the module probing sequence.

Loading and Executing PPG

The PPG program requires BASIC/UX (for HP 4062UX), BASIC (for HP 4062C), or BASIC/DOS (for HP 4062PC). You can run PPG independently from the measurement program using TIS, but executing the PPG program destroys the COM blocks established by the system START program. When executing the measurement program after the PPG execution, you must execute the SCRATCH A statement and re-execute the system START program.

When you're ready to execute PPG, perform the following procedure:

- For HP 4062UX:
  1. Load PPG using the BASIC/UX `LOAD` command, as follows:

     `LOAD "/usr/pcs/bin/PPG"` (Return)
  2. Select the `RUN` softkey.
- For HP 4062C/PC with a recommended directory structure:
  1. Load PPG using the BASIC `LOAD` command, as follows:

     `LOAD "/PCS/BIN/PPG"` (Return) *for HP 4062C/PC*
     `LOAD "\PCS\BIN\PPG"` (Return) *for HP 4062PC*
  2. Select the `RUN` softkey.
- For HP 4062C/PC with flexible disks:
  1. Insert the SYSTEM SOFTWARE (4) Disk into the flexible disk drive for the HP 4062C; insert the SYSTEM SOFTWARE (3) Disk for the HP 4062PC.
  2. Load PPG using the BASIC `LOAD` command, as follows:

     `LOAD "PPG"` (Return)
  3. Select the `RUN` softkey.

Select the `PPG` softkey after the following softkeys appear:

PPG	DISPLAY						END

Printing a Display Hardcopy (HP 4062UX only)

You can print a copy of the alpha or graphics display on the Shared Resource Management (SRM) Spool printer, HP-UX spool printer, or local printer, or you can create a file of the display during PPG operation.

To print an alpha display or create a file, press Shift Dump Alpha. To print a graphics display or create a file, press Shift Dump Graphics. The following message is displayed:

```
Select output destination, File/Srm/Hpux/Printer70X
```

Enter `F`, `S`, `H`, or `P` (uppercase) to indicate output print destination.

- Creating a file

  To create a display file, enter an uppercase `F` Return. The following message is displayed:

  ```
  Enter the file name.
  ```

  Enter your file name Return. For HFS formats, file names can be up to 14 characters long; for LIF formats or SRM systems, filenames can be up to 16 characters long. If you include a directory path and volume specifier (HFS or SRM only), the entire file specification can be up to 255 characters.

  When creating a file, be sure you create a file in your directory, *not* in the system software's directory.

  To exit this operation, press Return without entering a file name.

  If you entered the name of a file that already exists, the following message is displayed:

  File name `already exist !! Override/Re-try ( O or R ) ?`

  To overwrite the existing file, enter uppercase `O` Return. To retry this operation, enter uppercase `R` Return.

- Printing on the SRM spooler

  To print a display on the SRM spool printer, enter uppercase `S` Return. The following message is displayed:

  ```
  Enter the file name.
  ```

  Enter your file name Return. File names can be up to 16 characters long (cannot include the directory path and volume specifier). Note that your file must be placed in the SRM system's "spool" directory.

  To exit this operation, press Return without entering a file name.

  If you entered the name of a file that already exists, the following message is displayed:

  File name `already exist !!  Override/Re-try ( O or R ) ?`

  To overwrite the existing file, enter uppercase `O` Return. To retry this operation, enter uppercase `R` Return.

- Printing on HP-UX spooler

  To print a display on the HP-UX spool printer, enter uppercase `H` Return. The following message is displayed:

```
Enter HP-UX lp command or Press Return if destination is standard spooler.
```

To print a display on the standard lp spooler, press (Return). To print a display on another printer, enter the HP-UX's spool command.

For example:

Enter `lp -dhp2225a` (Return)

To print an alpha display on an HP 2225A ThinkJet Personal Printer.

Enter `lp -dhp2225a -or` (Return)

To print a graphics display on an HP 2225A ThinkJet Personal Printer.

A confirmation message is displayed. If the displayed command is correct, enter `Y` (Return). If the displayed command is not correct, enter `N` (Return) and re-enter the command.

- Printing on a local printer

  To print a display on a local printer whose select code and address are defined by the `PRINTER CONFIG` softkey, enter uppercase `P` (Return).

Note

Do not print while another process is using the local printer or the system software may *hang up*.

Wafer Parameter Setting Page

When you execute PPG, the Wafer Parameter Setting page is displayed as shown in Figure 6-3.

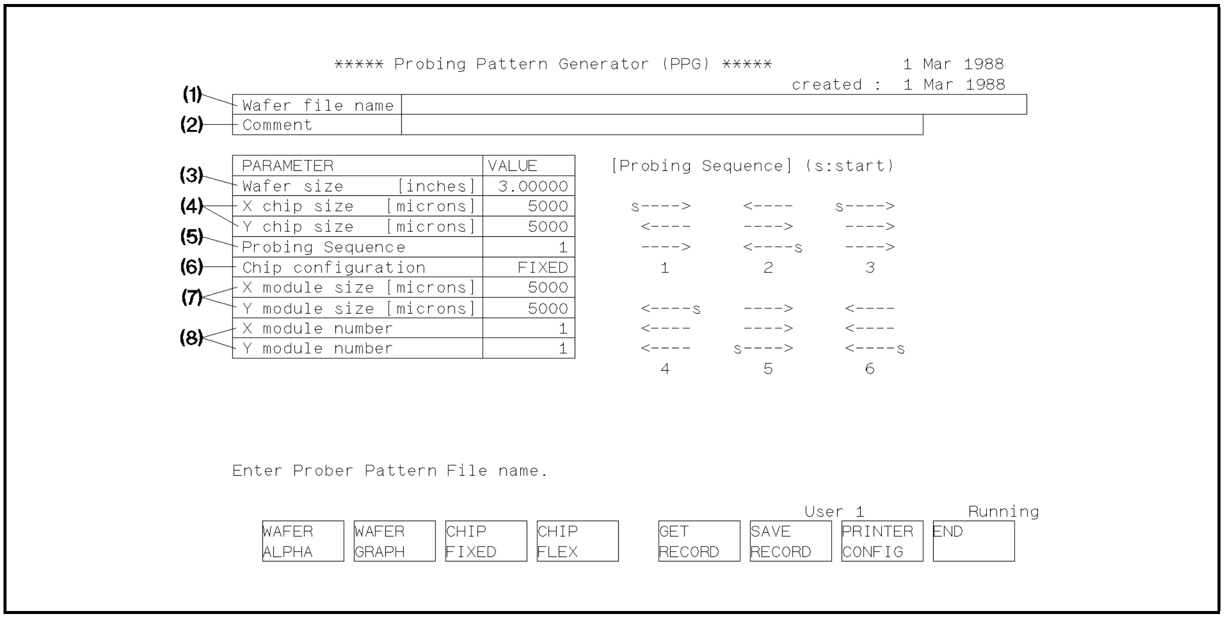


Figure 6-3. Wafer parameter Setting Page

(1) Wafer file name:

For entering a probing pattern data file name and mass storage specifier (maximum 60 characters). When your field pointer is positioned here, the following message is displayed:

`Enter probing pattern data file name and mass storage specifier.`

(2) Comment:

For entering a comment (maximum 50 characters) relative to your probing pattern data file. When your field pointer is positioned here, the following message is displayed:

`Enter comment.`

(3) Wafer size:

For entering the diameter of your wafer in inches. The allowable range is from 0.1 to 99.99999 inches with 0.00001 inch resolution. When your field pointer is positioned here, the following message is displayed:

`Enter wafer size in inches.`

(4) X- and Y-chip size:

For entering the X- and Y-chip sizes (horizontally and vertically). The allowable range is from 1 to 99999μm with 1μm resolution. When your field pointer is positioned in the X-chip size field, the following message is displayed:

`Enter X-direction chip size, including scribe line, in microns.`

When your field pointer is positioned in the Y-chip size field, the following message is displayed:

```
Enter Y-direction chip size, including scribe line, in microns.
```

Note

The system calculates the number of chips in the X- and Y-directions as the quotient of the specified wafer and chip sizes. Although you can specify chip sizes from 1 to 99999μm, the system limits are 255 chips in the X-direction and 255 chips in the Y-direction. If you specify a chip size that is too small, therefore, the calculated number of chips is too large, and an error message is displayed.

(5) Probing sequence:

For entering the number (1 to 6) of the desired wafer probing sequence. When your field pointer is positioned here, the following message is displayed:

```
Enter the desired wafer probing sequence (1 to 6).
```

(6) Chip configuration:

For specifying the FIXED pattern chip module configuration (`FIXED` softkey) or the FLEXIBLE pattern chip module configuration (`FLEXIBLE` softkey). When your field pointer is positioned here, the following message is displayed:

```
Select the chip configuration pattern setting.
```

(7) X- and Y-module size:

For entering the X- and Y-module sizes in μm. The allowable range is 1 to 99999μm with 1μm resolution. When your field pointer is positioned in the X-module size field, the following message is displayed:

```
Enter X-direction module size in microns.
```

When your field pointer is positioned in the Y-module size field, the following message is displayed:

```
Enter Y-direction module size in microns.
```

(8) X- and Y-module number:

For entering the number of test modules in the X- and Y-directions (1 to 6 in each direction). When your field pointer is positioned in the X-module number field, the following message is displayed:

```
Enter number of modules in X-direction.
```

When your field pointer is positioned in the Y-module number field, the following message is displayed:

```
Enter number of modules in Y-direction.
```

Softkeys:

`WAFER ALPHA` :

Displays the alphanumeric Chip Selection page for selecting the chips you want to probe.

WAFER GRAPH :

Displays the graphics Chip Selection page for selecting the chips you want to probe.

CHIP FIXED :

Displays the Fixed pattern Module Selection page for selecting the test modules you want to probe.

CHIP FLEX :

Displays the Flexible pattern Module Selection page for selecting the test modules you want to probe.

GET RECORD :

For retrieving a previously created probing pattern data file (specified in the Wafer file name field).

SAVE RECORD :

For saving the probing pattern data file specified in the Wafer file name field.

PRINTER CONFIG : (HP 4062UX only)

For changing the printer configuration. When you select this softkey, the following message is displayed.

```
Input the Printer Sc/Address.  Ex 701.
```

Type in the printer's select code (sc) and address (Return). To exit this operation, press (Return) without entering a value.

Example:

Enter 701 (Return)

If the printer is connected to the select code 7 HP-IB interface and the printer's address is set to 1.

Enter 9 (Return)

If the printer is connected to the select code 9 RS-232C interface.

A confirmation message is displayed. If the displayed select code and address are correct, enter Y (Return). If the displayed select code and address are not correct, enter N (Return) and re-enter the values.

END :

Exits PPG. If you select this softkey before you save your probing pattern data file, the following message is displayed:

```
Record is not saved.  You really terminate PPG ?
```

To exit PPG without saving your file, select the END softkey again. To return to the Wafer Parameter Setting Page, select the Return softkey.

FIXED :

This softkey is displayed when the field pointer is positioned in the Chip configuration field. Selecting this softkey sets the Fixed pattern chip module configuration for selecting test modules at fixed X-Y module intervals.

If you change the chip configuration from Flexible to Fixed, the following message is displayed:

`Initialize chip configuration? Yes (Y, Return)/No (N, Return)`

If you press `Y` Return, the chip configuration is initialized to Fixed.

`FLEXIBLE` :

This softkey is displayed when the field pointer is positioned in the Chip configuration field. Selecting this softkey sets the Flexible pattern chip module configuration for selecting test modules according to their X- and Y-coordinates.

If you change the chip configuration from Fixed to Flexible, the following message is displayed.

`Initialize chip configuration? Yes (Y, Return)/No (N, Return)`

If you press `Y` Return, the chip configuration is initialized to Flexible.

Alphanumeric Chip Selection Page

The alphanumeric Chip Selection page displays a wafer's alphanumeric representation, according to the parameters established on the Wafer Parameter Setting page, for selecting chips for probing. This page has the same capabilities as the Graphics Chip Selection page, but responds quicker than the Graphics Chip Selection page. When using the HP 4062UX, you can operate this page with character terminals or in windows that don't have graphics capabilities.

To display this page, select the WAFER ALPHA softkey on the Wafer Parameter Setting page.

Figure 6-4 shows an example alphanumeric Chip Selection page, and explains items specific to this page.

```
[Chip Selection]           +0         +5        +10       +15       +20
                                          v
X-coordinate                            o o @
          +8                      @ o o o o @ o o o
Y-coordinate      +15           @ @ @ @ @ @ @ @ @ @ @
         +17                  o o @ o o o o @ o o o o @
selected chips              o o o @ o o o o @ o o o o @ o
         213                o o o @ o o o o @ o o o o @ o
                            o o o @ o o o o @ o o o o @ o
Wafer coordinates +10     @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @ @
 +001  X  +017          > o o o o @ o o o o @ o o o o @ o o <
                          o o o o @ o o o o @ o o o o @ o o
+017                        o o o @ o o o o @ o o o o @ o
  Y                         o o o @ o o o o @ o o o o @ o
+001               +5       @ @ @ @ @ @ @ @ @ @ @ @ @ @ @
                              o o @ o o o o @ o o o o @
o @ : selected                  o @ o o o o @ o o o o
- + : unselected                  @ o o o o @ o o o
                                          ^
Select desired chips.

                                               User 1         Running
SELECT   DELETE            CONFIRM    MORE     ORIGIN             EXIT
ALL      ALL                          KEYS
```

Figure 6-4. Alphanumeric Chip Selection Page

All chips that can possibly exist on a wafer are displayed. The "o" and "@" symbols indicate chips selected for probing. Initially, all chips are selected.

To select or delete chips from the probing pattern, use the cursor control keys to position the cursor at the desired chip, then select the desired softkey. When you use the cursor control keys while pressing Shift, the cursor moves every five chips. The displayed symbols are explained as follows:

o: Selected for probing.

@: Same as "o", but displayed every 5 chips to segment wafer.

-: Deleted from probing.

+: Same as "—", but displayed every 5 chips to segment a wafer.

v, ^, >, <: Indicate a wafer's horizontal and vertical center axes.

Softkeys:

SELECT ALL :

Selects all chips (for probing).

`DELETE ALL` :

Deletes all chips (from probing).

`CONFIRM` :

Confirms your chip selections and returns to the Wafer Parameter Setting page.

`MORE KEYS` :

Displays the next set of softkeys.

`ORIGIN` :

Sets the origin of a wafer's X-Y coordinates. When you select this softkey, the cursor moves to the presently specified origin and the following message is displayed:

```
Move cursor to the desired origin for X-Y coordinates and press Return.
```

`EXIT` :

Returns you to the Wafer Parameter Setting page without updating your chip selections. If you select this softkey, the following message is displayed:

```
Select CONFIRM to update wafer configuration.  Select EXIT to cancel.
```

`SELECT COLUMN` :

Selects all chips in the column where the cursor is positioned.

`DELETE COLUMN` :

Deletes all chips in the column where the cursor is positioned.

`SELECT ROW` :

Selects all chips in the row where the cursor is positioned.

`DELETE ROW` :

Deletes all chips in the row where the cursor is positioned.

`TOGGLE` :

Toggles between select and delete at the cursor's position.

`SELECT AREA` :

Selects all chips in an area you specify. Selecting this softkey displays the following message:

```
Move cursor to the corner of the desired area and press Return.
```

Next, the following message is displayed:

```
Move cursor to the opposite corner of the desired area and press Return.
```

`DELETE AREA` :

Deletes all chips in an area you specify. The procedure for deleting chips in an area is the same as for the `SELECT AREA` softkey.

`UPPER AREA` :

Scrolls the wafer display up to show remaining chips if the wafer is too large for one display.

`LOWER AREA` :

Scrolls the wafer display down to show remaining chips if the wafer is too large for one display.

`LEFT AREA` :

Scrolls the wafer display left to show remaining chips if the wafer is too large for one display.

`RIGHT AREA` :

Scrolls the wafer display right to show remaining chips if the wafer is too large for one display.

`SPECIFY AREA` :

Lets you specify an X- or Y-coordinate, or both, for displaying a specific portion of the wafer display. Selecting this softkey displays the following message:

```
Enter X/Y coordinates separated by comma of desired area's upper left
corner.
```

To specify an X-coordinate only (present Y-coordinate retained), type in the X-coordinate (Return).

To specify a Y-coordinate only (present X-coordinate retained), type in a comma (,) followed by the Y-coordinate (Return).

Graphics Chip Selection Page

The graphics Chip Selection page displays a wafer's graphic representation, according to the parameters established on the Wafer Parameter Setting page, for selecting chips for probing. This page has the same capabilities as the Alphanumeric Chip Selection page, and is clearer than the Alphanumeric Chip Selection page. You can operate this page using mouse also.

Note

You cannot operate this page when using the HP 4062UX with character terminals or in windows that don't have graphics capability.

To display this page, select the `WAFER GRAPH` softkey on the Wafer Parameter Setting page.

Figure 6-5 shows an example graphics Chip Selection page, and explains items specific to this page.

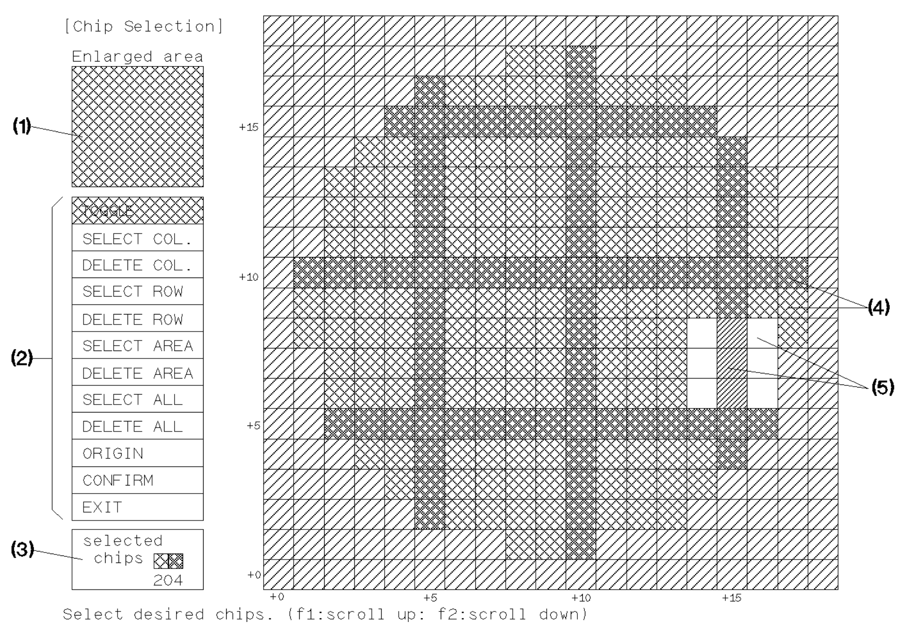


Figure 6-5. Graphics Chip Selection Page

All chips that can possibly exist on a wafer are displayed (inverse video). Initially, all chips are selected.

The methods for selecting and deleting chips are almost the same as for the alphanumeric Chip Selection page. The function menu appears on the left side of the wafer display.

To select menu items and to select or delete chips from the probing pattern, you can use a mouse and the cursor control keys. You can also use the `f1` (scroll up) and `f2` (scroll down) keys when selecting menu items.

When using a mouse, position the mouse's pointer (+) in the desired menu field, click the mouse's button, then position the mouse's pointer at the desired chip(s) and click the mouse's button.

When using the f1, f2, and cursor control keys, select the desired menu item using f1 or f2, position the pointer at the desired chip(s) using the cursor control keys, and press any key.

(1) Enlarged area:

Shows which section of your wafer is displayed (shaded area) if the wafer is too large for viewing on one display. If this is the case, this field is divided into sections, according to your wafer's size, and the shaded area indicates which section of your wafer is displayed. To view undisplayed sections, position your pointer in the desired unshaded section and click the mouse's button or press any key.

For this example, the wafer fits on one display, so the entire field is shaded.

(2) Function Menu:

Shows the menu items you can select on this page. To select an item, use the f1, f2, or cursor control keys, or the mouse, to highlight an item, then press any key or click the mouse's button.

(3) Number of Selected chips:

This field shows the number of chips selected for probing.

(4) Selected Chips:

Selected chips are displayed as inverse video squares: the darker of the two shades of selected chips are for segmenting a wafer only.

(5) Deleted Chips:

Deleted chips are displayed as non-inverse video squares: the partially shaded chips of deleted chip areas are for segmenting a wafer only.

Functions:

TOGGLE:

Toggles between select and delete at the pointer's position.

SELECT COLUMN:

Selects all chips in the column where the pointer is positioned.

DELETE COLUMN:

Deletes all chips in the column where the pointer is positioned.

SELECT ROW:

Selects all chips in the row where the pointer is positioned.

DELETE ROW:

Deletes all chips in the row where the pointer is positioned.

SELECT AREA:

Selects all chips in an area you specify. To specify an area, move the pointer to one corner of the desired area and click the mouse's button or press any key. Next, move the pointer to the opposite corner of the desired area and click the mouse's button or press any key once more.

DELETE AREA:

Deletes all chips in an area you specify. The procedure for deleting chips in an area is the same as for the SELECT AREA function.

SELECT ALL:

Selects all chips.

DELETE ALL:

Deletes all chips.

ORIGIN:

Sets the origin of a wafer's X-Y coordinates. To set the origin, move the pointer to the desired X-Y coordinates and click the mouse's button or select any key.

CONFIRM:

Confirms your chip selections and returns to the Wafer Parameter Setting page.

EXIT:

Returns you to the Wafer Parameter Setting page without updating your chip selections. If you select this function, the following message is displayed:

```
Select CONFIRM to update wafer configuration. Select EXIT to cancel.
```

Fixed Pattern Module Selection Page

The Fixed Pattern Module Selection page displays a chip's module configuration, according to the parameters established on the Wafer Parameter Setting page, for selecting modules for probing. To display this page, select the `CHIP FIXED` softkey on the Wafer Parameter setting page.

Figure 6-6 shows an example Fixed pattern Module Selection page, and explains items specific to this page.

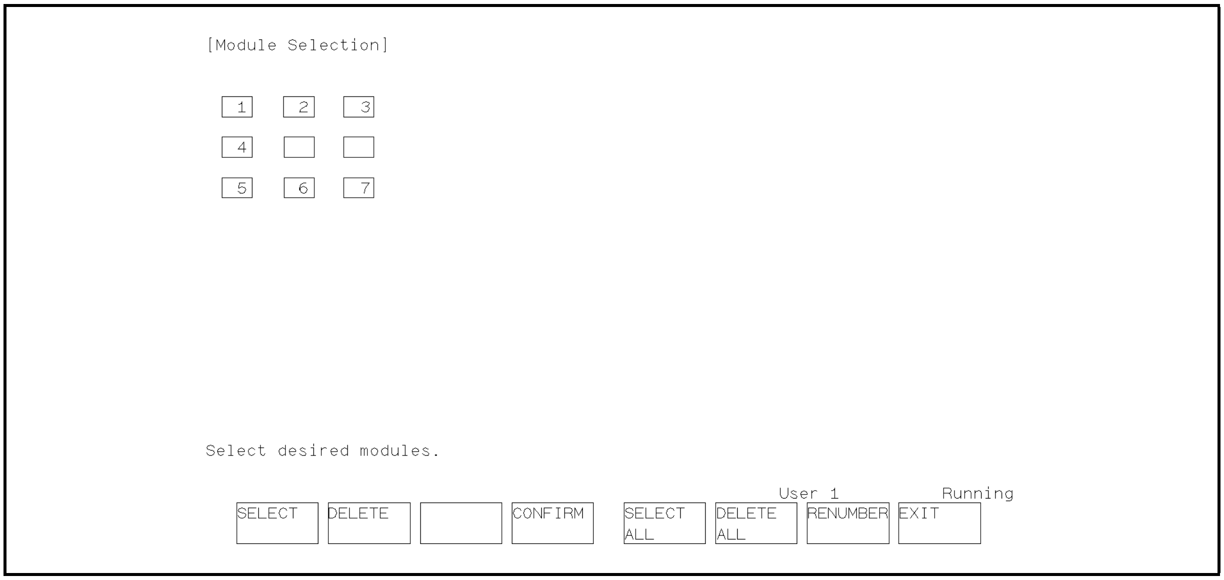


Figure 6-6. Fixed Pattern Module Selection Page

You can specify up to 36 test modules for probing (X_MAX=6, Y_MAX=6). Initially, all modules are selected for probing.

To select or delete modules, use the cursor control keys to position the cursor at the desired module, then select the desired softkey. Each selected module must have its own module number, and modules are probed in ascending order beginning with the lowest-numbered module.

Softkeys:

`SELECT` :

Selects (for probing) the test module at the cursor's position.

`DELETE` :

Deletes (from probing) the test module at the cursor's position.

`SELECT ALL` :

Selects all test modules for probing.

`DELETE ALL` :

Deletes all test modules from probing.

RENUMBER :

Lets you renumber selected test modules to establish the probing sequence you desire. To retain your renumbering, select the CONFIRM softkey. To exit this function without renumbering modules, select the EXIT softkey twice.

CONFIRM :

Confirms your test module selections and returns to the Wafer Parameter Setting page.

EXIT :

Returns you to the Wafer Parameter Setting page without updating your module selections. If you select this softkey, the following message is displayed:

```
Select CONFIRM to update chip configuration. Select EXIT to cancel.
```

Flexible Pattern Module Selection Page

The Flexible Pattern Module Selection page displays a chip's module configuration, according to the parameters established on the Wafer Parameter Setting page, for selecting modules for probing. To display this page, select the `CHIP FLEX` softkey on the Wafer Parameter setting page.

Figure 6-7 shows the first page of an example Flexible Pattern Module Selection page, and explains items specific to this page.

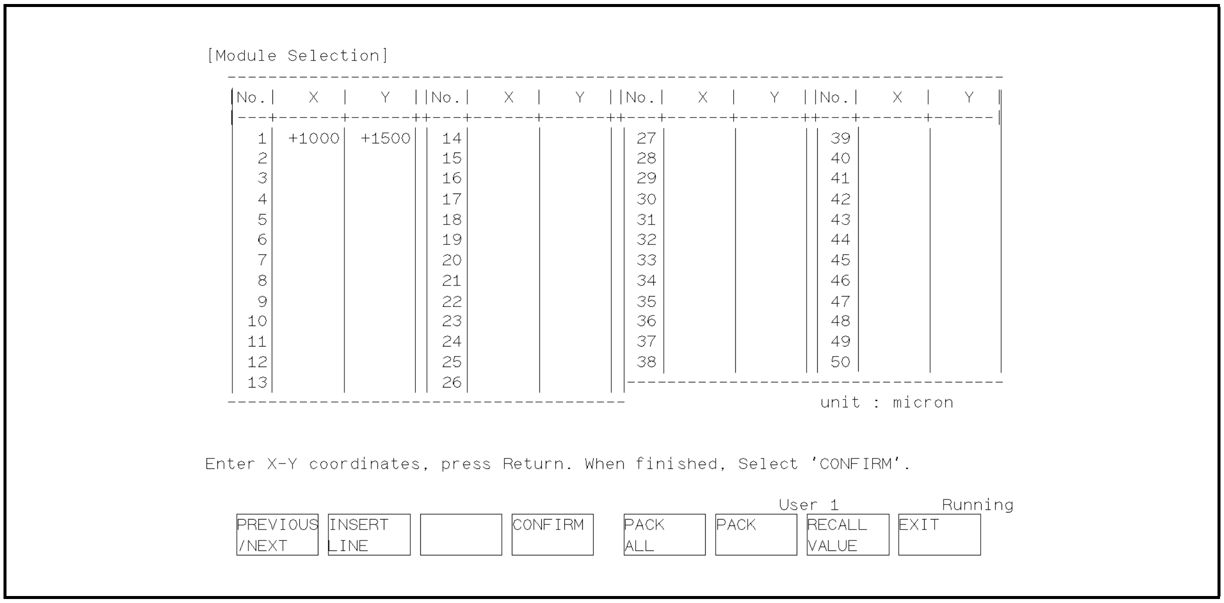


Figure 6-7. Flexible Pattern Module Selection Page

You can specify the X-Y coordinates of up to 100 test modules for probing. Initially, the first module's X-Y coordinates (0,0) are entered. The No. column lists test module numbers in their probing sequence. The X and Y columns are for entering a test module's X- and Y-coordinates in microns (μm).

To enter coordinates, position the cursor in the desired module row, enter the X-coordinate (Return), then the Y-coordinate (Return).

Softkeys:

`PREVIOUS/NEXT` :

Toggles between the first and second Module Selection pages.

`INSERT LINE` :

Inserts one line above the module row where the cursor is positioned if the row where the cursor is contains X-Y coordinate data.

`CONFIRM` :

Confirms your test module selections and returns to the Wafer Parameter Setting page.

`PACK ALL` :

Deletes all blank lines (compresses X-Y coordinate data).

PACK :

Deletes a blank line (each time you select 'PACK') if the cursor is positioned on a blank line between X-Y coordinate data.

RECALL VALUE :

Recalls the last ten coordinate values entered. Recalled values are displayed at the present cursor's position.

EXIT :

Returns you to the Wafer Parameter Setting page without updating your module selections. If you select this softkey, the following message is displayed:

```
Select CONFIRM to update chip configuration. Select EXIT to cancel.
```

Outputting the Probing Pattern Data

The PPG DISPLAY function outputs the probing pattern data to the CRT or printer. The probing pattern data consists of five pages: parameter display page, wafer configuration display page, chip number display page, chip coordinates display page, and module coordinates display page.

Entering the PPG DISPLAY Function

Starting the PPG DISPLAY Function. To start the PPG DISPLAY function from the HP BASIC idle status, perform the following procedure:

- For HP 4062UX:
  1. Load PPG using the BASIC/UX `LOAD` command, as follows:

     `LOAD "/usr/pcs/bin/PPG"` Return

  2. Select the `RUN` softkey.
- For HP 4062C/PC with a recommended directory structure:
  1. Load PPG using the BASIC `LOAD` command, as follows:

     `LOAD "/PCS/BIN/PPG"` Return *for HP 4062C/PC*
     `LOAD "\PCS\BIN\PPG"` Return *for HP 4062PC*

  2. Select the `RUN` softkey.
- For HP 4062C/PC with flexible disks:
  1. Insert the SYSTEM SOFTWARE (4) Disk into the flexible disk drive for the HP 4062C; insert the SYSTEM SOFTWARE (3) Disk for the HP 4062PC.
  2. Load PPG using the BASIC `LOAD` command, as follows:

     `LOAD "PPG"` Return

  3. Select the `RUN` softkey.

Select the `DISPLAY` softkey after the following softkeys appear:

PPG	DISPLAY						END

Moving into the PPG DISPLAY Function. To move into the PPG DISPLAY Function from the wafer parameter setting page, select the `END` softkey. Then select the `DISPLAY` softkey after the `PPG`, `DISPLAY`, and `END` softkeys appear.

Specifying the Probing Pattern Data File

After entering the PPG DISPLAY function, you are prompted to specify the probing pattern data file as follows:

```
Enter Probing Pattern File name. (Return to use current data in memory.)
```

When you create a probing pattern and want to output it, press Return key only. Because the probing pattern data created is still in memory.

To specify a probing pattern stored in a file, enter its file name. The specified probing pattern data is retrieved from memory.

Outputting to the CRT

To output to the CRT, select the `CRT` softkey after specifying the probing pattern data file.

Outputting to the Printer

To output to the printer, select the `PRINTER` softkey after specifying the probing pattern data file. Then select the `NEXT` softkey after the printing configuration page appears.

The printing configuration is stored in "DISP_CONF" file under the /usr/pcs/etc, /PCS/ETC, or \PCS\ETC directory.

Changing the Printer Configuration

You can change the printer configuration by selecting the `RECONFIG` softkey. The configuration parameters for printing are shown as follows:

PRINTER TYPE: LOCAL, FILE SPOOL, or HP-UX SPOOL (HP-UX SPOOL is for HP 4062UX only)

- When the LOCAL is selected, the printer address, printer type, baud rate (only for RS-232C interface) are specified.
- When the FILE SPOOL is selected, the spool directory is specified. The spool file name is fixed to "PPD_DISP*num*": *num* ranges 1 to 99.
- When the HP-UX SPOOL is selected, the spooling command of the HP-UX is specified. The command must begin with a pipe ("`|`"). For example, "`| lp`" or "`| cat > ppd_data`" is available.

PAGE LENGTH: The page length (lines/page) can be specified. The page length ranges 10 to 32767 for page-numbering OFF; 12 to 32767 for page-numbering ON.

PAGE WIDTH: The page width (columns/line) can be specified. The page width ranges 40 to 32767.

PAGE NUMBER: This parameter controls the page-numbering: ON or OFF. When the page-numbering is set to ON, the probing pattern data file name and printing date are printed with the page number.

MARGIN: This parameter specifies the top, bottom, and left margin. The following restrictions must be observed:

- top margin ≥ 0
- bottom margin ≥ 0
- top margin + bottom margin < page length − 10 (for page-numbering OFF)
- top margin + bottom margin < page length − 12 (for page-numbering ON)
- $0 \leq$ left margin $\leq$ page width − 40

Selecting the `SAVE` softkey stores the printing configuration data in the "DISP_CONF" file under the /usr/pcs/etc, /PCS/ETC, or \PCS\ETC directory.

To quit from the printing configuration page, select the `QUIT` softkey.

Example: Printing to HP-UX Spool Printer (for HP 4062UX). Use the following procedure to print to the HP-UX spool printer:

1. Select the `PRINTER TYPE` softkey and the `HP-UX SPOOL` softkey.
2. Select the `COMMAND` softkey and enter the spooling command of the HP-UX. For example, enter:

   `| lp -dlaser` (Return)

Example: Printing to SRM Spool Printer (for HP 4062C/UX/PC). Use the following procedure to print to the SRM spool printer:

1. Select the `PRINTER TYPE` softkey and the `FILE SPOOL` softkey.
2. Select the `SPOOL DIR.` softkey and enter the spool directory name of your SRM. For example, enter:

   `/spool:REMOTE` (Return)

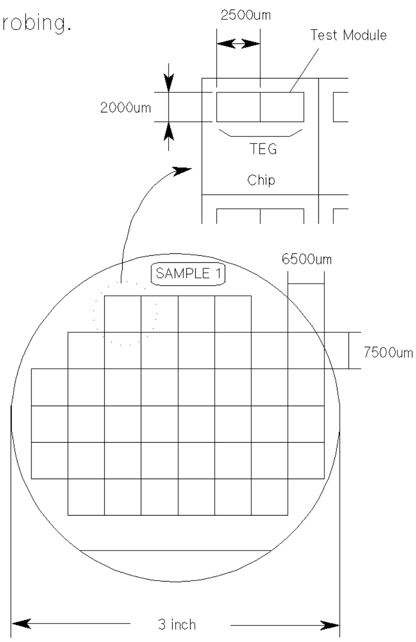
Example: Printing to MS-DOS Parallel Printer (for HP 4062PC). Use the following procedure to print to the MS-DOS Parallel printer (PRN or LPT1):

1. Select the `PRINTER TYPE` softkey and the `LOCAL` softkey.
2. Select the `PRINTER ADDR` softkey, enter the select code 26, and select `OTHER` as the printer interface.

PPG Example

Figure 6-8 and Figure 6-9 each show an example wafer probing pattern generated by PPG.

In this example, two test modules on each wafer chip are selected for probing.



Wafer Parameter Setting Page:

```
        ***** Probing Pattern Generator (PPG) *****           1 Mar 1988
                                                   created :  1 Mar 1988
```

Wafer file name	SAMPLE_W1
Comment	SAMPLE WAFER 1

PARAMETER	VALUE
Wafer size [inches]	3.00000
X chip size [microns]	6500
Y chip size [microns]	7500
Probing Sequence	1
Chip configuration	FIXED
X module size [microns]	2500
Y module size [microns]	2500
X module number	2
Y module number	1

```
[Probing Sequence] (s:start)

  s---->     <----     s---->
   <----     ---->      ---->
   ---->     <----s     ---->
     1         2          3

   <----s    ---->      <----
   <----     ---->      <----
   <----    s---->      <----s
     4         5          6
```

Figure 6-8. PPG Wafer Setup, Example 1

Alphanumeric Chip Seleciton Page:

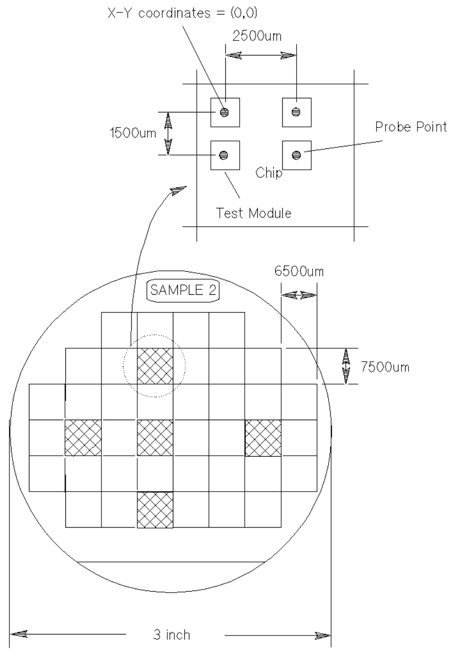
```
[Chip Selection]           +0        +5       +10       +15       +20
                                     v
 X-coordinate                  - - - + - - -
            +2               - - o o @ o - - -
 Y-coordinate              + o o o o @ o o o - +
            +8      +5   + + @ @ @ @ @ @ @ @ + + +
 selected chips          - @ o o o o @ o o o o + -
            64         > - @ o o o o @ o o o o + - <
                         - @ o o o o @ o o o o + -
Wafer coordinates        - + o o o o @ o o o - + -
  -001  X  +011     +0     + + @ @ @ @ @ @ + + +
                             - - - - + - - - -
 +008                          - - - + - - -
   Y                                 ^
 -002
                    -5
o @ : selected
- + : unselected
```

Fixed Pattern Module Selection Page:

```
[Module Selection]

  [1]   [2]
```

PPG Wafer Setup, Example 1 (Continued)

In this example, four test modules on five wafer chips are selected for probing.



Wafer Parameter Setting Page:

```
        ***** Probing Pattern Generator (PPG) *****           1 Mar 1988
                                               created :  1 Mar 1988
```

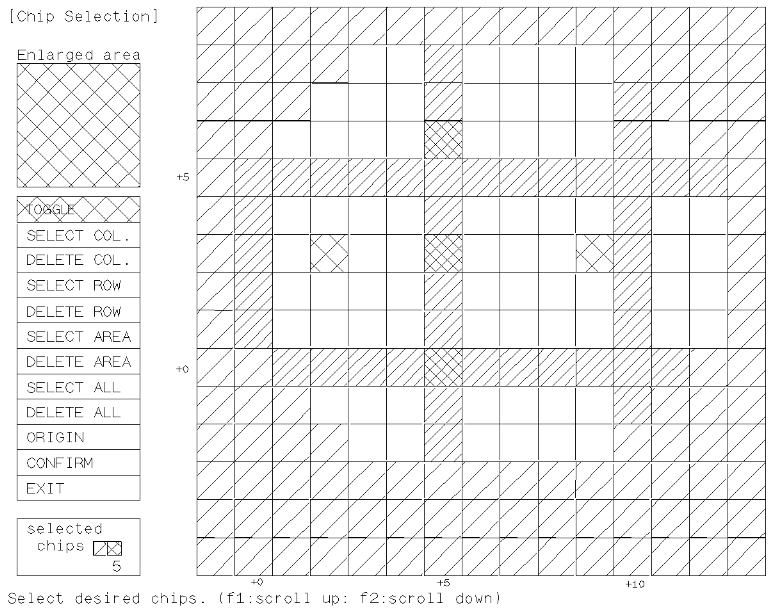
Wafer file name	SAMPLE_W2
Comment	SAMPLE WAFER 2

PARAMETER	VALUE
Wafer size [inches]	3.00000
X chip size [microns]	6500
Y chip size [microns]	7500
Probing Sequence	1
Chip configuration	FIXED
X module size [microns]	2500
Y module size [microns]	1500
X module number	2
Y module number	2

```
[Probing Sequence] (s:start)

  s---->     <----     s---->
   <----     ---->      ---->
   ---->     <----s     ---->
     1         2          3

   <----s    ---->      <----
   <----     ---->      <----
   <----    s---->      <----s
     4         5          6
```

Figure 6-9. PPG Wafer Setup, Example 2

Graphics Chip Selection Page:



Flexible Pattern Module Selection Page:

[Module Selection]

No.	X	Y	No.	X	Y	No.	X	Y	No.	X	Y
1	+0	+0	14			27			39		
2	+2500	+0	15			28			40		
3	+0	-1500	16			29			41		
4	+2500	-1500	17			30			42		
5			18			31			43		
6			19			32			44		
7			20			33			45		
8			21			34			46		
9			22			35			47		
10			23			36			48		
11			24			37			49		
12			25			38			50		
13			26								

unit : micron

PPG Wafer Setup, Example 2 (Continued)

Probing Control Library (PCL)

The probing control library (PCL) is a set of subprograms for controlling an automatic wafer prober. These subprograms are used with the probing pattern data file created by PPG. The probing control library is stored in the WAFER program file.

PCL subprograms provide functions such as retrieving a probing pattern data file, designating an initial probing position, specifying a chip and test module to be probed, and reporting the present probing position. PCL subprograms are used in the same way as TIS subprograms, and make it easy to control the prober.

PCL Programming

Most programs written for sequential probing require only three main PCL subprograms: Wget, Wstart_number, and Wmove_next. These three PCL subprograms are used more often than any others, and provide you with the easiest method for controlling a wafer prober from a program. This chapter describes how to create prober control programs from the various PCL subprograms by making extensive use of sample programs. For complete details on the syntax and semantics of each PCL subprogram, refer to the *Programming Reference* manual.

When writing probing control programs that contain PCL subprograms, be aware that there are certain restrictions under which you can use TIS subprograms. Pmove (TIS) cannot be used in a program that contains PCL subprograms. Pscale and Porig (TIS) cannot be used in a program that includes a Wstart_number or Wstart_xy PCL subprogram, because these PCL subprograms include functions identical to Pscale and Porig. If Pdown (TIS) is used in a program that contains PCL subprograms, raise the wafer chuck before any PCL subprograms execute. If Pimove (TIS) is used in conjunction with any PCL subprograms, the wafer chuck must be returned to its previous position before any PCL subprograms execute.

The PCL subprogram uses the TIS prober control subprogram. Link the TIS prober control subprograms for your prober. PCL subprograms are included in the WAFER program file. To link the necessary PCL subprograms, execute the following command:

- For HP 4062UX:

  `LOADSUB FROM "/usr/pcs/lib/WAFER"` Return

- For HP 4062C/PC with the recommended directory structure:

  `LOADSUB FROM "/PCS/LIB/WAFER"` Return *for HP 4062C/PC*
  `LOADSUB FROM "\PCS\LIB\WAFER"` Return *for HP 4062PC*

- For HP 4062C/PC with flexible disks:

  Insert SYSTEM SOFTWARE (2) disk into the disk drive.

  `LOADSUB FROM "WAFER"` Return

Note

Be sure to set the wafer prober to Remote and to manually probe the first chip before actually attempting to perform any measurements. Refer to Chapter 5.

Primary Prober Control Programming

By using HP BASIC or BASIC/UX language statements and the Wget, Wstart_number, and Wmove_next PCL subprograms, prober control programs can be written with ease, as illustrated in Figure 6-10 and Figure 6-11.

In this sample program, a hypothetical probing pattern data file named PP_DATA (previously created by PPG) is used to perform a wafer measurement. The specified wafer contains 100 chips, and one module on each chip is specified for probing.

```
10   !
20   !  Sample Program
30   !    Requirements: TIS,WAFER,!!Prober TIS!!
40   !
50   INTEGER I
60   Init_system
70   Wget("PP_DATA")
80   Wstart_number(1,1)
90   ! Pup
100  FOR I=1 TO 100
110    Test
120    Wmove_next
130  NEXT I
140  END
150  !
160  SUB Test
170  !
180  SUBEND
190  !
```

Figure 6-10. Sample Program: Prober Control, Example 1

Line 60: The Init_system subprogram is specified before any other subprograms because each PCL subprogram uses TIS.

Line 70: This subprogram gets the PPG-created probing pattern data file from the specified mass storage device, and stores this data in the COM blocks. The data contained in the probing pattern data file determines the direction and distance the wafer chuck is moved by subprograms such as Wmove_next.

Line 80: This subprogram specifies the number of the initial chip and test module to be probed. The first parameter indicates the chip number and the second parameter indicates the test module number. Both parameters are optional. The default value for the chip number is 1, and default for the test module is the lowest test module number specified by PPG. This subprogram must be specified after the Wget subprogram and before any other PCL subprograms because it determines the wafer prober starting position.

Note Be sure to set the wafer prober to Remote and to manually probe the first chip before actually attempting to perform any measurements. Refer to Chapter 5.

Line 90:	Depending on the kind of prober you are using, it may be necessary to manually perform such operations as loading and aligning wafers, entering the Remote state, raising the wafer chuck for probing, etc. If your prober can perform these operations under remote program control, however, this TIS subprogram (Pup) can be used to raise the wafer chuck. To use this subprogram, be sure to remove the exclamation mark (!). For more details, refer to Chapter 5. For details on the syntax and semantics of the Pup subprogram, refer to the *Programming Reference* manual.
Line 100:	Defines the loop required to measure 100 test modules.
Line 110:	Calls the measurement subprogram.
Line 120:	Moves the prober chuck to the next test module specified for probing in accordance with the set probing sequence. After the last test module is probed or if the next test module is not specified, the Wmove_next subprogram executes the Phome subprogram and the wafer chuck moves to the home position. For details on Phome see Chapter 5, and the *Programming Reference* .
Lines 160 through 180:	Contain the measurement subprogram.

Note Do not include the Init_system TIS subprogram in the measurement subprogram, because Init_system initializes the COM blocks for the prober control.

This sample program measures the wafer shown in Figure 6-8.

```
10   !
20   !  Sample Program
30   !    Requirements: TIS,WAFER,!!Prober TIS!!
40   !
50   INTEGER I
60   Init_system
70   Wget("SAMPLE_W1")
80   Wstart_number(1,1)
90   ! Pup
100  FOR I=1 TO 64
110    Test_1
120    Wmove_next
130    Test_2
140    Wmove_next
150  NEXT I
160  END
170  !
180  SUB Test_1
190  !
200  SUBEND
210  !
220  SUB Test_2
230  !
240  SUBEND
250  !
```

Figure 6-11. Sample Program: Prober Control, Example 2

Lines 60 through 90:	Same as for Figure 6-10.
Line 100:	Defines the loop required to measure 64 wafer chips.
Line 110:	Calls the measurement subprogram required for measuring test module 1.
Line 120:	Moves the prober chuck to test module 2.
Line 130:	Calls the measurement subprogram required for measuring test module 2.
Line 140:	Moves the prober chuck to test module 1 of the next chip to be probed.
Lines 180 through 240:	Contain the measurement subprogram.

Confirming the present probing position

You can use the following statement to verify the chip and test module presently being probed.

- Wpos_number(Chip_number,Module_number):

  Returns the present chip number to the first parameter, and the present module number to the second parameter.

Figure 6-12 measures the wafer shown in Figure 6-9.

```
10   !
20   !  Sample Program
30   !    Requirements: TIS,WAFER,!!Prober TIS!!
40   !
50   INTEGER Chip,Module
60   Init_system
70   Wget("SAMPLE_W2")
80   Wstart_number(1,1)
90   ! Pup
100  !
110  REPEAT
120    Wpos_number(Chip,Module)
130    DISP "CHIP Number =";Chip;"  MODULE Number =";Module
140    SELECT Module
150      CASE 1
160        Test_1
170      CASE 2
180        Test_2
190      CASE 3
200        Test_3
210      CASE 4
220        Test_4
230    END SELECT
240    Wmove_next
250  UNTIL Chip=5 AND Module=4
260  DISP "END"
270  END
280  !
290  SUB Test_1
300  !
310  SUBEND
320  !
330  SUB Test_2
340  !
350  SUBEND
360  !
370  SUB Test_3
380  !
390  SUBEND
400  !
410  SUB Test_4
420  !
430  SUBEND
440  !
```

Figure 6-12. Sample Program: Using Wpos_number

Lines 60 through 90:   Same as for Figure 6-10.

Line 120:	Returns the number of the chip and module presently being probed. The second parameter is optional. Both parameters must be type integer (see line 50).
Line 130:	Displays the chip number and module number presently being probed.
Lines 140 through 230:	Select the required measurement subprogram in accordance with the test module being probed.
Line 240:	Moves the prober chuck to the next test module specified for probing.
Lines 290 to end:	Same as for Figure 6-10.

“Free” probing

You can use the following statement to probe in an order not related to the probing sequence set in PPG.

- Wmove_number(Chip_number,Module_number):

  This subprogram moves the prober chuck to the test module designated by the subprogram parameters. The first parameter specifies the chip number, and the second parameter specifies the module number.

Figure 6-13 measures the wafer shown in Figure 6-8, except the Wmove_number subprogram is used so that only test module 1 is probed instead of test modules 1 and 2.

```
10   !
20   !  Sample Program
30   !    Requirements: TIS,WAFER,!!Prober TIS!!
40   !
50   INTEGER Chip_number
60   Init_system
70   Wget("SAMPLE_W1")
80   Wstart_number(1,1)
90   ! Pup
100  !
110  FOR Chip_number=1 TO 64
120    Wmove_number(Chip_number,1)
130    Test_1
140  NEXT Chip_number
150  Phome
160  END
170  !
180  SUB Test_1
190  !
200  SUBEND
210  !
```

Figure 6-13. Sample Program: “Free” Probing Control

Lines 60 through 90:	Same as for Figure 6-10.
Line 120:	Moves the prober chuck to test module 1 of the chip designated by the first parameter (Chip_number). The second parameter is optional. The default value for this parameter (Module_number) is the lowest test module number specified by PPG. Both parameters must be type integer (see line 50).
Line 130:	Calls the measurement subprogram.
Line 150:	Moves the prober chuck to the home position (executes Phome).
Lines 180 to end:	Same as for Figure 6-10.

Probing control using the X- and Y-chip coordinates

You can specify chips for probing by using X- and Y-coordinates instead of chip numbers. Chip_x and Chip_y are the X- and Y-coordinates of the chips set in PPG. The following three subprograms use the X- and Y-chip coordinates to control the prober:

- Wstart_xy(Chip_x,Chip_y,Module_number):

  The function of this subprogram is the same as Wstart_number.

- Wpos_xy(Chip_x,Chip_y,Module_number):

  The function of this subprogram is the same as Wpos_number.

- Wmove_xy(Chip_x,Chip_y,Module_number):

  The function of this subprogram is the same as Wmove_number.

Figure 6-14 measures the wafer shown in Figure 6-9, except this program only probes chips 1, 3, and 5.

```
10   !
20   !  Sample Program
30   !    Requirements: TIS,WAFER,!!Prober TIS!!
40   !
50   INTEGER Chip_y,Module_number,X,Y
60   Init_system
70   Wget("SAMPLE_W2")
80   Wstart_xy(0,3,1)
90   ! Pup
100  !
110  FOR Chip_y=3 TO -3 STEP -3
120    Wmove_xy(0,Chip_y,1)
130    REPEAT
140      Wpos_xy(X,Y,Module_number)
150      DISP "CHIP(";X;",";Y;")  MODULE =";Module_number
160      SELECT Module_number
170      CASE 1
180        Test_1
190      CASE 2
200        Test_2
210      CASE 3
220        Test_3
230      CASE 4
240        Test_4
250      END SELECT
260      IF NOT Module_number=4 THEN Wmove_next
270    UNTIL Module_number=4
280  NEXT Chip_y
290  Phome
300  DISP "END"
310  END
320  !
330  SUB Test_1
340  !
350  SUBEND
360  !
370  SUB Test_2
380  !
390  SUBEND
400  !
410  SUB Test_3
420  !
430  SUBEND
470  !
450  SUB Test_4
460  !
470  SUBEND
480  !
```

Figure 6-14. Sample Program: Probing Control Using X- and Y-Chip Coordinates

Lines 60 through 90:	Same as for Figure 6-10.
Line 80:	The first parameter is the X-chip coordinate, the second parameter is the Y-chip coordinate, and the third parameter is the test module number. This subprogram functions in the same way as if a Wstart_number(1,1) subprogram were specified. That is, the X- and Y-coordinates (0 and 3) correspond to chip number 1 and the module_number (1) corresponds to module number 1, as shown in Figure 6-9. The default values correspond to chip number 1 and the minimum module number. All parameters are optional.
Line 110:	Sets the Y-chip coordinate to 3, then 0, and then -3.
Line 120:	Moves the prober chuck to the first test module on the chip specified by the X-Y coordinates (0,Chip_y).
Line 140:	Returns the X-coordinate, the Y-coordinate, and the module number of the chip at the present probing position to the first, second, and third parameter, respectively. These parameters must be type integer (see line 50).
Line 260:	Moves the prober chuck to the next test module for probing, until module number 4 (last test module on the chip) is probed. After Module_number=4, the prober chuck is moved to the next test chip.
Lines 320 to end:	Same as for Figure 6-10.

File Creation Library (FCL)

The file creation library (FCL) is a set of subprograms used to create data files for wafer maps and statistical graphics. The FCL subprograms are stored in the WAFER program file. The structure of the data files created by FCL is described below. FCL created data files are compatible with BSDM. See Chapter 7 and Appendix B for an explanation of BSDM.

