CDE Creative Design Engineering, Inc.

ResMap

4 point probe Rs Mapping Tool

Operations Manual

Includes Operations, Setup,
Checkout and Troubleshoot

June 1997
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Contents:

1 GENERAL INFORMATION

1.1 INTRODUCTION

In this section, we shall give some background information of the 4 point probe techniques, the applications, CDE ResMap's role in this field and other semi-technical information.

1.1.1 What is a 4 point probe?

A 4 point probe [4pp] resistivity measurement tool is a precision instrument for measuring resistivity in a conductive media (usually a thin film the semiconductor applications), called sheet resistivity, Rs. The unit expressed is generally called Ω/☐ or ohms per square. The symbol , or square, is not a unit like cm^2, it is just a way to express the measure of a sheet or semi-large area (compared with the dimension of a probe).

The 4 point probe has 4 pins [#1, 2, 3 & 4] in contact with the conductor sample. Two pins apply a current and the voltage is measured across the other two pins. For our applications, the 4 pins are in a straight line with equal spacing (typical 1-mm). The pins are made of metal, typically Tungsten Carbide, with a pointed tip. The tips have typical radii of between 40 μm (0.0016" or 1.6 mils) to 500 μm (20 mils). The pins are located in a housing called a probe. It is loaded axially with springs, with forces of typically 100 gms. When the pins are pressed onto the sample, the spring is compressed so the pins are retracted (pushed) into the housing in order to make a good electrical contact for measurement. Later, we will show that this contact is very important.

If one puts a current I_{14} between pins 1 and 4, the measured voltage between pins 2 and 3 is V_{23}, then the sheet resistivity is,

$$Rs = \pi/\ln 2 \;.\; V_{23}/I_{14} = 4.532\; V_{23}/I_{14}$$

Modern techniques allow measurement of Rs to a very high accuracy (≤ ±0.5%) and very high precision (Repeatability ≤ ±0.1%).

1.1.2 Types of measurements

The 4 point probe measures sheet resistivity Rs directly for many applications such as implant film, metal film, etc. one either adopt or forces to adopt Rs as the native unit.

However, one can derive other units such as film thickness w, media bulk resistivity ρ or other types of measurements.

1.1.2.1 Film thickness

Since the thickness of a metal film cannot be measured optically like a dielectric film because it is, in general, not transparent to light, so the resistivity measurement can be used to calculate film thickness. If one assumes the film behaves like a bulk (or the electrical and mechanical properties do not change in the film), then one can express the thickness,
$w = \rho\ Rs^{-1}$, where ρ is the bulk resistivity. However, many films do not behave nicely and ρ is not a constant within the thickness of the film. If we assume that ρ decreases as a function of thickness buildup (typical within the first few hundred Angstroms) then one can express $w = \rho'\ Rs^{\beta}$. As an example for CVD W film, the thickness can be expressed as $w = 1950.1\ Rs^{-0.65567}$, over certain ranges of thickness [w in Å, and Rs in Ω/□]. Following is a table of commonly used parameters as provided by Sematech, after much characterization:

Film	ρ'	β
Ti	3652.99	– 0.689
TiN	3233.58	– 0.629
W	1950.1	– 0.65567
Al	337.17	– 0.92041
Cu	479.13	– 0.75681
	$w\ [Å] = \rho'\ Rs^{\beta}$	

Although people are used to expressing Rs as basic measurement unit for metal films, for film removal such as etch back or CMP process, if one wants to find out removal rate and uniformity, one cannot subtract Rs directly. One need to first convert the measurement to film thickness before subtracting.

1.1.2.2 Bulk resistivity.

Other applications of the four point porbe are for measuring the bulk resistivity, ρ, since $\rho = Rs \times w$.

For manufacturers of doped bare Silicon wafers, w, the thickness of the wafer, can be measured mechanically, then one can calculate ρ when Rs is measured.

For EPI films, one can also measure ρ. In this case the EPI thickness w is measured typically with an FTIR type instrument.

1.2 ResMap Models

The CDE ResMaps are a series of automatic resistivity mapping systems for various applications. The models and specifications are listed in the following table:

CDE ResMap 4 Point Probe Product Comparisons

Model	ResMap 168	ResMap 178	ResMap 273	ResMap 268-SMIF	ResMap 188	ResMap 363
Feature:	Auto Cassette Load	Manual Load "Baby"	Manual Load 12" ('Big Slice')	Integrated 6" & 8" SMIF, Mini-Environment	Flat Panel	Auto Cassette Load 12"
Wafer Size:	4" - 8" C-C 2"- 8" Manual	2" - 8"	2" - 12"	6", 8" Auto SMIF, 2"-8" manual	22" x 27" 550mm x 685mm	12", 8" & 6" Open Cassette
Max Round Sample: **Max Square Sample:**	8.2" ϕ 5.8" x 5.8"	8.2" ϕ 5.8" x 5.8"	12.1" ϕ 8.5" x 8.5"	8.5" ϕ 6" x 6"		12.1" ϕ 8.5" x 8.5"
Typical Measurement Time:	1-sec per site					
Typical Wafer Transport time (each way):	10-sec	N.A.	N.A.	20 + 10-sec	N.A.	20 + 10-sec
Throughput	40 wafers/hour 49-sites	1-min per wafer 49-sites	1-min per wafer 49-sites	35 wafers/hour 49-sites		35 wafers/hour 49-sites
Measurement Range:	5mΩ/□ - 5MΩ/□					
Repeatability [1σ-typical] **Single Spot (RsPak):** **Nearby Sites:**	±0.01% ±0.1%	±0.01% ±0.1%	±0.01% ±0.1%	±0.01% ±0.1%	±0.01% ±0.1%	±0.01% ±0.1%
Accuracy:	< ±0.5%	< ±0.5%	< ±0.5%	< ±0.5%	< ±0.5%	< ±0.5%
Minimum Edge Exclusion:	< 2-mm	< 2-mm	< 2-mm	< 2-mm	< 7-mm	< 2-mm
Size: Width x Height x Depth	12"W x 11"H x 29"D	12"W x 11"H x 19"D	15"W x 11"H x 19"D	17"W x 68"H x 30"D	28"W x 8"H x 34"D	17"W x 68"H x 35"D
AC power:	100V, 120V, 240V					
Computer System:	Pentium, K6, Celeron or equivalent >450MHz, 3.5FD, >10GB HD, CD-ROM, Color VGA Monitor, Color Injet Printer					
Mapping Patterns: [Up to 1,000 sites per map]	Polar, Rectangular, Line, User defined	Polar, Rectangular, Line, User defined	Polar, Rectangular, Line, User defined	Polar, Rectangular, Line, User defined	Rectangular, Line, User defined	Polar, Rectangular, Line, User defined
Plots:	Contour, 3D, Linear (Diameter), Data Values on Wafer, Histogram, Data Sequence Distribution, Data Radial Distribution, Data Angular Distribution, Trend Charts, etc.					

Other Features:

- Data files portable to Spread Sheet [e.g. EXCEL], Word Processor, Main Frame, Work Station, Apple, etc.
- Data maps can be spliced together for mapping larger samples in pieces.
- Lifetime FREE software upgrades.
- Simplicity in design, easy to service, high reliability,
- Open system in both Computer and Hardware.

1.4 Additional Information

1.4.1 Type of probes and proper choice thereof

Typically, the linear array 4 point probe are specified by the following parameters:

Pin material	Typically Tungsten Carbide
Pin spacing	Typically 1-mm; others available: 20 mil, 25 mil, 40 mil, 63 mil, etc. (1 mil = 0.001 inch = 25.4 μm, 1-mm ≈40 mil)
Pint tip radius	Typically Radii: 40μm, 100μm, 200μm, 500μm, etc.
Pin compression force	Typically 100 gm to 200 gm, 70 gm on D/70 probe.

For most of the probes used, the only really important distincton is the tip radius, which affects the pentration or contact pressure. The most commonly used probes are given names as type A, B, C, etc. The following is a summary of the most popular probe types:

Type	Tip R	Force	Spacing	Typical Applications
A	40μ	100g	1-mm	Metal film
B	100μ	100g	1-mm	General Metal, Hi dose implant
C	200μ	100g	1-mm	Medium dose implant [Rs ≈ 1000 Ω/□]
D/70	500μ	70g	1-mm	Low dose implant. Very thin metal film such as TiN, Ti, etc.
E	40μ	200g	1.58-mm	Thick substrate: doped silicon wafers, diffusion
F	40μ	100g	.635-mm	Similar to A probe for smaller [2mm] edge exclusion, higher resulution measurement
G	100μ	100g	.635-mm	Similar to B probe for smaller [2mm] edge exclusion, higher resulution measurement
H	200μ	100g	.635-mm	Similar to C probe for smaller [2mm] edge exclusion, higher resulution measurement
FC	100μ	100g	.5-mm	Similar to A probe for even smaller [1.5mm] edge exclusion, higher resulution measurement
GC	200μ	100g	.5-mm	Similar to C probe for even smaller [1.5mm] edge exclusion, higher resulution measurement

etc.

1.5 Useful Windows Utilities:

1.5.1 Windows Screen Printing

Most of the CDE ResMap screens such as contour plot, etc. can be printed directly with the print button. However, there are other screens that ResMap software does not have a printing button, such as repeatability data, etc. In this case, one can use the windows screen print utility:

On the screen you want to print, key Alt+PrintScreen, this will copy the screen into the clipboard, then go to WordPad (a Win 95 and 96 utility: Start + Program + Accessories + WordPad), do a paste (Edit + Paste or Ctrl+V). The ResMap screen is pasted into the WordPad. Note, you can also use Office Word instead of WordPad if you have it in you system. Office 97 word document is in general much smaller than WordPad and have more functions. Now you can either print out the WordPad/OfficeWord document or save it. If you choose to save it, then you can paste more than one screen and add text to make it a report to be printed together.

2 INSTALLATIONS / SETUP / CHECKOUT

2.1 FACILATIZATIONS:

This section describes the installation and facilatizations for a ResMap 4 point probe resistivity mapping system. The table below summarize the facility requirements for all ResMap Models:

Facility	ResMap 168	ResMap 178	ResMap 188	ResMap 273	ResMap 268-SMIF
Power: 115V or 230V, with a 4+ plugs power strip	Yes	Yes	Yes	Yes	Yes
House Vacuum better than 500mm Hg. On 1/8" flexible tube	Yes	Optional	No	Optional	Yes
Compressed Air > 2.5 Atm. On 1/8" flexible tube	No	No	No	No	Yes
Exhaust on 3" manifold	No	No	No	No	Yes

2.2 INSTALLATIONS:

The ResMap systems came in 4 major parts (except for ResMap 268-SMIF). There are [1] ResMap mapping unit, [2] the computer processor unit: CPU, and [3] the computer user interface system: including CRT, Keyboard and Mouse and the [4] Printer.

Besides power to most units, everything else is connected to the CPU. The connections are in general:

Power: **100/230VAC 50/60Hz**	Power to ResMap, CPU, CRT and Printer. Make sure everything are all connected to the same power strip to avoid ground loop noise and other ill effects.	
Signals:	CPU to Monitor	Monitor cable from the monitor
	CPU to Printer	Printer cable
	CPU to Keyboard	Cable from Keyboard
	CPU to Mouse:	Mouse plug, sometimes the pointing devise is a track ball mounted on the keyboard. However, the cable is still there.
	CPU to ResMap	64 wire ribbon cable. Note the proper polarity and make sure the connections are firm on both sides.
Vacuum: **House Vacuum > 600mm Hg**	Flexible 1/8" tube with barb fitting connect only to certain ResMap unit on the back of the right side.	
Compressed Air (50 psi)	For ResMap 266-SMIF and 286-SMIF only, typical house Compressed air with regulator is OK. Use 1/8 or 3/32 flexible tube on barb fitting	

Module	Width	Height	Depth
CPU	7" [18cm]	15" [38cm]	16" [41cm] (+3" [8cm] back)
CRT	14" [36cm]	14" [36cm]	16" [41cm] (+20" [50cm] front)
Keyboard	18" [46cm]	3" [8cm] (+6" [15cm] top)	7" [18cm]
Printer	17" [43cm]	8" [20cm] (+4" [10cm] top)	17" [43cm] (+10" [25cm] front)
ResMap 178	12" [30cm] (+2" [5cm] right)	11" [28cm] (+10" [25cm] top)	19" [48cm]
ResMap 168	12" [30cm] (+2" [5cm] right)	11" [28cm] (+10" [25cm] top)	28" [71cm]
ResMap 273	15" [38cm] (+2 [5cm] right)	11" [28cm] (+16" [41cm] top)	19" [48cm]
ResMap 268-SMIF (floor standing)	17" [43cm] (+2 [5cm] right)	60" [153cm]	32" [81cm]
ResMap 188	26" [66cm]	10" [25cm] (+20" [51cm] top)	34" [86cm]

The typical dimensions of each module are, the dimensions are in inches (") and cm and numbers in (#) are clearances required:

Typical layouts (except for ResMap 268-SMIF are one piece floor standing) are:

One Level: On table top: ResMap on the left, Monitor and Keyboards to the right of the ResMap. And CPU rotated 90 degrees are at the right next to CRT in the back and printer in front of CPU. This layout takes approx. 47" [120cm] of cleanroom width.

Two Levels: On table top: ResMap on the left, CRT and Keyboard right of ResMap, CPU and Printer below table near floor level, this layout take-up less table space: approximately 30" [76cm] in cleanroom width.

Stacked Up: ResMap on table top, Monitor and keyboard stacked on top of ResMap on separate shelves or racks, CPU and Monitor below CPU, this layout takes only 17" [43cm] width of your expensive cleanroom real-estate.

2.3 CHECKOUT

After setup the ResMap system, and plug in all components according to the descriptions above. Now it is time to checkup everything.

2.3.1 Before Turn on Power

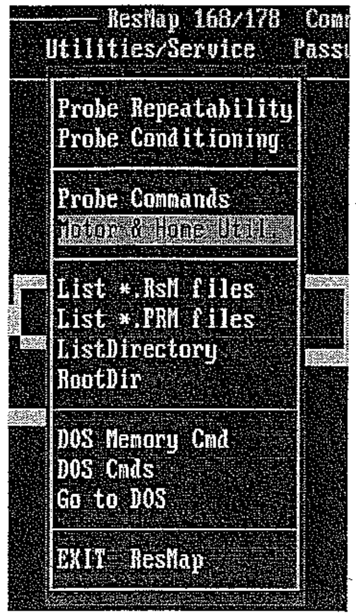
Make sure all the power are set to 115VAC (USA, Japan, Canada, Taiwan, etc.) and 230VAC for the rest of the world: (Europe, China, Singapore, Korea [Sometimes Korea has both 115 and 230V], etc.)

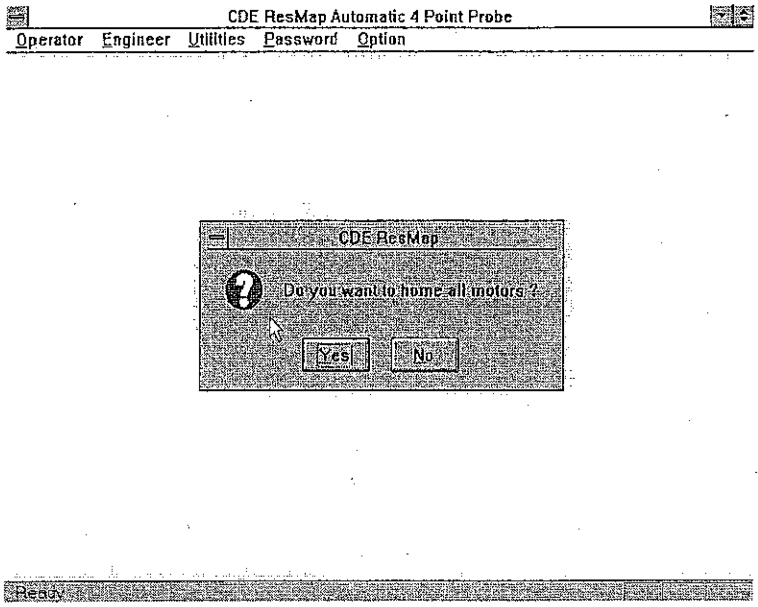
2.3.2 Turn on Power

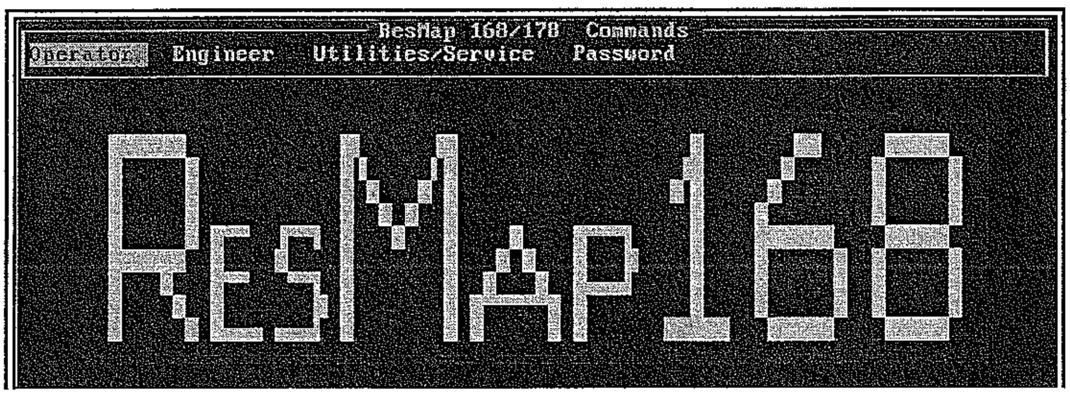
Turn on power of the power strip and all the systems, ResMap, CPU, Monitor, Printer, etc.

Put you hand under the ResMap near the power inlet to check whether the fans are blowing. If not check the fuse and the power.

The Computer system should be setup to go directly into the 4p program (4p3v in DOS or 4pw## in Windows). It will have a home all motors prompt. Select Yes to Homing all motor. You should see all the motors homes (go to find the home sensor) and then parks in a convenient location (parking coordinate). If this is not done correctly, check the 64-wire ribbon cable connections from computer to ResMap and power connections. If this still does not work, check diagnostics section.





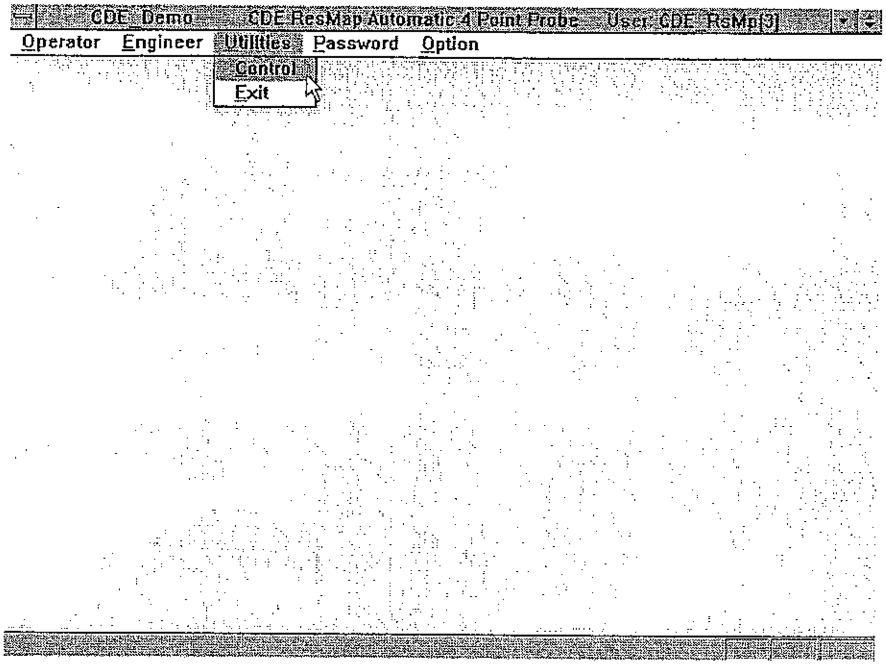


2.3.3 Log on.

For this step you need to log on as a service guy or higher. Although for normal operations in the fab, the operators need not log on.

The password setup from the factory is: "cde" (Lower case 'c' 'd' 'e' and then <enter>). In windows you need to select the user name CDE_RsMp first.

The password can be changed by the manager to the ResMap. So that the initial password is not available for everybody for ever.



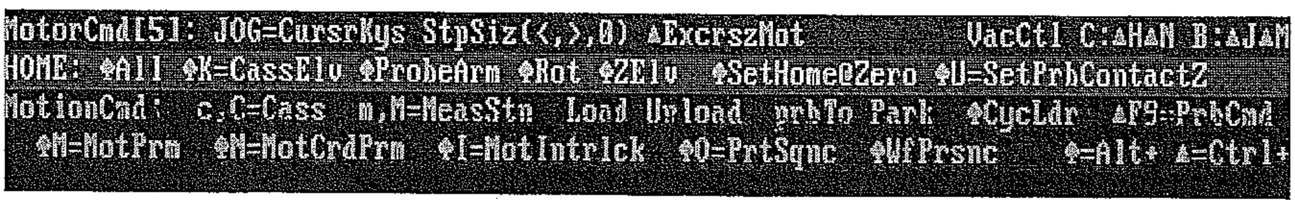
2.3.4 Check out the Motions for all motors

In this step, make sure that the probes are removed from the system. In case you hit some wrong key, there is no chance of damaging the system. The probe is the only vulnerable and consumable part subject to damage if mishandled. All the other components are very rugged and can stand a lot of abuse.

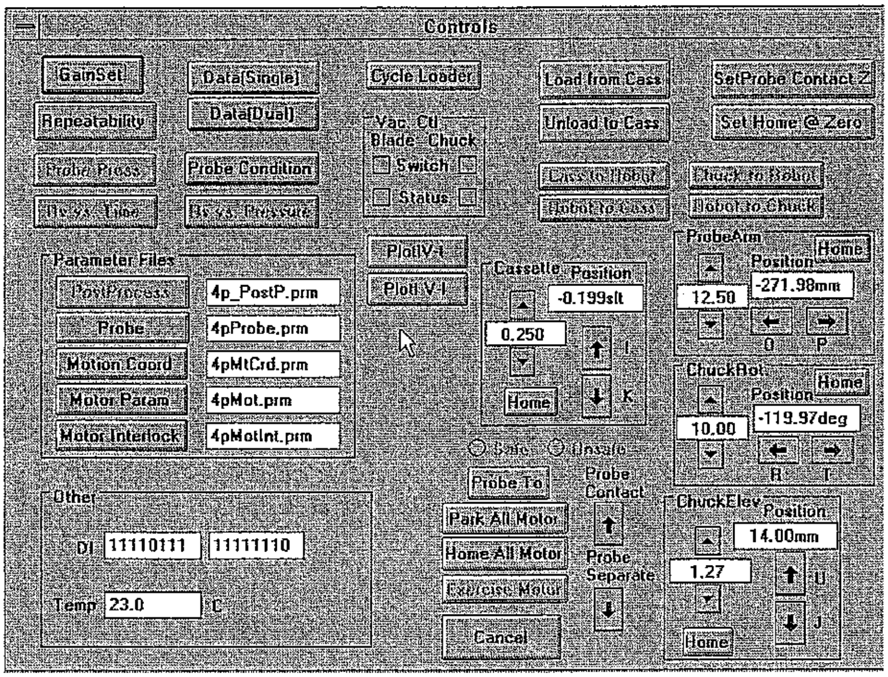
To actuate manual motion of the motors, you need to go to Utility/Service menu and then select Motor & Home Util (Control in Windows).

To jog the motors (jog is like a jump! each time the command is executed will cause an appropriate motor to move a fixed amount). The amount it moves is called the jog step (or how far it jumps!).

