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TYPE II

NAVY STANDARDS LABORATORY

SPRINGFIELD

LOCAL CALIBRATION PROCEDURE (LCP)

LCP-WJL-Ø24

for

GUILDLINE 9923 RANGE EXTENDER

Prepared by

Unified Industries, Inc

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ILLUSTRATIONS

TABLES

SECTION 1

INTRODUCTION AND DESCRIPTION

1.1 This procedure describes the calibration of the Guildline Model 9923 Range Extender. The instrument being calibrated is referred to herein as the TI (Test Instrument).

1.2 This procedure includes tests of essential performance parameters only. Any malfunctions noticed during calibration, whether specifically tested for or not, should be corrected.

Table 1. Calibration Description

TI Characteristics	Performance Specifications	Test Method
Transformation Ratio	Range: 10:1 Uncertainty: 0.5 ppm Range: 100:1 Uncertainty: 0.5 ppm Range: 1000:1 Uncertainty: 1 ppm	Comparison to an established standard resistance ratio measured by a resistance measurement system.

SECTION 2

EQUIPMENT REQUIREMENTS

NOTE

Minimum use specifications are the principal parameters required for performance of the calibration. All applicable equipment must bear evidence of current calibration.

Item	Minimum Use Specifications	Calibration Equipment
2.1 Direct Current Comparator Resistance Bridge	No substitute	Guildline 9975
2.2 Range Plug	No substitute	Guildline 99753
2.3 Reversing Switch	No substitute	Guildline 9606
2.4 DC Power Supply #1	Range: 0 to 2 Amp Uncertainty: ± 0.2% Stability: <0.03% of output	John Fluke 382A
2.5 DC Power Supply #2	Range: 0 to 10 Amp Uncertainty: ± 2% of fs Stability: <0.03% of output plus 20 mA	Hewlett Packard 6260B
2.6 Primary Standard Resistor (3 required)	Range: 1 ohm Uncertainty: ± 0.08 ppm (Calibrated by NBS and monitored by MCP-WJL-002. Limited to R1, R2 and R3 listed within the MCP.)	Leeds & Northrup 4210
2.7 Standard Resistor	Range: 0.001 ohm Uncertainty: ± 0.4 ppm (Established during procedure and IAW MCP-WJL-002)	Leeds & Northrup 4223

Item	Minimum Use Specifications	Calibration Equipment
2.8 Standard Resistor	Range: Ø.Ø1 ohm Uncertainty: ± Ø.2 ppm (Established during procedure and IAW MCP-WJL-ØØ2)	Leeds & Northrup 4222
2.9 Standard Resistor	Range: Ø.1 ohm Uncertainty: ± Ø.2 ppm (Established during procedure and IAW MCP-WJL-ØØ2)	Leeds & Northrup 4221
2.1Ø Standard Resistor	Range: 1Ø ohm Uncertainty: ± Ø.2 ppm (Established during procedure and IAW MCP-WJL-ØØ2)	Leeds & Northrup 4Ø25
2.11 Current Shunt	Range: 15 Amps/Ø.1 ohm Uncertainty: ± Ø.1%	Leeds & Northrup 436Ø
2.12 Digital Multimeter (DMM)	Range: Ø to 2 Vdc Uncertainty: ± Ø.1%	Datron 1Ø72
2.13 Oil Bath	Range: 25°C Uncertainty: ± Ø.Ø5°C	Guildline 973ØC
2.14 Shielded Copper Wire	Type: 22 AWG, twisted pair solid conductor	Guildline Type SCW or equivalent
2.15 Stranded Copper Wire	Must be capable of handling applied currents of up to 1Ø Amps (4ØØcm/Amp) 1 Amp - 2Ø AWG 1Ø Amp - 14 AWG	Local Supply
2.16 Computer	No Substitute	Hewlett-Packard HP-9816
2.17 Program	No Substitute	CALEXTENDR

SECTION 3

PRELIMINARY OPERATIONS

3.1 Ensure that all power switches are set to off or standby. Set all auxiliary equipment controls as necessary to avoid damage to the equipment and so that dangerous voltage will not be present on output terminals when the power switches are turned on.

3.2 Connect the auxiliary equipment to the appropriate power sources.

3.3 Turn the Resistance Bridge (Item 2.1) on and allow for a sufficient warm-up time. (Lab policy requires unit to be on at all times).

CAUTION

IF THE OSC LIGHT IS EXTINGUISHED AT ANY TIME WHEN THE POWER IS ON, TURN THE POWER OFF IMMEDIATELY AND TAKE CORRECTIVE ACTION AS NECESSARY.

3.4 Ensure the Resistance Bridge pre-operational checkout and setup procedure has been performed in the last 30 days in accordance with LCP-WJL-001 Appendix A.

3.5 Place the Standard Resistors (Item 2.6 through 2.10) in the Oil Bath (Item 2.13) and allow sixteen hours to attain temperature stability.

3.6 Set the Resistance Bridge controls as follows (see Figure 1 for switch/control locations):

Note

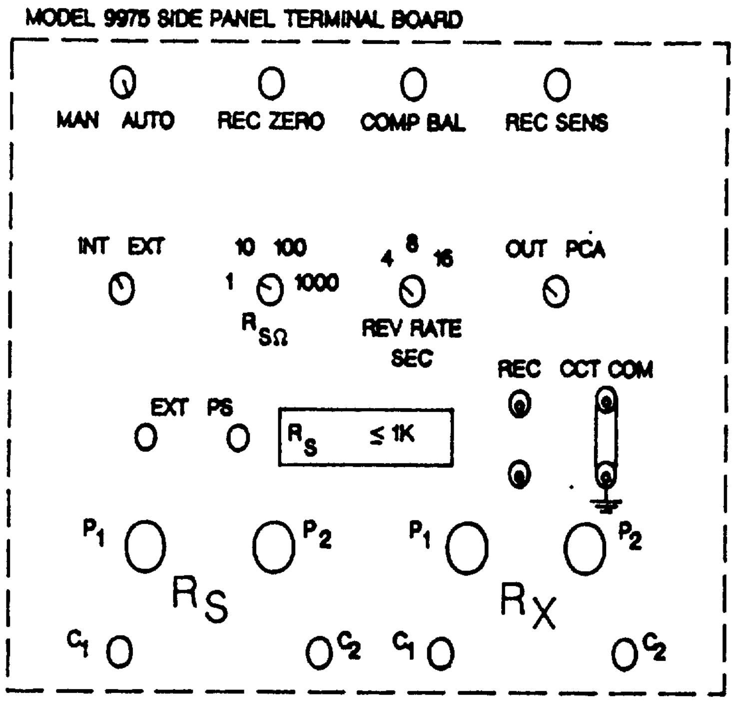
Ensure that Standard Resistors remain in the Oil Bath throughout the procedure to ensure the accuracy and stability of the resistance measurements.

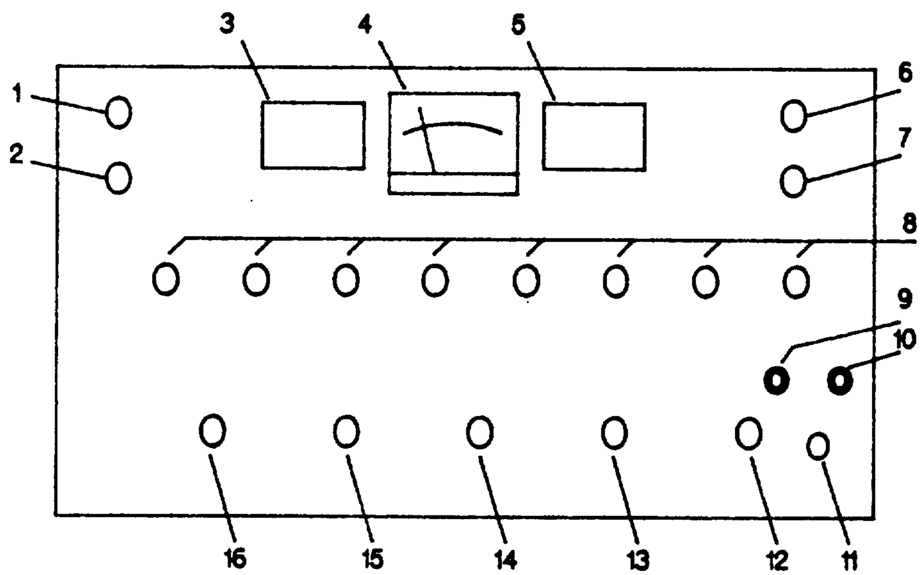
Side Panel Controls

PCA/OUT switch to	OUT
REV/RATE switch to	8
RsΩ switch to	1
MAN/AUTO switch to	MAN
INT/EXT switch to	INT
Rx/Rs dials to	10.00000-1

Front Panel Controls

CURRENT IxmA switch to	0
X1 X$\sqrt{2}$ switch to	X1
GALVANOMETER SENSITIVITY switch to	X1
GALVANOMETER D1/D2 switch to	D1
TIME CONSTANT switch to	1





1. CURRENT I_X mA switch
2. X1 x$\sqrt{2}$ switch
3. I_X meter
4. GALVANOMETER METER
5. AMPERE TURN BALANCE (ATB) meter
6. GALVANOMETER SENSITIVITY switch
7. GALVANOMETER D1/D2 switch
8. R_X/ R_S dials
9. OSC indicator
10. POWER indicator
11. POWER OFF/ON switch
12. TIME CONSTANT SEC switch
13. HIGH TRACK control
14. TRANSIENT SUPPRESSION control
15. GALV BALANCE control
16. CURRENT REVERSING switch

Figure 1. 9975 Resistance Bridge Controls

SECTION 4

CALIBRATION PROCESS

NOTE

Unless otherwise specified, verify the results of each test and take corrective action whenever the test requirement is not met, before proceeding.

