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**A TOOL FOR COLLECTION OF I-V  
STATISTICS USING THE HP 4062  
SEMICONDUCTOR PARAMETRIC  
TEST SYSTEM**

by

Chia-Ray Ni

Memorandum No. UCB/ERL M90/7

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# **A Tool For Collection Of I-V Statistics Using The HP 4062**

## **Semiconductor Parametric Test System**

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Department of Electrical Engineering and Computer Sciences

University of California, Berkeley

### **ABSTRACT**

The tuning of a statistical process simulator, such as FABRICS II, requires the collection of considerable numbers of I-V (current-voltage) characteristics of devices representing a technology.

A fully automatic I-V measurement program has been developed on the HP 9836 Pascal Workstation to drive the HP 4062 Semiconductor Parametric Test System and the Electroglas 2001X Automatic Wafer Probing System. This program can be used to probe single devices or entire wafers.

This paper describes the system setup and the operation of the program, in both single device mode and automatic mode. A simple example and some measurement results are attached.

November 22, 1989

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# **A Tool For Collection Of I-V Statistics Using The HP 4062**

## **Semiconductor Parametric Test System**

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### **1. INTRODUCTION**

This project was originally started by Paul Krueger as his Master of Science project [1].

A test chip containing devices necessary for measurement of device electrical characteristics had been designed and fabricated (Figure 1 & 2). However, only a small number of the devices had been sampled by manual measurement. These small number of measurements were insufficient to provide a good statistical analysis of device performance across the entire test wafer. Furthermore, due to some inaccuracies in processing the wafers, there were large discrepancies between the expected and the measured threshold voltages of the MOS's. These threshold voltage variations caused difficulties in device parameter extraction, and also in tuning FABRICS II.

As a result, a fully automatic probing and measuring program is developed to sample a larger number of devices. In addition, a new set of test wafers are fabricated in accordance to the Berkeley 2-micron p-well CMOS process [1] to use for measurement.

## **2. SYSTEM SETUP**

The HP 4062 Semiconductor Parametric Test System and the Electroglas 2001X Automatic Wafer Probing System had previously been used by Norman Yuen for his BSIM project [2]. The system was later used by Jay Fleischman in an optical lithography project [3]. A detailed description of the hardware configuration can be found in Norman Yuen's paper.

### **2.1. MOUNTING THE PROBE CARD**

In order to take any measurements using the automatic wafer probing system, the probe card has to be installed. First, remove the probe card carrier from the prober table. Then, plug in the probe card according to the appropriate pin positions. Note that on the probe card carrier, only 20 contact points between the probe card adapter and the personality ring had been soldered. Thus, when mounting the probe card onto the adapter, make sure the probes are in the positions that have adapter - personality ring connections.

Next, place the prober carrier, now with the probe card installed, back onto the prober table. Rotate the prober carrier so as to align the personality ring fingers to be in good contact with the HP 4085A Switching Matrix measurement pins. The HP 4085A Switching Matrix in our lab has only 22 sets of measurement pins installed. So, care is needed to align the existing matrix pins in good contact with the fingers on the personality ring, which are in turn connected with the probes to be used in measurement. This is a very critical step as it is the matrix pin numbers, not the numbers of the probes on the probe card, that are to be specified in the input files to the program.

Previously, there were no alignment marks to indicate the orientation of the personality ring such that good connections between the ring fingers and matrix pins could be assured. Now, a marker pointing to Finger #10 has been included on the prober table. This will facilitate the probe card setup and assure all connection points are in good contact.

After the personality ring fingers and the switching matrix pins have been aligned, secure the prober carrier on the prober table.

For our custom-made 2x5 probe card, the pin number connection of the probes to the probe card adapter, personality ring and switching matrix are as follows :

Matrix	:	32	34	36	38	40
Ring	:	32	34	36	38	40
Adapter	:	33	34	35	36	37
Probe	:	58	59	60	1	2

Probe	:	33	32	31	30	29
Adapter	:	8	7	6	5	4
Ring	:	20	18	16	14	12
Matrix	:	20	18	16	14	12

## 2.2. LOADING AND ALIGNING THE WAFER

We want to place the wafer on the wafer stage such that the contact pads for the devices are almost inline with the probes so that minimum alignment is required.

First, we have to set up the prober station. A detailed instruction on setting up the Electroglas 2001X from Norman Yuen's paper is included in the appendix.

For our particular wafer, we want to place the wafer in such way that the wafer flat is parallel to the right edge of the prober table. Then we press the ALIGN SCAN button on the monitor console keyboard to move the wafer stage to the center of the table.

Now we can align the wafer by looking through the microscope. First, we do a rough alignment across the entire wafer by using the index mode of the joy stick on the operator control console. This mode will move the prober station according to the distance set for the X and Y die sizes on the SET PRMTR display. We set X=10.89 and Y=10.89 (in microns), the x and y distance between two dies on our wafer. Move the wafer so that the probes are parallel to the horizontal edge of a die that is at the center of the wafer. Now, use the jump mode of the joy stick to move horizontally across the wafer and observe the rotational error of the wafer to the probers. Adjust the error using the Theta Manual Adjust Switch on the operator control console until the probes point to the same position on each die when the wafer is moved across horizontally and vertically.

Then, we can move the probes onto the pads of the first set of devices on the first die to be probed. This is done by using the slow jog mode of the joy stick. We can test to place the probes onto the contact pads by pressing the Z button on the operator console. Z-up limit of 294 mils and Z-down limit of 284 mils are found to give good contact between the probes and the pads.

The HP 9836 computer uses GPIB (the General Purpose Interface Bus) to "talk" to the Electroglas wafer prober system. Therefore, the IOMODE (line 7) on the SET MODE display for the automatic prober has to be set to *GPIB*, the prober's GPIB address has to be set to *14* (line 9), and the 'ON-LINE' button on the prober monitor console keyboard has to be pushed to *ON*. Failure to set the prober system to the appropriate modes will cause the system to hang.

Finally, note that the HP 9836 computer, its hard-drive system and printer, the 4141A DC Source/Monitor (DCS) and the 4084A Switching Matrix Controller (SMC) of the HP 4062A Semiconductor Parametric Test System, and the Electroglas 2001X Automatic Wafer Probing System, are all on the same HP-IB bus. Occasionally, the system might stall. If the system is checked to have set up correctly, check the cables to see if they are in good connection. If the problem persists, change a cable. It had been found in the past that a bad cable can cause the computer to loose control of the data flow on the bus.

### **3. OPERATING THE PROGRAM**

To boot up the HP 9836 workstation in Pascal system, simply power on the workstation, the memory expansion box and the hard disk. The program source code is in IV4062.TEXT and the executable program is IV4062.CODE. They are in the directory RAY1 on hard disk . There is a README file in the directory that explains how to edit, compile and execute the program.

The I-V measurement program can be operated in the single device mode, or in the automatic, multiple devices, multiple die mode (Figure 3). The single device mode enables the user to check the system and permits easy demonstrations. Furthermore, the device can be checked by plotting IDS vs VDS and/or IDS vs VGS curves. If the system functions without problems, the user can then switch to the automatic mode to collect I-V statistics.

#### **3.1. SINGLE DEVICE MODE**

In the single device mode, the program prompts the user to enter device information and matrix pin connections (Figure 4). The user then specifies the biasing voltages for the desired I-V measurements, and chooses whether to view the I-V curves (Figure 5). This procedure allows the user to check the measured data and device functionality.

The program then proceeds with the measurement, and it outputs the results to the file SINGLE.TEXT (Figure 6). The output consists of device information and the drain-source current biased at each vds, vgs and vbs voltage.

#### **3.2. AUTOMATIC MODE**

In the fully automatic mode, two input files must be created prior to running the program. They are the prober file and the biasing file.

##### **3.2.1. PROBER FILE**

First, it is the prober file (Figure 7) which describes the die size, probing locations, and device information such as P-channel or N-channel. Lines 1 and 2 contain the distance in microns, in the x and y directions respectively, between the same device on two adjacent die. This will allow

the system to move from one die to another (Figure 8).

Next, there is an 8x8 array representing all the available die on the wafer. The first member of the array is labeled as (500,500). The "X" indicates the origin die (ie. the first die to be probed). The probes must be manually aligned on this die before the program begins execution. Die locations marked with "1" will be probed, while die locations marked with "0" will not be probed.