In DOS the keys to jog the axes are list in the following table and in



windows the job keys for these axis are graphically represented and should be apparent, this table only applies to the ResMap models with a Rotation Chuck (ResMap 168, 178, 273 and 268):



<u>Axes</u>	<u>Mot #</u>	<u>Home Command</u>	<u>Jog [>>] Command</u>	<u>Jog [<<] Command</u>
Chuck Height	0	Alt+Z	<PageUp> = Chuck UP	<PageDown> = Chuck DOWN
Chuck Rotation	1	Alt+R	<Insert> = Rotate Left (Counter Clockwise)	<Home> = Rotate Right (Clockwise)
Probe Arm (Robot Blade)	3	Alt+P	<Delete> = Probe Out (toward front of system)	<End> = Probe In (toward to back of system)
Cassette Elevator (168 and 268 only)	4	Alt+K	<↑> = Cassette UP	<↓> = Cassette Down
		Alt+A = homes all motors		
		‘<‘ or ‘,’ halves the jog step to the last motor jogged		
		‘>‘ or ‘.’ doubles the jog step to the last motor		

	jogged

For the flat panel model ResMap 188, we have similar jogging commands:

Axes	**Mot #**	**Home Command**	**Jog [>>] Command**	**Jog [<<] Command**
Probe Height	0	Alt+Z	<PageUp> = Probe UP	<PageDown> = Probe DOWN
Probe X (horizontal movements)	1	Alt+X	<→> = Probe +X RIGHT	<←> = Probe -X LEFT
Probe Y (vertical movements)	2	Alt+Y	<↑> = Probe +Y UP	<↓> = Probe -Y Down
	Alt+A = homes all motors			
	'<' or ',' halves the jog step to the last motor jogged			
	'>' or '.' doubles the jog step to the last motor jogged			

You can also try to ProbeTo (small 'p') command and Park (capital 'P') command to position the probes.

Now that you are familiar with the positioning commands. These commands are very useful for placing the probe to do single measurements, to align the system, etc.

2.3.5 Load/Unload Wafers from Cassette (ResMap 168 and 268's only)

For the Auto Cassette load users. You can now try to Load and Unload wafers. Pre-align a cassette of wafers in the cassette (You should have at least a wafer in slots #1, 2, and 25. Conductive wafer is nice to have useful for the next few tests, however, non-conductive wafer is OK for this step.) with the flat aligned down. Place the cassette on the cassette mount plate. Make sure it seats properly and all the wafers are pushed back in the cassette.

Connect the house vacuum source to the ResMap and turn on vacuum.

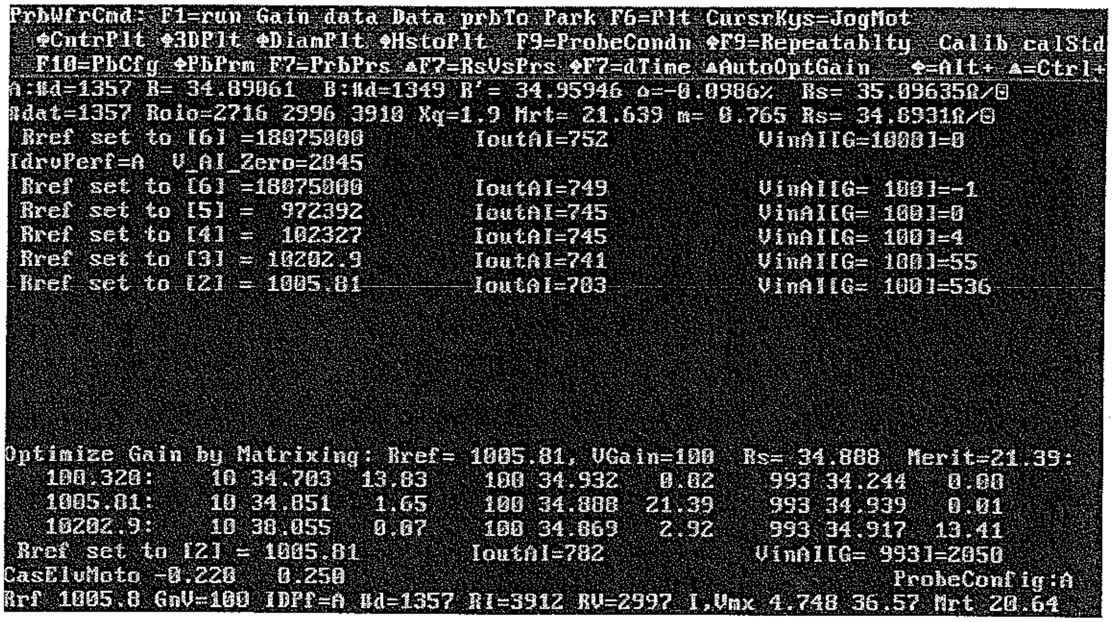
Make sure the motor parameter file is setup appropriate for your wafer size. Typically 4pMot8.prm for 8" wafers, 4pMot6.prm for 4", 5" and 6" wafers, or if you only have one size wafer setup for your system, then the motor parameter file is 4pMot.prm. This file name if found in the motor parameter screen (Alt+M and the Motor & Home Util in DOS or Control screen in windows).

Do a Load ('L' in DOS or the LOAD button in Windows), select the wafer #1 (typically bottom wafer). Observe the loading operation, check clearances and centering of the wafer on the chuck. Unload the wafer with "U" or UNLOAD command. Do this a few times to make sure everything looks good. Now try LOAD/UNLOAD wafer #2 and #25 to check out the Load/Unload operations. If something not quite right, need to go to maintenance and adjustment sections.

2.3.6 Measurements Setup

At this point, all the motor movements are in tune, you are ready to test the measurement's aspect.

If you have a resistor pack, this is the time to check this step. Still without a probe, connect the resistor pack (one of the resistor say near 100Ω) to the probe cable (a cheater Probe/Wafer combinations). Now, in DOS go to ProbeCmd under the Service/Utility menu (still Control Menu in windows). Do a Gain ('G' in DOS, GAIN button in windows). The screen will show a lot of numbers as follows :



If the Rs reading on the top right of the screen correct and the Merit reading at the bottom is OK (>5) then you are in good shape.

Now you are ready to do measurements on a wafer:

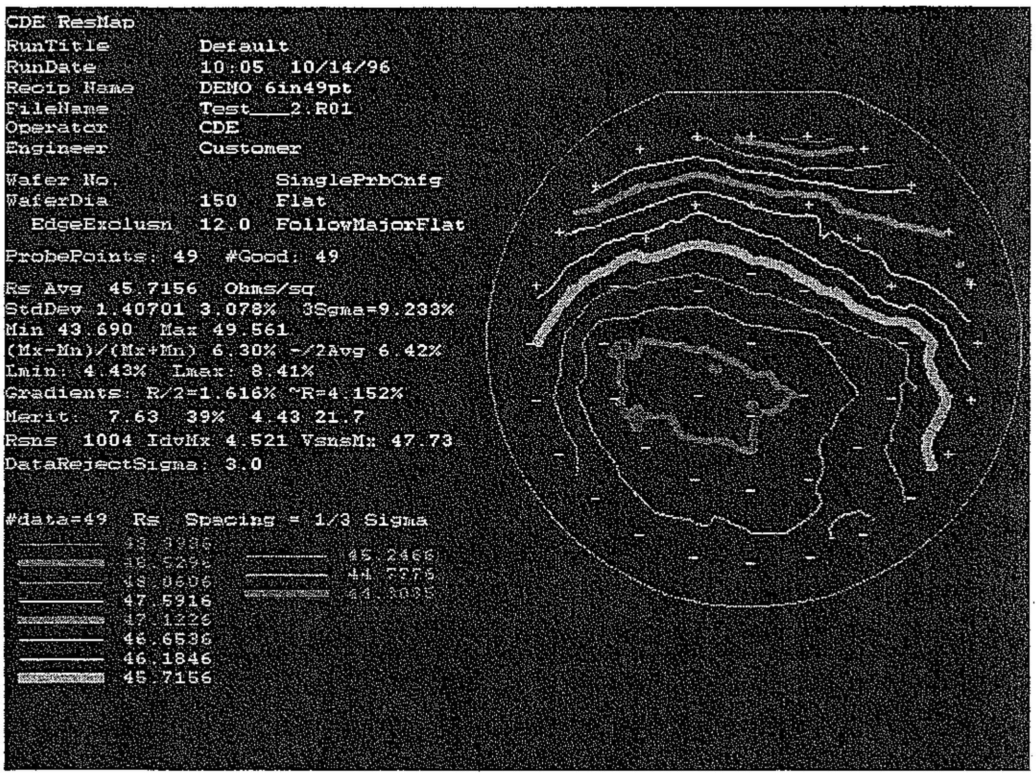
Place a conductive wafer [the only enemy to a 4 point probe is a non-conductive sample, it cannot do anything but complain] on the chuck, manually placed with flat or notch away from the groove (ResMaps 178, 168, 263) and along the groove for ResMap 273. Or you can automatically load one with the Load command described in 2.3.5.

Bring the probe to near the center of the wafer. Command the ProbeContact (in DOS it is PageUp in the ProbeCmd screen and in windows it is the ProbeContact command). Now the chuck is moved to where the probe should be in contact with the wafer. Now place the probe in its holder and let it drop so that the pins are touching the wafer. Check the clearance of the probe on the holder, it should be about 1-mm (for 1-mm pin compression). If this looks OK than bring the wafer down (ProbeSeparate or PageDown). Connect to probe to the cable connector, mount the probe, make sure the cable is not under the probe, and the probe seats at the bottom of the holder shelf and rotated slightly to the right and push against the left stop of the holder. Now tighten the lock screw (3/32" Allen wrench). Do

ProbeContact to check contact. You should see a gap between to bottom of the probe body and the wafer. In fact the distance between the bottom on the probe body and its reflection in the wafer should be between 1-mm and 2-mm (gap).

Now do a Gain command again. You should get a believable reading of Rs.

As a final check and have fun, now you should map a wafer. Go to MapWafer Command in Engineers Menu. Input the right wafer size, choose Area Map. Choose 49 points, choose follow flat, unless you have a notched wafer. Choose edge exclusion of 10 to 15 mm. Check ManualLoad or AutoLoad with proper wafer # as appropriate. (note in windows, the manual is chosen automatically when there are no wafers chosen), now choose RUN (F1 or F10 in DOS). You should see the system map the wafer, the data are displayed on the screen and when it finished mapping, you can get the Contour Map, 3D Map and other graphics, etc. Now that you have enjoyed the system. It is time to turn it over to the processing people.



The next few chapters will describe the detailed operations of the ResMap system.

IMPORTANT:

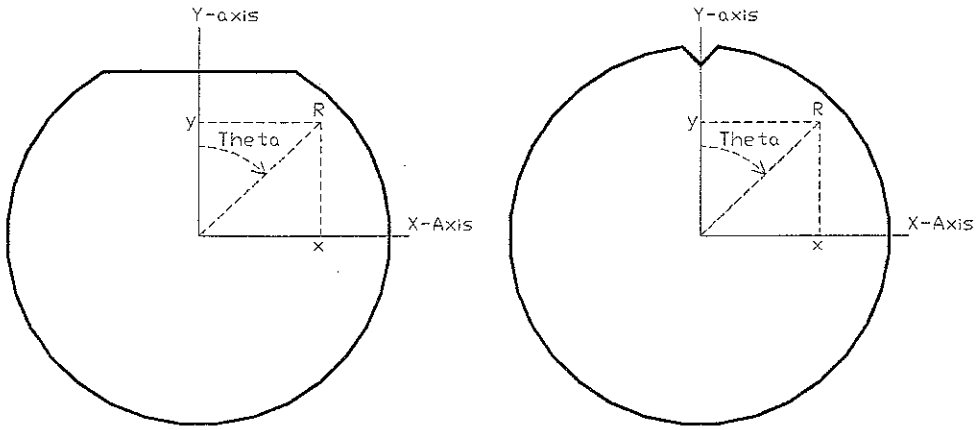
Don't forget to set the clock so that time and date are realistic in your local area!

3 DEFINITIONS / COORDINATE SYSTEMS

In this chapter, we will descript the coordinate systems we use and the definitions of commonly used terms:

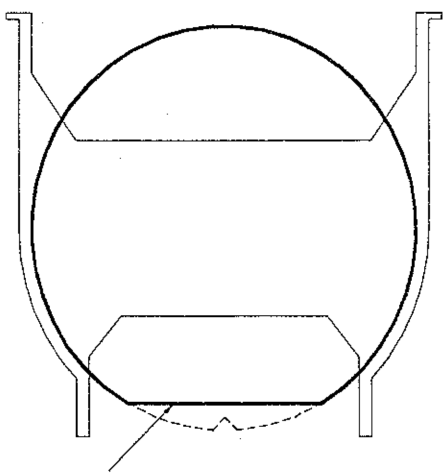
3.1 COORDINATE SYSTEM:

3.1.1 Coordinate system on the wafer:



Wafer with Major Flat Wafer with Notch

The Z axis comes out of the wafer.



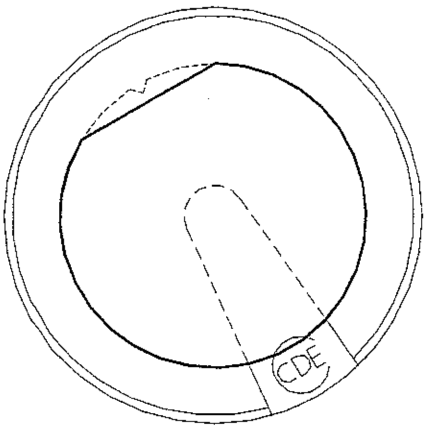
Wafer with Flat or Notch Down in Cassette

3.1.2 Coordinate system for the Cassette:

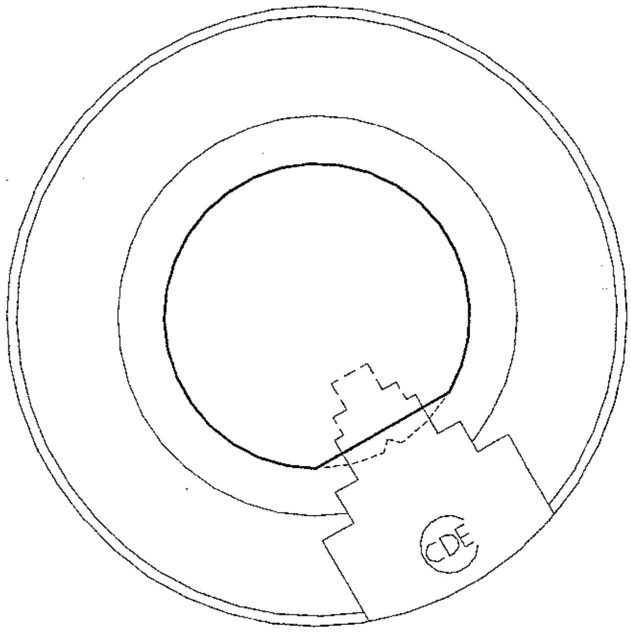
The nominal alignment is for the wafer with its flat down as shown. This can be changed in the Motion Coordinate Parameter to any alignment desired.

3.1.3 Wafer Alignment on the wafer chuck:

The 8" system [ResMap 178, 168 and 268] and the 12" system ResMap 173 alignment is opposite. The is demonstrated in the following figures. As before with the cassette alignment, this orientation can be changed.



Wafer Orientation on 8" chuck



Wafer Orientation on a 12" chuck

Shown above are with the chuck in the park position for ease of manual loading and unloading of wafers.

3.2 DEFINITIONS:

In this section we shall explain concepts of Merit (Figure of Merit) and Single vs Dual Probe Configurations:

3.2.1 Probe Configurations:

In Chapter 1 we have introduced the 4 point probe measurament principle.

We have:

$Rs = \pi/\ln 2 \, . \, V_{23}/I_{14} = 4.532 \, V_{23}/I_{14}$ .... [1]

In this section, we will expand this concept furthur. In equation, we have current flowing f\through pins 1 and 4 and we meaure voltage in pins 2 and 3. We call this probe configuration A. We can also have current flowing through pins 1 and 3 and measure voltage in pins 2 and 4. We shall call this probe configuration B. We will rewrite equations 1 for the two configurations:

Probe Configuration	**R = V/I**
A:	$R_a = V_{23}/I_{14}$
B:	$R_b = V_{24}/I_{13}$
[1]: Single Configuration:	$Rs[1] = 4.532 \, R_a$
[2]: Dual Configuration:	$Rs[2] = \{-14.696 + 25.173 (R_a/R_b) - 7.872(R_a/R_b)^2\} \, R_a$

Besides a complicated the dual configuration does offer some advantages as well as some panealties. These will be summerized in the following table:

Advantage of Single Configuration	Advantange of Dual Confuguration
Fast Better Signal to Noise Ratio	Corrects for pin wobbling Can measure closer to edge

In general, one should use dual configurations. If there is too much noise (low merit) one should try with single measurement for difficult situations. Also, if you are measuring thick conductors such as slugs or substrates with w/S > 0.5, where w = the thickness of the conductor and S = the pin spacing of the probe.

3.2.2 Merit

Merit or Figure of Merit is a measure of the goodness of a measurement. This will be explained in the following:

3.2.2.1 Introduction

This note explains what you want to know about *Merit* but could not get a satisfactory answer. Hopefully this note will help you understand and appreciate the power of *Merit* (= Goodness).

Did you ever have the experience that when you hit a tennis ball, at the instance the ball was hit, even before you have any idea where the ball is going, you have a good idea whether it is a good hit or not! Because you have some feel for the sound, the swing, etc. Also, when you are typing on your computer, even when you are not looking at the screen, you know when you have made a mistake! How do you know? Our non-expert explanation is that your experience have developed a touch, a feel of how a good shot should be like. This information or conclusion also arrives from a vast amount of data you have to analyze when the ball is hit or when the key is stroked!

What we try to do for ResMap during data collection is to formulate a way to classify how good a measurement is at the time of the measurement. You don't need to do any lengthy repeatability studies, nor any tedious gauge studies to find out whether the measurement is good or not. The *Merit* figure is an indicator or a foretaste at the time the measurement is performed to give you an answer.

3.2.2.2 What is it?

Because of the statistiscal and digital technology adopted for the CDE ResMap system, for each Rs measurement, the ResMap computer takes many samples -- as many as 4000 samples at different voltages and current levels. The resultant Rs is the slope of the Vin[pins 2,3] vs. Iout[pins 1,4]. The Rs is calculated from a linear least squares fit of these samples. We also incorporate the range of each curve, due to limited range available for the AD or DA (Analog to Digital or Digital to Analog converters), the wider the range, the finer the resolutions for each measurement, etc. We therefore empirically define the *Merit* (or sometimes called Figure of *Merit*) to be:

$$Merit = k \,.\, Ndata \,.\, Vr\text{-}in \,.\, Ir\text{-}out \,.\, Vr\text{-}drive \,/\, \chi^2 \,,$$

where: k = constant
Ndata = # of samples in Fig. 1, 2 or 3,
Vr-in = Vin [pins 2,3] range,
Ir-out = Iout [pins 1,4] range,
Vr-drive = Vdrive out range. (see Fig. 1),
and χ^2 = average distance squared from fitting line to each data point (the smaller the better).

The constant k is empirically adjusted so that an OK measurement yields a *Merit* of 1 (like a passing C grade), *Merit* higher than 1 is progressively better grade, an A grade may correspond to a *Merit* of 10, say. Likewise, for *Merit* < 1, the measurement becomes worse, for *Merit* = 0.1, we may have a D grade. And the measurement is less reliable.

3.2.2.3 Applications:

There are many applications to using the *Merit* figure. We will only illustrate a few here, as time goes on and more new applications are developed, we will add them to the list here.

1. Initial setup for Gain and Rref parameters:

During the Initialization phase when measuring a wafer, the ResMap control system check many Rref and Amplifier gains combinations to find the optimum Merit for the best operating conditions.

2. Check for probe performance:

   If the *Merit* decease after some time, it could be due to degradation from contamination, one can recondition the probe by using a ceramic plate to clean to probe tip.

3. Deciding the correct probe to use:

   What is the correct probe to use for a given film? Usually the supplier give some kind of guide line. However, the guide line is not a bible. We have a function called Rs and *Merit* vs. Probe pin pressure. In which we measure the Rs and *Merit* as we vary the pin compression distance or the pin pressure. One can easily choose the optimum probe from these measurements.

4. Mapping of *Merit* on wafer to check film *(This is not implemented yet).*

   A contour map of *Merit* can be performed on a wafer to check the *Merit* distributions. The variations could be due to surface conditions changes, doping level changes, etc.

4 MEASUREMENTS

In this chapter, we will describe how to do measurements using a recipe, this is the main function for a operator in the wafer fab. How to plot various graphics such as contour map, 3D map, etc. How to look at trend charts. How to change probes, etc.

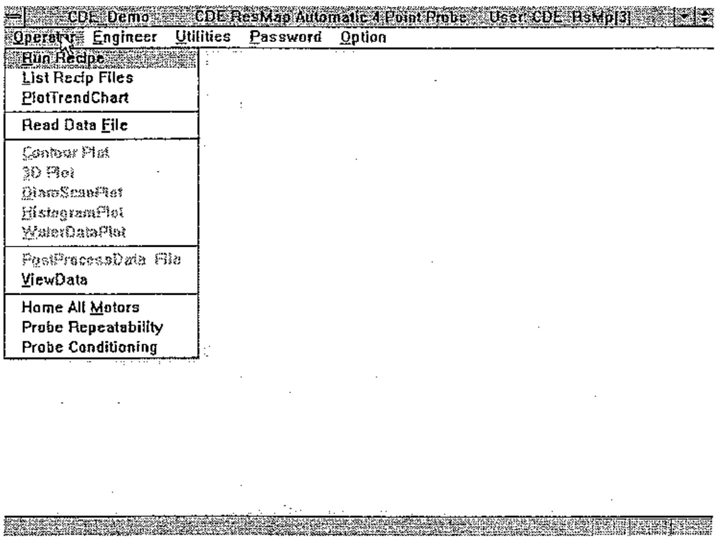
For the Engineers: How to create a recipe and edit and recipe. How to Calibrate.

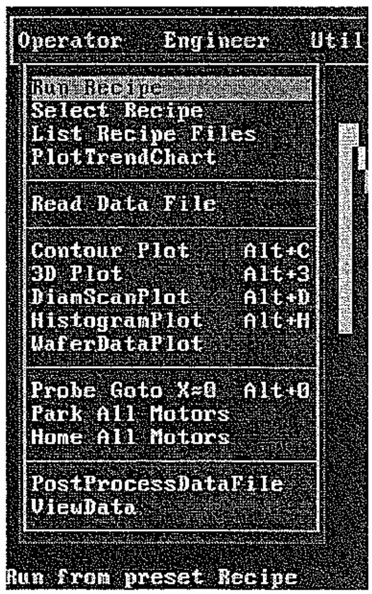
We will also describe limited amount of trouble shoot and diagnostics. However, the majority of these aspects will be illustrated in the Maintenance manual.

4.1 BASIC OPERATOR FUNCTIONS:

The Operator Menu is illustrated in the following:

We will go through them in order:





4.1.1 Run Recipe

The simplest way for an operator to take data or map a wafer is to use recipes. The recipes are setup by the Engineer (log on level 1 or above, in contrast, the operator need not log on, or level 0).

The ResMap Recipes are organized in two levels: top level are

Projects or in directory language c:\4p\###.prj, where ### = 1 to 8 alphanumeric characters [no spaces] like a file name. Of course, you recognize that the project is a 1st level subdirectory of the 4p directory, which we call the ResMap root directory. The recipe subdirectories are then subdirectories of the project subdirectory. In the directory language it is: c:\4p\###.prj\$$$.rcp, where $$$ means another 1 to 8 alphanumeric characters. We will describe these in detail later.