4.1 0.1 OHM AND 10 OHM STANDARD RESISTOR CALIBRATION

NOTE

The 0.1 ohm and 10 ohm Standard Resistors (Item 2.9 and 2.10) are calibrated against the Primary Standard Resistor(s) (Item 2.6) to establish an uncertainty of 0.2 ppm. Their values in conjunction with the Primary Standard Resistors will provide the reference ratios required to calibrate the TI 10:1 RATIO range.

4.1.2 Insert the Rs≤1k/Rs≥10k Range Plug (side panel) with the Rs≤1k side facing up.

4.1.3 Connect the equipment as shown in Figure 2, using the 0.1 ohm Standard Resistor as Rs, and the first (of three) Primary Standard Resistors as Rx. Record the 0.1 ohm Standard Resistor Serial Number on Worksheet no. 1.

NOTE

The Primary Standard Resistors must be used in the MCP-WJL-002 data base sequence to ensure valid cross references to the data base:

R1 - READING 1
R2 - READING 2
R3 - READING 3

Note

Ensure that all connections are secure to avoid possible errant thermal resistance.

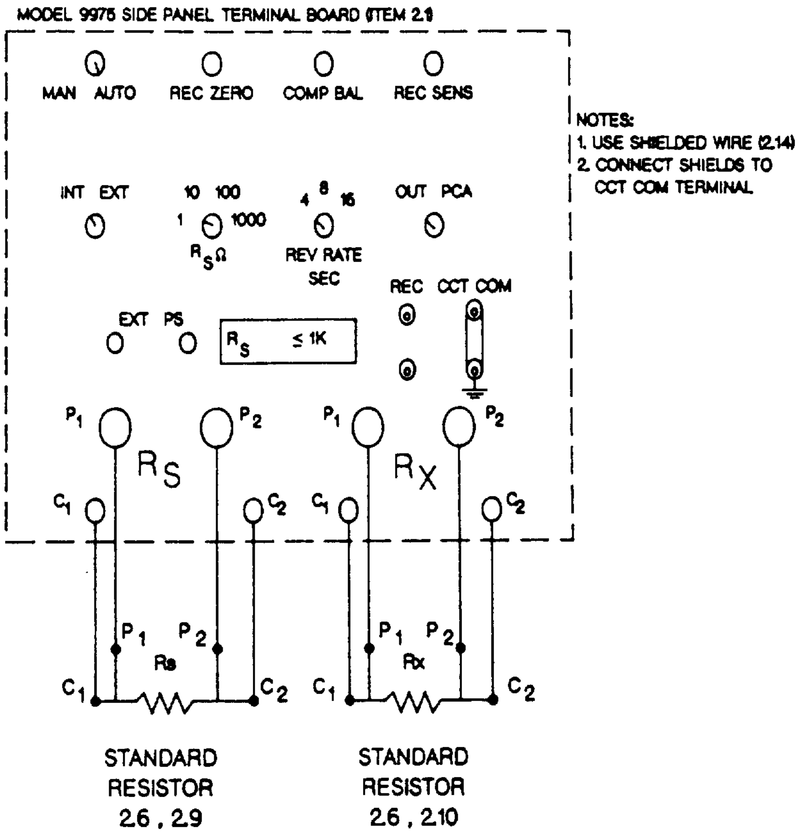


Figure 2. Resistance Test Setup

4.1.4 Adjust the 9460B Photocell Amplifier (part of Resistance Bridge) ZERO control for a null indication on the GALVANOMETER meter.

4.1.5 Set the MAN/AUTO switch (side panel) to AUTO.

NOTE

Automatic current reversing to be used as a convenience. For higher accuracy (particularly at low resistance values) a slower rate is required, either use a slower automatic rate (REV/RATE switch, side panel) or use manual switching (CURRENT REVERSING switch, front panel).

4.1.6 Set the PCA/OUT switch to PCA.

4.1.7 Set the GALVANOMETER D1/D2 switch to D2 and adjust the REC/ZERO control (side panel) for a null indication on the GALVANOMETER meter.

4.1.8 Set the GALVANOMETER D1/D2 switch to D1.

4.1.9 Set the CURRENT IxmA switch to 10 (mA)

NOTE

The above current level was selected to be large enough to minimize circuit noise effects while avoiding producing excessive self heating effects. If desired, self heating effects may be checked by measuring resistance at different current levels, which can be accomplished by setting the X1 $X\sqrt{2}$ switch to $X\sqrt{2}$ for the second measurement and subtracting the difference between the X1 and $X\sqrt{2}$ measurements to determine if the effects are present.

4.1.10 Adjust the HIGH TRACK control until no deflection is noted on the AMPERE TURN BALANCE meter upon current reversal.

4.1.11 Adjust the COMP BAL control (side panel) for a zero indication on the AMPERE TURN BALANCE meter, if necessary.

4.1.12 Adjust the GALV BALANCE control (front panel) to where the GALVANOMETER meter deflects equally on each side of center scale upon current reversal to compensate for thermal emf's.

4.1.13 Adjust the Rx/Rs dials for a balance indication on the GALVANOMETER meter.

NOTE

Balance is attained when the GALVANOMETER meter indication does not deflect upon current reversal.

4.1.14 Increase the GALVANOMETER SENSITIVITY by one (i.e. X1 to X2).

4.1.15 Readjust the GALV BALANCE control for thermal emf's, if necessary.

4.1.16 Readjust the Rx/Rs dials for a balance indication on the GALVANOMETER meter.

4.1.17 Repeat steps 4.1.14 through 4.1.16 for higher settings of the GALVANOMETER SENSITIVITY switch up to the setting which yields the required measuring sensitivity.

NOTE

The required measuring sensitivity is attained when the least significant Rx/Rs dial, which equals the Standard Resistor's required resolution (8th place), affects the balance indication on the GALVANOMETER meter.

4.1.18 Adjust the TRANSIENT SUPPRESSION control to minimize the transient "kick" on the GALVANOMETER meter.

4.1.19 Set the GALVANOMETER D1/D2 switch to D2.

4.1.20 Readjust the Rx/Rs dials for a final balance, using the GALVANOMETER meter as a null detector.

NOTE

Final balance is achieved when GALVANOMETER meter indication stops drifting.

NOTE

If the above balance was carried out in the automatic current reversing mode with the REV/RATE switch set to 8, it is recommended that balancing be repeated at a slower reversing rate (16) or use manual switching, unless previous experience proves otherwise.

NOTE

When using manual current reversing allow enough time for the GALVANOMETER meter indication to settle down before reversing current.

4.1.21 Record the Rx/Rs dials indication as READING 1 on Worksheet no. 1.

4.1.22 Set the Resistance Bridge controls as follows:

Front Panel Controls

GALVANOMETER SENSITIVITY switch to	X1
GALVANOMETER D1/D2 switch to	D1
CURRENT IxmA switch to	Ø
Rx/Rs dials to	1Ø.ØØØØØ-1

Side Panel Controls

PCA/OUT switch to	OUT
MAN/AUTO switch to	MAN

4.1.23 Disconnect the 1 ohm Primary Standard Resistor and replace it with the next Primary Standard Resistor.

4.1.24 Repeat steps 4.1.3 through 4.1.23 with remaining Primary Standard Resistors, recording the values as READING 2 and 3 on Worksheet no. 1.

4.1.25 Repeat steps 4.1.3 through 4.1.24 with the 10 ohm Standard Resistor as Rx and the 1 ohm Primary Standard Resistor(s) as Rs. Record the results on Worksheet no. 1 under 10 ohm Standard Resistor Calibration.

4.1.26 Disconnect the test setup.

4.1.27 Enter the Standard Resistor data and measured values recorded on Worksheet no. 1 into the HP 9816 computer (Item 2.16) program CALEXTENDR (Item 2.17) for both Standard Resistors (Refer to Appendix A for instructions).

NOTE

CALEXTENDR will determine the standard deviation and mean resistance value, correct for left/right balance (determined by MCP-WJL-002) and verify the Standard Resistance value tracks its previous calibration.

4.1.28 Enter the computed Standard Resistor values and uncertainties on Worksheet no. 1.

4.2 ZEROING THE TI

4.2.1 Adjust the TI HIGH TRACK control fully CCW.

NOTE

The TI must not have any current applied to its input or output terminals when zeroing.