The program can easily be modified to accommodate wafers having greater than 8x8 die matrix; simply go to the beginning of the source code and change the constant declaration *die\_array\_sizex* and *die\_array\_sizey* to the appropriate array size, recompile the program and run.

Since our ten-point probe is not enough to complete testing of a die location, the prober must be directed to move the probe within the die as well. So, the second part of the prober file contains information about the devices to be probed. Mx and my are the x and y coordinates (in microns) of a row of three devices to be measured by the ten-point probe. That is, these three devices on the same row have the same mx and my (Figure 9). When starting the program, the probes must be on the first row of devices to be probed (mx=my=0). Subsequent coordinates of devices to be probed are relative to the first row.

The device number, dv, labels the number of devices probed. dt is the device type (1=NMOS, -1=PMOS); ed is for enhancement (ed=1), depletion (ed=-1) or zero-threshold (ed=0); w and l are the respective drawn width and length, in microns, of the device.

Finally, four types of switching matrix pin connections have to be specified. They are pg, pd, ps and pb, which represent the respective matrix pin numbers that are connected to the probes in contact with the gate, drain, source and body of the device .

The last line in the prober file must be a blank line, otherwise, an ambiguous system error will be reported.

Comments for the prober file can be written between braces, { }, after each input line. In

addition, comments can be put in enclosed braces anywhere after the 8x8 die array. But long comments that stretch to several lines should have the comments start from the second column, NOT the first column, on the new line.

### 3.2.2. BIASING FILE

This input file (Figure 10) defines the gate, drain and body voltages desired for I-V measurement. The NMOS and PMOS devices each have a set of biasing voltages.

Due to the limitation of the run-time memory on the computer, only 24 devices per die, biased with 4 vgs voltages, 5 vds voltages and 3 vbs voltages, can be measured in a single run. For example, the NMOS can be biased with voltages vgs 1-4V step 1V, vds 1-5V step 1V, and vbs -2-0V step 1V. A measurement on 24 devices on a die using the above number of bias voltages takes about 5 minutes.

Similar to the prober file, the last line of the biasing file must be a blank line. However, comments can only be put in braces at the beginning of the biasing file, or on the same line after each input statement.

After the prober file and the biasing file have been prepared, the user can proceed to run the program in automatic mode. The program will request for the name of the prober file and biasing file, from which it will read the specified data. The program produces two output files, and these files are described below. The program will also ask for the names of the two output files to store the measured data (Figure 11).

During testing, a status page (Figure 12) displays on the terminal screen indicates the progress of the measurement.

### 3.2.3. AUTO OUTPUT FILE

The auto output file is similar to the single output file, only that it includes data for every device probed over the entire wafer. The program will first perform five device functionality tests to check for shorted gate, shorted junction, no junction, open drain-source, and shorted drain-source. The tests are done by measuring the gate, body and drain currents biased at some pre-

specified voltages. No measurements will be made on non-functioning devices, and the reason for device error will be determined and recorded in the auto output file.

#### **3.2.4. STATISTICAL FILE**

The STAT.TEXT file (Figure 13) averages the drain-source current for each vgs, vds and vbs bias voltages for the devices of the same type and size that are probed on each die across the entire wafer. The number of devices sampled and number of working devices are recorded. Standard deviations of the current measurements are calculated and printed in the last column.

#### **4. EXAMPLE**

Using a test wafer (CMOS12-7) designed and fabricated by Paul Krueger, the devices are probed with a custom-made 2x5 probe card. The probe card is mounted onto the adapter according to the pin number connection show in section 2.1

First, the program is ran in the single device mode for a  $w=10.00$ ,  $l=5.00$  NMOS enhancement mode device as shown in Figure 4 & 5, and the results are presented in Figure 6.

Next, the entire wafer is probed using the prober file in Figure 7 and the biasing file in Figure 10. The measurements are tabulated in Figure 13.

## 5. REFERENCES

- [1] Paul Krueger, *Tuning a Statistical Process Simulator to a Berkeley CMOS Process*, Memorandum No. UCB/ERL M88/82, UC Berkeley, December, 1989.
- [2] Norman Yuen, *A Fully Automated BSIM Parameter Extraction System Using the HP 4062 Test System*, UC Berkeley, April 27, 1986.
- [3] Jay Fleischman, *Electrical Probing of Test Structures for Optical Lithography*, Memorandum No. UCB/ERL M88/60, UC Berkeley, September 7, 1988.

## **ACKNOWLEDGEMENTS**

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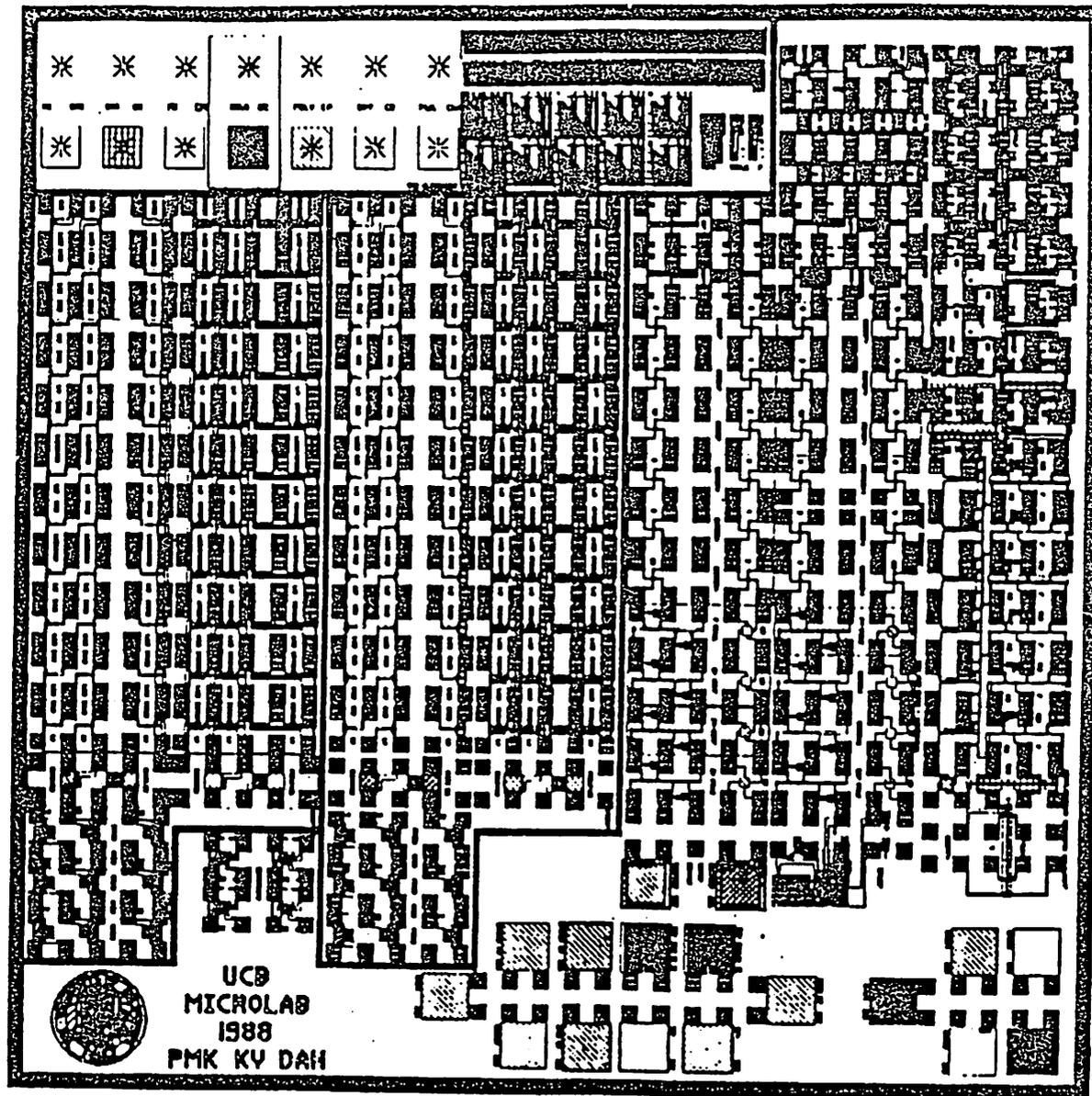