The operator selects Run Recipe menu and then selects Project and Recipe and the following screen appears:

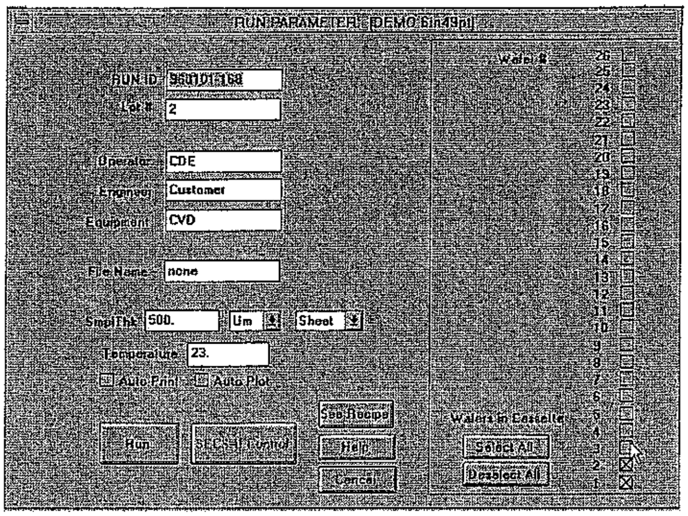
In DOS:

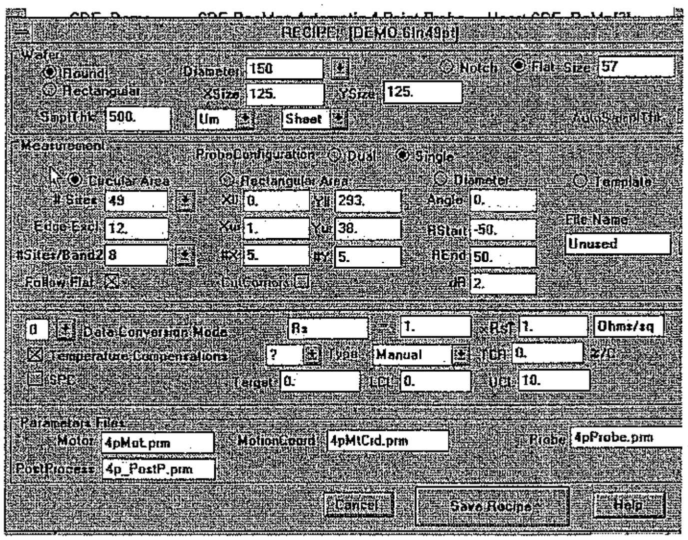
```
   R E S M A P   R E C I P E   S C R E E N   Default
Proj/Family: DEMO          Recipe: 61n49pt        #:  2

WAFER C  Dia 150 Flat 57.0  X,Ysz 125 125  PrbCnfg 1  DLRatio  1.000
    pnType ?  M TCR% 0.000 AutoSmplThk? N   SmplThk 500.00U S  DataReject> 3.0σ
MAPPING: Polar(A), Rect., Diam. or Template? A      TemplateFile: Unused
 POLAR: #ProbePoints:  49  FollowMajFlat? Y  EdgeExclusn:   12  #Pts[band2]: 8
 RECT:  LoLeft: 0.0 293   UpRight: 1.0  38   #XY:  5  5    CutCorners? N
 DIAM:  AngleScan: 0.000    StartScan:-50.00  EndScan: 50.00   DistBetw: 2.00

MEASUREMENT Mode: 0  0-> Rs       [Ohms/sq ] = 1.00000 x Rs ^ 1.0000

SPEC Control:  Target: 0.00000  LCL: 0.00000  UCL: 10.0000

PARAM FILES: Mot:4pMot.prm                      Motion:4pMtCrd.prm
          Probe:4pProbe.prm
DefaultLastRecipe? Y   SaveDataFile? N

Run 960101-168  Lot      2  Shf 1  Op CDE    Eqp CVD     AutoPrt? N  AutoPlt? N
WAFER LOAD: ManualOrAuto? A  SmplThk 500.00U S      Temp: 23.0   File:none
  Slot #: 1 2 3 4 5 6 7 8 9 10 1 2 3 4 5 6 7 8 9 20 1 2 3 4 5 6
          Y Y N N N N N N N N  N N N N N N N N N N  N N N N N
                                                  C:\4P\DEMO.PRJ\6IN49PT.RCP
Run Number
EDIT DATA: ARROWs to Move, <F1> or <F10>=OK, <ESC>=Cancel, CtrlD=DOS
```

The top part shows the contents of the Recipe which the operator can not change, the bottom boxed area is for the operator to enter the run parameter. After these are filled, he just press F1 or F10 to accept and proceed with the run. Or he may press <Esc> (Escape key) to cancel.

During the run, if he decide to abort, he just need to press the <Esc> to abort.

and In Windows:





The windows run screen is divide into two screens: (1) the Run Parameter (equivalent to the bottom box above) is for the operator to enter run information. He can also view (2) the Recipe Screen by clicking the See Recipe button. As before he can not make any changes to the recipe. He can switch back to the run parameter screen by clicking the Run Parameter button.

After he is completed with the run parameters, he can click the Run button to go ahead. Of course, cancel button has the usual meaning.

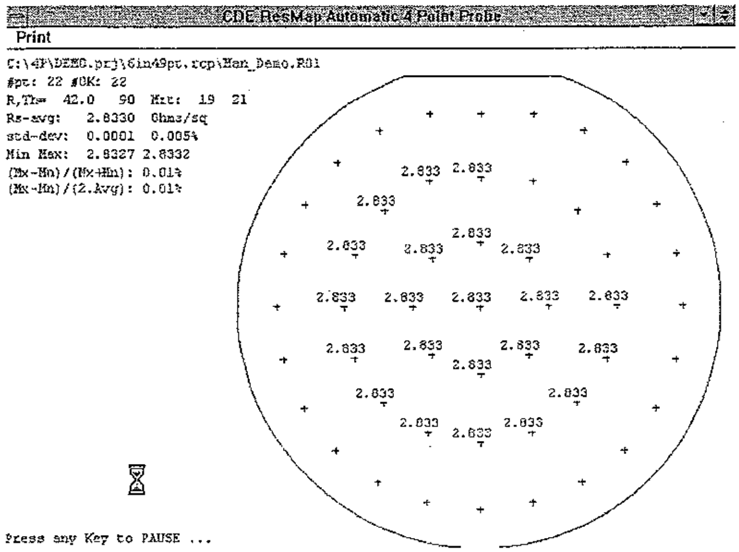
The data are stored in data file FILENAME.RsM for manual load FILENAME.R##, where ## is the cassette slot number from 01, .., 25

(26). Each file is stored on the disk (usually hard drive) in the recipe subdirectory.

The file name can be entered by operator in a 8 character alpha-numeric format, such as MyData. After the run the file name will be automatically incremented to MyData_2, etc. for convenience. If he does not want to enter a filename, the system gives a 8 character date-time code such as 6A22G103. which means YMDDhmms. where Y = last digit of current year 6=1996, M=month in Hex, A=10 or October, DD is the day of the month, h=hour in alphabet, A = midnight, B=1-am, etc. mm=minute, s=second/6. Note this style of file name always increase in time, and it advance every 6 seconds. The third choice for the file name is the string "none". In this case the filename will be none, the next time will be none again and write over the previous none. That mean only the last run will be saved and all previous none's will be discarded from the hard disk.

For the Auto Cassette Load ResMap models, such as ResMap 168 or ResMap 268-SMIF. The wafers to be mapped in the cassette are selected by selecting Auto Load in DOS and then select Y for the cassette slots. For Windows, this is done by clicking the wafer # boxes. The system selects Manual or AutoLoad automatically depends whether any wafers are selected. For automatic loading systems, manual load is performed the same way.

During data collection for each wafer, during the run, you will see the following screen:



For manual loading data taking, after the run, you are prompted to continue and then a contour map (or diameter scan map for diameter map, or no map will be plotted if the number or mapping points are less than five) will be plotted.

If select AutoPrint, then all the data will be printed automatically on the printer after each run. If you select AutoPlot, the corresponding map will be plotted. Note, the plotting of the contour map takes a few minutes, which may slow down throughput.

CDE ResMap Automatic 4 Point Probe

Print

Wfr#	FileName		DataAvg	StdDev	DatMin	DatMax	%	Lmin	Lmax
1	Man Demo.R01	49	2.83301	0.006%	2.83259	2.83331	0.0%	0.0%	0.0%
2	Man Demo.R02	49	2.83297	0.005%	2.83260	2.83329	0.0%	0.0%	0.0%
3	Man Demo.R03	49	2.83293	0.005%	2.83263	2.83326	0.0%	0.0%	0.0%
4	Man Demo.R04	49	2.83291	0.005%	2.83260	2.83321	0.0%	0.0%	0.0%
5	Man Demo.R05	49	2.83299	0.005%	2.83272	2.83328	0.0%	0.0%	0.0%
6	Man Demo.R06	49	2.83297	0.005%	2.83271	2.83335	0.0%	0.0%	0.0%
10	Man Demo.R10	49	2.83293	0.005%	2.83257	2.83327	0.0%	0.0%	0.0%
15	Man Demo.R15	49	2.83298	0.005%	2.83256	2.83329	0.0%	0.0%	0.0%
20	Man Demo.R20	49	2.83295	0.007%	2.83254	2.83342	0.0%	0.0%	0.0%
21	Man Demo.R21	49	2.83295	0.005%	2.83256	2.83325	0.0%	0.0%	0.0%
22	Man Demo.R22	49	2.83294	0.006%	2.83251	2.83329	0.0%	0.0%	0.0%
23	Man Demo.R23	49	2.83292	0.005%	2.83255	2.83321	0.0%	0.0%	0.0%
25	Man_Demo.R25	49	2.83292	0.005%	2.83268	2.83320	0.0%	0.0%	0.0%

ALL DATA:	Avg	StdDev	Min	Max	(Mx-Mn)/(Mx+Mn)
	2.83295	0.005%	2.83251	2.83342	0.016%

For automatically cassette load, the ResMap will not wait to prompt operator to continue after every run, it will go ahead to finish the entire cassette, and then display a wafer summary screen.

After you have finished a run, you can also go back to previous selected recipe by answering the prompt in DOS or select previous button in Win. This is designed to reduce number of key strokes or mouse clicks for most common operations.

4.1.2 Select Recipe Menu

This menu has similar meaning as Run Recipe except it does not continue to run the recipe.

4.1.3 List Recipe Files

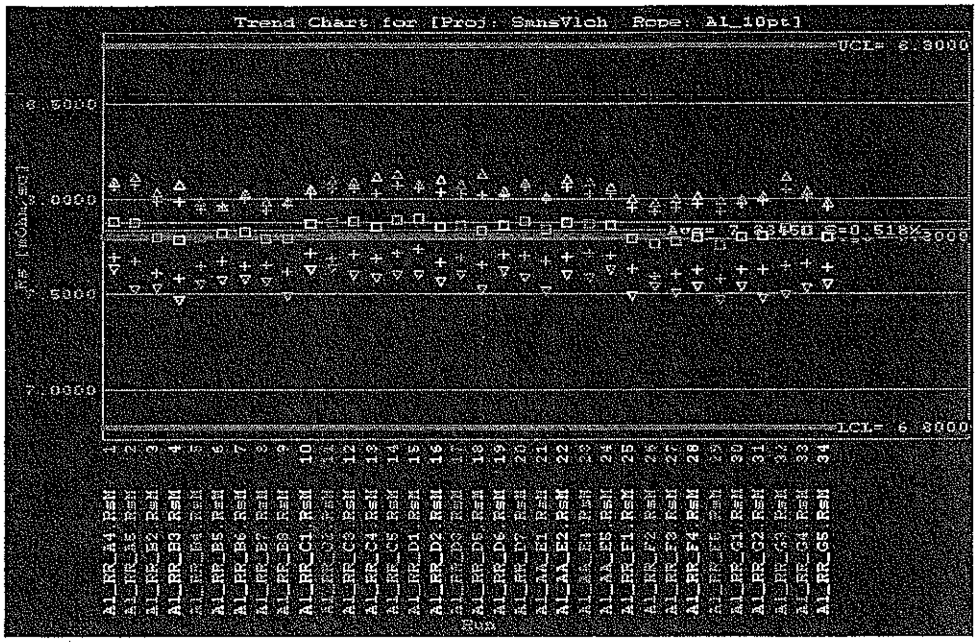
The allows you to select the summary data for all the data files in the recipe. Certain amount of edits are allowed and it can be printed out as a report. Also the highlighted run data can be read in easily for

```
File Summary:  Recipe[SmnsVlch Al_10pt]  Total files=34  #Selected=34
Sel #    FileName      #sites       Avg      Dev        Min    Max
»  1 Al_RR_A4.RsM   10   10 7.884036   2.36%   7.6353 8.0907   2.90%
»  2 Al_RR_A5.RsM   10   10 7.878774   2.54%   7.5235 8.1147   3.70%
»  3 Al_RR_B2.RsM   10   10 7.799992   2.39%   7.5298 8.0374   3.26%
»  4 Al_RR_B3.RsM   10   10 7.785849   2.57%   7.4697 8.0781   3.91%
»  5 Al_RR_B4.RsM   10   10 7.796860   1.87%   7.5497 7.9835   2.79%
»  6 Al_RR_B5.RsM   10   10 7.819327   1.83%   7.5725 7.9612   2.50%
»  7 Al_RR_B6.RsM   10   10 7.824507   2.22%   7.5816 8.0300   2.87%
»  8 Al_RR_B7.RsM   10   10 7.796435   1.85%   7.5651 7.9870   2.71%
»  9 Al_RR_B8.RsM   10   10 7.795259   2.27%   7.4926 7.9891   3.21%
» 10 Al_RR_C1.RsM   10   10 7.872310   1.98%   7.6251 8.0487   2.70%
» 11 Al_RR_C2.RsM   10   10 7.873274   2.29%   7.6337 8.1001   2.96%
» 12 Al_RR_C3.RsM   10   10 7.882014   2.22%   7.6009 8.0910   3.12%
» 13 Al_RR_C4.RsM   10   10 7.858063   2.18%   7.5835 8.1147   3.38%
» 14 Al_RR_C5.RsM   10   10 7.891527   2.22%   7.5988 8.1320   3.39%
» 15 Al_RR_D1.RsM   10   10 7.896218   2.01%   7.6009 8.0737   3.02%
» 16 Al_RR_D2.RsM   10   10 7.851943   2.34%   7.5629 8.1037   3.45%
» 17 Al_RR_D3.RsM   10   10 7.860895   2.09%   7.6013 8.0741   3.02%
» 18 Al_RR_D5.RsM   10   10 7.835503   2.32%   7.5234 8.1317   3.89%
» 19 Al_RR_D6.RsM   10   10 7.860859   1.94%   7.6221 8.0388   2.66%
» 20 Al_RR_D7.RsM   10   10 7.880580   2.27%   7.5074 8.0835   3.17%
» 21 Al_AA_E1.RsM   10   10 7.838245   2.10%   7.5173 8.0126   3.19%
Cmd: ↑ ↓ PgUP PgDn Home End Space=Select/DeSelect +=SelAll -=DeSelAll ReadDatFil
     PrintSelect Quit
```

quick reference.

4.1.4 Plot Trend Chart

This command also you to plot all the data in a recipe as a trend chart

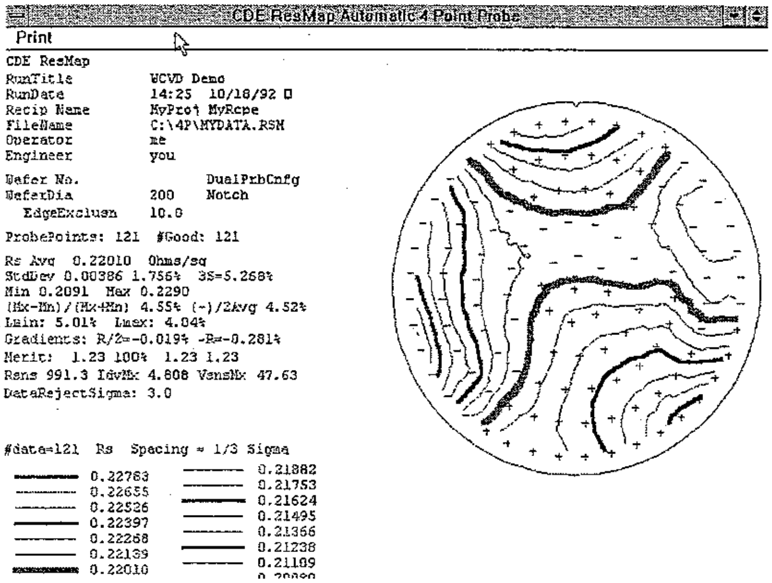


for statistical process control (SPC): On this chart, you can see the data for each run: average, standard deviation, minimum, and maximum. Also, for all the runs, the average and the standard deviation of the averages. Also shown are the target value and the UCL (Upper Control Limit) and LCL (Lower Control Limit).

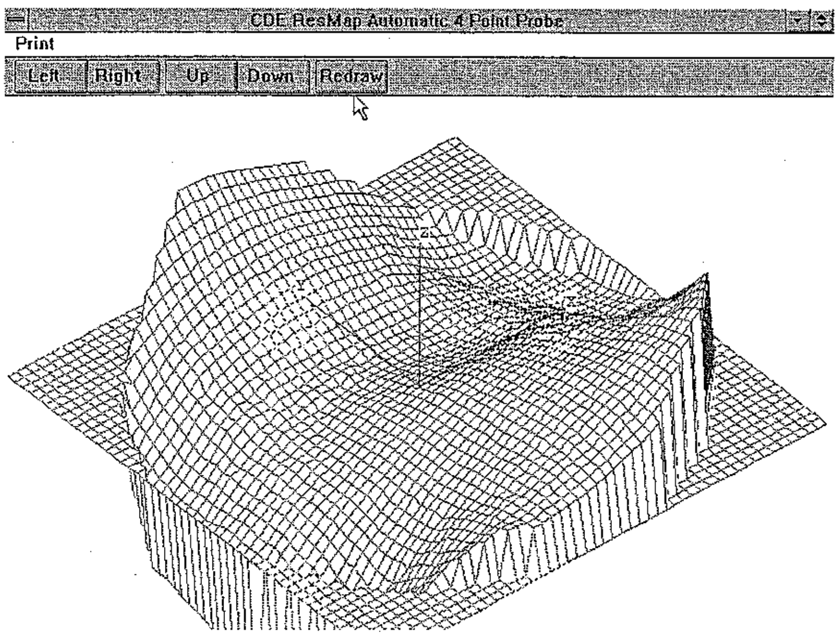
4.1.5 Read Data File

This command allow you to read any data file in any directory. After the read, the proper graphics such as contour or diameter map will be plotted. Normally, it is much easier to use List Recipe File command to read data.

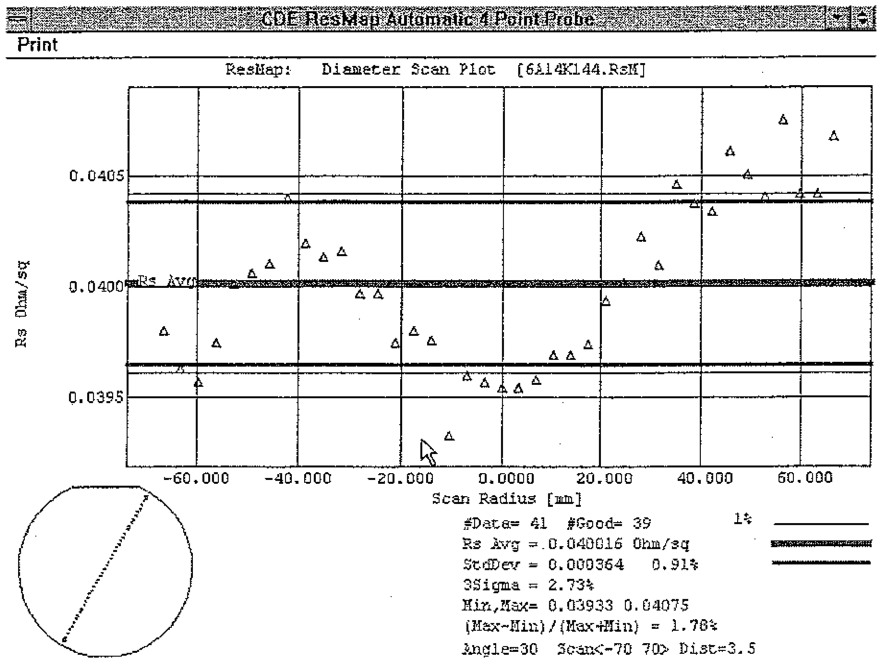
4.1.6 Contour Plot



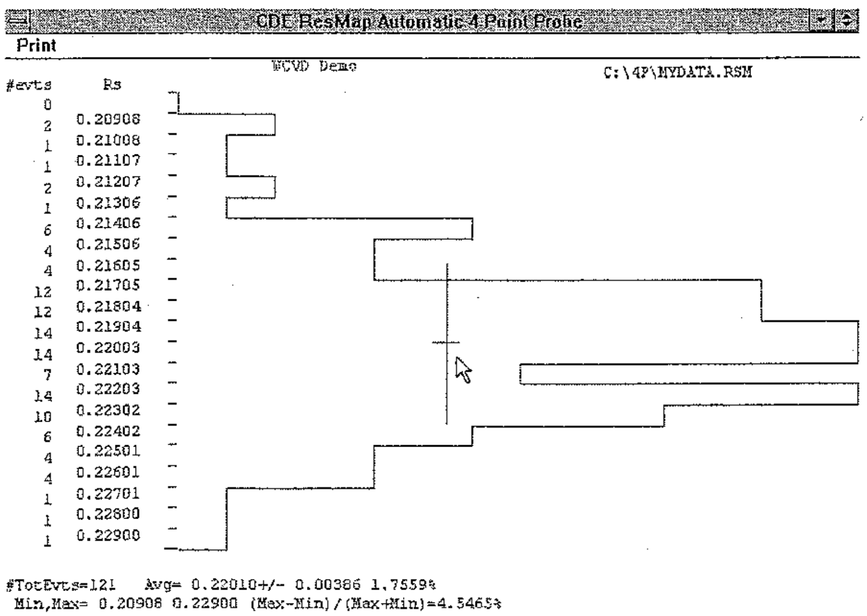
4.1.7 3D Plot



4.1.8 DiamScanPlot

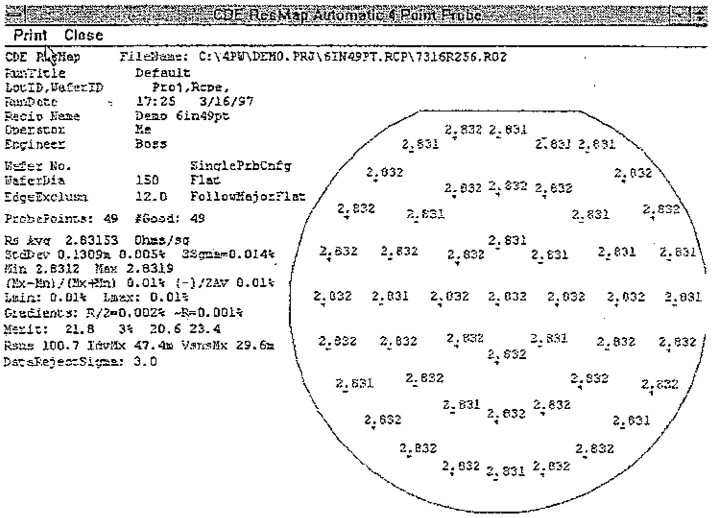


4.1.9 HistogramPlot



4.1.10 WaferData Plot

This plots the data on each site similar to the data acquisition screen while the ResMap is collecting data in real time (See Section 4.1.1 Run Recipe). Following is an example:



4.1.11 Probe Goto X≈0

This command moves to probe near the center of the chuck. It is useful for changing probe. Also it is useful to check resistivity near center of wafer. One need to use the GainSet/1pt Meas command in Engineering Menu.

4.1.12 Park All Motors

This command parks all motors, it is similar to Home All Motors except it is faster. It does not home the motors.

4.1.13 Home All Motors

This command homes all motors in the following sequence:

i:	Home Chuck Elevation motor
ii:	Home Chuck Rotation motor
iii:	Home Probe Arm motor
iv:	Home Cassette Elevation motor if exists.

This sequence is save in most circumstances. If there is a wafer on the blade, then the operator need to remove it by hand afterwards.