The FCL can also create a DOS text file that includes the measured data. The Wfile_type subprogram specifies the data file type: BASIC BDAT or DOS text file.

- File name and Title (comment):

  Data file names and file comments can be stored along with the data in a BSDM data file. Data is stored in rows = variables and columns = observations as shown in the following figure:

- Data set:

  Number of Data: $No \times Nv \leq 1500$

  (can be increased; refer to “Additional WAFER MAP Information”.)

  Number of Variables: $Nv \leq 50$

  where, No is the number of the observations, and Nv is the number of the variable.

- Data files for Wafer Maps:

  The number of the data must concur with the chip number. When the Wput_data subprogram is used, these numbers automatically concur.

- Data Files for Control Charts (Time Plots):

  The number of the data must concur with the plot order.

FCL Programming

As Figure 6-15 shows, there are three ways to create a measurement data file using FCL. Each method is described below:

- Wput_data and Wsave_data (Figure 6-17):

  This method can be used only when PCL subprograms are used to control the wafer prober. This method is ideal for creating measurement data files for wafer mapping, because measurement data are arranged in chip number order, not measurement order. Data files created in this way can also be used for creating histograms and scattergrams.

- Wput_array and Wsave_data (Figure 6-18):

  This method is used for generating measurement data files for statistical graphics. With this method, one-dimensional user-specified arrays are filled with measurement data, transferred to the COM blocks, and assigned variable names. COM block arrays are then combined to create a measurement data file. If Wput_array is used in a measurement program, Wput_data cannot be used, and vice versa.

- Wbuild_file (Figure 6-19):

  This subprogram creates and stores multiple parameter measurement data files for statistical graphics. The variable names used as parameters in this subprogram correspond to each row of the data array. The Wbuild_file subprogram does not require that COM blocks be established. This subprogram is unprotected and may be modified if required. For the complete syntax and semantics of the Wbuild_file subprogram, refer to the *Programming Reference* manual.

- Wfile_type

  This subprogram specifies the data file type: BASIC BDAT or DOS text file. The Wsave_data and Wbuild_file subprograms save a data file according to this file type setting. The default setting is a BASIC BDAT file.

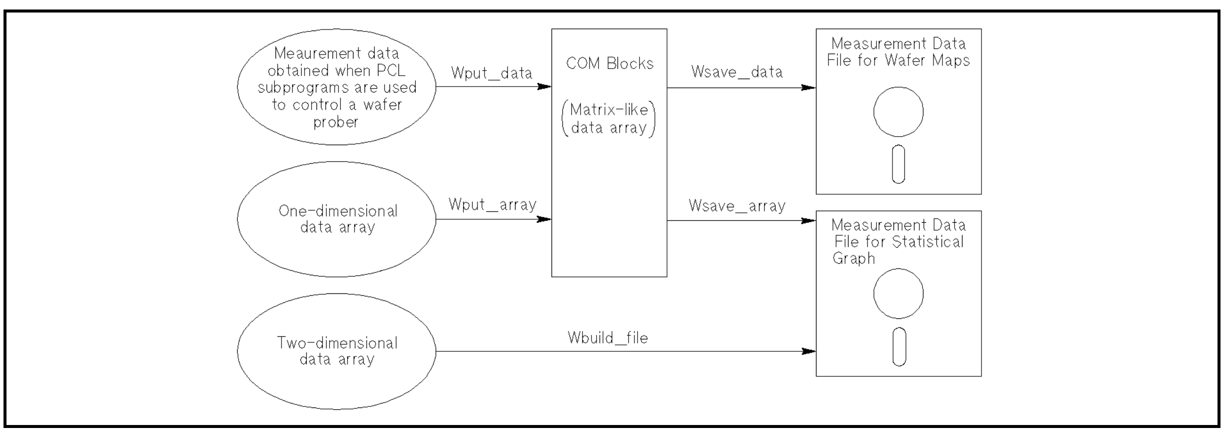


Figure 6-15. FCL Subprograms

FCL and PCL subprograms are stored in the WAFER program file. Execute the following command to link the necessary FCL subprograms with PCL.

- For HP 4062UX:

  `LOADSUB FROM "/usr/pcs/lib/WAFER"` (Return)

- For HP 4062C/PC with the recommended directory structure:

```
LOADSUB FROM "/PCS/LIB/WAFER" (Return)      for HP 4062C/PC
LOADSUB FROM "\PCS\LIB\WAFER" (Return)      for HP 4062PC
```

- For HP 4062C/PC with flexible disks:

  Insert SYSTEM SOFTWARE (2) disk into the disk drive.

```
LOADSUB FROM "WAFER" (Return)
```

Creating Data Files for Wafer Maps

The Wput_data and Wsave_data subprograms are primarily used to create data files for wafer mapping. The following examples show how these subprograms might be used:

- Wput_data("DELTA L",Delta_l):

  In this example, the Wput_data subprogram transfers the measurement data (Delta_l) into a specified position in the COM blocks with the variable name DELTA L.

- Wsave_data("DATA_W1","DATA OF WAFER 1"):

  In this example, the Wsave_data subprogram transfers all of the data saved by Wput_data into a data file named DATA_W1, with the comment, DATA OF WAFER 1.

For complete syntax and semantics of each FCL subprogram, see the *Programming Reference* manual. Data files created by the above two subprograms can also be used for statistical graphics. Figure 6-17 shows how these subprograms are used. Figure 6-16 shows the circuit and pin connections.

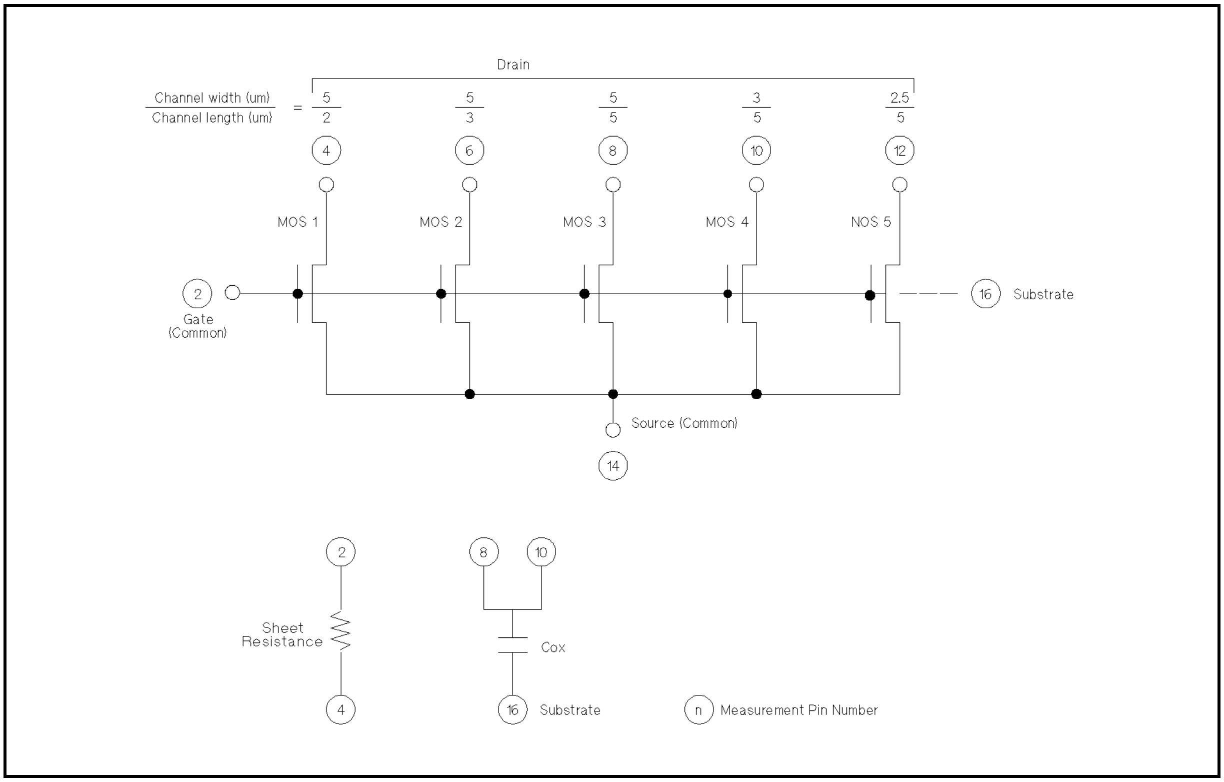


Figure 6-16. Test Module Connections

Figure 6-17 measures the wafer shown in Figure 6-8. Assume that the wafer's test modules have the circuits and pin connections shown in Figure 6-16. Lateral diffusion (ΔL) and field oxide encroachment (ΔW) are measured at test module 1, while resistance and capacitance are measured at test module 2. Note the positioning of each FCL subprogram.

```
10   !
20   !  Sample Program
30   !    Requirements: TIS,WAFER,PARA,!!Prober TIS!!
40   !
50   Init_system
60   Wafer1_meas
70   Init_system
80   END
90   !
100  !
110  SUB Wafer1_meas
120  DIM Title$[80]
130  INTEGER Rmt,Chip_number
140  !
150  LOOP
160    Prober_status(Rmt)
170  EXIT IF Rmt
180  END LOOP
190  !
200  Wget("SAMPLE_W1")
210  Wstart_number(1,1)
220  !
230  Pdown
240  Connect(FNCmh,8,10)
250  Connect(FNCml,16)
260  Set_cmu(3,1)
270  Measure_cmu(Coff)
280  Connect(0)
290  Pup
300  !
310  REPEAT
320    Wpos_number(Chip_number)
330    PRINT "CHIP NUMBER = ";Chip_number
340    Test_1
350    Wmove_next
360    Test_2(Coff)
370    Wmove_next
380  UNTIL Chip_number=64
390  !
400  Title$="MEASUREMENT DATA OF WAFER 1"
410  Wsave_data("DATA_W1",Title$) ! <============ FCL
420  SUBEND
430  !
440  !
450  SUB Test_1
460  !
```

Figure 6-17. Sample Program: Data Logging for Wafer Mapping

```
470  Setmultitr(14,2,16,4,6,8)
480  Delta_l=FNDelta_l(5,2,2,3,5)
490  Wput_data("DELTA L",Delta_l) ! <============ FCL
500  PRINT "DELTA L =";Delta_l;
510  !
520  Setmultitr(14,2,16,8,10,12)
530  Delta_w=FNDelta_w(5,2,5,3,2,5)
540  Wput_data("DELTA W",Delta_w) ! <============ FCL
550  PRINT "  DELTA W =";Delta_w
560  !
570  SUBEND
580  !
590  !
600  SUB Test_2(Coff)
610  !
620  R_sheet=FNR2t(2,4,1.0E-4,5)
630  Wput_data("SHEET-R",R_sheet) ! <============ FCL
640  PRINT "SHEET-R = ";R_sheet;
650  !
660  Connect(FNCmh,8,10)
670  Connect(FNCml,16)
680  Set_cmu(3,1)
690  Measure_cmu(Cox)
700  Connect(0)
710  Wput_data("Cox",Cox-Coff) ! <=============== FCL
720  PRINT "  Cox = ";Cox-Coff
730  !
740  SUBEND
750  !
```

Sample Program: Data Logging for Wafer Mapping (Continued)

Lines 50 through 80: The main program consists of these four statements. The TIS Init_system subprogram must be executed before any other TIS subprograms.

Lines 150 through 180: The program will not proceed past this loop until the wafer prober is set to the remote state. Prober_status is a TIS subprogram.

Lines 200 and 210: Refer to Figure 6-10 for an explanation of these subprograms.

Lines 230 through 290: This sequence of program lines uses TIS statements to lower the wafer chuck (Z stage), measure the capacitance zero offset (Coff), and raise the wafer chuck. This Coff value is then passed to the Test_2 subprogram. For an explanation of zero offset, see Chapter 3.

Lines 310 through 380: The same as lines 100 to 150 of Figure 6-11, except that the highest chip number (Chip_number=64) is used to terminate the loop. Therefore, the first chip to be probed does not have to be 1, and it is possible to change the Wstart_number parameter independently of other settings.

Line 410:	Creates the measurement data file, DATA_W1, in the specified mass storage device. This subprogram then transfers the measurement data saved by the Wput_data subprogram (see line 490), along with any file comments (Title$), into DATA_W1. File comments must not exceed 80 characters. Data file variables are numbered in the order in which the Wput_data subprograms are executed. In this sample program, variable 1 is DELTA L, variable 2 is DELTA W, and variables 3 and 4 are SHEET-R and Cox, respectively.
Lines 470 and 480:	These PARA subprograms measure ΔL.
Line 490:	Transfers the Delta_l (ΔL) measurement data and corresponding chip number into the COM blocks under the variable name DELTA L. This subprogram must be specified after the measurement, but before one of the Wmove subprograms is specified.
Lines 520 and 530:	These PARA subprograms measure ΔW.
Line 540:	Transfers the Delta_w (ΔW) measurement data into the COM blocks under the variable name DELTA W.
Line 620:	This PARA subprogram measures sheet resistance.
Line 630:	Transfers the sheet resistance measurement data into the COM blocks under variable name SHEET-R.
Lines 660 through 700:	These TIS subprograms measure Cox.
Line 710:	Subtracts the zero offset from the measured Cox and transfers the results to the COM blocks under the variable name Cox.

Creating Data Files for Statistical Graphics

The Wput_array and the Wbuild_file subprograms are mainly used to create data files for statistical graphics. An example of how each one of these subprograms might be used is as follows:

- Wput_array("hFE",D1(*)):

  In this example, the Wput_array subprogram transfers the measurement data contained in a one-dimensional array, D1(*), to the COM blocks under the variable name h_{FE}.

- Wbuild_file("DATA",D(*),"Data for Statistics","hFE","Vth"):

  In this example, the Wbuild_file subprogram stores the measurement data of two-dimensional array D(*) into data file DATA(with variable names h_{FE} and Vth assigned to row 1 and row 2 of the data file, respectively), with the comment "Data for Statistics".

Wput_array is used with Wsave_data in the same way as is Wput_data. However, Wput_array cannot be used in the same program with Wput_data.

Figure 6-18 uses the Wput_array and Wsave_data subprograms to create a data file for statistical graphics. This data file consists of the measurement data obtained from 50 h_{FE} measurements and 50 Vth measurements.

```
10    !
20    !  Sample Program
30    !    Requirements: TIS,WAFER
40    !
50    OPTION BASE 1
60    DIM Hfe(50),Vth(50)
70    INTEGER I
80    Init_system
90    !
100   FOR I=1 TO 50
110     Test(Hfe(I),Vth(I))
120   NEXT I
130   !
140   Wput_array("hFE",Hfe(*))
150   Wput_array("Vth",Vth(*))
160   !
170   Wsave_data("DATA_1","DATA FOR STATISTICS")
180   END
190   !
200   !
210   SUB Test(Hfe,Vth)
220   !
230   SUBEND
240   !
```

Figure 6-18. Sample Program: Creating a Data File for Statistical Graphics

Line 80: Init_system is required because TIS subprograms are used in the Test subprogram.

Line 110: Calls the required measurement subprograms, and assigns the measurement values to arrays h_{FE} and Vth.

Lines 140 and 150: Transfer the h_{FE} and Vth measurement data into the COM blocks under the variable names h_{FE} and Vth. The number of characters in each variable name must not exceed 10.

Line 170: Creates a measurement data file, DATA_1, and transfers the Vth and h_{FE} measurement data into the data file, along with any file comments.

Lines 210 through 230: Contain the measurement subprograms.

The Wbuild_file subprogram can be used by itself to create a measurement data file. Be careful to dimension and fill the measurement data array (2nd parameter of the Wbuild_file subprogram) properly, because this array is converted to the data file by the Wbuild_file subprogram. For details on the syntax and semantics of this subprogram, refer to the *Programming Reference* .

Figure 6-19 is identical to Figure 6-18, except that Figure 6-19 uses the Wbuild_file subprogram to create the measurement data file instead of the Wput_array and Wsave_data subprograms.

```
10   !
20   !  Sample Program
30   !    Requirements: TIS,WAFER
40   !
50   OPTION BASE 1
60   DIM Meas_data(2,50),Title$[80]
70   INTEGER I
80   Init_system
90   !
100  FOR I=1 TO 50
110    Test(Hfe,Vth)
120    Meas_data(1,I)=Hfe
130    Meas_data(2,I)=Vth
140  NEXT I
150  !
160  Title$="DATA FOR STATISTICS"
170  Wbuild_file("DATA_1",Meas_data(*),Title$,"hFE","Vth")
180  END
190  !
200  !
210  SUB Test(Hfe,Vth)
220  !
230  SUBEND
240  !
```

Figure 6-19. Creating a Data File for Statistical Graphics Using & Wbuild_file

Line 60:	Declares two-dimensional array Measure(2,50) and one-dimensional array Title$[80]. The measurement data is stored in the two-dimensional array: the first dimension (rows) is for variables, and the second dimension (columns) is for the measurement data for each variable. Because the maximum number of data items that are allowed by Wbuild_file is 1500, the following expression must be satisfied: (first dimension) $\times$ (second dimension) $\leq$ 1500. You can specify up to 10 variables (first dimension). Title$[80] is the file comment, and is set to size 80 because the file comment must not exceed 80.
Line 80:	Init_system is required because TIS subprograms are used in the Test subprogram.
Line 110:	Calls the required measurement subprograms, and assigns the resulting measurement values to variables h_{FE} and Vth.
Lines 120 and 130:	Transfer the measurement data to the two-dimensional array.
Line 170:	When the Wbuild_file subprogram executes, the Data_1 data file is created from the h_{FE} and Vth (variables) measurement data stored in the data array. A maximum of 10 variable names can be specified and each variable name must not exceed 10 characters. The measurement data is stored to correspond to the associated variable name.

Creating DOS Data Files

The Wsave_data and Wbuild_file subprograms can save measured data in a DOS file instead of the BDAT file formatted for the BSDM. The DOS file can be retrieved by any database and data analysis software because it is one of the ASCII text files.

The Wfile_type subprogram specifies the type of the data file created by the Wsave_data and Wbuild_file subprograms. The data file type is set to the BDAT file on initialization, and the Wfile_type subprogram with no parameter sets to the BDAT file.

The following example sets the data file type to a DOS file and creates a DOS data file using the Wsave_data subprogram.

```
10   !
20   !  Sample Program
30   !    Requirements: TIS,WAFER
40   !
50   OPTION BASE 1
60   DIM Hfe(50),Vth(50)
70   INTEGER I
80   Init_system
90   !
100  FOR I=1 TO 50
110    Test(Hfe(I),Vth(I))
120  NEXT I
130  !
140  Wput_array("hFE",Hfe(*))
150  Wput_array("Vth",Vth(*))
160  !
170  Wfile_type("DOS")                               Specifying the data file
                                                     type to DOS file
180  Wsave_data("DATA_2","DOS DATA FOR STATISTICS")
190  END
200  !
210  !
220  SUB Test(Hfe,Vth)
230  !
240  SUBEND
```

Sample Program: Creating a DOS Data File

For details on the program descriptions, see the descriptions of Figure 6-18.

WAFER MAP

WAFER MAP is a software utility that facilitates the creation of wafer maps, an example of which is shown in Figure 6-20. WAFER MAP uses the measurement data file created by FCL and the probing pattern data file created by PPG. This program makes it possible to create wafer maps with a minimum effort. It is also possible to generate wafer maps using a computer that is not connected to the HP 4062UX, because the WAFER MAP program does not access the system instruments.

```
                    SAMPLE DATA FOR WAFER MAP
                                                            DATE  | 1 Mar 1988|
ROW  |---+---------+---------+---------+|
     |                                  |     VAR NAME  |Del  w     |
     |                                  |
  5- |           + + + M n M            |-      CHIPs/WAFER =  122
     |         n + + + M M + +          |
     |     + n + + + + + + + + + -      |         **** LIMIT ****
     |     + n + + + + + + + + + +      |
     |   n n M + + + + + + n n M n +    |         M >=  1.100E+00
  0- |   + + M - + + + + + + + M + +    |-
     |   + + M + + + + : + + + M + +    |         n >=  1.000E+00
     |     + + + n + + + + + + + +      |
     |     + + n + + + + + + + + +      |         + >=  0.900E+00
     |       n n + + + M M + + +        |
 -5- |         + - + + + + + +          |-        : >=  0.800E+00
     |                                  |
     |                                  |         -  <  0.800E+00
     |---+---------+---------+---------+|
         0         5        10        15
                                  COLUMN
```

Figure 6-20. Sample Wafer Map

Loading and Executing the WAFER MAP Program

WAFER MAP requires BASIC/UX (for HP 4062UX), BASIC (for HP 4062C), or BASIC/DOS (for HP 4062PC). The WAFER MAP program is in the MAP program file. WAFER MAP can be run independently from the measurement program using TIS, but executing the MAP program destroys the COM blocks established by the system START program. When executing the measurement program after the MAP execution, you must execute the SCRATCH A statement and re-execute the system START program.

When you're ready to execute WAFER MAP, perform the following procedure:

- For HP 4062UX:
  1. Load MAP using the `LOAD` command.

     `LOAD "/usr/pcs/bin/MAP"` (Return)

  2. Select the `RUN` softkey

- For HP 4062C/PC with the recommended directory structure:
  1. Load MAP using the `LOAD` command.

     `LOAD "/PCS/BIN/MAP"` (Return) *for HP 4062C/PC*
     `LOAD "\PCS\BIN\MAP"` (Return) *for HP 4062PC*

  2. Select the `RUN` softkey

- For HP 4062C/PC with flexible disks:

1. Insert the SYSTEM SOFTWARE (4) disk into the disk drive for the HP 4062C; insert the SYSTEM SOFTWARE (3) disk for the HP 4062PC.
2. Load MAP using the `LOAD` command.

   `LOAD "MAP"` (Return)

3. Select the `RUN` softkey

Printing a Display Hardcopy (HP 4062UX only)

You can print a copy of the alpha or graphics display on the Shared Resource Management (SRM) Spool printer, HP-UX spool printer, or local printer, or you can create a file of the display during MAP operation.

To print an alpha display or create a file, press (Shift) (Dump Alpha). To print a graphics display or create a file, press (Shift) (Dump Graphics). The following message is displayed:

```
Select output destination, File/Srm/Hpux/Printer70X
```

Enter F, S, H, or P (uppercase) to indicate output print destination.

- Creating a file

  To create a display file, enter an uppercase F (Return). The following message is displayed:

  ```
  Enter the file name.
  ```

  Enter your file name (Return). For HFS formats, file names can be up to 14 characters long; for LIF formats or SRM systems, file names can be up to 16 characters long. If you include a directory path and volume specifier (HFS or LIF only), the entire file specification can be up to 255 characters.

  When creating a file, be sure you create a file in your directory, *not* in the system software's directory.

  To exit this operation, press (Return) without entering a file name.

  If you entered the name of a file that already exists, the following message is displayed:

  File name `already exist !! Override/Re-try ( O or R ) ?`

  To overwrite the existing file, enter uppercase `O` (Return). To retry this operation, enter uppercase `R` (Return).

- Printing on the SRM spooler

  To print a display on the SRM spool printer, enter uppercase `S` (Return). The following message is displayed:

  ```
  Enter the file name.
  ```

  Enter your file name (Return). File names can be up to 16 characters long (cannot include the directory path and volume specifier). Note that your file must be placed in the SRM system's "spool" directory.

  To exit this operation, press (Return) without entering a file name.

  If you entered the name of a file that already exists, the following message is displayed:

  File name `already exist !! Override/Re-try ( O or R ) ?`

  To overwrite the existing file, enter uppercase `O` (Return). To retry this operation, enter uppercase `R` (Return).

- Printing on HP-UX spooler

  To print a display on the HP-UX spool printer, enter uppercase `H` (Return). The following message is displayed:

`Enter HP-UX lp command or Press Return if destination is standard spooler.`

To print a display on the standard lp spooler, press (Return). To print a display on another printer, enter HP-UX's spool command.

For example:

Enter `lp -dhp2225a` (Return)

To print an alpha display on an HP 2225A ThinkJet Personal Printer.

Enter `lp -dhp2225a -or` (Return)

To print a graphics display on an HP 2225A ThinkJet Personal Printer.

A confirmation message is displayed. If the displayed command is correct, enter `Y` (Return). If the displayed command is not correct, enter `N` (Return) and re-enter the command.

- Printing on a local printer

  To print a display on a local printer whose select code and address are defined by the `PRINTER CONFIG` softkey, enter uppercase `P` (Return)..

Note

Do not print while another process is using the local printer or the system software may *hang up*.

Entering Measurement and Probing Pattern Data Files

1. Next, the following message is displayed:

   `Enter DATA file name`

   Enter the name of the measurement data file created by FCL.

   For example:

   Enter `DATA_W1` (Return)

   Data file DATA_W1 is loaded from the mass storage device set by the MASS STORAGE IS command.

2. Next, the following message is displayed:

   `Enter WAFER file name created by PPG`

   Enter the name of the probing pattern data file created by PPG. If you generate a wafer map from a user-defined measurement data file, press (Return) key with null input.

   For example:

   Type in `PP_DATA` (Return)

Setting Up and Displaying Wafer Maps

After you load the measurement and probing pattern data files, the Wafer Map setup page, similar to Figure 6-21, is displayed. If desired, you can change the information in the fields indicated by the black arrows in Figure 6-21. Changes can be made directly from the keyboard. The `NEXT VAR NAME` softkey changes the VAR NAME field to the next variable specified in the measurement data file. The cursor control keys and the rotary knob move the cursor one character at a time, while the (Tab) key moves the cursor one field at a time. The following keys can be used in the normal manner:

(Insert char)

(Delete char)

(Clear line)

(Shift) + (Clear line)

After you make the desired changes and press (Return), a wafer map is displayed in accordance with the specified wafer parameters. As an example, for the setup shown in Figure 6-21, the wafer map shown in Figure 6-22 is generated. An explanation of the wafer map setup screen is given in Figure 6-23.

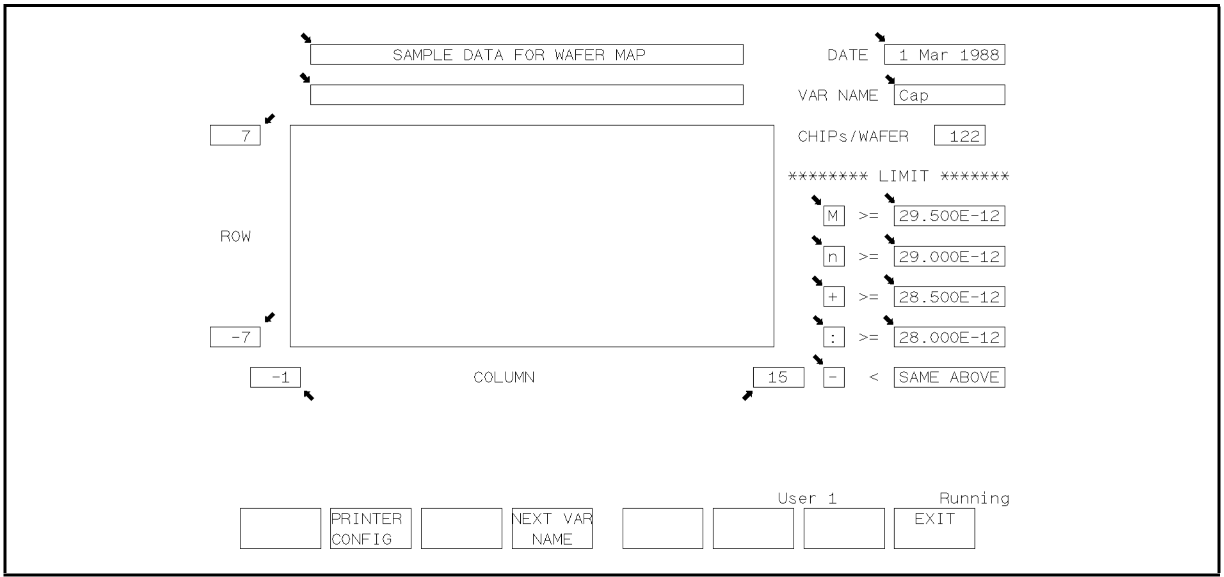


Figure 6-21. Wafer Map Setup Page

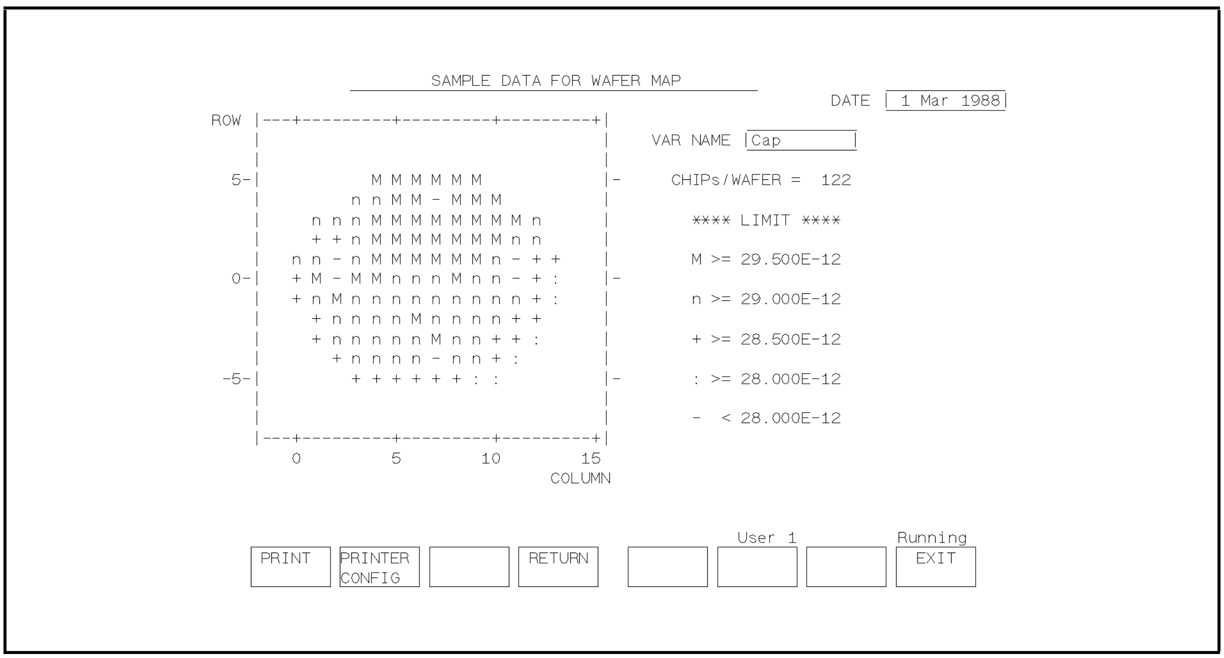


Figure 6-22. Example Wafer Map

The wafer map softkey functions are as follows:

`PRINT` :

Outputs the displayed wafer map to a printer.

`PRINTER CONFIG` :

Sets the printer's select code and address.

`RETURN` :

Returns to the setup page.

EXIT :

Ends the WAFER MAP program.

When there are more chips on a wafer than can be displayed at one time, the remaining chips can be reviewed by changing the upper and lower limits of row and column on the Setup Display. If your controller's CRT display is medium resolution display, you can use the arrow keys or the rotary knob to scroll the screen up or down.

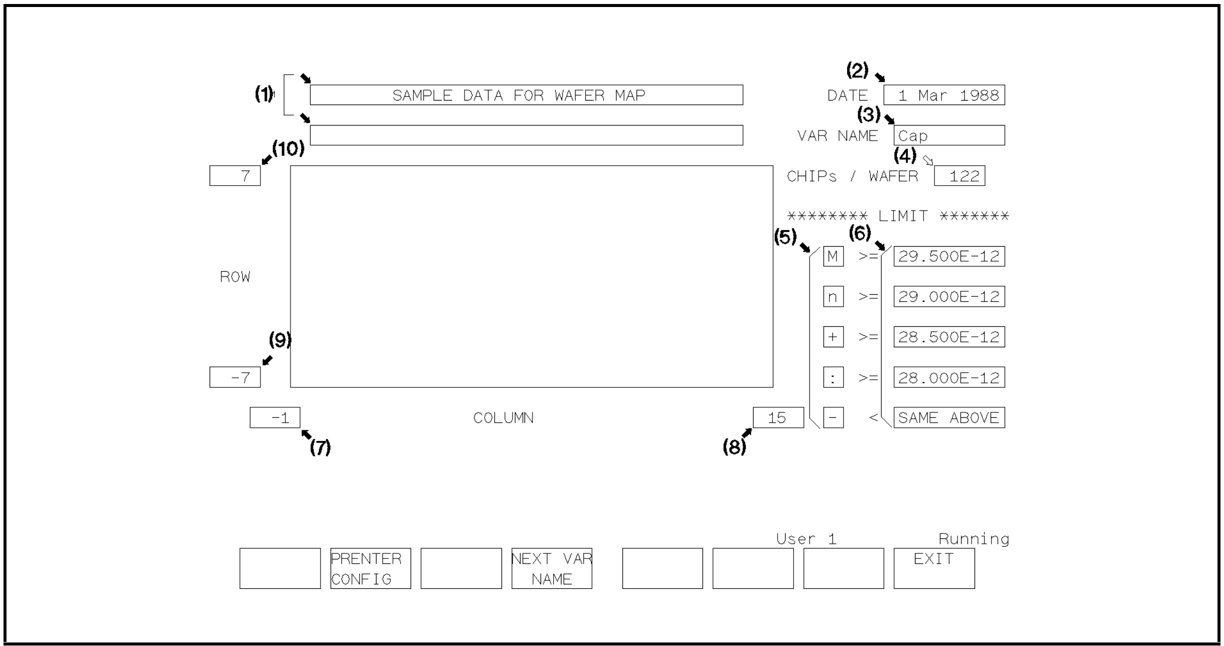


Figure 6-23. Wafer Map Setup Page Explanation

Black arrows indicate items that you can change; white arrows indicate items that you cannot change. If you generate a wafer map from a user-defined data file, however, the number of chips can be changed. The numbers in the illustration are keyed to the following descriptions:

(1) Comments associated with the measurement data file.

(2) The date when most recent START or a similar program was executed.

(3) The measurement data file variable whose wafer map is displayed if you press Return. To display the setup screen for the next variable in the measurement data file, select the NEXT VAR NAME softkey.

(4) The total number of chips per wafer.

(5)&(6) These five symbols are displayed on the wafer map to indicate the relative values of the measurement results. The value assigned to each symbol is shown to the right of that symbol. In the example above, any chip displayed on the wafer map with a value greater than or equal to 1.1 is displayed as an M. Any chip with a value greater than or equal to 1.0, but less than 1.1, is displayed as an n, and so on. A space is displayed for any chip whose value does not fall within the specified limits (-9999999.99999). Figure 6-9 shows the wafer map that would be generated from the parameters specified above.

(7)&(8) Indicate the lower and upper CHIP COORDINATES limits. The allowable COLUMN and ROW lower and upper range limits are from -999 to 999 under the following conditions:

COLUMN:

Lower Limit $\leq$ Upper Limit
Upper Limit $-$ Lower Limit $\leq$ 59 (medium resolution display)
Upper Limit $-$ Lower Limit $\leq$ 99 (high resolution display)

ROW:

Lower Limit $\leq$ Upper Limit
Upper Limit $-$ Lower Limit $\leq$ 49 (medium resolution display)
Upper Limit $-$ Lower Limit $\leq$ 34 (high resolution display)

`PRINTER CONFIG` : (HP 4062UX only)

For changing the printer configuration. When you select this softkey, the following message is displayed.

```
Input the Printer Sc/Address.  Ex 701.
```

Enter the printer's select code (sc) and address, and press (Return). To quit this operation press (Return) without entering a value.

For example:

- Enter `701` (Return)

  If the printer is connected to the select code 7 HP-IB interface and the printer's address is set to 1.

- Enter `9` (Return)

  If the printer is connected to the select code 9 RS-232C interface.

A confirmation message is displayed. If the displayed select code and address are correct, enter `Y` (Return). If the displayed select code and address are not correct, enter `N` (Return) and re-enter the values.

Additional WAFER MAP Information

The information described in the following paragraphs is not usually required, but may affect more advanced applications, such as larger data sets.

Data File Format

The format of the measurement data files created by FCL and loaded by WAFER MAP is compatible with BSDM data files as described in Chapter 7 For detailed information on the format of BSDM data files, see Appendix B. The format of FCL-created measurement data files is as follows:

- Record size: 1280 bytes
- Contents of each record:
  - Record Number 1:

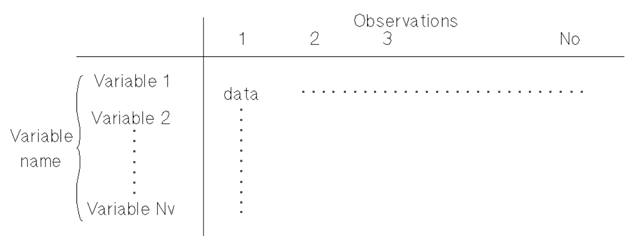
    Contains the file header, which consists of the following fields (in following order).

    T$: Title of data set (file comments—not to exceed 80 characters)
    No: Number of observations (data items) for each variable (type real, No $\times$ Nv $\leq$ 1500)
    Nv: Number of variables (type real, max. 50)
    Vn$(*): Variable names (Vn$(50)[10])
    Ns: Number of subfiles (type real, 0)

  - Record Number 2 and subsequent records: Contains the measurement data.

    D(*): D(Nv,No)

    Data is configured as shown in the following array.



  - Number of records depends on the number of observations. Use the following expression:

    2 + (8 $\times$ No $\times$ Nv) DIV 1280

Increasing Data Set Size

The maximum size of a data set (number of variables $\times$ number of observations) in FCL is 1500. If the number of required measurement items on a wafer exceeds 1500, however, you can do one of the following:

- You can create more than one data file.

Use this method if it is not necessary to permanently enlarge the size of a data set. When the Wput_data and Wsave_data subprograms are used, only one data file is created. To increase the number of data files, use the Wbuild_file subprogram in addition to Wput_data and Wsave_data subprograms, as shown in Figure 6-24.

- You can increase the size of the data set.

Use this method when it is necessary to permanently enlarge the size of a data set. This method requires that changes be made in the WAFER program file and in the programs and data files for statistical graphics. To modify the programs and data files for statistical graphics, see in Appendix B.

Modifying the Wafer Program File

1. Load WAFER.
2. Enter the following to change the maximum size:

   ```
   CHANGE "REAL D(1,1500)" TO "REAL D(1,XXXX)";ALL
   ```
   Return

   where XXXX is the desired maximum size of the data set. The value of XXXX must be greater than or equal to 1500.
3. Store the modified program:

Note The maximum number of variables is 50 and cannot be changed.

If the size of a data set exceeds 1500 during the measurement of a wafer, Figure 6-24 can be used to create two data files by using the Wbuild_file subprogram in addition to Wsave_data and Wput_data. In this example, the test wafers have 250 chips and one test module per chip.

```
10   !
20   !  Sample Program
30   !    Requirements: TIS,WAFER
40   !
50   OPTION BASE 1
60   DIM Cap(2,250),Title$[80]
70   INTEGER Chip_number
80   Init_system
90   Wget("WAFER_3")
100  Wstart_number(1)
110  !
120  REPEAT
130    Wpos_number(Chip_number)
140    Test(L1,L2,W1,W2,R1,R2,C1,C2)
150    Wput_data("DELTA L 1",L1)
160    Wput_data("DELTA L 2",L2)
170    Wput_data("DELTA W 1",W1)
180    Wput_data("DELTA W 2",W2)
190    Wput_data("R 1",R1)
200    Wput_data("R 2",R2)
210    Cap(1,Chip_number)=C1
220    Cap(2,Chip_number)=C2
230    Wmove_next
240  UNTIL Chip_number=250
250  !
260  Wsave_data("DATA_1","DATA OF WAFER 3  - 1")
270  Title$="DATA OF WAFER 3  - 2"
280  Wbuild_file("DATA_2",Cap(*),Title$,"CAP 1","CAP 2")
290  END
300  !
310  !
320  SUB Test(L1,L2,W1,W2,R1,R2,C1,C2)
330  !
340  SUBEND
350  !
```

Figure 6-24. Sample Program: Creating More Than One Data File

Lines 80 through 100: For explanations of these subprograms, refer to Figure 6-10.

Line 140: Calls the measurement subprogram.

Lines 150 through 200: Transfer measurement data L1 through R2 into the COM blocks.

Lines 210 and 220: Measurement data C1 and C2 are assigned to an array, and Chip_number is the subscript of the second dimension of the array. Measurement data is assigned in this way so that the data file

	created by Wbuild_file corresponds (data are stored in corresponding positions) to the file created by Wsave_data.		

Line 260: Creates the measurement data file, DATA_1, and transfers the L1 through R2 data from the COM blocks into the file.

Line 280: Transfers the C1 and C2 measurement data to a data file called DATA_2.

Lines 320 through 340: Contain the measurement subprogram.

User-Defined Data Files

If you are using a manual prober or an automatic prober that is not supported by the HP 4062C/UX/PC's software, you need to generate a measurement data file that includes probing pattern information (chip X- and Y-coordinates) and wafer measurement data. You can generate the data file by one of the following methods:

- Standard BASIC/UX or BASIC programming techniques
- BSDM data file creation methods
- Wbuild_file FCL subprogram

This data file must follow the FCL data file format described previously. See "Data File Format". The first two variables in your data file, however, must be specified as follows:

```
Vn$(1)="COLUMN"
Vn$(2)="ROW"
```

where variables 1 and 2 correspond to the chip's X- and Y-coordinates, respectively. You must assign probing and measurement data to the data file in the following manner:

	Observations 1	2 ···	No
COLUMN (Variable 1)	X-coordinate ···		
ROW (Variable 2)	Y-coordinate ···		
Variable 3	Data ···		
⋮	⋮		
Variable Nv			

Corresponds to the wafer chip X- and Y-coordinates.

Corresponds to the wafer chip measurement data at each coordinate.

To generate a wafer map from a user-defined measurement data file, a few of the steps are slightly different, as follows:

1. When the prompt

   ```
   Enter DATA file name
   ```

   is displayed, enter the name of the user-defined data file.

2. When the prompt

   ```
   Enter WAFER file name created by PPG
   ```

   is displayed, press (Return).

The wafer map setup screen appears. When using a user-defined data file, however, it is now possible to change the number of chips per wafer (see item 4 of Figure 6-23). As described previously, these items could not be changed when using data files defined by the HP 4062C/UX/PC's software.

Wafer Mapping Without "WAFER MAP"

You can generate wafer maps without using WAFER MAP. This is accomplished by using PPG-generated probing pattern data files and the FCL Wreturn_xy, FNWtotal_chip, and Wreturn_limit subprograms for wafer mapping in your program.

A sample program is stored in the "SAMPLEMAP" program file. Figure 6-25 is the listing of the sample_map subprogram that is used in the sample program. There is one restriction: the Wget subprogram used to load the probing pattern data file must come before the sample_map subprogram in the main program.

```
1019 SUB Sample_map
1020 !
1021   OPTION BASE 1
1022   INTEGER Var,Xmin,Xmax,Ymin,Ymax,Xpos,Ypos,Level,I
1023   REAL Nvar,Nobs,Limit(9)
1024   DIM Datafile$[30],Title$[80],Date$[15],Crt$[12]
1025 !
1026 ! --- Define variables ---
1027 !
1028   Var=1                              ! Variable number
1029   Date$="17 Jul 1986"                ! Date
1030   Datafile$="TESTDATA"               ! Datafile name
1031   FOR I=1 TO 9                       ! Define levels of data
1032     Limit(I)=.2*I
1033   NEXT I
1034   Wreturn_limit(Xmin,Xmax,Ymin,Ymax) ! Get the wafer size
1035 !
1036   ASSIGN @File TO Datafile$          ! Read the datafile
1037   OUTPUT @File,1                     ! Move file pointer to record 1
1038   ENTER @File;Title$,Nobs,Nvar
1039   ALLOCATE Vname$(Nvar)[10],REAL Measdata(Nvar,Nobs)
1040   ENTER @File;Vname$(*)
1041   OUTPUT @File,2                     ! Move file pointer to record 2
1042   ENTER @File;Measdata(*)
1043   ASSIGN @File TO *
1044 !
1045 ! --- Initialize graphics parameter ---
1046 !
1047   OUTPUT KBD;"  K";                  ! Clear screen
1048   GINIT                              ! Initialize graphics parameters
1049   Crt$=SYSTEM$("CRT ID")             ! Get CRT ID
1050   IF Crt$[7;1]="C" THEN              ! Color display
1051     PLOTTER IS CRT,"INTERNAL";COLOR MAP
1052                                      ! Use COLOR MAP in color display
1053     SET PEN 0 INTENSITY .4,.4,.4     ! Pen for background
1054     SET PEN 15 INTENSITY 1,1,1       ! Pen for labels
1055     FOR I=1 TO 10                    ! Pen for each data level
1056       SET PEN I COLOR 4/6-4/6*I/10,1,I*.05+.5
1057     NEXT I
1058   ELSE                               ! Monochromatic display
1059     PLOTTER IS CRT,"INTERNAL"        ! Use DITHER in monochromatic dis
play
1060   END IF
1061   GCLEAR
```

Figure 6-25. Sample Program: Sample_map Program Listing

```
1062 !
1063 ! --- Draw wafer map shape ---
1064 !
1065 Init_map(Xmin,Xmax,Ymin,Ymax,Limit(*),Title$,Vname$(Var),Date$,Crt$)
1066 !
1067 ! --- Paint chips on wafer own level color ---
1068 !
1069   FOR I=1 TO FNWtotal_chip
1079     IF Measdata(Var,I)-9999999.99999 THEN
1071       Wreturn_xy(Xpos,Ypos,I)
1072       Level=FNFind_level(Measdata(Var,I),Limit(*))
1073       IF Crt$[7;1]="C" THEN
1074         AREA PEN Level              ! Use COLOR MAP in color display
1075       ELSE
1076         AREA INTENSITY .1*Level,.1*Level,.1*Level
1077                                     ! Use DITHER in monochromatic dis
play
1078       END IF
1079       MOVE Xpos-.5,Ypos-.5
1080       RECTANGLE 1,1,FILE,EDGE
1081     END IF
1082   NEXT I
1083 !
1084 SUBEND
```

Sample Program: Sample_map Program Listing (Continued)

Lines 1022 through 1024:	Declare the necessary variables and arrays.
Line 1030:	Defines the measurement data file name.
Lines 1031 through 1033:	Define the limit value to classify the measurement data.
Line 1034:	Gets the minimum and maximum X-axis and Y-axis values.
Lines 1036 through 1043:	Load the file header from record 1 of the measurement data file and load the measurement data from record 2.
Lines 1051 through 1057:	Define a color for each classification.
Line 1065:	Initializes the wafer map
Line 1069 to 1082:	Classify the measurement data and perform an area fill using the color defined in lines 1051 through 1057 in color display or using dither in monochromatic display.

Converting a BDAT Data File to a DOS File

FCONV, which is an HP BASIC program file, is a utility program to convert a BDAT data file to a DOS text file. For revision 6.0 or earlier, the FCL only creates BDAT data files formatted for the BSDM. For revision 6.2 or later, the FCL can create BDAT or DOS data files (see "Creating DOS Data File"). Once you convert your BDAT data files to DOS text files, you can use the data files in any database and data analysis software, because the DOS data file includes ASCII characters not binary codes.

Note

FCONV has no capability to convert a DOS data file to BDAT file.

Hint

DOS text file format differs from the HP-UX file format. HP-UX lines are terminated by the line-feed (LF) character. DOS text lines are terminated by the two-character sequence: carriage return (CR) and line feed (LF).

The HP-UX command *dos2ux* converts the DOS text file to the HP-UX file; the HP-UX command *ux2dos* converts the HP-UX text file to the DOS file. For details, see DOS2UX reference pages.

Using the FCONV Utility Program

To start the FCONV utility program, use the following procedure:

- For HP 4062UX:
  1. Load FCONV using the BASIC/UX `LOAD` command, as follows:

     `LOAD "/usr/pcs/bin/FCONV"` Return

  2. Select the `RUN` softkey.

- For HP 4062C/PC with a recommended directory structure:
  1. Load FCONV using the BASIC `LOAD` command, as follows:

     `LOAD "/PCS/BIN/FCONV"` Return *for HP 4062C/PC*
     `LOAD "\PCS\BIN\FCONV"` Return *for HP 4062PC*

  2. Select the `RUN` softkey.

- For HP 4062C/PC with flexible disks:
  1. Insert the SYSTEM SOFTWARE (3) Disk into the flexible disk drive.
  2. Load FCONV using the BASIC `LOAD` command, for example, as follows:

     `LOAD "FCONV:,702"` Return *for HP 4062C*
     `LOAD "FCONV:DOS,A"` Return *for HP 4062PC*

  3. Select the `RUN` softkey.

The following FCONV page appears:

```
   ***** File Conversion Utility *****

Source File :

Destination File :

Wafer File :

Conversion Mode : BS&DM BDAT to DOS text




Enter Source File Name.

 Convert                                             Exit
```

Figure 6-26. FCONV Page

After filling the Source File, Destination File, and Wafer File (if needed) fields with desired file names, select the `Convert` softkey. To move the field pointer (inverse video area), use ↑ and ↓ keys.

To exit from the FCONV, select the `Exit` softkey.

Each field is described as follows:

Source File	The name of the BSDM formatted BDAT file to be converted. This file includes measured data created by FCL.
Destination File	The name of the DOS text file in which the measured data converted by this utility is stored.
Wafer File	The name of the probing pattern data file (PPF) created by the PPG. This file name must be specified when the source file is used for the WAFER MAP. If the source file is used for statistical graphics, you can leave this area blank.

Format of a DOS Data File

The format of a DOS data file that is created by the FCONV utility and FCL is as follows:

```
"title"

"No=num_obs"
"Nv=num_var"

" " "var1" "var2" "var3" · · · "varN"
" " data(1,1) data(2,1) data(3,1) · · · data(num_var,1)
   . . . . . . . . .
   . . . . . . . . .
" " data(1,num_obs) data(2,num_obs) data(3,num_obs) · · · data(num_var,num_obs)
```

Each line is terminated by the carriage return (CR) and line feed (LF) characters.

When the data file is created for the WAFER MAP, the *var1* and *var2* are set to `COLUMN` and `ROW`, respectively.

Figure 6-27. Format of DOS Data File

For example, the following data file is created when three device parameters are measured at six chips:

```
"MEASURED DATA NO.5"

"No=6"
"Nv=4"

" " "COLUMN" "ROW" "RES" "VTH" "Cox"
" " 4 4 1003.3453388 2.1334981092 4.6789325992E-11
" " 4 8 1000.3593288 2.023613842 4.9003821789E-11
" " 4 12 999.37328911 2.2894342247 4.8773284323E-11
" " 10 4 1005.87894386 2.1973657737 4.5782276192E-11
" " 10 8 1001.0038727 2.0903827877 5.0032891898E-11
" " 10 12 1000.5389001 2.2144738287 4.7336892818E-11
```

7

Statistical Graphics

Introduction

This chapter discusses Basic Statistics and Data Manipulation (BSDM) and Statistical Graphics programs (time plot, histogram, and scattergram), and includes sections on data entry methods, how to use BSDM and statistical graphics, methods for creating data files for generating control charts, and how to use user-defined transformations.

Description

Statistical processing and graphic representation of HP 4062C/UX/PC measurement data are handled by (1) basic statistics and data manipulation (BSDM) software, and (2) statistical graphics software, respectively.

BSDM software provides 7 program and 2 data files for entering measurement data, performing various data manipulation operations and basic statistics calculations, and storing processed data on a mass storage device. BSDM program and data files are as follows:

BSDM Software

- Program Files

  AUTOST,FILE1,FILE2,FILE3,ADVST,FUNCTION,RBSDM3

- Data Files

  DATA,BACKUP

Statistical graphics software also provides 7 program and 2 data files for creating time plots (control charts), histograms, and scattergrams using measurement data entered and processed by BSDM. Statistical graphics program and data files are as follows:

Statistical Graphics Software

- Program Files

  ADVST,ADVST2,RBSDM2,GRAPH,SCAT,TIME,HIST

- Data Files

  DATA,BACKUP

Figure 7-1, Figure 7-2, and Figure 7-3 show control chart, histogram, and scattergram examples.

Note that except for the AUTOST program, which you must run before you can perform either BSDM or statistical graphics operations, you cannot load or run BSDM or statistical graphics programs individually.

BSDM and statistical graphics programs are completely interactive, and display operating instructions and information during execution to guide you through the entire process—from initial data entry to final graphics plot.

BSDM and statistical graphics programs are capable of batch data processing only.

Also, these programs destroy the COM blocks established by the START program. This means that if you're doing a lot of statistical processing, the system instruments are idle much of the time, and you have to run the START program for each new measurement.

One way around this is to configure a shared resource management (SRM) system consisting of your HP 4062C/UX, a mass storage device, and two workstations. One workstation controls the measurement process and creates measurement data files using the file creation library (FCL), while the other workstation handles statistical data processing chores.

See Appendix B for more detailed BSDM and statistical graphics information. Appendix B also provides instructions on how to modify these programs so you can manipulate data sets larger than 1500.