4.2.2 Set the TI POWER switch to ON.

CAUTION

IF THE OSC LIGHT DOES NOT COME ON IMMEDIATELY, SET THE POWER TO OFF AND TAKE CORRECTIVE ACTION AS NECESSARY.

4.2.3 Adjust the ZERO ADJ for a null indication on the NULL meter.

4.2.4 Set the TI POWER switch to OFF.

4.3 TI MEASUREMENT PROCESS

NOTE

Due to the number of times this process will be performed, this Subsection is dedicated to the process only. The subsequent Subsections will describe the parameters tested and the test configuration changes. Proceed to Subsection 4.4 and refer back when directed.

4.3.1 Set the Resistance Bridge controls as follows (see Figure 1 for switch/control locations).

Side Panel Controls

PCA/OUT switch to	OUT
REV/RATE switch to	8
RsΩ switch to	100
MAN/AUTO switch to	MAN
INT/EXT switch to	EXT

Front Panel Controls

CURRENT IxmA switch to	0
X1 $X\sqrt{2}$ switch to	X1
GALVANOMETER SENSITIVITY switch to	X1
GALVANOMETER D1/D2 switch to	D1
TIME CONSTANT SEC switch to	1
Rx/Rs dials to	1.000000-1

4.3.2 Remove the Resistance Bridge Rs≤1k/Rs≥10k Range Plug (side panel) and replace it with the 99753 Range Plug (Item 2.2).

4.3.3 Connect the equipment as shown in Figure 3, using the appropriate Standard Resistors and Power Supply as directed. Record the Standard Resistor used in the calibration Serial Numbers on the appropriate Worksheet.

NOTE

Make all connections as short as practical and ensure the Copper Wire (Item 2.15) will handle the applied current to avoid entering errant resistance values.

1 Amp - 20 AWG
10 Amp - 14 AWG

4.3.4 Connect the Shielded Wire (Item 2.14) shields to the Resistance Bridge CCT COM terminal (side panel).

4.3.5 Set the TI RATIO switch to the selected terminal connection position.

4.3.6 Set the Resistance Bridge CURRENT IxmA switch to 100.

4.3.7 Set the Resistance Bridge CURRENT REVERSING switch from A to B then B to A, and listen for an audible click(s) to ensure activation of the Reversing Switch (Item 2.3).

4.3.8 Adjust the TI's HIGH TRACK control fully CW.

4.3.9 Set the TI's ON/OFF switch to ON.

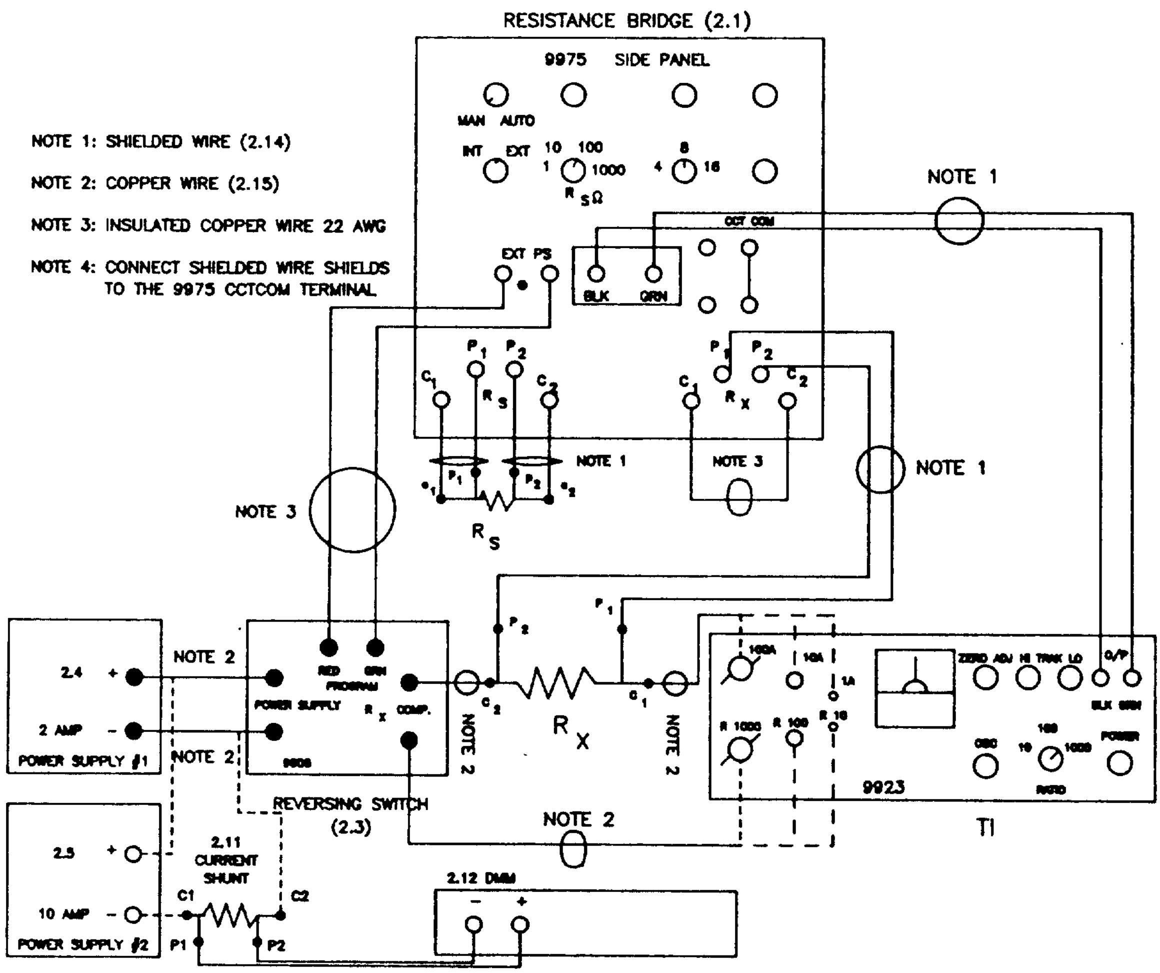


Figure 3. Ratio Test Setup

CAUTION

DO NOT ALLOW THE DC POWER SUPPLY (ITEM 2.4/2.5) TO BE ON WHEN THE TI IS OFF. FAILURE TO OBSERVE WILL CAUSE THE TI'S TRANSFORMER TO BECOME MAGNETIZED.

CAUTION

IF AT ANY TIME THE TI'S OSC LIGHT IS EXTINGUISHED, TURN THE DC POWER SUPPLY AND TI POWER TO OFF IMMEDIATELY. THIS CONDITION INDICATES THE OSCILLATOR HAS STOPPED DUE TO OVERLOAD. ALLOW 30 SECONDS FOR THE OSCILLATOR TO RESET, THEN TURN THE POWER SWITCHES BACK ON. IF THE OSC LIGHT REMAINS EXTINGUISHED, TURN THE POWER SWITCHES TO OFF AND TAKE CORRECTIVE ACTION AS NECESSARY.

4.3.10 Set the appropriate DC Power Supply as follows:

2 Amp DC Power Supply #1 (Item 2.4)

METER switch to	A
V-A Range switch to	2A
V LIMIT control to	Mid-range
A LIMIT control to	Max (fully CW)
CURRENT LIMIT RANGE switch to	2A
Decade Dial switches to	0.00000
Power switch to	ON

10 Amp DC Power Supply #2 (Item 2.5)

VOLTAGE coarse and fine controls to	fully CCW
CURRENT coarse and fine controls to	fully CCW
LINE power switch to	ON

4.3.11 Adjust the TI's LOW TRACK control for a null indication on the NULL meter.

4.3.12 Adjust the Resistance Bridge COMP BAL (side panel) control for a null indication on the AMPERE TURN BALANCE meter.

CAUTION

DO NOT EXCEED THE TI INPUT CURRENT LIMITS.

RATIO 1000	**terminal**	**=**	**100 Amp**
RATIO 100	**terminal**	**=**	**10 Amp**
RATIO 10	**terminal**	**=**	**1 Amp**

4.3.13 Adjust the DC Power Supply output controls to approximately 10% of the selected current.

4.3.14 Adjust the Resistance Bridge HIGH TRACK control to minimize the deflections on the AMPERE TURN BALANCE meter, while reversing the current with the CURRENT REVERSING switch.

4.3.15 Adjust the TI HIGH TRACK control to minimize the deflections on its NULL meter, while reversing the current with the Resistance Bridge CURRENT REVERSING switch (as in Step 4.3.14).

4.3.16 Readjust the TI LOW TRACK control for a null indication on the NULL meter.

4.3.17 Set the Resistance Bridge PCA/OUT switch to PCA.

4.3.18 Set the Resistance Bridge MAN/AUTO switch to AUTO.

NOTE

Automatic current reversing to be used as a convenience. For higher accuracy (particularly at low resistance values) a slower rate is required, either use a slower automatic rate (REV/RATE switch, side panel) or use manual switching (CURRENT REVERSING switch, front panel).