Figure 1: Plot of the Test Chip

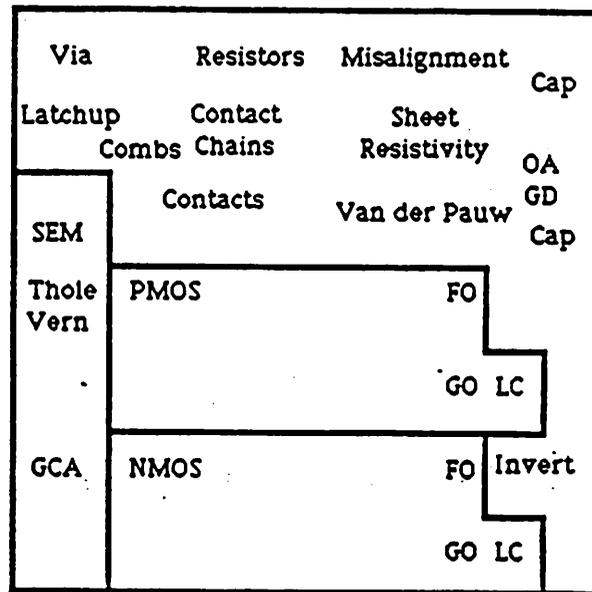


Figure 2: Location of Groups of Structures on the Test Chip

**MOS DEVICES STATISTICAL I-V MEASUREMENT PROGRAM  
UC BERKELEY ELECTRONICS RESEARCH LAB, VERSION 1.0P**

This program can be used in either of the following modes:

[1] Fully Automatic or [2] Single Device Operation.

**FULLY AUTOMATIC OPERATION** requires a prober file, a biasing file and tests all devices in the file without interruption.

This mode requires an automatic prober, eg. Electroglas 2001X Prober System.

**SINGLE DEVICE OPERATION** allows the user to analyze an individual device, and view the I-V curves.

Select a Mode of Operation >

[1]: FULLY AUTOMATIC

[2]: SINGLE DEVICE

[3]: EXIT PROGRAM

**Figure 3: Main Menu**

\*\*\*\* SINGLE DEVICE OPERATION \*\*\*\*

Process Name=*CMOS*  
Lot=*12*  
Wafer=*7*  
Date=*5-3-89*  
Operator=*CHIA-RAY NI*  
Output File=*SINGLE.TEXT*

DIE XPOS=*502* YPOS=*500*  
MOS type=*1* [1] NMOS, [-1] PMOS  
drawn width (microns)=*10.00*  
drawn length (microns)=*5.00*  
Device type=*1* [1] enhancement, [2] zero-threshold,  
[3] depletion

PIN connected to GATE=*18*  
PIN connected to DRAIN=*16*  
PIN connected to SOURCE=*36*  
PIN connected to BODY=*14*

Figure 4: Single Device Operation Menu  
(user inputs are in *italic*)

\*\*\*\* BIASING & I-V GRAPHICS MENU \*\*\*\*

The I-V graphics routines will measure and draw I-V data.

SELECT A NUMBER FOR A GIVEN MEASUREMENT TYPE=*1*

- 1)IDS versus VDS
- 2)IDS versus VGS

VSOURCE =*0.00*

VG\_START=*1.00* VG\_END=*4.00* VG\_STEP=*1.00*

VD\_START=*1.00* VD\_END=*5.00* VD\_STEP=*1.00*

VB\_START=*-2.00* VB\_END=*0.00* VB\_STEP=*1.00*

I-V GRAPHICS PLOT WANTED ? (Y/N) *Y*

SET the probes down and the system ready for measurement.  
HIT a "C" for changes, or any other key to start.

Figure 5: Biasing and I-V Graphics Menu  
(user inputs are in *italic*)

\*\*\*\* I-V MEASUREMENTS FOR MOS DEVICES \*\*\*\*

\* Process : CMOS  
\* Lot : 12  
\* Wafer : 7  
\* Date : 5-3-89  
\* Operator: CHIA-RAY NI  
\* Output File: SINGLE.TEXT

\* Die Number: 502 - 500  
\* Device Number: 1  
\* Device Type : NMOS  
\* Width : 10.00 microns  
\* Length: 5.00 microns

	Amperes
VGS[ 1]: 1.00, VDS[ 1]: 1.00, VBS[ 1]: -2.00	= 5.10988E-006
VGS[ 1]: 1.00, VDS[ 2]: 2.00, VBS[ 1]: -2.00	= 7.68994E-006
VGS[ 1]: 1.00, VDS[ 3]: 3.00, VBS[ 1]: -2.00	= 1.12012E-005
VGS[ 1]: 1.00, VDS[ 4]: 4.00, VBS[ 1]: -2.00	= 1.54245E-005
VGS[ 1]: 1.00, VDS[ 5]: 5.00, VBS[ 1]: -2.00	= 2.01760E-005
VGS[ 2]: 2.00, VDS[ 1]: 1.00, VBS[ 1]: -2.00	= 3.03958E-005
VGS[ 2]: 2.00, VDS[ 2]: 2.00, VBS[ 1]: -2.00	= 4.12234E-005
VGS[ 2]: 2.00, VDS[ 3]: 3.00, VBS[ 1]: -2.00	= 5.02348E-005
VGS[ 2]: 2.00, VDS[ 4]: 4.00, VBS[ 1]: -2.00	= 5.90854E-005
VGS[ 2]: 2.00, VDS[ 5]: 5.00, VBS[ 1]: -2.00	= 6.76722E-005
VGS[ 3]: 3.00, VDS[ 1]: 1.00, VBS[ 1]: -2.00	= 6.74934E-005
VGS[ 3]: 3.00, VDS[ 2]: 2.00, VBS[ 1]: -2.00	= 1.00398E-004
VGS[ 3]: 3.00, VDS[ 3]: 3.00, VBS[ 1]: -2.00	= 1.18133E-004
VGS[ 3]: 3.00, VDS[ 4]: 4.00, VBS[ 1]: -2.00	= 1.33034E-004
VGS[ 3]: 3.00, VDS[ 5]: 5.00, VBS[ 1]: -2.00	= 1.46462E-004
VGS[ 4]: 4.00, VDS[ 1]: 1.00, VBS[ 1]: -2.00	= 1.03954E-004
VGS[ 4]: 4.00, VDS[ 2]: 2.00, VBS[ 1]: -2.00	= 1.72130E-004
VGS[ 4]: 4.00, VDS[ 3]: 3.00, VBS[ 1]: -2.00	= 2.08430E-004
VGS[ 4]: 4.00, VDS[ 4]: 4.00, VBS[ 1]: -2.00	= 2.31776E-004
VGS[ 4]: 4.00, VDS[ 5]: 5.00, VBS[ 1]: -2.00	= 2.51202E-004
VGS[ 1]: 1.00, VDS[ 1]: 1.00, VBS[ 2]: -1.00	= 1.06343E-004
VGS[ 1]: 1.00, VDS[ 2]: 2.00, VBS[ 2]: -1.00	= 1.76332E-004
VGS[ 1]: 1.00, VDS[ 3]: 3.00, VBS[ 2]: -1.00	= 2.13924E-004
VGS[ 1]: 1.00, VDS[ 4]: 4.00, VBS[ 2]: -1.00	= 2.38388E-004
VGS[ 1]: 1.00, VDS[ 5]: 5.00, VBS[ 2]: -1.00	= 2.58758E-004
VGS[ 2]: 2.00, VDS[ 1]: 1.00, VBS[ 2]: -1.00	= 3.15840E-005
VGS[ 2]: 2.00, VDS[ 2]: 2.00, VBS[ 2]: -1.00	= 4.29660E-005
VGS[ 2]: 2.00, VDS[ 3]: 3.00, VBS[ 2]: -1.00	= 5.26170E-005
VGS[ 2]: 2.00, VDS[ 4]: 4.00, VBS[ 2]: -1.00	= 6.21958E-005
VGS[ 2]: 2.00, VDS[ 5]: 5.00, VBS[ 2]: -1.00	= 7.14750E-005
VGS[ 3]: 3.00, VDS[ 1]: 1.00, VBS[ 2]: -1.00	= 6.94598E-005
VGS[ 3]: 3.00, VDS[ 2]: 2.00, VBS[ 2]: -1.00	= 1.03594E-004
VGS[ 3]: 3.00, VDS[ 3]: 3.00, VBS[ 2]: -1.00	= 1.22199E-004
VGS[ 3]: 3.00, VDS[ 4]: 4.00, VBS[ 2]: -1.00	= 1.37978E-004
VGS[ 3]: 3.00, VDS[ 5]: 5.00, VBS[ 2]: -1.00	= 1.52220E-004
VGS[ 4]: 4.00, VDS[ 1]: 1.00, VBS[ 2]: -1.00	= 1.06284E-004
VGS[ 4]: 4.00, VDS[ 2]: 2.00, VBS[ 2]: -1.00	= 1.76286E-004
VGS[ 4]: 4.00, VDS[ 3]: 3.00, VBS[ 2]: -1.00	= 2.13876E-004
VGS[ 4]: 4.00, VDS[ 4]: 4.00, VBS[ 2]: -1.00	= 2.38316E-004
VGS[ 4]: 4.00, VDS[ 5]: 5.00, VBS[ 2]: -1.00	= 2.58682E-004