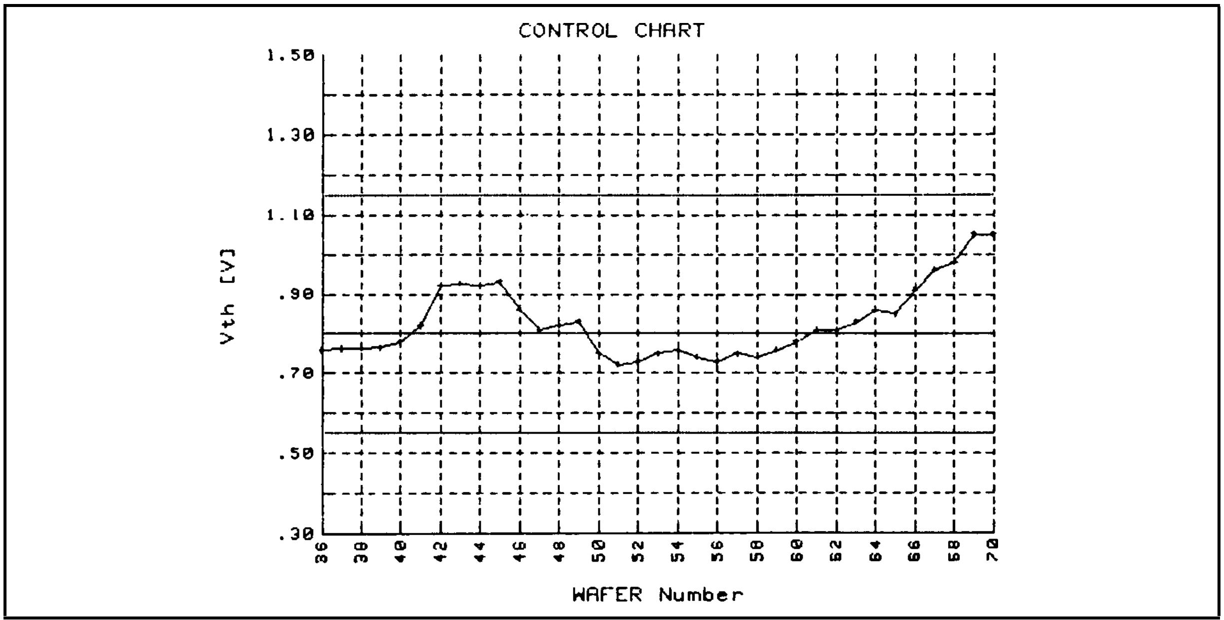


Figure 7-1. Example Control Chart

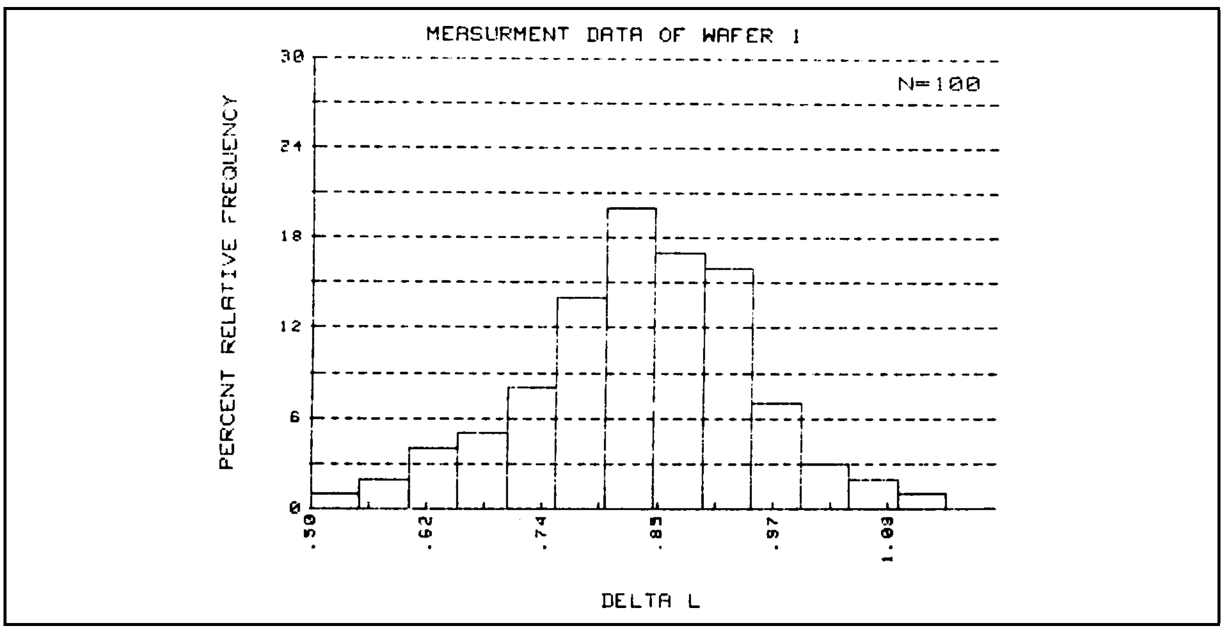


Figure 7-2. Example Histogram

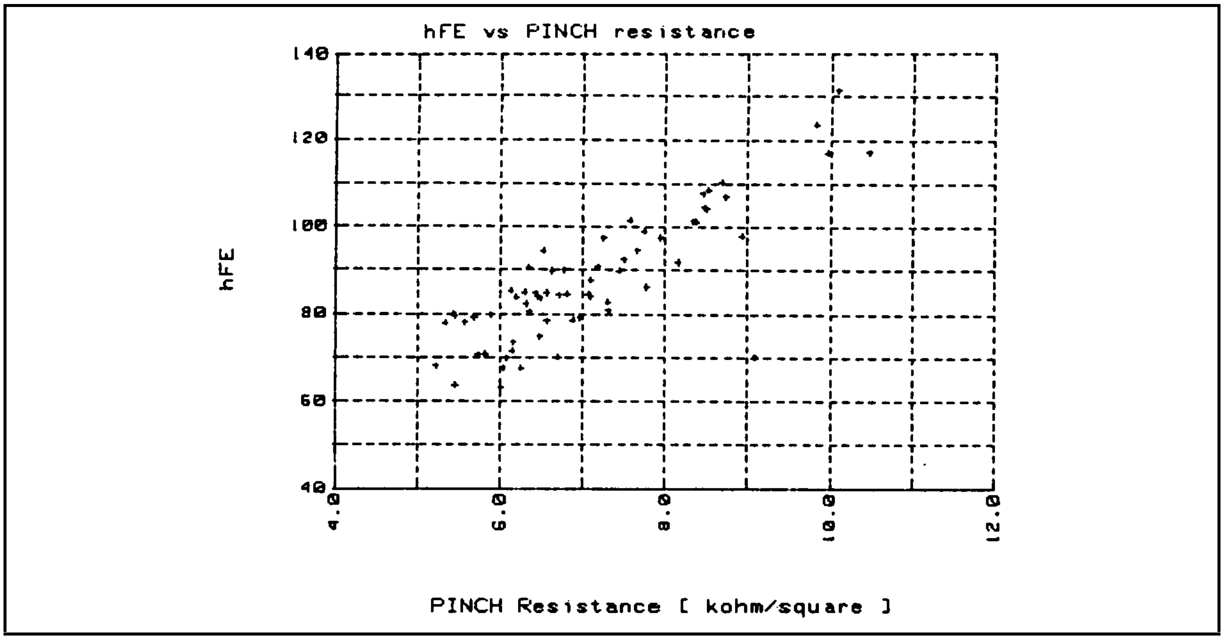


Figure 7-3. Example Scattergram

Entering Data

You can enter data for statistical graphics from your system controller's keyboard, from a peripheral input device such as a graphics tablet, or from an existing data file on a mass storage device.

The last method is the most versatile of the three because it lets you use either matrix-type or BSDM compatible data files, and is the recommended method for statistically processing measurement data.

You create BSDM compatible data files using the File Creation Library (FCL). For a detailed FCL description, along with sample programs for creating data files, see "File Creation Library (FCL)" in Chapter 6.

Using BSDM

BSDM can be run independently of the system software.

BSDM is initiated by the AUTOST program. When you're ready to execute BSDM, perform the following procedure:

1. Specify the system mass storage as follows:
   - For HP 4062UX:

     `MSI "/usr/pcs/bsdm"` (Return)
   - For HP 4062C/PC with the recommended directory structure:

     `MSI "/PCS/BSDM"` (Return) *for HP 4062C/PC*
     `MSI "\PCS\BSDM"` (Return) *for HP 4062PC*
   - For HP 4062C/PC with the flexible disks:

     Insert the SYSTEM SOFTWARE (3) disk into the current system mass storage.

Note When you use BSDM, the system mass storage must be the directory or the disk drive where the BSDM files exist.

2. Load AUTOST using the LOAD command as follows:

   `LOAD "AUTOST"` (Return)
3. Select the `RUN` softkey.

Figure 7-4 shows the overall flow initiated by the AUTOST program. Follow the instructions and respond to the displayed prompts.

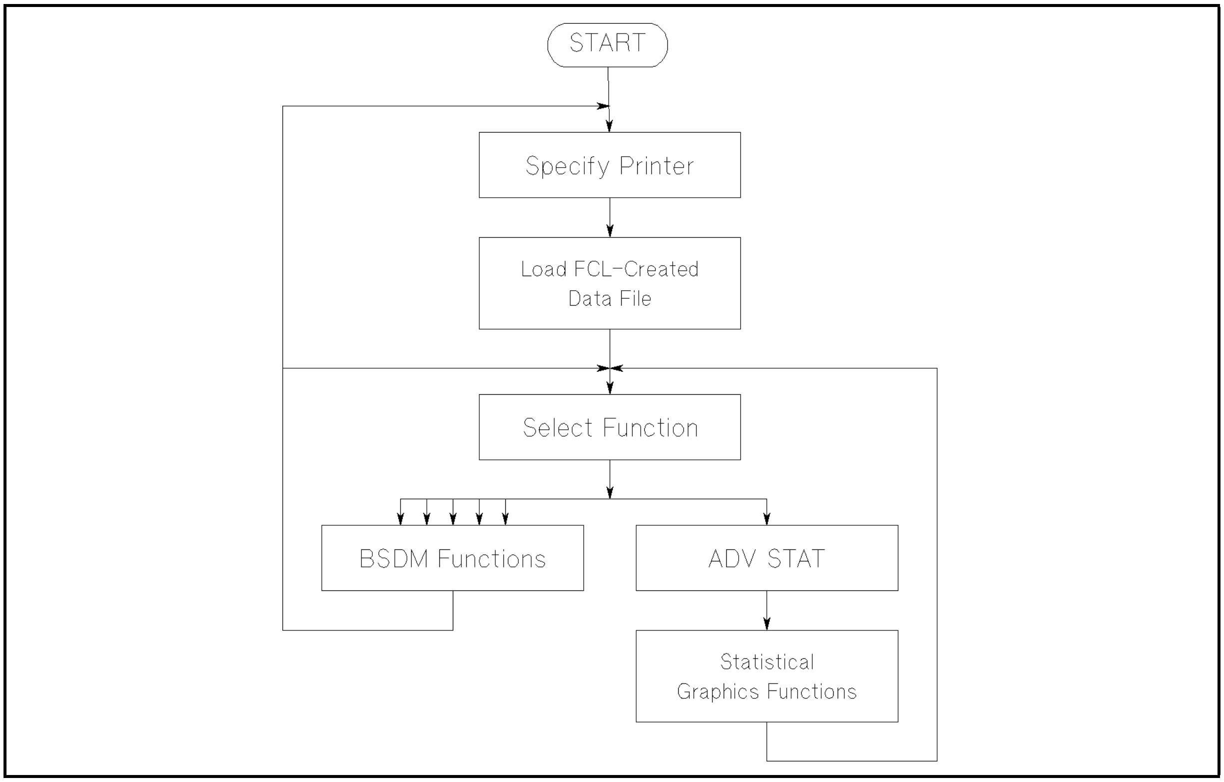


Figure 7-4. BSDM and Statistical Graphics Flow

The following is an annotated example of using BSDM to process an FCL-created data file named DATA_W.

1.

```
BASIC STATISTICS AND DATA MANIPULATION

c Copyright Hewlett Packard Co. 1982
        All rights are reserved

             Revision B


[Answer all yes/no questions with Y/N]
```

```
Are you going to use user defined transformation
or do Non-linear regression ? (Y/N)
```

Enter `N` (Return)

The usual response is `N`. If you enter `Y`, notes for using "User-defined transformations" or "Non-linear regressions" (not included in the HP 4062C/UX/PC's software) are displayed.

For HP 4062UX, proceed to step 2.

For HP 4062C/PC, proceed to step 3.

2. For HP 4062UX only:

```
You are running on HP-UX.

Select the destination of PRINTER output.

    1.  --  Use CRT or Printer 70x --------> 1
    2.  --  Use a FILE  -------------------> 2



Note:
     You can output a FILE to spooler of HP-UX or SRM if you
     select 2.
```

```
Input a number.
```

Enter `1` (Return)

To display results or print them on an HP-IB printer, enter `1` (Return). To create a file of the display or to print results to the HP-UX spool printer or SRM spool printer, enter `2` (Return) and enter the file name.

```
Are you using an HPIB Printer ?  (Y/N)
```

Enter `Y` (Return)

To display results on the CRT, enter `N` (Return) and select the **Continue** softkey.

```
Enter select code.  bus address (if 7,1 press CONT) ?
```

If the printer's HP-IB address is 701, select the **Continue** softkey.

3.

```
******************************************************************************
*                              DATA MANIPULATION                             *
******************************************************************************

             NOTE:
              Certain advanced statistics packages, including
              Analysis of Variance and Principal Components and
              Factor Analysis, require that the data be entered
              in a certain manner.  Please consult the appropri-
              ate section of the manual before entering your
              data. If the data is entered in an incorrect form,
              some analyses cannot be performed and the data
              will have to be re-entered.


       Press 'CONTINUE' when ready ...
```

Read the note, then select the `Continue` softkey.

4.

```
              TYPE OF DATA TO BE ENTERED:

                The RAW (original, transformed or coded) DATA -- 1

                A COVARIANCE MATRIX ---------------------------- 2
                A CORRELATION MATRIX --------------------------- 3
                A FACTOR MATRIX -------------------------------- 4
                A CROSS-TABULATION TABLE ----------------------- 5

                NOTE:  All advanced statistics packages will
                accept raw data (type 1).

                Principal Components and Factor Analysis will
                accept data type 1,2,3,&4.

                Survey Tables will accept data types 1 and 5.
```

```
Enter DATA TYPE (Press CONTINUE for RAW DATA):
```

FCL-created data files contain raw data only. Select the `Continue` softkey to select data type 1. Data types 2 through 5 are not used with the HP 4062C/UX/PC's software.

5.

```
              DATA ENTRY MODES

        KEYBOARD ----------------------- 1
        MASS STORAGE ------------------- 2
        GRAPHICS TABLET ---------------- 3
        OTHER (See manual for details) - 4
```

```
Mode number = ?
```

Enter `2` (Return)

To read data from an FCL-created data file in mass storage, enter 2 for the mode number.

```
Is data stored on program's scratch file (DATA) ?
```

Enter `N` (Return)

BSDM and Statistical Graphics programs use the DATA scratch file to transfer data between programs. Because no data is stored in the scratch file, enter `N`.

6.
```
     File names must be<=10 characters.  Use only letters and numbers in file
name.  Special characters not allowed.  If STORING ON an internal device,
enter file name followed by ':INTERNAL'.  IF storing on an external device,
enter file name followed by a colon and mass storage specifier.  See
examples below.


NAME:INTERNAL              (Internal storage)
NAME:INTERNAL,4,1          (2nd internal floppy)
NAME:HP82902,700           (HP82902 Disc Drive)
NAME:HP9895,700            (HP9895 Disc Drive)
NAME:{other mass storage specifier}
```

`Data file name = ?`

Enter `/users/user1/DATA_W:HFS` Return

"DATA_W", the object data file, is stored in the "/users/user1" directory.

`Was data stored by the BS&DM system ?`

Enter `Y` Return

FCL-created data file format is compatible with BSDM, so enter `Y`.

`Is data medium placed in device HFS ?`

Enter `Y` Return

`Is program medium placed in correct device ?`

Enter `Y` Return

7.
```
Data file name: /users/user1/DATA_W:HFS

Data type is:   Raw data

Number of observations:    145
Number of variables:         1


Variable names:
   1. Vth

Subfiles:  NONE
```

The list is printed on the specified print device.

BSDM stores the object data file contents into the DATA scratch data file, and the BACKUP data file. Only the data in the scratch data file is used. If data is destroyed, original data is kept intact in the backup file.

After the object data is stored in the DATA and BACKUP files, the following softkeys are displayed. The data stored in the DATA file is the object of all data manipulations and graphics display operations.

- For HP 4062UX:

RESTART	EDIT	SUBFILES	STORE	BACKUP	NAMES	STATS	ADV STAT

To display the next softkeys, press Shift Menu.

SORT	SELECT	LIST	TRANSF.	JOIN	RECODE	PRINTER	OUTPUT SPOOL

- For HP 4062C/PC:

EDIT	SUBFILES	STORE	BACKUP	NAMES	STATS	ADV STAT	SORT

To display the next softkeys, press Shift Menu.

SELECT	LIST	TRANSF.	JOIN	RECODE	PRINTER	CHANGE " " TO ""	INDENT

Softkey functions are described as follows:

RESTART : (For HP 4062UX only) For returning control to the beginning of the program so a new data file can be loaded or the scratch data file can be updated from the backup data file. Refer to Appendix B.

EDIT : For correcting, deleting, adding, or inserting data stored in the scratch data file. Refer to Appendix B.

SUBFILES : For specifying subfiles or logical groupings. Refer to Appendix B.

STORE : For writing processed data to mass storage under a user-specified file name. This function can also be used to store required variables. Refer to Appendix B.

BACKUP : For transferring data from the DATA scratch data file to the BACKUP data file, and vice versa. Refer to Appendix B.

NAMES : For changing title, variable names, and subfile names. Refer to Appendix B.

STATS : For calculating summary statistics such as sum, mean, variance, and standard deviation. Refer to Appendix B.

ADV STAT : For entering the statistical graphics routine to create control charts (time plots), histograms, and scattergrams. Refer to Appendix B.

SORT : For sorting data according to the values of the variables. Refer to Appendix B.

`SELECT` : For selecting or displaying data within specified limits. Refer to Appendix B.

`LIST` : For listing data stored in the scratch data file. Refer to Appendix B.

`TRANSF.` : For transforming (converting) data between various types. For example, this softkey performs algebraic transformations and user-defined transformations, and creates rank variables and uniform random number variables. Refer to Appendix B.

`JOIN` : For joining a specified data set or specified variables to a data set in memory. Refer to Appendix B.

`RECODE` : For assigning codes to different classes of data. Refer to Appendix B.

`PRINTER` : For changing the specified printer. Refer to step 2 for HP 4062UX or "Printer Is" in Appendix B.

`OUTPUT SPOOL` : (For HP 4062UX only) For selecting the printer if you selected "Use a file" in step 2 or you selected the `PRINTER` softkey. When this softkey is selected, the following message is displayed:

```
Where would you like to put your print out ?

     0 --- Exit.
     1 --- CRT.
     2 --- HP-UX spooler.
     3 --- SRM spooler.

Enter a number ...
```

Using Statistical Graphics

To create a statistical graph, enter and process the data using BSDM. When the following softkeys are displayed, select the `ADV STAT` softkey and follow the displayed instructions.

The following annotated example shows how to create a histogram with a normal overlay.

1.

```
Remove current program medium and insert medium
containing the desired advanced statistics package
Press CONTINUE when ready.
```

Ignore the message and select the `Continue` softkey.

2.

```
                        STAT GRAPHICS 1A MENU

Plot variable in increasing units of TIME ------ 1
HISTOGRAM- of data created --------------------- 2
SCATTERGRAM - plots points for two variables --- 3


Return to Basic Stat & Data Manipulation ------- 4
Select another Advanced Statistics Package ----- 5

                   NOTE:  On STAT GRAPHICS 1B you will find
                        SEMI-LOG PLOT - X plotted on log scale
                        LOG-LOG PLOT - X, Y plotted on log scale
                        3D PLOT - simulated 3-D graph
                        ANDREW'S PLOT - multidimensions in 2-D
```

`Enter number of desired function:`

Enter `2` Return

The statistical graphics menu is displayed. Select histogram by entering `2`. Enter `1` to create control charts (time plots), or `3` to create scattergrams.

3.

```
Variable 1 will be used

Number of valid cases = 145
The mean is calculated to be= .792520487777
The variance is calculated to be= .374917489861


                                  OBSERVED
CELL    MINIMUM      MAXIMUM     FREQUENCY
  1       -.930        -.559          2
  2       -.559        -.189          2
  3       -.189         .182         23
  4        .182         .552         26
  5        .552         .923         27
  6        .923        1.293         32
  7       1.293        1.664         22
  8       1.664        2.034         11
```

Other variables may be used.

The calculated values are output.

4.

```
                    PLOTTING CHARACTERISTICS
 0 - Basic statistic calculation --------------  0
 1 - PLOT-Construct graph or plot points ------  1

 2 - RESTART HIST plotting function.
     Values=default ---------------------------  2
 3 - Set X-AXIS parameters --------------------  3
 4 - Set Y-AXIS parameters --------------------  4
 5 - Change graph LABELS ----------------------  5
 6 - Specify CELL LIMITS ----------------------  6
 7 - DUMP CRT GRAPHICS to thermal printer -----  7
 8 - SELECT PLOTTER ---------------------------  8
 9 - SELECT PEN NUMBERS -----------------------  9
10 - NORMAL CURVE OVERLAY --------------------- 10
11 - STORE plotting characteristics to file --- 11
12 - LOAD plotting charactertistics from file - 12

13 - RETURN to main STAT GRAPHICS MENU -------- 13
```

`Enter number of desired function:`

Enter `1` (Return)

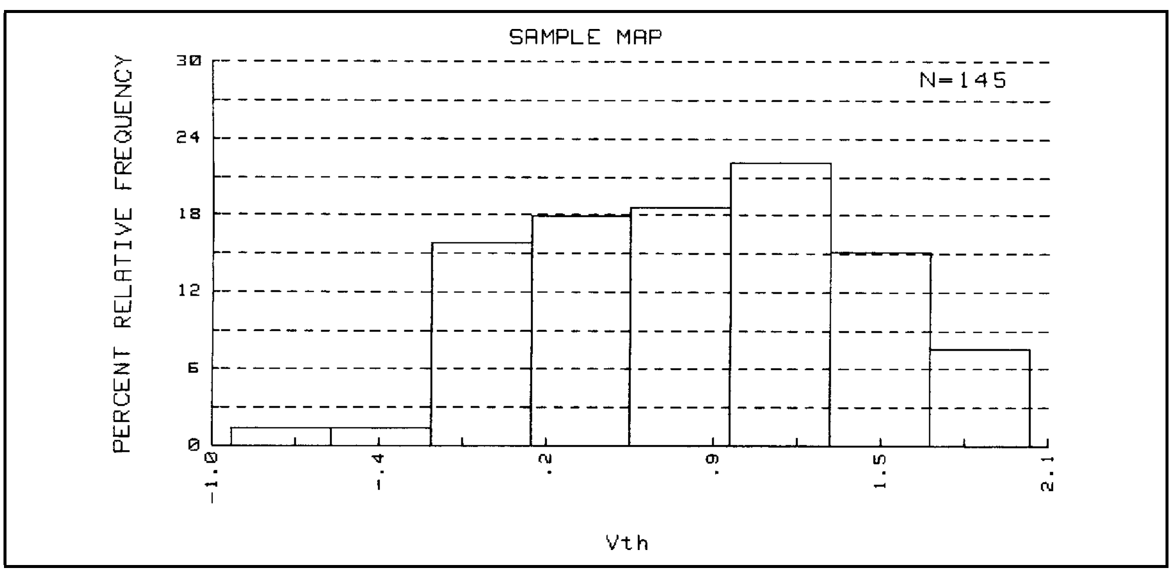
The plot menu is displayed. Enter `1` to start the plot. For more details on each function listed in the menu, refer to Appendix B.

Press (Menu) to clear the softkey labels so they don't interfere with the displayed X-axis parameters and label.

`Are horizontal grid lines to be plotted ?`

Enter `Y` (Return)

5. `BEEP will sound when plot done then Press CONT.`



Press (Menu) to display the softkey labels and select the `Continue` softkey to return to the plot menu.

6. `Enter number of desired function:`

Enter `6` (Return)

Enter 6 to change the cell width, number of cells, etc.

7.

```
OPTION   DESCRIPTION
   1     Number of cells, Minimum, Maximum
   2     Number of cells, Minimum, Cell width


              NOTE:  X axis labels and cell limits are set
              independently and will not automatically line up.
```

`Enter histogram option ?`

Enter `2` (Return)

Change the number of cells, minimum values, and cell widths.

`Enter number of cells (1 < number of cells < 41) ?`

Enter `14` (Return)

`Enter minimum values <-.929710593024 ?`

Enter `-1` (Return)

`Enter cell width > .216734596809 ?`

Enter `.25` (Return)

8.

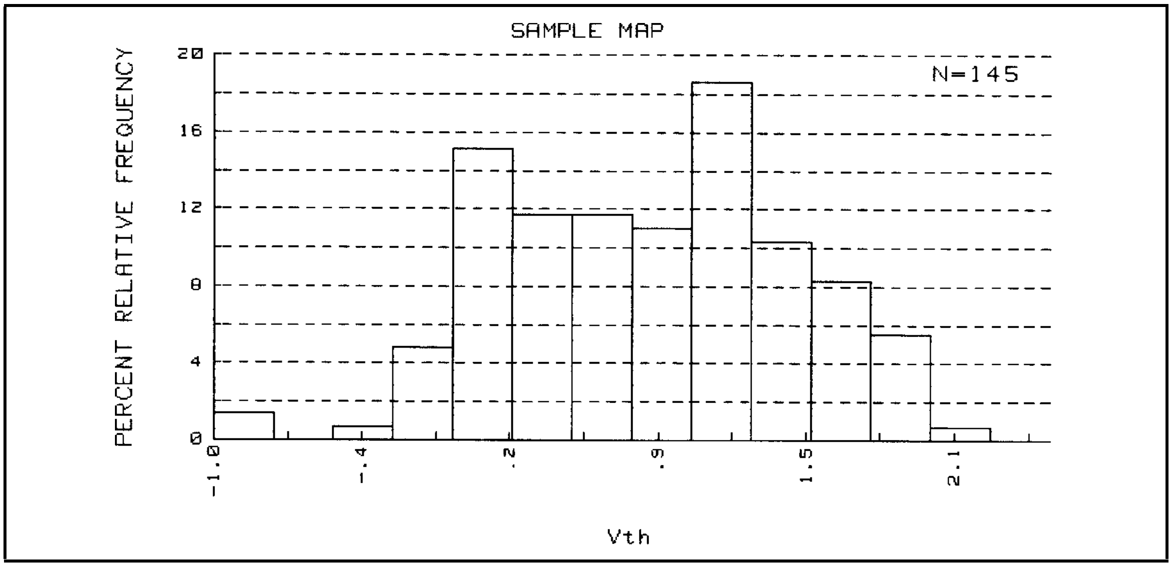
CELL	MINIMUM	MAXIMUM	OBSERVED FREQUENCY
1	-1.000	-.750	2
2	-.750	-.500	0
3	-.500	-.250	1
4	-.250	0.000	7
5	0.000	.250	22
6	.250	.500	17
7	.500	.750	17
8	.750	1.000	16
9	1.000	1.250	27
10	1.250	1.500	15
11	1.500	1.750	12
12	1.750	2.000	8
13	2.000	2.250	1
14	2.250	2.500	0

The calculated values are output.

9. `Enter number of desired function:`

Enter `1` (Return)

Enter 1 to display the graph again.



Select the `Continue` softkey to return to the plot menu.

10. `Enter number of desired function:`

Enter 3 (Return)

Enter 3 to rescale the X-axis.

```
        DATA CHARACTERISTICS

    X data minimum =-.929710593042
    X data maximum = 2.03428435532

        PLOTTING CHARACTERISTICS

    X plotting minimum =-1
    X plotting maximum = 2.5
    X tic = .31
    Label every 2  th tic mark
    to 1  places.

    If you do not want to change a characteristic,
    PRESS CONTINUE.
                  NOTE: X axis labels and cell limits are set
                  independently and will not automatically line up.
```

`X plotting minimum ?`

`X plotting maximum ?`

`X tic ?`

Enter .25 (Return)

`Label every Kth tic mark ?`

`Number of decimal places for labeling the X axis ?`

To leave items as they are except for X tic, select the `Continue` softkey.

11. `Enter number of desired function:`

Enter `4` (Return)

Enter 4 to rescale the Y-axis.

```
                    DATA CHARACTERISTICS

                Y data minimum = 0
                Y data maximum = 18.6206896552

                    PLOTTING CHARACTERISTICS

                Y plotting minimum = 0
                Y plotting maximum = 20
                Y tic = 2
                Label every 2  th tic mark
                to 0  places.

                If you do not want to change a characteristic,
                PRESS CONTINUE.
```

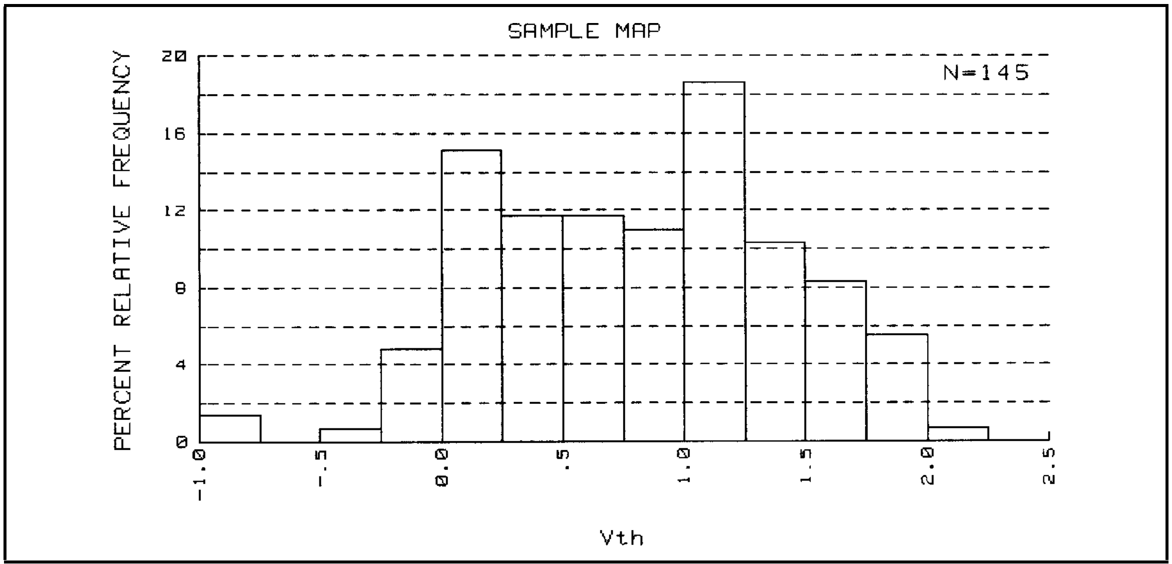
```
Y plotting minimum ?

Y plotting maximum ?

Y tic ?

Label every Kth tic mark ?

Number of decimal places for labeling the Y axis ?
```

To leave items as they are, select the `Continue` softkey.

12. `Enter number of desired function:`

Enter `1` (Return)

Displays the graph again.



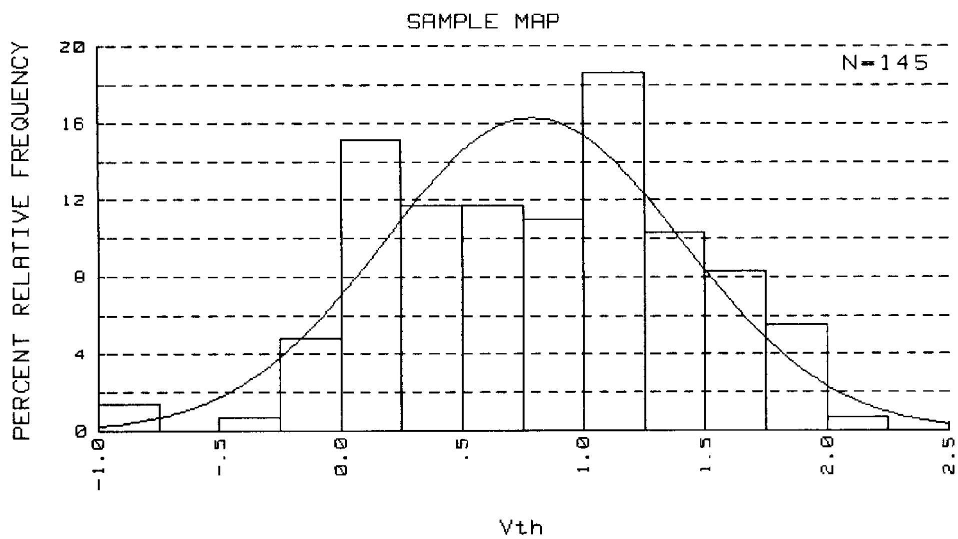
Select the `Continue` softkey to return to the plot menu.

13. `Enter number of desired function:`

Enter `10` Return

Enter 10 to plot a normal curve over the histogram.

CELL	MINIMUM	MAXIMUM	OBSERVED FREQUENCY	EXPECTED FREQUENCY	CONTRIBUTION TO CHI-SQUARE
1	-Infinity	-7.5000E-01	2	.853	v
2	-7.5000E-01	-5.0000E-01	0	1.669	v
3	-5.0000E-01	-2.5000E-01	1	3.905	1.827
4	-2.5000E-01	0.0000E+00	7	7.751	.073
5	0.0000E+00	2.5000E-01	22	13.053	6.132
6	2.5000E-01	5.0000E-01	17	18.650	.146
7	5.0000E-01	7.5000E-01	17	22.605	1.390
8	7.5000E-01	1.0000E+00	16	23.246	2.259
9	1.0000E+00	1.2500E+00	27	20.282	2.226
10	1.2500E+00	1.5000E+00	15	15.012	0.000
11	1.5000E+00	1.7500E+00	12	9.427	.702
12	1.7500E+00	2.0000E+00	8	5.022	1.765
13	2.0000E+00	2.2500E+00	1	2.270	1.808
14	2.2500E+00	Infinity	0	1.254	^



Creating Data Files for Control Charts

The following three methods are for creating data files for control charts (time plots):

1. Include a file creation routine in your measurement program.
2. Use BSDM's file creation capabilities.
3. Write a program to create data files from existing measurement data files.

The first method is the most effective if you're measuring many wafers, or if you're measuring wafers that have only a few test chips.

The second method requires keyboard data entry, the EDIT function, or one of the other BSDM data entry functions. This method may be a little slow, but it lets you use data from functions such as STATS.

The third method requires a program for creating data files from existing measurement data files. If this is done, however, various items such as the file name of each measurement data file and the number of variables must be standardized. Figure 7-5, starting on the next page, provides an example of this third method.

This sample program creates a single data file from 100 existing measurement data files originally created by Wsave_data or a similar subprogram. The measurement data files are sequentially numbered from WAF_1 through WAF_100. The program calculates the means of the measurement data in all 100 files, and stores the results in a single data file, which can then be used to create a control chart.

```
10   !
20   !  Sample Program
30   !    Requirement: NONE
40   !
50   OPTION BASE 1
60   DIM T$[80],Vn$(50)[10],Sn$(20)[10],Sc(20)
70   INTEGER Waf_num,Start_num,End_num,Variable
80   !
90   File_head$="WAF__"
100  Start_num=1
110  End_num=100
120  !
130  ASSIGN @File TO File_head$&VAL$(Start_num)
140  ENTER @File,1;T$,No,Nv,Vn$(*),Ns,Sn$(*),Sc(*)
150  ASSIGN @File TO *
160  !
170  ALLOCATE Waf_data(1:Nv,1:No),Time_data(1:Nv,Start_num:End_num),X(1:Nv)
180  !
190  FOR Waf_num=Start_num TO End_num
200    !
210    ASSIGN @File TO File_head$&VAL$(Waf_num)
220    ENTER @File,2
230    ENTER @File;Waf_data(*)
240    ASSIGN @File TO *
250    !
260    MAT X= RSUM(Waf_data)
270    MAT Y= X/(No)
280    !
290    FOR Variable=1 TO Nv
300      Time_data(Variable,Waf_num)=X(Variable)
310    NEXT Variable
320    !
330  NEXT Waf_num
340  !
350  T$=" Wafer Number: "&VAL$(Start_num)&" through "&VAL$(End_num)
360  Nt=End_num-Start_num+1
370  !
```

Figure 7-5. Sample Program: Creating a Data File for Control Charts

```
380  CREATE BDAT "WAF_TIME",((8*Nt*Nv) DIV 1280)+2,1280
390  ASSIGN @File TO "WAF_TIME"
400  OUTPUT @File,1;T$,Nt,Vn,Vn$(*),Ns,Sn$(*),Sc(*)
410  OUTPUT @File,2
420  OUTPUT @File;Time_data(*)
430  ASSIGN @File TO *
440  !
450  END
```

Sample Program: Creating a Data File for Control & Charts (Continued)

Lines 90 to 130: Set the first part of the file name (File_head$) to WAF_, the starting number for the numeric part (Start_num) of the file name to 1, and the last file number (End_num) to 100. They also obtain the number of data items for each variable (No), the number of variables (Nv), etc., from the header part of measurement data file WAF_1.

Lines 190 to 330: This loop reads in the measurement data from each file and calculates the mean of the data.

Lines 210 to 240: Read in data from the specified data file and store the data in a two dimensional numeric array named Waf_data.

Lines 260 to 270: Use the MAT statement to calculate the mean of each variable.

Lines 290 to 310: Assign the calculated mean data from a one dimensional array (X) to a two dimensional array (Time_data).

Line 350: Specifies the title of the data file for the control chart.

Line 360: Calculates the number of data items per variable in accordance with the number of the measurement data files.

Lines 380 to 430: Store the calculated mean data (Time_data) into the data file as WAF_TIME.

Using User-Defined Transformations

BSDM's TRANSF. function allows the use of user-defined transformations, as described in Appendix B. This function makes it easy to process measurement data because the data can be freely transformed using user-created subprograms.

For example, the following subprogram shows how the data of variable 1 can be transformed to a missing value (-9999999.99999) if its value is equal to or greater than 1.5. Missing data is not displayed on graphs such as histograms or wafer maps, and is disregarded during statistics and calculations. Therefore, if a missing value is assigned to any data that is meaningless, such as when a probing error occurs or a defective test device is measured, data analysis can still be performed correctly.

```
10   SUB Function(D(*),Z,I)
20   !
30   ! This function sets a missing value.
40   !
50   IF D(1,I)>=1.5 THEN D(Z,I)=-9999999.99999
60   IF D(1,I)<1.5 THEN D(Z,I)=D(1,I)
70   SUBEND
```

The first subscript (1 or Z) of array D represents a variable number in this program.

8

HP IMA Operation

The HP 4062C/UX/PC can be optionally equipped with Interactive Measurement and Analysis (HP IMA) software. HP IMA offers easy systemization and a wide range of applications. The HP IMA softpanels provide you with an interactive interface to the DC Subsystem (DCS), thus eliminating the need to program. Complete setup and analysis requires just four softpanels.

This chapter describes the following information:

- How to start HP IMA with an HP 4062C/UX/PC.
- How to start and use SWM_PANEL.
- How to program using the Analysis Instruction Set (AIS) of HP IMA with the Test Instruction Set (TIS) of the HP 4062C/UX/PC.

Note

This chapter assumes that your HP 4062C/UX/PC is equipped with the HP IMA support option and that the HP IMA software is installed. If the HP IMA software is not installed, refer to the *HP 4062C/UX/PC Installation Manual* to install the HP IMA software.

How to Start HP IMA with an HP 4062C/UX/PC

To start the HP IMA with an HP 4062C/UX/PC, perform the following procedure:

1. Load the START_IMA program.

   a. For the HP 4062UX:

      `LOAD "/usr/pcs/ima/START_IMA"` [Return]

   b. For the HP 4062C/PC with the recommended directory structure (see Figure 1-5 or Figure 1-6 in this manual for directory structure information):

      `LOAD "/PCS/IMA/START_IMA"` [Return] *for HP 4062C/PC*
      `LOAD "\PCS\IMA\START_IMA"` [Return] *for HP 4062PC*

   c. For the HP 4062C/PC with flexible disks:

      Insert IMA System Disk (1) into the flexible disk drive.

      `LOAD "START_IMA"` [Return]

   Select the **RUN** softkey.

2. The following Selection Menu page is displayed:

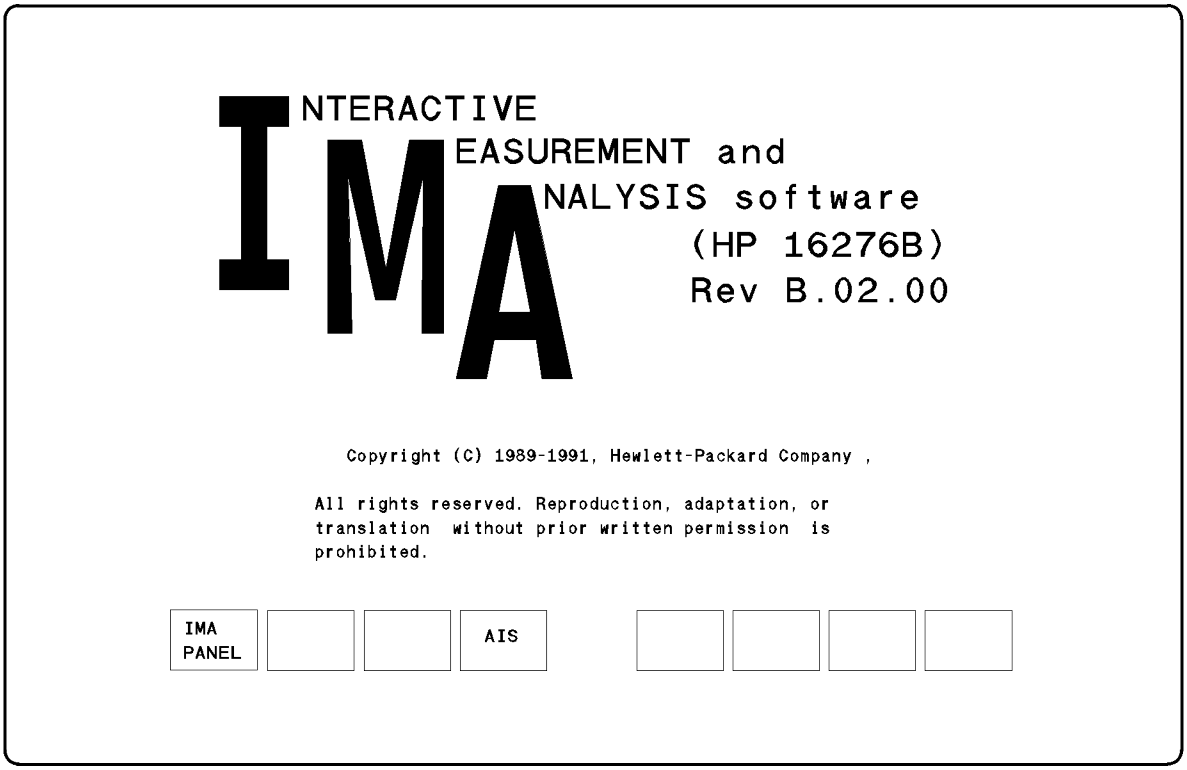


Figure 8-1. HP IMA Selection Menu Page

Select the `IMA PANEL` or `AIS` softkey.

3. The following message is displayed:

   `Start up IMA with 4142B ?  (Y/N)`

   If you have a DCS and want to control it, select the `Yes` softkey.

   If you do not have a DCS or do not want to control it, select the `No` softkey.

4. The START program begins, and the HP IMA moves into the desired environment.

   For details on using the HP IMA software, refer to the *HP IMA Operating and Programming Manual* and the *HP IMA Reference Manual*.

SWM Panel

You can interactively control the Switching Matrix Subsystem (SWM) through the SWM panel, without having to program.

Open the SWM panel from the HP IMA softpanel or the measurement program.

How to Open the SWM Panel from the HP IMA Softpanel

You can open the SWM panel from the UNIT DEFINITION, SOURCE SET UP, DISPLAY MODE SET UP, or GRAPHICS & ANALYSIS page of the HP IMA softpanel.

1. Select the `IMA PANEL` softkey on the Selection Menu page to open the softpanel.

   The CONFIGURATION page is displayed.

2. If you want to change or set the MSI (USER), PRINTER, or PLOTTER, type in the address.

   Select the `Continue` softkey. The MENU page is displayed.

3. Select the `UNIT DEF`, `SOURCE SET UP`, `DISP SET UP`, or `GRAPH & ANALYSIS` softkey on the MENU page.

4. Select the `more 1/2` softkey to display the following softkey labels:

AUX	CONFIG	HELP	PRINT/ PLOT	FILE	SWM PANEL	EXIT PANEL	more 2/2

5. Select the `SWM PANEL` softkey to open the SWM panel. The following SWM panel is displayed:

```
             ****    SWM PANEL    ****
                                             Switching Matrix Status
                                             CONNECTED   OPEN   NOT UPDATED

PORT ID   | UNIT ID    | V NAME | I NAME | DUT PINS                          |< >
GNDU      | GNDU       | GND    | [----] |                                   |
SMU1      | SMU1(HP)   | V1     | I1     |                                   |
SMU2      | SMU2(MP)   | V2     | I2     |                                   |
SMU3      | SMU3(MP)   | V3     | I3     |                                   |
SMU4      | SMU4(HP)   | V4     | I4     |                                   |
AUX1      | VSU1       | VS1    | [----] |                                   |
AUX2      | VSU2       | VS2    | [----] |                                   |
AUX3      | VMU1       | VM1    | [----] |                                   |
AUX4      | VMU2       | VM2    | [----] |                                   |
GSMU      | SMU1G(HP)  | [----] | [----] |                                   |
GCMU      | [----]     | [----] | [----] |                                   |



Enter pin number(s)

                                                   User 1          Running
CONNECT  OPEN     UPDATE                                           EXIT SWM
                  DISPLAY                                          PANEL
```

Figure 8-2. SWM Panel Example

How to Open the SWM Panel from a Measurement Program

To open the SWM Panel from a measurement program, use the SWM_PANEL subprogram. Be sure to link SWM_PANEL before you execute the measurement program. To link SWM_PANEL, perform the following procedure:

- For the HP 4062UX:

  `LOADSUB ALL FROM "/usr/pcs/lib/SWM_PANEL"` (Return)

- For the HP 4062C/PC with the recommended directory structure (see Figure 1-5 or Figure 1-6 in this manual for directory structure information):

  `LOADSUB ALL FROM "/PCS/LIB/SWM_PANEL"` (Return) *for HP 4062C/PC*
  `LOADSUB ALL FROM "\PCS\LIB\SWM_PANEL"` (Return) *for HP 4062PC*

- For the HP 4062C/PC with flexible disks:

  Insert the SYSTEM SOFTWARE (4) disk into the disk drive;
  insert the SYSTEM SOFTWARE (2) disk into the disk drive.

  `LOADSUB ALL FROM "SWM_PANEL"`

Figure 8-9 is an example program using the SWM_PANEL subprogram.

How to Operate the SWM Panel

- PORT ID

  Lists the names of all the SWM ports as follows:

  GNDU
  SMU1
  SMU2
  SMU3
  SMU4
  AUX1
  AUX2
  AUX3
  AUX4
  GSMU
  GCMU

- UNIT ID

  Identifies the units connected to the port of the SWM as follows:

Table 8-1. Definition for UNIT ID

Unit ID	Definition	Related PORT ID
GNDU	HP 4142B GNDU	GNDU
SMU*n*(MP)	HP 41421B SMU	SMU1, SMU2, SMU3, SMU4
SMU*n*(HP)	HP 41420A SMU	SMU1, SMU2, SMU3, SMU4
SMU*n*G(MP)	HP 41421B SMU	GSMU
SMU*n*G(HP)	HP 41420A SMU	GSMU
VSU*n*	HP 41424A VS/VMU	AUX1, AUX2, AUX3, AUX4
VMU*n*	HP 41424A VS/VMU	AUX1, AUX2, AUX3, AUX4
AFU	HP 41425A AFU	—
CMU	HP 4280A CMU	GCMU
CMH	HP 4280A CMU (High)	AUX3
CML	HP 4280A CMU (Low)	AUX4
CMU84	HP 4284A CMU84	GCMU
CMU84H	HP 4284A CMU84 (High)	AUX3
CMU84L	HP 4284A CMU84 (Low)	AUX4

- V NAME, I NAME

  Identifies the units that are used for setting up measurements and displaying the measurement results on the HP IMA pages. The units are defined in the UNIT DEFINITION page.

- DUT PINS

  Specifies the Device Under Test (DUT) pins connected to the port of the SWM.

  Refer to "Connecting Measurement Pins to Ports" and "Disconnecting Measurement Pins from Ports" in this chapter to connect or disconnect the DUT pins.

- < >

  Displays "<" or ">," or both, when the DUT PINS field cannot display all the pins connected to the port.

  The "<" indicates that the left part of the field is hidden. When the "<" is displayed, the SCROLL LEFT softkey is displayed. To display the hidden pins, scroll the field using the SCROLL LEFT softkey.

  The ">" indicates that the left part of the field is hidden. When the ">" is displayed, the SCROLL RIGHT softkey is displayed. To display the hidden pins, scroll the field using the SCROLL RIGHT softkey.

- Switching Matrix Status

  CONNECTED
  Indicates that the SWM panel setting matches the actual SWM setting.
  OPEN
  Indicates that all the pin boards are disconnected.
  NOT UPDATED
  Indicates that the SWM panel setting does not match the actual SWM setting.

- Softkeys:

  CONNECT

  Disconnects all the pin boards in the SWM, then connects the pin boards as they are set on this page. The Switching Matrix Status changes to CONNECTED.

  OPEN

  Disconnects all the pin boards in the SWM. The Switching Matrix Status changes to OPEN.

  UPDATE DISPLAY

  Shows the current setup of the SWM.

  SCROLL LEFT, SCROLL RIGHT

  Appears when the DUT PINS field cannot display all the pins connected to the port. To display the hidden pins, scroll the field using these softkeys.

  EXIT SWM PANEL

  Exits the SWM panel.

To move the field pointer, use ▲, ▼, ◀, ▶, or Tab.

To print a display to the printer, use Dump Graphics or Dump Alpha.

Connecting Measurement Pins to Ports

Position the field pointer in the `DUT PINS` field next to the desired port, and type in the pin numbers you wish to connect. Use a "`,`" (comma) or " " (blank space) to delimit the pins.

Press (Return). The `Switching Matrix Status` field is set to `NOT UPDATED`.

When you set all the pins you wish to connect, select the `CONNECT` softkey. The `Switching Matrix Status` field is set to `CONNECTED`.

Disconnecting Measurement Pins from Ports

Move the field pointer to the pin number you wish to disconnect. The pins connected to the port are displayed at the message line. Delete the pin number you wish to disconnect using (Delete) ((DEL CHR)), (Clear line), (Shift) + (Clear line), or ( ) (space bar) and press (Return). The `Switching Matrix Status` field is set to `NOT UPDATED`.

To disconnect all the pins from the ports, press the `OPEN` softkey. The `Switching Matrix Status` field is set to `OPEN`.

Error Messages

The following error messages may be displayed when you select the `CONNECT` softkey:

- `Duplicate port connection for pin` <*n*>

  A pin is connected to more than one port.

- `Illegal pin specification` <*n*>

  An illegal pin, such as -5, is specified.

- `No existing pin board` <*n*>

  A specified pin board is not installed in the SWM. Check the pin board configuration.

The following error message may be displayed when you press (Return):

- `Exceeding DUT pin specifications have been truncated.`

  The DUT PINS setting expression exceeds 160 characters.

The following error messages may be displayed when you select the `UPDATE DISPLAY` softkey:

- `Can't get correct setup. Too many pins are connected to the port.`

  When you select the `UPDATE DISPLAY` softkey, the current DUT PINS setting expression exceeds 160 characters.

- `Can't get correct setup. Illegal pin board relay pattern found.`

  When you select the `UPDATE DISPLAY` softkey, an illegal pin board relay pattern is found.

  Either select `OPEN` to disconnect the illegal pin board relay pattern, or use Page 3 or 4 of the HP 4062C/UX/PC Virtual Front Panel (VFP) to set the pin board relay pattern.

How to program using the AIS of HP IMA with TIS

You can create programs using the AIS commands with subprograms of the HP 4062C/UX/PC, such as TIS, PARA, and so on.

The following paragraphs provide sample programs using AIS and TIS commands.

Be sure to link AIS & TIS before you execute a measurement program. To link AIS and TIS, select the `Link AIS & TIS` softkey from the USER 3 softkeys.

Delete (unlink) AIS & TIS before you store a measurement program to save memory space. To delete AIS and TIS, select the `Delete AIS & TIS` softkey from the USER 3 softkeys.

Note

The AIS Measure and Panel instructions indirectly call certain TIS commands or affect certain TIS settings. For best results, don't use the following TIS commands with AIS Measure and Panel instructions. Refer to "AIS Measure and Panel Instructions" in this chapter for details.

Force_i
Force_v
Force_meas
Set_smu
Set_vm
Set_iv
Set_piv
Set_pbias
Set_sync
Ch_sw_on
Ch_sw_off
Disable_port
Set_asearch
Set_bsearch
Set_lsearch

Sample Program 1

Figure 8-3 is an example program for measuring and displaying the collector characteristics of a bipolar transistor.