4.3.19 Adjust the Resistance Bridge Rx/Rs dials for an approximate balance on the GALVANOMETER meter.

NOTE

Balance is attained when the GALVANOMETER meter indication does not change upon current reversal.

4.3.20 Adjust the Resistance Bridge GALV BALANCE control to center the GALVANOMETER meter, if necessary.

4.3.21 Adjust the DC Power Supply output controls to 100% of the selected current. If using DC Power Supply #2 note the DMM indication.

4.3.22 Readjust the HIGH TRACK controls on both the Resistance Bridge and TI until no change is observed on the AMPERE TURN BALANCE and NULL meter respectively, upon current reversal.

4.3.23 Adjust the Resistance Bridge GALV BALANCE control to where the GALVANOMETER meter deflects equally on each side of center scale upon current reversal to compensate for thermal emf's.

4.3.24 Adjust the Resistance Bridge TRANSIENT SUPPRESSION control to minimize the transient "kick" on the GALVANOMETER meter.

4.3.25 Readjust Resistance Bridge Rx/Rs dials for a balance indication on the GALVANOMETER meter.

4.3.26 Increase the Resistance Bridge GALVANOMETER SENSITIVITY switch setting by one (i.e., X1 to X2).

4.3.27 Readjust the Resistance Bridge GALV BALANCE control, if necessary.

4.3.28 Readjust the Rx/Rs dials for a balance indication on the GALVANOMETER meter.

4.3.29 Repeat steps 4.3.26 through 4.3.28 for the GALVANOMETER SENSITIVITY switch up to the setting which yields the required measuring sensitivity (8th place).

NOTE

When measuring a 1:1 Rx/Rs ratio the required measuring sensitivity is attained when the 8th place resolution can be interpolated from the GALVANOMETER meter indication.

4.3.30 Set the Resistance Bridge GALVANOMETER D1/D2 switch to the D2.

4.3.31 Readjust the Resistance Bridge Rx/Rs dials for a final balance using the GALVANOMETER meter as a null detector.

NOTE

Final balance is achieved when the GALVANOMETER meter indication stops drifting.

NOTE

If the above balance was carried out in the automatic current reserving mode with the REV/RATE switch set to 8, it is recommended that balancing be repeated at a slower rate (16) or use manual switching, unless previous experience proves otherwise.

NOTE

When using manual current reversing allow enough time for the GALVANOMETER meter indication to settle down before reversing current.

4.3.32 Record the Resistance Bridge Rx/Rs dials indication on the appropriate Worksheet as READING 1.

4.3.33 Set the equipments controls (in sequence) as follows:

1. Resistance Bridge

GALVANOMETER SENSITIVITY switch to	X1
GALVANOMETER D1/D2 switch to	D1
MAN/AUTO switch to	MAN

2. DC Power Supply

#1 (2 Amp)

Decade Dial switches to	0.00000
POWER switch to	OFF

#2 (10 Amp)

CURRENT controls	fully CCW
VOLTAGE controls	fully CCW
LINE power switch to	OFF

3. TI:

ON/OFF switch to	OFF

4. Resistance Bridge

PCA/OUT switch to	OUT
CURRENT IxmA switch to	0
Rx/Rs dials to	1.000000-1

4.3.34 Repeat steps 4.3.6 through 4.3.33 two more times, allowing time for the Standard Resistor(s) to cool (approximately 5 minutes) before testing. Recording the values as READING 2 and 3 on the appropriate Worksheet.

4.3.35 Enter the Standard Resistor data and the measured values recorded on the appropriate Worksheet into the HP9816 Computer Program CALEXTENDR. (See Appendix A for instructions.)

4.3.36 Record the CALEXTENDR computed values on the appropriate Worksheet.

4.3.37 Proceed to Subsection 4.4, 4.5, 4.6, 4.7 and 4.8 as applicable.

4.4 10:1 RATIO TEST

4.4.1 Perform Subsection 4.3 using equipment, control positions and outputs listed below. Record the measured values on Worksheet no. 2 under 10:1 RATIO Test No. 1.

TI Terminal Connection	TI RATIO Switch Position	Rs	Rx	DC Power Supply	Current
1A/R10	10	10Ω	1Ω	#1	10 mA 10% 100 mA 100%

NOTE

Exchange the Rx Primary Standard Resistor for reading 1, 2, and 3 as indicated by Worksheet no. 2.

4.4.3 Disconnect the Standard Resistors from the test setup.

4.4.4 Perform Subsection 4.3 using the equipment, control positions and outputs listed below. Record the measured values on Worksheet no. 2 under 10:1 RATIO Test No. 2.

TI Terminal Connection	TI RATIO Switch Position	Rs	Rx	DC Power Supply	Current
1A/R10	10	1Ω	0.1Ω	#1	30 mA 10% 300 mA 100%

NOTE

Exchange the Rs Primary Standard Resistor for reading 1, 2, and 3 as indicated by Worksheet no. 2.

4.4.5 Record the CALEXTENDR computed RATIO average value on Worksheet no. 2 and verify it is within ± 0.5 ppm of nominal (10.00000).

4.4.6 Disconnect the Standard Resistors from the test setup.

4.5 0.1 OHM AND 0.01 OHM STANDARD RESISTOR CALIBRATION

NOTE

The 0.1 ohm and 0.01 ohm Standard Resistors are calibrated on the TI 10:1 Range to establish an uncertainty of 0.4 ppm. The Standard Resistors will be used when calibrating the 100:1 RATIO range.

NOTE

Due to the uncertainty requirements the 0.1 ohm Standard Resistor requires recalibration at 1 Amp (used in the 100:1 Ratio Tests) because self-heating effects may cause a change in value greater than 0.5 ppm from the value recorded in Subsection 4.1.

4.5.1 Perform Subsection 4.3 using the equipment, control positions and outputs listed below. Record the measured values on Worksheet no. 3 under 0.1 ohm and 0.01 ohm calibration.

TI Terminal Connection	TI RATIO Switch Position	Rs	Rx	DC Power Supply	Current
1A/R10	10	*1Ω	0.1Ω	#1	100 mA 10% 1 A 100%
		0.1Ω	0.01Ω	#1	100 mA 10% 1 A 100%

*NOTE

Exchange the Rs Primary Standard Resistor for reading 1, 2, and 3 as indicated by Worksheet no. 3.

4.5.2 Disconnect the Standard Resistors from the test setup.

4.6 100:1 RATIO TEST

4.6.1 Perform Subsection 4.3 using the equipment, control positions, and outputs listed below. Record the measured values on Worksheet no. 4 under 100:1 RATIO Test No. 1.

TI Terminal Connection	TI RATIO Switch Position	Rs	Rx	DC Power Supply	Current
10A/R100	100	1Ω	0.01Ω	#1	100 mA 10% 1 A 100%

NOTE

Exchange the Rs Primary Standard Resistor for reading 1, 2, and 3 as indicated by Worksheet no. 4.

4.6.2 Disconnect the Standard Resistors.

4.6.3 Perform Subsection 4.3 using the equipment, control positions and outputs listed below. Record the measured values on Worksheet no. 4 under 100:1 RATIO Test No. 2.

TI Terminal Connection	TI RATIO Switch Position	Rs	Rx	DC Power Supply	Current
10A/R100	100	10Ω	0.1Ω	#1	100 mA 10% 1 A 100%

4.6.4 Record the CALEXTENDR computed RATIO average value on Worksheet no. 4 and verify it is within $\pm$ 0.5 ppm of nominal (100.0000).

4.6.5 Disconnect the Standard Resistors and DC Power Supply from the test setup.

4.7 0.01 OHM and 0.001 OHM STANDARD RESISTOR CALIBRATION

NOTE

The 0.01 ohm and 0.001 ohm Standard Resistors are calibrated on the TI 100:1 range to establish an uncertainty of 0.4 ppm. The Standard Resistors will be used when calibrating the 1000:1 RATIO range.

NOTE

Due to the uncertainty requirements the 0.01 ohm Standard Resistor requires recalibration at 10 Amps (used in the 1000:1 RATIO test) because self heating effects may cause a change in value greater than 0.5 ppm from the value recorded in Subsection 4.5.

NOTE

The 15 AMP Current Shunt (Item 2.11) and DMM (Item 2.12) are added to the test configuration to ensure DC Power Supply #2 (Item 2.5) current output is at the desired level and will be <u>resettable</u> when verifying the TI 1000:1 RATIO range.

4.7.1 Perform Subsection 4.3 using the equipment, control positions and outputs listed below. Setting the DC Power Supply #2 current output for the desired level, note the DMM indication. Record the measured values on Worksheet no. 5 under 0.01 ohm and 0.001 ohm calibration.

TI Terminal Connection	TI RATIO Switch Position	Rs	Rx	DC Power Supply	Current Current	DMM Ind.
10A/R100	100	0.1Ω	0.001Ω	#2	1 A 10% 10 A 100%	.1 Vdc 1 Vdc
		*1Ω	0.01Ω	#2	1 A 10% 10 A 100%	.1 Vdc 1 Vdc

*NOTE

Exchange the Rs Primary Standard Resistor for reading 1, 2, and 3 as indicated by Worksheet no. 5.