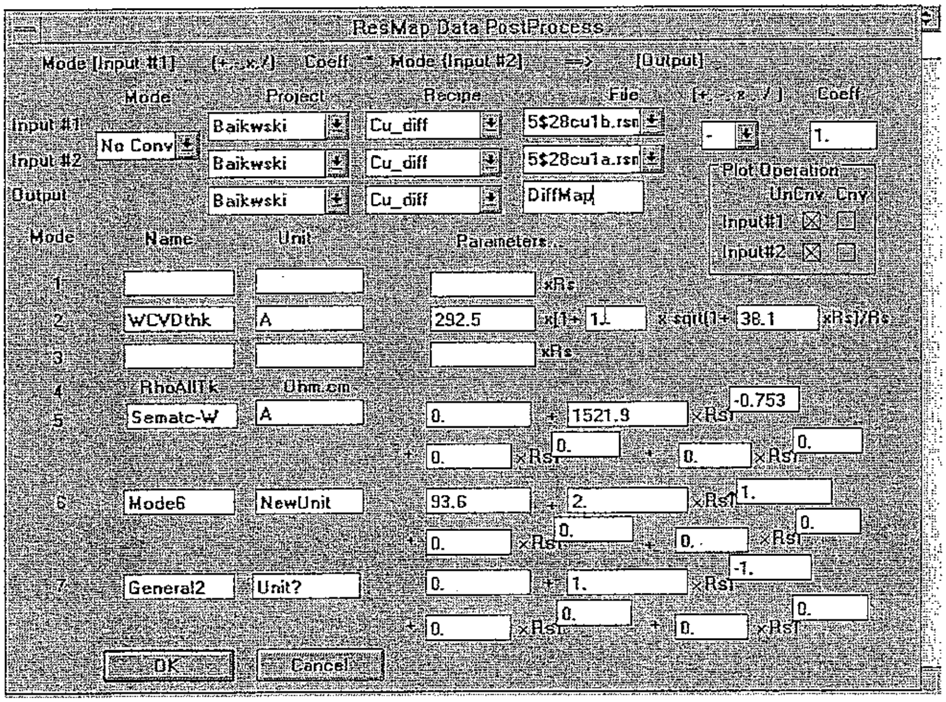
4.1.14 PostProcessDataFile

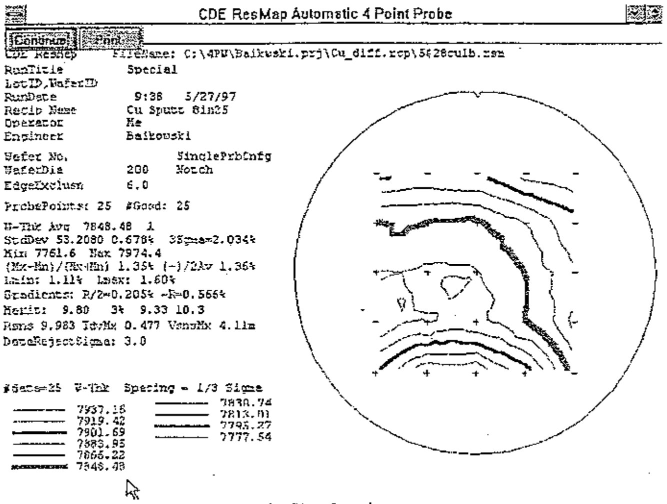
This is a very powerful command which allows one to do something to data already collected. It operates on the Data files *.RsM or *.R##. Some of the applications are:

1: Converting units from the measured Rs to something like thickness using convertion formulas stored in modes.

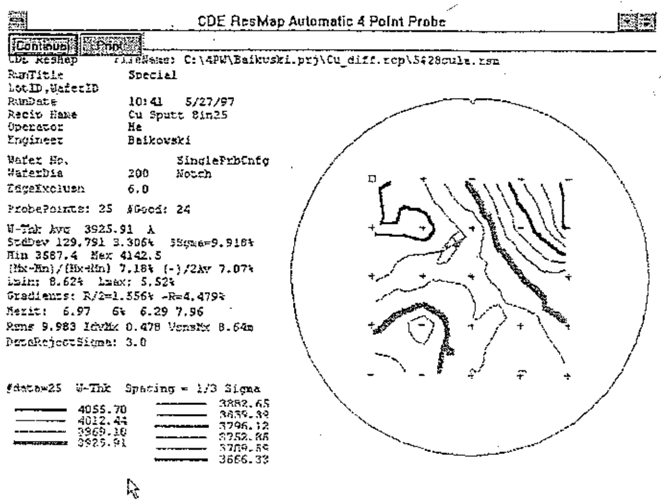
2: Do operations on 2 files such as subtractions for CMP or Plasma etchback for metal films, in this case one can calculate and display removal rate and distributions. An example is displayed in the following figures.

3: Other operations such as multiplication's of 2 files point by point for Rs x W = ρ, (where the W = film thickness measured with another operation such as FTIR for EPI thickness, or thickness of bare wafers with other gauge.)

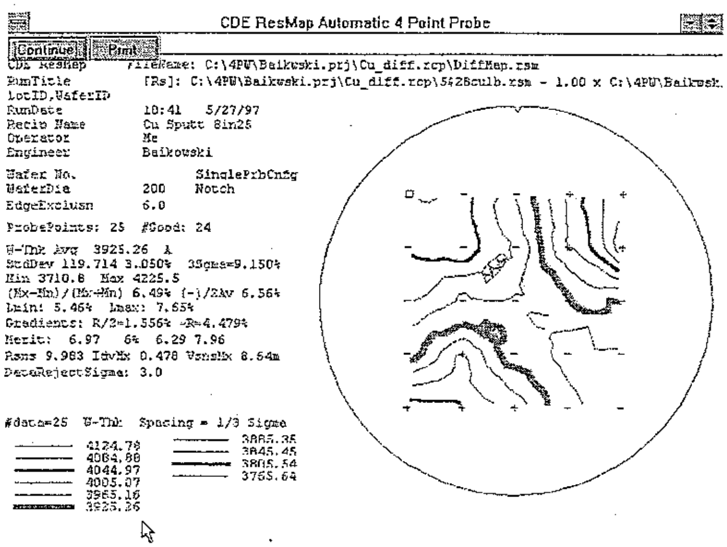




WCVD film as deposited, (Before)



WCVD after CMP, (After)



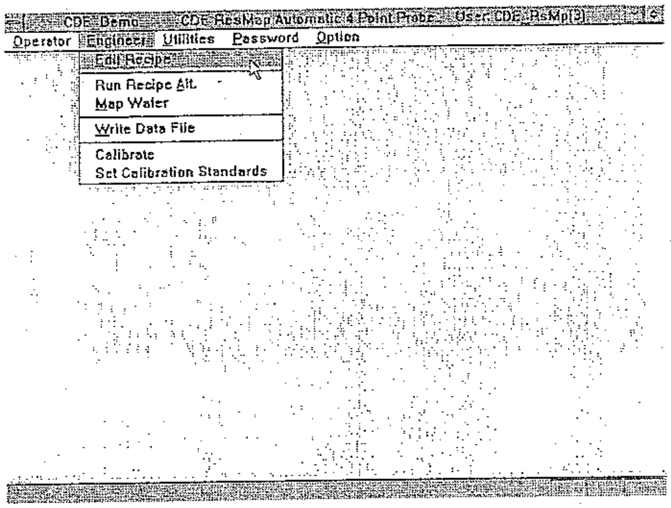
WCVD difference = Before - After

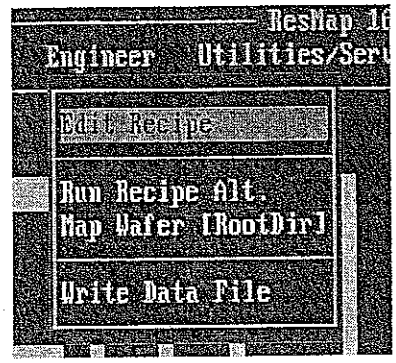
4.1.15 ViewData

This command allows the viewing of data file text.

4.2 ENGINEERING OPERATIONS

The Engineering menu is show in the following for DOS, the windows has similar appearance:





4.2.1 Edit Recipe

The ResMap recipe is constructed in 2 levels, Project and Recipe:

1. Project:

   In this level, typically higher level of the recipe is specified, typically, like Implant, PVD, etc. or relating to different departments, such as Thin Film, EPI, etc.

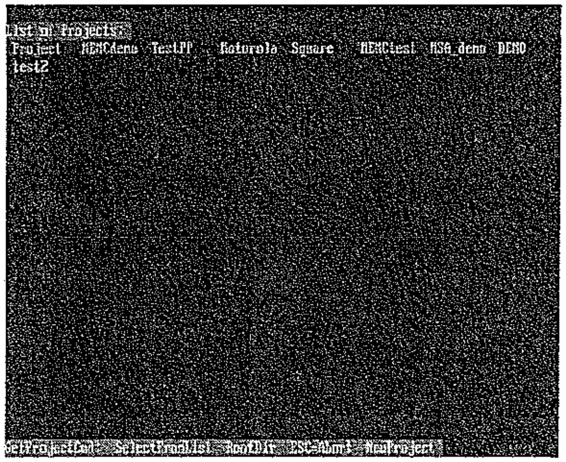
   The names of the project list are stored in a file in c:\4p\Project.lst. Each project has an 1 to 8 character directory name such as c:\4p\Implant.prj. In the project directory, there is a file which contains the recipe list: Recipe.lst, such as: c:\4p\Implant.prj\Recipe.lst.

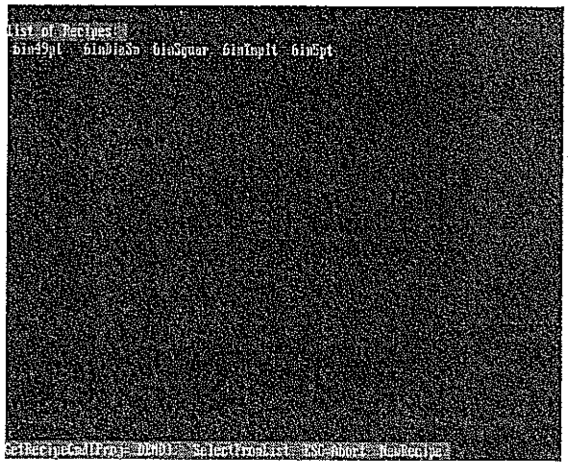
2. Recipe:

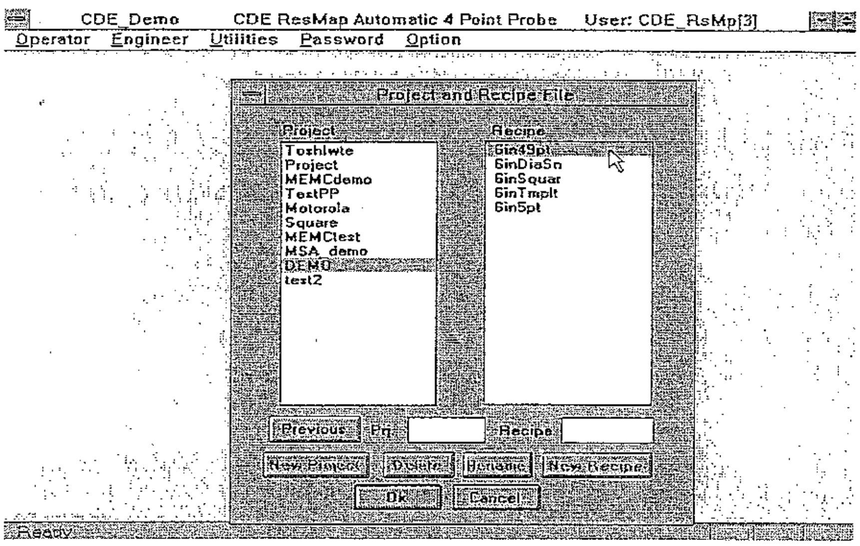
   The recipe names are listed as described above, and the recipes are in the recipe directory. Typical directories are like 6in49pt, etc. You can think of recipe as reporting to the projects in a organization chart sense.

Typical recipe subdirectory is like: c:\4p\Implant.prj\6in49pt.rcp. in this recipe, there stores all the recipe parameter file, named Recipe.dat, list of all run data summary file: RunFile.lst and all the data files. One can also store local copy of parameter file to personalize the recipe operations. We do not recommend this unless you are very familiar with the ResMap 4p software.

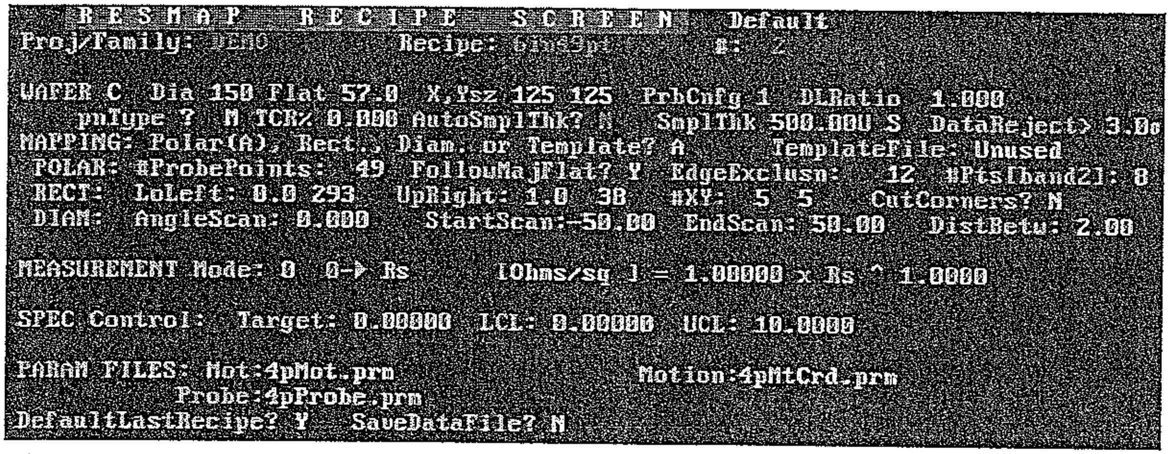
Typical, Project and Recipe screens are shown in following:



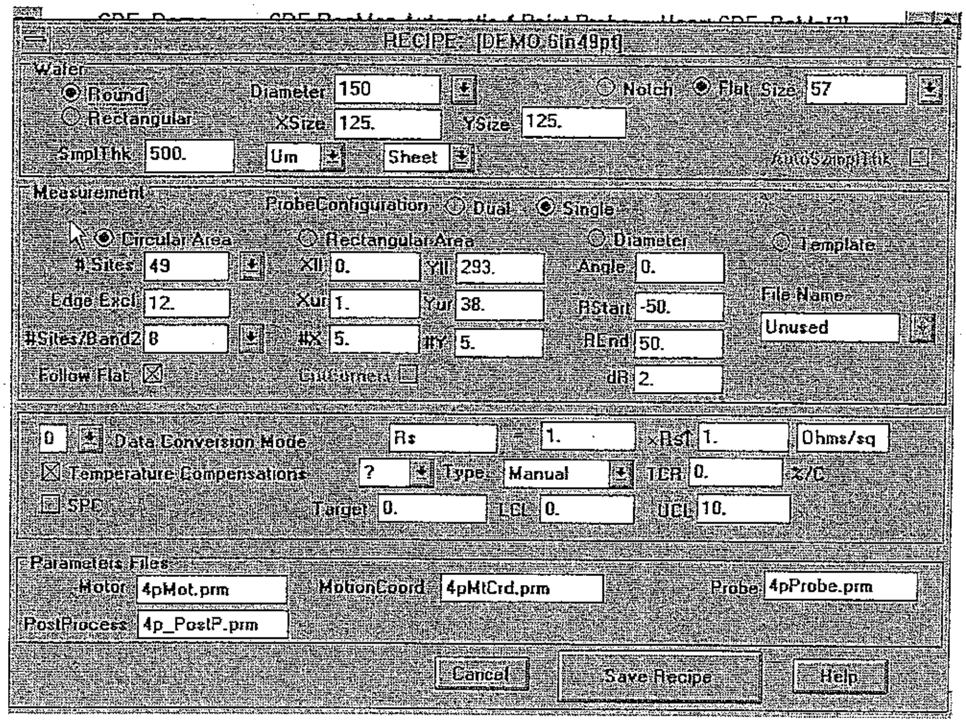




When editing a project or recipe, select the proper name and press enter, when you want to create new project or recipe, just press N for new. The ResMap Recipe Screen will appear and you can command the recipe to perform the mapping functions you desire:



Now we will go through each parameter in the Recipe Screen, the parameters in yellow can be entered by the user, the parameters in brown are fixed:


RECIPE: [DEMO 6in49pt]
Wafer
Round
Rectangular
Diameter 150
XSize 125.
YSize 125.
Notch
Flat
Size 57
SmplThk 500.
Um
Sheet
Measurement
ProbeConfiguration
Dual
Single
Circular Area
Rectangular Area
Diameter
Template
#Sites 49
Edge Excl 12.
#Sites/Band2 8
Follow Flat
Xll 0.
Yll 293.
Xur 1.
Yur 38.
#X 5.
#Y 5.
Angle 0.
RStart -50.
REnd 50.
dR 2.
File Name
Unused
0
Data Conversion Mode
Rs
1.
1.
Ohms/sq
Temperature Compensations
?
Type
Manual
TCR 0.
%/C
SPC
Target 0.
LCL 0.
UCL 10.
Parameters Files
Motor 4pMot.prm
MotionCoord 4pMtCrd.prm
Probe 4pProbe.prm
PostProcess 4p_PostP.prm
Cancel
Save Recipe
Help

Parameter	Explanation	On above screen
[Title]	Two lines of text	Default
Wafer [Shape]	C for circular, R for rectangular	C
Dia	For circular wafer, diameter in mm	150
Flat	For circular wafer, flat length in mm	57.0
X,Ysz	For rectangular wafer, X and Y size	125 125
PrbCnfg	Probe configuration, [1] for single, [2] for dual	1
DLRatio	For EPI double layer ratio, to calculate last layer ρ	1.000
pnType	For Doped Si semiconductor, P for P-type, etc. This is used for Auto TCR from ASTM-table	?
[TCR source]	M for Manual enter, A for ASTM table (see explanation below)	M
TCR%	Temperature Compensation in %[ρ]/C°	0.000
SmplThk	Sample [conductive layer] thickness, for ρ calculations. (see explanations for thickness corrections below)	500.00
[unit]	Unit of thickness: A=Angstron, U=μm, M=mm, C=cm	U
[Meas type]	S=Sheet Rs, B=Bulk Resistivity [ρ]	S
DataReject> σ	For rejection measurements > # sigma from average	3.0
MAPPING: ...	Type of mapping: A or P for Polar map [r, θ] coord, R for Rectangular coord [x,y grid], D for diameter [line] scan, and T for Template, which the mapping coords are stored in a template file	A
TemplateFile:	Template file name for Template Mapping mode	Unused
POLAR:	Polar mapping [r, θ] mode parameters in this line	
#ProbePoints:	# of sites to probe [maximum is 1000 sites]	49
FollowMajFlat?	Y or N to follow or not to follow flat on for constant edge exclusion on the mapping pattern (see figures below)	Y
EdgeExclusn:	Edge exclusion in mm minimum is about 2.5-mm	12
#Pts[band2]:	This is number of sites in the 2nd ring, after the center point. this uniquely defines the mapping pattern (see figures below)	8
RECT:	For rectangular mapping [x,y grid] mode parameters	
LoLeft:	Lower left corner coord in mm, [0,0] is center of sample	0.0 293
UpRignt:	Upper right corner coord...	1.0 38

#XY:	# of columns and rows of grid [maximum is 1000 sites]	5 5
CutCorners?	Delete the 4 corner sites from the Map Y or N	N
DIAM:	For Diameter or Line scan along diameter of sample	
AngleScan:	The Bearing of the scan line, 0-deg = 12 O'clock, 90-deg = 3 O'clock directions, see Chapter 3: Coordinate system	0.000
StartScan:	Start scan radius in mm, 0 is at center of sample [wafer]	-50.00
EndScan:	End scan radius ...	50.00
DistBetw:	Spacing between the sites [>0.2mm]	2.00
MEASUREMENT Mode:	This is to apply formula to convert measurement Rs [in Ω/☐] to other parameters such as thickness, ρ, etc. For mode 0, the formula to the right is used, for other modes [1 to 7], the modes are defined in PostProcessDataFile menu	0
0 → [type]	For mode 0 only, the type of Measurement e.g. Al-thk	Rs
[unit]	Unit of measurement such as A [Angstrom]	Ohms/sq
[A]	Parameter A for type = $A\ Rs^{B}$, see Chapter 1: Film Thickness	1.00000
[B]	Parameter B as defined above	1.0000
SPEC Control:	For Statistical Process Control	
Target:	Target value of measurements for this recipe, this is used for Trend Charts see Chapter 4: Plot Trend Chart	0.00000
LCL:	Lower control limit	0.00000
UCL:	Upper control limit	10.0000
PARAM FILES:	The recipe allows you to use specialized parameter files for unique applications, such as different calibrations, or special sample thickness, etc.	
Mot:	Low level motor parameter file	4pMot.prm
Motion:	System coordinate parameter file	4pMtCrd.prm
Probe:	Probe parameter file, such as calibrations, etc.	4pProbe.prm
Default LastRecipe?	For prompting after each run	Y
SaveDataFile?	To save or not to save data files on disk.	N

4.2.1.1 Temperature Corrections:

If we know what the temperature is during measurement and we also know what the Temperature Coefficient of Resistivity [TCR] is, then we can correct the results to another temperature, usually 23°C. The formula is linear:

$$\rho(\text{at } 23°C) = \rho(\text{at temp T}) * [1 + (23 - T) * TCR],$$

Where TCR is in units $\Delta\rho/C°$.

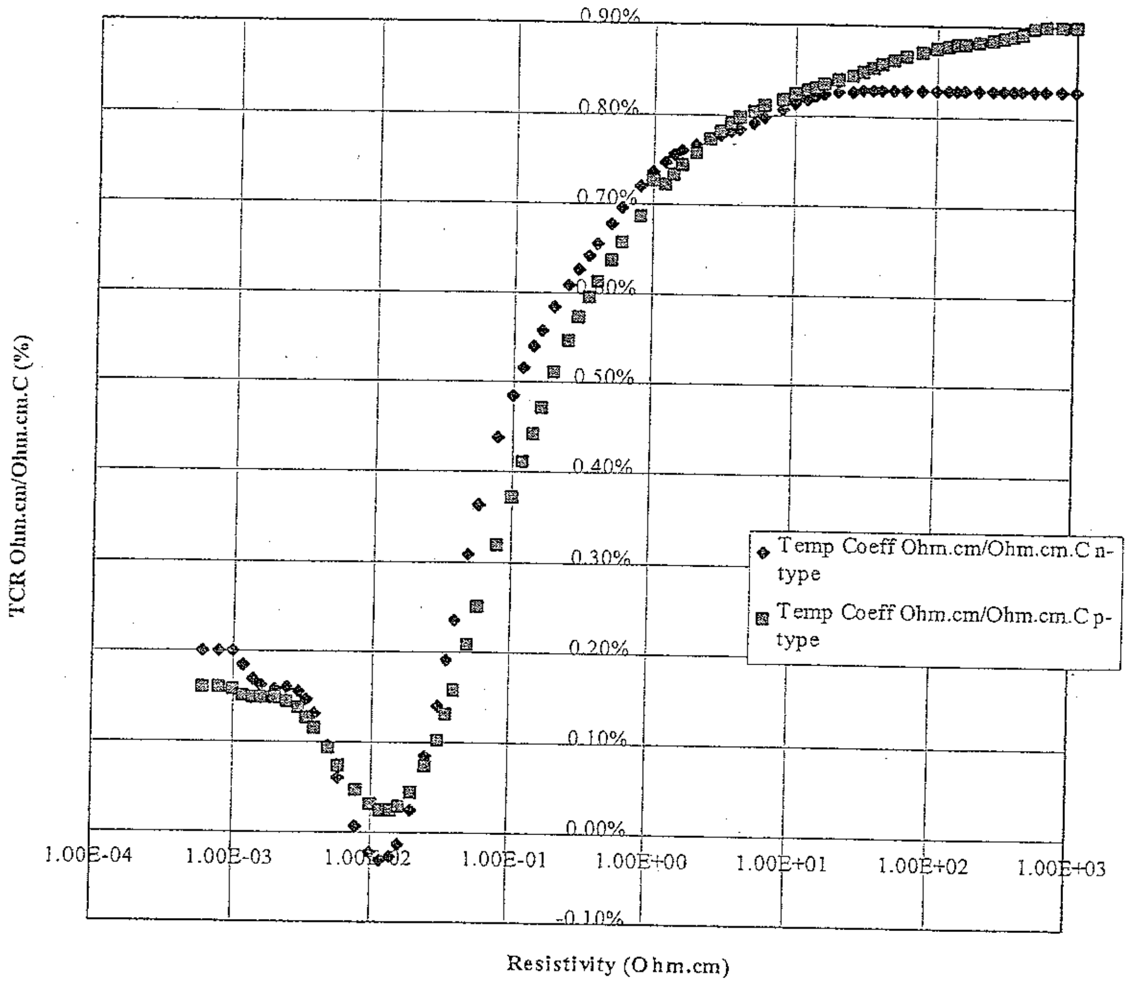
We have available thermal couple to measure the ambient temperature the wafer is experiencing, and we have also implemented the ASTM-F84 table of TCR in the software. So, the temperature correction is automatic. Below is a list of the ASTM-F84 temperature correction table and a plot of the data.