VGS[ 1]: 1.00, VDS[ 1]: 1.00, VBS[ 3]: 0.00 = 1.09733E-004  
VGS[ 1]: 1.00, VDS[ 2]: 2.00, VBS[ 3]: 0.00 = 1.82124E-004  
VGS[ 1]: 1.00, VDS[ 3]: 3.00, VBS[ 3]: 0.00 = 2.21316E-004  
VGS[ 1]: 1.00, VDS[ 4]: 4.00, VBS[ 3]: 0.00 = 2.47102E-004  
VGS[ 1]: 1.00, VDS[ 5]: 5.00, VBS[ 3]: 0.00 = 2.68634E-004  
VGS[ 2]: 2.00, VDS[ 1]: 1.00, VBS[ 3]: 0.00 = 3.37232E-005  
VGS[ 2]: 2.00, VDS[ 2]: 2.00, VBS[ 3]: 0.00 = 4.59030E-005  
VGS[ 2]: 2.00, VDS[ 3]: 3.00, VBS[ 3]: 0.00 = 5.64402E-005  
VGS[ 2]: 2.00, VDS[ 4]: 4.00, VBS[ 3]: 0.00 = 6.69902E-005  
VGS[ 2]: 2.00, VDS[ 5]: 5.00, VBS[ 3]: 0.00 = 7.71764E-005  
VGS[ 3]: 3.00, VDS[ 1]: 1.00, VBS[ 3]: 0.00 = 7.25292E-005  
VGS[ 3]: 3.00, VDS[ 2]: 2.00, VBS[ 3]: 0.00 = 1.08297E-004  
VGS[ 3]: 3.00, VDS[ 3]: 3.00, VBS[ 3]: 0.00 = 1.28035E-004  
VGS[ 3]: 3.00, VDS[ 4]: 4.00, VBS[ 3]: 0.00 = 1.44972E-004  
VGS[ 3]: 3.00, VDS[ 5]: 5.00, VBS[ 3]: 0.00 = 1.60214E-004  
VGS[ 4]: 4.00, VDS[ 1]: 1.00, VBS[ 3]: 0.00 = 1.09708E-004  
VGS[ 4]: 4.00, VDS[ 2]: 2.00, VBS[ 3]: 0.00 = 1.82100E-004  
VGS[ 4]: 4.00, VDS[ 3]: 3.00, VBS[ 3]: 0.00 = 2.21306E-004  
VGS[ 4]: 4.00, VDS[ 4]: 4.00, VBS[ 3]: 0.00 = 2.47088E-004  
VGS[ 4]: 4.00, VDS[ 5]: 5.00, VBS[ 3]: 0.00 = 2.68590E-004

**Figure 6: Single Output File or Auto Output File**

10890 {distance, in microns, between the same device on two}  
10890 {adjacent die in the x and y directions respectively}

00X01000 {8x8 array representing the dies on the wafer}  
01010100 {X indicates the origin die}  
10101010 {1 indicates dies to be probed}  
01010101 {0 indicates dies not be prober}  
10101010  
01010101  
00101010  
00010100

mx=0 {x & y coordinates, in microns, of the first row of devices}  
my=0 {Subsequent rows of devices have coordinates relative to this}  
dv1 {device number, the following are its specifications}  
w=5 {drawn width = 5 microns}  
l=5 {drawn length= 5 microns}  
dt=1 {device type, 1=NMOS, -1=PMOS}  
ed=1 {1=enhancement, 0=zero-threshold, -1=depletion}  
pg=34 {switching matrix pin number connected to the gate}  
pd=20 {switching matrix pin number connected to the drain}  
ps=32 {switching matrix pin number connected to the source}  
pb=14 {switching matrix pin number connected to the body}

dv2  
w=10  
l=5  
dt=1  
ed=1  
pg=18  
pd=16  
ps=36  
pb=14

dv3  
w=50  
l=5  
dt=1  
ed=1  
pg=38  
pd=12  
ps=40  
pb=14

mx=0 {second row of devices are 960 microns below the first row}  
my=960  
dv4  
w=5  
l=3  
dt=1  
ed=1  
pg=34  
pd=20  
ps=32