4.7.2 Disconnect the Standard Resistors and DC Power Supply from the test setup.

4.8 1000:1 RATIO TEST

4.8.1 Perform Subsection 4.3 using the equipment, control positions and outputs listed below. Setting DC Power Supply #2 current output (DMM indication) to the value noted in Subsection 4.7. Record the measured values on Work sheet no. 6 under 1000:1 RATIO Test No. 1.

TI Terminal Connection	TI RATIO Switch Position	Rs	Rx	DC Power Supply	Current Current	DMM Ind.
100A/R1000	1000	10Ω	0.01Ω	#2	1 A 10% 10 A 100%	.1 Vdc 1 Vdc

4.8.2 Disconnect the Standard Resistors from the test setup.

4.8.3 Perform Subsection 4.3 using the equipment, control positions and outputs listed below. Setting DC Power Supply #2 current output (DMM indication) to the value noted in Subsection 4.7. Record the measured values on Worksheet no. 6 under 1000:1 RATIO Test No. 2.

TI Terminal Connection	TI RATIO Switch Position	Rs	Rx	DC Power Supply	Current Current	DMM Ind.
100A/R1000	1000	1Ω	0.001Ω	#2	1 A 10% 10 A 100%	.1 Vdc 1 Vdc

NOTE

Exchange the Rs Primary Standard Resistor for each reading 1, 2, and 3 as indicated by Worksheet no. 6.

4.8.4 Record the CALEXTENDR computed RATIO average value on Worksheet no. 6 and verify it is within ± 1 ppm of nominal (1000.000).

4.8.5 Unless additional tests are to be performed, turn all the power to off or standby and disconnect the test setup.

LCP-WJL-024

WORKSHEET no.1 DATE: ________

0.1 STANDARD RESISTOR CALIBRATION		
Rs = 0.1	Rx = 1	Rx/Rs Dials
Model no. 4221 Serial no. _____	Model no. 4210 no.1 Serial no. 1631004	Reading no. 1 ________
	Model no. 4210 no. 2 Serial no. 1630985	Reading no. 2 ________
	Model no. 4210 no. 3 Serial no. 1616926	Reading no. 3 ________
Computed Value ________ Uncertainty ________ ppm		

10 STANDARD RESISTOR CALIBRATION		
Rs = 1	Rx = 10	Rx/Rs Dials
Model no. 4210 no.1 Serial no. 1631004	Model no. 4025 Serial no. _____	Reading no. 1 ________
Model no. 4210 no. 2 Serial no. 1630985		Reading no. 2 ________
Model no. 4210 no. 3 Serial no. 1616926		Reading no. 3 ________
Computed Value ________ Uncertainty ________ ppm		

WORKSHEET no. 2 DATE: ______

10 : 1 RATIO TEST NO. 1		
Rs = 10	Rx = 1	Rx/Rs Dials
Model no. 4025 Serial no. ____	Model no. 4210 Serial no. 1631004 no.1	Reading no. 1 ________
	Model no. 4210 Serial no. 1630985 no. 2	Reading no. 2 ________
	Model no. 4210 Serial no. 1616926 no. 3	Reading no. 3 ________
Computed Value ________ Uncertainty ______ ppm		
Computed 10 : 1 RATIO ________		

10 : 1 RATIO TEST NO. 2		
Rs = 1	Rx = 0.1	Rx/Rs Dials
Model no. 4210 Serial no. 1631004 no.1	Model no. 4221 Serial no. ____	Reading no. 1 ________
Model no. 4210 Serial no. 1630985 no. 2		Reading no. 2 ________
Model no. 4210 Serial no. 1616926 no. 3		Reading no. 3 ________
Computed Value ________ Uncertainty ______ ppm		
Computed 10 : 1 RATIO ________		

WORKSHEET no. 3

DATE: _______

0.1 STANDARD RESISTOR CALIBRATION		
Rs = 1	Rx = 0.1	Rx/Rs Dials
Model no. 4210 Serial no. 1631004 Model no. 4210 Serial no. 1630985 Model no. 4210 Serial no. 1616926	Model no. 4221 Serial no. _____	Reading no. 1 ___________ Reading no. 2 ___________ Reading no. 3 ___________
Computed Value ___________ Uncertainty _______ ppm		

0.01 STANDARD RESISTOR CALIBRATION		
Rs = 0.1	Rx = 0.01	Rx/Rs Dials
Model no. 4221 Serial no. _____	Model no. 4222 Serial no. _____	Reading no. 1 ___________ Reading no. 2 ___________ Reading no. 3 ___________
Computed Value ___________ Uncertainty _______ ppm		

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WORKSHEET no. 4 DATE: ______

100 : 1 RATIO TEST NO. 1		
Rs = 1	Rx = 0.01	Rx/Rs Dials
Model no. 4210 no. 1 Serial no. 1631004 Model no. 4210 no. 2 Serial no. 1630985 Model no. 4210 no. 3 Serial no. 1616926	Model no. 4222 Serial no. _____	Reading no. 1 ________ Reading no. 2 ________ Reading no. 3 ________
Computed Value ________ Uncertainty ________ ppm		
Computed 100 : 1 RATIO ________		

100 : 1 RATIO TEST NO. 2		
Rs = 10	Rx = 0.1	Rx/Rs Dials
Model no. 4025 Serial no. _____	Model no. 4221 Serial no. _____	Reading no. 1 ________ Reading no. 2 ________ Reading no. 3 ________
Computed Value ________ Uncertainty ________ ppm		
Computed 100 : 1 RATIO ________		

WORKSHEET no. 5 DATE: ______

0.001 STANDARD RESISTOR CALIBRATION		
Rs = 0.1	Rx = 0.001	Rx/Rs Dials
Model no. 4221 Serial no. ____	Model no. 4223 Serial no. ____	Reading no. 1 ________ Reading no. 2 ________ Reading no. 3 ________
Computed Value ________ Uncertainty ______ ppm		

0.01 STANDARD RESISTOR CALIBRATION		
Rs = 1	Rx = 0.01	Rx/Rs Dials
Model no. 4210 Serial no. 1631004 Model no. 4210 Serial no. 1630985 Model no. 4210 Serial no. 1616926	Model no. 4222 Serial no. ____	Reading no. 1 ________ Reading no. 2 ________ Reading no. 3 ________
Computed Value ________ Uncertainty ______ ppm		

WORKSHEET no. 6

DATE: ______

1000 : 1 RATIO TEST NO. 1		
Rs = 10	Rx = 0.01	Rx/Rs Dials
Model no. 4025 Serial no. _____	Model no. 4222 Serial no. _____	Reading no. 1 __________ Reading no. 2 __________ Reading no. 3 __________
Computed Value __________ Uncertainty ________ ppm		
Computed 1000 : 1 RATIO__________		

1000 : 1 RATIO TEST NO. 2		
Rs = 1	Rx = 0.001	Rx/Rs Dials
Model no. 4210 Serial no. 1631004 no. 1 Model no. 4210 Serial no. 1630985 no. 2 Model no. 4210 Serial no. 1616926 no. 3	Model no. 4223 Serial no. _____	Reading no. 1 __________ Reading no. 2 __________ Reading no. 3 __________
Computed Value __________ Uncertainty ________ ppm		
Computed 1000 : 1 RATIO__________		

APPENDIX A

CALEXTENDR PROGRAM INSTRUCTIONS

A.1 CALEXTENDR PRELIMINARY PREPARATION

A.1.1 Load CALEXTENDR program into the HP 9816 computer.

A.1.2 Press RUN.

A.1.3 Enter Date: Year/Month/Day

A.1.4 CALEXTENDR will load the Standard Resistor historical values as recorded by MCP-WJL-002 into data files for comparison and verification of measured values.

A.1.5 CALEXTENDR will display Calibration Menu:

Subsection	
4.1	0.1 & 10 Ohm Calibration
4.4	10:1 RATIO Test
4.5	0.1 & 0.01 Ohm Calibration
4.6	100:1 RATIO Test
4.7	0.01 & 0.001 Ohm Calibration
4.8	1000:1 RATIO Test

A.1.6 Select the Subsection Calibration being performed.

NOTE

The Subsection calculations must be performed in sequence to ensure valid results.

A.2 STANDARD RESISTOR CALCULATIONS

NOTE

These calculations will be performed for Subsection 4.1, 4.5, and 4.7.

A.2.1 Enter the serial number of the Standard Resistor being measured.

A.2.2 CALEXTENDR will verify the correct serial number was entered. If the serial number is incorrect, CALEXTENDR will request that it be re-entered or the procedure be restarted.

A.2.3 Enter READING 1, 2 and 3.

A.2.4 CALEXTENDR will display the values entered and ask if they are correct. If incorrect, the values may be re-entered.

A.2.5 CALEXTENDR will calculate the Standard Resistor's value and standard deviation.

NOTE

When the Standard Resistor is measured utilizing the TI, the measured RATIO value will be figured into the calculations.