ASTM F84 TCR between 18C and 28C		
Resistivity	TCR (%)	
Ohm.cm	n-type	p-type
0.0006	0.200%	0.160%
0.0008	0.200%	0.160%
0.0010	0.200%	0.158%
0.0012	0.184%	0.151%
0.0014	0.169%	0.149%
0.0016	0.161%	0.148%
0.0020	0.158%	0.148%
0.0025	0.159%	0.145%
0.0030	0.156%	0.137%
0.0035	0.146%	0.127%
0.0040	0.131%	0.116%
0.0050	0.096%	0.094%
0.0060	0.060%	0.074%
0.0080	0.006%	0.046%
0.010	-0.022%	0.031%
0.012	-0.031%	0.025%
0.014	-0.026%	0.025%
0.016	-0.013%	0.029%
0.020	0.025%	0.045%
0.025	0.083%	0.073%
0.030	0.139%	0.102%
0.035	0.190%	0.131%
0.040	0.235%	0.158%
0.050	0.309%	0.208%
0.060	0.364%	0.251%

0.080	0.439%	0.320%
0.10	0.486%	0.372%
0.12	0.517%	0.412%
0.14	0.540%	0.444%
0.16	0.558%	0.471%
0.20	0.585%	0.512%
0.25	0.609%	0.548%
0.30	0.627%	0.575%
0.35	0.643%	0.596%
0.40	0.656%	0.613%
0.50	0.678%	0.639%
0.60	0.696%	0.659%
0.80	0.720%	0.687%
1.0	0.736%	0.727%
1.2	0.747%	0.722%
1.4	0.755%	0.734%
1.6	0.761%	0.744%
2.0	0.768%	0.759%
2.5	0.774%	0.773%
3.0	0.778%	0.783%
3.5	0.782%	0.791%
4.0	0.785%	0.797%
5.0	0.791%	0.805%
6.0	0.797%	0.811%
8.0	0.806%	0.819%
10	0.813%	0.825%
12	0.818%	0.829%
14	0.822%	0.832%
16	0.824%	0.835%
20	0.826%	0.840%
25	0.827%	0.845%
30	0.828%	0.849%
35	0.829%	0.853%
40	0.830%	0.857%
50	0.830%	0.862%
60	0.830%	0.867%
80	0.830%	0.872%
100	0.830%	0.876%
120	0.830%	0.878%
140	0.830%	0.879%
160	0.830%	0.880%
200	0.830%	0.882%
250	0.830%	0.884%
300	0.830%	0.886%
350	0.830%	0.888%
400	0.830%	0.891%
500	0.830%	0.897%
600	0.830%	0.900%
800	0.830%	0.900%

1000	0.830%	0.900%

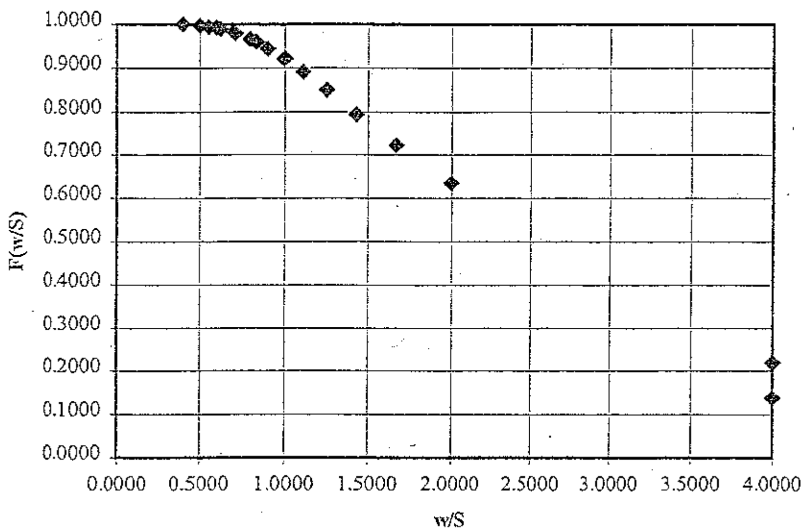
Plot of ASTM TCR(%)



4.2.1.2 Sample Thickness Correction:

Following is a table of correction factor, F(w/S) as a function of w/S. Where w = conducting layer thickness (film or substrate), and S = probe adjacent pin spacing.

Plot of F(w/S): thickness corrections



w/S	F(w/S)	
0.4000	0.9995	
0.5000	0.9970	
0.5550	0.9948	
0.6000	0.9920	
0.6250	0.9898	
0.7000	0.9820	
0.7143	0.9798	
0.8000	0.9660	
0.8333	0.9600	
0.9000	0.9440	
1.0000	0.9210	
1.0000	0.9214	
1.1111	0.8907	
1.2500	0.8490	
1.4286	0.7938	
1.6666	0.7225	
2.0000	0.6336	
4.0000	0.1386	S=1.0 mm
4.0000	0.2201	S=1.6 mm

In the near future, we will implement other corrections such as J.I.T. methods and Yamishita methods for thickness and edge corrections.

4.2.2 Run Recipe Alt.

This command allows an engineer to modify [alternate] the following run according to a recipe, the original recipe remains unchanged. The data file will be saved in the recipe directory. This is useful for an engineer to do some diagnostics. For instance, if a recipe is mapping 5 points for a production monitoring. If there is something unusual for a particular wafer, the engineer can make a 49 point map for the same wafer without creating a new recipe. Another example: if something does not look right near the edge of a wafer, the engineer may want to make a series of runs with different edge exclusions.

4.2.3 Map Wafer

This is similar to Run Recipe Alt. There is no recipe associate with the data. The engineer must enter all the important parameters. This is like a one of a kind data. This is useful for unknown wafer or doing R&D or engineering studies.

4.2.4 GainSet/1 pt Meas.

This is for doing one point measurement at the present probe position. In conjunction with the Probe Go To X Near 0 command in Operator's menu, this command allows the engineer to make a center point measurement on the wafer without using a recipe. If the sample is very small or irregular, the engineer can jog the probe to the correct position over the sample and do the measurement there.

This command prints out a sequence of how the system sets gain of amplifiers and chooses of the proper reference resistors for the measurements. These information also gives important diagnostic information.

4.2.5 Write Data File

This command allows the engineer to write data file from memory to the present subdirectory. This can be useful if he wishes to make a copy of data with a different name (like Save As), or he can do some data conversion using PostProcessing and then save the data on the hard drive. He can also reads in a data file from the hard drive and then save it to another drive such as a floppy disk or to a remote drive.

4.2.6 Calibrate

This command simplifies calibrations. Also the ResMap does not need frequent calibrations, however, making this simpler and foolproof is still welcome.

The calibration standards' information is stored in a disk file by using the Set Calibration Standards command. We normally stores a series of calibration resistor pack values.

Then when you execute the Calibrate command, you connect a particular standard and select it in the Measure recipe. The system will perform the measurement and list the results for all the internal reference resistors that applies. You then select the next standard and do likewise. Up to 6 standards can be used at one setting, which is more than enough to set all the reference resistors in the ResMap. After all the measurements are done. You next push the CalibrateCalculation button and the system with find the best values for all the internal reference resistors. This procedure is very fast and simple. These are demonstrated in the follow figures.

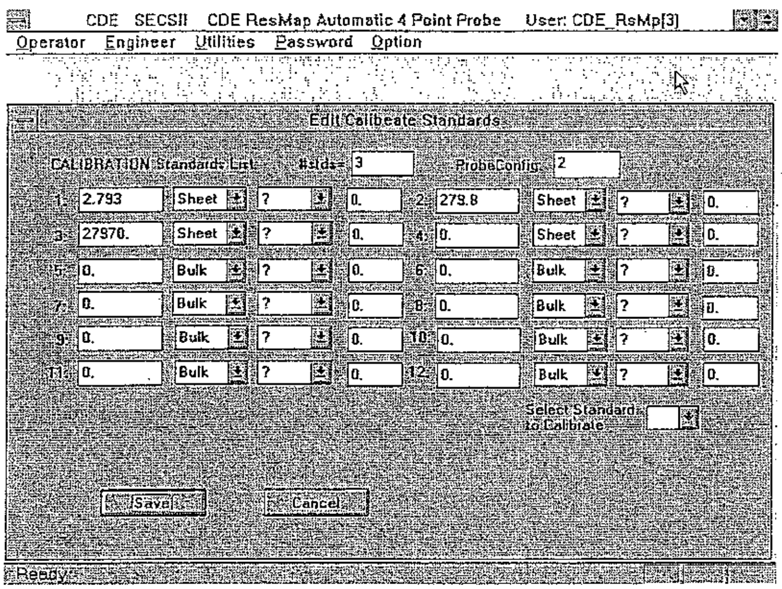


Fig 4.2.6.1: The Calibration Standards List

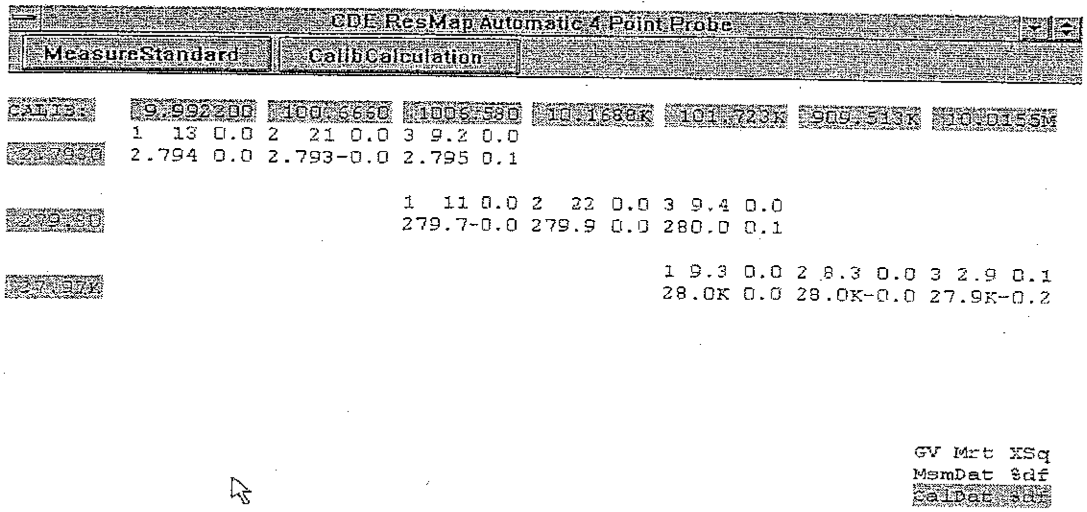


Fig 4.2.6.2 The Calibration Measurements:

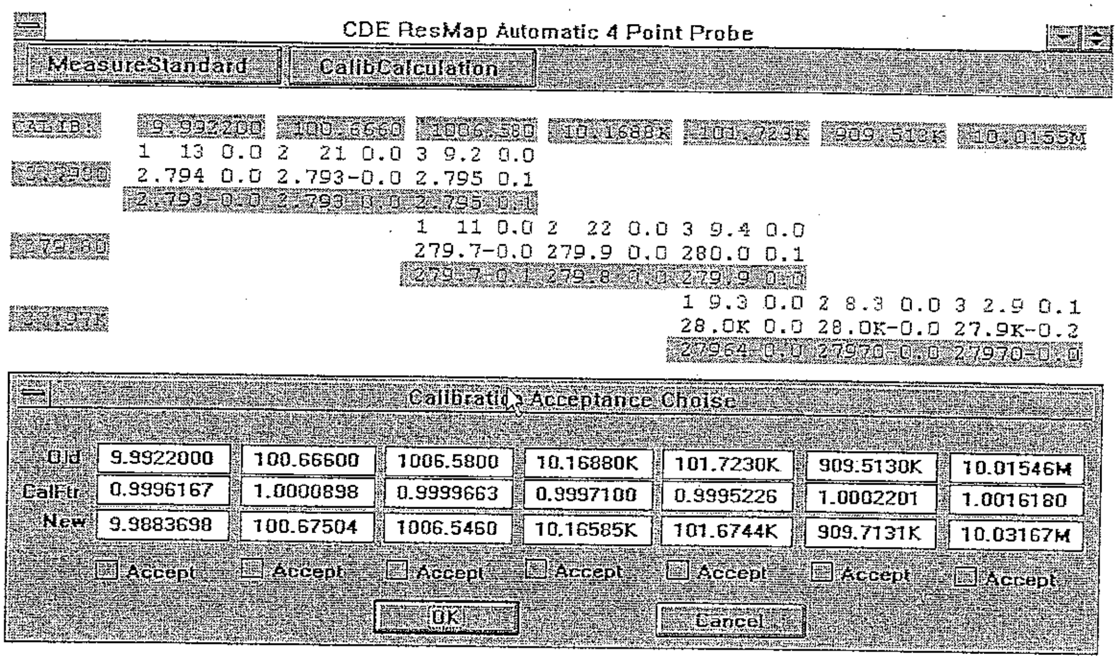


Fig 4.2.6.3 The Calibration results and recommended reference resistors settings

Here is the step by step procedure:

Step 0: **Setup** the Calibration **Standards** (Engineering + Set Calibration Standards), This is to be done only once for your standards, we do recommend calibrate with the Calibration Resistor Park (ResCal) supplied with your system. See Fig 4.2.6.1.

Step 1: Now your are ready to **calibrate**. Go to Engineer + Calibrate

Step 2: Select MeasureStandard and standard 1 (or other # you desire), pick OK and connect standard 1, OK and the software will measure standard #1

Step 3: Select other standards and repeat Step 2, until all the internal resistors on top of the screen has data below it, see Fig. 4.2.6.2.

Step 4: Now Press CalibCalculation button and the system will calculate the best calibration from the data and display the results in the dialog box. Now you can pick accept or not for each internal calibration resistor, afterwards, you can hit OK to save the newly calibrated results. See Fig 4.2.6.3.

4.2.7 Set Calibration Standards

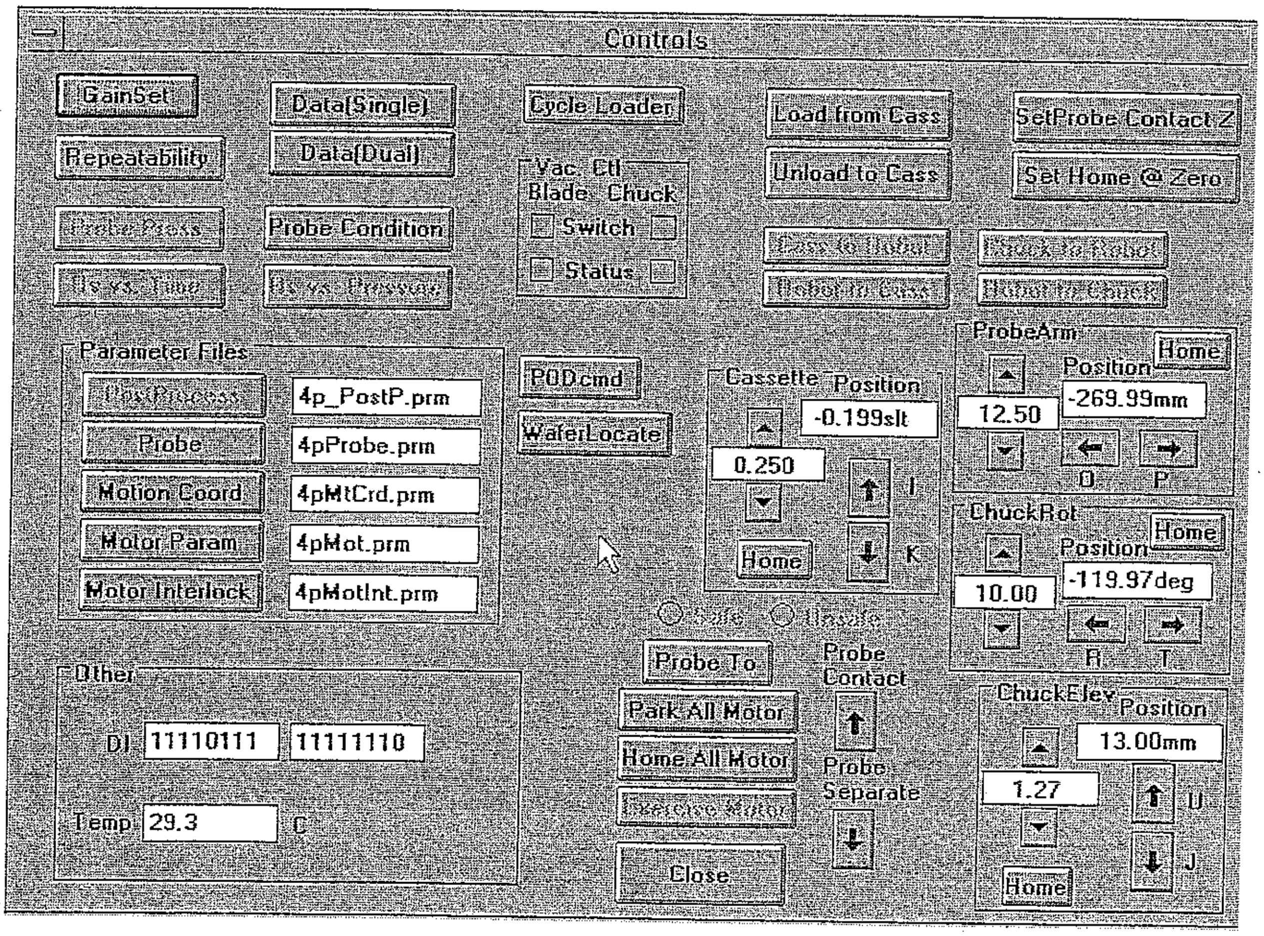
This is already described in the last section and a figure illustrating this screen is shown above.

5 SETUP / SERVICE / UTILITIES

In this chapter, we will show you the utilities you can use to setup and test the systems. Some of these commands can be dangerous for the untrained and the not in trained.

To access it requires a password logon level of 2 or above. Many of these commands are very low leveled and not much protections applies. Except for a few commands such as gain set, or set probe height, etc., to be on the safe side, it is much better if you will remove the probe for most of these commands. Since the only thing vulnerable and easily damaged is the probe. Most other components in the system is quite rugged and can stand a lot of abuse.

Following is the Control screen from Utilities Menu:



We shall explain these commands:

5.1 Motor Controls:

The motors used in ResMap are DC stepping motors, these motor are brushless, clean and very reliable. In ResMap, we use a user oriented coordinate system, such as, Chuck Height and Probe Arm position is expressed in mm. Chuck Rotation is expressed in degrees and Cassette Elevation is expressed in slot pitch. So the coordinate ≈ slot# - 1. This applies for 6", 8" or 12" wafers or any special cassettes.

The following tables summarize the stepping motors used in all CDE ResMap models.

A. CDE ResMap Motors using R-θ-Z coordinates -- for ResMap 178, 168, 268, 266, 273, 363, etc.:

motor #	name	Explanation	Jogging Cmd	(DOS)	(Windows)
0	ChuckElv	Moves Chuck up and down for Probe to Wafer Contact and wafer transfer, zero is when flush with (robot blade, only in Autoload models)	Chuck UP: Down:	PageUP PageDown	U J
1	ChuckRot	Rotates Chuck, zero is slot towards back and in direction of flat/notch	ClkWse: CntrClk:	Home Insert	T R
3	ProbeArm	The arm where the probe and robot blade (Autoload models) is mounted, zero is when probe is centered in chuck	Out: In:	Delete End	O P
4	CasElev	The Cassette elevator, For Autoload models only, zero is when robot blade just touch bottom of bottom wafer.	Cassette Up: Down:	↑ ↓	I K

B. For the ResMap 188, flat panel system which uses X-Y-Z coordinate:

motor #	name	Explanation	Jogging Cmd (DOS)	
0	Probe Z	Moves Probe up and down for Probe to Wafer Contact	Probe UP:	PageUP
			Down:	PageDown
1	Probe X	Moves Probe Left and Right	Probe Right:	←
			Left:	→
2	Probe Y	Moves Probe towards Back and towards Front	Probe Back:	↑
			Forward:	↓

5.1.1 Homing Commands:

When you first start ResMap program, it will prompt you about homing the motors. You can also home the motors at anytime with the appropriate Home Commands. When homing individual motors, see homing button for each motor in the control screen above. If the motor is previously homed, it will compare the new home position with the previous home position and it will print out the differences. This is an important check for motor performance, whether it has miss steps in between. If so, it indicated that the motors may be faulty. This features are used in many places to assure the motors are performing correctly. However when you home all the motors together, use Home All Motors button. The sequence typically assures safety, or no damage can be caused to the wafer probe or robot, etc.. In this case, it does not use previous homing information, typically this is used from a cold start or after a crash.

5.1.2 Jogging Commands:

These commands are for very intricate movements of the motor positions. They can be used to position the probes, align the arms, etc. The jogging commands are listed in the above tables. If you are positioning the arms, chuck, etc., make sure the motors are already homed. The jogged step size is displayed and you can change it by clicking the appropriate button (in DOS, you hit '>' to double the step size and '<' to half the step size on the last motor jogged).

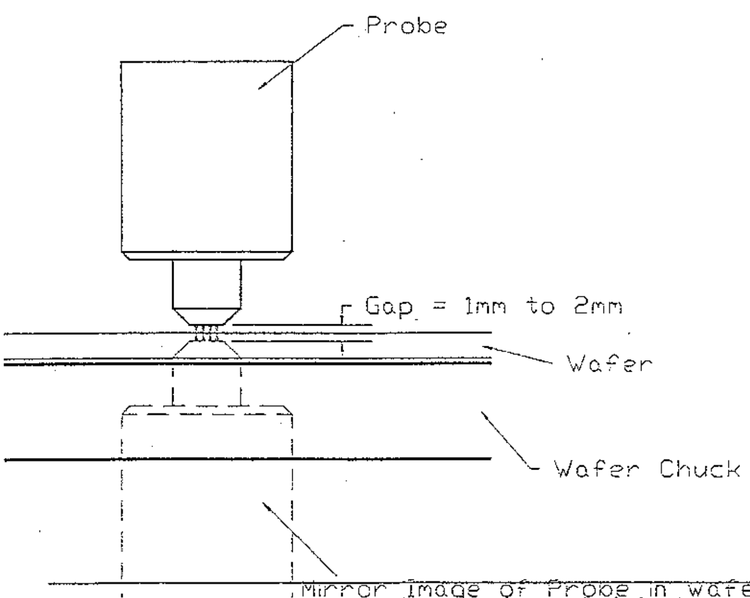
5.1.3 Setting Home Positions:

To set home position, you first make sure the motor is homed, jog the motor to the zero position. Then hit the "Set Home @ Zero" button (in DOS hit Alt+S in Motor command), select the motor that is set, and the system will change the Home Sensor coordinate to reflect the change of zero and update the affected parameter file.

For ChuckRot and ProbeArm motor, align the actuator hole to a corresponding hole in the base plate and hit "Set Home @ Zero" button. For ChuckElevation and Cassette ChuckElevation, set the robot blade to just rub the bottom of the wafer on chuck or bottom slot in cassette and hit "Set Home @ Zero" button to set. The "just rub" position can be easily determined by moving the robot blade in and out about 1/2" while raised and lowered the wafer slightly (<.2mm). You can determine the "just rub" position with great repeatability.