Figure 8-4 shows the measurement circuit used.

This program uses a page setting file created with the HP IMA softpanels. Figure 8-5, Figure 8-6, and Figure 8-7 show the setups needed in the HP IMA softpanels. Open the softpanels and make the changes needed for the file. Use the FILE page to save the page settings in a file called P_TR.

Figure 8-8 shows the measurement results.

```
10    !
20    ! Sample Program
30    !   Requirements: TIS, AIS
40    !
50    OPTION BASE 1
60    INTEGER Collector,Base,Emitter
70    !
80    Init_ais                        ⇐ AIS
90    Init_system                     ⇐ TIS
100   !
110   Collector=40
120   Base=42
130   Emitter=44
140   Connect(FNSmu(1),Collector)     ⇐ TIS
150   Connect(FNSmu(2),Base)          ⇐ TIS
160   Connect(FNGnd,Emitter)          ⇐ TIS
170   !
180   Get_f("P_TR")                   ⇐ AIS
190   Measure                         ⇐ AIS
200   Analysis                        ⇐ AIS
210   !
220   Connect                         ⇐ TIS
230   END
230   !
```

Figure 8-3. Sample Program 1: Collector Characteristics Measurement

line 80	Sets the parameters of the HP IMA software to the initial condition and sets the DCS to the idle state.
line 90	Initializes the HP 4062C/UX/PC system.
lines 140 through 160	Connect the specified pins and measurement ports.

line 180 Receives the file of the softpanel settings for measurement setup information.

line 190 Executes the measurements.

line 200 Opens the GRAPHICS & ANALYSIS page.

line 220 Disconnects all the pins and measurement ports.

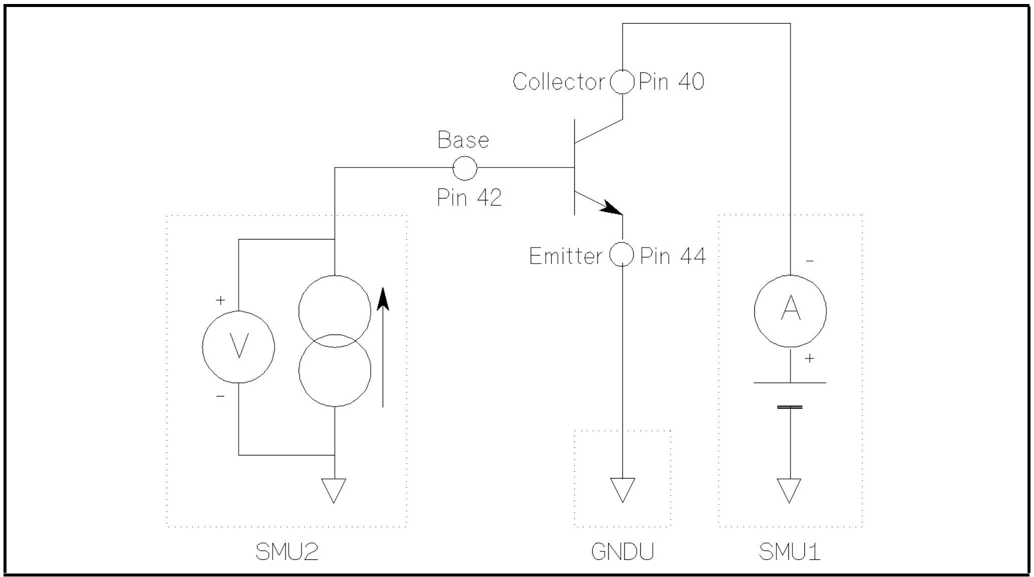


Figure 8-4. Collector Characteristics Measurement Circuit

```
                **** UNIT DEFINITION ****                    | 5 Apr 1990  |
                                                             |             |
| SLOT NO | UNIT ID  | V NAME  | I NAME  | MODE  | FUNCTION | | | HELP     | |
| -----   | GNDU     | Ve      | [----]  |[ V ]  | [ COM ]  | | | PRINT/PLOT | |
|   2     | SMU1(HP)| Vc      | Ic      |  V    |  VAR1    | | | FILE     | |
|   3     | SMU2(MP)| Vb      | Ib      |  I    |  VAR2    | |*MENU        |
|   4     | SMU3(MP)|         |         |       |          | |             |
|   6     | SMU4(HP)|         |         |       |          | |             |
|   7     | VSU1     |         | [----]  |[ V ]  |          | |             |
|   7     | VSU2     |         | [----]  |[ V ]  |          | |             |
|   7     | VMU1     |         | [----]  |       |  [----]  | |             |
                                                             |             |
*USER FUNCTION                                               |             |
|NO | NAME   (UNIT) = EXPRESSION                            | |*OPTION      |
| 1 |        (    ) =                                       | | PHYS CONST  |
|   |                                                       | | EXTN USR FN |
| 2 |        (    ) =                                       | |             |
|   |                                                       | |             |
```

Figure 8-5. UNIT DEFINITION Page for Collector Characteristics Measurement

```
                **** SOURCE SET UP ****                          |  5 Apr 1990   |
 *VARIABLE                                                       |               |
|           | [ VAR1 ] | [ VAR2 ] |                              | | HELP      | |
| NAME      | [Vc]     | [Ib]     |                              | | PRINT/PLOT| |
| SWEEP MODE| SINGLE   | [SINGLE] |                              | | FILE      | |
| LIN / LOG | LINEAR   | [LINEAR] |                              |*MENU          |
| START     | 0.00000 V| 3.00000uA|                              |  SINGLE       |
| STOP      | 1.00000 V| 9.00000uA|                              |  DOUBLE       |
| STEP      | 20.0000mV| 3.00000uA|                              |               |
| NO OF STEP|    51    |    3     |                              |               |
| COMPLIANCE| 100.000mA| 1.00000 V|                              |               |
| POWER COMP| ---------|  [----]  |                              |               |
                                                                 |               |
 *CONSTANT                                                       |*OPTION        |
| NAME      |  [----]  |  [----]  |  [----]  |  [----]  |        | EXTN CONST    |
| MODE      |  [----]  |  [----]  |  [----]  |  [----]  |        | PULSE         |
| VALUE     |  [----]  |  [----]  |  [----]  |  [----]  |        | TIME DOMAIN   |
| COMPLIANCE|  [----]  |  [----]  |  [----]  |  [----]  |        |               |
```

Figure 8-6. SOURCE SET UP Page for Collector Characteristics Measurement

```
              **** DISPLAY MODE SET UP ****                      |  5 Apr 1990   |
         *MODE SELECT                                            |               |
           | <GRAPHICS> |  LIST    |                             | | HELP      | |
 -----------------------------------------------                 | | PRINT/PLOT| |
 *GRAPHICS                                                       | | FILE      | |
| AXIS      |    X     |    Y1    |    Y2    |                   |*MENU          |
| NAME      | Vc       | Ic       |          |                   |               |
| SCALE     |  LINEAR  |  LINEAR  |          |                   |               |
| MIN       | 0.00000 V| 0.00000 A|          |                   |               |
| MAX       | 1.00000 V| 2.00000mA|          |                   |               |
| STEP      | 100.000mV| 500.000uA|          |                   |               |
                                                                 |               |
                                                                 |               |
                                                                 |*OPTION        |
                                                                 | DISP FUNC     |
                                                                 |               |
                                                                 |               |
                                                                 |               |
```

Figure 8-7.
DISPLAY MODE SET UP Page for Collector Characteristics Measurement

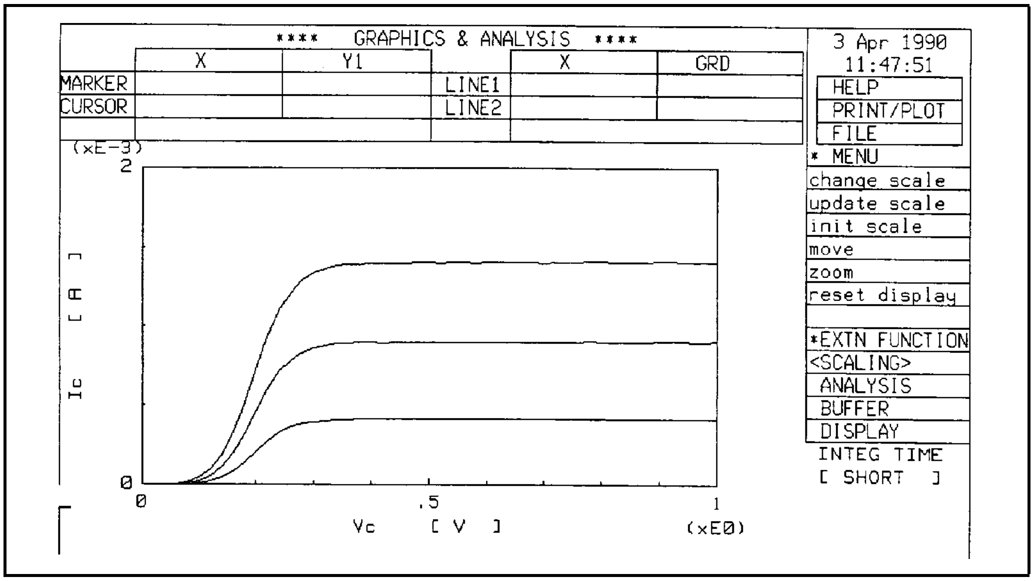


Figure 8-8. Collector Characteristics Example

Sample Program 2

Figure 8-9 is also an example program that measures and displays the collector characteristics of a bipolar transistor. This program opens the SWM panel during program execution.

Figure 8-4 shows the measurement circuit used.

The program uses a page setting file created with the HP IMA softpanels. Figure 8-5, Figure 8-6, and Figure 8-7 show the setups needed in the HP IMA softpanels. Open the softpanels and make the changes needed for the file. Use the FILE page to save the page settings in a file named P_TR.

Figure 8-8 shows the measurement results.

```
10    !
20    ! Sample Program
30    !   Requirements: TIS, AIS, SWM_PANEL
40    !
50    OPTION BASE 1
60    !
70    Init_ais                            ⇐ AIS
80    Init_system                         ⇐ TIS
90    !
100   Swm_panel                           ⇐ SWM_PANEL
110   !
120   Get_f("P_TR")                       ⇐ AIS
130   Measure                             ⇐ AIS
140   Analysis                            ⇐ AIS
150   !
160   Connect                             ⇐ TIS
170   END
180   !
```

Figure 8-9. Sample Program 2: Collector Characteristics Measurement Using SWM Panel

line 100	Calls the SWM Panel. To exit from the SWM Panel, select the `EXIT SWM PANEL` softkey.

Sample Program 3

Figure 8-10 is an example program for measuring the threshold voltage (Vth) of a MOSFET.

Figure 8-11 shows the measurement circuit used.

This program uses a page setting file created with the HP IMA softpanels. Figure 8-12, Figure 8-13, and Figure 8-14 show the setups needed in the IMA softpanels. Open the softpanels and make the changes needed for the file. Use the FILE page to save the page settings in a file named P_VTH.

Figure 8-15 shows the measurement results.

```
10    !
20    ! Sample Program
30    !   Requirements: AIS, TIS
40    !
50    OPTION BASE 1
60    INTEGER Drain,Source,Gate,Substrate
70    DIM D_ana(14)
80    !
90    Init_ais                                ⇐ AIS
100   Init_system                             ⇐ TIS
110   !
120   Source=24
130   Gate=26
140   Drain=28
150   Substrate=22
160   Connect(FNGnd,Source)                   ⇐ TIS
170   Connect(FNSmu(1),Gate)                  ⇐ TIS
180   Connect(FNSmu(2),Drain)                 ⇐ TIS
190   Connect(FNSmu(3),Substrate)             ⇐ TIS
200   !
210   Get_f("P_VTH")                          ⇐ AIS
220   Measure                                 ⇐ AIS
230   Auto_scale                              ⇐ AIS
240   Disp_graph(0,"Id - Vgs")                ⇐ AIS
250   Select_curve(1)                         ⇐ AIS
260   Search_data(2,SQRT(1.E-6),Vg,Y)         ⇐ AIS
270   !
280   Loop_p=0
290   Grad1=0
300   Vth=99999.9999
310   Step_v=.05
320   LOOP
330     Draw_regress(1,Vg+Step_v*Loop_p,3)    ⇐ AIS
340     Get_ad(D_ana(*))                      ⇐ AIS
350   EXIT IF D_ana(7)<Grad1
360     Grad1=D_ana(7)
370     Vth=D_ana(5)
380     Loop_p=Loop_p+1
390   END LOOP
```

```
400   !
410   Set_graph(1,1)                  ⇐ AIS
420   Disp_graph                      ⇐ AIS
430   DISP "Vth=";Vth
440   !
450   Connect                         ⇐ TIS
460   END
470   !
```

Figure 8-10. Sample Program 3: Vth Measurement

line 230	Automatically selects the optimum scale.
line 240	Displays a graph on the screen.
line 250	Selects the measurement curve that is drawn for the y1 axis.
line 260	Positions the marker at the Id=1 μA on the measurement curve.
Lines 280 through 390	Searches for the threshold voltage on the X axis intersection of the regression line when the slope becomes the maximum value.
line 410 and 420	Display the measurement curve, marker, and regression line.
line 430	Displays the threshold voltage.

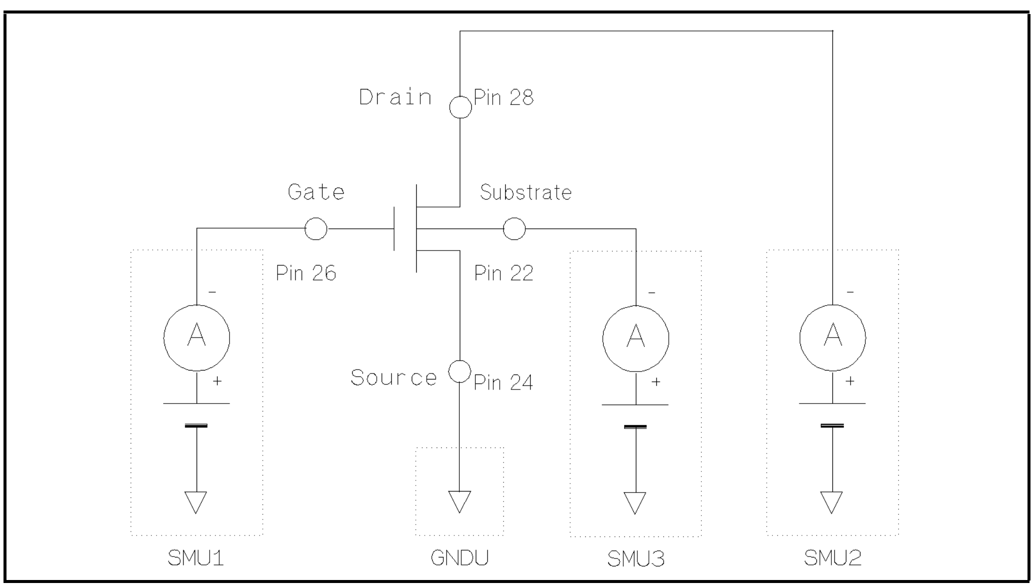


Figure 8-11. Vth Measurement Circuit

```
              ****   UNIT DEFINITION   ****                 |  5 Apr 1990    |
                                                            |                |
 | SLOT NO  | UNIT ID  | V NAME   | I NAME   | MODE  | FUNCTION |  | | HELP       | |
 | -----    |  GNDU    |  Vs      |  [----]  |[ V ]  | [ COM ]  |  | | PRINT/PLOT | |
 |   2      |  SMU1(HP)|  Vg      |  Ig      |  V    |  VAR1    |  | | FILE       | |
 |   3      |  SMU2(MP)|  Vd      |  Id      |  V    |  CONST   |  |*MENU          |
 |   4      |  SMU3(MP)|  Vsub    |  Isub    |  V    |  CONST   |  |               |
 |   6      |  SMU4(HP)|          |          |       |          |  |               |
 |   7      |  VSU1    |          |  [----]  |[ V ]  |          |  |               |
 |   7      |  VSU2    |          |  [----]  |[ V ]  |          |  |               |
 |   7      |  VMU1    |          |  [----]  |       |  [----]  |  |               |
                                                            |                |
 *USER FUNCTION                                             |                |
 |NO | NAME   (UNIT) = EXPRESSION                        |  |*OPTION         |
 | 1 |SQRT_I  ( A  ) = SQRT(ABS(Id))                     |  | PHYS CONST     |
 |   |                                                   |  | EXTN USR FN    |
 | 2 |        (    ) =                                   |  |                |
 |   |                                                   |  |                |
```

Figure 8-12. UNIT DEFINITION Page for Vth Measurement

```
                ****   SOURCE SET UP   ****                 |  5 Apr 1990    |
  *VARIABLE                                                 |                |
 |           |  [ VAR1 ] |  [ VAR2 ] |                      | | HELP       | |
 |  NAME     | [Vg]      |   [----]  |                      | | PRINT/PLOT | |
 | SWEEP MODE|  SINGLE   |   [----]  |                      | | FILE       | |
 | LIN / LOG |  LINEAR   |   [----]  |                      |*MENU           |
 |  START    | 0.00000 V |   [----]  |                      |  SINGLE        |
 |  STOP     | 10.0000 V |   [----]  |                      |  DOUBLE        |
 |  STEP     | 200.000mV |   [----]  |                      |                |
 | NO OF STEP|    51     |   [----]  |                      |                |
 | COMPLIANCE| 100.000uA |   [----]  |                      |                |
 | POWER COMP| --------- |   [----]  |                      |                |
                                                            |                |
  *CONSTANT                                                 |*OPTION         |
 |  NAME     | [Vd]      | [Vsub]    |   [----]  |  [----]  |  | EXTN CONST  |
 |  MODE     |   [ V ]   |   [ V ]   |   [----]  |  [----]  |  | PULSE       |
 |  VALUE    | 5.00000 V | 0.00000 V |   [----]  |  [----]  |  | TIME DOMAIN |
 | COMPLIANCE| 100.000mA | 100.000uA |   [----]  |  [----]  |  |             |
```

Figure 8-13. SOURCE SET UP Page for Vth Measurement

```
          ****  DISPLAY MODE SET UP  ****                |  5 Apr 1990  |
     *MODE SELECT                                        |              |
       | <GRAPHICS> |   LIST    |                        | | HELP      | |
----------------------------------------------           | | PRINT/PLOT | |
*GRAPHICS                                                | | FILE      | |
| AXIS      |     X      |    Y1     |    Y2     |       |*MENU         |
| NAME      |   Vg       |  SQRT_I   |           |       |              |
| SCALE     |   LINEAR   |  LINEAR   |           |       |              |
| MIN       | 0.00000 V  | 0.00000 A |           |       |              |
| MAX       | 10.0000 V  | 50.0000mA |           |       |              |
| STEP      | 2.00000 V  | 10.0000mA |           |       |              |
                                                         |              |
                                                         |              |
                                                         |*OPTION       |
                                                         | DISP FUNC    |
                                                         |              |
                                                         |              |
                                                         |              |
```

Figure 8-14. DISPLAY MODE SET UP Page for Vth Measurement

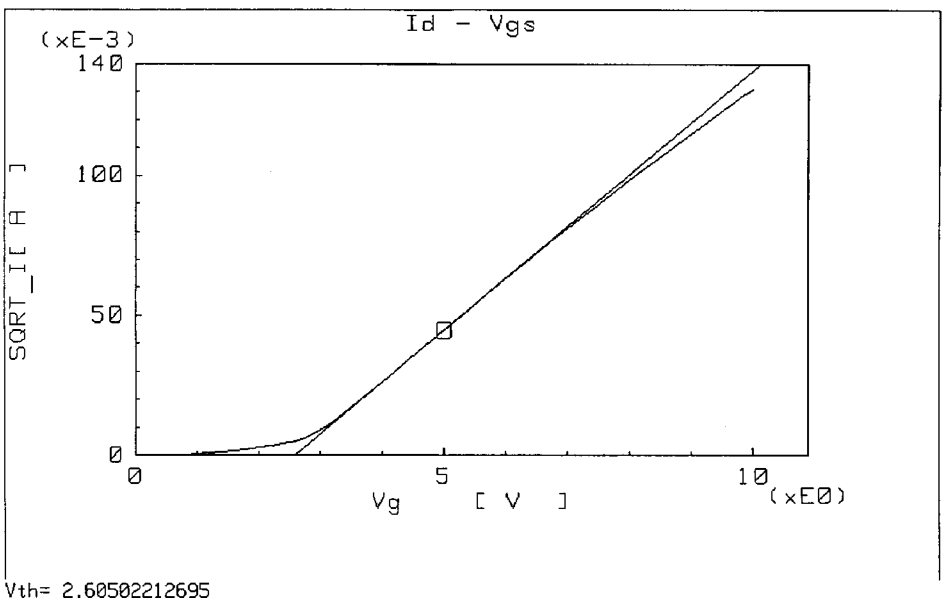


Figure 8-15. Vth Example

AIS Measure and Panel Instructions

The AIS Measure and Panel instructions internally execute some or all of the following tasks:

1. Uses TIS Set_smu (Short, Medium, or Long) to set Measurement Integration Time.
2. Uses TIS Set_vm (differential or normal) to set VM mode.
3. Uses TIS Ch_sw_off to set the Channel Switch of the NOT USE unit(s) to OFF.
4. Uses TIS Force_v, Force_i, Set_iv, Set_piv, or Set_pbias to set up Sweep, Pulse, and Constant value for SMU and VS.
5. Uses TIS Measure_v, Measure_i, Measure_p, Rsweep_iv, or Rsweep_miv to trigger the DCS.
6. Uses TIS Ch_sw_on to set the Channel Switch of the NOT USE unit(s) to ON.
7. Uses TIS Force_v to set all SMUs and VSs to idle state.
8. Uses TIS Set_vm to set the VM mode to normal.
9. Uses TIS Disable_port to clear the SMU and VS pulse mode.

A

Error Messages

Introduction

If your HP 4062C/UX/PC detects a hardware failure or an illegal operation, an error message or error code, often both, appears on the system controller's display. Errors are divided into two basic categories: system controller-related and HP 4062C/UX/PC-related, as explained here.

- System Controller Errors

  If a system controller error occurs, a BASIC or BASIC/UX language system error code is displayed, as in the following example:

  ```
  Error 7 in 1250  Undefined function or sub
  ```

  If a system controller hardware failure occurs, a SYSTEM ERROR message is displayed. Refer to the *BASIC* or *BASIC/UX Language Reference Manual* for details on system errors.

- HP 4062C/UX/PC Errors

  If an HP 4062C/UX/PC error occurs, an error message is displayed, as in the following example:

  ```
  TIS ERROR 20 Device not present.
  ERROR 449 IN 10
  ```

  Error message prefixes give the name of the program or subprogram in which the error occurred. In the example above, the error occurred in TIS. In some cases, only an error code is displayed.

This appendix lists all the HP 4062C/UX/PC error messages and includes a partial listing of system controller error codes. For details on system controller error codes, refer to the *BASIC* or *BASIC/UX Language Reference Manual*.

Error Messages Listings

This appendix lists the following HP 4062C/UX/PC system software file error messages:

START, TIS, PGMLIB, VFP, PPG, and DIAG.

Note

If an error occurs when using files other than those listed above, an error code is displayed. If an error occurs when using PARA, however, a TIS error message is displayed.

START Errors

This section lists errors related to your HP 4062C/UX/PC's START program.

- `START ERROR 0 Not authorized to use the software.`
- `START ERROR 0 Not authorized to use the software. No CODEWORD file found.`

  The ID Module is not connected—or not connected properly—to your system controller, the CODEWORD file does not exist, or the codeword in the CODEWORD file is incorrect.

- `START ERROR 1 SWM/SWC failed power-on test.`
- `START ERROR 2 No pin boards installed in SWM.`
- `START ERROR 3 SWM down. SRQ asserted.`

  A hardware failure occurred during the SWC/SWM power-on self test. Check for one of the following possible causes:

  - ☐ A momentary power loss may have occurred.
  - ☐ The control cable interconnecting the SWM and SWC is disconnected, making poor contact, or defective.
  - ☐ The SWM control bus cable is disconnected, making poor contact, or defective.

  After checking the above, rerun the START program. If the same error code is displayed, contact your system administrator or nearest HP Service Office.

- `START ERROR 4 SWM syntax error. SRQ asserted.`

  The SWC received an illegal program code. Rerun the START program.

- `START ERROR 5 SWM pin board malfunction. SRQ asserted.`

  Pin board failure occurred during the SWC/SWM power-on self test.

- `START ERROR 6 Switching matrix is open.`

  Enable the SWM by installing the Test Fixture Adapter on the SWM (closes the FIXTURE CLOSED DETECT switch) or by pressing and holding the SWM's WAFER PROBER SENSE switch, and rerun the START program.

- `START ERROR 7 This version of switching matrix controller not supported: HP 4084A REV.` *xx*`.`*xx*

  HP 4062C/UX/PC supports only the HP 4084B (Rev. 2.0 or later) SWC.

- `START ERROR 10 DCS failed power-on test.`

  A hardware failure occurred during DCS self-test.

- `START ERROR 11 DCS syntax error. SRQ asserted. : Error` *xxx*

  The DCS received an illegal program code. Rerun the START program. The *xxx* above is the DCS's error code. Refer to the HP 4142B's *Operation Manual*, for details on DCS error codes.

- `START ERROR 12 DCS not interlocked. SRQ asserted.`

  The interconnect cable assembly is disconnected, making poor contact, or defective. Check these possible causes and rerun the START program.

- START ERROR 13 DCS shutdown. SRQ asserted.

  DCS output is disabled because of a momentary power loss or because voltage or current in excess of an SMU's maximum current, voltage, or power was applied to an SMU. Rerun the START program.

- START ERROR 14 DCS calibration error. SRQ asserted. : Error *xxx* in slot *y*

  A hardware failure occurred during DCS calibration. The *xxx* above is the DCS's error code and *y* is the slot number of the failed module. For example, if the module in slot 1 is not functioning properly, the following error message is displayed.

  ```
  START ERROR 14 DCS calibration error.  SRQ asserted.  : Error 420 in slot 1
  ```

  If this error occurs, contact your system administrator or nearest HP Service Office. For emergency repair, replace or remove the module in the slot indicated and rerun the START program.

- START ERROR 15 CMS syntax error. SRQ asserted.
- START ERROR 16 CMS illegally programmed. SRQ asserted.
- START ERROR 17 CMS triggered too fast. SRQ asserted.

  Check your cabling configuration and BNC shorting cap connections, and rerun the START program.

- START ERROR 18 CMS sweep/bias error. SRQ asserted.

  The BNC shorting cap is not connected to the CMS's front panel REMOTE ON/OFF connector. Connect the BNC shorting cap and rerun the START program.

- START ERROR 19 CMH terminal improperly connected.
- START ERROR 19 CMH84 terminal improperly connected.
- START ERROR 20 CMH terminal connected to CML (AUX*xx*) port on SWM.
- START ERROR 20 CMH84 terminal connected to CML (AUX*xx*) port on SWM.
- START ERROR 20 CMH terminal connected to AUX*xx* port on SWM.
- START ERROR 20 CMH84 terminal connected to AUX*xx* port on SWM.
- START ERROR 21 CML terminal improperly connected.
- START ERROR 21 CML84 terminal improperly connected.
- START ERROR 22 CML cable connected to CMH(AUX3) port on SWM.
- START ERROR 22 CML84 terminal connected to CMH (AUX*xx*) port on SWM.
- START ERROR 22 CML terminal connected to AUX*xx* port on SWM.
- START ERROR 22 CML84 terminal connected to AUX*xx* port on SWM.

  The CML or CMH cable is connected to the wrong terminal. Check for proper connection between the CMS and SWM, and rerun the START program.

- START ERROR 23 CMS INT BIAS switch improperly set.

  The CMS's INT BIAS switch is set to the ±42 V MAX position. Set the switch to ±100 V MAX and rerun the START program.

- `START ERROR 24 CMS cable impedance incorrect.`

  CMH or CML cable impedance is either too high or too low. Use the cables furnished with the system and rerun the START program.

- `START ERROR 25 CMU84 SRQ. Error code` *xxx*`. Check the cabling configuration and rerun the pcsstart program. * START ERROR 26 Relays for AUX`*yy* `of port expander cannot be controlled.`

  The Port Expander relays can not be controlled because one of the Port Expander relay control boards is either missing or incorrectly installed. The *yy* above refers to the AUX relays controlled. Check the installation and rerun the START program.

- `START ERROR 51 HVU/HCU NOT supported (remove HVU/HCU).`

  This error is reported with a full screen warning message whenever you attempt to install either an HVU or an HCU into the HP 4062UX system. Shared memory space, which is essential to TIS operation, is intentionally destroyed to avoid HVU/HCU operation during TIS programming.

- `START ERROR 90 SYSCONFIG file not found; on-line mode is not available.`

  Since SYSCONFIG does not exist in "/usr/pcs/etc" directory, you can perform only the off-line mode operation.

- `START ERROR 91 The instruments are being used in another session.`

  Another session already locks the instruments. You can perform only the off-line mode operation until the session is stopped or changed to off-line mode.

- `START ERROR 92 HP-IB timeout is detected at address` *xxx*`.`

  An expected interrupt did not occur within the specified limits. Check for one of the following possible causes:

  - The HP-IB cables interconnecting the system controller and instruments were *not* connected, making poor contact, or defective, when the START program executed.
  - Instruments were *not* On when the START program executed.
  - HP-IB Interface was *not* functioning properly.

  After checking the above, rerun the START program. If the same error code is displayed, exit from BASIC/UX and HP-UX, then reload HP-UX and BASIC/UX and rerun the START program.

- `START ERROR 100 DUMCONFIG file (`*xxx*`) not found.`
- `START ERROR 101 Non ASCII character '`*xxx*`' in DUMCONFIG file.`
- `START ERROR 102 Error in DUMCONFIG: File incompletely terminated.`
- `START ERROR 110 Error in DUMCONFIG: Invalid pin description:`
- `START ERROR 120 Error in DUMCONFIG: Invalid DCS configuration description:`
- `START ERROR 121 Error in DUMCONFIG: Invalid slot number:`
- `START ERROR 122 Error in DUMCONFIG: HP 41420A can not be installed in DCS slot 1.`
- `START ERROR 123 Error in DUMCONFIG: HP 41420A requires slot X to be empty.`
- `START ERROR 124 Error in DUMCONFIG: Slot X is already occupied by an HP` 41420A."

- `START ERROR 125 Error in DUMCONFIG: Two or more units assigned in slot X.`
- `START ERROR 126 Error in DUMCONFIG: Unrecognized module` *xxxx* `.`
- `START ERROR 130 Error in DUMCONFIG: Invalid cabling description:`
- `START ERROR 131 Error in DUMCONFIG: Only Cmu(1) is attachable to CMH port:`
- `START ERROR 132 Error in DUMCONFIG: Only Cmu(2) is attachable to CML port.`
- `START ERROR 133 Error in DUMCONFIG: Invalid DCS/CMS unit address:`
- `START ERROR 134 Error in DUMCONFIG: Invalid SWM port address:`
- `START ERROR 135 Error in DUMCONFIG: Corresponding unit not installed:`
- `START ERROR 136 Error in DUMCONFIG: Multiple units are attached to SWM port X.`
- `START ERROR 137 Error in DUMCONFIG: SMU` *xxx* `has multiple cabling to SWM ports.`
- `START ERROR 138 Error in DUMCONFIG: VS` *xxx* `has multiple cabling to SWM ports.`
- `START ERROR 139 Error in DUMCONFIG: VM` *xxx* `has multiple cabling to SWM ports.`
- `START ERROR 140 Error in DUMCONFIG: Invalid CMS port connection:`

  The description of DUMCONFIG is not proper. Rerun the START program. If the same error code is displayed, contact your system administrator or nearest HP Service Office.

- `START ERROR 141 Error in DUMCONFIG: Invalid CMU84 port connection:` *xxx* `.`
- `START ERROR 142 Error in DUMCONFIG: CMU(`*xxx*`) has multiple cabling to SWM ports.`
- `START ERROR 143 Error in DUMCONFIG: CMU84(`*xxx*`) has multiple cabling to SWM ports.`

  The description of DUMCONFIG is not proper. The *xxx* above refers to the unit number. The X refers to a slot or port number. Rerun the pcsstart program. If the same error code is displayed, contact your system administrator or nearest HP Service Office.

- `START ERROR 201 Illegal command parameter ---` *xxx* `.`

  Rerun the START program. If the same error code is displayed, contact your system administrator or nearest HP Service Office.

- `START ERROR 202 Session` *xxx*`: Permission denied.`

  The session that is specified by environment variable PCS_SESSION_ID does not allow accessing. Rerun the START program. If the same error code is displayed, contact your system administrator or nearest HP Service Office.

- `START ERROR 203 Session` *xxx* `busy.`

  Another process is making measurements using TIS statements or locks the instruments.

- `START ERROR 300 PCS_SESSION_ID not defined.`
- `START ERROR 301 Session ID` *xxxx* `too long.`
- `START ERROR 310 Group 'pcs' not registered.`
- `START ERROR 320 Non ASCII character '`*xxx*`' in SYSCONFIG file.`
- `START ERROR 321 Invalid SYSCONFIG entry.`
- `START ERROR 322 SYSCONFIG file contains no effective description.`

- START ERROR 323 Error in SYSCONFIG: HP-IB select code must be identical.
- START ERROR 324 Error in SYSCONFIG: HP-IB address XXX not identical among components.
- START ERROR 325 Error in SYSCONFIG: Invalid HP-IB address *xxx*.
- START ERROR 326 Error in SYSCONFIG: Invalid select code *xxx*.
- START ERROR 327 Error in SYSCONFIG: *xxx* is not supported as SWM.
- START ERROR 327 Error in SYSCONFIG: *xxx* is not supported as SWC.
- START ERROR 327 Error in SYSCONFIG: *xxx* is not supported as DCS.
- START ERROR 327 Error in SYSCONFIG: *xxx* is not supported as CMS.
- START ERROR 330 Device file /dev/rmb/hpib*xx* not found.
- START ERROR 331 HP-IB interface card not on select code *xxx*.
- START ERROR 332 /dev/rmb/hpib*xx* is not an HP-IB device file.
- START ERROR 333 HP-IB device file /dev/rmb/hpib*xx* is not for select code *xx*.
- START ERROR 334 /dev/rmb/hpib*xx* is not a raw HP-IB device file.
- START ERROR 340 Test session is in bad state; No control terminal.
- START ERROR 341 Can not create session key file; directory /usr/pcs/sessions not found.
- START ERROR 350 Error on pcsstart invocation; *xxx*

  Check for one of the following possible causes:

  - The system software is not installed properly.
  - System files are destroyed.
  - Cluster node is not added properly.

  Contact your system administrator or nearest HP Service Office.
- START ERROR 400 Test session pcs_*xxx* is in bad state.
- START ERROR 401 Test session is in bad state; No shared memory.
- START ERROR 402 Test session is in bad state; No semaphore.
- START ERROR 404 Invalid shared memory segment.
- START ERROR 405 Invalid shared memory segment.
- START ERROR 406 Invalid semaphore entity.
- START ERROR 407 Semaphore ID mismatched.
- START ERROR 408 Session ID inconsistent between key file and shared memory.
- START ERROR 409 Daemon process ID mismatched.
- START ERROR 410 Pcsstart co-exists; Shared memory found.
- START ERROR 411 Pcsstart co-exists; Semaphore found.
- START ERROR 412 Semaphore removed.

- `START ERROR 413 The online_lock file seems to be snatched by other session.`
- `START ERROR 450 Fatal error in pcsstart command.`

  Quit the BASIC/UX, log out, log in again, and restart the BASIC/UX. Then execute the START program. If the same error is detected, contact your system administrator or nearest HP Service office.

TIS Errors

This section lists errors related to your system's TIS software.

`ERROR 392`

An illegal value is specified in a TIS subprogram. For example, if you specify "200" in the "Disable_port" subprogram, this is illegal and must be changed. This error also occurs if the COM blocks established during START are lost and you execute a TIS Init_system subprogram. Rerun the START program.

`ERROR 449`

This error code is preceded by one of the following TIS errors:

- `TIS ERROR 1 Not authorized to use the software.`

  The ID Module is not connected—or not connected properly—to your system controller. Correct the connection and rerun the START program.

- `TIS ERROR 10 HP-IB time out error.`

  An expected interrupt did not occur within the specified limits or a system fatal error occurred. For example, an ON TIMEOUT statement is used abnormally in a measurement program. Initialize the system by executing the Init_system subprogram. If the same error code is displayed, contact your system administrator or nearest HP Service Office.

- `TIS ERROR 11 HP-IB SRQ time out error.`

  An expected interrupt did not occur within the specified limits. The system's control settings were changed or your HP 4062C/UX/PC is trying to execute an illegal program operation. For example, a Connect statement is executed with the SWM open. Initialize the system by executing the Init_system subprogram.

- `TIS ERROR 20 Device not present.`

  An instrument that was not present during START (displayed as Not Present) is specified, or the COM blocks are lost. Check the connection between the instruments and rerun the START program.

- `TIS ERROR 21 Invalid port or pin assigned.`

  A port or pin board is illegally specified. For example, a VS is specified in a Force_i statement; or an illegal pin, such as -5, is specified in a Force_v statement.

- `TIS ERROR 22 Improper number of pass parameters specified.`

  In the Sweep_miv subprogram's calling context, the number of measurement ports in the measurement port list is different than the number of measurement data arrays.

- `TIS ERROR 23 Improper size of pass parameters specified.`

  In the Sweep_miv subprogram's calling context, the size of the measurement data arrays is different than the number of sweep points.

- `TIS ERROR 24 Improper pass parameters' value specified.`

  Improper pass parameter value in a feedback measurement subprogram.

- `TIS ERROR 25 Between PREPARE ... EXECUTE, a port is measure-assigned twice.`

One port is assigned to perform two or more functions within one Prepare ... Execute construct. Rewrite the measurement commands and assign only one function to a port within each Prepare ... Execute construct. Initialize your system using the Init_system subprogram.

- `TIS ERROR 26 Do not execute TIS while using DCS program memory library.`

  After invoking a DCS program memory segment with the Run_dcs_program function, you called a regular TIS function. Only an Init_system, Long_cal, Short_cal, or Disable_port function is allowed to be executed after the execution of the DCS program memory segment.

- `TIS ERROR 30 SWM down. SRQ asserted.`

  The SWC or SWM is not functioning properly. Check your cabling configuration and rerun the START program.

- `TIS ERROR 31 SWM syntax error. SRQ asserted.`

  The SWC received an illegal program code. Initialize your system using the Init_system subprogram.

- `TIS ERROR 32 SWM open. SRQ asserted.`

  SWM output is disabled. This may occur if you're using a wafer prober and your SWM is not mounted properly on the prober; if the Test Fixture Adapter is mounted on SWM but its cover is not closed; or if there is nothing mounted on the SWM.

- `TIS ERROR 33 Specified pin board not present. SRQ asserted.`

  A pin board registered during START (pin number displayed) is specified, but cannot be accessed. Check for proper pin board configuration and installation. If you rearranged pin boards, make sure they are properly installed and that the control bus cable is connected.

- `TIS ERROR 34 Pin board not present.`

  A specified pin board is not installed in the SWM. Check for proper pin board configuration and rerun the START program.

- `TIS ERROR 35 (first pin number) >= (last pin number)`

  In the Connect_th subprogram's calling context, the first specified pin number is larger than the last specified pin number.

- `TIS ERROR 40 DCS reports the error code. Error code is` *xxxx*`.`

  The DCS received an illegal program code. Initialize your HP 4062C/UX/PC using the Init_system subprogram. The *xxxx* is the DCS's error code.

- `TIS ERROR 41 DCS not interlocked. SRQ asserted.`

  The interconnect cable assembly is disconnected and an attempt was made to output voltage in excess of ±42 V. Connect the cable assembly.

- `TIS ERROR 44 VS output voltage incompatible with set voltage range.`

  A VS's specified output voltage exceeds the selected voltage range. Decrease the output voltage or increase the voltage range setting.

- `TIS ERROR 45 Improper SMU current source, range, or compliance specified.`

The specified compliance value of an SMU is too large for the selected range or specified output value. Decrease the current compliance or the output value, or increase the voltage range setting.

- `TIS ERROR 46 Illegal sweep power-compliance specified.`

  In the Set_iv subprogram's calling context, the specified power compliance is larger than the SMU's maximum output power. Decrease the power compliance setting.

- `TIS ERROR 47 Start and stop value are not same polarity.`

  In the Set_iv subprogram's calling context, the start value and stop value for a current sweep measurement must be the same polarity.

- `TIS ERROR 49 Illegal SMU measurement function assigned.`

  During a sweep or pulsed measurement, an SMU is set to the wrong mode for the specified measurement. SMUs must be set to VS mode for current measurements, and IS mode for voltage measurements.

- `TIS ERROR 50 Target value incompatible with compliance value.`

  In the Set_asearch, Set_bsearch, or Set_lsearch subprograms' calling context in the measurement mode, the target value is larger than the sense unit's compliance value.

- `TIS ERROR 51 This port must be the same V/I mode as the control variable.`

  In the Set_sync subprogram's calling context, the search port's and synchronous search port's output modes (VS or IS) must be the same.

- `TIS ERROR 52 Improper search offset value specified.`

  MAX(|minimum control value| or |start value|) and MAX(|maximum control value| or |stop value|) + |offset| must be within the search unit's range.

- `TIS ERROR 53 Sense port must be different from search port.`

  In the Set_asearch subprogram's calling context, the search and sense ports are both specified (illegally) as the same port (unit).

- `TIS ERROR 54 Target value out of range.`

  The specified target value exceeds the sense unit's measurement range.

- `TIS ERROR 55 Illegal search v_range, time, and speed combination specified.`

  In the Set_asearch subprogram's calling context, the start value, stop value, ramp rate, and feedback integration time settings are incompatible.

- `TIS ERROR 56 SMU output voltage incompatible with set voltage range.`

  An SMU's specified output voltage exceeds the selected voltage range. Decrease the output voltage or increase the voltage range setting.

- `TIS ERROR 57 Analog Feedback Unit (AFU) not present.`

  The AFU is specified for use in a measurement, but is not registered during START, or the COM blocks are lost. Make sure your AFU is installed in the DCS and rerun the START program.

- `TIS ERROR 58 Pulse period incompatible with pulse width.`

The specified pulse width is greater than 50% of the specified pulse period. Decrease the pulse width or increase the pulse period.

- `TIS ERROR 59 Improper DCS sweep, search, and pulse settings.`

  In a sweep, search, or pulsed measurement, the measurement execution subprogram executed before you established the measurement conditions. For example, a Sweep_iv subprogram executed before its corresponding Set_iv subprogram executed.

- `TIS ERROR 60 Improper search values (start_value and stop_value) specified.`

  In the Set_asearch subprogram's calling context, start and stop values must satisfy the following conditions:

  $|\text{start value}| \leq 2$ and $|\text{stop value}| \leq 2$, then $|\text{start} - \text{stop value}| \leq 2$
  $|\text{start value}| \leq 20$ and $|\text{stop value}| \leq 20$, then $|\text{start} - \text{stop value}| \leq 20$

- `TIS ERROR 61 Base_value and peak_value are not same polarity.`

  In a pulsed current measurement, the specified pulse base and peak values must be of the same polarity.

- `TIS ERROR 62 Specified VM is still set to Differential Voltage Measurement mode.`

  In a pulsed measurement, a VM's differential voltage measurement mode cannot be used.

- `TIS ERROR 63 Sync range adjustment error.`

  The synchronous search port's range must be the same as the search port's range. Also, the synchronous search port cannot be set to a range equal to MAX(|maximum search value| or |stop value|) and MAX(|minimum search value| or |start value|) + |offset|.

- `TIS ERROR 64 Cannot specify zero (0) specified for sweep or bias&sweep.`

  In a pulsed sweep or sweep with pulsed bias measurement, you cannot set the pulse period to 0.

- `TIS ERROR 65 Improper pulse measurement pass parameter specified for Set_iv.`

  In the Set_iv subprogram's calling context, the specified compliance value is invalid or the logarithmic sweep mode is specified.

- `TIS ERROR 66 Improper pulse measurement range specified.`

  In a pulsed current measurement, the specified current range is too low for the voltage range set. If the voltage range is larger than 2 V, the current range must be $\geq$ 1E-4 A.

- `TIS ERROR 68 Set_sync and Set_iv cannot specify the same port.`

  The Set_sync and Set_iv subprograms cannot specify the same port.

- `TIS ERROR 69 Set_sync cannot be used with Set_piv or Set_pbias.`

  The secondary sweep parameter cannot be used with pulsed or pulsed bias sweep measurements.

- `TIS ERROR 70 Start or Stop value is out of minimum resolution.`

  Unsuitable start or stop values are set in the Set_iv subprogram, or unsuitable offset or ratio is set in the Set_sync subprogram.

- `TIS ERROR 71 VS cannot be used if the primary SMU is current source mode.`

When using a VS as a secondary sweep source, the VS and SMU must be the same source mode.

- `TIS ERROR 72 Set_sync cannot be used before primary search or sweep setup.`

  The primary sweep port must be set before the secondary sweep port is set.

- `TIS ERROR 73 The secondary sweep port is not set.`

  The secondary sweep port must be set before the secondary sweep array name is specified.

- `TIS ERROR 74 In high voltage state, output relay can't be disconnected.`
- `TIS ERROR 75 In high voltage state, output relay can't be connected.`

  DCS cannot disconnect or connect the output relay when the output voltage is more than 42 V.

- `TIS ERROR 76 Source SMU or VS unit is masked.`

  The specified DCS's module is masked by Ch_sw_off statement. Unmask the module by running the START program or executing the Init_system, Long_cal, or Short_cal subprograms.

- `TIS ERROR 77 TIS cannot be used with this revision.`

  Quasi-pulsed measurements are available for HP 4142B Rev. 4.0 or later.

- `TIS ERROR 80 CMS syntax error. SRQ asserted.`
- `TIS ERROR 81 CMS illegally programmed. SRQ asserted.`

  The CMS received an illegal programming code. Initialize your HP 4062C/UX/PC using the Init_system subprogram.

- `TIS ERROR 82 CMS triggered too fast. SRQ asserted.`

  The CMS received a trigger signal while outputting measurement data from the previous measurement. Make sure that nothing is connected to the CMS's rear panel EXT TRIGGER terminal.

- `TIS ERROR 83 CMS sweep/bias error. SRQ asserted.`

  The BNC shorting cap was removed from the CMS's front panel REMOTE ON/OFF connector. Connect the BNC shorting cap and initialize your HP 4062C/UX/PC using the Init_system subprogram.

- `TIS ERROR 84 CMS output voltage incompatible with set voltage range.`

  The CMS's specified output voltage exceeds the selected voltage range. Decrease the output voltage or increase the voltage range setting.

- `TIS ERROR 85 CMU84 reports an SRQ. Error code is` *xxxx*.

  The CMU84 caused a service request. The *xxxx* is the error code of the CMU84. For the error code, see the *HP 4284A Operation Manual*.

- `TIS ERROR 86 CMU84 Option 001 is not present.`

  In order to force arbitrary voltage by the HP 4284A (CMU84), the HP 4284A must be furnished with Option 001.

- `TIS ERROR 94 Voltage difference between start and stop is less than 10 V.`

The conditions for Set_bdv or Set_ileak are not being met.

For the Set_bdv function, the start and stop values must satisfy the following conditions:

- Stop $\geq$ start + 10

For the Set_ileak function, the start and stop values must satisfy the following conditions:

- Start $\leq$ voltage − 10

- `TIS ERROR 95 Measure_bdv can not be used before Set_bdv.`

  You called the Measure_bdv function before setting up the measurement conditions with the Set_bdv function.

- `TIS ERROR 96 Measure_ileak can not be used before Set_ileak.`

  You called the Measure_ileak function before setting up the measurement conditions with the Set_ileak function.

- `TIS ERROR 100 This TIS subprogram is not supported by off-line mode.`

  A TIS subprogram that is not supported by off-line mode is used.

- `TIS ERROR 101 Specified file cannot be opened.`

  The file specified by the Off_line_data subprogram cannot be opened. One of the following may be the cause:

  - The file does not exist.
  - The directory pathname is incorrect.

- `TIS ERROR 102 Specified file cannot be opened.`

  The file specified by the Data_creation subprogram cannot be created. One of the following may be the cause:

  - A file with the same name already exists and is protected.
  - The directory pathname is incorrect.

- `TIS ERROR 103 Invalid file data is found.`

  While reading the data from the file, invalid data are found. Check for one of the following possible causes:

  - TIS subprogram name is not proper: The TIS subprogram that is executed in the program is different from the TIS subprogram that is declared in the file, a name that is not TIS subprogram name is detected, or not allowable characters are used.
  - Measurement data are not proper: data that are not number are detected or not allowable separators are used.
  - Data that is specified in option parameter does not exist in the file.
  - During reading the data, the end of file has come.

- `TIS ERROR 200 No test session; TIS is used before START program.`

  TIS subprograms are called before the START program is executed.

- `TIS ERROR 201 Permission denied to access this session.`

  The session that is specified by environment variable PCS_SESSION_ID does not allow accessing. Rerun the START program. If the same error code is displayed, contact your system administrator or nearest HP Service Office.

- `TIS ERROR 202 Session locked.`

  Another process in the same session locks the instruments.

- `TIS ERROR 203 Test session not ready; TIS in used after START failed.`

  TIS subprograms are called after the START program is failed.

- `TIS ERROR 204 Number of session processes exceeds the system limit.`

  More than 11 processes in one session call the TIS subprograms.

- `TIS ERROR 205 No valid HP-IB address; TIS is used after START failed.`

  TIS subprograms are called after the START program is failed.

- `TIS ERROR 220 PCS_SESSION_ID not defined.`
- `TIS ERROR 221 Session identifier too long.`
- `TIS ERROR 222 Failed to attach shared memory.`

  System software is not installed or customized properly. Contact your system administrator or nearest HP Service Office.

- `TIS ERROR 240 Fatal error ( errno =` *xxx* `)`
- `TIS ERROR 241 Fatal error ( errno =` *xxx* `)`
- `TIS ERROR 242 Fatal error ( errno =` *xxx* `)`
- `TIS ERROR 243 Fatal error ( errno =` *xxx* `)`
- `TIS ERROR 244 Fatal error ( errno =` *xxx* `)`
- `TIS ERROR 245 Fatal error ( errno =` *xxx* `)`
- `TIS ERROR 246 Fatal error ( errno =` *xxx* `)`
- `TIS ERROR 247 Fatal error ( errno =` *xxx* `)`
- `TIS ERROR 248 Fatal error ( errno =` *xxx* `)`
- `TIS ERROR 249 Fatal error ( errno =` *xxx* `)`
- `TIS ERROR 250 Fatal error ( errno =` *xxx* `)`
- `TIS ERROR 251 Fatal error ( errno =` *xxx* `)`
- `TIS ERROR 252 Fatal error ( errno =` *xxx* `)`
- `TIS ERROR 253 Fatal error ( errno =` *xxx* `)`
- `TIS ERROR 254 Fatal error ( errno =` *xxx* `)`
- `TIS ERROR 255 Fatal error ( errno =` *xxx* `)`
- `TIS ERROR 256 Fatal error ( errno =` *xxx* `)`
- `TIS ERROR 257 Fatal error ( errno =` *xxx* `)`
- `TIS ERROR 258 Fatal error ( errno =` *xxx* `)`
- `TIS ERROR 259 Fatal error ( errno =` *xxx* `)`
- `TIS ERROR 260 Fatal error ( errno =` *xxx* `)`
- `TIS ERROR 261 Fatal error ( errno =` *xxx* `)`

- `TIS ERROR 262 Fatal error ( errno =` *xxx* `)`
- `TIS ERROR 263 Fatal error ( errno =` *xxx* `)`
- `TIS ERROR 264 Fatal error ( errno =` *xxx* `)`
- `TIS ERROR 265 Fatal error ( errno =` *xxx* `)`
- `TIS ERROR 266 Fatal error ( errno =` *xxx* `)`
- `TIS ERROR 267 Fatal error ( errno =` *xxx* `)`
- `TIS ERROR 268 Fatal error ( errno =` *xxx* `)`
- `TIS ERROR 269 Fatal error ( errno =` *xxx* `)`

  A fatal system error occurred. The *xxx* above is the system call's error code. Contact your system administrator or nearest HP Service Office.

PGMLIB Errors

This section lists errors related to the DCS Program Memory Library (PGMLIB). You need to use the error handling facilities of the C Library and the HP 4062UX to see the PGMLIB error numbers and messages.

- `PGMLIB ERROR 1 Pgm_start is not declared.`

  DCS Program Library functions, such Pgm_force_v, are used before the Pgm_start function.

- `PGMLIB ERROR 2 Pgm_start is nested.`

  Pgm_start is called twice before the first Pgm_start is ended by a Pgm_end function.

- `PGMLIB ERROR 20 Device not present.`

  The DCS is not on line; that is, it is not recognized by the START program.

- `PGMLIB ERROR 21 Invalid port assigned.`

  An invalid port address or a unit address is specified to the function. Note that a SWM pin number is not accepted as the unit specifier for the PGMLIB functions.

- `PGMLIB ERROR 24 Improper pass parameter specified.`

  The parameter value passed is incompatible with the corresponding range restrictions.