A.2.6 CALEXTENDR will determine whether the value is in tolerance or not. If out of tolerance, CALEXTENDR will request the READINGS to be re-checked/re-entered or be re-measured.

A.2.7 CALEXTENDR will store and print the Standard Resistors:

Serial no.

MCP Value:

Ref. Value: (to be used in RATIO tests)

Standard Deviation:

A.2.8 Record the values on the Worksheet.

A.2.9 Repeat steps A.2.1 through A.2.8 for the second Standard Resistor's calculation.

A.2.10 CALEXTENDR will return to Calibration Menu.

A.2.11 Proceed with the next subsection calibration.

A.3 RATIO TEST CALCULATIONS

NOTE

These calculations will be performed for Subsection 4.4, 4.6 and 4.8.

A.3.1 Enter the serial number of the Standard Resistor being measured.

A.3.2 CALEXTENDR will verify the correct serial number was entered. If the serial number is incorrect, CALEXTENDR will request that it be re-entered or the procedure be restarted.

A.3.3 Enter READING 1, 2 and 3.

A.3.4 CALEXTENDR will display the values entered and ask if they are correct. If incorrect, the values may be re-entered.

A.3.5 CALEXTENDR will calculate the Standard Resistor's value, standard deviation and the TI's RATIO value.

A.3.6 CALEXTENDR will determine whether the values are within tolerance or not. If out of tolerance, CALEXTENDR will request the READINGS to be rechecked/re-entered or be remeasured.

NOTE

The Standard Resistor value is compared to the value determined in the previous Standard Resistor calibration to determine the TI RATIO value.

A.3.7 CALEXTENDR will store and print:

Serial no.

Ref. Value: (measured in Standard Resistor Calibration)

Measured Value: (measured in RATIO test)

Standard Deviation:

RATIO Value:

A.3.8 Record the values on the Worksheet.

A.3.9 Repeat Steps A.3.1 through A.3.8 for the second RATIO test.

A.3.10 CALEXTENDR will calculate and print the average RATIO value.

A.3.11 Record the average RATIO value on the Worksheet.

A.3.12 CALEXTENDR will return to the Calibration Menu.