5.1.4 Setting the Probe Contact Position:

The probe contact position is set with a wafer (or sample) on the chuck, bring the probe to somewhere over the wafer and then jog the wafer up (or probe down) until the pins get compressed about 0.5 mm to 1.0 mm. Then click the "Set Probe Contact Z" button (Alt+U in DOS) to set the position. The compression is easily set with the aid of the following drawing, you need to set the Gap between the bottom of the probe body and its image



inside the wafer to be between 1 mm to 2 mm:

5.1.5 Probe Go To (R, θ) coordinate:

Use the "Probe To" command to move the probe to any position. It will automatically lower the chuck so there is no danger of damaging the probe. If the coordinates to go to is protect by the Motor Interlock parameters it will give you a warning message.

5.1.6 Park All Motors:

Use this command to move all the motors to its park position specified in the Motor Parameter file. The purpose is to restored the motor position after some setup command.

5.1.7 Home All Motors:

This command will home all the motors in a safe sequence. It is used after power off, crash or other interruptions. After each motor homed it will go to its park position specified in the Motor Parameter file. This command is also available in the Operators menu.

5.1.8 Load and Unload Wafers from Cassette:

Use the "Load from Cassette" and the "Unload to Cassette" commands to transfer wafer to and from cassette to wafer chuck. In DOS these commands are L=Load and U=Unload.

5.1.9 Cycle Loader:

This command allows you to cycle loader, i.e. Load and Unload wafer cycles. This is used for reliably of the loader test.

5.2 **Vacuum Control** (ResMap 168 and other autoload systems only):

The switch turns on and off the vacuum to the Wafer Chuck or the Robot Blade.

The status indicate whether the vacuum is held or released. If the is no wafer on the chuck, whether the vacuum is on or not, there will be no status for vacuum held. This is used to check the vacuum control operations as well as used by the system to check whether wafer is present on Chuck or Blade.

5.3 PODcmd:

This dialog box has commands that controls the POD for the SMIF systems such as ResMap 268-SMIF or the ResMap 266-SMIF systems. Its detail operation will be described later.

5.4 WaferLocate:

This dialog box contains commands that setup and execute commands for the Notch/Flat/Center finder standard on the ResMap 266-SMIF (6" SMIF), ResMap 268-SMIF (8" SMIF) and the ResMap 363 (12" Auto Load system). It detail operation will be described later.

5.5 Other Displays and Monitors:

5.5.1 DI: this 2x 8 displays the Digital input status of the sensors. In particular interest are the last 4 bits on the right, they are corresponding to the ChuckElv home sensor (last on right going left), ChuckRot home sensor, ProbeArm home sensor and CassElv home sensor. If the motor does not home correctly, one can check these displays.

5.5.2 Temp: This display the TC temperature reading for systems equipped with a temperature sensor. Otherwise, it will display 23°C at all times.

5.6 Probe Related Commands:

This commands are for checking probing, reading data, checking repeatability in measurements as well as conditioning the probe.

5.6.1 GainSet:

This is a very useful command for testing the film, the probe or the entire measurement system. It is also available in the Engineering menu as “GainSet/1ptMeas” command.

5.6.2 Data (Single) or Data (Dual)

These command are for measurement of the data with single probe configuration mode or dual probe configuration mode. These commands are also available inside the “GainSet” command.

5.6.3 Repeatability:

This command is for measurement of the probe repeatability, it is already described in the Operators’ menu.

5.6.4 Probe Condition:

This command is for conditioning the probe using a ceramic plate. It is already described in the Operators’ menu.

5.7 Parameter Files:

The ResMap system is governed by personal parameters. Such as how many motor steps per mm of travel for the Probe Arm. What are the internal calibrations for the Rs in different ranges. Where to pickup the first wafer in a give cassette. Where is zero coordinate for the chuck, etc. By using parameters stored in a file, one can use the same software for different systems. Moreover, one case use the same software for a range of different ResMap models.

These files can reside in 2 places.

1. Root directory of CDE ResMap, typically c:\4p
2. Local recipe subdirectry for a given recipe, e.g.

c:\4p\WCVD.prj\12in121p.rcp.

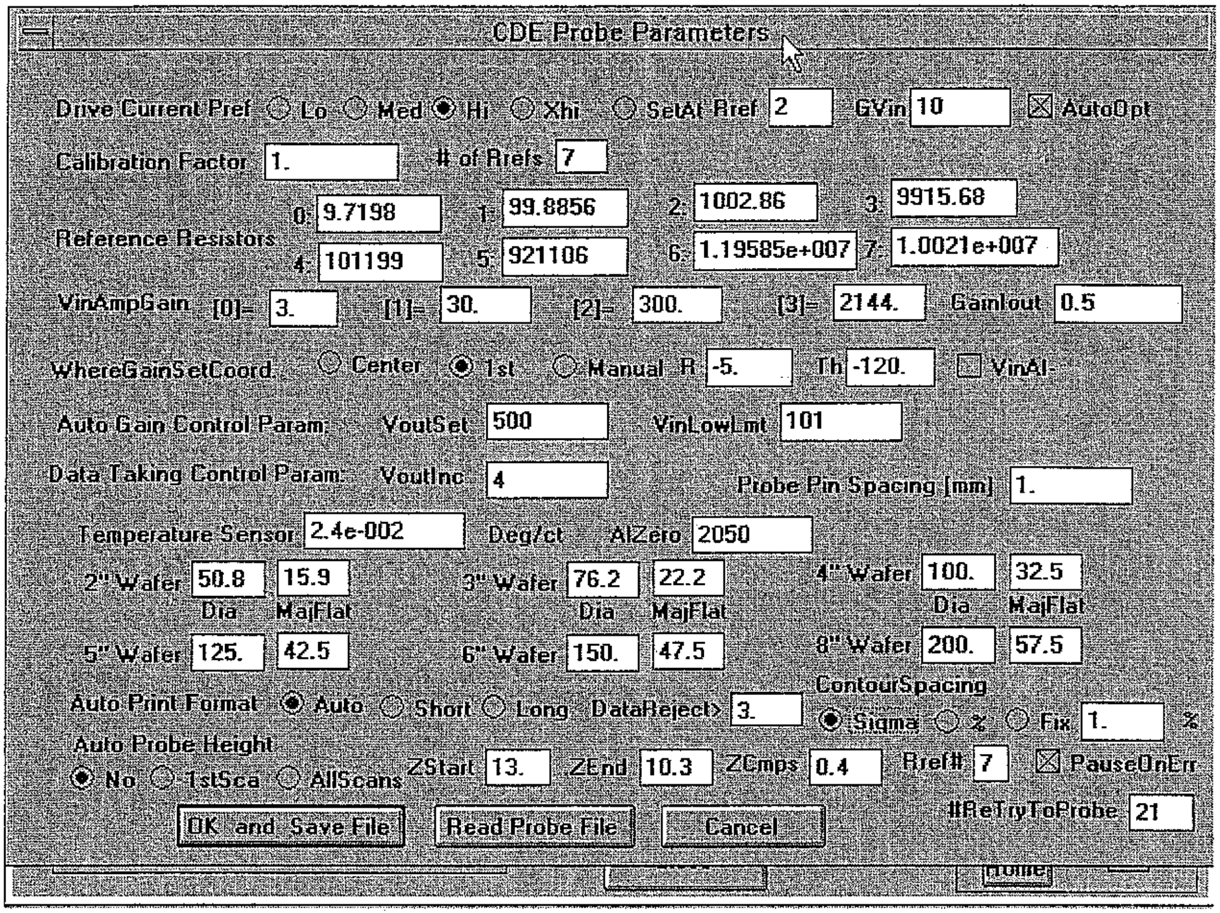
The are also specified in each recipe. For example, an 8 inch system will probable use an 8 in Motor and Motion parameter that may be different from a 6 in recipe. When a parameter file is stored in a local recipe subdirectory, the system will use that when the recipe is used to do the measurement. If the parameter file do not exist in the recipe subdirectory, then the system will search it in the ResMap root directory. These features greatly increase the system flexibility.

These files are summarized in the following table, the details will be listed individually:

Parameter	**Function**	**Default File Name**	**Variations Examples**
Probe	All Probing related parameters	4pProbe.prm	4pProbeX.prm -- for recipes with different calibrations
Motor	All lower level parameters for controlling the motors and home coordinates	4pMot.prm	4pMot6.prm, 4pMot8.prm or 4pMot12.prm for different cassette sizes.
Motion	All system related coordinates	4pMtCrd.prm	4pMtCrd6.prm for alignment, 4pMtThk.prm for different thickness samples.
Motor Interlock	Interlock parameters for each motor	4pMotInt.prm	Not used in recipe.

5.7.1 Probe Parameter Screen:

The following screen represents a typical probe parameter screen. It is activated by clicking the Probe button inside the Parameter File Box:



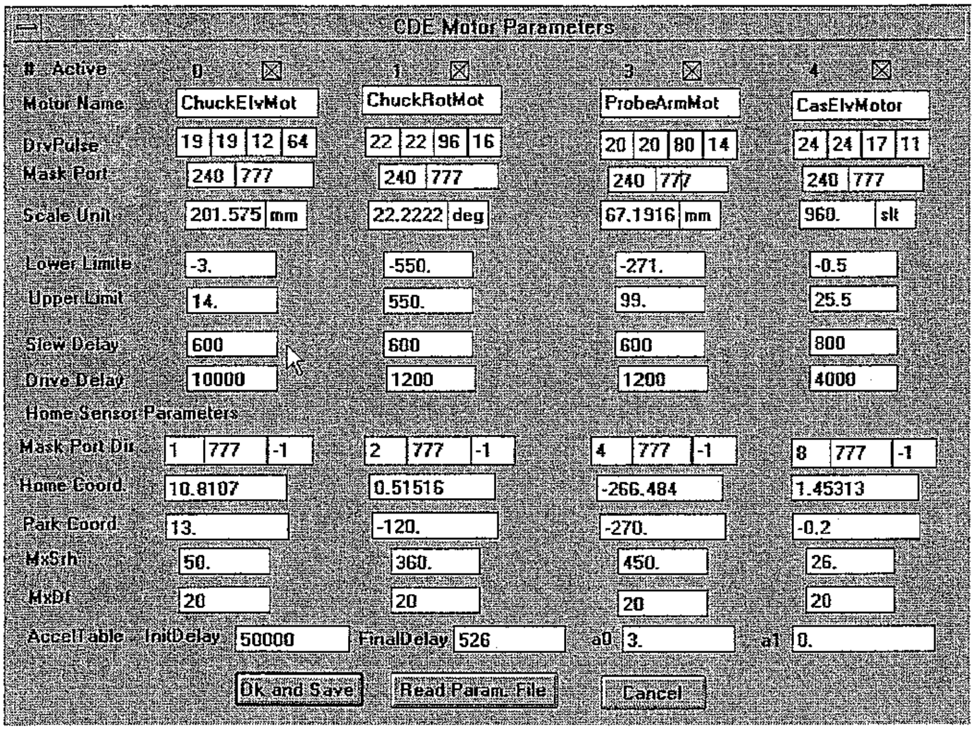
The following table summarize all the parameters and its functions:

Param	Type	Values	Typical	User Change?	Explanations
Drive Current Pref	Radio Button	Lo, Med, Hi, Xhi & SetAt	Hi	YES	For Drive current preferences and Manual set at specific Rref and GVin
SetAt Rref GVin	integer	Rref: 0 - 6 GVin: 0 - 3		YES	If the SetAt is selected in Drive Current Pref, then this is a manual setting

Calibration Factors	Real	0.1 to 10	1.0	YES	This is for force calibration to change all Rs measurement reading either Higher or Lower.
Reference Resistors	Real	10Ω, 100Ω, .. 10MΩ		NO	These are reference resistors used by ResMap for measurements, the values are set by Calibration commands.
VinAmp Gain	Real	3, 30, 300, 2000		NO	Set Amplifier chip compound gains
GainIout	Real	0.1 to 2	0.5	NO	Hardware related
WhereGain SetCoord	Radio Button	Center, 1st, Manual	1st	YES	Initialization coordinate for each wafer
R, Th	Real	coordinates		YES	for Manual GainSet coordinate
VinI-	Check			NO	Hardware related
AutoGain Control...	Integer		500, 101	NOT Recom.	VoutSet=AO setting for Gain set, VinLoLmt=Low Limit for valid Vin
VoutInc	Integer	2 to 8	4	NOT Recom.	For generate drive voltage sampling #AO counts to skip
Probe Pin Spacing	Real	.5 to 2 mm	1 mm	YES	Probe adjacent pin spacing.
Temperature Sensor	Real Integer	.0024 & 2048	same	NO	TC scale C°/AI_count, If no TC, then parameter <0, offset of AI
Wafers	Real			YES	Semi or special wafer diameters and flat size
Auto Print Format	Radio			YES	Print format for AutoPrint -- choice of Auto, Short and Long
DataReject	Real	2 to 10	3	YES	Data Reject if variation is outside
Contour Spacing	Radio		Sigma	YES	Sigma = 1/3 sigma spacing, %=auto in %, and Fix%
AutoProbe Height	Real			YES	No=manual probe height set with SetProbeContactZ, 1stSite=auto set on 1st site, AllSites=Auto set on all sites Zstart=start scan posn typ. = ZChkSeparate, Zend=end scan typ. = ZChkContact-1, Zcmps = amt pin compression, Rref# = Rref to set to use for current sense contact
#RetryTo Probe	Integer	1 to 21	5	YES	# times to retry probing for a bad site.

5.7.2 Motor Parameter Screen:

The following screen represents a typical motor parameter screen. It is activated by clicking the "Motor Param" button inside the Parameter File Box, this screen contains all hardware level parameters for the motors and home sensors:



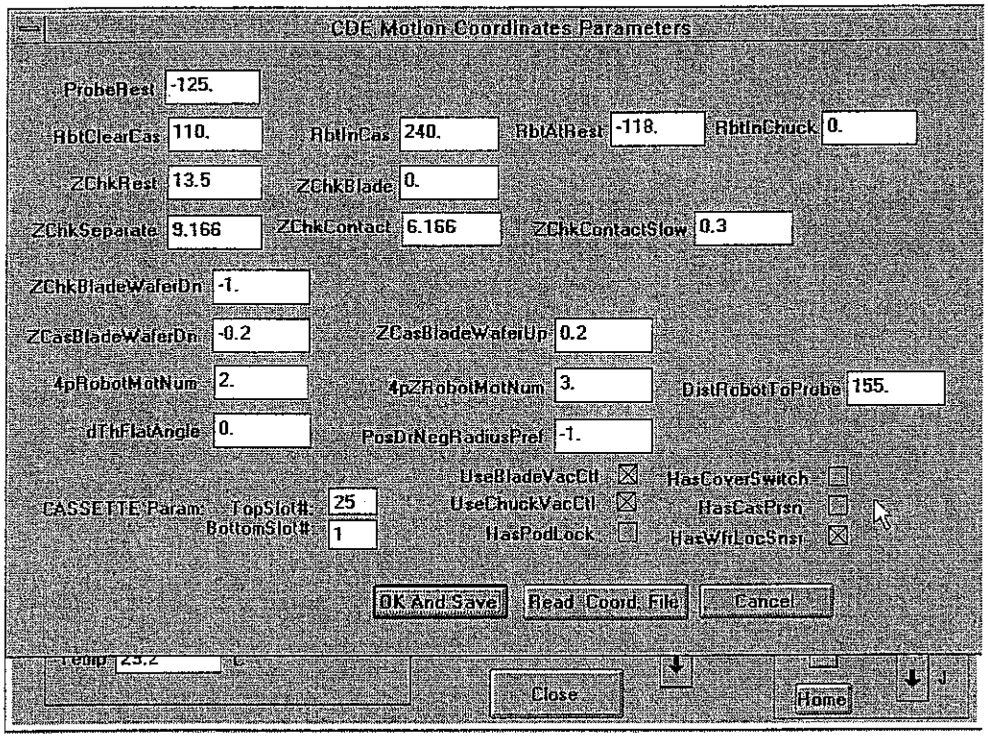
In this screen, we have 4 motors plus acceleration parameters. The parameters for each motors have the same meanings. So we will describe them together whenever applicable. The following table summarize all the parameters and its functions:

Param	Type	Values	Typical	User Change?	Explanations
# Active	Check			NO	Active = motor in use. so for ResMap 178, CasElvMotr is not in use.
MotorName	Chars			NO	Names for each motor
DrvPulse	integer			NO	Hardware motor drive pulse byte format, do not change
Mask / Port	integer			NO	Hardware motor drive parameters, do not change

Scale / Unit	Real / chars			NO	The # of motor step units / unit of motion, e.g. Chuck Rotation motor is geared at 22.2222 steps per degree. Note also the CasElv motor unit is in slot pitch
Lower / Upper Limit	real			YES	The range of legal motion for each motors
Slew / Drive Delay	integer			YES	Delay in CPU counts per step of motor, the larger the number, the slower motor drives. Slew = fastest speed from point to point, Drive = slow movements, such as soft touch of probe, cassette index just before wafer is removed or inserted.
Home: Mask / port	integer			NO	Hardware and electrical connections for each home sensor
Dir	int	-1 and 1		NO	For homing direction
Home Coord	real			YES	set by Set Home @ Zero commands
Park Coord	real			YES	Parking coord. for each motor, for CheckElv, and ProbeArm motors, it must be between Home and Upper Limit.
MxSrh.	real			YES	Max distance to search for home before it complains, for motor hardware checks
MxDf	integer		20	YES	Max difference of new home coord to previous home in motor steps to complain that there is problem with homing
Accel Table, InitDelay	integer	20000 to 65000		YES	This is the initial motor delay for acceleration, Depends on CPU speed,
FinalDelay	integer			NO	Set by system based on a0
a0	real	.1 to 3	1.2	YES	Acceleration parameter, larger means faster ramps
a1	real		0	NO	Not used

5.7.3 Motion Coordinates Parameter Screen:

The following screen represents a typical motion coordinate parameter screen. It is activated by clicking the "Motion Coord" button inside the Parameter File Box, this screen contains all system coordinates used by ResMap:



We have added a virtual motor which is the Robot coordinate (Mot #2). Since the system is integrated, both the Robot and the Probe shares the same drive. So the

Robot coord = Probe coord + DistRobotToProbe,

zero is when mark on Robot Blade is centered on the Wafer Chuck. The following table summarize all the parameters and its functions:

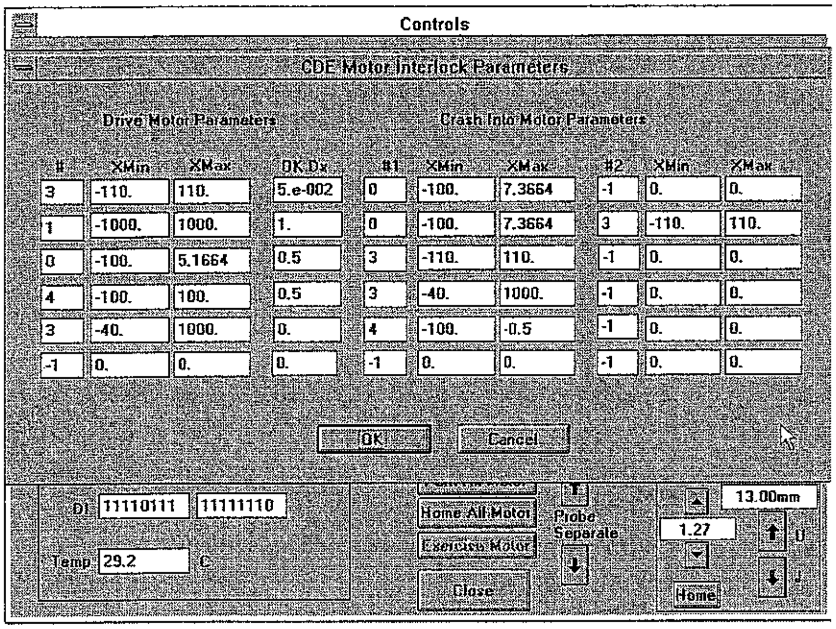
Param	Type	Values	Typical	User Change?	Explanations
ProbeRest	real		-125	YES	Probe arm position for probe rest during wafer transfers
RbtClearCas	real		110	YES	Robot Coord outside the cassette so the cassette is save to index.
RbtInCas	real		240	YES	Robot coord to pickup wafer in cassette, Smaller RbtInCas has the effect of loading wafer on chuck toward front.

RbtAtRest	real		-118	YES	Robot position where the wafer chuck can index. Should set = ProbePark + DistRobotToProbe.
RbtInChuck	real		0	NO	Position where wafer is deposited in Wafer Chuck
ZChkRest	real		= Chk Park	YES	Chuck Z coord to clear Robot movement
ZChkBalde	real		0	NO	Chuck Z for load/unload wafer from check
ZChk Separate	real		10	YES	Chuck Z for probe separate from wafer, set by SetProbeContactZ command
ZChk Contact	real		7	YES	Chuck Z coordinate for probe in contact for measurement, set by SetProbeContactZ command
ZChk Contact Slow	real	0 to 1	0.5	YES	Chuck Z last dist before contact for soft touch
ZChkBlade WaferDn	real	0 to -3	-1	YES	Distance robot blade below wafer chuck to pickup wafer or remove after drop off
ZCasBlade WaferDn	real	-.1 to -.5	-.2	YES	Distance below wafer bottom in cassette for robot to insert or withdraw empty blade
ZCasBlade WaferUp	real	.1 to .5	.3	YES	Distance above wafer bottom in cassette for robot to insert or withdraw wafer on blade
4pRobot MotNum	real	2	2	NO	Robot Coordinate Motor #, tie to Probe Arm Motor
4p2Robot MotNum	real	3	3	NO	Robot Coordinate Motor # two, same as Probe Arm Motor
DistRobot ToProbe	real		155	YES	Distance from center of Robot Center to Probe Center
dThFlat Angle	real	-180 to 180	0	YES	Angle of wafer flat/notch on chuck, 0 = flat/notch away from slot
PosOrNeg RadiusPref	int	-1 or 1	-1	YES	Preference of mapping radius for Area Mapping, note: $(R, \theta) = (-R, \theta+180)$
CASSETTE Param, Top, BottSlot#	int	Top=25 or 1 Bott=1 or 26 or 25	25 1	YES	For numbering wafer # in cassette, most cases bottom slot#=1, top#=25

UseBlade VacCtl	check box			YES	System has robot blade vacuum control valve, for autoload systems
UseChuck VacCtl	check box			YES	System has wafer chuck vacuum control valve, for autoload systems
Has Cover Switch	check box			YES	System has cover switch sensor, only very few made
HasCasPrsn	check box			YES	System has Cass Presence Switch, for SMIF systems
HasPodLock	check box			YES	System has POD locking mechanism, for SMIF systems
HasWfrLoc Snsr	check box			YES	System has wafer on chuck locating (flat/notch/center) sensor.

5.7.4 Motor Interlock Parameter Screen:

The following screen represents a typical motor interlock parameter screen. It is activated by clicking the "Motor Interlock" button inside the Parameter File Box, this screen contains all system coordinate interlock (forbidden areas) used by ResMap:



The above screen table consists of two regions: **Drive Motor Parameters**, this is the motor being driven, it then checks if it is inside the range **XMin** and **XMax**, if so, it checks up to two other motors in the **Crash Into Motors**'s range (**XMin** to **XMax**). If the any crash into motor is in its range, then the Drive motor can only move a maximum small amounts specified by **OK Dx**. If more, it will display an error message. The motor numbers are 0 to 4 for valid motors specified in table in 5.1, and Motor # = -1 means no motor is specified. Only 6 Interlock conditions are allowed.

For example, line 1 says the arm (motor #3) cannot move more than 0.05mm if it were in the range -110mm to 110mm (over chuck) and if the chuck is in the range -100 mm and 7.2664 mm (to high and may crash).

Another example, line 2 says the chuck cannot rotate (motor #1) anywhere by more than 1.0-deg if the chuck is too high and the arm is over the chuck.

6 Maintenance

There is no regular maintenance [PM] or lubrication requirements for the ResMap system, due to the simplicity and robust design.