- `PGMLIB ERROR 100 Error in Pcs_hpib_open.`
- `PGMLIB ERROR 101 Error in Pcs_hpib_output.`
- `PGMLIB ERROR 102 Error in Pcs_hpib_enter.`
- `PGMLIB ERROR 103 Error in Pcs_hpib_clear.`
- `PGMLIB ERROR 104 Error in Pcs_hpib_spoll.`

  The PGMLIB functions failed to operate on the HP-IB. Check the connection of the HP-IB.

VFP Errors

This section lists errors related to your HP 4062C/UX/PC's VFP function.

- `WARNING 1 SWM open`

  SWM output is disabled. This may occur if you're using a wafer prober and your SWM is not mounted properly on the prober; if the Test Fixture Adapter is mounted on SWM but its cover is not closed; or if there is nothing mounted on the SWM.

- `WARNING 2 DCS shutdown`

  DCS output is disabled because of a momentary power loss or because voltage or current in excess of an SMU's maximum current or voltage is applied to an SMU. Initialize your HP 4062C/UX/PC using the Init_system subprogram.

- `WARNING 3 DCS not interlocked`

  The interconnect cable assembly is disconnected and an attempt was made to output voltage in excess of ±42 V. Connect the cable assembly.

- `VFP ERROR 1 Improper cursor position`

  The cursor is not positioned correctly for the parameter being set, or you pressed the wrong key when changing a parameter. This error occurs under the following circumstances:

  - If you select the `[    ]` softkey when the cursor is *not* positioned in a `[    ]` field.
  - If you press a numeric key or the space bar when the cursor is positioned in a `[    ]` field.
  - If you select the `[    ]`, `EXECUTE ON / OFF`, or `MEAS / NOT MEAS` softkey when the cursor is positioned in the PIN CONNECTION area.
  - If you rotate the keyboard's rotary knob when output is enabled (EXEC mode) and the cursor is *not* positioned in an output value field.

  Note that you *cannot* change the cursor's position when the EXEC mode is enabled.

- `VFP ERROR 2 Illegal value`

  A value exceeding a parameter's specified limits was entered.

- `VFP ERROR 3 Not allowed while OFF status`

  While in the EXEC mode, an attempt was made to sweep the output of a source device (an SMU, a VS, or the CMS's internal dc bias source) that was set to Off. Set the source device to On by exiting from the EXEC mode and selecting the `EXECUTE ON / OFF` softkey.

- `VFP ERROR 4 Not allowed while ON status`

  An attempt was made to change the voltage range or compliance setting of a source device (an SMU or the CMS's internal dc bias source) that was set to On. Set the source device to Off by selecting the `EXECUTE ON / OFF` softkey before changing parameters.

- `VFP ERROR 5 Not allowed in EXEC mode`

  While in the EXEC mode, an attempt was made to change a control setting, or you pressed a key or selected a softkey other than the `EXECUTE ON / OFF` softkey.

- `VFP ERROR 6 Return (or Enter) key was not pressed`

A parameter is set or a control setting is changed, but not entered, because you did not press Return or Enter.

- `VFP ERROR 7 DCS output voltage incompatible with set voltage range`

  An SMU's specified output voltage exceeds the selected voltage range. Decrease the output voltage or increase the voltage range setting.

- `VFP ERROR 8 SMU voltage compliance incompatible with set current value`

  The product of an SMU's compliance setting multiplied by the SMU's specified output value exceeds the SMU's maximum power. Decrease either the compliance setting or the specified output value.

- `VFP ERROR 9 SMU current compliance incompatible with set voltage value`

  An SMU's specified current compliance setting is too high for the selected voltage range. Decrease the current compliance setting or increase the voltage range setting.

- `VFP ERROR 10 CMS output voltage incompatible with set voltage range`

  The CMS's specified output voltage exceeds the selected dc bias range. Decrease the output voltage or increase the voltage range setting.

- `VFP ERROR 11 Illegal key`

  A key other than a VFP control key was pressed.

- `VFP ERROR 12 DCS not present`

  The DCS was not registered during START (displayed as Not Present) and an attempt was made to operate the DCS. Make sure the DCS is turned on and the HP-IB cable is connected. Rerun the START program.

- `VFP ERROR 13 CMS not present`

  The CMS was not registered during START (displayed as Not Present) and an attempt was made to operate the CMS. Make sure the CMS is turned on and the HP-IB cable is connected. Rerun the START program.

- `VFP ERROR 14 SWM not present`

  The SWM was not registered during START (displayed as Not Present) and an attempt was made to operate the SWM. Make sure the SWC is turned on and the HP-IB cable is connected. Rerun the START program.

- `VFP ERROR 15 Pin board not present`

  A pin board not registered during START (pin number not displayed) is specified. Check for proper pin board configuration and installation. If you rearranged pin boards, make sure they are properly installed and that the control bus cable is connected. Rerun the START program.

- `VFP ERROR 16 System is already locked, not allowed to enter Control mode.`

  The `Lock & Control` softkey is selected while another process locks the instruments.

PPG Errors

This section lists errors related to your HP 4062C/UX/PC's PPG.

- `PPG ERROR 1 Printer timeout.`

  A printer is not connected, or the HP-IB address of the printer is not set to 1. Make sure a printer is connected and that its HP-IB address is 1.

- `PPG ERROR 6 File name is not specified.`

  The file name is not specified when you save the probing pattern data.

- `PPG ERROR 7 Duplicate file name. Overwrite or Abort ("O", "o": others) ?`

  The specified file name already exists in the directory when you save the probing pattern data.

- `PPG ERROR 8 Max. module number is too large.`

  The maximum module number exceeds the allowable limits because the specified module size is too small. Re-enter the appropriate module size.

- `PPG ERROR 11 Chip size > Wafer size`

  The specified chip size is too large for the specified wafer size. Re-enter the appropriate chip size.

- `PPG ERROR 12 Number of chips is too large ( MAX X=255 Y=255 )`

  The calculated number of chips exceeds the allowable limits (max. 255 for the X-coordinate; 255 for the Y-coordinate) because the specified chip size is too small. Re-enter the appropriate chip size.

- `PPG ERROR 13 Module size * Module number > Chip size`

  The module size multiplied by the module number exceeds the specified chip size. The specified module size is too large or the chip size is too small. Re-enter the appropriate module or chip size.

- `PPG ERROR 14 Module size > Chip size`

  The module size exceeds the specified chip size. The specified module size is too large or the chip size is too small. Re-enter the appropriate module or chip size.

- `PPG ERROR 15 Probing sequence number must be 1 to 6`

  The probing sequence number exceeds the allowable limits. The probing sequence number must be 1 through 6. Re-enter the appropriate probing sequence number.

- `PPG ERROR 16 Wafer size must be 0.1 to 99.99999 inches`

  The wafer size exceeds the allowable limits. The wafer size must be 0.1 through 99.99999 inches. Re-enter the appropriate wafer size.

- `PPG ERROR 17 Chip X-Y size must be 1 to 99999 microns.`

  The X- or Y- chip size exceeds the allowable limits. The X- and Y- chip size must be 1 through 99999 microns. Re-enter the appropriate chip size.

- `PPG ERROR 18 Module X-Y size must be 1 to 99999 microns.`

The X- or Y- module size exceeds the allowable limits. The X- and Y- module size must be 1 to 99999 microns. Re-enter the appropriate module size.

- `PPG ERROR 19 Number of X-Y modules must be 1 to 6.`

  The X- or Y- module number exceeds the allowable limits. The X- and Y- module number must be 1 through 6. Re-enter the appropriate module number.

- `PPG ERROR 21 Illegal input`

  An attempt was made to enter a value that exceeds the specified limits.

- `PPG ERROR 22 No modules have been selected`

  No modules are selected. You must select at least one module. To select modules individually, place the cursor at the desired module and select the SELECT softkey. To select all modules, select the SELECT ALL softkey.

- `PPG ERROR 26 Number of selected chips is too large. (MAX 32760)`

  The calculated number of chips exceeds the allowable limits (max. 32760) because the specified chip size is too small. Re-enter the appropriate chip size.

- `PPG ERROR 27 No chips have been selected`

  No chips are selected. You must select at least one chip. To select chips individually, place the cursor at the desired chip and select the SELECT softkey. To select all chips, select the SELECT ALL softkey.

- PPG ERROR 28 X or Y (No. *xxx*) not set. Enter missing value, or delete (no. *xxx*).

  The X- or Y- coordinate is not entered. The *xxx* above is the module number. Enter the appropriate coordinate or delete it.

- `PPG ERROR 31 Wget is not declared`

  The Wget subprogram is not included in your measurement program, or is placed out of sequence. The Wget subprogram must precede the Wstart_number or Wstart_xy subprogram.

- `PPG ERROR 32 Improper number of pass parameters specified`

  Only one coordinate (X- or Y-) is specified in the Wstart_xy subprogram. You must specify both X- and Y-coordinates.

- `PPG ERROR 33 Wstart_xy or Wstart_number is not declared`

  The Wstart_number or Wstart_xy subprogram is not included in your measurement program, or did not precede a Wmove_next, Wmove_number, or Wmove_xy subprogram.

- `PPG ERROR 34 Illegal chip coordinate`

  The X- and Y-chip coordinates specified in the Wmove_xy subprogram designate a non-existent chip.

- `PPG ERROR 35 CHIP not registered`

  A chip not registered during the WAFER configuration stage is specified in a Wmove_number or Wmove_xy subprogram. Execute PPG and register the chip, or delete all references to the chip in your Wmove_number or Wmove_xy subprogram.

- `PPG ERROR 36 MODULE not registered`

A module not registered during the CHIP configuration stage is specified in a Wmove_number or Wmove_xy subprogram. Execute PPG and register the chip, or delete all references to the chip in your Wmove_number or Wmove_xy subprogram.

- `PPG ERROR 41 Illegal VAR NAME ( no VAR NAME in DATA file )`

  A VAR NAME not listed in the data file is specified.

- `PPG ERROR 42 Illegal LIMIT value`

  One or all of the wafer map LIMIT values is specified out of sequence. For example, the uppermost LIMIT value must be $\geq$ the second LIMIT value; the second LIMIT value must be $\geq$ the third LIMIT value, and so on.

- `PPG ERROR 43 Illegal COORDINATE value`

  The X- or Y-axis of the wafer map is improperly scaled. For example, the X-axis minimum value is greater than the X-axis maximum value.

- `PPG ERROR 44 Illegal input ( MAX COLUMN=xx  ROW=yy )`

  The value specified for the X- or Y-axis of the wafer map exceeds the allowable limit (max. xx for the X- [COLUMN] axis, yy for the Y- [ROW] axis).

- `PPG ERROR 71 Illegal DATA file ( MIN Nv=3 )`

  The minimum number of variables (Nv) required for generation of a wafer map is not specified in the data file. At least three (3) variables must be specified (COLUMN, ROW, and measurement data).

- `PPG ERROR 72 Illegal DATA file ( Vn$(1)="COLUMN"  Vn$(2)="ROW" )`

  Illegal string variable is specified. VN$(1) must be "COLUMN" and VN$(2) must be "ROW."

- `PPG ERROR 73 Illegal DATA NAME in SUB Wput_data or SUB Wput_array`

  Null data (" ") is specified as the string variable (DATA NAME) in a SUB Wput_array or SUB Wput_data subprogram.

- `PPG ERROR 74 DATA NAME overflow`

  The number of characters specified in the data file name exceeds the allowable limit (max. 50 characters).

- `PPG ERROR 75 DATA number overflow`

  The number of data file variables multiplied by the number of chips exceeds the allowable limit (max. 1500).

Note

BASIC/UX Language System errors occurring in PPG are displayed between two graphics arrows, as in the following example:

```
====> ERROR 53 IN 1950 Improper file name <====
```

For details on BASIC/UX errors, refer to the *BASIC* or *BASIC/UX Language Reference Manual*.

Diagnostics (DIAG) Errors

This section lists errors related to the HP 4062C/UX/PC's DIAG software.

- `DIAG. ERROR 10 Switching Matrix not ready.`

  The SWC is not turned on, or the HP-IB cable is not connected (SWC displayed as Not Present during START). Stop the program, check the power and the HP-IB cable, and select the `RUN` softkey.

- `DIAG. ERROR 11` (Switching Matrix error)

  A relay failure is detected in the SWM. The displayed error message indicates the failure location. Make sure the Relay Test Adapter is installed securely on the SWM, and select the `RETRY` softkey.

  If the same error occurs at the same location, contact your nearest HP Service Office. If emergency repair is necessary, replace the defective pin board. See the *System Information* manual for details on replacing pin boards.

  If a DIAG. ERROR 11 followed by the message `A relay is stuck` ... is displayed, you may be able to repair the relay itself. See the *System Information* manual for details.

  Whenever a relay failure occurs, repair or remove the faulty pin board and rerun the relay test to check for additional failures.

- `DIAG. ERROR 12 Leakage in Switching Matrix.`

  Excessive leakage current is detected in the SWM, or in the cabling to the SWM. Contact your nearest HP Service Office.

- `DIAG. ERROR 13 Leakage in Switching Matrix.`

  Excessive leakage current is detected on a pin board. If a test fixture is mounted in the Test Fixture Adapter, remove the fixture and select the `RETRY` softkey. If the same error occurs, contact your nearest HP Service Office.

- `DIAG. ERROR 14 Some pin boards are not installed.`

  Pin boards required for DIAG program are not installed.

- `DIAG. ERROR 19 Block` *x* `Input Relay K`*yz* `test failed.`

  An Input Relay failure is detected in the SWM. The displayed error message indicates the failure location. Make sure the Relay Test Adapter is installed securely on the SWM, and select the `RETRY` softkey. If the same error occurs at the same location, contact your nearest HP Service Office.

- `DIAG. ERROR 20 DC Source/Monitor not ready.`

  The DCS is not turned on, its HP-IB cable is not connected (DCS displayed as Not Present during START), or a plug-in module required for a test's execution is not present or is not connected to the SWM. Stop the program, check these items, and select the `RUN` softkey.

- `DIAG. ERROR 21 DC Source/Monitor failed SELF TEST.`

  An SMU failure is detected during the DCS's self-test. Contact your nearest HP Service Office.

- `DIAG. ERROR 22 I-V measurement test failed.`

- `DIAG. ERROR 23 I-V measurement test failed.`
- `DIAG. ERROR 24 I-V measurement test failed.`
- `DIAG. ERROR 25 I-V measurement test failed.`

  An SMU failure is detected. If the relay test has not yet been performed, run the relay test, then retry the SMU test. If the same error occurs, contact your nearest HP Service Office. If emergency repair is necessary, replace the defective SMU plug-in module. See the *System Information* for details.

- `DIAG. ERROR 26 VS`x `and VS`y `are not connected.`
- `DIAG. ERROR 26 VS`x `is not connected.`

  Where x and y are integers from 1 to 16, and x is a lower integer than y. If the first error occurs, connect VSx to the AUX1 port, VSy to the AUX2 port, and perform the VS Test again. If the second error occurs, connect VSx to the AUX1 port, and perform the VS Test again.

- `DIAG. ERROR 27 Voltage output test failed.`

  A VS failure is detected. Contact your nearest HP Service Office.

- `DIAG. ERROR 28 VM`x `and VM`y `are not connected.`
- `DIAG. ERROR 28 VM`x `is not connected.`

  Where x and y are integers from 1 to 16, and x is a lower integer than y. If the first error occurs, connect VMx to the AUX1 port, VMy to the AUX2 port, and perform the VM Test again. If the second error occurs, connect VMx to the AUX1 port, and perform the VM Test again.

- `DIAG. ERROR 29 Voltage measurement test failed.`

  A VM failure is detected. Contact your nearest HP Service Office.

- `DIAG. ERROR 30 C Meter/C-V Plotter not ready.`

  The CMU is not turned on, its HP-IB cable is not connected (CMU displayed as Not Present during START), or it is not connected to the SWM. Stop the program, check the CMU's power, HP-IB cable, and SWM interconnection cables, and select the `RUN` softkey.

- `DIAG. ERROR 31 C Meter/C-V Plotter failed SELF TEST.`

  The CMU failed its self-test. Contact your nearest HP Service Office.

- `DIAG. ERROR 32 C-G measurement test failed.`

  A CMU or CMU84 measurement circuit failure is detected. Contact your nearest HP Service Office.

- `DIAG. ERROR 33 Stray capacitance too high.`

  Stray capacitance in the SWM or the CMH or CML cable exceeds 10 pF. Contact your nearest HP Service Office.

- `DIAG. ERROR 34 Bias output test failed.`

  A CMU and CMU84 internal dc bias source failure is detected. Contact your nearest HP Service Office.

- `DIAG. ERROR 35 Rear panel short-cap disconnected.`

A BNC shorting cap is not connected to the CMU's rear panel EXT. BIAS-SLOW connector.

- `DIAG. ERROR 36 Analog Feedback Unit test failed.`

  A failure is detected in the AFU of the DCS. If this error occurs when all SMUs are functioning normally, contact your nearest HP Service Office.

- `DIAG. ERROR 40` (CMU84 not ready)

  The CMU84 is not turned on, its HP-IB cable is not connected (CMU84 displayed as `Not present` during START), or it is not connected to the SWM. Stop the program, check the CMU84's power, HP-IB cable, and SWM interconnection cables, and select the `RUN` softkey.

- `DIAG. ERROR 45 Port Expander Relay` K*xx* *yyy* `side test failed.`

  DIAG program detected an malfunctioning Port Expander relay K*xx* (where *xx* is one of the relay number). The *yyy* in the above message should be replaced by either `force` or `guard`.

BASIC or BASIC/UX Language System Errors

This section lists several of the more common errors related to the BASIC or BASIC/UX language system. For more details, refer to the *BASIC* or *BASIC/UX Language Reference Manual*.

- `ERROR 5`

  Improper context terminator. You forgot to put an END statement in the program. Also applies to SUBEND and FNEND.

- `ERROR 7`

  Undefined function or subprogram. An attempt was made to call a SUB or user-defined function that is not in memory. Look out for program lines that assume an optional CALL.

- `ERROR 8`

  Improper parameter matching. A type mismatch between a pass parameter and a formal parameter of a subprogram. See *Programming Reference* for parameter types.

- `ERROR 9`

  Improper number of parameters. Passing either too few or too many parameters to a subprogram. Applies only to non-optional parameters. See *Programming Reference* for details on the number of parameters.

- `ERROR 53`

  Improper file name. File names are limited to 10 characters. Foreign characters are allowed, but punctuation is not.

- `ERROR 56`

  File name is undefined. The specified file name does not exist in the directory. Check your disk's contents using the CAT command.

- `ERROR 145`

  May not build COM at this time. An attempt was made to add or change COM while a program was running. For example, a program does a LOADSUB, and the COM in the new subprogram does not match the existing COM. Rerun the START program.

- `ERROR 392`
- `ERROR 499`

  See TIS Errors.

- `ERROR 902`

  Must delete entire context. An attempt was made to delete a SUB or DEF FN statement without deleting its entire context. Easiest way to delete is with DELSUB.

B

BSDM and Statistical Graphics

Basic Statistics and Data Manipulation

General Information

Description

Basic Statistics and Data Manipulation (BSDM) programs let you create a statistical database that can be accessed by other Hewlett-Packard statistical routines. It alleviates the need to enter data each time you use a new statistical procedure.

BSDM capabilities include data entry and data manipulation functions that let you obtain a wide variety of summary statistics. Also, BSDM's attention to human interfacing makes each BSDM program application easy-to-use. BSDM programs provide the following capabilities:

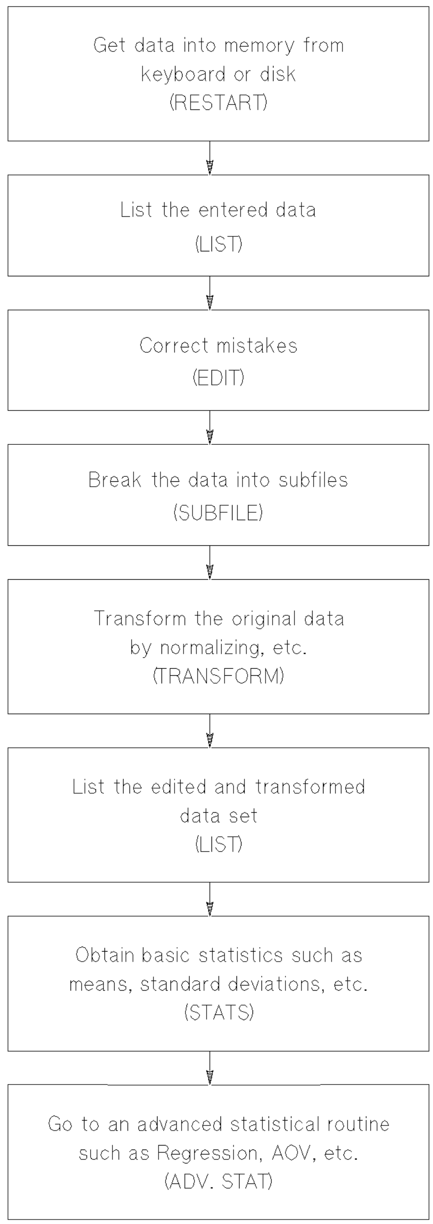
Data Entry:	Keyboard
	Magnetic media (flexible disks)
	Graphics tablet
	Other input devices (paper tape, etc.)
Data Manipulation:	Edit incorrect/incomplete data sets
	Transform—both algebraic and non-algebraic
	Assign codes to intervals of data
	Sort
	Divide data set into subfiles
	Join two data sets
	Select portions of the data
Summary Statistics:	Basic Statistics (mean, standard deviation, etc.)
	Correlation matrixes
	Order statistics (max, min, median, etc.)
Other Features:	Error detection
	Easy error correction
	Variables can be named
	Data can be stored for future reference
	Data can be listed
	Data can be scanned for specified qualities

A backup file of the data can be recalled

Printer unit can be changed

Missing data values can be assigned

Typical Program Flow



Special Considerations

Data Matrix Configuration

Think of the data matrix incorporated in this program as a p-by-n array in which columns correspond to observations and rows correspond to variables, as shown below.

		Observations
		$\mathbf{O_1\ \ O_2\ \ O_3\ \cdots\ O_n}$
	V_1	
	V_2	
Variable	V_3	
	:	
	:	
	V_p	

Subfiles may be created, in which case the structure becomes only slightly more complex as shown below.

		Subfile 1	**Observations**	$\cdots$	**Subfiles**
		$\mathbf{O_1\ O_2\ \cdots\ O_{n1}}$	**Subfile 2**		$\mathbf{\cdots\ O_{n1+\cdots ns\text{-}1}\ \cdots\ O_{n1+}\ \cdots\ {+ns}}$
			$\mathbf{O_{n1+1}\ \cdots\ O_{n1+n2}}$		
	V_1				
	V_2				
Variables	V_3				
	:				
	:				
	V_p				

Scratch Data Sets

The statistical database uses two data files: DATA and BACKUP. DATA contains the most current form of your data matrix, and is updated upon completion of any procedure that modifies the data matrix or any variable names. Thus, DATA contains the data that is used for any statistical calculations. BACKUP, on the other hand, is not updated automatically. After data is first entered, a copy of the DATA file is automatically put into BACKUP. From then on, BACKUP can only be modified manually via the BACKUP PROCEDURE. This procedure also lets you retrieve the BACKUP file and copy it to the DATA file. So, if you erroneously alter your data matrix, the original data set is still retrievable.

Data File Configuration

The scratch file on the program medium DATA, and any files created to hold stored data and related information, are configured as follows:

The data file is broken into logical records of 1280 bytes each. The first logical record is a header file, which contains information pertinent to the data set stored in the remaining logical records. The header file contains the following information (variables):

data set title (T$)	80 characters

number of observations (No)	No×Nv≤1500
number of variables (Nv)	50
variable names (Vn$(*))	10 characters each
number of subfiles (Ns)	20
subfile names (Sn$(*))	10 characters each
subfile characterizations (Sc(*))	N/A

The remaining logical records contain D(*,*), the data matrix.

For a detailed explanation of the data file, see "Changes Necessary For Larger Data Sets".

Parser

BSDM is equipped with an elementary parser. This means that wherever an answer could require multiple responses, the parser separates your response into its individual parts. For example, when asked `What variables are desired?` you may respond in three ways:

1. `ALL`: enter ALL if you want to use the entire set of variables.
2. `1, 2, 3,` ···: enter the specific variables you want.
3. `4 - 7`: enter a dash (-) if you want all variables from 4 to 7.

So, a sample response for the question might be:

```
1, 2, 5 - 8, 10, 15, 21 - 25
```

The response is interpreted to mean that you requested variables.

1, 3, 5, 6, 7, 8, 10, 15, 21, 22, 23, 24, and 25.

Thus, anywhere multiple values may be input, you may enter the responses in this manner.

In several cases, `NONE` or `NO` are also possible responses. When they are allowed, it is mentioned in the prompt. There words may be used interchangeably.

Note

Entering negative numbers is the same as entering positive numbers. For example, the input:

```
-10 - -3, 1 - 4
```

means all numbers between −10 and −3 and all numbers between 1 and 4.

Incorrect Responses

If you enter a response outside the range of plausible responses, an appropriate message is displayed on the CRT. Program execution is resumed by asking the question, or in some cases, a previous question, again.

If you give a plausible response, but it is not correct, a couple of possibilities exist. First, if you entered an incorrect value for a data point, you can correct it using the EDIT program. Second, in many cases, responses to several questions are printed on the CRT. Then a question such as `Is the above information correct?` is asked. This lets you change any of the printed information.

Hardware Requirements

An HP 9000 Series 300 computer is required.

An external printer is also required. Though you can use your system controller's display as the printer, results are difficult to read and understand.

Other peripherals, such as an external plotter and an external mass storage device, are optional.

Note The user-defined transformation option requires that you specify the form of the functions before you begin BSDM.

Getting Started

1. Make sure BASIC or BASIC/UX is ready and all peripherals are properly connected and turned on.
2. Type: `SCRATCH A` (Return)
3. Specify the system mass storage where the BSDM files exist.

   For example:

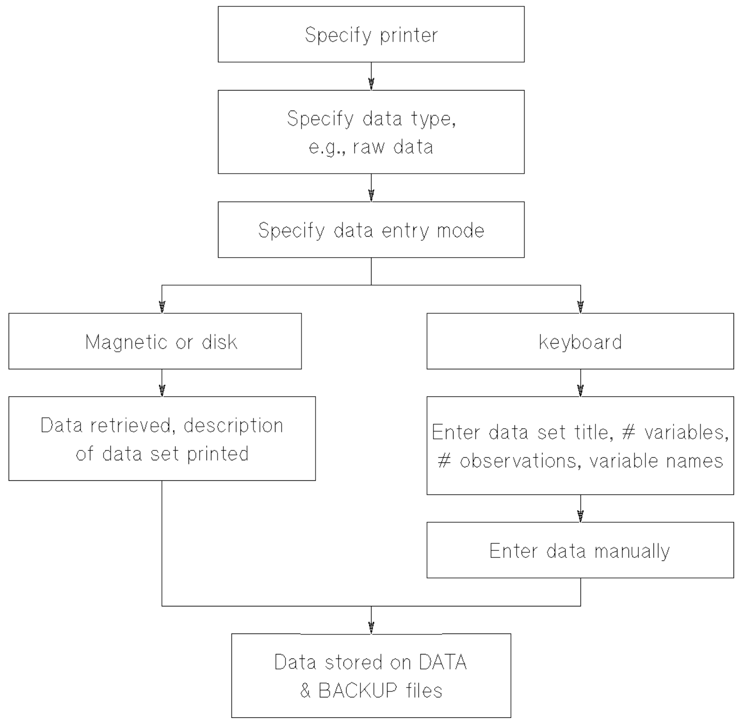
   Type: `MSI "/usr/pcs/bsdm"` (Return)
4. Type: `LOAD "AUTOST",1` (Return)
5. You are asked a series of questions that are self-explanatory. If you have any questions, turn to the Special Considerations section of the procedure in question. You will find some general comments on how that section of the program works.

Start

Object of Program

This program lets you enter a data matrix into memory. The data may be entered from the keyboard, or from some other input device such as a graphics tablet, and so on. Conversely, the data may have been entered previously and stored in the program scratch file DATA, or in a user-created file on a flexible disk or hard disk. In this case, the function of this program is to retrieve the previously stored data and place it into memory so that further operations can be performed. After the data is in memory, a listing option is available to obtain a complete or partial copy of the data.

Typical Program Flow



Special Considerations

Terminology. The displayed prompts concerning the scratch file DATA, whether the data is stored by this program, and whether the data is in the proper configuration are explained here and in the Special Considerations section of General Information for BSDM.

The prompts concerning the data medium and program medium may cause confusion. The word "medium" is used since the set of programs making up this software package may be on a flexible disk. Thus, the "program medium" refers to the disk in which the programs making up this package are stored. Conversely, the "data medium" refers to the disk in which the file containing the data matrix resides. In some cases, the program medium and the data medium are the same. However, this is not determined by the program and hence, the prompts are displayed to make sure the correct medium is in the correct device.

Data on Mass Storage. If the data is on a mass storage device, it may have been stored in one of four ways. The following discussion explains the prompts that apply to each situation.

1. If the data is entered using this statistics package (and is the last data set used in this package), it is on the disk in the scratch file called "DATA," Thus, an affirmative answer to the prompt `Is data stored on the program medium's scratch file (DATA)?` retrieves the data and related information.
2. The data may have been entered using the Basic Statistics and Data Manipulation routines and then stored using the STORE routine of BSDM. After specifying the file name and the storage unit in which the data resides, answer `Yes` to the prompt `Was data stored by this program?` Then, the data and related information is retrieved.

3. The data may be stored as: all observations of variable one followed by all observations of variable two, and so on. This is in the same configuration as data stored by the BSDM routines, i.e., variables = rows and observations = columns. To retrieve the data, give a `Yes` response to the prompt `Is the data in proper configuration ... ?`
4. The data may be stored as: all variables of observation one followed by all variables of observation two, etc. This is the transpose of what is expected by the BSDM routines, i.e., observations = rows, variables = columns. To retrieve this type of data, give a `Yes` response to the prompt `Data stored as contiguous array with observations = rows ... ?`

Notice that in case 2 and 4, the data is stored by a program other than a statistics routine. Thus, no variable names or other auxiliary information is stored along with the data.

As an example, suppose you have run your own program where you have created a file by storing data acquired from three sensors as it came in from the devices. A picture of the five readings (observations) from the sensors look like this:

	Reading				
	1	**2**	**3**	**4**	**5**
Sensor1	7	6	8	8	5
Sensor2	8	9	8	7	8
Sensor3	8	7	7	8	7

If the data is stored in this order: 7, 6, 8, 8, 5, 8,. . . . , 7, 8, 7, then it is in what we call the proper configuration, and the situation is that described in note 3 above.

Conversely, if the data is stored as: 7, 8, 8, 6, 9, 7, . . . , 5, 8, 7, then it is the transpose of what is expected and the situation is that described in note 4 above.

Keyboard Entry. When entering data from the keyboard, an option to enter data one case at a time is offered. The following example explains this feature. Suppose an investigator collects four observations on each of three variables. He has the following data matrix:

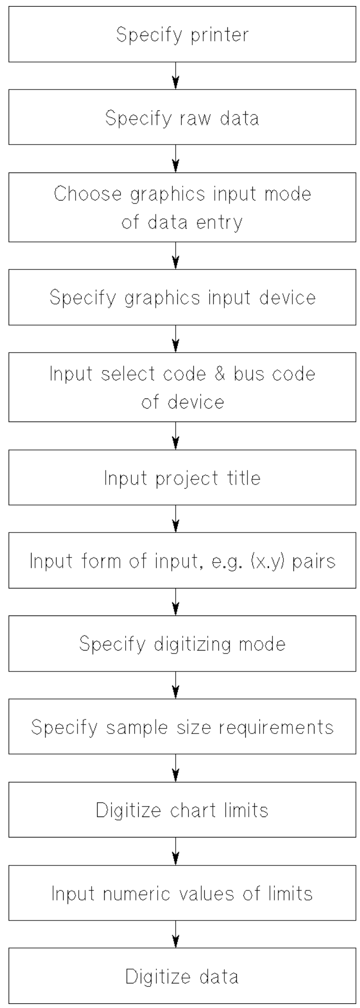
		Variable		
		1	**2**	**3**
	1	10	2	5
Observation	2	11	2	6
	3	9	3	7
	4	9	2	6

He elects to enter the data one case at a time. Then, when the prompt `Observation #, all variables (separated by commas) = ?` is displayed, he enters `10, 2, 5` and selects `Continue` softkey, etc. This allows for quick entry of the data.

The other form of keyboard entry prompts you at each observation for the required variable.

Missing Values. If you have missing values, use an unused number for a temporary code for a missing value. Subsequently you can change your values to the program's value of −9999999.99999 by using the TRANSFORM operation.

Graphics Input. Data may be input by digitizing from a graphics tablet. You may find this form of input very useful. The following diagram briefly describes the types of information requested by the program.



"Other" Input. Because of the wide variety of formats that can be used when entering data from "other" devices, the necessary statements are not programmed in. It is necessary for you to provide the statements before using the program. In general, though, use the following format:

1. Type: `LOAD "FILE1"` (Return)
2. Type: `EDIT Other_input` (Return)
3. Change the 0 to a 1 in line 1731: `Other_input : Implemented=0`
4. Press: (Return)
5. Press: (Stop)
6. Type: `EDIT Otherin` (Return)

7. Type in and enter the appropriate statements for “other” input.

Edit

Object of Program

This program lets you perform a variety of editing procedures on your data set. The editing capabilities include:

Correct a data value
Correct an entire observation
Delete a variable
Delete an observation
Add a variable
Add an observation
Insert an observation (in ordered data)
Delete a subfile

All of these operations may be performed repeatedly. For example, three variables may be added in succession. After the data matrix is edited, you are given the option of listing the data.

Special Considerations

Order of Corrections. As stated in the program note printed on the screen, the data is renumbered after deletions or insertions are performed. For this reason, if more than one deletion (insertion) is to be performed, it is recommended that the highest-numbered observation (or variable) be deleted, then the next highest-numbered, etc.

For example, if observations three and eight are to be deleted, then it is recommended to delete observation eight first, then observation three. Notice that if observation three is deleted first, the subsequent renumbering moves observation eight to portion seven.

The recommendation is meant to alleviate confusion that may occur due to the renumbering. If you delete several observations at once using the answering technique described in the Special Considerations section of BSDM General Informations under “Parser,” you do not need to worry about the renumbering problem.

Your responses are stored from highest to lowest automatically. To delete observations five through eight, just enter `5-8` and you have no problem.

Subfiles. Insertions or deletions of observations affect the content of subfiles that exist at the time of editing. For example, if subfile one consists of the first 10 observations while subfile two consists of the last 20 and if observation five is deleted, then observation ten (formerly numbered 11) jumps from subfile two to subfile one. Thus, it may be necessary to change the subfile structure after editing. It is recommended that subfiles be created only after all editing is performed.

Correcting Data Value(s). When correcting a data value, you must specify the variable number and observation number of the value to be corrected. Then, the old value is displayed prior to your correction so you can be sure you are altering the correct value.

Correcting Observation(s). When correcting an entire observation, you specify the observation to be corrected. The old values are then listed on the screen and you may then enter the new values one at a time.

Adding Observation(s). In adding observations you are asked to enter the number of observations that are to be placed at the end of the data matrix. Enter observations one at a time with the data values separated by commas.

If an observation is to be inserted, the position of the insertion must be specified by entering the number of the existing observation that the insertion needs to precede. For example, if an observation is to be inserted between observations 8 and 9, you must enter `9` when the prompt `Insertion to precede observation #?` is displayed. You are then asked to enter the number of observations that are to be inserted at this point.

Deleting Observation(s). You are asked to enter the numbers corresponding to the observations to be deleted. They are stored and the observations are deleted from highest-numbered to lowest-numbered to avoid renumbering confusion.

Deleting Subfile(s). This option works the same as deleting observations. All you need to specify is the subfile number and all observations within the subfile are deleted. All observations after the ones deleted are renumbered.

Deleting Variable(s). You are asked to enter the numbers corresponding to variables to be deleted. They are stored and the variables are deleted from highest-numbered to lowest-numbered.

Exceeding Program Limitations. If the addition of an observation or of a variable exceeds program limitations, these options are not executed.

Methods and Formulas

The data matrix is redimensioned into a row vector to facilitate the shuffling of elements necessitated by the editing operations. The vector contains all the observations of variable one, followed by the observations of variable two, etc. When an observation is inserted, for example, the elements of the data vector are shuffled one at a time to make room for the incoming observation. Similarly, when an observation is deleted, the remaining observations are "packed" together so that the resultant data vector has no "holes" between observations.

Transform

Object of Program

This procedure lets you transform your data. The transformations available fall into three categories. Algebraic transformations let you perform the standard algebraic operations on one or two variables in the data set. There is also the capability for you to define your own transformation. The second category of transformations is the assigning of missing values. With this section you may assign any value in the data set to correspond to missing data. The final section is new variables. Here, you may perform such operations as generating uniform random numbers, standardizing variables, lagging variables, creating rank variables, sequence variables, and variables corresponding to subfiles.

In all the sections, the transformed results are placed in a variable you specify, either old or newly-created. Hence, transformations on more than two variables may be performed repeatedly or via a transformation defined by you.

Special Considerations

Missing Values (Algebraic Transformations). None of the pre-specified algebraic transformations are applied to missing values. Thus, missing values are unaffected by these transformations. However, this is not necessarily the case with the user-defined transformation. If you define a transformation and there are missing values, you must make provisions to ensure that the transformation is not applied to the missing values (unless, of course, this is desired). This may be accomplished as explained below.

User-Defined (Algebraic Transformations). Before you start to run the Basic Statistics and Data Manipulation program, prepare your own transformation function and store it on the data storage medium. Consider the following example. Suppose your data set consists of four variables. There are missing values. You desire to form variable five as the sum of the exponential of variables one and three. If there is a missing value in either of these variables, you want to assign a missing value to the transformed variable. Recall that the data is of the form D(J,I) where J is the variable number and I is the observation number. In the transformation routine the variable Z is used to denote the variable where the transformed data is to be stored. Thus, to accomplish the above-described transformation, follow the instructions below:

1. Insert flexible disk into the disk drive.
2. Type: `SCRATCH A` (Return)
3. Type: `EDIT` (Return)
4. Now you should be able to see "line number=10" on the upper-left corner of the CRT. Start to type in your function as a subprogram. Press ENTER after each line. For example:

   ```
   10 !A comment to identify perhaps your file name.

   20  SUB Function (D(*),Z,I)
   ```

   this line must be exactly the same as above.

   ```
   30  IF D(1,I)−9999999.99999 AND D(3,I)−9999999.99999 THEN 60
   40  D(Z,I)=−9999999.99999
   50  GO TO 80
   60  D(Z,I)=EXP(D(1,I))+EXP(E(3,I))

   70 !
   ```

   The value of Z will be asked by the program. You must specify the variable numbers for the right hand side of the equation (i.e., 1 and 3)

   ```
   80  SUBEND
   ```

   This line must be the last line of the subroutine

5. Press: CLR SCR
6. Type: `STORE "`*your filename: mass storage identifier*`"` (Return)

Now you can proceed with data entry through BSDM.

Declaring Missing Values. This section lets you assign missing values to any or all of the variables in the data set. It may be used successively so that you can assign different missing values to each variable or different sets of variables. The program asks you to enter the variables to which a missing value is to be assigned. You are then asked what numbers are to be considered missing values for that group of variables. Then, these variables are scanned and all missing values are transformed to −9999999.99999, which is the standard missing value code.

Create Rank Variables. This operation takes a variable, ranks its values in ascending order, and places the resulting ranks in a variable specified by you.

As an example, consider the following variable, which has four observations:

Variable 1
23
25
29
20

You could create a second variable that contains the ranks corresponding to the observations in the first variable. You obtain the following:

Variable 1	Variable 2
23	2
25	3
29	4
20	1

Creating Variables by Subfile. This option may only be used when a subfile structure is present. If used, this option assigns the subfile number associated with each observation to the specified variable.

For a simple example, suppose you have a data set with one variable containing five observations. Subfile one consists of the first two observations, while subfile two has the last three observations. In this case, you could create a second variable whose observations correspond to the subfile numbers associated with the original variable. This variable looks like the following:

Variable 2
1
1
2
2
2

Creating Variables by Sequence Number. By selecting this option, you can place the observation numbers is a specified variable. For example, in a data set with five observations, you could create a second variable that looks like the following:

Variable 2
1
2
3
4
5

Creating Standardized Score Variables. In this option, a chosen variable is standardized by the following formula:

$$New\ Variable = \frac{Specified\ Variable - Mean\ of\ Specified\ Variable}{Standard\ Deviation\ of\ Specified\ Variable}$$

The new variable can be placed in any variable you specify. Notice that standardized variables have a mean of zero and a standard deviation of now.

Creating Lag Variables. The lag variable operation takes the value of a chosen variable n-lags before and uses it as the current observation of the lagged variable being created. As an example, consider the following data set:

		Var.1	Var.2
	1	2	3
	2	1	4
Obs.#	3	4	6
	4	1	2
	5	2	4

We can create variable 3 by lagging variable two by one lag. We can also create variable four by lagging variable one by two lags. We obtain the following:

		Var.1	Var.2	Var.3	Var.4
	1	2	3	MV	MV
	2	1	4	3	MV
Obs.#	3	4	6	4	2
	4	1	2	6	1
	5	2	4	2	4

Notice that missing values are placed in the first n observations of an n-lag variable since lagged values cannot be assigned.

Creating Uniform Random Number Variables. This option lets you generate uniform random numbers between zero and one and have them placed in a variable of your choice.

As an example of the use of this option, you could select a random sample of the observations in your data set to be used in a subsequent analysis. To do this, you could first use the uniform random number option to assign a uniform random number to each observation. Then, you could use the select procedure (described later) to choose a portion of the data set based on the uniform random numbers. For example, if you selected observations that had a corresponding random number value between zero and one-half, you expect to have selected about one-half of your data set.

Recode

Object of Program

This program lets you assign codes to various categories or classes of data. The categories are intervals along the real number line and 20 of these may be specified. The recoding is done on one variable at a time. The same coding scheme may be used repeatedly on successive variables. A summary of the coding intervals, codes, and number of observations assigned to each code is printed as hard copy.

Special Considerations

Coding Schemes. Four coding schemes are available for the sole purpose of eliminating unnecessary entries from the keyboard. If the coding intervals are all of the same length and are contiguous, they form a connected interval, then the interval construction can be accomplished internally knowing only the interval length and lower limit for the first interval. Similarly, if the intervals are if equal length but noncontiguous, for example,

```
[10,20),[25,35),[35,45),[50,60)
```

then the lower limit of each interval needs to be specified but the upper limit may be computed internally. Hence, the coding schemes are meant only to minimize the amount of information that needs to be entered from the keyboard. Clearly, the coding intervals could all be constructed by requiring you to enter the lower and upper limits for each and every interval (which is necessary and is done, if the intervals are unequal and noncontiguous).

Coding is carried out one observation at a time. If you want to recode more than one variable you must use the procedure successively, once for each variable to be recoded. Listed below are the available recoding options.

1. Contiguous intervals of equal length
2. Contiguous intervals of unequal length
3. Non-contiguous intervals of equal length
4. Non-contiguous intervals of unequal length

Option 1 recodes a variable into equally spaced intervals that are side by side. The second option recodes based on intervals of unequal length that are side by side. Option 3 and 4 recodes into intervals that need not be side by side. For equally spaced intervals, use option 3 and for unequally spaced intervals use option 4.

Brackets. The brackets used to denote the coding intervals are meant to follow their usual mathematical interpretation, that is, the intervals are closed on the left and open on the right. Hence, if you want a value to fall into a certain interval, make sure it is strictly less than the upper limit for the interval.

Observations That Do Not Fall in an Interval. If an observation does not fall into any of the coding intervals, a table gives you three options on how to handle these values. You may either 1) leave them unrecoded, 2) assign them a special code, or 3) assign them the missing value code.

Sort

Object of Program

This program allows the data matrix, or individual subfiles of the data matrix, to be sorted according to the values of one variable. For example, suppose you have five observations of three variables, say height, weight, and age, and want to arrange the observations in ascending order according to age. This is accomplished by sorting the data matrix according to variable three. The data may be sorted in ascending or descending order.

If you want to perform a hierarchical sort, the sort procedure must be used successively. For example, suppose you want to sort a data set by weight, and within weight by age. To do this, sort first on age, then use the sort procedure again and sort on weight. The sort procedure also sorts either in ascending or descending order. A sort in ascending order places the observations in order from lowest to highest based on the variable sorted. A descending-order sort puts the observations in order from highest to lowest.

Special Considerations

Subfile Structure Options. If subfiles are ignored, the entire data set is sorted and, in the process, the composition of the subfiles is subject to change. The option of sorting certain subfiles may be used to sort a single subfile or a set of successive subfiles according to one variable. The option of sorting all subfiles may be used to sort each and every subfile. The options of sorting certain subfiles and sorting all subfiles treat each subfile as if it is a separate data set. Thus, the sort is done with respect to one subfile at a time.

What Happens. It is important to note that entire observations are moved when the sort is carried out. Thus, referring to the example given in the Object of Program section above, a person's height and weight remain with the person's age as shown below.

Original Data Set

		Height	Variable Weight	Age
	1	72	170	21
	2	70	165	25
Observation	3	69	150	20
	4	70	165	25
	5	73	160	19

Data Set Sorted by Age

		Height	Variable Weight	Age
	1	73	160	19
	2	69	150	20
Observation	**3**	72	170	21
	4	70	165	25
	5	70	165	25

Subfiles

Object of Program

This program lets you specify subfiles or logical groupings of the observations. This may be accomplished by entering the number of observations in each subfile or by entering the observation number of the first observation in each subfile. A third option is to create subfiles for each level of a specified variable. Names for the subfiles are entered in all cases. A fourth option lets you destroy the existing subfile structure.

Special Considerations

Use of Subfiles. Subfiles may be created in order to specify logical groupings of observations. A subfile structure lets you consider each subfile as a separate data set, or to lump all the subfiles together and analyze the overall data set. For example, suppose you want to determine the output generated each day by each of three shifts. You want to analyze the data separately for each of the three shifts as well as for the work force as a whole. You could form three separate data sets and do the individual analyses, then later join the three sets together for the overall analysis. However, since the same variables are measured for each of the shifts, the situation is well handled by specifying a subfile for each shift. The subfile structure options make it possible to do the analysis by subfile as well as for the overall data set.

Change Names

Object of Program

This program lets you rename the data set, variables, and subfiles. These names are then stored, along with the data, on the program medium's DATA scratch file. You may change a single variable or subfile name, or you may change a set of names.

Store Data

Object of Program

This program lets you store the entire data matrix and related information in a file so that it may be retrieved at later data for further analysis. Alternatively, a subset of the data matrix may be stored by specifying which variables and/or subfiles are to be saved.

Special Considerations

Use of Program. The store feature is useful in two different situations. First, if an investigator has a data set that he may want to analyze further at a later date, he may store it and retrieve it later via the Basic Statistics and Data Manipulation Start routine. Secondly, if several people have access to the data input programs, it becomes mandatory that each be able to store his data set in a unique place. Note that if only one person uses the routine on one data set it is unnecessary to use the store feature since the data and related information are kept in DATA—the scratch file on the program medium.

Protecting Existing Data. The existence of a file is checked in the program in an attempt to avoid the accidental loss of existing data. Thus, when a file is specified to receive the data, an attempt is made to ensure that you are not accidentally storing the new data in a file that you did not know existed.

List

Object of Program

This program lets you obtain a listing of the data matrix. The listing appears on the device that is specified for hard copy in the Start routine or in the Output Unit routine. You can list all the data, or a specified subset of the data. You may also specify how you want the data listed: by observation, by variable, etc.

Join

Object of Program

This program lets you join or combine two data sets into a single unit. One data set must be in memory and the other data set must have been previously stored by the Basic Statistics and Data Manipulation program. Two options are available. First, observations may be added together (if both sets have the same number of variables). Second, variables may be added together (if both sets have the same number of observations). A check is made in the program to make sure the two sets can be joined. Also, summary information on both data sets is printed before the joining operation is performed. Thus, the joining can be aborted if the resultant set is not as expected.

Special Considerations

Adding Observations. Suppose data on six variables are gathered in each of the 52 weeks in 1975, analyzed, and stored on an auxiliary data disk. Suppose the same variables are measured in 1976, analyzed, and stored. If you are interested in lumping the two sets of data together for an overall analysis, you may use the Add Observations option of the joining routine. One set of data must be retrieved via the Start routine. Then, after entering the Join routine, the second set may be retrieved and the joining carried out. Notice that the variables must be in the same order in the two data sets.

Adding Variables. Suppose you measure five variables on each of 50 subjects in an experiment. These are analyzed and stored on disk. Later, you realize that three more variables are of interest. You measure these variables on the subjects in the same order as before and analyze them. All eight variables measured on each subject could be combined into a single data set via the joining routine.

Subfiles. If variables are added, the subfile structure assigned to the resultant data set is the subfile structure of data set #1, that is, the data set that is in memory prior to the joining operation. If observations are added, the following procedures are employed: 1) If no subfiles exist in either data set, the resultant data set has no subfiles. 2) If data set #1 has no subfiles, but data set #2 does, then a subfile named "SET #1" is created that consists of data set #1; and the subfiles of data set #2 remain unchanged. 3) If data set #1 contains subfiles, but data set #2 does not, then a subfile named "SET #2" is created that consists of data set #2; and the subfiles of data set #1 remain unchanged. 4) If both data sets contain subfiles, all of the subfiles of data set #1 are retained and as many data set #2 subfiles as possible are retained—the upper limit of total subfiles for the resultant set being determined by the program limitations (see Special Considerations of Basic Statistics and Data Manipulation).

Printer Is

Object of Program

This program lets you specify the device on which the hard-copy output is printed, or conversely, to specify that no hard copy is desired (output is to be directed to the CRT).

Special Considerations

The hard copy option can be changed in two ways:

1. Select the `PRINTER IS` softkey when you are asked to `SELECT ANY KEY`.
2. This option can only be used when the program is not expecting an answer. For example, when Notes are displayed on the CRT and you are asked to select the `Continue` softkey when ready. The printer may be changed as follows:

   For Non-HP-IB Printer:

   a. Type: `Hc =` *(the select code of the desired printer)* Return

   b. Type: `Hcbus = 999` Return

   For HP-IB Printer:

   a. Type: `Hc =` *(the select code of the desired printer)* Return

   b. Type: `Hcbus =` *(the bus address of the HP-IB device)* Return

Select and Scan

Object of Program

This program lets you look at a portion of your data set that satisfies a conditional statement. If you are scanning the data set, your output includes the observation numbers satisfying the scanning criterion and their distribution throughout the subfile structure. The data set that you are scanning remains unaltered. When using the select option, your output is the same as scanning, but the data set is reduced to just those observations satisfying the selection criterion. Remember, the BACKUP file (explained in Special Considerations of Basic Statistics and Data Manipulation) contains the original data set. The selection and scanning procedure may be performed over all subfiles or over a user-specified subset of the data.

Special Considerations

There are four different scanning or selection criteria offered in this routine. Explanations of each conditional statement follow.

One Variable. This option lets you "edit" your data set based on specified values for one chosen variable. For example, you may scan (or select from) your data set based on variable number two and have the routine report the observations where variable two has any of the following values: 1, 2.6, 4–8.

Variable A OR Variable B. This option lets you "edit" your data set based on specified values of two chosen variables. An OR operation links the two variables. For example, if two of your variables are temperature and humidity, you may want to select (or scan) all observations that have a temperature of 70–80 degrees, OR have a humidity level of 50–80.

Variable A AND Variable B. This option performs much like the OR option, except it uses an AND operator. For example, you may want to select (or scan) all observations that have a temperature of 72 degrees AND a humidity level of 50–80.

Variable A = Variable B. In this case, the observations that are selected (or scanned) are the observations where Variable A has the same value as Variable B. For example, you might want to know which observations have equal temperature and humidity levels.

Basic Statistics

Object of Program

This program computes a variety of summary statistics for data that are entered via BSDM's Start routine. The statistics may be computed by subfile or for the entire data set (ignoring subfiles). Basic statistics that are computed include: number of observations, number of missing values, sum, mean, variance, standard deviation, coefficient of skewness, coefficient of kurtosis, coefficient of variation, standard error of the mean, and a confidence interval on the mean. An option is available to compute a correlation matrix for data sets having more than one variable. Order statistics computed include: the maximum, the minimum, range, and midrange. Additional order statistics that may be computed include: the median, 25th percentile, 75th percentile, Tukey's middlemeans, and user-specified percentiles. These statistics are divided into three groups. You may specify nay or all of the groups for output.

Special Considerations

Parser on Statistics Options. Three options for statistics are offered. They are 1) the common summary statistics, 2) the correlation matrix, and 3) the order statistics such as maximum, minimum, median, etc. You may respond "ALL" to the prompt asking you for your choice of options. Or, you may choose a portion of the options by responding as documented in the General Information section of Basic Statistics and Data Manipulation, for example, 1–2.

Data Type. If the data input type is not RAW DATA, the Basic Statistics may not be computed. For example, Basic Statistics cannot be computed if the covariance matrix is entered as data.

Hard-Copy Output. If a hard-copy of the statistics is not being made, the program halts occasionally so that you may study the results on the CRT. In this case, simply press CONTINUE to continue program execution.