A.3.13 Proceed with next Subsection calibration.

```
10   ! PROGRAM: CALEXTENDR
20   ! WRITTEN 12/17/86 BY JOE
30   ! PROGRAM TO CALCULATE VALUES FOR STANDARD RESISTORS
40   ! BEING USED TO CALIBRATE THE RANGE EXTENDER AND CALCULATE
50   ! THE RATIOS OF THE EXTENDER
60     OPTION BASE 1
70     COM @Standard,@Memory
80     COM Values(60,6),L1(60),Std(3,4),Valu(15,2),W(12),Y(3),St(3),R1,R2,R3,Sd,V
(3),Ratio10,Ratio100
90     ASSIGN @Memory TO "Stdresist"
100    FOR I=1 TO 60
110      FOR J=1 TO 6
120        ENTER @Memory;Values(I,J)
130      NEXT J
140    NEXT I
150    FOR I=1 TO 60
160      IF Values(I,1)=0 THEN 190
170      Q=I
180      L1(I)=Values(I,4)
190    NEXT I
200    FOR I=1 TO Q
210      Lr1=Lr1+L1(I)
220    NEXT I
230    Lr1=Lr1/Q
240    ASSIGN @Standard TO "Std"
250    FOR I=1 TO 3
260      FOR J=1 TO 4
270        ENTER @Standard;Std(I,J)
280      NEXT J
290    NEXT I
300    FOR I=1 TO 3
310      V(I)=Std(I,1)
320    NEXT I
330    M=(V(1)+V(2)+V(3))/3
340    ASSIGN @Memory TO "Valu"
350    FOR I=1 TO 15
360      FOR J=1 TO 2
370        ENTER @Memory;Valu(I,J)
380      NEXT J
390    NEXT I
400    Z=0
410    PRINT "ENTER 1 IF YOU ARE AT 4.1 0.1 & 10 OHM CALIBRATION"
420    PRINT "ENTER 2 IF YOU ARE AT 4.4 10:1 RATIO TEST"
430    PRINT "ENTER 3 IF YOU ARE AT 4.5 0.1 & 0.01 OHM CALIBRATION"
440    PRINT "ENTER 4 IF YOU ARE AT 4.6 100:1 RATIO TEST"
450    PRINT "ENTER 5 IF YOU ARE AT 4.7 0.01 & 0.001 OHM CALIBRATION"
460    PRINT "ENTER 6 IF YOU ARE AT 4.8 1000:1 RATIO TEST"
470    INPUT Z
480    IF Z=1 THEN 550
490    IF Z=2 THEN 1160
500    IF Z=3 THEN 1880
510    IF Z=4 THEN 2400
520    IF Z=5 THEN 3110
530    IF Z=6 THEN 3630
540    GOTO 400
550    INPUT "ENTER FROM KEYBOARD TODAYS DATE (YYMMDD)",Date
560    INPUT "WHAT SERIAL NUMBER FOR 0.1 OHM RESISTOR ?",B
570    IF B<>Valu(3,2) THEN 590
580    GOTO 620
590    PRINT "ERROR IN DATA PLEASE RE-ENTER OR START OVER !!!"
```

```
600   BEEP 1000,1
610   GOTO 560
620   FOR I=1 TO 12
630     W(I)=0
640   NEXT I
650   GOSUB Enterdata
660   R1=V(1)/Y(1)
670   R2=V(2)/Y(2)
680   R3=V(3)/Y(3)
690   Res=(R1+R2+R3)/3
700   W(1)=PROUND(Res,-9)
710   St1=V(1)/W(1)
720   St2=V(2)/W(1)
730   St3=V(3)/W(1)
740   GOSUB Compsd
750   PRINTER IS 706
760   IF PROUND(W(1)-Valu(3,1)*10,-8)>2.E-7 THEN 780
770   GOTO 800
780   PRINT "DIFFERENCE IS ";PROUND(W(1)-Valu(3,1),-9)*1.E+7;"PPM"
790   GOTO 4330
800   PRINT USING 820;Valu(3,2),Valu(3,1),W(1),PROUND(Sd*1.E+5,-3)
810   PRINT
820   IMAGE "SERIAL NUMBER : ",7D,L,"MCP VALUE : ",Z.11D,L,"REF. VALUE : ",Z.11D
,L,"STANDARD DEVIATION :  ",1Z.3D
830   IMAGE "SERIAL NUMBER : ",7D,L,"NEW REF. VALUE : ",Z.11D,L,"STANDARD DEVIAT
ION : ",1Z.3D
840   IMAGE "SERIAL NUMBER : ",7D,L,"REF. VALUE : ",Z.11D,L,"MEASURED VALUE : ",
Z.11D,L,"STANDARD DEVIATION : ",1Z.3D
850   IMAGE "SERIAL NUMBER : ",7D,L,"MCP VALUE : ",2Z.8D,L,"REF. VALUE : ",2Z.8D
,L,"STANDARD DEVIATION : ",1Z.3D
860   IMAGE "SERIAL NUMBER : ",7D,L,"REF. VALUE : ",2Z.8D,L,"MEASURED VALUE : ",
2Z.8D,L,"STANDARD DEVIATION : ",1Z.3D
870   PRINTER IS 1
880   INPUT "WHAT SERIAL NUMBER FOR 10 OHM RESISTOR ?",B
890   IF B<>Valu(5,2) THEN 910
900   GOTO 940
910   PRINT "ERROR IN DATA PLEASE RE-ENTER OR START OVER !!!"
920   BEEP 1000,1
930   GOTO 880
940   GOSUB Enterdata
950   GOSUB Stdisrs
960   Res=(R1+R2+R3)/3
970   W(2)=PROUND(Res,-7)
980   St1=W(2)/V(1)
990   St2=W(2)/V(2)
1000  St3=W(2)/V(3)
1010  GOSUB Compsd
1020  PRINTER IS 706
1030  IF PROUND((W(2)-Valu(5,1))/10,-8)>2.E-7 THEN 1050
1040  GOTO 1070
1050  PRINT "DIFFERENCE IS ";PROUND(W(2)-Valu(5,1),-7)*1.E+5;"PPM"
1060  GOTO 4330
1070  PRINT USING 850;Valu(5,2),Valu(5,1),W(2),PROUND(Sd*1.E+5,-3)
1080  PRINT
1090  PRINTER IS 1
1100  PRINT "TIME TO MAKE NEXT SERIES OF MEASUREMENTS ."
1110  ASSIGN @Memory TO "HOLDDATA"
1120  FOR I=1 TO 12
1130    OUTPUT @Memory;W(I)
1140  NEXT I
```

```
1150  GOTO 4640
1160  ASSIGN @Memory TO "HOLDDATA"
1170  FOR I=1 TO 12
1180    ENTER @Memory;W(I)
1190  NEXT I
1200  INPUT "WHAT SERIAL NUMBER FOR 10 OHM RESISTOR ?",B
1210  IF B<>Valu(5,2) THEN 1230
1220  GOTO 1260
1230  PRINT "ERROR IN DATA PLEASE RE-ENTER OR START OVER !!!"
1240  BEEP 1000,1
1250  GOTO 1200
1260  GOSUB Enterdata
1270  R1=(V(1)*10)/Y(1)
1280  R2=(V(2)*10)/Y(2)
1290  R3=(V(3)*10)/Y(3)
1300  Res=(R1+R2+R3)/3
1310  W(3)=PROUND(Res,-7)
1320  St1=(V(1)*10)/W(3)
1330  St2=(V(2)*10)/W(3)
1340  St3=(V(3)*10)/W(3)
1350  GOSUB Compsd
1360  PRINTER IS 706
1370  IF PROUND((W(3)-W(2))/10,-8)>5.E-7 THEN 1390
1380  GOTO 1410
1390  PRINT PROUND(W(3)-W(2),-7)*1.E+5;"PPM"
1400  GOTO 4330
1410  PRINT USING 860;Valu(5,2),W(2),W(3),PROUND(Sd*1.E+6,-3)
1420  Ratio1=10.0000000+PROUND(((W(2)-W(3))),-7)
1430  PRINT
1440  PRINT "RATIO IS :";PROUND(Ratio1,-7)
1450  PRINT
1460  PRINTER IS 1
1470  INPUT "WHAT SERIAL NUMBER FOR 0.1 OHM RESISTOR ?",B
1480  IF B<>Valu(3,2) THEN 1500
1490  GOTO 1530
1500  PRINT "ERROR IN DATA PLEASE RE-ENTER OR START OVER !!!"
1510  BEEP 1000,1
1520  GOTO 1470
1530  GOSUB Enterdata
1540  GOSUB Stdisrs
1550  Res=(R1+R2+R3)/3
1560  W(4)=PROUND(Res/10,-9)
1570  St1=W(4)*10/V(1)
1580  St2=W(4)*10/V(2)
1590  St3=W(4)*10/V(3)
1600  GOSUB Compsd
1610  PRINTER IS 706
1620  IF PROUND((W(4)-W(1))*10,-8)>3.E-7 THEN 1640
1630  GOTO 1660
1640  PRINT PROUND(W(4)-W(1),-9)*1.E+7;"PPM"
1650  GOTO 4330
1660  PRINT USING 840;Valu(3,2),W(1),W(4),PROUND(Sd*1.E+6,-3)
1670  PRINT
1680  Ratio2=10.0000000+PROUND(((W(1)-W(4))*100),-7)
1690  PRINT "RATIO IS :";PROUND(Ratio2,-7)
1700  PRINT
1710  PRINT
1720  IF PROUND(Ratio1-Ratio2,-8)*1.E+6<-5 OR PROUND(Ratio1-Ratio2,-8)*1.E+6>5 T
HEN 1770
1730  Ratio10=PROUND((Ratio1+Ratio2)/2,-7)
```

```
1740  PRINT "RATIO OF TIMES 10 RANGE IS :";PROUND(Ratio10,-7)
1750  PRINT
1760  GOTO 1810
1770  PRINT "RATIO IS OUT OF TOLERANCE !!   RATIO IS :";PROUND((Ratio1+Ratio2)/2
,-7)
1780  PRINT "RE-MEASURE THEN TRY AGAIN !!"
1790  PRINTER IS 1
1800  GOTO 4640
1810  PRINTER IS 1
1820  PRINT "TIME TO MAKE NEXT SERIES OF MEASUREMENTS ."
1830  ASSIGN @Memory TO "HOLDDATA"
1840  FOR I=1 TO 12
1850    OUTPUT @Memory;W(I)
1860  NEXT I
1870  GOTO 4640
1880  ASSIGN @Memory TO "HOLDDATA"
1890  FOR I=1 TO 12
1900    ENTER @Memory;W(I)
1910  NEXT I
1920  INPUT "WHAT SERIAL NUMBER FOR 0.1 OHM RESISTOR ?",B
1930  IF B<>Valu(3,2) THEN 1950
1940  GOTO 1980
1950  PRINT "ERROR IN DATA PLEASE RE-ENTER OR START OVER !!!"
1960  BEEP 1000,1
1970  GOTO 1920
1980  GOSUB Enterdata
1990  GOSUB Stdisrs
2000  Res=(R1+R2+R3)/3
2010  W(5)=PROUND(Res/10,-9)
2020  St1=W(5)/V(1)*10
2030  St2=W(5)/V(2)*10
2040  St3=W(5)/V(3)*10
2050  GOSUB Compsd
2060  PRINTER IS 706
2070  PRINT USING 830;Valu(3,2),W(5),PROUND(Sd*1.E+6,-3)
2080  PRINT
2090  PRINTER IS 1
2100  INPUT "WHAT SERIAL NUMBER FOR 0.01 OHM RESISTOR ?",B
2110  IF B<>Valu(2,2) THEN 2130
2120  GOTO 2160
2130  PRINT "ERROR IN DATA PLEASE RE-ENTER OR START OVER !!!"
2140  BEEP 1000,1
2150  GOTO 2100
2160  GOSUB Enterdata
2170  R1=Y(1)*W(1)
2180  R2=Y(2)*W(1)
2190  R3=Y(3)*W(1)
2200  Res=(R1+R2+R3)/3
2210  W(6)=PROUND(Res/10,-10)
2220  St1=W(6)/W(1)*10
2230  St2=W(6)/W(1)*10
2240  St3=W(6)/W(1)*10
2250  GOSUB Compsd