pb=14

dv5

w=10

l=3

dt=1

ed=1

pg=18

pd=16

ps=36

pb=14

dv6

w=50

l=3

dt=1

ed=1

pg=38

pd=12

ps=40

pb=14

<blank line>

**Figure 7: Prober File**

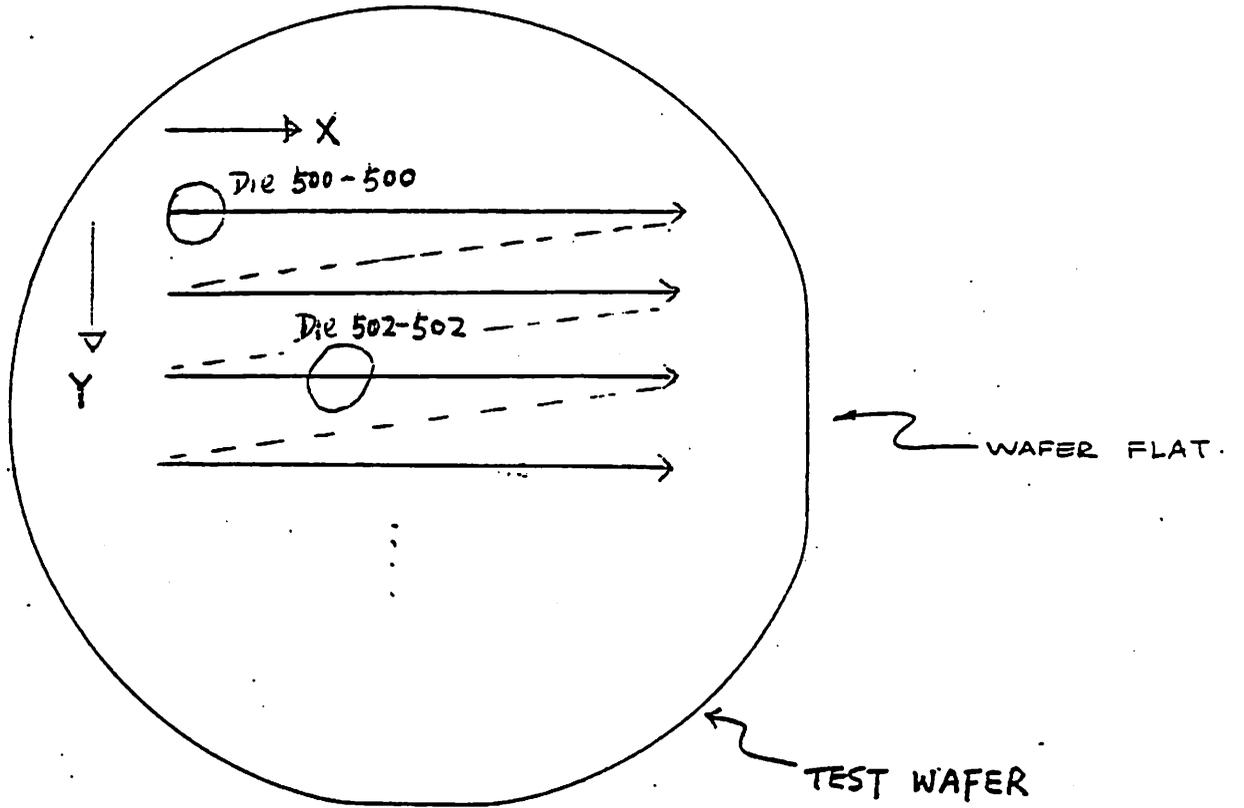


Figure 8: Prober Movement

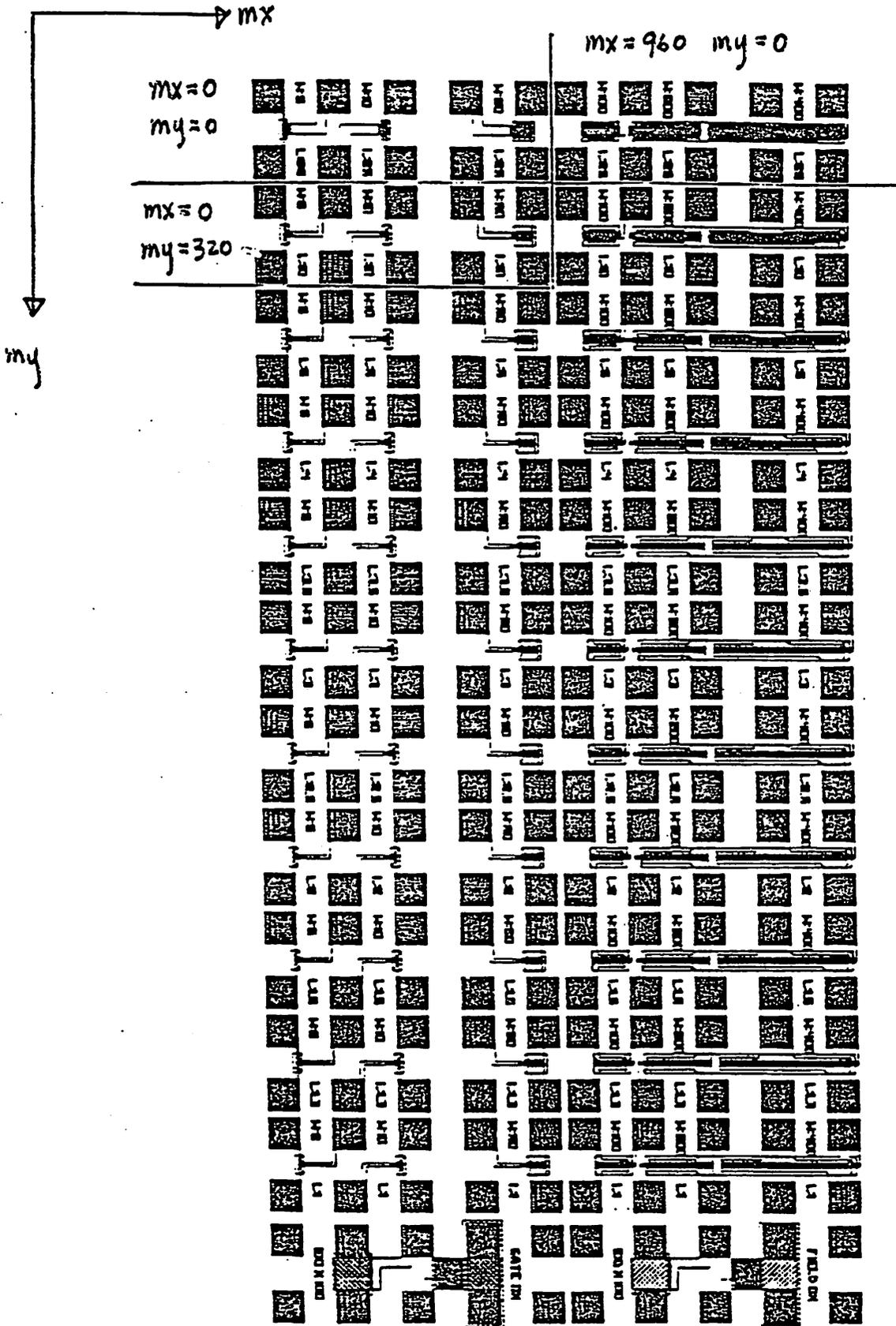


Figure 9: MOS Transistor Matrix

```
NMOS      {These are the bias voltages for NMOS devices}
vsource   0
vgstart   1
vgend     4
vgstep    1
vdstart   1
vdend     5
vdstep    1
vbstart   -2
vbend     0
vbstep    1

PMOS      {These are the bias voltages for PMOS devices}
vsource   0
vgstart   -4
vgend     -1
vgstep    1
vdstart   -5
vdend     -1
vdstep    1
vbstart   0
vbend     2
vbstep    1
<blank line>
```

**Figure 10: Biasing File**

\*\*\*\* AUTOMATIC OPERATION \*\*\*\*

Process Name=*CMOS*  
Lot=*12*  
Wafer=*7*  
Date=*5-3-89*  
Operator=*CHIA-RAY NI*  
Prober File=*PROBER.TEXT*  
Biasing File=*BIAS.TEXT*  
Output File=*AUTO.TEXT*  
Statistical File=*STAT.TEXT*

SELECT A NUMBER FOR A GIVEN MEASUREMENT TYPE= *>1*

- 1) IDS versus VDS
- 2) IDS versus VGS

**Figure 11: Automatic Operation Menu**  
(user inputs are in *italic*)

\*\*\*\* I-V MEASURING STATUS \*\*\*\*

PROCESS: CMOS  
LOT: 12  
WAFER: 7  
DATE: 5-3-89  
OPERATOR: CHIA-RAY NI  
PROBER FILE: PROBER.TEXT  
BIASING FILE: BIAS.TEXT  
OUTPUT FILE: AUTO.TEXT  
STATISTICAL FILE: STAT.TEXT

DIE NUMBER: 502 - 500  
DEVICE TYPE: NMOS  
WIDTH : 5.00 MICRONS  
LENGTH: 5.00 MICRONS  
MESSAGE FROM PROGRAM : MEASURING IDS vs VDS DATA

**Figure 12: Measuring Status Display**

\*\*\*\* STATISTICAL I-V MEASUREMENTS FOR MOS DEVICES \*\*\*\*

\* Process : CMOS  
\* Lot : 12  
\* Wafer : 7  
\* Date : 5-3-89  
\* Operator: CHIA-RAY NI  
\* Prober File: PROBER.TEXT  
\* Biasing File: BIAS.TEXT  
\* Output File: AUTO.TEXT

\* Die Number: 502 - 500  
\* Device Number: 1  
\* Device Type : NMOS  
\* Width : 5.00 microns  
\* Length: 5.00 microns