Additional Order Statistics. If the option to obtain additional order statistics (Tukey's middlemeans and percentiles) is exercised, the data matrix is sorted and the observations of each variable are arranged in ascending order. At the end of the program the original data matrix is re-loaded into memory. Thus, if the program is aborted, that is, if the program is stopped before the reloading can occur, the data matrix is in the sorted state. So, if the portion of the program used to calculate additional order statistics is accessed, abortion of the program is discouraged.

Methods and Formulas. Variance: The best unbiased estimator is calculated by these programs. That is, the denominator in the formula is $N-1$, where N is the number of observations used in the calculation.

Correlations: Suppose you have the following data matrix :

		Observation				
		1	**2**	**3**	**4**	**5**
	1	5	M	3	4	5
Variable	2	6	7	M	6	4
	3	1	3	2	1	1

Here, an M denotes a missing value. When computing the correlation between variables 1 and 2, we discard observations 2 and 3 since variable 1 is missing a data value for observation 2 and variable 2 is missing the data value for observation 3. However, when computing the correlation between variables 1 and 3, we need only discard observation 2. Similarly, the correlation between variables 2 and 3 is computed by discarding observation 3. Hence, the correlations many be based on different numbers of observations. An observation is thrown out if a data value from that observation is missing from one of the two variables for which the correlation is being computed.

Tukey's Middlemeans. Midmean: The midmean is the sum of all observations between (and including, if applicable) the 25th and 75th percentiles divided by the number of observations between those two percentiles. That is, it is the mean of all observations between the 25th and 75th percentiles.

Trimean: The trimean is a weighted average of the median and the 25th and 75th percentiles:

(1/4)(25th percentile + 2(median) + 75th percentiles).

Midspread: The midspread is the difference between the 75th and 25th percentiles:

75th percentile − 25th percentile.

Go To Advanced Stat

Objective

This procedure loads a file. Select the `Continue` softkey. The new routines are then prepared to carry on further analyses on the data in memory.

Return To BSDM

Objective

This procedure operates in the reverse of "Go To Advanced Stat" and is used when you want to return to the BSDM routines from an advanced statistics routine.

Backup

Objective

This routine lets you transfer the original data that is stored in the file called BACKUP to the program scratch file called DATA. You might find this useful in a case where the data currently in the DATA file is not the data you want to analyze. This could occur, for example, if you inadvertently store a transformed variable in place of one of your original variables. Note that no operations, including editing, are performed on the data stored in the BACKUP file.

This routine also lets you transfer the data set in the opposite direction. That is, you may transfer the data stored in DATA to the BACKUP file. You might choose to do this after you have edited the original data set but before you perform any other operations. Then, the BACKUP file contains the corrected original data without any further manipulations or modifications.

Statistical Graphics

General Information

Object of Program

This group of nine programs let you quickly get a graphical representation of your data with a minimum number of questions on the CRT screen or an HP-IB Peripheral Plotter.

The entry to every program requires that you specify only the variables to be used and how subfiles are to be treated if they exist. From here on, all plotting parameters are determined by the program, and a plot may be constructed immediately by selecting the plot option from the plotting characteristics menu.

Once the data are specified, you have the option of changing nearly all the plotting parameters in order to construct a more personalized plot. This is done by selecting the option from the plotting characteristics menu.

Any time new variables are defined by selecting the "RESTART" option from the menu, all previous parameters that had been defined are reset to a default value for this particular data set. In order to save the plotting characteristics you have specified, select the store option available in the menu. This stores the plotting characteristics by selecting the load option.

Special Considerations

1. Every time you select a graph type, the CRT is declared as the standard plotting device. This unit may be changed by the "Select Plotter" option from the plotting characteristics menu.
2. Every program begins its execution by reloading the data contained in the "DATA" file.
3. The "RESTART" option always initializes the plotting parameters to default values as follows:
   - The axes labels default to the name of the variable being plotted.
   - The graph title contains the first 33 characters of the data set title. If a subfile is declared, the graph title preceded by the 10-character name given to the subfile.
   - The plotting symbol is a plus sign.
   - Pen numbers are set to 1.
   - The axis parameter is wide enough to contain the data set and has 10 equally spaced tic marks with every second tic mark being labeled.
   - In the special case of the log axis, only complete cycles are plotted on a log scale might be scaled so that it fits in an entire cycle.
   - The graphics device used for plotting is reset to CRT.

Note

After selecting the "OVERLAY" option, new data may be plotted on the previously constructed graph. But, the default values are in effect for pen number and symbol. These may be changed by selecting the "SELECT PLOTTER" and "SELECT NUMBER" options from the Plotting Characteristics menu.

4. Whenever the program identifies an incorrect response, the question is asked again, until the correct response is given.
5. Most plotting symbols are centered on top of the point they are designating. For some special characters, like the period and comma, the symbols are plotted in a lower position.
6. The graphics programs allow up to six decimal places for labeling the axis tic marks. For data that needs more, it is suggested that it be transformed.
7. Each program handles missing values in a different way. See the individual programs for details.
8. When asking for labeling information, error 18 occurs if the label is too long. To recover, shorten the label and re-enter the information.
9. Do not select the RUN softkey or press Shift Break (Reset) keys unless it is necessary. The RUN softkey erases all variables, and Reset may erase memory.
10. To prevent a graph segment from being plotted, assign a pen number of -1 for the CRT or 0 for an external plotter to that segment using the select pen numbers option.

Note Statistical Graphics may be entered from the BSDM system by selecting the Advanced Statistics option. Once in the Statistical Graphics package, select the type of plot you want to do from the menu provided.

Common Plotting Characteristics

The following options are available for all nine of the plots, so their description and operation are explained in this section. There are slight deviations in the way some of these options work for the different plots. these differences are explained in the sections that describe each plot. It is recommended that you read through the section for the particular plot you want to do before using the program. Not all plotting characteristics can be changed in each program.

Restart

When this option is selected, all plotting parameters for the data set are reset to the default values that the program determines for the data set. At this time a new variable to be plotted may be selected.

Plot

This option plots the variable(s) being considered. The plot is done on the CRT if no other device is specified. If you have not specified any plotting parameters, the ones determined by the program are used, otherwise, the plotting characteristics you specified are used. You may choose whether or not to connect the points on most of the graphs, and whether or not to put grid lines on the graph.

X-axis

This option lets you designate the scale for the x-axis. You determine the minimum x value, the maximum y value, the distance between the tic marks on the axis, and how many places after the decimal point you want printed. Since complete cycles on the x-axis are required by the semi-log, log-log, normal and Weibull plots, this option may not be used in those routines.

Y-axis

This option lets you designate the scale for the y-axis. You determine the minimum y value, the maximum y value, the distance between the tic marks on the axis, and how many places after the decimal point you want printed. Since full cycles on the y-axis by the log-log and Weibull plots, this option may not be used in those routines.

Labels

This option lets you change the labels of your graph. You have an opportunity to change the x-axis label, the y-axis label, and the title of the graph.

Symbols

This option lets you change the labels of your graph. You have an opportunity to change the x-axis label, the y-axis label, and the title of the graph.

Dump Graphics On CRT

This option prints the most recent CRT graph on the printer. This option may be used *only* if your printer has graphics capabilities.

Select Plotter

This option lets you select the plotting device on which you want to have the plot drawn. You may have the plot done on the CRT or and external plotter. You need to input the select and bus codes. You also need to input a plotter identification string.

Select Pen Color

This option lets you select the pen number you want to use for plotting your graph. The pen number used may be changed for axes and numeric labels, grid lines, labels, points and center line, upper control line and lower control line of the time plot.

Overlay

This option, when available, lets you add another plot of the same type with new variables on the previously constructed plot. The plotting limits remain as you have specified.

Store

This option lets you store the plotting characteristics that you have specified so that they may be retrieved at a later time. To do this, you need to specify a file name and where you want to store the information.

Load

This option lets you retrieve the plotting characteristics that are stored previously for this type of plot. You need to specify the name of the file and where it is stored. The program then lists the stored plotting characteristics.

Return

This option returns the program to the main STATISTICAL GRAPHICS MENU.

Time Plot

Object of Program

This program plots any variable in increasing units of time or sequence number. This plot is useful in determining the effect that time/sequence may have on a variable. The program allows the initial time to begin the plotting and the time period between points to be set by selecting the "X AXIS" option. If the plot option is selected first, the program defaults to a starting time of 1 and time increment period of 1.

Special Considerations

1. Missing values are not plotted. The value at this time period is left blank.
2. When doing an overlay of the data, the initial time and time increments are 1 unless changed by selecting the x-axis option. Once the values have been changed, they retain the new values until they are changed again.

Special Plotting Characteristics

X-axis. This option lets you determine the scale for the time axis. You need to specify the minimum and maximum time values, and the distance between tic marks. In addition, you need to specify the initial time for beginning series, the point in time that the plotting begins, and time increments between points, how much time passes between each plotted point.

Overlay. This option lets you plot another variable over an already constructed graph.

References

1. EXPLORATORY DATA ANALYSIS, John W. Tukey; 1977; Addison Wesley.
2. "A Review of Some Smoothing and Forecasting Techniques," T. J. Boardman and M. C. Bryson, Journal of Quality Technology, Volume 10, Number 1, January, 1978.

Histogram

Object of Program

This program creates a histogram with up to forty cells. For every data set, the sample mean, the sample variance, the number of cases used to calculate them, and the cell statistics are printed.

Different histograms may be created by specifying the number of cells to be used, and the cell locations, or by specifying the number of cells, the location of the first cell, and the cell width. These specifications may be given by selecting the "CELL LIMIT" option from the Plotting Characteristics menu.

A normal curve overlay and the corresponding Chi-squared goodness-of-fit statistic may be obtained by selecting the "NORMAL CURVE OVERLAY" option from the Plotting Characteristics menu.

Special Considerations

1. Missing values are not considered in any calculation, and are not considered in constructing any cell.

2. Maximum number of forty cells may be obtained.
3. At least four cells are needed to perform a chi-squared goodness-of-fit test.

Special Plotting Characteristics

Cell Limits. This option lets you specify the cell size for the histogram. There are two ways of doing this:

1. Enter the number of cells (greater than 1 but not more than 40), and enter the minimum cell value and the maximum cell value that is used.
2. Enter the number of cells (greater than 1 but less than 40), and enter the minimum cell value and the width of the cell.

The program then gives you a list of the number of cells, their minimum and maximum bounds, and the number of observations in each cell.

Normal Curve Overlay. This option does a chi-square goodness-of-fit test of the data. In order to do this at least four cells must be specified; if four cells have not been specified, an error is printed. The descriptive statistics for each cell are printed. the contributions to the chi-squared statistics are added together to get the final value. The cells on the tails collapse together until an expected frequency of at least three and less than seven is found, and then the contribution is calculated. If, after collapsing the end cells to get high enough frequencies, the number of terms in the contribution of the chi-squared value go below for then another error is printed.

Once this is done the normal curve for the desired plot is plotted over the histogram.

Methods and Formulae

Xi = ith observation of the selected variable that is not a missing value

N = number of valid observations

$$\overline{X} = \sum_{i=1}^{N} \frac{X_i}{N}$$

$$Variance = \frac{\sum_{i=1}^{N} {X_i}^2 - \frac{\left(\sum_{i=1}^{N} X_i\right)^2}{N}}{N-1}$$

$$Normal\ Curve\ overlay = \frac{100 \times (Cell\ width) \times EXP\left(\frac{X-\overline{X})^2}{2 \times Variance}\right)}{\sqrt{2\pi \times Variance}}$$

$${\chi_{df}}^2 = \sum_{i=1}^{\sharp\ cells} \frac{(Observed\ frequency\ in\ cell\ i - Expected\ frequency\ in\ cell\ i)^2}{Expected\ frequency\ in\ cell\ i}$$

df = (# of cells) − 3; because 1 degree of freedom is lost for number of cells, 1 for the estimated mean, and one for the estimated variance.

The expected frequency of cell i = area under the normal curve overlay that falls in cell i is calculated by determining the left side of the cell i(A), and the right side of the cell i(B) and finding:

$$\Phi\left(\frac{B - Xbar}{standard\ deviation}\right) - \Phi\left(\frac{B - Xbar}{standard\ deviation}\right)$$

Then use the following approximation for the area between A and B in a standard normal.

$$\Phi(X) = 1 - Z(X)(b_1 t + b_2 t^2 + b_3 t^3 + b_4 t^4 + b_5 t^5) + E(X)$$

$$where|E(X)| < 7.5 \times 10^{-8}$$

$$t = (1 + 0.231649X)^{-1}$$

$$b_1 = 0.31938153$$

$$b_2 = 0.35656378$$

$$b_3 = 1.781477939$$

$$b_4 = 1.821255978$$

$$b_5 = 1.330274429$$

$$for X > 0$$

$$and 1 - \Phi(|X|) for X \leq 1$$

$$Z(X) = \frac{1}{\sqrt{2\pi}} exp\left(-\frac{X^2}{2} right\right)$$

To calculate the right tailed probability value associated withe the Chi-square value we use

$$P(X^2\nu > calculated\ value) = 1 - \frac{\frac{\chi^2}{2} exp\left(-\frac{\chi^2}{2}\right)}{\Gamma\left(\frac{\nu+2}{2}\right)} times C$$

$$C = 1 + \sum_{R=1}^{\chi} \frac{\chi^{2R}}{(\nu+2)(\nu+4)\cdots(\nu+2R)}$$

References.

1. An Introduction to Statistical Methods and Data Analysis, Lyman Ott; 1977; Wadsworth.
2. Statistics for Modern Business Decisions, Second Edition, Lawrence Lapen; 1978; Harcourt, Brace, Jovanovich
3. Statistical Analysis for Decision Making, Second Edition, Morris Hamburg; 1977; Harcourt, Brace, Jovanovich
4. Fundamental Statistics for Business and Economics, Fourth Edition; Neter, Wasserman, and Whitmore; 1973; Allyn and Bacon
5. Handbook of Mathematical Functions, Abramowitz, Stegun; Fifth Printing; 1965 Dover Publications.

Scattergram

Object of Program

This program plots points on a graph according to the two variables you specify. The plot is useful in determining if there is any relationship between two variables.

Special Considerations

For any point where either the X or Y coordinate is missing, the point is not plotted.

Changes Necessary For Larger Data Sets

Caution

Increasing the size of the data set may cause a problem. There may not be enough room on the program disc to store the enlarged data set. To find out, proceed as follows.

a. Perform the following check on the Basic Statistics disk and the Advance Statistics disk:

1. Make sure nothing of value is in the scratch file “DATA.” If there is, use the STORE routine to save it.
2. Type: `PURGE "DATA"` (Return)
3. Type: `CREATE "DATA", 2+(8*n) DIV 1280, 1280` (Return)

   where n is the maximum number of data values you want to use in the statistics routines (and is equal to number of variables times number of observations per variable).

In addition, follow the above procedure for the file name “BACKUP” on the Basic Statistics disk.

If you obtain an error using the above procedure on any of the program tapes or discs, you must transfer all data to a larger media in order to expand the data set.

b. Make the following change to Basic Statistics to Data Manipulation:

1. Type: `LOAD "FILE1"` (Return)
2. Type: `CHANGE "Mno=1500" TO "Mno=xxxx"` (Return)

   where `xxxx` is the maximum number of data values you want to use in the statics routines. This must be more than or equal to 1500.
3. Press: (Return)
4. Type: `PURGE "FILE1"` (Return)
5. Type: `STORE "FILE1"` (Return)

Note

Maximum number of variables is 50 and cannot be changed by the user.

Statistics Library Data Formats

The following is a description of the data format used in the Statistics Library. Also included is an explanation of the steps you need to perform to have a program create data compatible with the library.

Method 1: Numeric Data Only

If you want to have another program, write a data file that is compatible with the library. It is important to note that the actual numeric data could be written in one of two forms:

		Observations				
		0_1	**0_2**	**0_3**	$\cdots$	**on**
	V_1					
	V_2					
Variables	V_3					
	:					
	:					
	Vp					

OR

		Variables				
		V_1	**V_2**	**V_3**	$\cdots$	**V_p**
	O_1					
	O_2					
Observations	O_3					
	:					
	:					
	O_n					

The statistics library prompts you for additional information such as sample size (No), number of variables (Nv), title of the data set, and names of the variables. The statements needed to store the data are as follows:

```
10  OPTION BASE 1
20  Nv=3
30  No=10
40  ALLOCATE D(Nv,No)
50  !
60  ! Put data into matrix D
70  !
80  CREATE BDAT "DATA_FILE",2+((8*Nv*No) DIV 1280),1280
90  ASSIGN @File TO "DATA_FILE"
100 OUTPUT @File;D(*)
110 ASSIGN @File TO *
120 END
```

8bytes per entry and 1280 bytes per ligical record

Method 2: Numeric Data and Descriptive Data

If you want to have another program, write a data file that is compatible with the library and, if you want to have it store descriptive information as well, you need to prepare the file in a slightly different manner.

The following data is stored in record 1 of the data file:

Data set title	T$[80]
Number of observations	No
Number of variables	Nv (max. is 50)
Variable names	Vn$(50)[10]

Number of subfiles	Ns (max. is 20)
Subfile names	Sn$(20)[10]
Subfile characterizations	Sc(20)

Note Declare No, Nv, Ns, and the array Sc(*) in real precision.

Starting with record 2, the Statistics Library expects to find the data array. The statements needed to store the data are as follows:

```
10  OPTION BASE 1
20  Nv=3
30  No=10
40  ALLOCATE D(Nv,No)
50  DIM T$[80],Vn$(50)[10],Sn$(20)[10],Sc(20)
60  !
70  ! Put data into matrix D and descriptive data into other variables
80  !
90  CREATE BDAT "DATA_FILE",2+((8*Nv*No),Ns,Sn$(*),Sc(*)
100 ASSIGN @File TO "DATA_FILE"

110 OUTPUT @File,1;T$,No,Nv,Vn$(*),Ns,Sn$(*),Sc(*)
```

Write record 1

```
120 OUTPUT @File,2
130 OUTPUT @File;D(*)
```

Write record 2,3,..

```
140 ASSIGN @File TO *
150 END
```

When using this format and the Statistics Library asks you the question, `Was the data stored by the BS&DM system?`, answer `Yes`. This tells the library to expect the header record as record #1.

C

System Software Enhancements

To get the most out of your HP 4062C/UX/PC, this appendix provides several easy-to-implement system software enhancements and modifications that can enhance the performance of your HP 4062UX.

Software Organization (HP 4062C/PC)

All the HP 4062C/PC software is contained on five 3.5 inch micro flexible disks. If you store your system software on an external mass storage device, you can substantially reduce software loading time by eliminating the need to manually change disks.

The START Program

By altering the START program in a few places, you can simplify system operation and facilitate operator convenience.

Caution

Do not modify or delete any of subprogram names (Error_recover3, Set_clock, and so on). Doing so may result in incorrect START program execution.

For HP 4062UX

Figure C-1 shows a partial listing of the START program. The program labels listed in this figure indicate where to make the suggested modifications. The numbers in Figure C-1 are keyed to the following enhancement hints:

1. The START program is a compilation of subprograms you can use to create your own autostart program. If you are using an external mass storage device, an autostart program is particularly useful because the START program is executed immediately when you turn your HP 4062UX on, thereby eliminating the need to manually load and run START each time you turn your system on.
2. The START program has an optional parameter for setting the test execution mode. Parameter 0 is for the online mode; parameter 1 is for the online debug mode; parameter 2 is for the offline mode. When you want the HP 4062UX in the online mode only, modify the START program as follows:

```
! "@(#) PROGRAM START
!                                     Copyright Hewlett-Packard Company.
 !!!!
```

```
 Start(0)
 END
!*********************************************************************
!
```

3. This START program segment loads KEY300, which is the file that contains the system softkey definitions and labels. To make it easier to perform functions particular to your system, you can generate a softkey file to suit your measurement needs, and use this file to replace KEY300, as in the following example:

   ```
   LOAD KEY "/users/etc/MYKEY"
   ```

```
1. and 2.

 ! "@(#) PROGRAM START
 !                                        Copyright Hewlett-Packard Company.
  Start
  !!!!  Start(0)
  END
 !*********************************************************************
 !
!
  SUB Start


3.

Error_recover3:!
       OFF ERROR
       Prober_init(Prober_name$)
       Display_config(Prober_name$,Session_id$,Mode)
!
!     *---
          :
!
!     *---            ;;; Load Aid Key Definitions
          ON ERROR GOTO Error_recover4
          LOAD KEY "/usr/pcs/etc/KEY300:HFS"
```

Figure C-1. START Program Enhancements of HP 4062UX

For HP 4062C/PC

Figure C-2 shows a partial listing of the START program. The program labels listed in this figure indicate where to make suggested modifications. The numbers in Figure C-2 are keyed to the following enhancement hints:

1. The START program is a compilation of subprograms you can use to create your own autostart program. If you are using an external mass storage device, an autostart program is particularly useful because the START program is executed immediately when you turn

your HP 4062C/PC on, thereby eliminating the need to manually load and run START each time you turn your system on.

2. This START program segment loads KEY300, which is the file that contains the system softkey definitions and labels. To make it easier to perform functions particular to your system, you can generate a softkey file to suit your measurement needs, and use this file to replace KEY300, as in the following example:

   ```
   LOAD KEY "/USERS/ETC/MYKEY"
   ```

3. This START program segment lets you update time and date information. If you decide that this is not necessary, you can omit this portion of the program. To do so, delete the INPUT statements as shown in Figure C-2.

   It is also advisable to omit the PRINT statements from this portion of the program. Even if you have omitted Set_clock, you can still set the system date and time by using the SET TIMEDATE command. Refer to the *BASIC Programming Techniques Manual* for details.

4. This START program segment loads your CODEWORD, which is the file that contains the special codeword that lets you access your HP 4062C software. You can shorten the loading time of the codeword file by writing your codeword into the START program as shown in Figure C-2.

```
1.

  ! "@(#) PROGRAM  START
  !                                  Copyright Hewlett-Packard Company.
  !
  Start
  END
  !*******************************************************************
  !
  SUB Start


2.

 S2:!
!
!     *---                        ;;; Load Aid Key Definitions
    CONTROL KBD,14;0
    STATUS KBD,9;Stat
    Itfkbd=(BINAND(Stat,35)=32)
    CLEAR ERROR
    ON ERROR GOTO Loadkey_err
    IF Itfkbd THEN
      LOAD KEY "/usr/pcs/etc/KEY300:HFS"
    ELSE
      LOAD KEY "200"
    END IF


3.

 Set_clock:
    OFF ERROR
    BEEP 600,.1
    PRINT TABXY(1,18);"System date & time:  ";
    PRINT DATE$(TIMEDATE);"  ";TIME$(TIMEDATE)
    Systime$=""
  ! INPUT "New system date ?",Systime$
    ON ERROR GOTO Set_clock
    IF Systime$"" THEN SET TIMEDATE DATE(Systime$)+TIME(TIME$(TIMEDATE))
    OFF ERROR
    PRINT TABXY(1,19);"System date & time:  ";
    PRINT DATE$(TIMEDATE);"  ";TIME$(TIMEDATE)
    Systime$=""
  ! INPUT "New system clock time ?",Systime$
    ON ERROR GOTO Set_clock
    IF Systime$"" THEN SET TIME TIME(Systime$)
    OFF ERROR
```

Figure C-2. START Program Enhancements of HP 4062C

```
 4.

  Generate_com;!
     INTEGER I,J
     DIM Codewords$(1:100)[16],S$[255]
 !
 !     *---                      ;;; Generate CSUB TIS COM Area
     I=-1
     ON ERROR GOTO Err_codeword
     Codewords$(1)="1234567890123456"
  Err_codeword;!
     OFF ERROR
     Setup_com(Codeword$(*),I,Authorized)
     IF NOT Authorized THEN CALL Error_rep(0)
 !
   SUBEND
```

START Program Enhancements of HP 4062C (Continued)

Softkeys

Suppose you frequently run a program called "WAFER_TEST", and this program requires that TIS be linked. You could define one of the KEY300 softkeys as follows:

- For the HP 4062UX

  When the file is stored in the /users/user1 directory:

  ```
  KEY 1
  K#  TEST  K#LOAD "/users/user1/WAFER_TEST:HFS"KELOADSUB ALL FROM
  "/usr/pcs/lib/TIS:HFS"KE
  ```

- For the HP 4062C/PC

  When the file is stored in the /USERS/USER1 directory:

  ```
  KEY 1
  K# TEST K#LOAD "/USERS/USER1/WAFER_TEST:HFS"KELOADSUB ALL FROM
  "/PCS/LIB/TIS:HFS"KE
  ```

Subprogram Library File

All the HP 4062C/UX/PC subprograms that you can call are categorized according to their function. If all of these subprograms are combined into one "subprogram library file," you can link them all by performing only one operation instead of linking each subprogram separately. In addition, if you've written a subprogram that you need to run often, include your subprogram in your library file, too. The procedure for creating this file from TIS, PARA, XYGRAPH, and WAFER subprograms is as follows:

1. Clear your system controller's memory.

   `SCRATCH A` (Return)

2. Load TIS.

   - For HP 4062UX:

     `LOAD "/usr/pcs/lib/TIS"` (Return)

   - For HP 4062UX with the recommended directory structure:

     `LOAD "/PCS/LIB/TIS"` (Return)

3. Load the VFP, PARA, XYGRAPH, and WAFER subprograms one at a time.

   - For HP 4062UX:

     `LOADSUB ALL FROM "/usr/pcs/lib/`*subprogram*`"` (Return)

   - For HP 4062C/PC with the recommended directory structure:

     `LOADSUB ALL FROM "/PCS/LIB/`*subprogram*`"` (Return)

4. Add a comment to show the contents of your subprogram library file, as follows:

```
10  ! LIBRARY "LIB_4062" (TIS,VFP,PARA,XYGRAPH,WAFER)
20  !                                  Copyright Hewlett-Packard Company.
30  END
40  !***************************************************************
```

5. Store your file.

   - For HP 4062UX:

     `STORE "/users/LIB_4062"` (Return)

   - For HP 4062C/PC with the recommended directory structure:

     `STORE "/USERS/LIB_4062"` (Return)

6. Define your file to a softkey in place of LINK TIS, as follows:

   - For HP 4062UX:

     `LOADSUB FROM "/users/LIB_4062"`

   - For HP 4062C/PC with the recommended directory structure:

     `LOADSUB FROM "/USERS/LIB_4062"`

Now, whenever you need to load any of these subprograms, all you need to do is select the softkey you defined.

Note

For BASIC or BASIC/UX subprograms, only the subprograms that are actually called in your measurement program will load when you load LIB_4062. For CSUBs (compiled subprograms), however, all CSUBs will load, even if you only call one CSUB in your measurement program.

D

PARA and XYGRAPH Programming Hints

The PARA and XYGRAPH subprogram libraries are for users who are not accustomed to using TIS or who are not familiar with the intricacies of graphics programming. Though versatile, PARA and XYGRAPH subprograms are general in nature and may not satisfy the requirements of specific applications.

For example, PARA subprograms reduce measurement speed, and XYGRAPH subprograms may not be able to correctly plot the Vgs-Id curves of some FETs. These are not severe limitations, however, since, unlike TIS subprograms, PARA and XYGRAPH subprograms are not secured. You can modify them to satisfy your application needs.

This appendix contains hints on how to modify PARA and XYGRAPH. Included for reference purposes are flow diagrams of each subprogram and listings of the variables used in the subprograms.

PARA Functions and Subprograms

PARA functions and subprograms are written with versatility in mind, to enable you to use them in virtually any application program. The main features of PARA functions and subprograms are as follows:

- Efficient use of ports.
- PARA functions affect only the specified connections and settings. Other pin-to-port connections and the settings of other ports are unchanged by PARA functions.
- PARA functions establish pin-to-port connections before a measurement begins, set the ports used in a measurement to Zero Output status, and disconnect pin-to-port connections after a measurement.
- Sets optimum hold times to ensure correct measurement results.
- Returns −9999999.99999 as a measurement result if an abnormal status is detected during a measurement.

This section provides PARA operating hints, flow diagrams, and variable lists to facilitate your use of these functions and subprograms.

FNR2t

Operating Hints

- Detecting an Invalid Measurement:

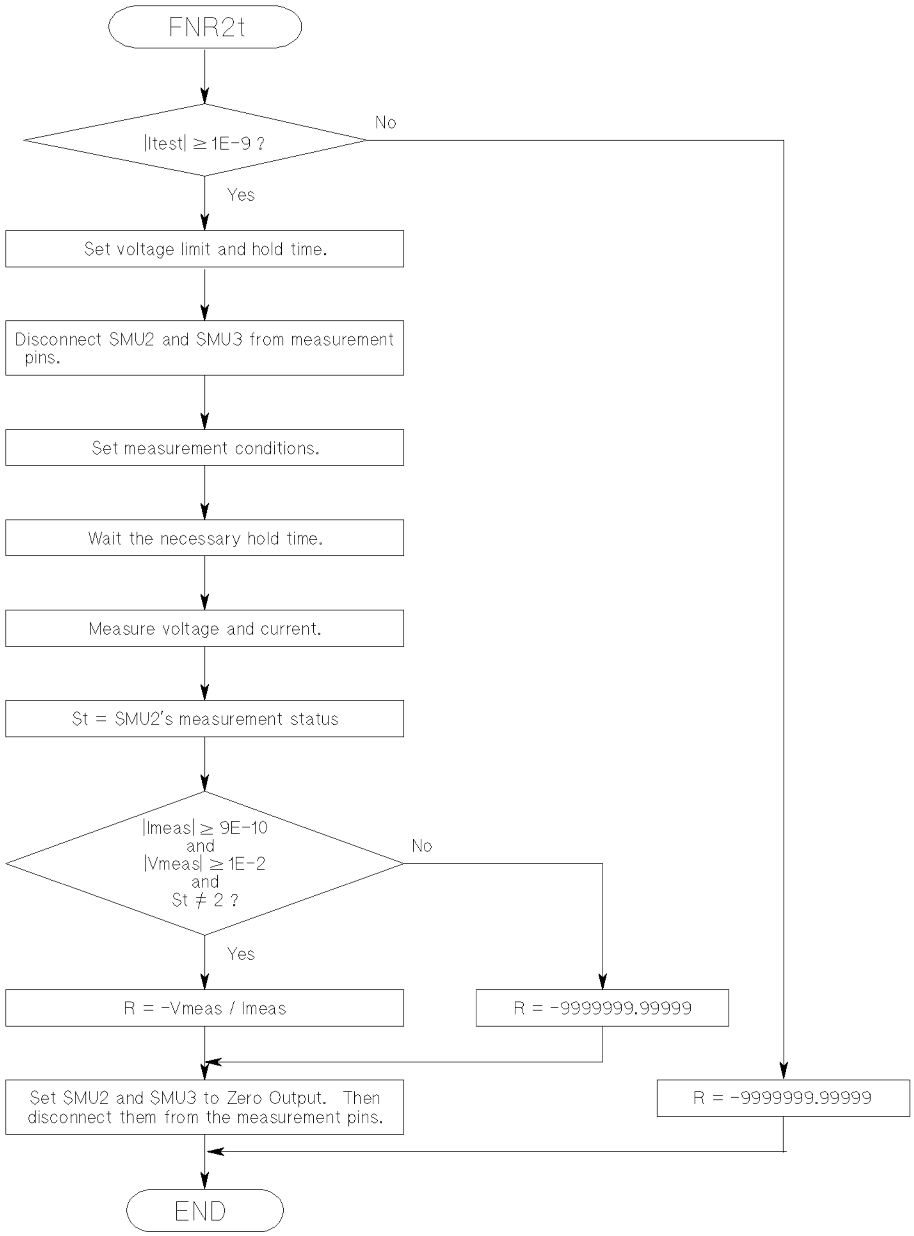
  FNR2t returns −9999999.99999 instead of the actual measurement results if an abnormal condition occurs during a measurement. For example, if SMU2's current measurement value is less than 900 pA, if SMU3's voltage measurement value is less than 10 mV, or if SMU2 reaches compliance, FNR2t returns −9999999.99999.

  To prevent the occurrence of abnormal conditions such as these, set a fairly high test current when measuring low resistance devices. Note, however, that if you set the test current to 100 mA, SMU2 may reach compliance.

- Increasing Measurement Speed:

  Set the test current for a measurement to greater than 20 μA to reduce hold time. FNR2t sets hold time in accordance with the specified test current to ensure that a measurement is performed after your test device reaches stability. Change hold times as required, depending on the characteristics of your test devices.

FNR2t


FNR2t
|Itest| ≥ 1E-9 ?
No
Yes
Set voltage limit and hold time.
Disconnect SMU2 and SMU3 from measurement pins.
Set measurement conditions.
Wait the necessary hold time.
Measure voltage and current.
St = SMU2's measurement status
|Imeas| ≥ 9E-10 and |Vmeas| ≥ 1E-2 and St ≠ 2 ?
No
Yes
R = -Vmeas / Imeas
R = -9999999.99999
Set SMU2 and SMU3 to Zero Output. Then disconnect them from the measurement pins.
R = -9999999.99999
END

FNR2t Variables

Variable Name	Description
Iforce	Absolute value of Itest
Imeas	SMU2's current measurement value
Itest	SMU3's output current (pass parameter)
Pin1	Measurement pin to be connected to SMU2 (pass parameter)
Pin2	Measurement pin to be connected to SMU3 (pass parameter)
Port(2)	SMU2's port address (32702)
Port(3)	SMU3's port address (32703)
R	Resistance calculated from the voltage and current measurement values (return parameter)
St	SMU2's measurement status
Twait	Hold time to allow a test device to stabilize:
	Twait = 0.01 when 1E−1 $\geq$ |Itest| > 2E−5
	Twait = 0.4 when 2E−5 $\geq$ |Itest| > 3E−8
	Twait = 5 when 3E−8 $\geq$ |Itest| > 5E−9
	Twait = 10 when 5E−9 $\geq$ |Itest| > 1E−9
Vlim	Voltage limit across a test device (pass parameter)
Vlimit	SMU3's voltage compliance (=Vlim)
	If Vlim is 0 or is not included in the pass parameter list, Vlimit is set to 20.
Vmeas	SMU3's voltage measurement value

FNR2t Port-Related Variables/Constants

Measurement Pin Variables	Port Variables/Constants				
	Port	Mode	I/V Output	I/V Measurement	Compliance
Pin1	SMU2	VS	0 [V]	Imeas	1E−1 [A]
Pin2	SMU3	IS	Itest [A]	Vmeas	Vlimit [V]

FNR4d

Operating Hints

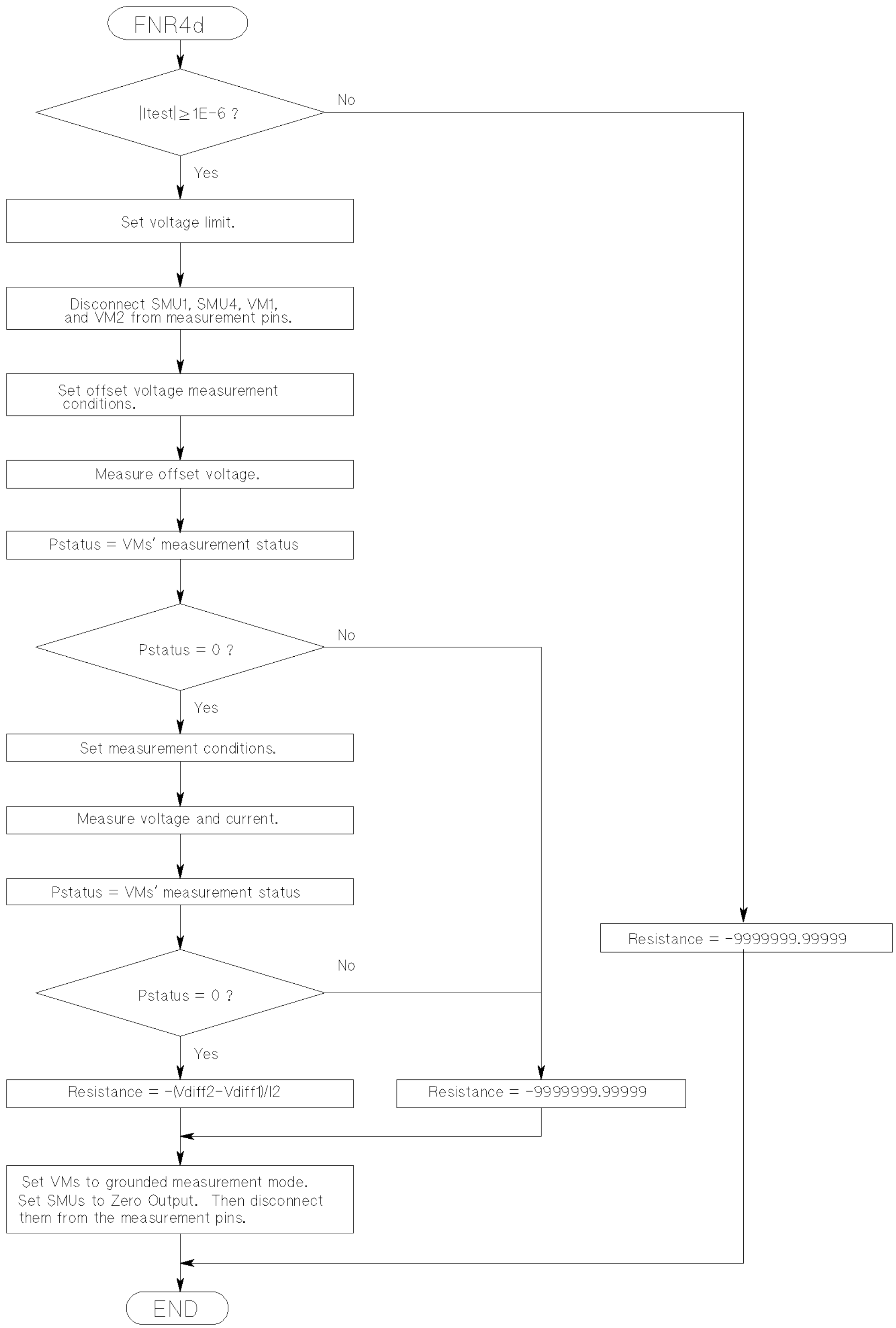
- Detecting an Invalid Measurement:

  FNR4d returns −9999999.99999 instead of the actual measurement results if an abnormal condition occurs during a measurement. For example, if the specified test current is less than 1 μA, if a VM's voltage measurement value is greater than 2 V, or if SMU1 reaches compliance, FNR4d returns −9999999.99999.

  To prevent the occurrence of abnormal conditions such as these, set a fairly high test current when measuring low resistance devices. Note, however, that if you set the test current to 100 mA, SMU4 may reach compliance.

- Increasing Measurement Speed:

  Set the test current for a measurement to greater than 20 μA to reduce hold time. FNR4d sets hold time in accordance with the specified test current to ensure that a measurement is performed after your test device reaches stability. Change hold times as required, depending on the characteristics of your test devices.


FNR4d
|Itest| ≥ 1E-6 ?
No
Yes
Set voltage limit.
Disconnect SMU1, SMU4, VM1, and VM2 from measurement pins.
Set offset voltage measurement conditions.
Measure offset voltage.
Pstatus = VMs' measurement status
Pstatus = 0 ?
No
Yes
Set measurement conditions.
Measure voltage and current.
Pstatus = VMs' measurement status
Pstatus = 0 ?
No
Yes
Resistance = -(Vdiff2-Vdiff1)/I2
Resistance = -9999999.99999
Resistance = -9999999.99999
Set VMs to grounded measurement mode. Set SMUs to Zero Output. Then disconnect them from the measurement pins.
END

FNR4d Variables

Variable Name	Description
I2	SMU4's current measurement value
Ipin1	Measurement pin to be connected to SMU1 (pass parameter)
Ipin2	Measurement pin to be connected to SMU4 (pass parameter)
Itest	SMU1's output current (pass parameter)
Pstatus	VMs' measurement status
Resistance	Resistance calculated from voltage and current measurement values (return parameter)
Vdiff1	VM offset voltage measurement value
Vdiff2	VM voltage measurement value
Vlim	Voltage limit across a test device (pass parameter)
Vlimit	SMU1's voltage compliance (= Vlim)
	If Vlim is 0 or is not included in the pass parameter list, Vlimit is set to 20
Vpin1	Measurement pin to be connected to VM1 (pass parameter)
Vpin2	Measurement pin to be connected to VM2 (pass parameter)

Measurement Circuit 1 Port-Related Variables

Measurement Pin Variables	Port Variables/Constants				
	Port	Mode	I/V Output	I/V Measurement	Compliance
Ipin1	SMU1	IS	Itest [A]	I2	Vlimit [A]
Ipin2	SMU4	VS	0 [A]	—	1E−1 [A]
Vpin1	VS1	—	—	Vdiff2	—
Vpin2	VS2	—	—	Vdiff2	—

Measurement Circuit 2 Port-Related Variables

Measurement Pin Variables	Port Variables/Constants				
	Port	Mode	I/V Output	I/V Measurement	Compliance
Ipin2	SMU4	VS	0 [A]	—	1E−1 [A]
Vpin1	VS1	—	—	Vdiff1	—
Vpin2	VS2	—	—	Vdiff1	—

FNR4t

Operating Hints

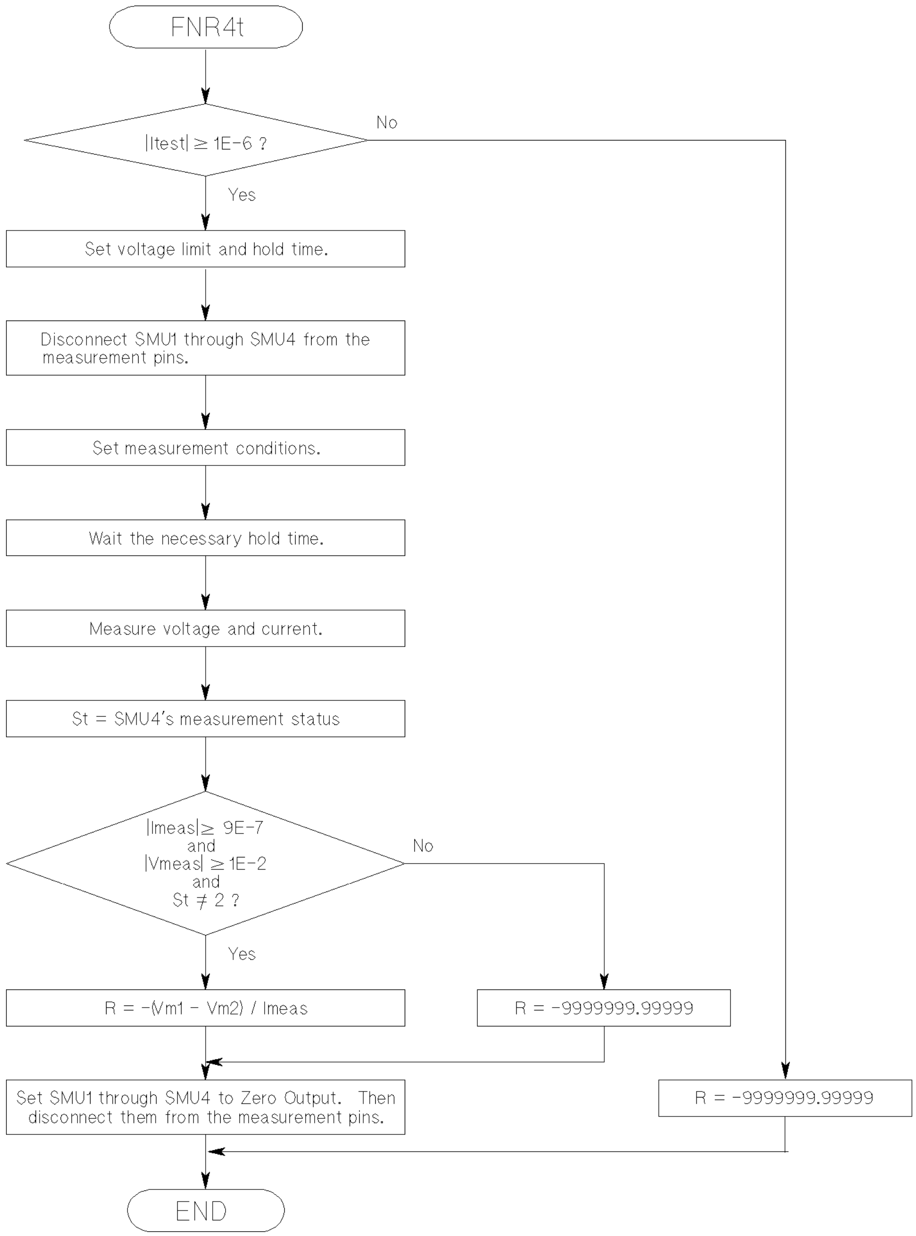
- Detecting an Invalid Measurement:

  FNR4t returns −9999999.99999 instead of the actual measurement results if an abnormal condition occurs during a measurement. For example, if SMU4's current measurement value is less than 900 nA, if SMU2's voltage measurement value is less than 10 mV, or if SMU4 reaches compliance, FNR4t returns −9999999.99999.

  To prevent the occurrence of abnormal conditions such as these, set a fairly high test current when measuring low resistance devices. Note, however, that if you set the test current to 100 mA, SMU4 may reach compliance.

- Increasing Measurement Speed:

  Refer to the Operating Hints for FNR2t.


FNR4t
|Itest| ≥ 1E-6 ?
No
Yes
Set voltage limit and hold time.
Disconnect SMU1 through SMU4 from the measurement pins.
Set measurement conditions.
Wait the necessary hold time.
Measure voltage and current.
St = SMU4's measurement status
|Imeas| ≥ 9E-7 and |Vmeas| ≥ 1E-2 and St ≠ 2 ?
No
Yes
R = -(Vm1 - Vm2) / Imeas
R = -9999999.99999
Set SMU1 through SMU4 to Zero Output. Then disconnect them from the measurement pins.
R = -9999999.99999
END

FNR4t Variables

Variable Name	Description
Iforce	Absolute value of Itest
Imeas	SMU4's current measurement value
Ipin1	Measurement pin to be connected to SMU1 (pass parameter)
Ipin2	Measurement pin to be connected to SMU4 (pass parameter)
Itest	SMU1's output current (pass parameter)
P	Port number
Port(1:4)	Port addresses of SMU1 through SMU4
R	Resistance calculated from voltage and current measurement values (return parameter)
St	SMU4's measurement status
Twait	Hold time to allow a test device to stabilize:
	Twait = 0.01 when 1E−1 $\geq$ |Itest| > 2E−5
	Twait = 0.4 when 2E−5 $\geq$ |Itest| > 1E−6
Vlim	Voltage limit across a test device (pass parameter)
Vlimit	SMU3's voltage compliance (= Vlim)
	If Vlim is 0 or is not included in the pass parameter list, Vlimit is set to 20.
Vm1	SMU2's voltage measurement value
Vm2	SMU3's voltage measurement value
Vpin1	Measurement pin to be connected to SMU2 (pass parameter)
Vpin2	Measurement pin to be connected to SMU3 (pass parameter)

FNR4t Port-Related Variables/Constants

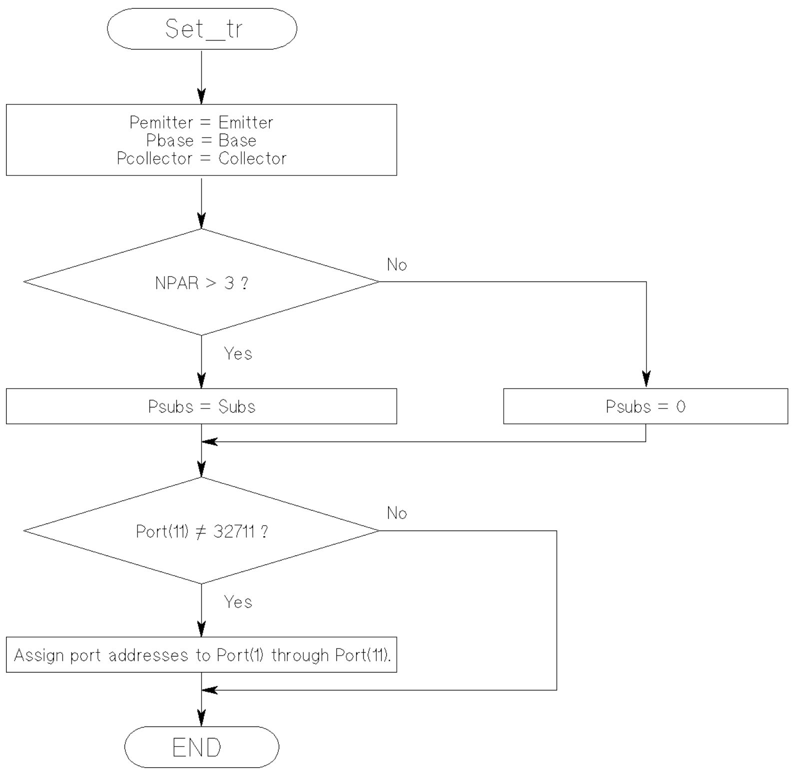
Measurement Pin Variables	Port Variables/Constants				
	Port	Mode	I/V Output	I/V Measurement	Compliance
Ipin 1	SMU1	IS	Itest [A]	—	Vlimit [V]
Vpin 1	SMU2	IS	1E−10 [A]	Vm1	Vlimit [V]
Ipin 2	SMU3	IS	1E−10 [A]	Vm2	20 [V]
Vpin 2	SMU4	VS	0 [V]	Imeas	1E−1 [A]

Set_tr

Operating Hints

Set_tr establishes a COM block for passing port addresses and measurement pin numbers to other PARA functions via the Set_tr COM block. Once established, the Set_tr COM block can be changed only by another Set_tr.

Hence, you can pass the same parameters to FNBvcbo, FNBvces, FNHfe, FNHfe1, FNVth1, FNVth2, FNVth2m, FNVth3, FNVth4, FNVth5, and FNIds from a single Set_tr subprogram. The Set_tr COM block is different from the COM block established by the Setmultitr subprogram.



FNBvcbo

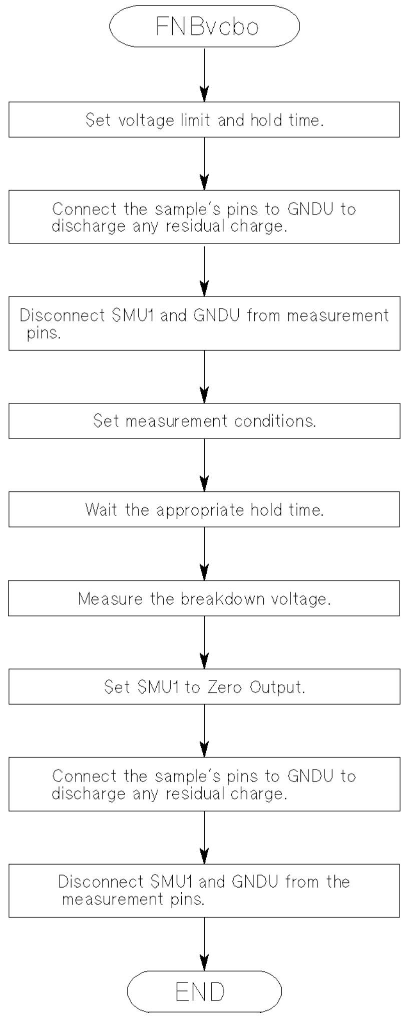
Operating Hints

- Obtaining Correct Measurement Results:

  Set an appropriate hold time. This function forces a test current to the collector of the transistor under test and measures the resulting voltage drop across the collector-base junction with the emitter open. You must set the hold time so the measurement performs after the transistor's carrier density stabilizes. The default hold time is 400 ms.

- Other Measurement Applications:

  FNBvcbo measures breakdown voltage by connecting the pin specified by Set_tr's second parameter (Base) to the GNDU, and by forcing a test current from the pin specified by Set_tr's third parameter (Collector). You can perform other breakdown voltage measurements also. For example, to measure V(BR)CEO, reverse Set_tr's first and second parameters.


FNBvcbo
Set voltage limit and hold time.
Connect the sample's pins to GNDU to discharge any residual charge.
Disconnect SMU1 and GNDU from measurement pins.
Set measurement conditions.
Wait the appropriate hold time.
Measure the breakdown voltage.
Set SMU1 to Zero Output.
Connect the sample's pins to GNDU to discharge any residual charge.
Disconnect SMU1 and GNDU from the measurement pins.
END

FNBvcbo Variables

Variable Name	Description
Ic	SMU1's output current (pass parameter)
N	Number of pass parameters (=NPAR)
Time	User-specified hold time (pass parameter)
Twait	Hold time (=Time)
	If Time is not included in the pass parameter list, Twait is set to 0.4.
Vlim	Collector voltage limit during a measurement (pass parameter)
Vlimit	SMU1's voltage compliance (=Vlim)
	If Vlim is 0 or is not included in the pass parameter list, Vlimit is set to 20
Vmeas	SMU1's voltage measurement value (returned parameter)

FNBvcbo Port-Related Variables

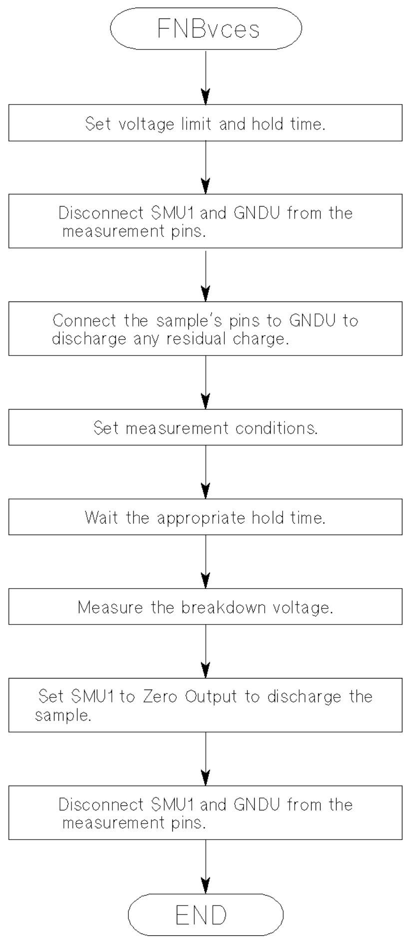
Measurement Pin Variables	Port Variables				
	Port	Mode	I/V Output	I/V Measurement	Compliance
Pcollector	SMU1	IS	Ic [A]	Vmeas	Vlimit [V]
Pbase	GNDU	—	—	—	—

FNBvces

Operating Hints

- Obtaining Correct Measurement Results:

  Set an appropriate hold time. FNBvces forces a test current to the collector of the transistor under test and measures the resulting voltage drop across the collector-base junction with the emitter shorted to the base. You must set the hold time so the measurement performs after the transistor's carrier density stabilizes. The default hold time is 400 ms.