2260  PRINTER IS 706
2270  IF ABS(PROUND((W(6)-Valu(2,1))*100,-8))>5.E-7 THEN 2290
2280  GOTO 2310
2290  PRINT "DIFFERENCE IS ";PROUND((W(6)-Valu(2,1))*100,-8)*1.E+6;"PPM"
2300  GOTO 4330
2310  PRINT USING 820;Valu(2,2),Valu(2,1),W(6),PROUND(Sd*1.E+6,-3)
2320  PRINT
```

```
2330  PRINTER IS 1
2340  PRINT "TIME TO MAKE NEXT SERIES OF MEASUREMENTS ."
2350  ASSIGN @Memory TO "HOLDDATA"
2360  FOR I=1 TO 12
2370    OUTPUT @Memory;W(I)
2380  NEXT I
2390  GOTO 4640
2400  ASSIGN @Memory TO "HOLDDATA"
2410  FOR I=1 TO 12
2420    ENTER @Memory;W(I)
2430  NEXT I
2440  INPUT "WHAT SERIAL NUMBER FOR 0.01 OHM RESISTOR ?",B
2450  IF B<>Valu(2,2) THEN 2470
2460  GOTO 2500
2470  PRINT "ERROR IN DATA PLEASE RE-ENTER OR START OVER !!!"
2480  BEEP 1000,1
2490  GOTO 2440
2500  GOSUB Enterdata
2510  GOSUB Stdisrs
2520  Res=(R1+R2+R3)/3
2530  W(7)=PROUND(Res/100,-10)
2540  St1=W(7)*100/V(1)
2550  St2=W(7)*100/V(2)
2560  St3=W(7)*100/V(3)
2570  GOSUB Compsd
2580  PRINTER IS 706
2590  IF ABS(PROUND((W(7)-W(6))*100,-8))>5.E-7 THEN 2610
2600  GOTO 2630
2610  PRINT "DIFFERENCE IS ";PROUND((W(7)-W(6))*100,-8)*1.E+6;"PPM"
2620  GOTO 4330
2630  PRINT USING 840;Valu(2,2),W(6),W(7),PROUND(Sd*1.E+6,-3)
2640  PRINT
2650  Ratio1=100.000000+PROUND(((W(7)-W(6))*1.E+4),-6)
2660  PRINT "RATIO IS :";PROUND(Ratio1,-6)
2670  PRINT
2680  PRINTER IS 1
2690  INPUT "WHAT SERIAL NUMBER FOR 0.1 OHM RESISTOR ?",B
2700  IF B<>Valu(3,2) THEN 2720
2710  GOTO 2750
2720  PRINT "ERROR IN DATA PLEASE RE-ENTER OR START OVER !!!"
2730  BEEP 1000,1
2740  GOTO 2690
2750  GOSUB Enterdata
2760  R1=Y(1)*W(2)
2770  R2=Y(2)*W(2)
2780  R3=Y(3)*W(2)
2790  Res=(R1+R2+R3)/3
2800  W(8)=PROUND(Res/100,-9)
2810  St1=W(8)*100/W(2)
2820  St2=St1
2830  St3=St1
2840  GOSUB Compsd
2850  PRINTER IS 706
2860  IF PROUND(W(8)-W(5)*10,-8)>5.E-6 THEN 2880
2870  GOTO 2900
2880  PRINT "DIFFERENCE IS ";PROUND(W(8)-W(5)*10,-8)*1.E-6;"PPM"
2890  GOTO 4330
2900  PRINT USING 840;Valu(3,2),W(5),W(8),PROUND(Sd*1.E+6,-3)
2910  PRINT
2920  Ratio2=100.000000+PROUND((W(5)-W(8))*1.E+4,-6)
```

```
2930  PRINT "RATIO IS :";PROUND(Ratio2,-6)
2940  PRINT
2950  PRINT
2960  IF PROUND(Ratio1-Ratio2,-5)*1.E+5<-5 OR PROUND(Ratio1-Ratio2,-5)*1.E+5>5 T
HEN 3010
2970  Ratio100=PROUND((Ratio1+Ratio2)/2,-6)
2980  PRINT
2990  PRINT "RATIO OF TIMES 100 RANGE IS :";PROUND(Ratio100,-6)
3000  GOTO 3040
3010  PRINT "RATIO IS OUT OF TOLERANCE !!   RATIO IS :";PROUND((Ratio1-Ratio2)/2
,-5)
3020  PRINT "RE-MEASURE THEN TRY AGAIN !!"
3030  GOTO 4640
3040  PRINTER IS 1
3050  PRINT "TIME TO MAKE NEXT SERIES OF MEASUREMENTS ."
3060  ASSIGN @Memory TO "HOLDDATA"
3070  FOR I=1 TO 12
3080    OUTPUT @Memory;W(I)
3090  NEXT I
3100  GOTO 4640
3110  ASSIGN @Memory TO "HOLDDATA"
3120  FOR I=1 TO 12
3130    ENTER @Memory;W(I)
3140  NEXT I
3150  INPUT "WHAT SERIAL NUMBER FOR 0.001 OHM RESISTOR ?",B
3160  IF B<>Valu(1,2) THEN 3180
3170  GOTO 3210
3180  PRINT "ERROR IN DATA PLEASE RE-ENTER OR START OVER !!!"
3190  BEEP 1000,1
3200  GOTO 3150
3210  GOSUB Enterdata
3220  R1=Y(1)*W(1)
3230  R2=Y(2)*W(1)
3240  R3=Y(3)*W(1)
3250  Res=(R1+R2+R3)/3
3260  W(9)=PROUND(Res/100,-11)
3270  St1=W(9)*100/W(1)
3280  St2=St1
3290  St3=St1
3300  GOSUB Compsd
3310  PRINTER IS 706
3320  IF ABS(PROUND((W(9)-Valu(1,1))*1000,-8))>5.E-7 THEN 3340
3330  GOTO 3360
3340  PRINT "DIFFERENCE IS ";PROUND(W(9)-Valu(1,1)*1000,-9)*1.E+6;"PPM"
3350  GOTO 4330
3360  PRINT USING 820;Valu(1,2),Valu(1,1),W(9),PROUND(Sd*1.E+6,-3)
3370  PRINT
3380  PRINTER IS 1
3390  INPUT "WHAT SERIAL NUMBER FOR 0.01 OHM RESISTOR ?",B
3400  IF B<>Valu(2,2) THEN 3420
3410  GOTO 3450
3420  PRINT "ERROR IN DATA PLEASE RE-ENTER OR START OVER !!!"
3430  BEEP 1000,1
3440  GOTO 3390
3450  GOSUB Enterdata
3460  GOSUB Stdisrs
3470  Res=(R1+R2+R3)/3
3480  W(10)=PROUND(Res/100,-10)
3490  St1=W(10)*100/V(1)
3500  St2=W(10)*100/V(2)
```

```
3510  St3=W(10)*100/V(3)
3520  GOSUB Compsd
3530  PRINTER IS 706
3540  PRINT USING 830;Valu(2,2),W(10),PROUND(Sd*1.E+6,-3)
3550  PRINT
3560  PRINTER IS 1
3570  PRINT "TIME TO MAKE NEXT SERIES OF MEASUREMENTS ."
3580  ASSIGN @Memory TO "HOLDDATA"
3590  FOR I=1 TO 12
3600    OUTPUT @Memory;W(I)
3610  NEXT I
3620  GOTO 4640
3630  ASSIGN @Memory TO "HOLDDATA"
3640  FOR I=1 TO 12
3650    ENTER @Memory;W(I)
3660  NEXT I
3670  INPUT "WHAT SERIAL NUMBER FOR 0.01 OHM RESISTOR ?",B
3680  IF B<>Valu(2,2) THEN 3700
3690  GOTO 3730
3700  PRINT "ERROR IN DATA PLEASE RE-ENTER OR START OVER !!!"
3710  BEEP 1000,1
3720  GOTO 3670
3730  GOSUB Enterdata
3740  R1=Y(1)*W(2)
3750  R2=Y(2)*W(2)
3760  R3=Y(3)*W(2)
3770  Res=(R1+R2+R3)/3
3780  W(11)=PROUND(Res/1000,-10)
3790  St1=W(11)*1000/W(2)
3800  St2=St1
3810  St3=St1
3820  GOSUB Compsd
3830  PRINTER IS 706
3840  IF ABS(PROUND((W(11)-W(10))*100,-8))>1.E-6 THEN 3860
3850  GOTO 3880
3860  PRINT "DIFFERENCE IS ";PROUND((W(11)-W(10))*100,-8)*1.E+6;"PPM"
3870  GOTO 4330
3880  PRINT USING 840;Valu(2,2),W(10),W(11),PROUND(Sd*1.E+6,-3)
3890  PRINT
3900  Ratio1=1000.00000+PROUND((W(11)-W(10))*1.E+5,-5)
3910  PRINT "RATIO IS :";PROUND(Ratio1,-5)
3920  PRINT
3930  PRINTER IS 1
3940  INPUT "WHAT SERIAL NUMBER FOR 0.001 OHM RESISTOR ?",B
3950  IF B<>Valu(1,2) THEN 3970
3960  GOTO 4000
3970  PRINT "ERROR IN DATA PLEASE RE-ENTER OR START OVER !!!"
3980  BEEP 1000,1
3990  GOTO 3940
4000  GOSUB Enterdata
4010  GOSUB Stdisrs
4020  Res=(R1+R2+R3)/3
4030  W(12)=PROUND(Res/1000,-11)
4040  St1=W(12)*1000/V(1)
4050  St2=W(12)*1000/V(2)
4060  St3=W(12)*1000/V(3)
4070  GOSUB Compsd
4080  PRINTER IS 706
4090  IF ABS(PROUND((W(12)-W(9))*1000,-8))>5.E-6 THEN 4110
4100  GOTO 4130
```

```
4110  PRINT "DIFFERENCE IS ";PROUND(W(12)-W(9)*1000,-7)*1.E+6;"PPM"
4120  GOTO 4330
4130  PRINT USING 840;Valu(1,2),W(9),W(12),PROUND(Sd*1.E+6,-3)
4140  PRINT
4150  Ratio2=1000.00000+PROUND((W(12)-W(9))*1.E+6,-5)
4160  PRINT "RATIO IS :";PROUND(Ratio2,-5)
4170  PRINT
4180  PRINT
4190  IF PROUND(Ratio1-Ratio2,-4)*1.E+3<-1 OR PROUND(Ratio1-Ratio2,-4)*1.E+3>1 T
HEN 4230
4200  PRINT "RATIO OF TIMES 1000 RANGE IS :";(Ratio1+Ratio2)/2
4210  OUTPUT 706;"
```

```
4220  GOTO 4260
4230  PRINT "RATIO IS OUT OF TOLERANCE !!   RATIO IS :";(Ratio1-Ratio2)/2
4240  PRINT "RE-MEASURE THEN TRY AGAIN !!"
4250  GOTO 4640
4260  PRINTER IS 1
4270  PRINT "FINISHED !!!!!!!!!!!"
4280  ASSIGN @Memory TO "HOLDDATA"
4290  FOR I=1 TO 12
4300    OUTPUT @Memory;W(I)
4310  NEXT I
4320  GOTO 4640
4330  PRINTER IS 706
4340  PRINT "DIFFERENCE IS TOO LARGE !!!!!"
4350  PRINT
4360  PRINT "CHECK YOUR VALUES AND EITHER RE-MEASURE OR RE-ENTER !!"
4370  PRINT "YOU MUST RE-START PROGRAM !!!!"
4380  GOTO 4640
4390 Enterdata: !SUB
4400  FOR U=1 TO 3
4410    PRINT "ENTER ON KEYBOARD OBSERVATION",U
4420    INPUT Y(U)
4430  NEXT U
4440  A$=""
4450  PRINT "YOU HAVE ENTERED THIS DATA :"
4460  FOR U=1 TO 3
4470    PRINT Y(U)
4480  NEXT U
4490  PRINT "IS IT CORRECT ? (ENTER 'N' OR CONT)"
4500  INPUT A$
4510  IF A$="N" THEN 4400
4520  RETURN
4530 Stdisrs: !SUB
4540  R1=Y(1)*V(1)
4550  R2=Y(2)*V(2)
4560  R3=Y(3)*V(3)
4570  RETURN
4580 Compsd: !SUB
4590  S1=Y(1)-St1
4600  S2=Y(2)-St2
4610  S3=Y(3)-St3
4620  Sd=SQR(S1^2+S2^2+S3^2)
4630  RETURN
4640  PRINTER IS 1
4650  END
```