Amperes

\* Total number of device measured: 26  
\* Number of good devices: 25

VGS[ 1]: 1.00, VDS[ 1]: 1.00, VBS[ 1]: -2.00 =	1.47827E-006	2.67975E-006
VGS[ 1]: 1.00, VDS[ 2]: 2.00, VBS[ 1]: -2.00 =	1.79047E-006	3.30798E-006
VGS[ 1]: 1.00, VDS[ 3]: 3.00, VBS[ 1]: -2.00 =	2.11038E-006	4.08988E-006
VGS[ 1]: 1.00, VDS[ 4]: 4.00, VBS[ 1]: -2.00 =	2.50094E-006	4.84278E-006
VGS[ 1]: 1.00, VDS[ 5]: 5.00, VBS[ 1]: -2.00 =	2.94007E-006	5.53741E-006
VGS[ 2]: 2.00, VDS[ 1]: 1.00, VBS[ 1]: -2.00 =	9.71616E-006	5.52595E-006
VGS[ 2]: 2.00, VDS[ 2]: 2.00, VBS[ 1]: -2.00 =	1.18691E-005	7.26373E-006
VGS[ 2]: 2.00, VDS[ 3]: 3.00, VBS[ 1]: -2.00 =	1.31625E-005	8.23207E-006
VGS[ 2]: 2.00, VDS[ 4]: 4.00, VBS[ 1]: -2.00 =	1.44241E-005	9.07067E-006
VGS[ 2]: 2.00, VDS[ 5]: 5.00, VBS[ 1]: -2.00 =	1.57694E-005	9.84414E-006
VGS[ 3]: 3.00, VDS[ 1]: 1.00, VBS[ 1]: -2.00 =	2.48539E-005	7.61847E-006
VGS[ 3]: 3.00, VDS[ 2]: 2.00, VBS[ 1]: -2.00 =	3.38265E-005	1.19949E-005
VGS[ 3]: 3.00, VDS[ 3]: 3.00, VBS[ 1]: -2.00 =	3.74469E-005	1.37642E-005
VGS[ 3]: 3.00, VDS[ 4]: 4.00, VBS[ 1]: -2.00 =	4.02422E-005	1.47846E-005
VGS[ 3]: 3.00, VDS[ 5]: 5.00, VBS[ 1]: -2.00 =	4.29344E-005	1.56889E-005
VGS[ 4]: 4.00, VDS[ 1]: 1.00, VBS[ 1]: -2.00 =	4.23646E-005	8.11956E-006
VGS[ 4]: 4.00, VDS[ 2]: 2.00, VBS[ 1]: -2.00 =	6.47016E-005	1.48349E-005
VGS[ 4]: 4.00, VDS[ 3]: 3.00, VBS[ 1]: -2.00 =	7.38642E-005	1.87967E-005
VGS[ 4]: 4.00, VDS[ 4]: 4.00, VBS[ 1]: -2.00 =	7.91300E-005	2.03835E-005
VGS[ 4]: 4.00, VDS[ 5]: 5.00, VBS[ 1]: -2.00 =	8.36248E-005	2.14581E-005
VGS[ 1]: 1.00, VDS[ 1]: 1.00, VBS[ 2]: -1.00 =	4.55226E-005	9.44961E-006
VGS[ 1]: 1.00, VDS[ 2]: 2.00, VBS[ 2]: -1.00 =	6.98088E-005	1.68315E-005
VGS[ 1]: 1.00, VDS[ 3]: 3.00, VBS[ 2]: -1.00 =	8.00368E-005	2.14005E-005
VGS[ 1]: 1.00, VDS[ 4]: 4.00, VBS[ 2]: -1.00 =	8.62534E-005	2.33824E-005
VGS[ 1]: 1.00, VDS[ 5]: 5.00, VBS[ 2]: -1.00 =	9.13218E-005	2.47631E-005
VGS[ 2]: 2.00, VDS[ 1]: 1.00, VBS[ 2]: -1.00 =	1.12899E-005	7.82882E-006
VGS[ 2]: 2.00, VDS[ 2]: 2.00, VBS[ 2]: -1.00 =	1.40095E-005	1.06742E-005
VGS[ 2]: 2.00, VDS[ 3]: 3.00, VBS[ 2]: -1.00 =	1.57942E-005	1.21373E-005
VGS[ 2]: 2.00, VDS[ 4]: 4.00, VBS[ 2]: -1.00 =	1.75609E-005	1.33920E-005
VGS[ 2]: 2.00, VDS[ 5]: 5.00, VBS[ 2]: -1.00 =	1.92894E-005	1.45536E-005
VGS[ 3]: 3.00, VDS[ 1]: 1.00, VBS[ 2]: -1.00 =	2.74412E-005	9.17300E-006
VGS[ 3]: 3.00, VDS[ 2]: 2.00, VBS[ 2]: -1.00 =	3.75722E-005	1.46608E-005
VGS[ 3]: 3.00, VDS[ 3]: 3.00, VBS[ 2]: -1.00 =	4.19292E-005	1.69774E-005
VGS[ 3]: 3.00, VDS[ 4]: 4.00, VBS[ 2]: -1.00 =	4.54736E-005	1.84019E-005
VGS[ 3]: 3.00, VDS[ 5]: 5.00, VBS[ 2]: -1.00 =	4.86424E-005	1.96374E-005
VGS[ 4]: 4.00, VDS[ 1]: 1.00, VBS[ 2]: -1.00 =	4.54756E-005	9.44572E-006
VGS[ 4]: 4.00, VDS[ 2]: 2.00, VBS[ 2]: -1.00 =	6.97414E-005	1.68235E-005

VGS[ 4]: 4.00, VDS[ 3]: 3.00, VBS[ 2]: -1.00 = 7.99924E-005 2.13829E-005  
VGS[ 4]: 4.00, VDS[ 4]: 4.00, VBS[ 2]: -1.00 = 8.62342E-005 2.33776E-005  
VGS[ 4]: 4.00, VDS[ 5]: 5.00, VBS[ 2]: -1.00 = 9.13040E-005 2.47593E-005  
VGS[ 1]: 1.00, VDS[ 1]: 1.00, VBS[ 3]: 0.00 = 4.99470E-005 1.21596E-005  
VGS[ 1]: 1.00, VDS[ 2]: 2.00, VBS[ 3]: 0.00 = 7.71004E-005 2.12783E-005  
VGS[ 1]: 1.00, VDS[ 3]: 3.00, VBS[ 3]: 0.00 = 8.90642E-005 2.70868E-005  
VGS[ 1]: 1.00, VDS[ 4]: 4.00, VBS[ 3]: 0.00 = 9.63672E-005 2.97477E-005  
VGS[ 1]: 1.00, VDS[ 5]: 5.00, VBS[ 3]: 0.00 = 1.02222E-004 3.14961E-005  
VGS[ 2]: 2.00, VDS[ 1]: 1.00, VBS[ 3]: 0.00 = 1.38866E-005 1.14126E-005  
VGS[ 2]: 2.00, VDS[ 2]: 2.00, VBS[ 3]: 0.00 = 1.77436E-005 1.66525E-005  
VGS[ 2]: 2.00, VDS[ 3]: 3.00, VBS[ 3]: 0.00 = 2.04812E-005 1.92366E-005  
VGS[ 2]: 2.00, VDS[ 4]: 4.00, VBS[ 3]: 0.00 = 2.29669E-005 2.11000E-005  
VGS[ 2]: 2.00, VDS[ 5]: 5.00, VBS[ 3]: 0.00 = 2.53106E-005 2.26965E-005  
VGS[ 3]: 3.00, VDS[ 1]: 1.00, VBS[ 3]: 0.00 = 3.13224E-005 1.20684E-005  
VGS[ 3]: 3.00, VDS[ 2]: 2.00, VBS[ 3]: 0.00 = 4.33804E-005 1.98060E-005  
VGS[ 3]: 3.00, VDS[ 3]: 3.00, VBS[ 3]: 0.00 = 4.90144E-005 2.33647E-005  
VGS[ 3]: 3.00, VDS[ 4]: 4.00, VBS[ 3]: 0.00 = 5.34486E-005 2.53624E-005  
VGS[ 3]: 3.00, VDS[ 5]: 5.00, VBS[ 3]: 0.00 = 5.73200E-005 2.70004E-005  
VGS[ 4]: 4.00, VDS[ 1]: 1.00, VBS[ 3]: 0.00 = 4.99220E-005 1.21482E-005  
VGS[ 4]: 4.00, VDS[ 2]: 2.00, VBS[ 3]: 0.00 = 7.70860E-005 2.12551E-005  
VGS[ 4]: 4.00, VDS[ 3]: 3.00, VBS[ 3]: 0.00 = 8.90574E-005 2.70579E-005  
VGS[ 4]: 4.00, VDS[ 4]: 4.00, VBS[ 3]: 0.00 = 9.63564E-005 2.97117E-005  
VGS[ 4]: 4.00, VDS[ 5]: 5.00, VBS[ 3]: 0.00 = 1.02205E-004 3.14574E-005

...

**Figure 13: Statistical File**

# Appendix A

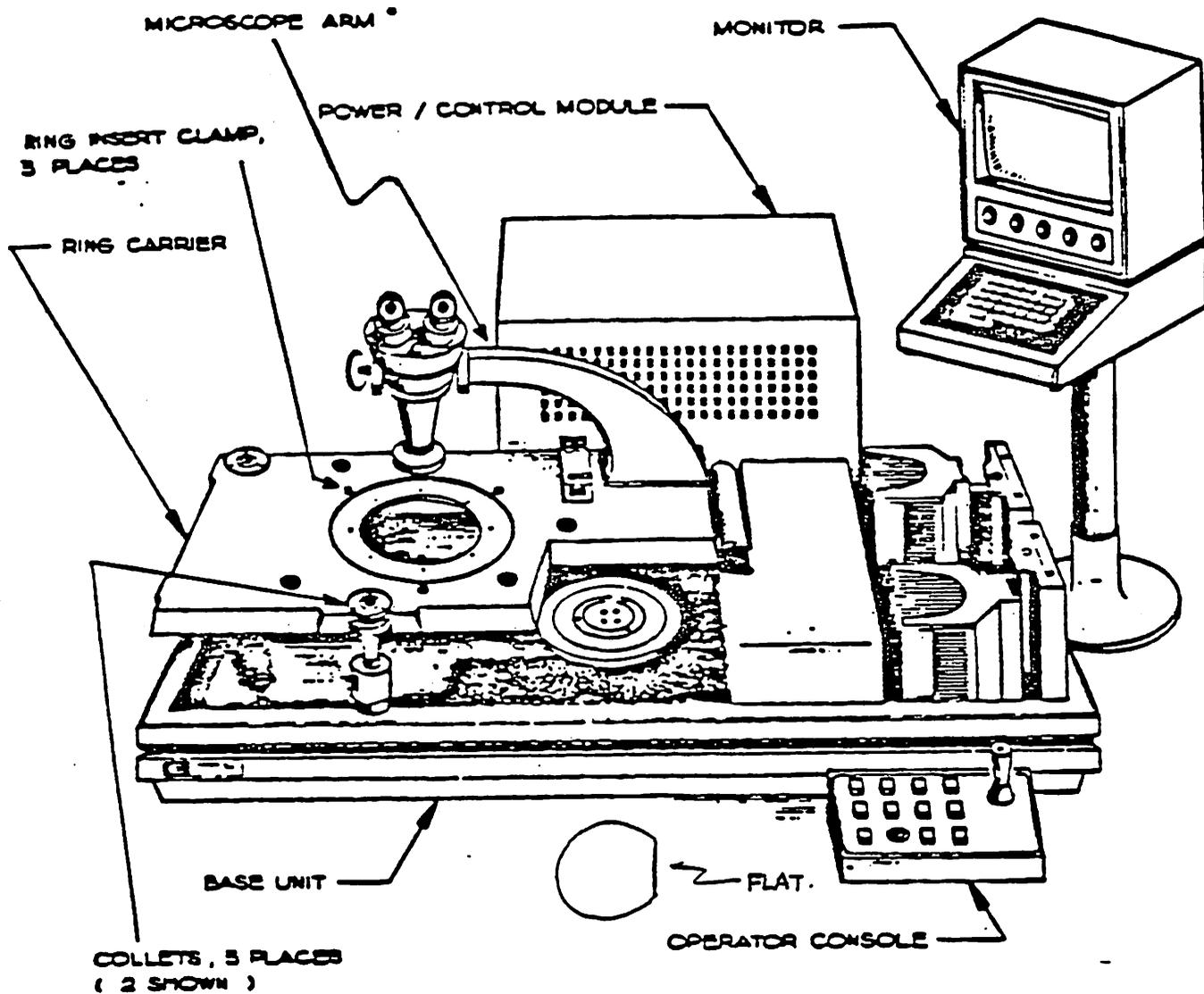
## Automatic Prober Hardware

Equipment and set-up Procedure

From

Norman Yuen's Thesis

\*\* NOTE WAFER FLAT ORIENTATION WHEN MOUNTING THE WAFER



\*The microscope arm shown will not work with the 4062 system. The arm must have a rectangular shape so that the microscope can reach over and into the matrix.

Figure 3-2. Electroglas 2001X Automatic Prober

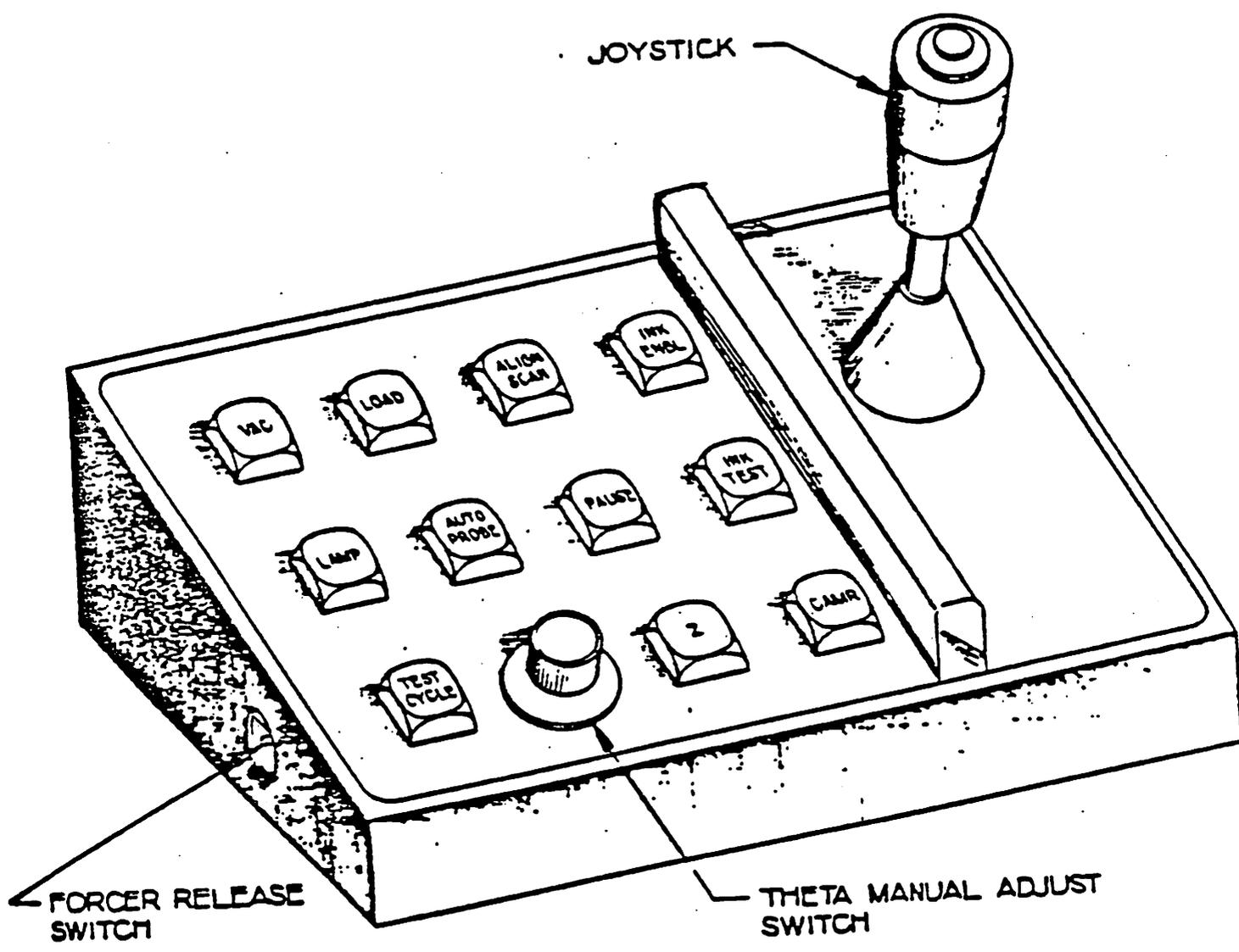


Figure 4-2. Operator Control Console

```

06:50:38
POS X.....0
Y.....0.
Z.....DOWN
WAFER.....OFF
EDGE.....DIS
CHUCK VAC....OFF
PROBE.....MATRX

INDEX

MM
DIE X.....10.8850
Y.....5.8850
DIA.....115MM
INKER.....DIS
ONLINE

WAFER#.....0
GOOD DIE.....0
BAD DIE.....0

```

figure 4-4a. Default Display

```

01 METRIC/ENGLISH.....METRIC
02 QUADRANT SELECT.....2
03 FLAT SELECT.....0
04 AUTOPROBE PATTERN.....MATRX
05 EDGE SENSOR.....DIS
06 SNIPDIE FUNCTION.....DIS
07 IOMODE.....GPIB
08 BAUDCODE.....0
09 GPIB ADDRESS.....14
10 LINE FREQ.....60
11 PRINT ERROR MESSAGES.....DIS
12 PRINT WAFER LOG.....DIS
13 PRINT CASSETTE LOG.....DIS
14 WAFER EDGE INNING.....DIS
LINE?

```

figure 4-4b. SET MODE Display

01 DIE	X.....10.8850 MM
	Y.....5.8850 MM
02 PRESET	X.....0 Y.....0 DIE
03 MATRIX	X.....0 Y.....0 DIE
04 INKER OFFSET.....	0 DIE
05 TURNAROUND.....	0 DIE
06 WAFER DIAMETER.....	115 MM
07 Z OVERTRAVEL.....	0.00 MILS
08 Z CLEARANCE.....	0.00 MILS
09 Z UP LIMIT.....	294 MILS
10 Z DOWN LIMIT.....	284 MILS
11 Z ALIGN.....	200 MILS
12 NEXT PAGE	

LINE?

figure 4-4c. SET PRMTR Display

	SETPARM PAGE #2
01 ALIGN SCAN VEL.....	300 MPS
02 REPROBE LIMIT.....	0 DIE
03 SET RUNTIME DISPLAY CLOCK	

LINE?

figure 4-4d. SET PRMTR Page 2 Display

01 AUTOLOAD SWITCH.....DIS  
02 AUTOALIGN SWITCH.....DIS  
03 AUTOPROFILE SWITCH.....DIS

LINE?

figure 4-4e. SET OPTION Display

so that all these steps will be done automatically upon power-on. An example of an AUTOSTART file is shown in figure 4-1.

### 4.3. Setting Up The Electroglas 2001X

- 1) Plug in the appropriate probe card.
- 2) Turn ON the prober.
- 3) If the monitor is not already ON, turn it ON.
- 4) Answer the questions on the monitor or else wait for default response from prober. It takes about 30 seconds for a default response.

*Type Message Plus Enter=> Enter key  
Wait for Pattern Rec I/O Test... Wait about 30 seconds  
Rom Test? Y  
Repeat Test? Enter key*

- 5) Now you will see **"XY MOTOR BLANK"** at the bottom of the screen. The stage is now floating on the platform. Pull it to the front right corner against the 2 edges.
- 6) Press the button inside the left side of the joystick control panel (figure 4-2). **THE PROBER WILL NOT RESPOND UNTIL YOU PRESS THIS BUTTON.**
- 7) Pull out the vacuum level at the front panel. A hissing noise indicates compressed air coming into the probe station.
- \* \* 8) Using the monitor console keyboard (figure 4-3), set up the prober as shown in figures 4-4b to 4-4e. Of course, the parameters **DIE**, **WAFER DIAMETER**, **ZUP LIMIT**, and **Z DOWN LIMIT** will depend on your particular wafer. To get any of the screens, press the appropriate key on the monitor console keyboard.
- 9) Place the wafer on the chuck and press **VAC** and **LAMP**. The device pads must be roughly parallel to the probes.
- 10) Align the wafer (i.e., rotate the chuck until the device pads are perfectly parallel to the probes). The following section describes more fully how to align the wafer.
- 11) After the wafer is aligned, use the joystick to move the wafer so that the probes are directly over the pads of the devices to be tested. The die should be the origin die and the devices should be the origin row of devices within that die, as specified in the prober file.

- 12) Press **Z** to raise the wafer to the probes. You may have to reset the *Z UP LIMIT* parameter (see figure 4-4c) in the **SET PRMTR** mode. If the probes are not touching the pads, slightly increase *Z UP LIMIT* and then press **Z** twice (once to lower wafer, once to raise it). When you see that all the probes are barely touching all the pads, increase *Z UP LIMIT* by 0.5 to 1.0 MILS to provide some overdrive. Too much overdrive will wear out the probes and the pads very quickly.

#### 4.3.1. Aligning the Wafer

Aligning the wafer will take some practice. Alignment is done when the wafer (actually the stage holding the wafer) is moving from side to side under the probes.

The idea is to rotate the wafer until the device pads are parallel to the probes. When they are not parallel, then even if the probes are directly over the pads at one end of the wafer, the probes will not be directly over the corresponding pads at the other end of the wafer (figure 4-5).

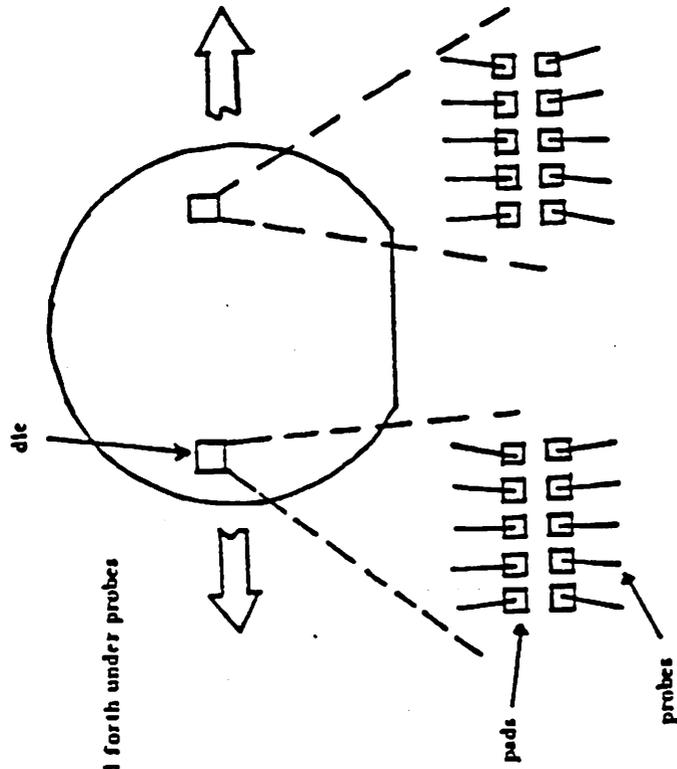
Initially, the prober should be setup similar to the one shown in figures 4-4b to 4-4e. Some prober parameters will depend on the particular wafer being used. The *WAFER DIAMETER* parameter tells the prober how far the stage should move before reversing the direction of movement. The *ALIGN SCAN VEL* parameter (**SET PRMTR**, page 2) sets how fast the stage will move. Three hundred MPS is a reasonable speed for wafer alignment.

##### 4.3.1.1. Alignment Instructions

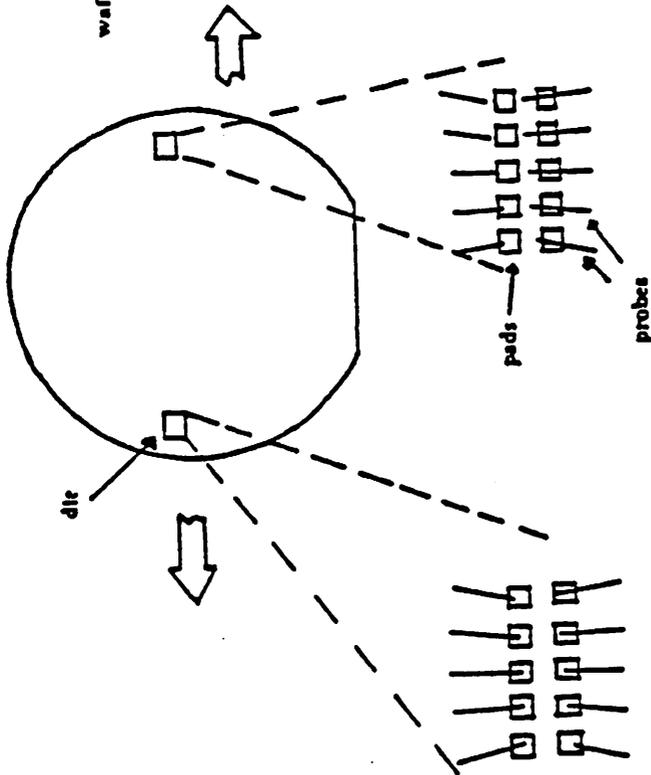
Refer to the operator control console (figure 4-2) while reading the following instructions. The rectangularly enclosed words below represent keys on the joystick panel.

- 1) Follow steps 1 to 9 of section 4.3.
- 2) Press **ALIGN SCAN**.  
This causes the stage to move from the right front corner to the right of the probes.

- 3) Press **PAUSE**.  
The stage moves to the left of the probes.
- 4) Turn the joystick until you see "scan" at the lower left column of the monitor. Use the joystick to move the wafer until you see some linear pattern below the probes. You will use this pattern in step 6) to judge whether the probes are parallel to the pads or not. The pattern can be the pads of a row of devices or the edge of the dies.
- 5) Press **PAUSE**.  
The stage now moves back and forth. Successively pressing **PAUSE** causes the stage alternately to stop and start moving.
- 6) As the wafer is moving, look under the microscope and compare the probes to the pattern. If they are not parallel from one end of the wafer to the other, then turn the theta knob, causing the wafer to rotate. Play with the knob until the probes are parallel to the pattern.
- 7) When you are confident that they are parallel, use the joystick to move the pads to directly underneath the probes. You can use the joystick to move it fast (scan), slow (jog), or fixed (index). How far the stage moves in index mode depends on what the X and Y die sizes are set to (see figure 4-4c).



Properly Aligned



Not Properly Aligned

Figure 4-5. Wafer Alignment