FNBvces

FNBvces Variables

Variable Name	Description
Ic	SMU1's output current (pass parameter)
N	Number of pass parameters (=NPAR)
Time	User-specified hold time (pass parameter)
Twait	Hold time (=Time)
	If Time is not included in the pass parameter list, Twait is set to 0.4.
Vlim	Collector voltage limit during a measurement (pass parameter)
Vlimit	SMU1's voltage compliance (=Vlim)
	If Vlim is 0 or is not included in the pass parameter list, Vlimit is set to 20
Vmeas	SMU1's voltage measurement value (returned parameter)

FNBvces Port-Related Variables

Measurement Pin Variables	Port Variables				
	Port	Mode	I/V Output	I/V Measurement	Compliance
Pcollector	SMU1	IS	Ic [A]	Vmeas	Vlimit [V]
Pemitter	GNDU	—	—	—	—
Pbase	GNDU	—	—	—	—
Psubs	GNDU	—	—	—	—

FNHfe

Operating Hints

This function uses Newton's method to find the base current necessary to cause a specified collector current to flow. The initial base current used in the search is determined by grounding the base and forcing a current equal to the specified collector current to the emitter. The resulting base current is then measured, and this measurement value is used as the initial base current.

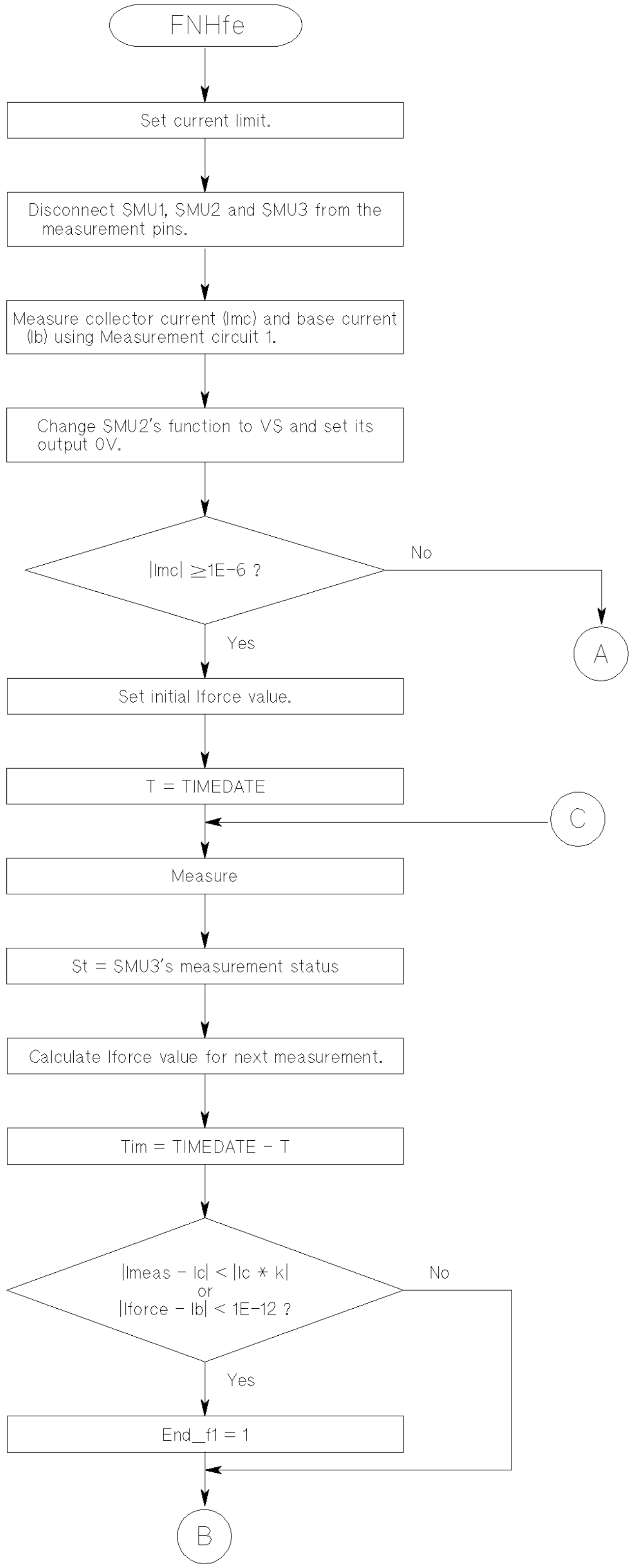
- Detecting an Invalid Measurement:

  The search for the appropriate base current aborts and −9999999.99999 is returned as the h_{FE} value if an abnormal condition occurs, if the base current reaches the collector current limit, or if the appropriate base current is not found within 10 seconds. The value −9999999.99999 may be returned if you set the measurement integration time to LONG. Also, an incorrect h_{FE} value may be returned if the transistor is not biased for operation in its active region.

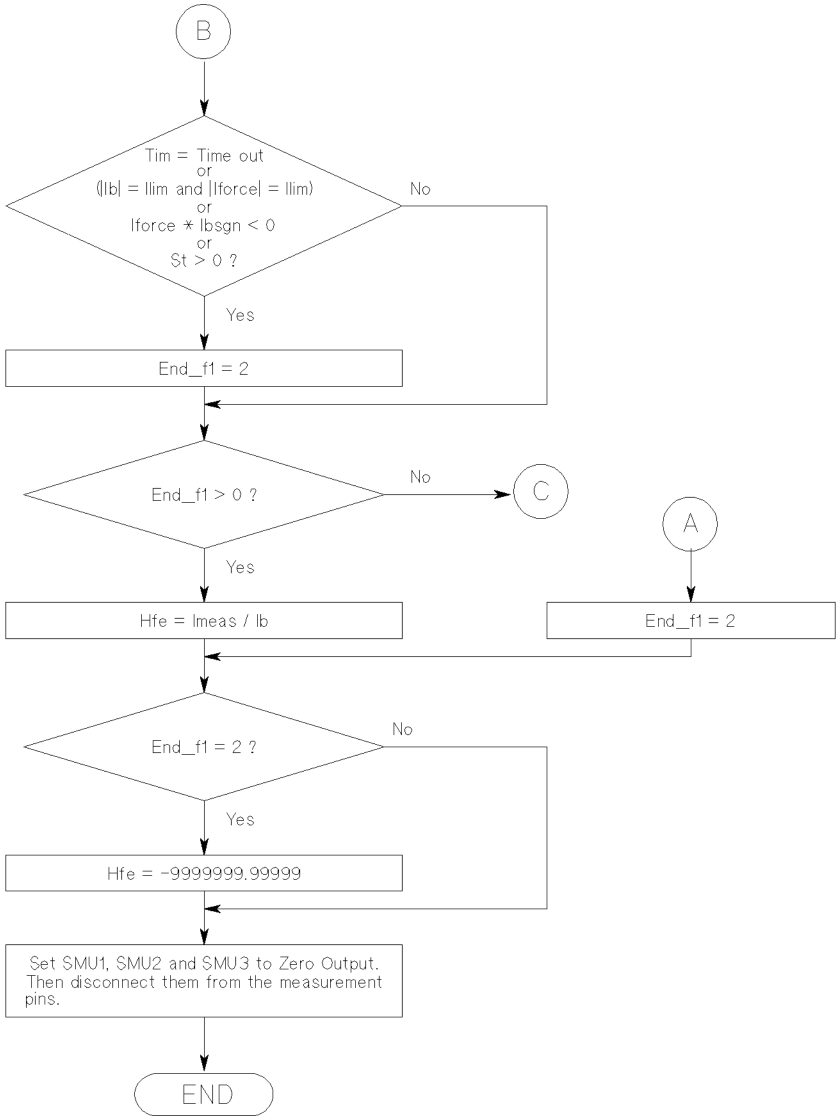
- Increasing Measurement Speed:

  If you know your test transistor's approximate h_{FE}, you can reduce the time required to measure h_{FE} by modifying FNHfe. To do so, delete the FNHfe function that determines the initial base current, calculate the initial base current from the approximate h_{FE} value and the desired collector current ($Ib=Ic/h_{FE}$), and assign this value to the variable Ib.

FNHfe



FNHfe
Set current limit.
Disconnect SMU1, SMU2 and SMU3 from the measurement pins.
Measure collector current (Imc) and base current (Ib) using Measurement circuit 1.
Change SMU2's function to VS and set its output 0V.
|Imc| ≥1E-6 ?
No
A
Yes
Set initial Iforce value.
T = TIMEDATE
C
Measure
St = SMU3's measurement status
Calculate Iforce value for next measurement.
Tim = TIMEDATE - T
|Imeas - Ic| < |Ic * k| or |Iforce - Ib| < 1E-12 ?
No
Yes
End_f1 = 1
B


B
Tim = Time out
or
(|Ib| = Ilim and |Iforce| = Ilim)
or
Iforce * Ibsgn < 0
or
St > 0 ?
No
Yes
End_f1 = 2
End_f1 > 0 ?
No
C
A
Yes
Hfe = Imeas / Ib
End_f1 = 2
End_f1 = 2 ?
No
Yes
Hfe = -9999999.99999
Set SMU1, SMU2 and SMU3 to Zero Output. Then disconnect them from the measurement pins.
END

FNHfe Variables

Variable Name	Description
D_ib	Ib(n) − Ib(n−1)
D_im	Imeas(n) − Imeas(n−1)
End_f1	Flag to discontinue the base current search
	Set to 1 when the appropriate base current is found
	Set to 2 when an abnormal measurement condition is detected in SMU3, when the base current equals the collector current limit, or when the appropriate base current is not found within 10 seconds
Hfe	h_{FE} value obtained by this measurement (return parameter)
Ib	Base current [corresponds to Ib(n−1)]
Ibsgn	Polarity of Vce. Distinguishes between npn's and pnp's.
Ic	Specified collector current (pass parameter)
Ilim	SMU3's current compliance
	Ilim = 1E−1 when $\lvert Vce \rvert \leq 20$
	Ilim = 5E−2 when $20 < \lvert Vce \rvert \leq 40$
	Ilim = 2E−2 when $40 < \lvert Vce \rvert \leq 100$
Im	Collector current measurement value [corresponds to Imeas(n−1)]
Imc	Measurement Circuit 1 collector current measurement value
Imeas	Collector current measurement value [corresponds to Imeas(n)]
K	Collector current accuracy (=0.01)
St	SMU3's measurement status
T	Time at the start of the base current search
Tim	Elapsed time of the base current search
Time_out	Time limit for the base current search
Vce	Collector-emitter voltage (pass parameter)

Measurement Circuit 1 Port-Related Variables

Measurement Pin Variables	Port Variables				
	Port	Mode	I/V Output	I/V Measurement	Compliance
Pbase	SMU1	VS	0 [V]	Ib	2E−2 [A]
Pemitter	SMU2	IS	−Ibsgn×Ie [A]	—	3 [V]
Psubs	SMU2	IS	−Ibsgn×Ie [A]	—	3 [V]
Pcollector	SMU3	VS	Vce [V]	Imc	Ilim [A]

Measurement Circuit 2 Port-Related Variables

Measurement Pin Variables	Port Variables				
	Port	Mode	I/V Output	I/V Measurement	Compliance
Pbase	SMU1	IS	Iforce [A]	—	3 [V]
Pemitter	SMU2	VS	0 [V]	—	1E−1 [A]
Psubs	SMU2	VS	0 [V]	—	1E−1 [A]
Pcollector	SMU3	VS	Vce [V]	Imeas	lim [A]

FNHfe1

Operating Hints

FNHfe1 uses an analog search method to find the base current necessary to cause a specified collector current to flow.

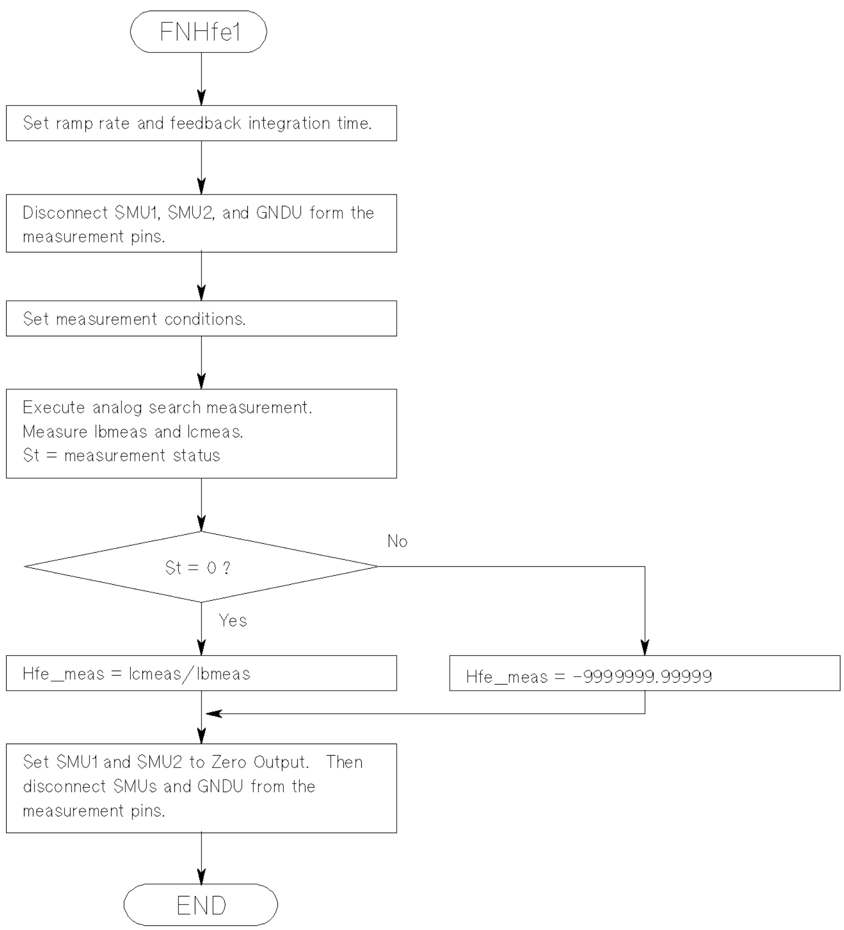
- Detecting an Invalid Measurement:

  FNHfe1 returns −9999999.99999 instead of the measurement results if an abnormal condition occurs during a measurement. For example, if the monitored collector current does not converge with the specified value, FNHfe1 returns −9999999.99999.

  To prevent the occurrence of abnormal conditions, calculate the optimum ramp rate and feedback integration time parameter values by using the Para_hfe subprogram.

- Increasing Measurement Speed:

  Modify FNHfe1 by changing the Set_asearch subprogram's delay time and base current compliance parameter values to the values calculated by the Para_hfe subprogram.



FNHfe1 Variables

Variable Name	Description
Hfe_meas	Hfe value calculated from the base and collector current measurement values (return parameter)
Ibmeas	SMU1's base current measurement values
Ic	Target collector current value (pass parameter)
Icmeas	SMU2's collector current measurement value
Integ	Feedback integration time (= Integtime)
	If Integtime is not included in the pass parameter list, Integ is set to 5E−3
Integtime	Feedback integration time (pass parameter)
St	Measurement status
Vbrate	Ramp rate (= Vspeed)
	If Vspeed is not included in the pass parameter list, Vbrate is set to 500
Vbspeed	Ramp rate (pass parameter)
Vbstart	Start base voltage (pass parameter)
Vbstop	Stop base voltage (pass parameter)
Vc	SMU1's voltage compliance

FNHfe1 Port-Related Variables

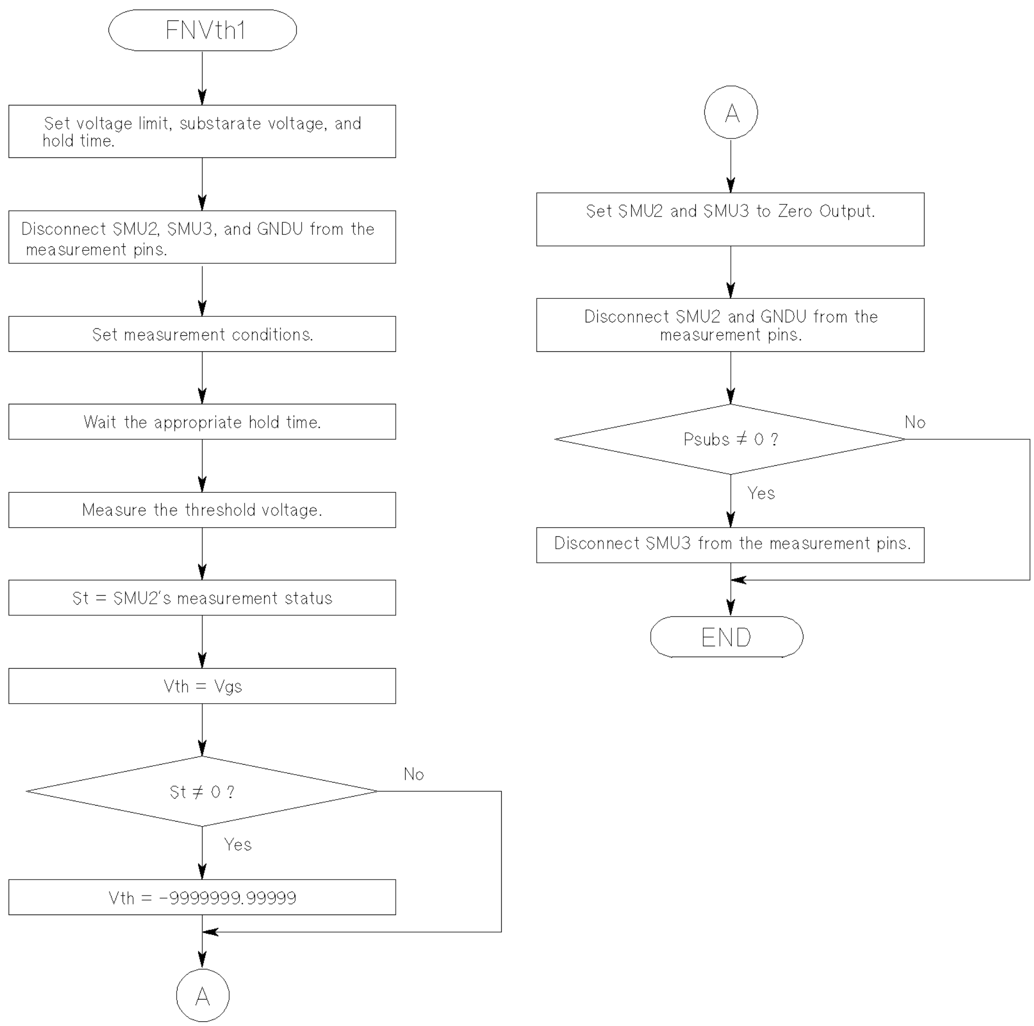
Measurement Pin Variables	Port Variables				
	Port	Mode	I/V Output	I/V Measurement	Compliance
Pbase	SMU1	VS	Vbstart to–Vbstop	Ibmeas [A]	Ic×1.15/50 [V]
Pemitter	GNDU	—	—	—	—
Pcollector	SMU2	VS	—	Icmeas [A]	Ic×1.15 [A]

FNVth1

Operating Hints

- Obtaining Correct Measurement Results:

  FNVth1 sets a hold time that allows your test device to stabilize before a measurement is made. A hold time of .01, .1, 1, or 2 seconds is set depending on the specified test current. These hold times may not be ideal for certain devices when the test current is low. You may have to change these hold times to satisfy the characteristics of the device you're testing.



FNVth1 Variables

Variable Name	Description
Ids	SMU2's output current (pass parameter)
Iforce	Absolute value of Ids
N	Number of pass parameters (=NPAR)
St	SMU2's measurement status
Twait	Hold time Twait = 0.01 when 1E−1 $\geq$ |Itest| > 2E−5
	Twait = 0.1 when 2E−5 $\geq$ |Itest| > 3E−8
	Twait = 1 when 3E−8 $\geq$ |Itest| > 5E−9
	Twait = 2 when 5E−9 $\geq$ |Itest|
Vgs	SMU2's voltage measurement value
Vlim	Gate voltage limit (pass parameter)
Vlimit	SMU2's voltage compliance (=Vlim)
	If Vlim is 0 is or not included in the pass parameter list, Vlimit is set to 20
Vsubs	Substrate-source voltage (pass parameter)
Vsubs1	SMU3's output voltage (=Vsubs)
	If Vsubs is not included in the pass parameter list, Vsubs1 is set to 0
Vth	Gate-source threshold voltage (return parameter)

FNVth1 Port-Related Variables

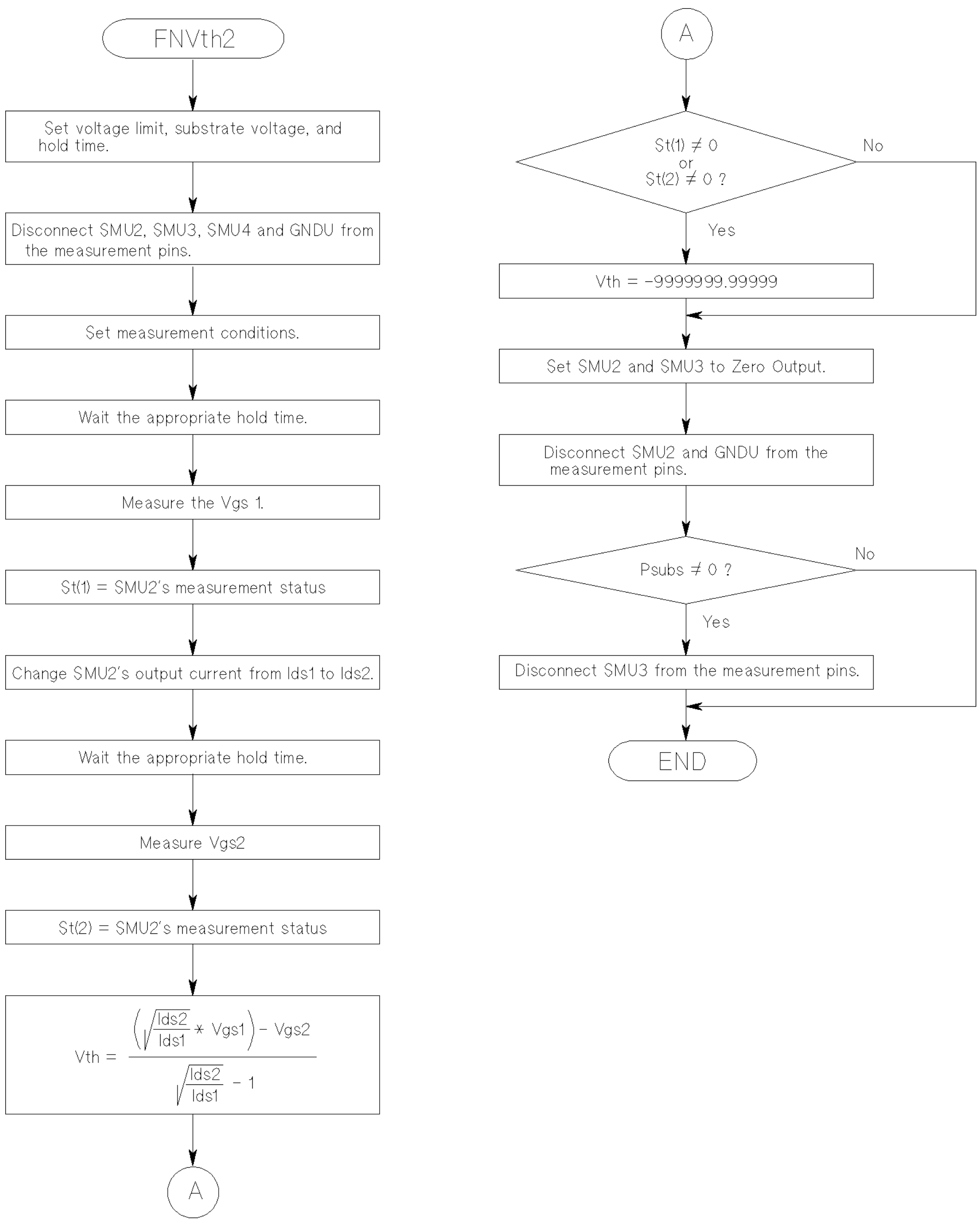
Measurement Pin Variables	Port Variables				
	Port	Mode	I/V Output	I/V Measurement	Compliance
Pcollector	SMU2	IS	Ids [A]	Vgs	Vlimit [V]
Pbase	SMU2	IS	Ids [A]	Vgs	Vlimit [V]
Psubs	SMU3	VS	Vsubs1 [V]	—	1E−3 [A]
Pemitter	GNDU	—	—	—	—

FNVth2

Operating Hints

- Preventing Incorrect Measurement Results:

  FNVth2 returns a test device's threshold voltage value by performing two FNVth1-equivalent measurements, each with a different test current, then by calculating the threshold voltage value using linear extrapolation. If the specified drain current is too low or too high, however, an incorrect threshold voltage value may be returned. To prevent this, specify medium current values.



FNVth2 Variables

Variable Name	Description
Ids1	SMU2's output current: Measurement #1 (pass parameter)
Ids2	SMU2's output current: Measurement #2 (pass parameter)
Iforce	Absolute value of output from SMU2
N	Number of pass parameters (=NPAR)
St(1:2)	SMU2's measurement status during each measurement
Twait	Hold time
	Twait = 0.01 when 1E−1 $\geq$ Iforce > 2E−5
	Twait = 0.1 when 2E−5 $\geq$ Iforce > 3E−8
	Twait = 1 when 3E−8 $\geq$ Iforce > 5E−9
	Twait = 2 when 5E−9 $\geq$ Iforce
Vgs1	SMU2's voltage measurement value: Measurement #1
Vgs2	SMU2's voltage measurement value: Measurement #2
Vlim	Gate voltage limit (pass parameter)
Vlimit	SMU2's voltage compliance (=Vlim)
	If Vlim is 0 or is not included in the pass parameter list, Vlimit is set to 20
Vsubs	Substrate-source voltage (pass parameter)
Vsubs1	SMU3's output voltage (=Vsubs)
	If Vsubs is not included in the pass parameter list, Vsubs1 is set to 0
Vth	Gate threshold voltage (return parameter)

FNVth2 Port-Related Variables

Measurement Pin Variables	Port Variables				
	Port	Mode	I/V Output	I/V Measurement	Compliance
Pcollector	SMU2	IS	Ids1, Ids2 [A]	Vgs1, Vgs2	Vlimit [V]
Pbase	SMU2	IS	Ids1, Ids2 [A]	Vgs1, Vgs2	Vlimit [V]
Psubs	SMU3	VS	Vsubs1 [V]	—	1E−3 [A]
Pemitter	GNDU	—	—	—	—

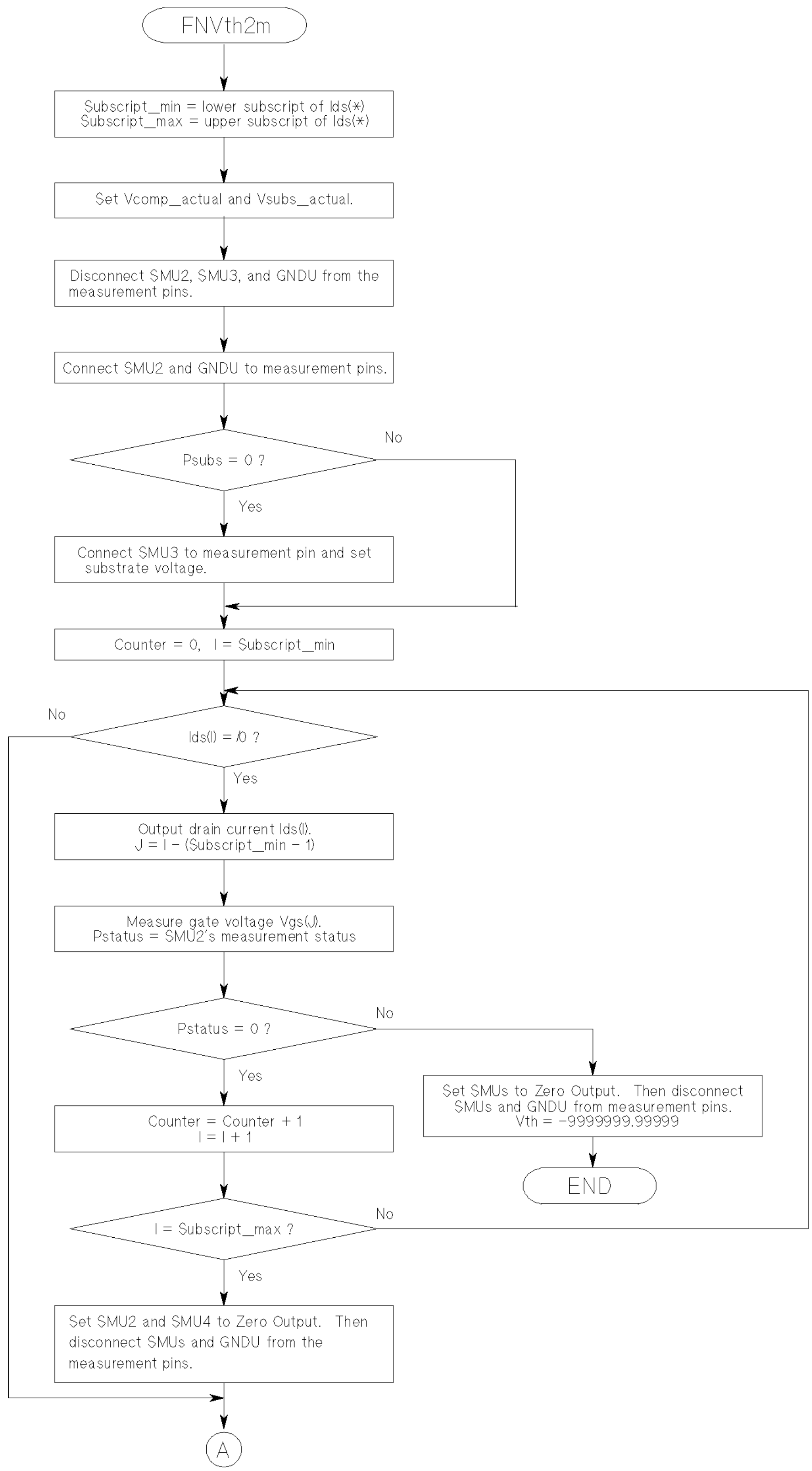
FNVth2m

Operating Hints

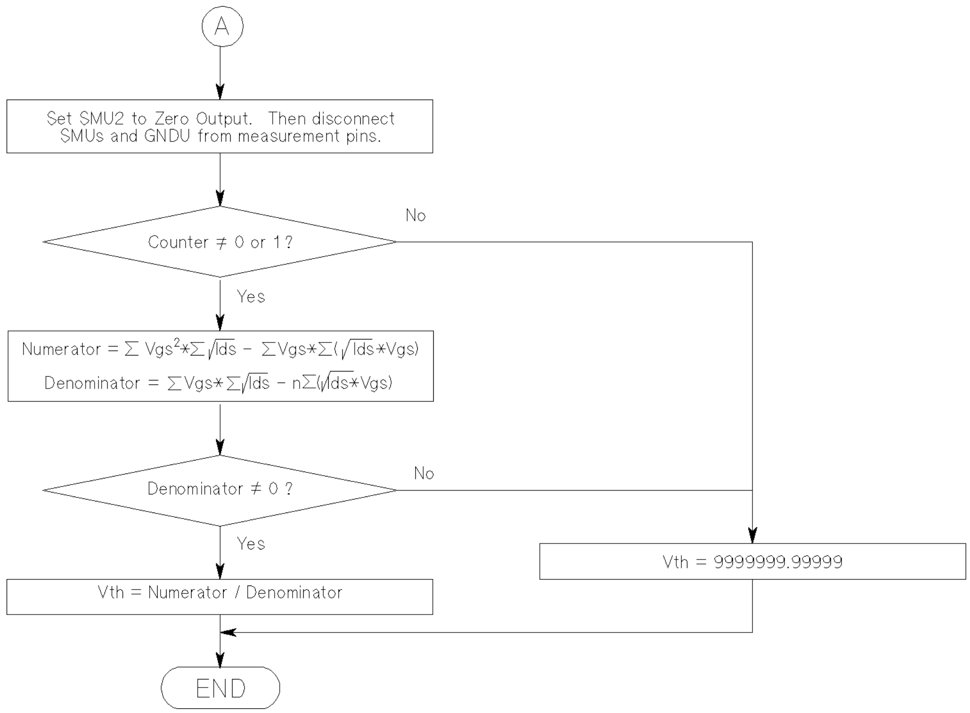
- Detecting an Invalid Measurement:

  FNVth2m returns the threshold voltage value of a test device by performing multiple FNVth1-equivalent measurements, each with a different test current, then by calculating the threshold voltage value using the least squares method.

  If an SMU reaches compliance, FNVth2m returns 9999999.99999. If the number of elements in the specified drain current array is only one, or if the least squares method calculation does not converge, this function also returns 9999999.99999.


FNVth2m
Subscript_min = lower subscript of Ids(*)
Subscript_max = upper subscript of Ids(*)
Set Vcomp_actual and Vsubs_actual.
Disconnect SMU2, SMU3, and GNDU from the measurement pins.
Connect SMU2 and GNDU to measurement pins.
Psubs = 0 ?
No
Yes
Connect SMU3 to measurement pin and set substrate voltage.
Counter = 0, I = Subscript_min
No
Ids(I) = /0 ?
Yes
Output drain current Ids(I).
J = I − (Subscript_min − 1)
Measure gate voltage Vgs(J).
Pstatus = SMU2's measurement status
Pstatus = 0 ?
No
Yes
Set SMUs to Zero Output. Then disconnect SMUs and GNDU from measurement pins.
Vth = −9999999.99999
END
Counter = Counter + 1
I = I + 1
I = Subscript_max ?
No
Yes
Set SMU2 and SMU4 to Zero Output. Then disconnect SMUs and GNDU from the measurement pins.
A

FNVth2m



FNVth2m Variables

Variable Name	Description
Counter	Variable for counting the number of measurement data
Denominator	Variable used for threshold voltage calculations
	Vgs(J) $\times$ Ids(I) $-$ n (Ids(I) $\times$ Vgd(J))
I	Drain current array subscript
J	Gate voltage array subscript
Ids(I)	Drain currents (pass parameter)
Numerator	Variable used for threshold voltage calculations
	Vgs(J)^2 $\times$ Ids(I) $-$ Vgs(J) $\times$ (Ids(I) $\times$ Vgs(J))
Pstatus	SMU2's measurement status
Ridsi	Variable used for threshold voltage calculations Ids(I)
Ridsi_vgsi	Variable used for threshold voltage calculations (Ids(I) $\times$ Vgs(J))

FNVth2m Variables (continued)

Variable Name	Description
Subscript_max	Drain current array upper subscript
Subscript_min	Drain current array lower subscript
Vcomp_actual	SMU2's voltage compliance (= Vlim) If Vlim is 0 or is not included in the pass parameter list, Vcomp_actual is set to 20
Vgs(J)	SMU2's collector voltage measurement values
Vgsi	Variable used for threshold voltage calculations Vgs(J)
Vgsi2	Variable used for threshold voltage calculations $Vgs(J)^2$
Vlim	Voltage limit across a test device (pass parameter)
Vsubs	Substrate voltage (pass parameter)
Vsubs_actual	Substrate voltage (= Vsubs)
	If Vsubs is not included in the pass parameter list, Vsubs_actual is set to 0
Vth	Threshold voltage calculated from Numerator and Denominator (return parameter)

FNVth2m Port-Related Variables

Measurement Pin Variables	Port Variables				
	Port	Mode	I/V Output	I/V Measurement	Compliance
Pcollector	SMU2	IS	Ids(I) [A]	Vgs(J)	Vcomp_actual
Pbase	SMU2	IS	Ids(I) [A]	Vgs(J)	Vcomp_actual
Psubs	SMU3	VS	Vsubs_actual	—	1E−3 [A]
Pemitter	GNDU	—	—	—	—

FNVth3

Operating Hints

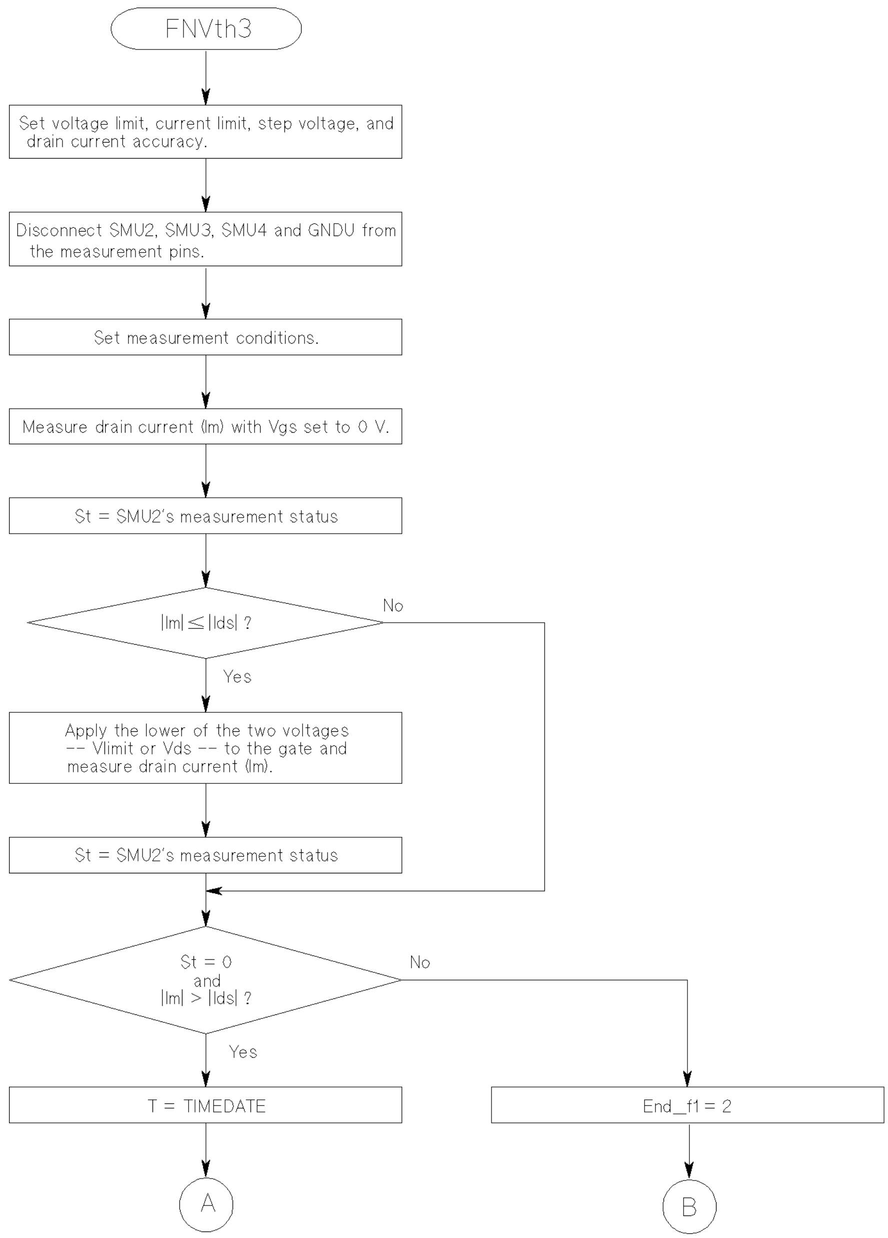
FNVth3 first determines whether the test FET is an enhancement or depletion type FET by measuring the drain current while applying 0 V to the gate. Then, using the Newton method, FNVth3 searches for the gate voltage that causes a specified drain current to flow. The initial gate voltage used in the search is 0 V for depletion type FETs. For enhancement type FETs, however, the initial gate voltage is equal to either the drain voltage or the maximum gate voltage, whichever is less.

- Detecting an Invalid Measurement:

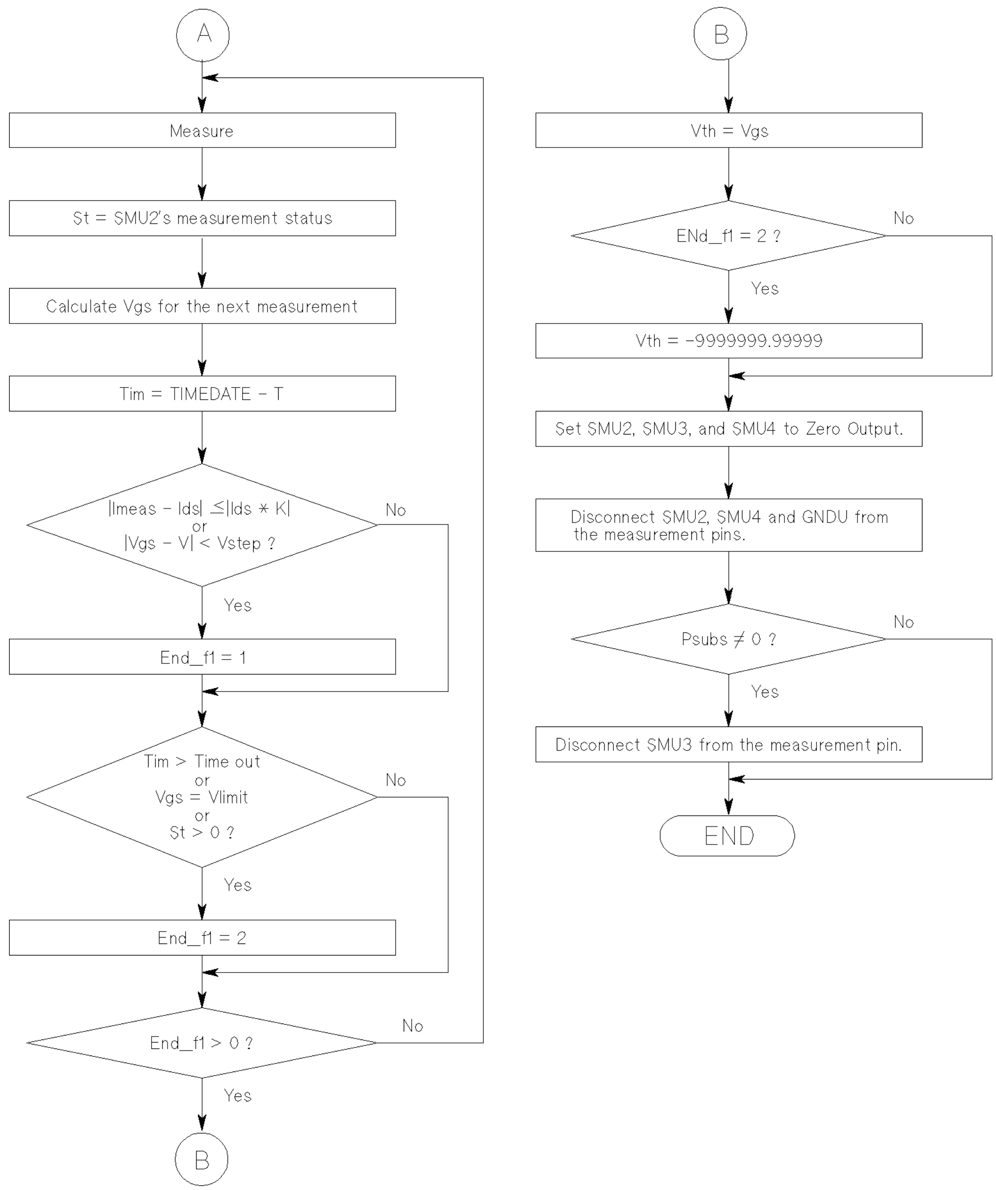
  The search for the appropriate gate voltage aborts and −9999999.99999 is returned as the threshold voltage if an abnormal condition occurs, if the gate voltage reaches the maximum gate voltage, or if the appropriate gate voltage is not found within 10 seconds. The value −9999999.99999 may be returned if you set the measurement integration time to LONG.

- Increasing Measurement Speed:

  If you know the approximate threshold voltage and the transistor's type (depletion or enhancement), delete the portion of FNVth3 that determines the transistor's type and sets the initial gate voltage.


FNVth3
Set voltage limit, current limit, step voltage, and drain current accuracy.
Disconnect SMU2, SMU3, SMU4 and GNDU from the measurement pins.
Set measurement conditions.
Measure drain current (Im) with Vgs set to 0 V.
St = SMU2's measurement status
|Im| ≤ |Ids| ?
No
Yes
Apply the lower of the two voltages -- Vlimit or Vds -- to the gate and measure drain current (Im).
St = SMU2's measurement status
St = 0 and |Im| > |Ids| ?
No
Yes
T = TIMEDATE
End_f1 = 2
A
B

FNVth3


A
Measure
St = SMU2's measurement status
Calculate Vgs for the next measurement
Tim = TIMEDATE − T
|Imeas − Ids| ≤ |Ids * K| or |Vgs − V| < Vstep ?
No
Yes
End_f1 = 1
Tim > Time out or Vgs = Vlimit or St > 0 ?
No
Yes
End_f1 = 2
End_f1 > 0 ?
No
Yes
B
B
Vth = Vgs
ENd_f1 = 2 ?
No
Yes
Vth = −9999999.99999
Set SMU2, SMU3, and SMU4 to Zero Output.
Disconnect SMU2, SMU4 and GNDU from the measurement pins.
Psubs ≠ 0 ?
No
Yes
Disconnect SMU3 from the measurement pin.
END

FNVth3 Variables

Variable Name	Description
D_i	Ids(n) − Ids(n−1)
D_v	Vgs(n) − Vgs(n−1)
End_f1	Flag to discontinue search when gate voltage is found
	Set to 1 when gate voltage found
	Set to 2 if an abnormal measurement condition is detected in SMU2, if the gate voltage equals the maximum gate voltage, or if the appropriate gate voltage is not found within 10 seconds
Ids	Specified drain current (pass parameter)
Ilim	SMU2's current compliance
	Ilim = 1E−1 when Vlimit $\leq$ 20
	Ilim = 5E−2 when 20 $<$ Vlimit $\leq$ 40
	Ilim = 2E−2 when 40 $<$ Vlimit
Im	Drain current measurement value [corresponds to Ids(n−1)]
Imeas	Drain current measurement value [corresponds to Ids(n)]
K	Specified drain current accuracy
	K = 0.005 when 1E−1 $\geq$ |Ids| $>$ 1E−6
	K = 0.01 when 1E−6 $\geq$ |Ids| $>$ 1E−8
	K = 0.05 when 1E−8 $\geq$ |Ids|
N	Number of pass parameters
Sign	Drain voltage polarity [=SGN(Vds)]
St	SMU2's measurement status
T	Time at the start of the gate voltage search
Tim	Elapsed time of the gate voltage search
Tim_out	Time limit for the gate voltage search
V	Gate-source voltage [corresponds to Vgs(n−1)]
Vds	Drain-source voltage (pass parameter)
Vglim	Maximum gate voltage (pass parameter)
Vgs	Gate-source voltage [corresponds to Vgs(n)]

FNVth3 Variables (continued)

Variable Name	Description
Vlimit	Gate-source voltage limit (=|Vglim|)
	If Vglim is 0 or is not included in the pass parameter list, Vlimit is set to 20
Vstep	Gate-source voltage resolution
	Vstep = 5E−3 when 100 ≥ Vlimit > 40
	Vstep = 2E−3 when 40 ≥ Vlimit > 20
	Vstep = 1E−3 when 20 ≥ Vlimit
Vsubs	Substrate-source voltage (pass parameter)
Vsubs1	SMU3's output voltage (=Vsubs)
	If Vsubs is not included in the pass parameter list, Vsubs1 is set to 0
Vth	Threshold voltage (returned parameter)

FNVth3 Port-Related Variables

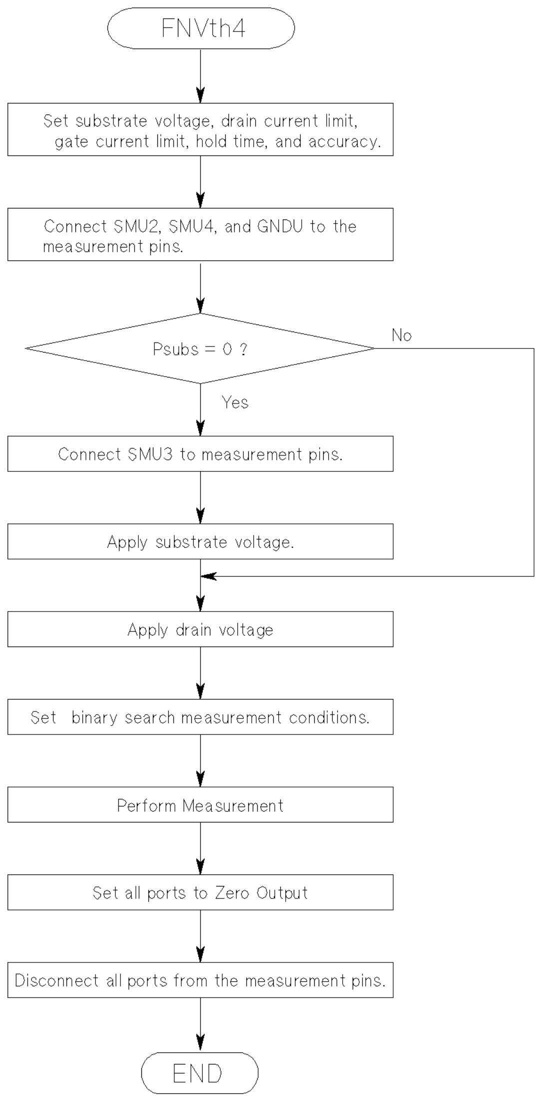
Measurement Pin Variables	Port Variables				
	Port	Mode	I/V Output	I/V Measurement	Compliance
Pcollector	SMU2	VS	Vds [V]	Im, Imeas	Ilim [A]
Pbase	SMU4	VS	V, Vgs [V]	—	1E−5 [A]
Pemitter	GNDU	—	—	—	—
Psubs	SMU3	VS	Vsubs1 [V]	—	1E−3 [A]

FNVth4

Operating Hints

- Obtaining Correct Measurement Results:

  FNVth4 executes a binary search and returns the test device's threshold voltage value. Because a binary search is used, the threshold voltage value must be between a specified minimum and maximum gate voltage.



FNVth4 Variables

Variable Name	Description
Vsubs1	SMU3's output voltage (=Vsubs)
Vsub	Substrate voltage (pass parameter)
Idlim	Drain current limit (pass parameter)
Iglim	Gate current limit (pass parameter)
Wait_time	Hold time
Accuracy	Convergent accuracy
Vds	Drain voltage (pass parameter)
Vgmin	Minimum gate voltage (pass parameter)
Vgmax	Maximum gate voltage (pass parameter)
Ids	Drain current
Value	Gate threshold voltage (return parameter)
Status	Measurement status
Meas	Measurement data at convergence

FNVth4 Port-Related Variables

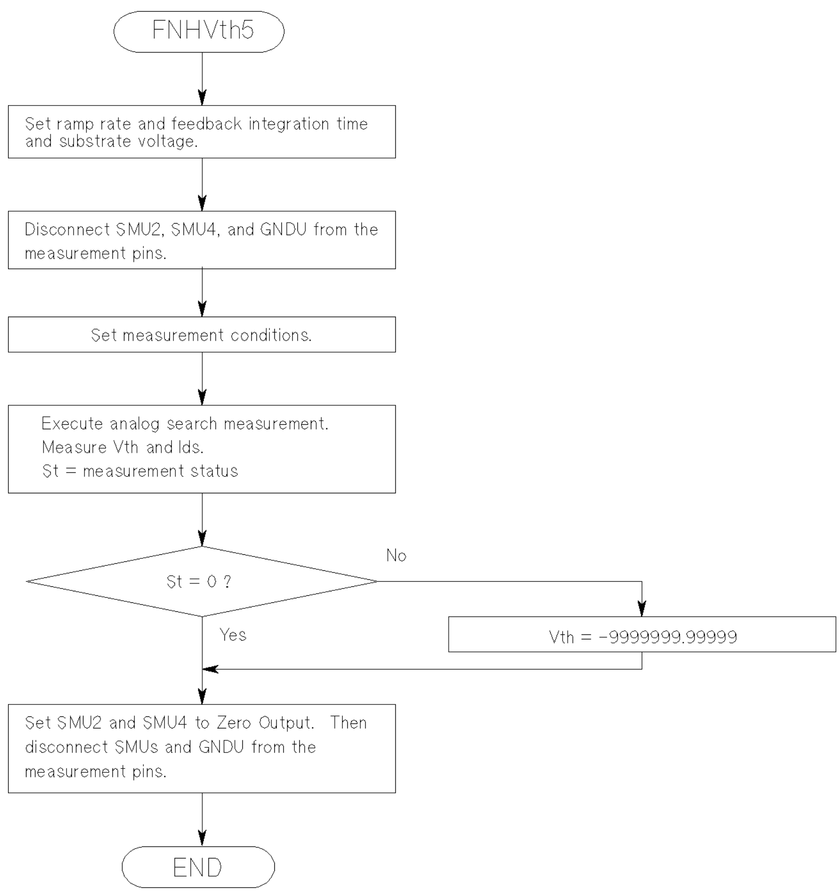
Measurement Pin Variables	Port Variables				
	Port	Mode	I/V Output	I/V Measurement	Compliance
Pcollector	SMU2	VS	Vds [V]	Meas [A]	Idlim [A]
Pbase	SMU4	VS	Vgmin–Vgmax [V]	—	Iglim [A]
Pemitter	GNDU	—	—	—	—
Psubs	SMU3	VS	Vsubs1 [V]	—	1E−3 [A]

FNVth5

Operating Hints

- Detecting an Invalid Measurement:

  FNVth5 executes an analog search and returns a test device's threshold voltage value. If an abnormal condition occurs, for example, if the monitored drain current does not converge with the specified value, this function returns −9999999.99999. To prevent this abnormal condition, calculate the optimum ramp rate and feedback integration time parameter values.