The following is a guide to common sense guide to do's:

1. After wafer broke, clean up debris, vacuum all exposed surfaces from broken wafers, especially below the chuck, you may want to remove the chuck to perform this.
   After lots of breakage, the X-Arm lead screw may be coated by Silicon dust and prevent smooth operation, in this case, you need to remove the skins, and clean the lead screw with IPA and then put a coat of light oil on the shaft.
2. Clean the wafer chuck and the robot blade with IPA or DI water once per week.
3. Condition probe once per week or when the merit dropped by 1/2X from nominal values. Do not over condition the probe.

7 Trouble Shooting

We will divide the trouble shooting into Motor Drive Control System, the Pneumatic Control System and the Probe Control System.

7.1 Motor Drive Control System:

Motor and Home Sensors:
There are 4 motors and corresponding home sensors for the Auto Cassette load ResMaps (168, 266-SMIF, 268-SMIF, 363, 463 and 463-FOUP) models, there are only 3 for the manual load systems such as ResMap 178, 188 and 273.
In Appendix A, we have shown the connection and schematic diagram for these components.
The motors are driven by pulses from the computer connected to the P4 Motor Drive connector of the ResCtrl [CDE ResMap Interface Board] board. The drive cable is split into 4X 3-pin MTA connectors, We call it Motor 0 ['Z' or Chuck Elevation Motor], Motor 1 ['θ' or Chuck Rotation Motor], Motor 3 ['X' or Probe Arm and Robot Motor] and Motor 4 ['C' or Cassette Elevation Motor]. Note, there is no Motor 2 [this got RIFed when we did a simplification of the system], and note also the Motor 4 only applies to auto cassette load systems. For each motor, there associated a home sensor, we use a CDE Proprietary optical interrupting sensor integrated to a 3 pin MTA connector connected to P3 LimSw connector of the ResCtrl board. The home sensor has same name as the corresponding motors. Typically, these home sensors are located near one end of the axis travel (exception for rotation, which has no end!). For example, Z-axis, the home sensor is located near the bottom, the X-axis, near back end, the C-axis, near top end.
The connector connects to the home sensor is connected to one bit of the DI-1 byte, please see the Controls screen on page 5., the 2X DI's are located in the 'Other' box at the lower left corner of the screen. These 2 bytes are DI-0 and DI-1. The last 4 bits in DI-1 are: C-motor home sensor, bit 3, [bit $7 = 2^7$ is the MSB, and bit $0 = 2^0$ is the LSB]; X-motor, bit 2; θ-motor, bit 1 and Z-motor, bit 0. The bits shows a '1' when the sensor is blocked or disconnected, a '0' when the sensor is un-blocked. You can try blocking and unblocking each sensor with a key or screw driver or with the axis flags and observe the effect.

They must respond correctly or else the motor will not home correctly. If one sensor does not respond correctly, you can connect the sensor connector to another sensor to check whether the sensor is functioning or not. If the sensor is OK, then you should trace the cabling by check conductivity all the way to the AIODIO board in the computer. If everything is still OK, then replace U10 - 74LS244 on the AIODIO board.

Similarly, it the motor does not rotate when jogged, or only rotate in one direction, then interchange the connectors to the drive amplifier board, interchange the motor to the drive amplifier board the verify whether the motor or drive amplifier is faulty. If neither, then check the connecting cable for continuity. Also the following chips are responsible for the motor drive: On the ResCtrl board: U1-74LS138 and U2 & U3-74HC02; Also on the board, U11-74LS374. You can replace these IC's to isolate the problem.

7.2 Pneumatic Control System

All pneumatic controls utilizing a solenoid valve (Clippard EV-3M-24-H for vacuum and EV-3M-24 for compressed air). Controlled by a drive IC, U15, on the ResCtrl board. Each drive has a LED to indicate its activation and controlled by a button on the Control screen. The sensors are divided into 2 types, Vacuum sensors for Chuck and Blade Vacuum and micro-switch sensors for all the end position sensors when the vacuum or compressed is applied to air cylinders.

7.2.1 Chuck and Blade Vacuum Controls and Vacuum Sensors:

These controls includes vacuum solenoid valves controlling vacuum directly connected by tubing to the Chuck or Blade. Then the Vacuum sensors U19 ad U18 are connected directly to Chuck and Blade via tubing's. When there is a wafer and the vacuum control is turned on, the sensor will activate and the corresponding LED will be turned on. See also the Vac. Ctl block in the Control screen. The vacuum sensor threshold should be adjusted as follows:

When there is no wafer on the Chuck (or Blade), turn on the corresponding vacuum control, the drive LED should be on and the sense LED should be off. Adjust the Pot [R27 or R32] near the sensor counter-clockwise until the sense LED just turned on, then turn back [CW] 5 turns. You can check with a wafer on the Chuck (or Blade), now turn on and off the vacuum solenoid, the sense LED should be turned on or off in response.

7.2.2 All other Pneumatic Controls:
These control all use an air cylinder actuator such as SMIF POD door open or close, Pop Chuck Up or Down, Probe Changer A or B, FOUP slide, FOUP Door Lock and FOUP Door Open/Close controls, etc. All these controls has micro-switch position sensors to sense the One End or the Other End position of the air cylinder actuator. All IO bits will be listed in following table.

7.3 Probe Control System:

If the probing gives error, first thing to check is where there are any broken pins on the probe. You should see all 4 pins on the probe. If not, replace probe.

Next, check whether the probe is contacting wafer properly. See Fig on 5.1.4 Setting the Probe Contact Position for proper probe pin compression during mapping. If the probes are not compressed enough, most likely the probe has slide up in it holder from multiple probing when tend to push the probe upwards if it is not tightened correctly. Loosing the probe mount, push the probe down and tighten the lock screw.

If still no luck, blame on the wafer! Most likely, the wafer may not conduct, either it is not coated with conductive layer or it has insulating layers such as oxide on the surface. Sometimes condition the probe may help, because it may have accumulated debris on the tip of the pins and made it not a good contact to wafer. You can also replace probe to check this.

Now, if all fails, then, next step it to place the Calibration Resistor Pack (ResCal) and measure that. If it measures correctly, then the problem is between the ResAmp board and the wafer, and it should be easy to find the problem. If it still does not work, check the cable connectivity between the ResAmp and ResCtrl board and the Cable between ResCtrl and AIODIO board. If this still fails, call us at CDE or CDE's local service technician.

We still have a few tricks before we need to replace the boards. You can also print a copy of the gain screen and fax to CDE for factory diagnostics.

7.4 Following are Bit and Channel assignment for all ResMap IO's:

Device	Ch #	pin #'s	Function	Polarity
AO [analog output]	0	J1-4	Vout drive	
AI [analog input]	0	20,19	Iout sense	
	1	18,17	Vin sense	
	6	08,07	TC	
	3	16,16	Notch/Flat/Center Detector	
DO-0 [digital output]	0,1	44,43	Vin Sensor Gain	
	2	42	Probe Select	H=A, L=B
	3,4,5	41,40,39	Rsens Select	
	6	38	Probe Select	H = B
	7	37	Pop chuck	H = Up
DO-1 [digital output]	0	54	Blade Vac	H = On
	1	53	Chuck Vac	H = On
	2	52	Pod Lock Close	
	3	51	Pod Lock Open	
	4,5	50,49	Motor Select	
	6	48	Motor CW Pulse	
	7	47	Motor CCW Pulse	
DI-0 [digital input]	0	34	Blade Vac	
	1	33	Chuck Vac	
	2	32	Pop Chuck Down	L = On
	4	30	Pop Chuck Up	
	5	29	Probe A Select	
	6	28	Probe B Select	

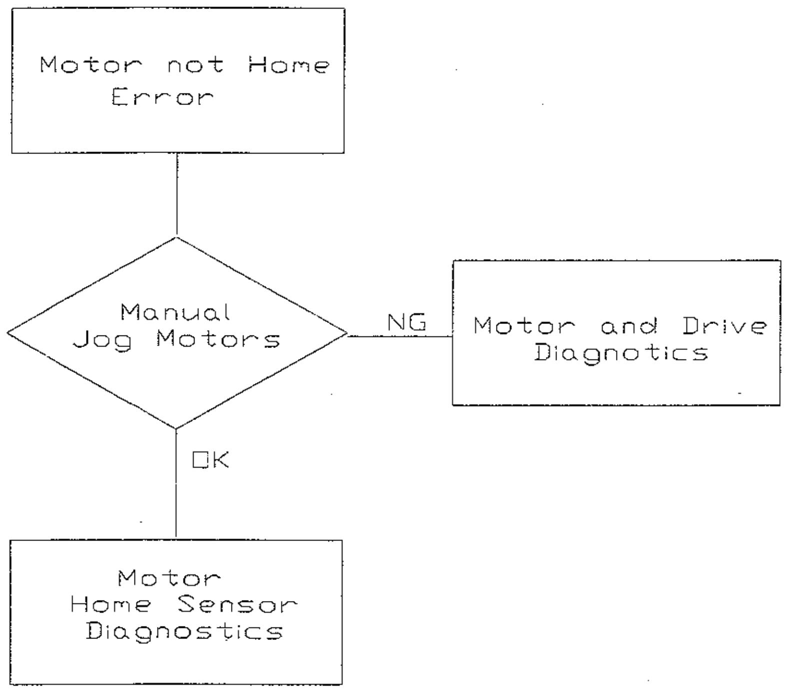
DI-1 [digital input]	0	64	Chuck Elv Home	
	1	63	Chuck Rot Home	
	2	62	Probe Arm Home	
	3	61	Cassette Elv Home	
	4	60	Cover Open	Open = L
	5	59	POD/CAS/FOUP Present	L = Yes
	6	58	POD/FOUP Lock Open	
	7	57	POD/FOUP Lock Closed	
DO-3 [digital output]	0	J101-30	FOUP Slide Out/In	
	1	29	FOUP Door Lock/Unlock	
	2	28	FOUP Door Open/Closed	
DI-2 [digital input]	0	10	FOUP Slide Out	
	1	09	FOUP Slide In	
	2	08	FOUP Door Locked	
	3	07	FOUP Door Unlocked	
	4	06	FOUP Door Closed	
	5	05	FOUP Door Open	

7.5 Diagnostics Flow Charts

Following are flow charts for the various diagnostics described above;

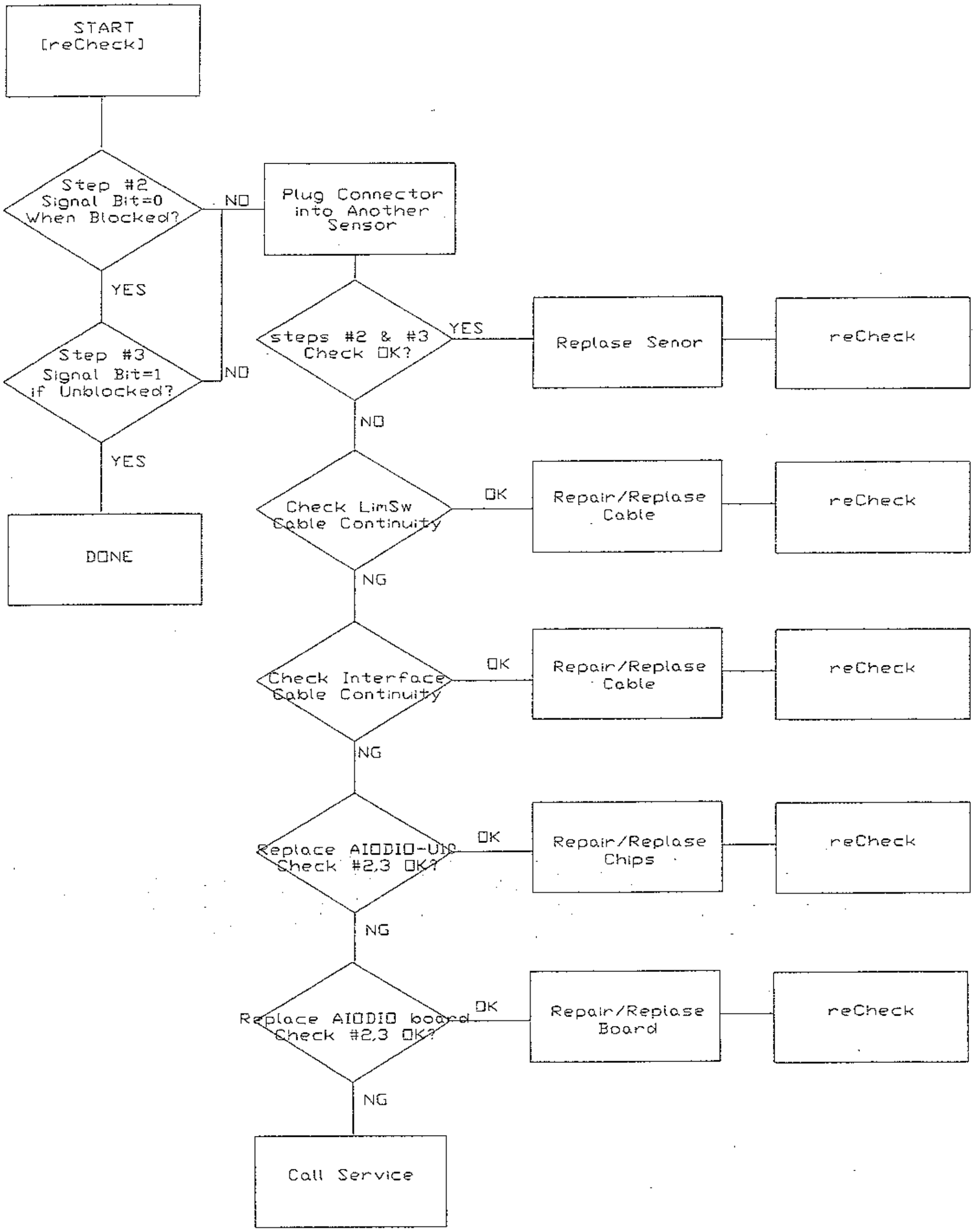
7.5.1 Motor Drivers and Home Sensors

When you get Motor cannot Home error message, determine which is at fault:



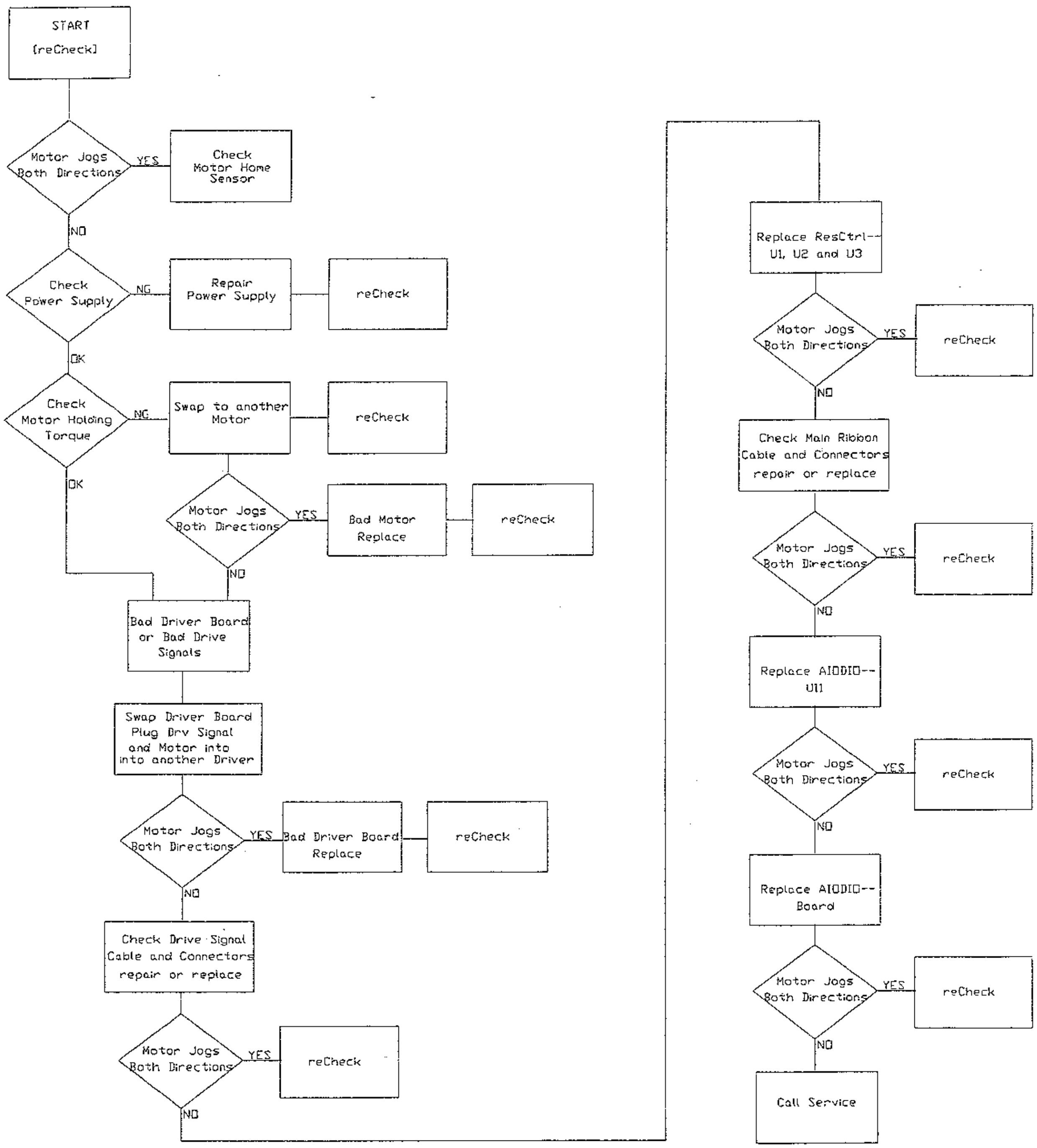
7.5.1.1 Home Sensors

For Home Sensor error, use following flow chart:



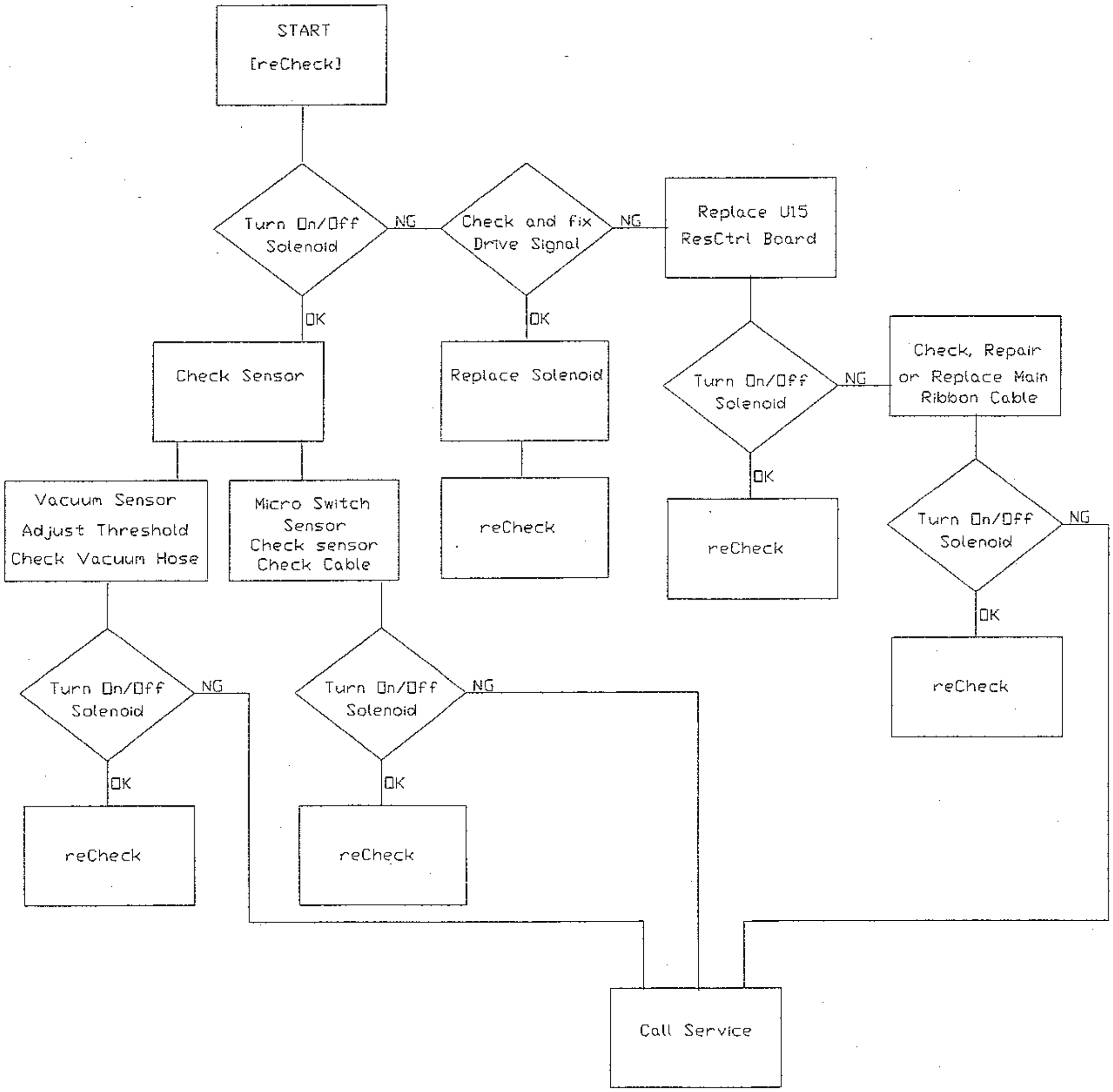
7.5.1.2 Motor and Motor Drivers

For Motor/Driver Error, follow the flow chart below:



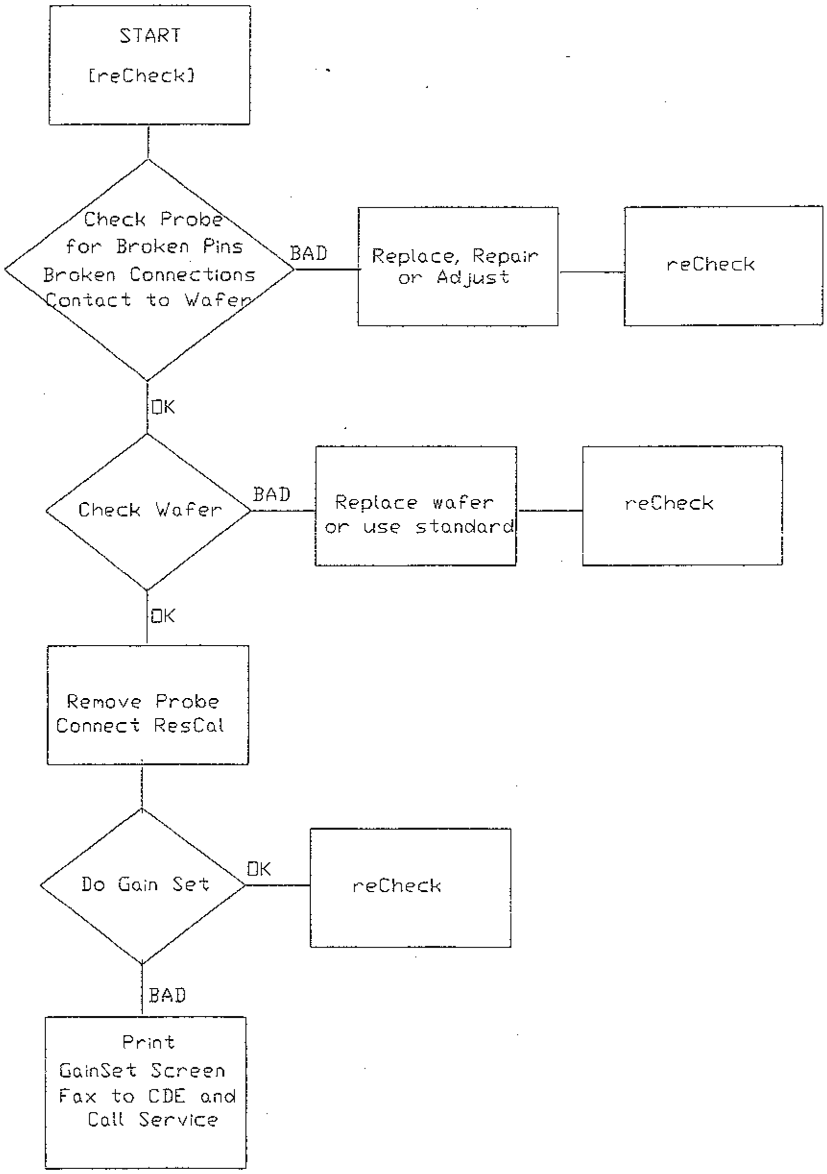
7.5.2 Pneumatic Controls and Sensors

For Pneumatic Control and Sensors, check out:



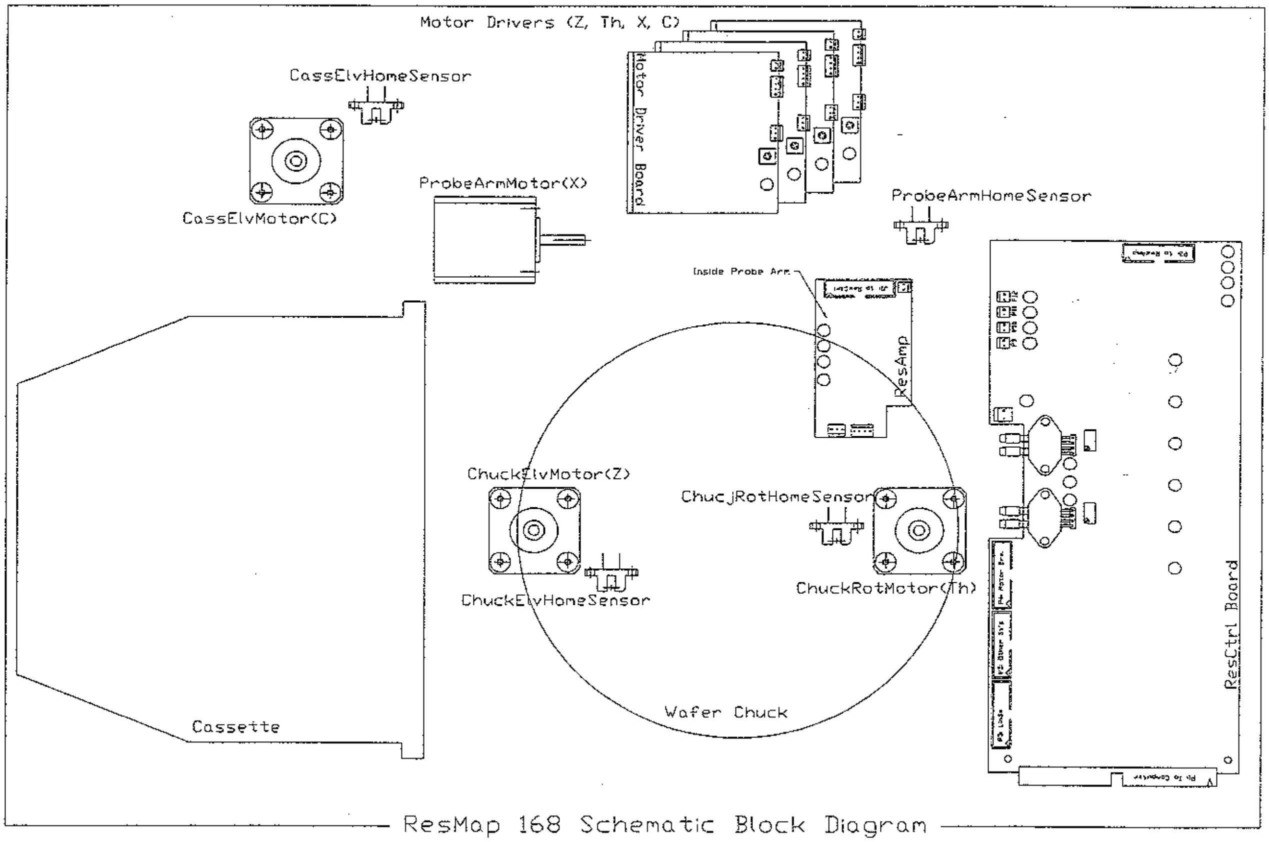
7.5.3 Probing System

For Probing errors:



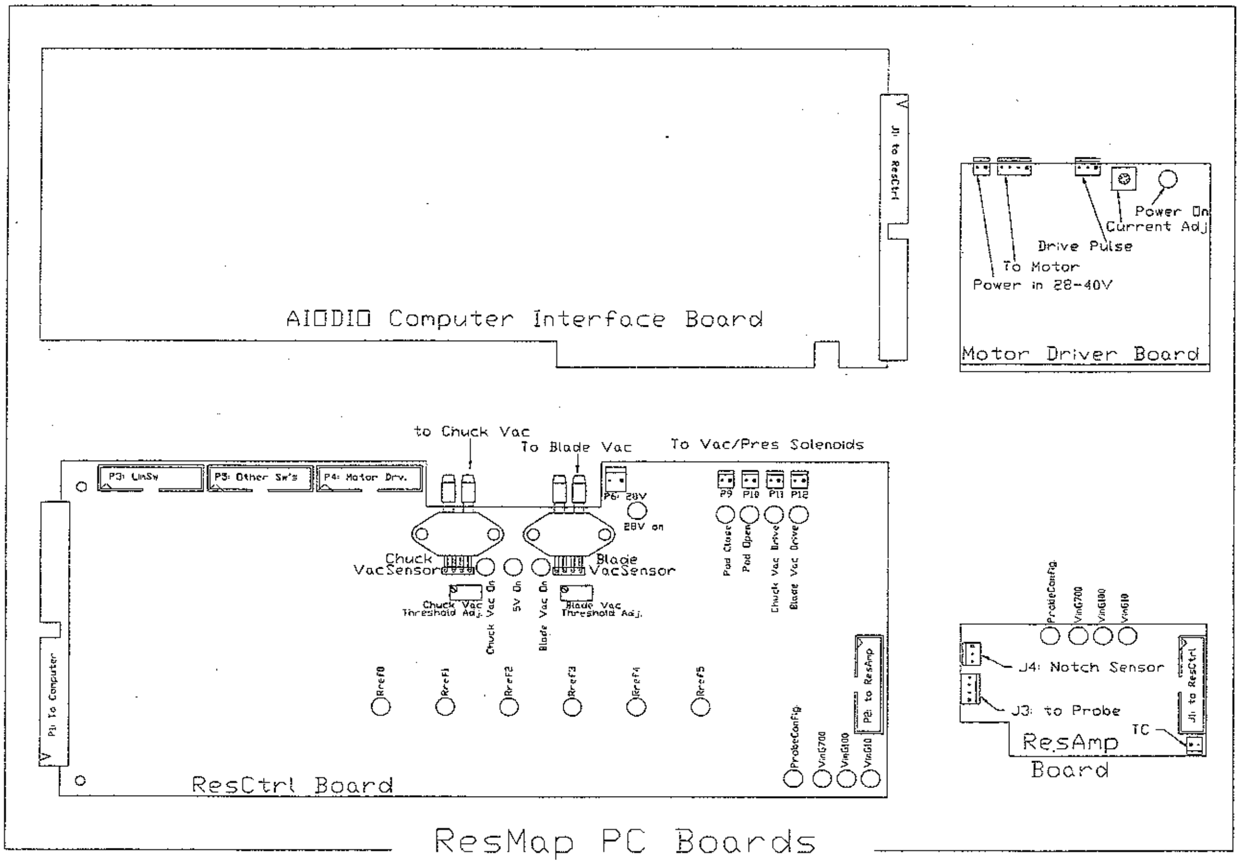
Appendix A: Electrical Block Diagram

Following is a schematic block diagram of the PC boards and other components used in CDE ResMap 168 system, the other ResMap systems are very similar and the differences will be summarized in the tables following.

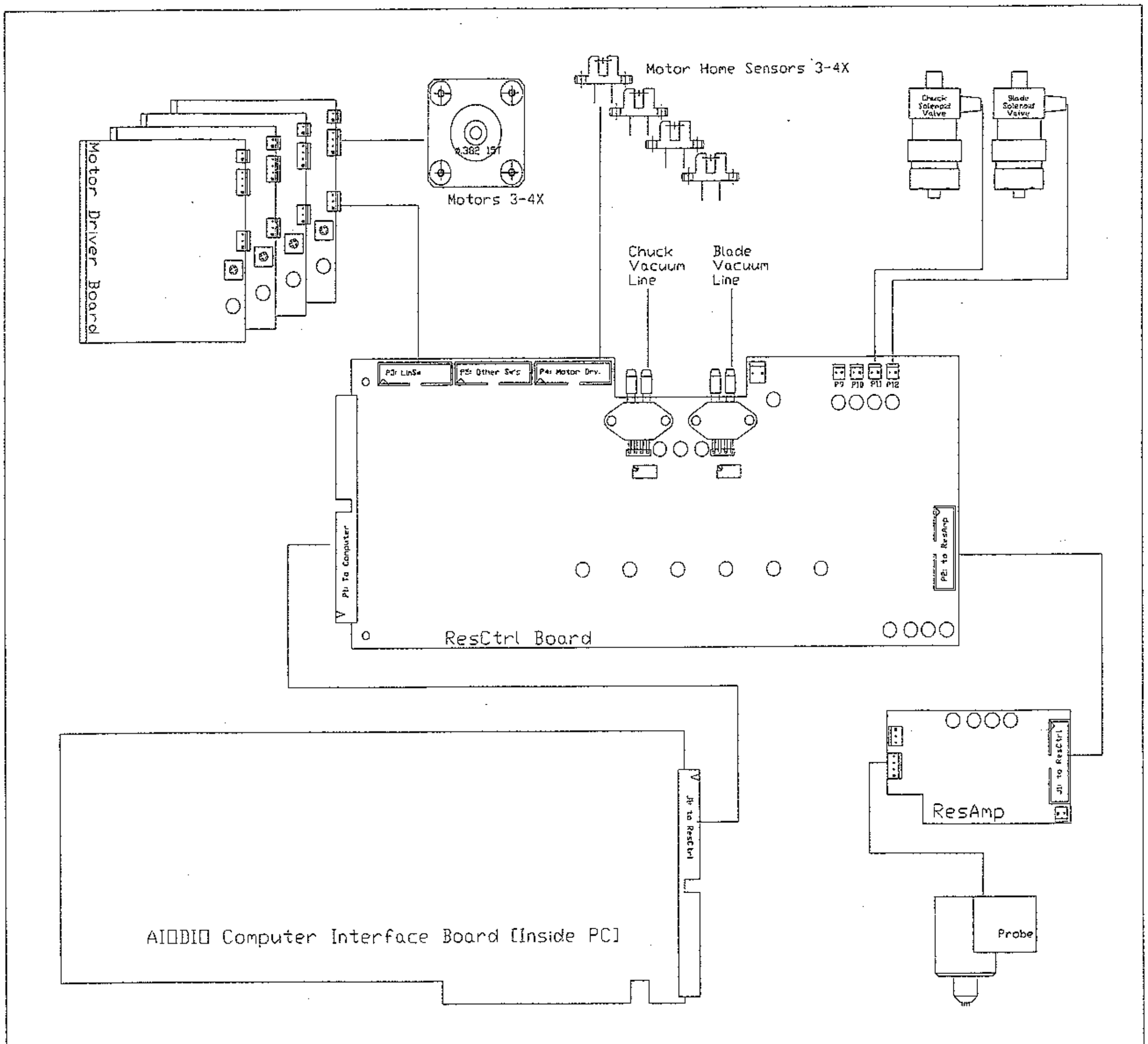


ResMap 168 Schematic Block Diagram

Following is a layout block diagram of the PC boards from the above schematic.



These boards and other components are interconnected as follows:



ResMap Board Connections

Their usage for various components in the various ResMap models will be summarized:

Model	System Description	AIODIO Board	ResCtrl Board	ResAmp Board	Motors, Home Sensors & Drivers	Solenoids	Notch / Flat Finder
ResMap 168	4"-8" Auto Load	Yes	Yes	Yes	4 = Z,θ,X,C	2 = Blade & Chuck Vac	Optional
ResMap 178	2" - 8" Manual Load	Yes	Yes	Yes	3 = Z,θ,X	0	No
ResMap 188	600mm x 800mm Flat Panel	Yes	Yes	Yes	3 = X,Y,Z	0	No
ResMap 268/266-SMIF	8"/6" SMIF	Yes	Yes	Yes	4 = Z,θ,X,C	2 = Blade & Chuck Vac 2 = Pod Open Close Air	Standard
ResMap 273	3" - 12" Manual Load	Yes	Yes	Yes	3 = Z,θ,X		No
ResMap 363	12", 8" & 6" Auto Load	Yes	Yes	Yes	4 = Z,θ,X,C	2 = Blade & Chuck Vac	Standard

The Connections of these boards to other boards and components will be summarized:

Board	Connector	Type	Cable	Connect To
AIODIO	J1	IDC64	64-wire Ribbon cable	ResCtrl: P1[IDC64]
ResCtrl	P3	IDC20	LimSw = 20-wire ribbon cable	Limit Switches
	P4	IDC20	Motor = 20-wire ribbon cable	Motor Drivers Drive Pulse P1B [MTA3]
	P5	IDC20	20-wire ribbon cable	Cass Presence and POD Lock Sensor
	P2	IDC20	20-wire ribbon cable	ResAmp: J1[IDC20]
	P11	MTA2	Chuck Vac Solenoid Valve	
	P12	MTA2	Blade Vac Solenoid Valve	
	P9	MTA2	POD Close Compress Air Solenoid Valve	
	P10	MTA2	POD Open Compress Air Solenoid Valve	
	Chuck Vac Sensor		1/8" ID Tubing, to Chuck	
	Blade Vac Sensor		3/32" ID Tubing, to Blade	
	J3	MTA4	4 point Probe	
	J4	MTA3	Notch/Flat Finder Module	
	TC	MTA2	Thermal Couple	
Motor Driver	P3A	MTA2	DC Power In: 28V - 40V DC power supply	
	P2A	MTA4	Stepper Motors	

Appendix B: **Rigorous System Robot Alignment** 15 October 1977

Following is a rigorous alignment procedure for the ResMap 168/268/363/463/468 wafer-handling robot. Normally, the procedure is needed to be performed only once in the factory. The only reason it might be checked in the field is after a crash and the robot blade is bent. Go to the Utility | Control screen (in DOS: Utility | Motor and Home Utility) screen, home all motors. Remove the probe and carefully cap it and put it in the accessory box.

1. **Blade Parallel to Chuck:**

   1.1. Move Blade to X = –150 for ResMap 168/268; X = –190 for ResMap 363, (=Blade Length in Motion Coordinate Screen), so that the center of the Blade is at the center of the Chuck.

   1.2. Place a wafer on Blade centered over the Chuck, the wafer should be next size smaller than the Chuck, e.g. 6" wafer over an 8" Chuck, or 8" wafer over a 12" Chuck. Turn on Blade vacuum, the wafer should be tightly held and hard to move by hand.

   1.3. Check front and back distance from the wafer edge to the Chuck, it should be within 0.5mm, if not then bent the Blade slight near the base (back).

   1.4. Check the left to right distance from the wafer edge to the Chuck, it should be 0.5mm, if not, bent the Blade slightly near the base (back), recheck front to back (1.3).

2. **Set Chuck Rotation Motor Zero:**
   Home all motors, rotate (jog) the Chuck so that the index mark on the Chuck is line-up with the mark on the base plate. For ResMap 168/268, this is near the back of the near the CDE logo; for ResMap 363, this is one the side. Then set home at zero for Chuck rotation motor.

3. **Set Probe Arm Motor Zero:**
   Jog the arm to center it on the Chuck, set rotation to 0-deg, align the seam of the arm on the right of the probe mount to the center radial line on the Chuck. Set home at zero for the Probe Arm motor.

4. **Set Chuck Elevator Motor Zero:**

   4.1. Move blade to X = –150 for ResMap 168/268; X = –190 for ResMap 363, (Blade Length in Motion Coordinate Screen), so that the center of the Blade is at the center of the Chuck.

   4.2. Place a wafer on the Blade, turn off vacuums.

4.3. Raise the Chuck until it just touch the wafer, this can be done by the drag method — move the Blade in and out at 10 – 20 mm steps, then raise or lower the Chuck at small increments (< 0.1mm) until the wafer is just dragged by the Blade on the Chuck.

4.4. Set home at zero for the Chuck Elevation Motor.

5. Set Cassette Elevator Motor Zero:

5.1. Place a cassette on the cassette elevator, make sure it has at least wafers in slots 1, 2 and 25 (for a 12" 13 slot cassette, then slots 1, 2 and 13). Slot 1 is at the bottom.

5.2. Make sure you have correct Cassette Elevator Scale factor (slot pitch) in the 4pMot#.prm file. For 168/268, it is typically 960 steps per slot pitch for 4", 5" and 6" wafers (3/16" pitch), 1280 steps/slot for 8" cassette (1/4" pitch).
For ResMap 363, it is typically 2351.7058 for 12" cassette (10-mm pitch), 1493.3333 for 8" cassette and 1200 for 6" pitch.
For ResMap 363H and 468 models, it is typically 1679.79 for 12" cassette, 1066.67 for 8" cassette and 800 for 6" pitch.

5.3. Home all motors remove any wafers on Chuck or Blade and turn off vacuum.

5.4. Jog Cassette Elevator motor and Probe Arm motor (blade), so that the Blade just tough the bottom of the bottom wafer (#1). Use drag method described in 4.3.

5.5. Set home at zero for Cassette Elevator Motor.

6. Wafer Transfer and Wafer Placement on Chuck:

6.1. Now you can transfer the wafers from slots 1, 2 and 25. They should all work but may not be centered on the chuck. The centering procedure will be described later.

6.2. For bottom wafer (slot 1). Make sure the wafers are all the way in the cassette. Load it on the Chuck and check wafer position.

6.3. The left or right offset can be corrected by moving the cassette register plate left or right by loosening the three 8-32 socket head screws at the bottom of cassette plate. Shift the cassette register plate left or right and slight tighten the above 3 screws and recheck the center by loading and unloading the wafer in slot 1 (6.2). You may want to repeat this step until the wafer is centered well left and right on the chuck.

6.4. The front and back position can be adjusted by software by changing the RbtInCas parameter in the Motion Coordinate parameter screen. Increasing this number means the Blade will go deeper into the cassette to pick up the wafer, so the wafer will be placed further back on the Chuck, etc. Adjust this until wafer is well-centered on Chuck, recheck 6.3 again.

6.5. Now load top wafer (slot 25 or 13 for 12" open cassette), check centering of this wafer on Chuck. For left-right shifting, loosening the two 8-32 cap screw locks at bottom of cassette register (6.3) close to the Chuck. Turn the set screws equal amount in opposite directions to tilt the cassette left or right and retry until the wafer is centered left and right. For front and back shift, unlock the bottom 8-32 cap screw lock close to the front of ResMap to adjust the front to back tilt until the wafer is center on the chuck, lock the three screws slightly (not too) tight. Then goes through steps 6.1 to 6.5 again to make sure everything is OK.

7. Some other Parameters and their Effects:

7.1. **ZCasBladeWaferDn** (nominal value –0.25 slot pitch). The distance below the wafer in cassette when the Blade in inserted to pickup wafer or exit after returning wafer. It should be adjusted so the Blade has equal clearance between the wafers above and below. Best to use slot 2.

7.2. **ZCasBladeWaferUp** (nominal value 0.25 slot pitch). The distance above the wafer in cassette when the blade is moving the wafer out of the cassette or entering the cassette when returning the wafer. This should be adjusted so that the wafer leaves the cassette at the widest part of the cassette.

7.3. **ZChkBladeWaferUp** (nominal value –0.7 mm), position of the Blade below wafer on Chuck to enter Chuck when picking up wafer on Chuck. This should be adjusted for equal clearance top and bottom of Blade.

7.4. **ZCasPodLoad** for position of SMIF or FOUP pod at unlock position.

8. Final Touch:

Now you need to adjust the probe contact height: Place wafer on the Chuck, bring arm to center of wafer, mount probe in arm, slowly raise check until the probe pins are compressed half way. Then do SetProbeContactZ. (See section 5.1.4 on probe contact adjustment). You can check the operation by doing GainSet to read the wafer if the it is conducting.

Notes on GainSet on demand in a Template

We have now added GainSet commands in a Template for Mapping with template. This software is implemented in both DOS (4p3v.exe >8/1/97) and windows > 4pw1mm.exe.

The template file is very similar to the original template data line (record). i.e.:

```
  R(mm)    Th(deg)          //for each site in the template file
```

The only addition feature for GainSet at a point R,Th is to have a upper case G in the first column of the coordinate data.

```
  G  R(mm)  Th(deg)          //for each site in the template file
```

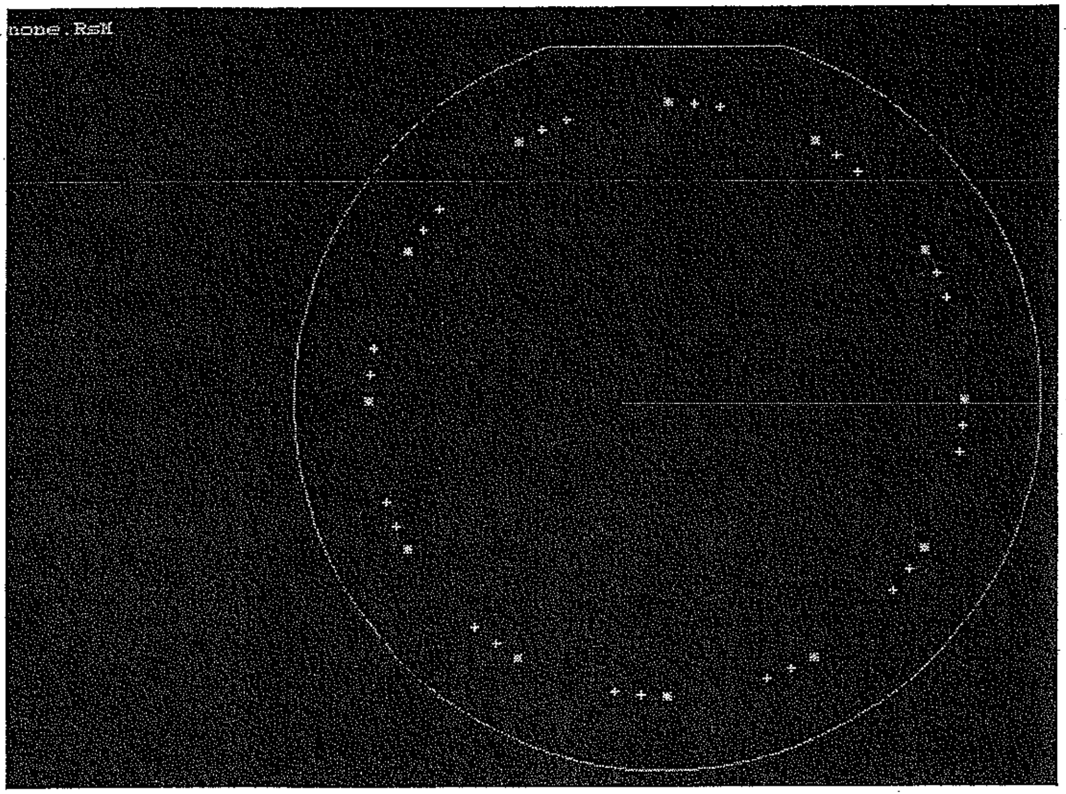
The new software is totally compatible to old templates, no changes are necessary. Following is an example:

Template file G2.tpl:

```
G2.tpl  set gain at different places


  36  1
G     20      0
      20      5
      20     10
G     20     30
      20     35
      20     40
G     20     60
      20     65
      20     70
G     20     90
      20     95
      20    100
G     20    120
      20    125
      20    130
G     20    150
      20    155
      20    160

etc. ................................

G     20    330
      20    335
      20    340
```

```
line 1: title
line 2: reserved
line 3: reserved
line 4: #sites  ProbeConfig
line 5 to 5 + #sites:
         [G] R(mm) Th(deg)
etc.
```

The corresponding pattern is plotted as follows:



The points with a '+' is where the data will be read and the '*' corresponds to where gain will be set (reset) and data will also be read.