FNVth5 Variables

Variable Name	Description
Ids	Drain current (pass parameter)
Integ	Feedback integration time (= Integtime)
	If Integtime is not included in the pass parameter list, Integ is set to 5E−3
Integtime	Feedback integration time (pass parameter)
St	Measurement status
Vds	Drain voltage (pass parameter)
Vgrate	Ramp rate (= Vgspeed)
	If Vgspeed is not included in the parameter list, Vgrate is set to 500
Vgspeed	Ramp rate (pass parameter)
Vgstart	Start gate voltage (pass parameter)
Vgstop	Stop gate voltage (pass parameter)
Vsubs	Substrate voltage (pass parameter)
Vsubs1	Substrate voltage (= Vsubs)
	If Vsubs is not included in the pass parameter list, Vsubs1 is set to 0

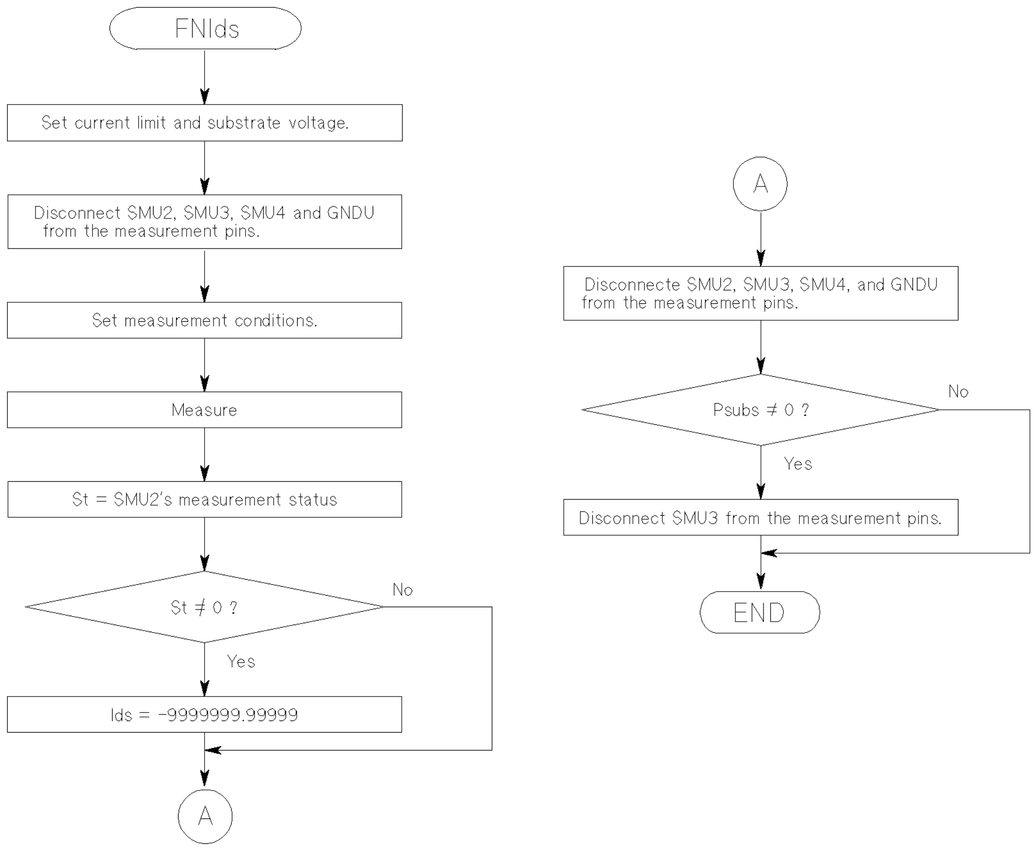
FNVth5 Port-Related Variables

Measurement Pin Variables	Port Variables				
	Port	Mode	I/V Output	I/V Measurement	Compliance
Pcollector	SMU2	VS	Vds	Ids	Ids×1.15
Pbase	SMU4	VS	Vgstart–Vgstop	—	1E−4 [A]
Pemitter	GNDU	—	—	—	—
Psubs	SMU3	VS	Vsubs1 [V]	—	1E−3 [A]

FNIds

Operating Hints

FNIds establishes the same pin-to-port connections as those established by FNVth3. If you use both FNIds and FNVth3 in one program, delete the connection setting portion of either function, thereby reducing program execution time. Keep in mind, however, that if you do this, the modified function must follow that of the unmodified function.



FNIds

FNIds Variables

Variable Name	Description
Ids	Drain current measurement value (return parameter)
Idslim	Drain current limit during a measurement (pass parameter)
Ilimit	SMU2's current compliance (=Idslim)
	If Idslim is not included in the pass parameter list, Ilimit is set to 1E−6
N	Number of pass parameters
St	SMU2's measurement status
Vds	Drain-source voltage (pass parameter)
Vgs	Gate-source voltage (pass parameter)
Vsubs	Substrate-source voltage (pass parameter)
Vsubs1	SMU3's output voltage (=Vsubs)
	If Vsubs is not included in the pass parameter list, Vsubs1 is set to 0.

FNIds Port-Related Variables

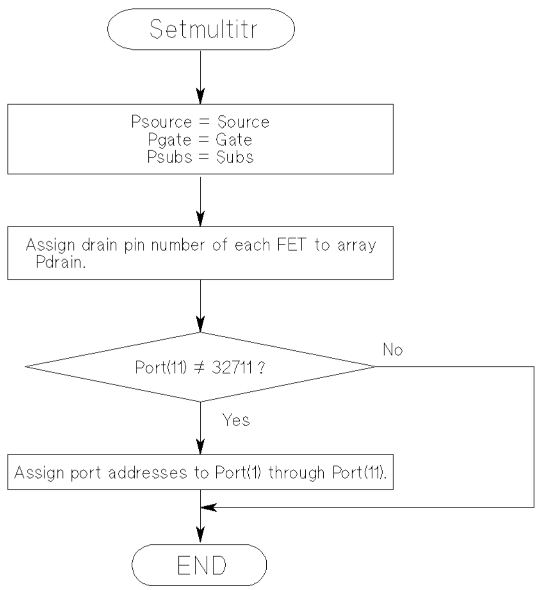
Measurement Pin Variables	Port Variables				
	Port	Mode	I/V Output	I/V Measurement	Compliance
Pcollector	SMU2	VS	Vds [V]	Ids	Ilimit [A]
Pbase	SMU4	VS	Vgs [V]	—	1E−5 [A]
Pemitter	GNDU	—	—	—	—
Psubs	SMU3	VS	Vsubs1 [V]	—	1E−3 [A]

Setmultitr

Operating Hints

Setmultitr establishes a COM block for passing port addresses and measurement pin numbers to other PARA functions via the Setmultitr COM block. Once established, the Setmultitr COM block can be changed only by another Setmultitr.

Hence, you can pass the same parameters to FNDelta_l and FNDelta_w from a single Setmultitr subprogram. The Setmultitr COM block is different from the COM block established by the Set_tr subprogram.



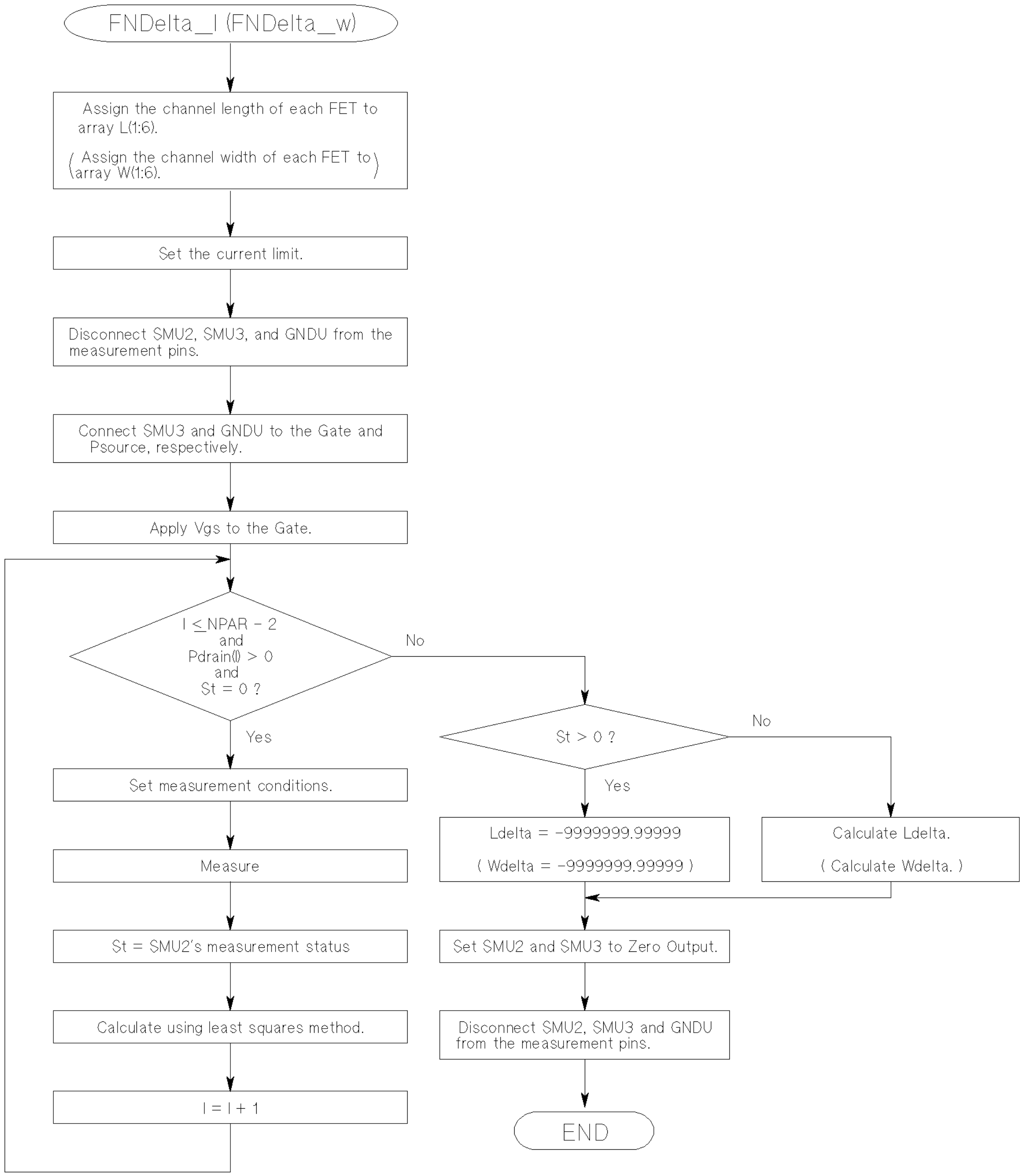
FNDelta_l, FNDelta_w

- Obtaining Correct Measurement Results:

  The order in which you specify channel lengths or channel widths must correspond to the order of the drain pin numbers in the Setmultitr subprogram. Since ΔL or ΔW is calculated from drain current measurement values and channel lengths or channel widths using the least squares method, you must set a drain voltage and a gate voltage that ensures that each FET is operating in its active region.

- Increasing Measurement Speed:

  If the number of FETs is four or less, you can modify FNDelta_l, FNDelta_w, and Setmultitr so that separate SMUs are used to perform simultaneous drain current measurements, and the two VSs are used for biasing.



Items enclosed in parentheses apply to FNDelta_w

FNDelta_l Variables

Variable Name	Description
I	Number of the FET to be measured
Ids	Drain current measurement value
Ilim	SMU2's current compliance Ilim = 0.1 when $\lvert Vds \rvert \leq 20$ Ilim = 0.05 when $20 < \lvert Vds \rvert \leq 40$ Ilim = 0.02 when $40 < \lvert Vds \rvert \leq 100$
L(1:6)	Each FET's channel length (= Lch1 through Lch6) If one of the channel length parameters is not included in the pass parameter list, the corresponding L is set to 0
Lch1	FET1's channel length (pass parameter)
Lch2	FET2's channel length (pass parameter)
Lch3	FET3's channel length (pass parameter)
Lch4	FET4's channel length (pass parameter)
Lch5	FET5's channel length (pass parameter)
Lch6	FET6's channel length (pass parameter)
Ldelta	ΔL value obtained from the measurement (return parameter)
N	Number of optional pass parameters
St	SMU2's measurement status
Vds	Drain-source voltage (pass parameter)
Vgs	Gate-source voltage (pass parameter)
W01	Variable used in the least squares calculation (1/Ids(k))
W0f	Variable used in the least squares calculation L(k)
W11	Variable used in the least squares calculation $(1/Ids(k))^2$
W1f	Variable used in the least squares calculation (1/Ids(k))*L(k)

FNDelta_w Variables

Variable Name	Description
I	Number of the FET to be measured
Ids	Drain current measurement value
Ilim	Current compliance for SMU2
	Ilim = 0.1 when $\lvert Vds \rvert \leq 20$
	Ilim = 0.05 when $20 < \lvert Vds \rvert \leq 40$
	Ilim = 0.02 when $40 < \lvert Vds \rvert \leq 100$
N	Number of optional pass parameters (=NPAR−4)
St	SMU2's measurement status
Vds	Drain-source voltage (pass parameter)
Vgs	Gate-source voltage (pass parameter)
W(1:6)	Each FET's channel width (= Wch1 through Wch6)
	If one of the channel width parameters is not included in the pass parameter list, the corresponding W is set to 0
W01	Variable used in the least squares calculation Ids(k)
W0f	Variable used in the least squares calculation W(k)
W11	Variable used in the least squares calculation $(1/Ids(k))^2$
W1f	Variable used in the least squares calculation Ids(k)
Wch1	FET1's channel width (pass parameter)
Wch2	FET2's channel width (pass parameter)
Wch3	FET3's channel width (pass parameter)
Wch4	FET4's channel width (pass parameter)
Wch5	FET5's channel width (pass parameter)
Wch6	FET6's channel width (pass parameter)
Wdelta	ΔW value obtained from the measurement (return parameter)

FNDelta_l and FNDelta_w Port-Related Variables

Measurement Pin Variables	Port Variables				
	Port	Mode	I/V Output	I/V Measurement	Compliance
Pgate	SMU3	VS	Vgs [V]	—	1E−5 [A]
Pdrain	SMU2	VS	Vds [V]	—	Ilim [A]
Psource	GNDU	—	—	—	—
Psubs	GNDU	—	—	—	—

XYGRAPH (Lingraph, Cvgraph, Loggraph)

This section provides XYGRAPH operating hints, flow diagrams, and variable lists to facilitate your use of these functions and subprograms.

Operating Hints

- Using An External Plotter:

  XYGRAPH subprograms contain a GINIT statement, which, among other things, assigns your system controller's display as the system's plot device. If you want to plot your graphs on an external plotter, however, you must insert PLOTTER IS 705, "HPGL" following the GINIT statement.

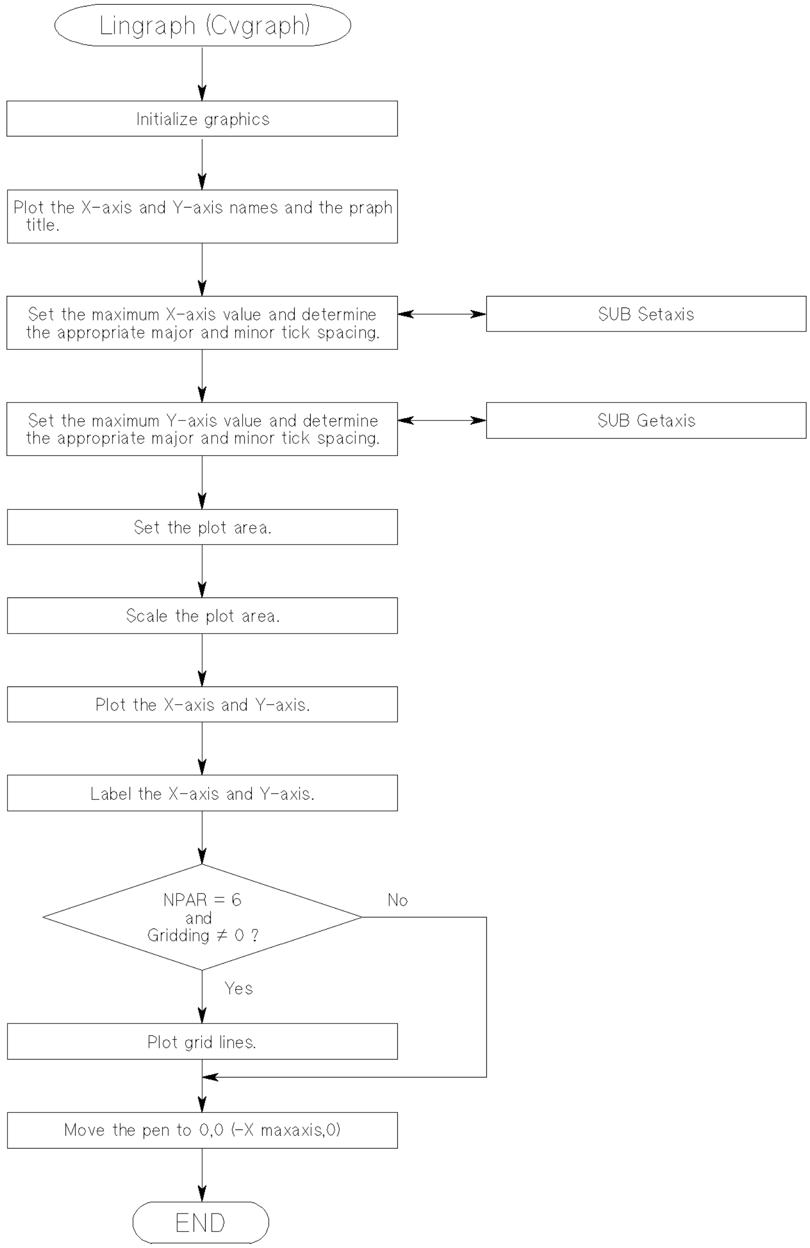
- Changing the Graph Size and Location:

  You can change the size and location of your graphs by changing the parameters of the VIEWPORT statement. Remember, though, that the VIEWPORT statement does not control the size or location of the X- and Y-axes names and the graph name, so you may need to adjust these items also.

- Changing Tick Spacing:

  To change tick spacing, modify the Getaxis or Getlogaxis subprogram. Linear tick spacing is determined by the most significant digit of the Maxval pass parameter, whereas logarithmic tick spacing is determined by the ratio of the Minval and Maxval parameters. Refer to the Getaxis and Getlogaxis flow diagrams.

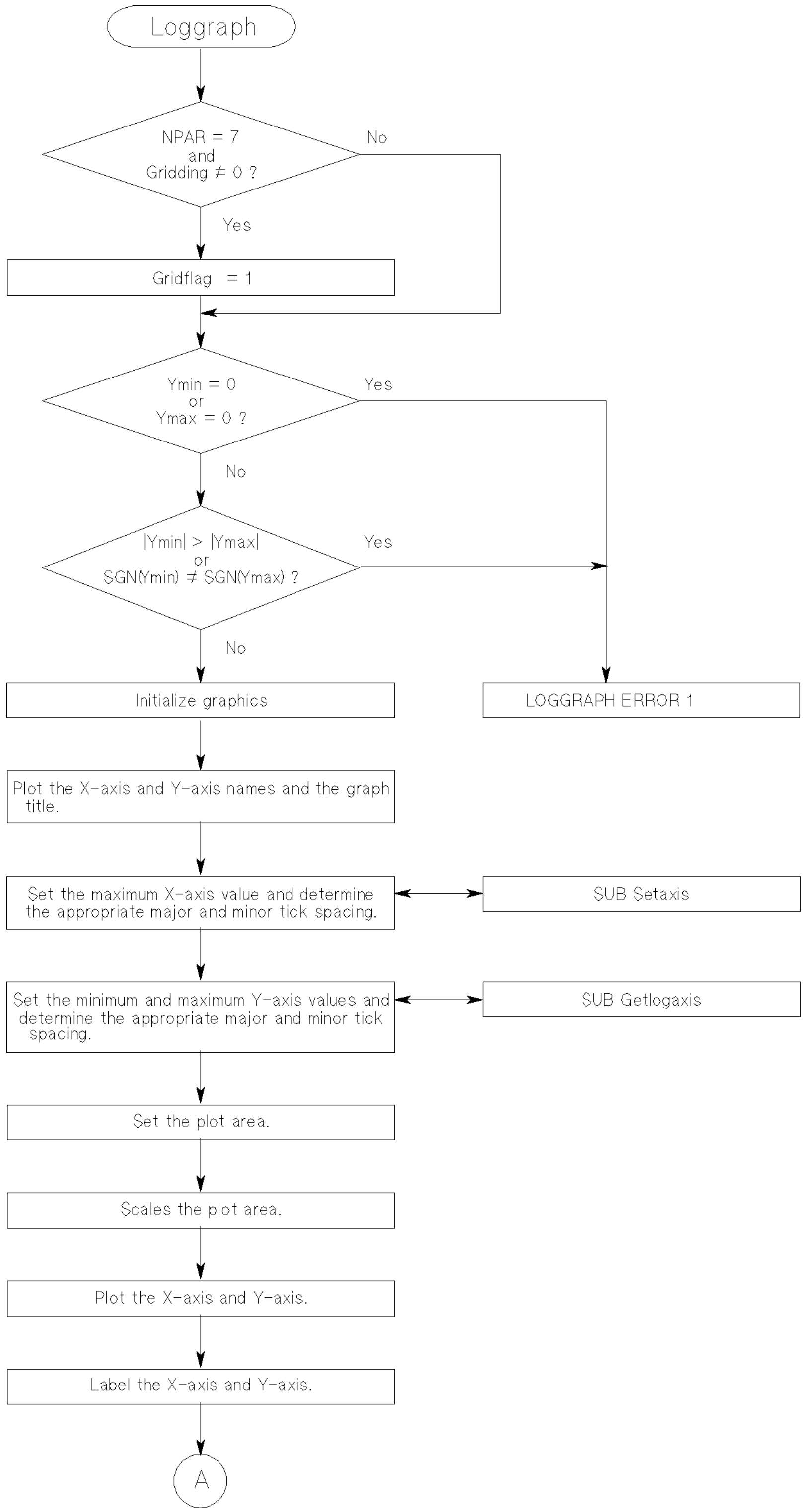
Lingraph and Cvgraph

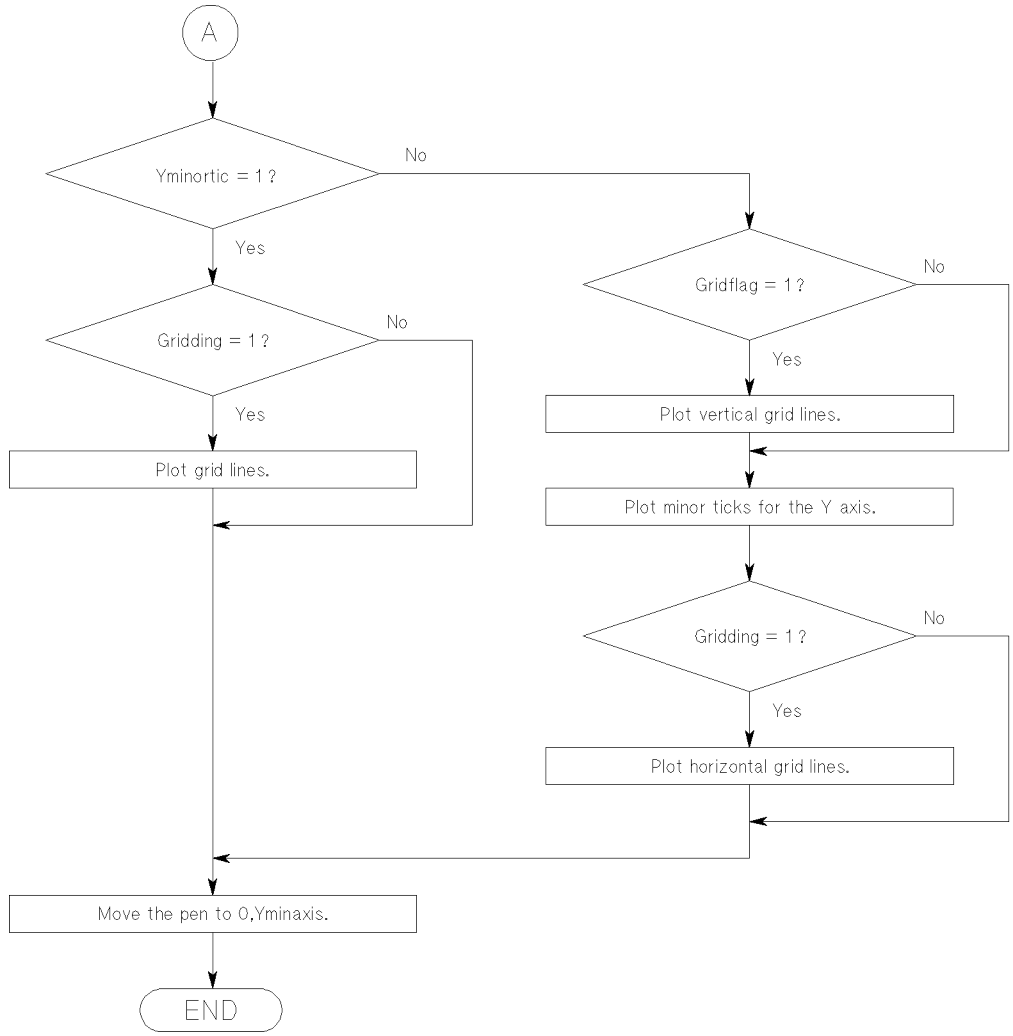


Lingraph and Cvgraph Variables

Variable Name	Description
Gridding	On/off control of grid lines (pass parameter)
Title$	Graph title (pass parameter)
Xlabelpos	Position of the X-axis labels
Xmajortic	X-axis major tick spacing
Xmax	Largest value plotted along the X-axis (pass parameter)
Xmaxaxis	Maximum X-axis value
Xminortic	X-axis minor tick spacing
Xname$	X-axis name (pass parameter)
Ylabelpos	Position of the Y-axis labels
Ymajortic	Y-axis major tick spacing
Ymax	Largest value plotted along the Y-axis (pass parameter)
Ymaxaxis	Maximum Y-axis value
Yname$	Y-axis name (pass parameter)

Loggraph

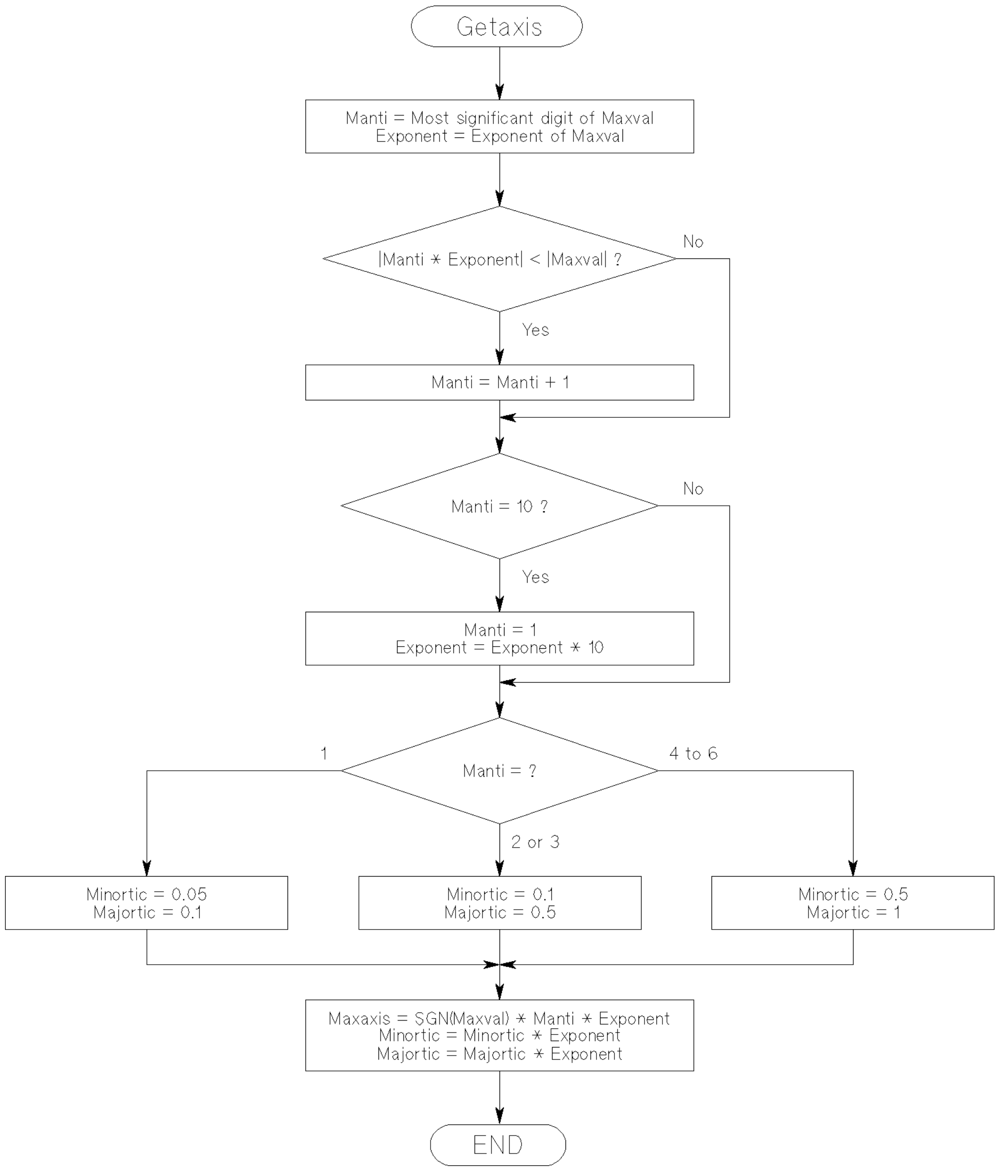

Loggraph
NPAR = 7
and
Gridding ≠ 0 ?
No
Yes
Gridflag = 1
Ymin = 0
or
Ymax = 0 ?
Yes
No
|Ymin| > |Ymax|
or
SGN(Ymin) ≠ SGN(Ymax) ?
Yes
No
Initialize graphics
LOGGRAPH ERROR 1
Plot the X-axis and Y-axis names and the graph title.
Set the maximum X-axis value and determine the appropriate major and minor tick spacing.
SUB Setaxis
Set the minimum and maximum Y-axis values and determine the appropriate major and minor tick spacing.
SUB Getlogaxis
Set the plot area.
Scales the plot area.
Plot the X-axis and Y-axis.
Label the X-axis and Y-axis.
A


A
Yminortic = 1 ?
No
Yes
Gridding = 1 ?
No
Yes
Plot grid lines.
Gridflag = 1 ?
No
Yes
Plot vertical grid lines.
Plot minor ticks for the Y axis.
Gridding = 1 ?
No
Yes
Plot horizontal grid lines.
Move the pen to 0,Yminaxis.
END

Loggraph Variables

Variable Name	Description
Gridding	On/off control of grid lines (pass parameter)
Gridflag	On/off control of grid lines
Title$	Graph title (pass parameter)
Xlabelpos	Position of the X-axis labels
Xmajortic	X-axis major tick spacing
Xmax	Largest value plotted along the X-axis (pass parameter)
Xmaxaxis	Maximum X-axis value
Xminortic	X-axis minor tick spacing
Xname$	X-axis name (pass parameter)
Ygridpos	Position of horizontal grid lines
Ylabelpos	Position of the Y axis labels
Ymajortic	On/off control of the Y-axis major ticks (decade spacing)
Ymax	Largest value plotted along the Y-axis (pass parameter)
Ymaxaxis	Maximum Y-axis value
Ymin	Smallest value plotted along the Y-axis (pass parameter)
Yminaxis	Minimum Y-axis value
Yminortic	On/off control of the Y axis minor ticks (0.1 decade spacing)

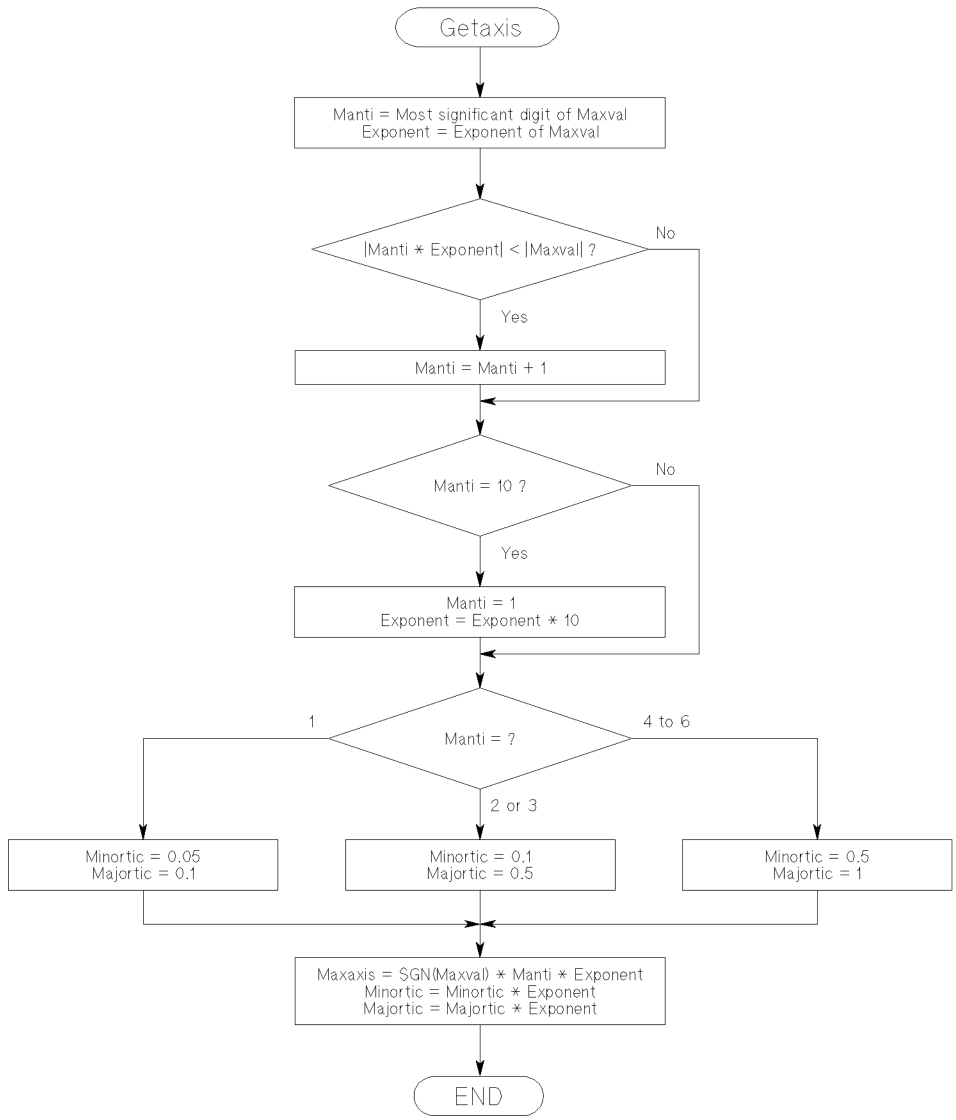
Getaxis


Getaxis
Manti = Most significant digit of Maxval
Exponent = Exponent of Maxval
|Manti * Exponent| < |Maxval| ?
No
Yes
Manti = Manti + 1
Manti = 10 ?
No
Yes
Manti = 1
Exponent = Exponent * 10
Manti = ?
1
4 to 6
2 or 3
Minortic = 0.05
Majortic = 0.1
Minortic = 0.1
Majortic = 0.5
Minortic = 0.5
Majortic = 1
Maxaxis = SGN(Maxval) * Manti * Exponent
Minortic = Minortic * Exponent
Majortic = Majortic * Exponent
END

Getaxis Variables

Variable Name	Description
Exponent	Exponent of Maxval
Majortic	Major tick spacing
Manti	Most significant digit of Maxval
Maxaxis	Maximum axis value
Maxval	Maximum value
Maxval$	String that contains Maxval formatted as a one digit mantissa and exponent
Minortic	Minor tick spacing

Getlogaxis


Getaxis
Manti = Most significant digit of Maxval
Exponent = Exponent of Maxval
|Manti * Exponent| < |Maxval| ?
No
Yes
Manti = Manti + 1
Manti = 10 ?
No
Yes
Manti = 1
Exponent = Exponent * 10
Manti = ?
1
4 to 6
2 or 3
Minortic = 0.05
Majortic = 0.1
Minortic = 0.1
Majortic = 0.5
Minortic = 0.5
Majortic = 1
Maxaxis = SGN(Maxval) * Manti * Exponent
Minortic = Minortic * Exponent
Majortic = Majortic * Exponent
END

Getlogaxis Variables

Variable Name	Description
Majortic	On/off control of major tick (decade spacing)
Maxaxis	Maximum axis value
Maxval	Maximum value (pass parameter)
Minaxis	Minimum axis value
Minortic	On/off control of minor ticks (0.1 decade spacing)
Minval	Minimum value (pass parameter)

E

Unsupported Wafer Prober

Introduction

This appendix provides information about using unsupported wafer probers with HP 4062C/UX/PC.

When you want to use unsupported wafer probers, the probers must have the HP-IB interface and the following HP-IB capabilities.

Moving the X-Y positioner
Raising and lowering the chuck
Unloading wafers

Creating Prober Control Subprograms

To use unsupported wafer probers, you must create the prober control subprograms for unsupported wafer probers. Refer to the prober manuals for details.

The easiest way to create the prober control subprograms for unsupported wafer probers is to copy and modify the prober control TIS subprograms that already exist in the HP 4062C/UX/PC system software (EGX, EGY, TSK, TEL, or MJC). TIS prober control subprograms are written in BASIC or BASIC/UX and are unprotected.

When you want to control unsupported wafer probers using PCL and PPG, prober control subprogram names for unsupported wafer probers must be same as those for supported wafer probers (Pdown, Pup, Pmove, and so on).

Modifying the SYSCONFIG file and START Program

This section provides information to modify the SYSCONFIG file and START program for unsupported wafer probers.

SYSCONFIG file

To use unsupported wafer probers, you must add mnemonics and device selectors for the probers to the SYSCONFIG file. The mnemonic and device selectors should be different from other system instruments.

For example, if a wafer prober in which the HP-IB address is 9 is connected to an HP-IB interface in which the select code is 25, a mnemonic may be “PROBER1” and a device selector is 2509. Add the mnemonic and the device selector as follows:

1. Load BASIC or BASIC/UX.

2. Specify the system mass storage as follows:
   - For HP 4062UX:

     `MSI "/usr/pcs/etc"` Return

   - For HP 4062C/PC with the recommended directory structure:

     `MSI "/PCS/ETC"` Return

   - For HP 4062C/PC with flexible disks:

     Insert the SYSTEM SOFTWARE (1) disk into the current system mass storage.

3. Load SYSCONFIG using the GET command as follows:

   `GET "SYSCONFIG"` Return

4. Select the EDIT softkey.

5. Add the mnemonics and device selector as follows:

```
     :
     :
1050 !
1060 ! WPS   EG1034X   2501
1070 ! WPS   EG2001X   2502
1080 ! WPS   TEL4000A  2503
1090 ! WPS   TEL4400A  2503
1100 ! WPS   TEL19S    2503
1110 ! WPS   TEL20S    2503
1120 ! WPS   APM3000A  2505
1130 ! WPS   APM6000A  2505
1140 ! WPS   APM7000A  2505
1150 ! WPS   SP900B    2508
1160 ! WPS   SP1000B   2508
1170 ! WPS   SP1100B   2508
1180 ! WPS   PROBER1   2509
```

6. Save the SYSCONFIG file as follows:

   `RE-SAVE "SYSCONFIG"`

START Program

To use an unsupported wafer prober, the START program must recognize that the prober exists. You must modify the START program to do so.

For example, if the mnemonic for the unsupported wafer prober is "PROBER1," modify the START program as follows:

1. Load BASIC or BASIC/UX.
2. Specify the system mass storage as follows:
   - For HP 4062UX:

     `MSI "/usr/pcs/bin"` Return

   - For HP 4062C/PC with the recommended directory structure:

```
MSI "/PCS/BIN" Return
```

- For HP 4062C/PC with the flexible disks:

  Insert the SYSTEM SOFTWARE (1) disk into the current system mass storage.

3. Load the START program using the LOAD command.

```
LOAD "START"
```

4. Select the EDIT softkey.
5. Find Prober_models subprograms.

```
FIND "Prober_models" Return
```

6. Insert the recognition routines for the unsupported wafer prober as follows:

```
     :
     :
CASE "APM3000A","APM6000A","APM7000A"
     Prober_name$="A-PM-3000/6000/7000A"
CASE "SP900B","SP1000B","SP1100B"
     Prober_name$="SP-900/1000/1100B"
     OUTPUT Paddress;"S2E"
CASE "TEL3300A"
CASE "R&K1032"
     OUTPUT Paddress;"E2"&CHR$(19)
CASE "PROBER1"
     Prober_name$="My prober"
CASE ELSE
     Prober_name$=""
     Paddress=0
     :
     :
```

7. Store the START program as follows:

```
RE-STORE "START"
```

F

Manual Backdates

HP 4062C/UX/PCs may vary slightly, depending on the revision of the system software. The information in this manual applies directly to HP 4062C/UX/PC system software revision 6.2 and above. This appendix contains information for customizing this manual, so that all the information pertains to the HP 4062C/UX/PC that you are using.

Table F-1. Manual Backdating by Software Revision

Software Revision	Make Manual Backdates
Rev. C.06.00 and X.06.00	1
Rev. C.05.60 and X.05.60	1, 2

- BACKDATE 1
  - HP 4062PC

    The system software revisions before revision 6.2 do not support HP 4062PC.

    Throughout this manual, delete any descriptions referring to the HP 4062PC.
  - "Introduction" in Chapter 6

    Delete the description about the FCONV program file.
  - "File Creation Library (FCL)" in Chapter 6

    The FCL cannot create a DOS text file and the Wfile_type does not exist.
  - "Creating DOS Data Files" in Chapter 6

    Delete entire section.
  - "Converting a BDAT Data File to a DOS File" in Chapter 6

    Delete entire section including two subsections.

■ BACKDATE 2

□ "Switching Matrix (SWM)" in Chapter 1

Delete the description about the port exponder.

□ "PreSTART Execution Conditions" in Chapter 1

The CMU84 or LCR is connected to the system controller's internal HP-IB interface (select code 7).

□ "Configuration Display Page" in Chapter 1

1. Delete the following paragraph from the `**************** SYSTEM CONFIGURATION ****************:`

   If a port expander (Option 340) is equipped with the SWM, the "`(Opt. 340`" is shown after the `SWITCHING MATRIX`.

2. Delete the following paragraph from the `************ AUXILIARY PORT CONFIGURATION ************:`

   If your SWM is an HP 4089B with Option 340 (adds a port expander), the AUXILIARY PORT CONFIGURATION block may vary. For instance, it may be displayed as follows:

   ```
   AUX11:VS1  12:     13:VM1   AUX31:CMH84 32:     33:     |
   AUX21:VS2  22:     23:VM2   AUX41:CML84 42:     43:     |
   ```

   A blank field means either no instrument or an unsupported instrument is connected.

□ "Executing the START Program of HP 4062C" in Chapter 1

1. Delete the following paragraph from the `**************** SYSTEM CONFIGURATION ****************:`

   If a port expander (Option 340) is equipped with an SWM, the "`(Opt. 340)`" is shown after the `SWITCHING MATRIX`.

2. Delete the following paragraph from the `************ AUXILIARY PORT CONFIGURATION ************:`

   If your SWM is an HP 4089B with Option 340 (adds a port expander), the AUXILIARY PORT CONFIGURATION block may vary. For instance, it may be displayed as follows:

   ```
     .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .
   AUX11:VS1  12:     13:VM1   AUX31:CMH84 32:     33:     |
   AUX21:VS2  22:     23:VM2   AUX41:CML84 42:     43:     |
     .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .
   ```

   A blank field means either no instrument or an unsupported instrument is connected.

□ "Introduction" in Chapter 2

Delete the following note.

Note The VFP does *not* support the port expander. No relays in the port expander can be controlled with the VFP. If the port expander is installed on your SWM, the AUX11, AUX21, AUX31, and AUX41 ports are recognized as AUX1, AUX2, AUX3, and AUX4, respectively.

□ "Capacitance Measurement Using CMU84" in Chapter 3

1. When using DVR4284 subprograms, be sure to link DVR4284 to your measurement program.
2. Change Figure 3-30 as follows:

```
.
.
30   !    Requirements: TIS,XYGRAPH,DVR4284   ⇐
.
.
230  Frequency84(Freq)                        ⇐
.
.
310  Force_v84(Vstart)                        ⇐
.
.
360    Force_v84(Vdata(I))                    ⇐
```

3. Change Figure 3-32 as follows:

```
.
.
30   !    Requirements: TIS,XYGRAPH,DVR4284   ⇐
.
.
210  Frequency84(Freq)                        ⇐
```

□ "High Speed Measurement Programming Hints" in Chapter 3

Delete the paragraph about the "Use the program memory function of the DCS".

□ "Using DCS Program Memory Functions" in Chapter 3

Delete this section and all its subsections.

□ "Port Status" in Chapter 4

Change the first paragraph as follows:

TIS's Port_status subprogram or DVR4284's Port_status84 returns a specified port's status when a measurement completes and is particularly useful for determining the cause of abnormal measurement results.

- "System Software Support Levels" in Chapter 4

  Change Table 4-1 as follows:

System Software Support Levels

Support Level	Software
Supported	TIS[1] , PARA, VFP, START, DVR4284[2]
Not operational	DPROBER[3] , WAFER[4]
Unsupported	EGX, EGY, TSK, DIAG, PV4062, DVR4274
Not related	TIS_UTIL, XYGRAPH, PPG, MAP, BSDM

1 TIS performs pass parameter checking and returns dummy data.

2 File data simulation mode is not supported.

3 DPROBER is a dummy prober driver.

4 WAFER can be used in conjunction with DPROBER.

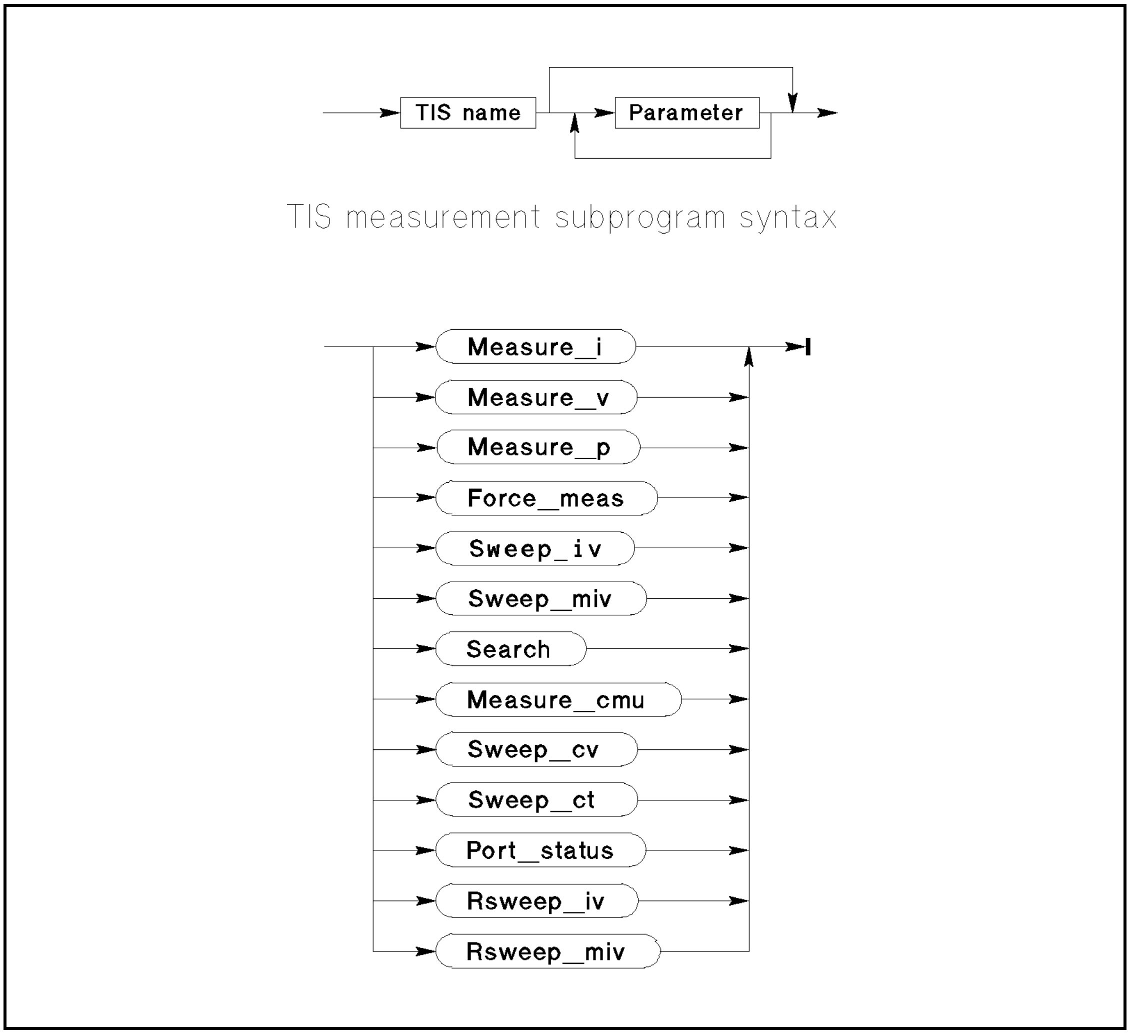
- "Offline Data Simulation" in Chapter 4

  Remove the following subprograms from the list:

  Measure_cmu84
  Port_status84
  Sweep_cv84
  Rsweep_iv
  Rsweep_miv
  Readout_dcs
  Readsweep_dcs

- "Constant Data Simulation" in Chapter 4

1. Remove the description about Readout_dcs and Readsweep_dcs.
2. Change Figure 4-7 as follows:



Simulation File Data Record Syntax

- "How to Start HP IMA with an HP 4062C/UX/PC" in Chapter 8

  Change the startup procedure as follows:

1. Load the START_IMA program.
   a. For the HP 4062UX:

      `LOAD "/usr/pcs/ima/START_IMA"` (Return)

   b. For the HP 4062C with the recommended directory structure (see Chapter 1 in this manual for directory structure information):

      `LOAD "/PCS/IMA/START_IMA"` (Return)

   c. For the HP 4062C with flexible disks:

      Insert IMA System Disk (1) into the flexible disk drive.

      `LOAD "START_IMA"` (Return)

   Select the `RUN` softkey.
2. The following message is displayed:

   `Start up IMA with 4142B ?  (Y/N)`

   If you have a DCS and want to control it, select the `Yes` softkey. Proceed to step 3.

   If you don't have a DCS or don't want to control it, select the `No` softkey. Proceed to step 5.
3. The following message is displayed:

   `System should be initialized ?  (Y/N)`

   If you have never initialized the system as either an HP 4062C/UX or HP IMA, select the `Yes` softkey. Proceed to step 4.

   If you have initialized the system as either an HP 4062C/UX or HP IMA and you want to skip the initialization process, select the `No` softkey. Proceed to step 5.
4. The START program begins.

   For HP 4062Cs: The following messages is displayed:

   `New system date ?`

   `New system clock time ?`

   Update the date and time, if either is incorrect.

   If you don't need to update the date and time, press (Return).
5. The Selection Menu page is displayed: