Errata

Document Title: Simplification of DC Characterization and Analysis of Semiconductor Devices (AN 383-1)

Part Number: 5950-2396

Revision Date: December 1989

HP References in this Application Note

This application note may contain references to HP or Hewlett-Packard. Please note that Hewlett-Packard's former test and measurement, semiconductor products and chemical analysis businesses are now part of Agilent Technologies. We have made no changes to this application note copy. The HP XXXX referred to in this document is now the Agilent XXXX. For example, model number HP8648A is now model number Agilent 8648A.

About this Application Note

We've added this application note to the Agilent website in an effort to help you support your product. This manual provides the best information we could find. It may be incomplete or contain dated information, and the scan quality may not be ideal. If we find a better copy in the future, we will add it to the Agilent website.

Support for Your Product

Agilent no longer sells or supports this product. You will find any other available product information on the Agilent website:

www.agilent.com

Search for the model number of this product, and the resulting product page will guide you to any available information. Our service centers may be able to perform calibration if no repair parts are needed, but no other support from Agilent is available.

Agilent Technologies

HEWLETT PACKARD

Simplification of DC Characterization and Analysis of Semiconductor Devices

HP IMA (HP 16276A) Practical Measurement for the HP 4142B

Application Note 383-1

TABLE OF CONTENTS

1. INTRODUCTION

The HP 16276A Interactive Measurement and Analysis (IMA) software turns the HP 4142B Modular DC Source/Monitor into an automatic semiconductor DC parameter analyzer by providing an interactive, softpanel user interface. Without having to program with BASIC, you can quickly make measurements in several different applications. Besides the softpanel operation, you can easily perform automated measurements and analysis using the Analysis Instruction Set (AIS), which is a high level subprogram library.

Using real examples, this application note shows you how to use the high speed and superior accuracy of an HP 4142B to perfrorm high quality measurements and data analysis. A bipolar transistor, a MOSFET, and a photocoupler are evaluated.

2. FEATURES & SPECIFICATIONS

2.1 Features

■ Use HP IMA for fast measurements and easy operation.

The display of the HP IMA is made up of four pages, from setting up the measurement to displaying the measurement results. All you have to do is fill in the blanks with the necessary information (like channel names, source mode, output parameters), using a mouse or the softkeys. The measurements are made automatically. You can store the measurement setup and measurement data to a disk and easily print or plot the information later.

■ Powerful graphical analysis functions help you analyze test results quickly and easily.

With IMA, data evaluation is simple. In the graphics and analysis softpanel, you can read data or draw lines and evaluation procedures are easily recalled and edited.

The user functions of HP IMA save you time. Four user functions, which can be treated the same as measurement data, can calculate parameters during the measurement. Two user display functions calculate required parameters with marker, cursor, and line data. The graphics and analysis page also provides several powerful functions, like scaling and buffer operations.

■ AIS automates the evaluation procedure.

The Analysis Instruction Set (AIS) is a subprogram library to automate measurements. Using AIS, you can call the HP IMA softpanel which is used to monitor, change a parameter, or add an analysis. The resulting data can be incorporated as a parameter to customize your program. Therefore, the time required to create a program is drastically reduced with AIS.

■ Easy system expansion.

HP IMA consists of subprograms written in HP BASIC, which is an extremely efficient software language for developing test programs and for utilizing test equipment in your system.
It's easy to develop lab-automation or system-like process evaluations that control functions like switching matrices, probers, and capacitance meters. You can analyze the measurement data obtained from the test system on the HP IMA GRAPHICS & ANALYSIS page, making efficient use of analysis time.

2.2 Main Specifications

■ Voltage/Current sweep parameters.

VAR1:	main sweep, single or double sweep, selectable linear or logarithmic
VAR2:	subordinate linear staircase sweep
VAR1':	staircase sweep synchronized with the VAR1 sweep
CONSTANT:	every source unit can be set as a constant voltage or current source
TIME DOMAIN SWEEP:	selectable time domain when VAR1 is not set
PULSE:	every source unit can be set as a pulse source
MEASUREMENT MODES:	single, append, repeat, or manual
INTEGRATION TIME:	short, medium, or long
DISPLAY MODES:	graphics or list

■ Analysis Capabilities

USER FUNCTIONS:	up to four user functions can be defined
USER DISPLAY FUNCTIONS:	up to two user functions can be defined as numeric expressions with the marker, cursor, or line analysis data
MARKER FUNCTION:	interpolation, marker → min/max, or direct marker
CURSOR FUNCTION:	cursor → marker
LINE FUNCTION:	regression line, tangent line
SCALING FUNCTION:	auto scale, move, zoom, init scale, change scale, or reset display
BUFFER FUNCTION:	four buffers are available: store, recall, recall off, or exchange
DISPLAY FUNCTION:	part display, full display

3. BASIC OPERATION

3.1 Construction

HP IMA consists of five softpanel pages that you can use to perform measurement and analysis with easy fill-in-the-blank operation. The softpanel pages consist of the following functions:

MENU	Advances the pages.
↓ UNIT DEFFINITION	Selects the channels, assigns the source and monitor name, and specifies source modes and functions.
↓ SOURCE SET UP	Sets the output parameter for each SMU.
↓ DISPLAY MODE SET UP	Selecs the mode for displaying the measurement results.
↓ GRAPHICS & ANALYSIS	Measurement data is displayed for analysis.

Throughout this application note, ■ represents a softkey function, ▢ represents a key on the keyboard, [ ] represents a select menu key (select menu is displayed on the right side of the CRT).

When using fill-in-the-blank operation, move the field-pointer to the position you need to fill, and use the keyboard or the select menu to fill in the parameter. The field-pointer can be moved by either the keyboard arrow keys or a mouse. Select menu and softkeys can also be operated by either the keyboard or a mouse. For quickest results, we recommend using a mouse.

3.2 Measurement Example

The basic measurement procedure of HP IMA is best described by making an actual measurement. In the following example, we measure and graphically display the characteristics of a bipolar transistor connected for common emitter operation. Base-emitter voltage is swept and the base and collector currents are measured.

1) CONNECTIONS

Turn off the HP 4142B and connect the HP 16088A test fixture as shown in Figure 6(a). Set up the HP 16088A personality board as shown in Figure 6(c) and insert a transistor into the DUT socket.

2) MENU

On the MENU page, select a page number displayed on the CRT to advance through the pages. There are three ways to select the page:

1. Type the number of the desired page from the keyboard.
2. Position the field pointer on the desired page number field using the arrow keys (or mouse), and press return (or click).
3. Select the appropriate softkey from the lower display of the CRT.

In any page, if you press PREV (or NEXT) key, the display page changes to the previous (or next) page. Press NEXT key in the MENU page to change the page to the UNIT DEFFINITION page.

3) UNIT DEFINITION

On this page, we select the channels to use in the measurement (SMUs, voltage source, and voltage monitors), assign source and monitor names, specify source modes and functions, and define USER FUNCTION.
The initial set-up on this page is for general use and not used in this measurement. Enter the following sequence to change the setup to the one shown in Figure 5. Use the field pointer to define or specify each parameter.

Move the field pointer to the V NAME field of GNDU.

V E ↵ V C ↵ I C ↵ [V] [VAR1']
V B ↵ I B ↵ [V] [VAR1]

If you define a parameter in the USER FUNCTION area (shown in the lower part of the CRT), you can treat it like measurement data in your program. The parameter can even be plotted in the graph. Enter the following sequence to define a parameter in the USER FUNCTION area.

Move the filed pointer to the USER FUNCTION area.

H F E ↵ ↵ I C / I B ↵

Press NEXT to display SOURCE SET UP page.

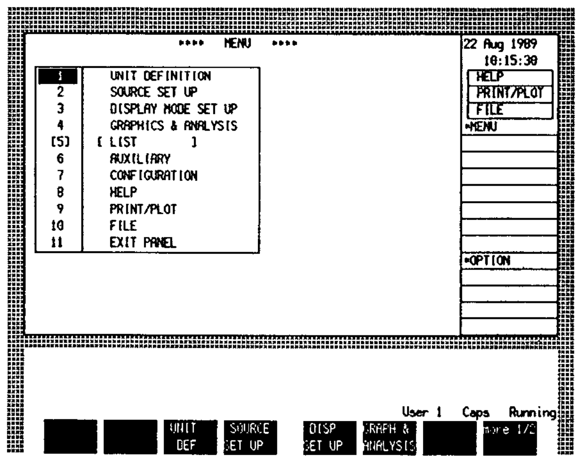


Figure 1

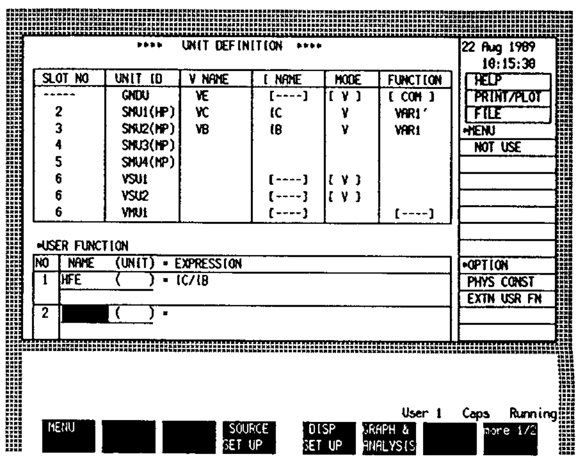


Figure 2

4) SOURCE SET UP

On this page, we set the output parameters (output voltage, current, compliance, etc.) for each SMU selected in the UNIT DEFINITION page. Note that the source names (VE, VB, and VC) already appear in the appropriate fields.

Specify Sweep mode by selecting SINGLE ( ) or DOUBLE ( ). Specify linear sweep or logarithmic sweep by selecting LINEAR or LOG in LIN/LOG. In this example, use single and linear sweep.

Next, use the keyboard to set the start value (100 mV), stop value (900 mV), number of steps (81), voltage/current compliance (5 mA), and power compliance of sweep bias. To set up the page shown in Figure 6, enter the following sequence:

Move the field pointer to the SWEEP MODE field area of VAR1.

[SINGLE] [LINEAR] [1] [0] [0] [M] [↵] [9] [0] [0] [M] [↵]
[8] [1] [↵] [5] [M] [↵] [↵] [1] [↵] [0] [↵] [3] [0] [0] [M] [↵] [↵]
[0] [↵] [1] [0] [0] [M] [↵]

After finishing the setup, press [NEXT] to advance to next page.

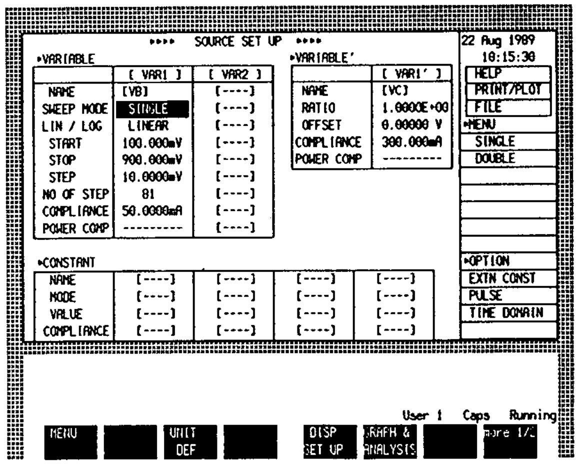


Figure 3

5) DISPLAY MODE SET UP

On this page, select the mode for displaying the measurement results. GRAPHICS and LIST mode are available for display mode. For this measurement, select GRAPHICS mode.

Assign which parameter is to be plotted along each axis by specifying the display mode (linear or logarithmic), and set the maximum and the minimum value of scaling. In this example, base voltage (V_B) is plotted along the X-axis, collector current (I_C) is plotted along the Y1 axis, and base current (I_B) is plotted along the Y2-axis.

Move the field pointer to the GRAPHICS and enter the following sequence.

[↵] [VB] [LINEAR] [0] [↵] [1] [↵] [5] [0] [M] [↵]
[IC] [LOG] [1] [F] [↵] [1] [0] [↵] [↵] [IB]
[LOG] [1] [F] [↵] [1] [0] [↵] [↵]

After finishing this setup, press [NEXT] to advance to the next page.

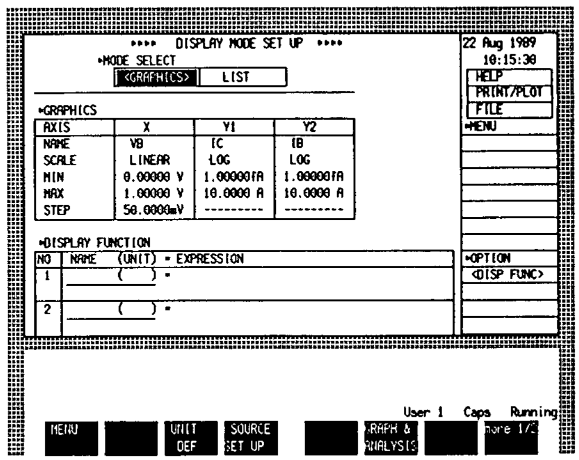


Figure 4

6) MEASUREMENT, DISPLAY, AND ANALYSIS

All measurement conditions are set and the system is ready to make measurements. Close the test fixture lid (shield the DUT from RFI and EMI sources) and press [single] keys. The measurement is made and plotted on the CRT, as shown in Figure 5. If you have a color display, the line plotted with the same color as Y1-axis is the collector current, and the line plotted with the same color as Y2-axis is the base current.

Detailed analysis can be made by selecting an extended function (SCALING, ANALYSIS, BUFFER, DISPLAY). For example, the measurement results are plotted in the best proportions by selecting [SCALING] and [auto scale]. The marker appears by selecting [ANALYSIS] and [marker]. Move the marker with the keyboard arrow keys or the mouse. Read the value of the IC that corresponds to VB. More information about detailed analysis appears in the next section.

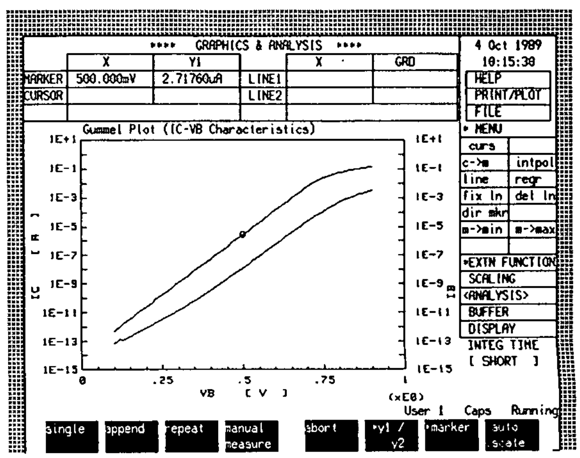


Figure 5

General Connection

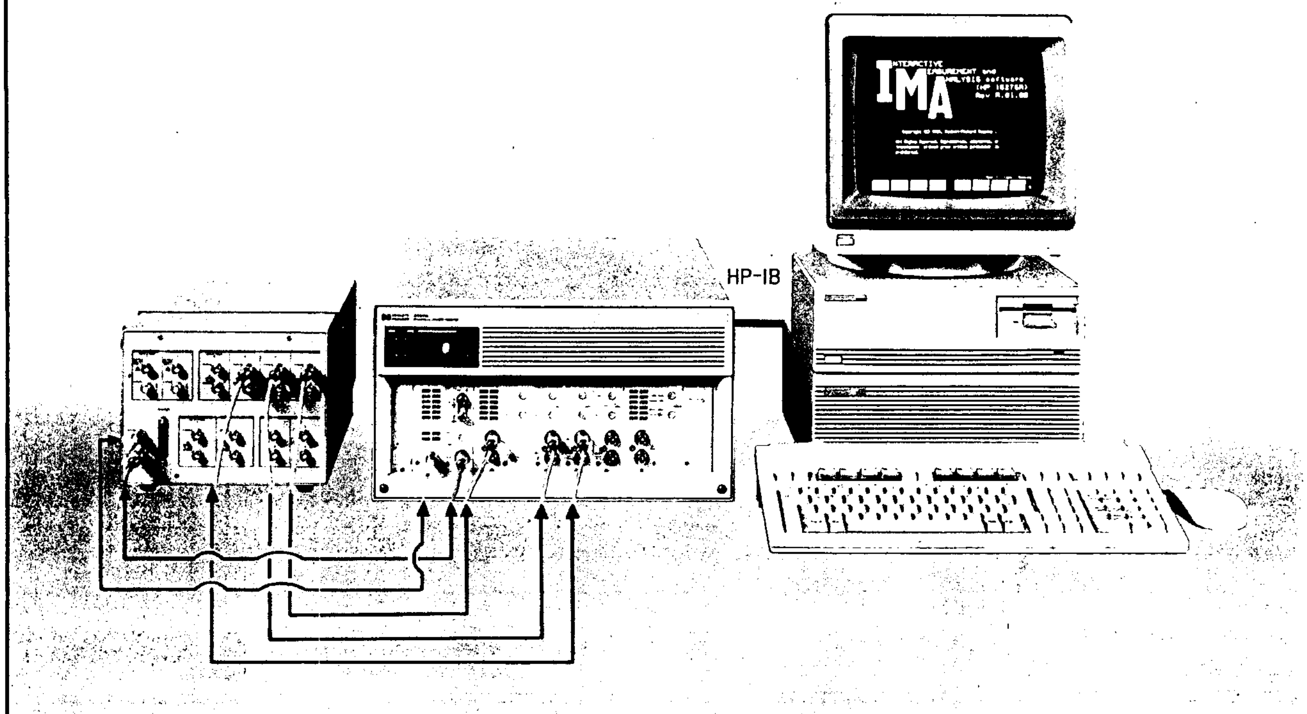


Figure 6 (a)

Connection Diagram

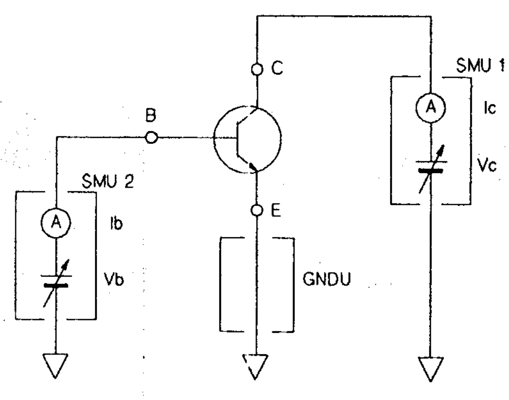


Figure 6 (b)

HP 16088A Test fixture Connection

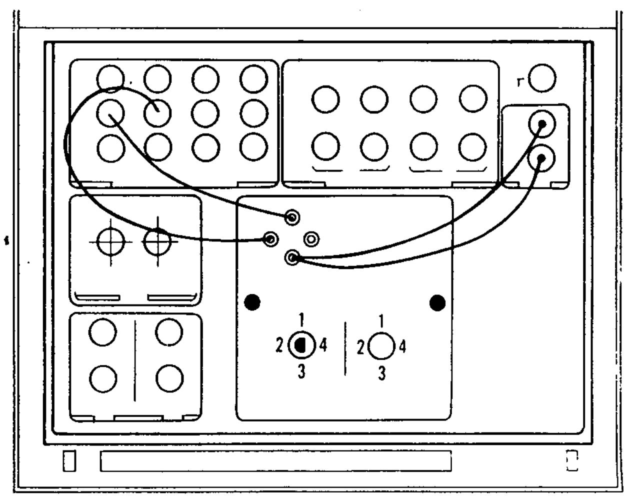


Figure 6 (c)

4. APPLICATIONS

4.1 Evaluating Bipolar Devices

Application Example 1
Static Collector Characteristics

In this example, the collector characteristics of a bipolar transistor are measured and graphically displayed. Results are analyzed to obtain early voltage (VA) and collector output resistance (rc).

Connect the DUT as shown in Figure 7 and set up the UNIT DEFINITION, SOURCE SET UP, and DISPLAY MODE SET UP pages as shown at the right. On the DISPLAY MODE SET UP page, define VA and rc by entering the following sequence.

Move the field pointer to the DISPLAY FUNCTION field.

[V][A][↵][V][↵][X][L][1][↵][R][C][↵][↵][1][/][G]
[1][↵]

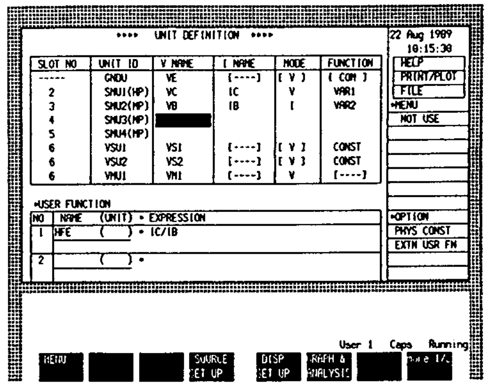
XL1: cross point of line 1 and X-axis
G1: gradient of line 1

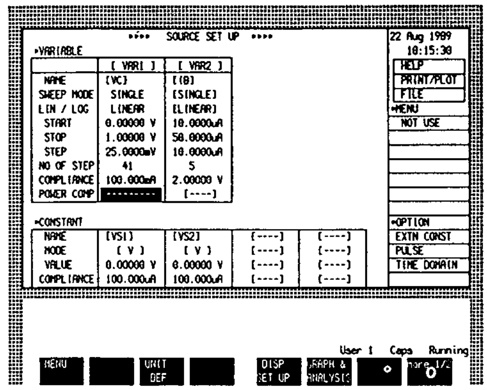
Measurement results are shown in Figure 8. Draw a regression line from point A.

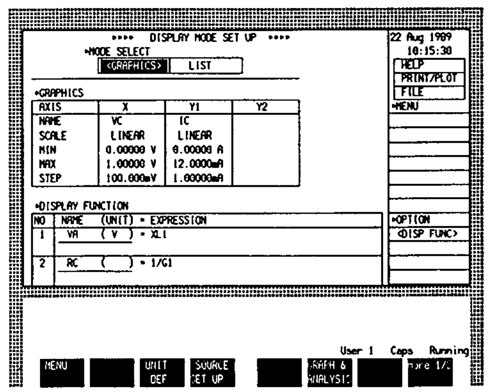
[ANALYSIS] [marker] [→] (Move the marker to point A)
[regr] [0] [↵]

You can read VA and rc directly from the above plot area. The measurement setup and results of this example are used in Example 7, so store the information to a disk by entering the following sequence:

[FILE] [SAVE] [D][_][E][X][_][1][↵]







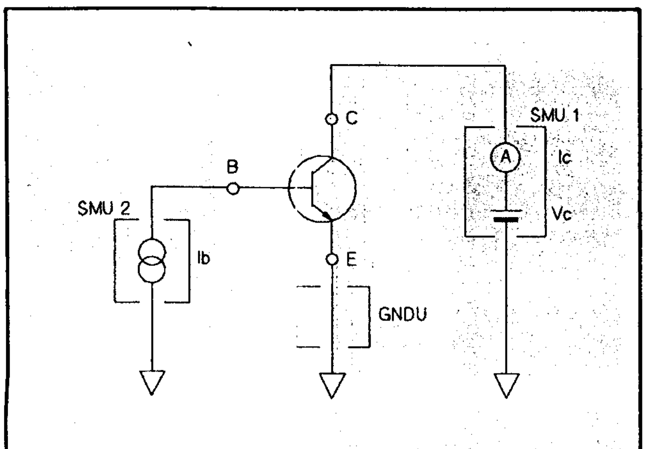


Figure 7

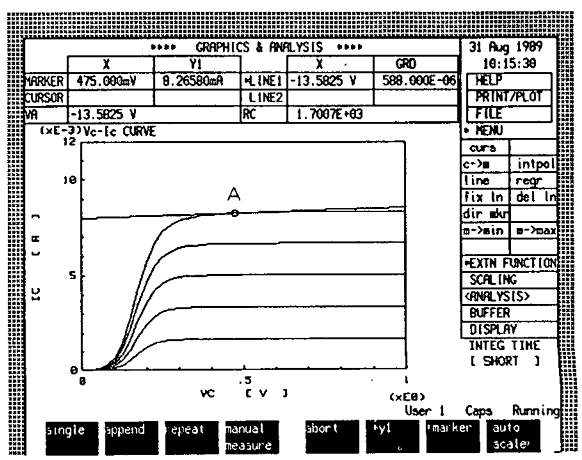


Figure 8

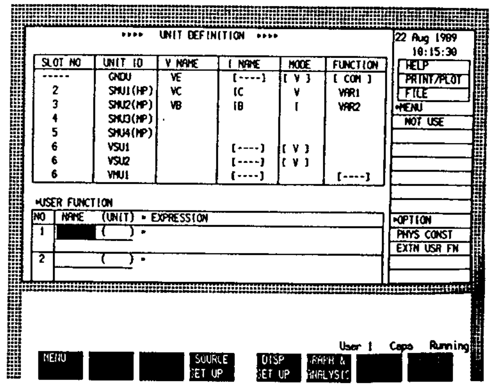
Application Example 2
Static Collector Characteristics (Pulsed sweep)

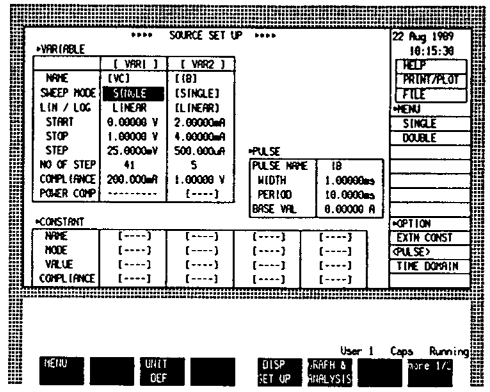
The measurement taken in Example 1 is useful when the collector current is low. When the collector current is larger than 100 mA, the heat generated by high current causes problems. Using pulsed output, Ic-Vc characteristics in the high current region can be collectively measured because thermal drift is reduced.

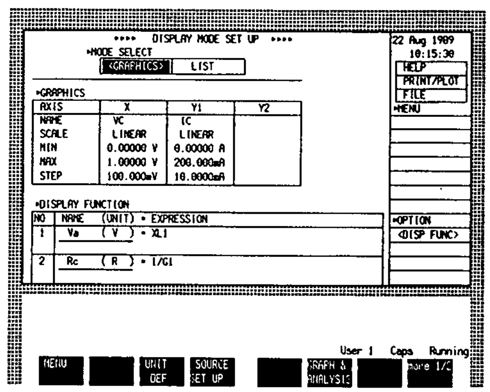
To use the pulse sweep, pulse output must be defined on the SOURCE SET UP page as follows.

[PULSE] [IB] [1] [M] [↵] [1] [0] [M] [↵] [0] [↵]

Except for the SOURCE SET UP page, the setup is the same as Example 1. Connections are the same as shown in Figure 7. Measurement results are shown in Figure 9. VA and rc are acquired by drawing regression lines from point A (shown in Example 1).







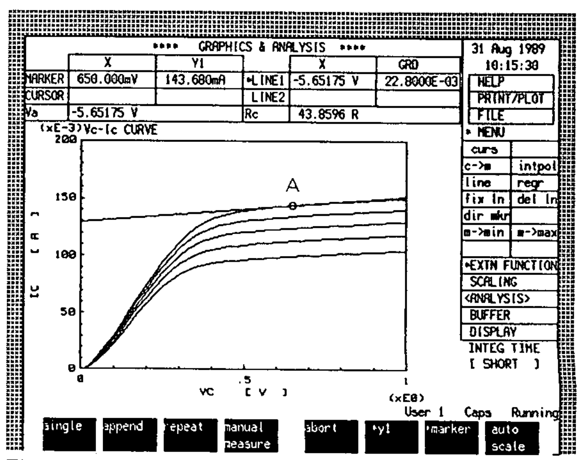


Figure 9

Application Example 3
I_C-V_B, I_B-V_B Characteristics

One of the most important steps in evaluating semiconductor parameters is measuring collector current and base current as a function of base emitter voltage. These measurements can be graphically analyzed to obtain the saturation current, collector current constant, h_{FE}-I_C characteristics, along with the base resistance and recombination current characteristics.
Connect the DUT as shown in Fiugure 10.
On the UNIT DEFINITION page, define h_{FE} as a USER FUNCTION by entering the following sequence.

[H] [F] [E] [↵] [↵] [I] [C] [/] [I] [B]

On the DISPLAY MODE SET UP page, define r_b as a DISPLAY FUNCTION by entering the following sequence.

[R] [B] [↵] [↵] [(] [X] [M] [−] [X] [C] [)] [/] [Y] [2] [M] [↵]
[I] [1] [↵] [A] [↵] [Y] [L] [1] [↵]

XM: marker x coordinate   XC: cursor x coordinate
Y2M: marker Y2 coordinate
XL1: line 1 selected y axis intersection
The measurement results are shown in Figure 11. The upper characteristics curve represents collector current, which is usually expressed as

$$I_C = I_1 \exp\left(q(V_B - I_B r_b)/kT\right) + I_2$$

I_1: collector current constant I_2: saturation current
r_b: equivalent base resistance
Connect points A and B with a straight line, which is represented by the above equation. In this case, I_2 can be ignored. The Y1-axis intercept data can be read directly as I_1 (I_1 = 12.3fA).
To obtain r_b, move the cursor to point D where the collector current is the same as that at point C.
Calculate r_b by dividing the voltage difference between D and C by the base current at point C (i.e. the base current at point E).
Read r_b in the RB field shown above the plot area.
The following is the operation related above.

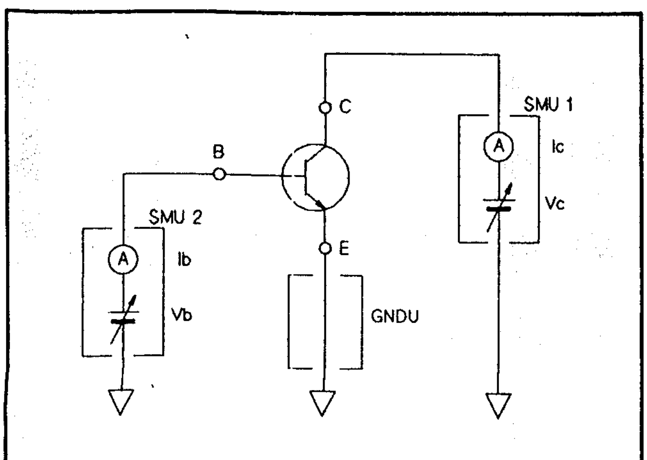


Figure 10

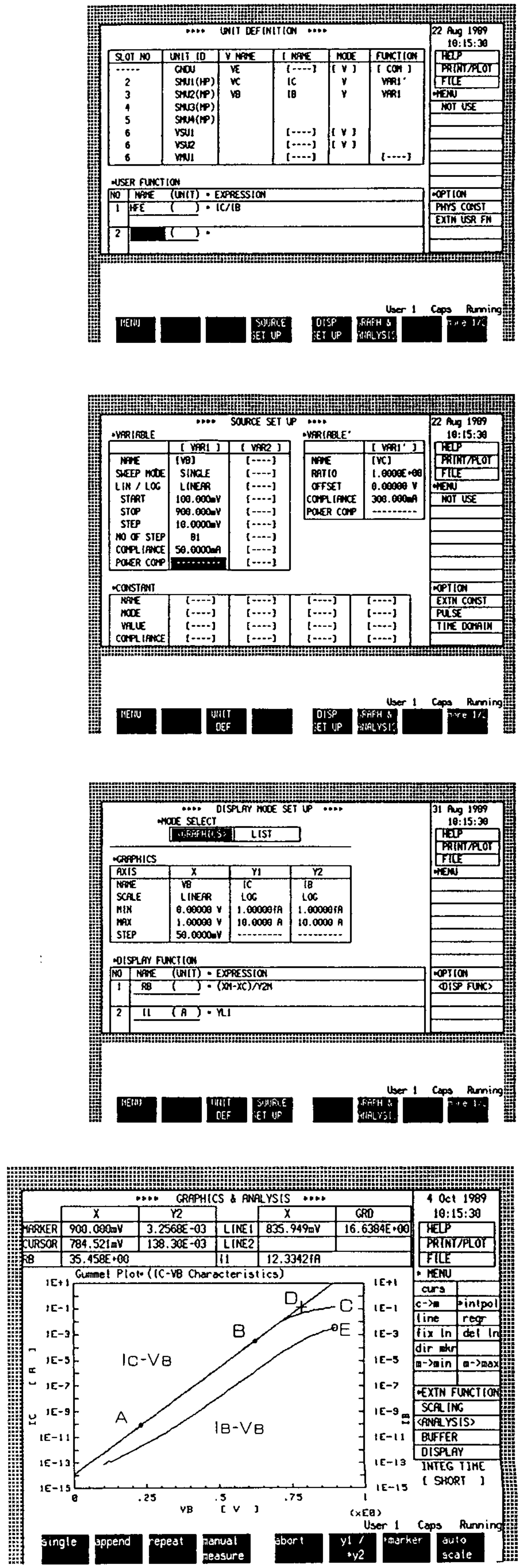


Figure 11

ANALYSIS marker → (Move the marker to point A)
c–>m marker → (Move the marker to point B)
line fix ln → (Move the marker to point C)
curs c–>m ← (Move the cursor to point D by arrow keys)
marker yl/y2 → (Move the marker to point E)

We use the measurement setup and results of this example again in Example 6. Store the information by entering the following sequence.

FILE SAVE D _ E X _ 3 ↵

Application Example 4
Emitter Resistance

The series resistance in the emitter (re) of a bipolar transistor can be determined by simulating the base current and measuring the voltage between the collector and emitter. The results are the inverse of the characteristics curve gradient. The connection for this setup is shown in Figure 12.
The collector voltage (Vc) is shown on the X-axis, and the base current (IB) is shown on the Y-axis. In the DISPLAY MODE SET UP page, define Re to display on the GRAPHICS & ANALYSIS page.

R E ↵ ↵ 1 / G 1 ↵

Figure 13 shows the measurement results. Select two points on the linear region of the graph, and connect them with a straight line by entering the following sequence.

ANALYSIS marker → or ← (Move the marker to point A)

c–>m → or ← (Move the marker to point B) line

Read re directly from the Re field above the plot area.
The value for re in this example is 0.77Ω.

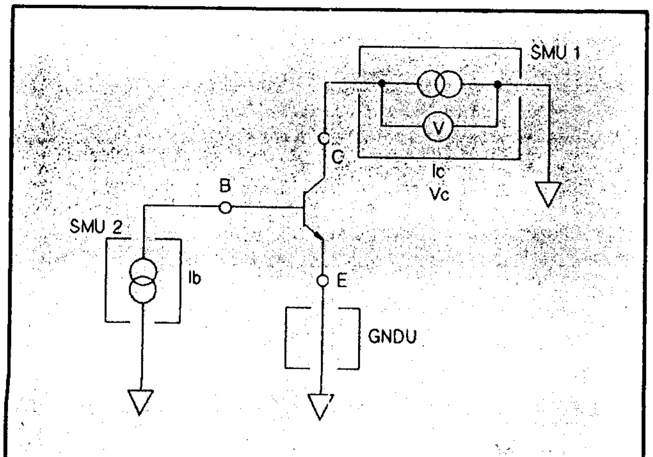
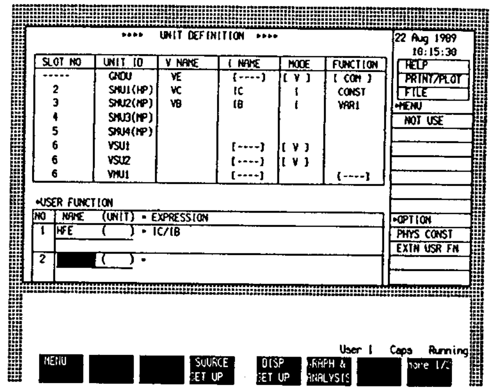
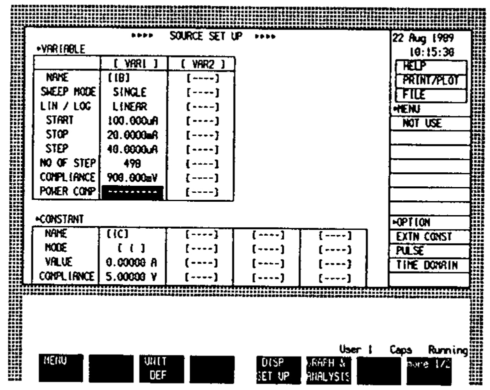
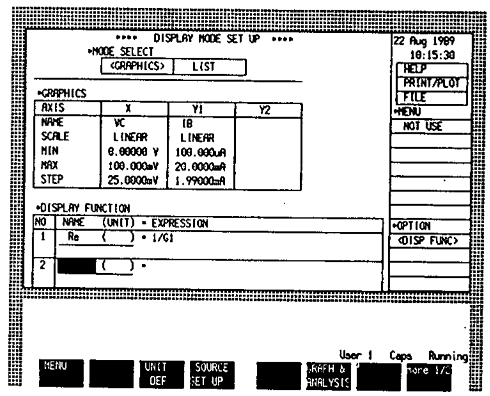


Figure 12







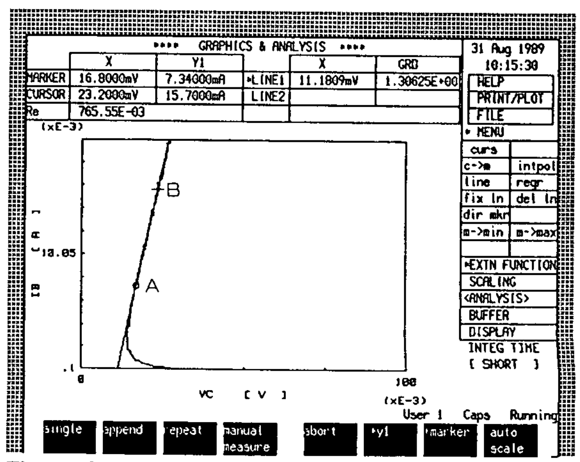


Figure 13

Application Example 5
Collector Resistance

Measuring series resistance of the collector (r_C) in a bipolar transistor is similar to measuring emitter resistance (shown in Example 4). In this example, current is applied to the base and collector, and the collector voltage (Vc) is measured.

To characterize I_B-Vc, two collector current values (I_{C1} and I_{C2}) are measured. The relationship between the I_{C1}-I_{B1} and I_{C2}-I_{B2} points on the characteristic curve are equal ($I_{C1}/I_{B1} = I_{C2}/I_{B2}$). Measuring the Vc voltage difference (ΔV) between these points provides the values required for obtaining collector resistance, which is calculated as $r_C = \Delta V/(I_{C2}-I_{C1})$.

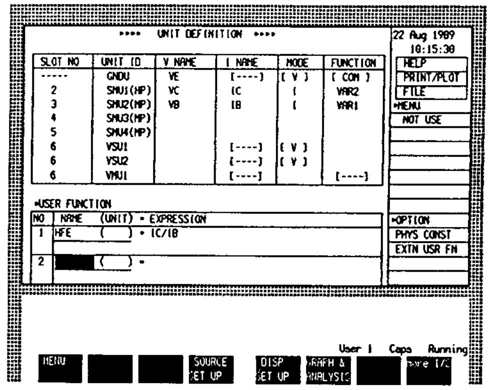
Connect the DUT as shown in Figure 14.

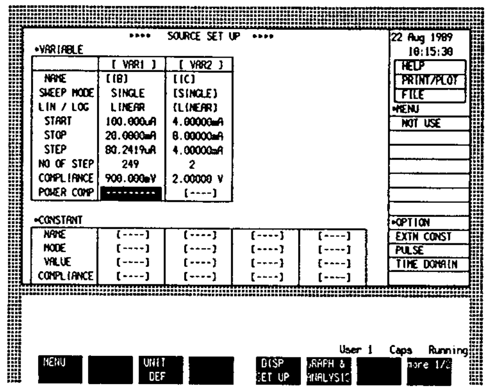
In the DISPLAY MODE SET UP page, define r_C by entering the following sequence.

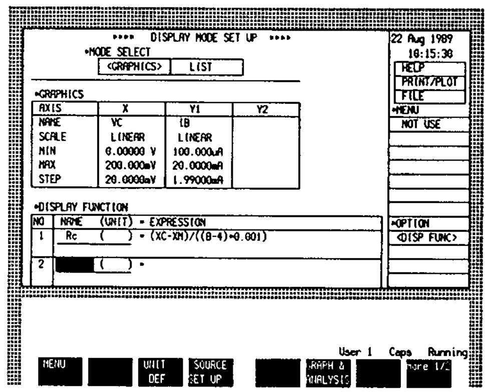
[R] [C] [↵] [↵] [(] [X] [M] [−] [X] [C] [)] [/] [(] [(] [8] [−] [4]
[)] [*] [0] [.] [0] [0] [1] [)]

Figure 15 shows the measurement results.

In this example, I_{C1} = 4 mA and I_{C2} = 8 mA. Move the marker to point A and the cursor to point B, so that I_B is the same as point A. You can read r_C directly from the r_C field above the plot area. In this example r_C = 2.01 Ω.







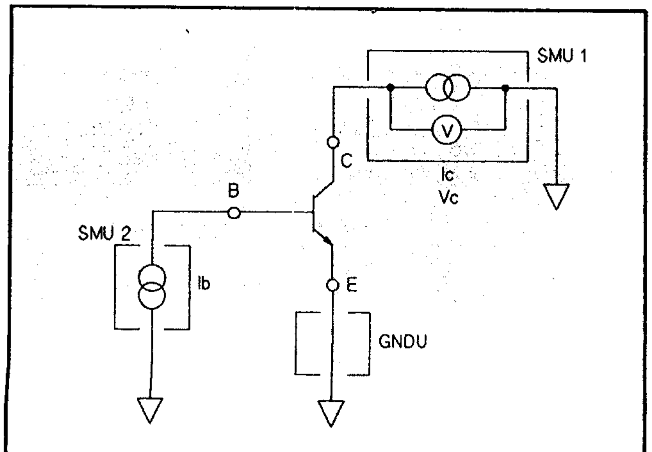


Figure 14

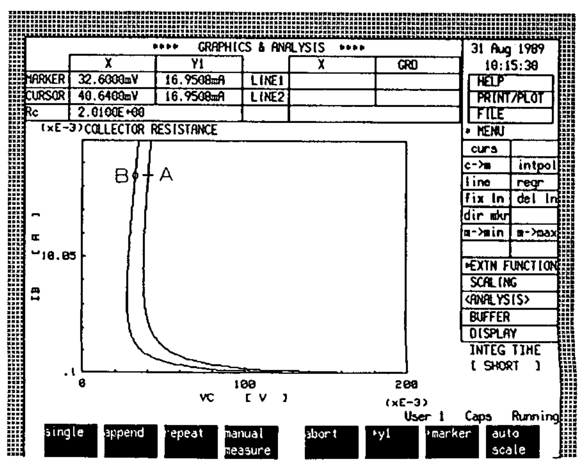


Figure 15

Application Example 6
h_{FE}-Ic

By making a few simple changes in the DISPLAY MODE SET UP page in Example 3, you can quickly get the h_{FE}-Ic characteristics of the transistor.

Enter the following sequence to recall the measurement setup of Example 3:

[FILE] [GET] [D] [_] [E] [X] [_] [3]

Set the DISPLAY MODE SET UP page shown below to plot Ic along to the X-axis, and to plot h_{FE} along to the Y-axis.
Both Ic and h_{FE} are plotted logarithmatically.
The measurement results are shown in Figure 16. You can quickly examine the variation of h_{FE} over the broad range of Ic with the graph. If the marker is used, you can read h_{FE} at various values of Ic directly from the display. The h_{FE} decay constant can be read directly from the display using line function to draw a line tangent to the linear portion of the h_{FE}-Ic curve, as shown in Figure 16. The gradient of that line is equal to the decay cosntant. This is useful for detailed evaluation of a device in which the recombination current can't be neglected (for example, a very low noise transistor).

This application can be extended to obtain temperature dependence of the h_{FE}, which can be acquired by measuring h_{FE}-Ic during temperature change.

Application Example 7
List Display

The measurement results can be displayed in a list format. To do this, select LIST in MODE SELECT on the DISPLAY MODE SET UP page.

In this example, the measurement results of Example 1 are displayed in list format. Enter the following sequence to recall the measurement setup and the data of Example 1.

On DISPLAY MODE SET UP PAGE

[FILE] [GET] [D] [_] [E] [X] [_] [1] [↵]

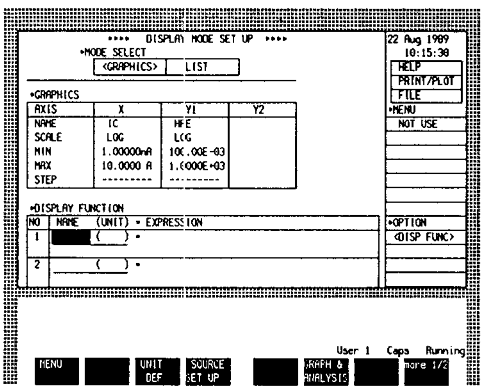
You can easily input the parameter by clicking the select menu located at the right side of the display.

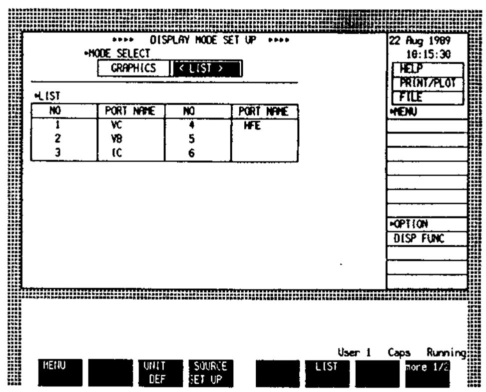
In this example, Vc, V_B, Ic, and h_{FE} are displayed.
Enter the sequence below.

Select LIST with the field pointer

[V_C] [V_B] [I_C] [h_{FE}] [NEXT] [single]

The example of list display is shown in Figure 17.





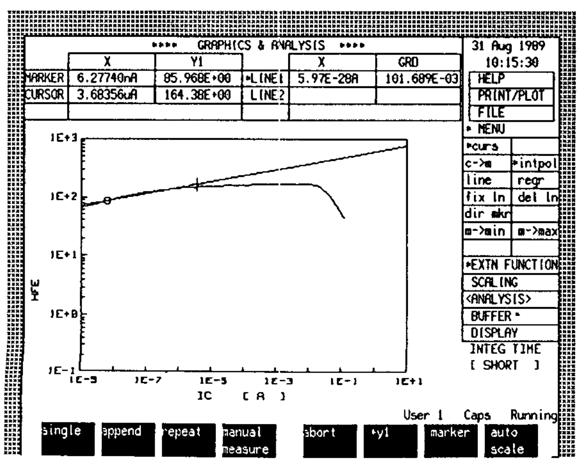


Figure 16

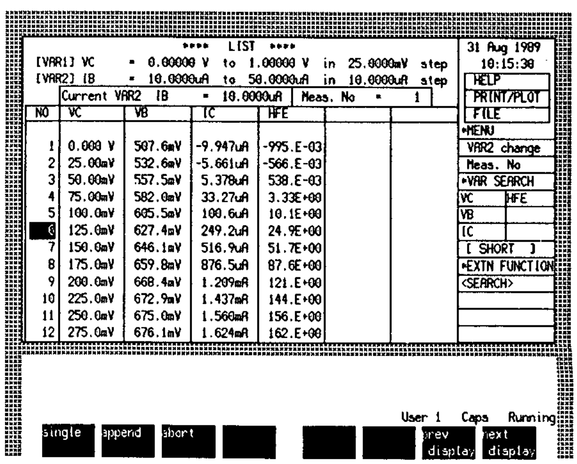


Figure 17

4.2 Evaluating MOS Devices

Application Example 8
Measuring Threshold Voltage (Vth) of MOSFETs

The threshold voltage of an enhancement type MOSFET is defined as the gate voltage that is required to get a predetermined drain current. In this example, Vth is the gate voltage required for 10μA of drain current.

Connect the DUT as shown in Figure 18. VAR1 source sweeps the gate voltage (V_G), and VAR2 source sweeps the source substrate voltage (V_{SB}). Gate voltage is linearly plotted along the X-axis and drain current (I_D) is plotted along the Y-axis. Measurement results are shown in Figure 19.

The left-most curve shows the drain current variation when substrate voltage is constant at 0V. To obtain Vth, move the marker along the left-most curve until $I_D = 10\mu A$ and read the gate voltage (X-axis) displayed above the plot area.

Because of the body effect in the device, threshold voltage changes as substrate voltage changes. Thus, if $Vth|_{V_{SB}=0}$ is known, Vth at any value of V_{SB} can be calculated as:

$$Vth = V_{T0} - \gamma\,[(V_{SB} + 2\varphi_F)^{1/2} - (2\varphi_F)^{1/2}]$$

V_{T0}: threshold voltage ($V_{SB} = 0$)
γ: body effect coefficient, φ_F: the Fermi potential.

You can also get the body effect coefficient from this equation.

We use this measurement result in section 4, so enter the following sequence to store the information as "B_MOS1" to the disk.

[FILE] [SAVE] [B] [_] [M] [O] [S] [1] [↵] [EXIT]

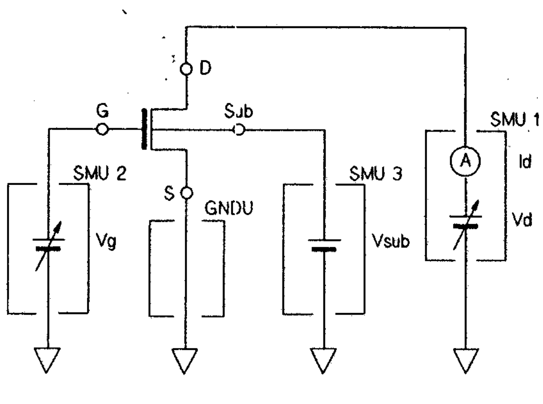


Figure 18

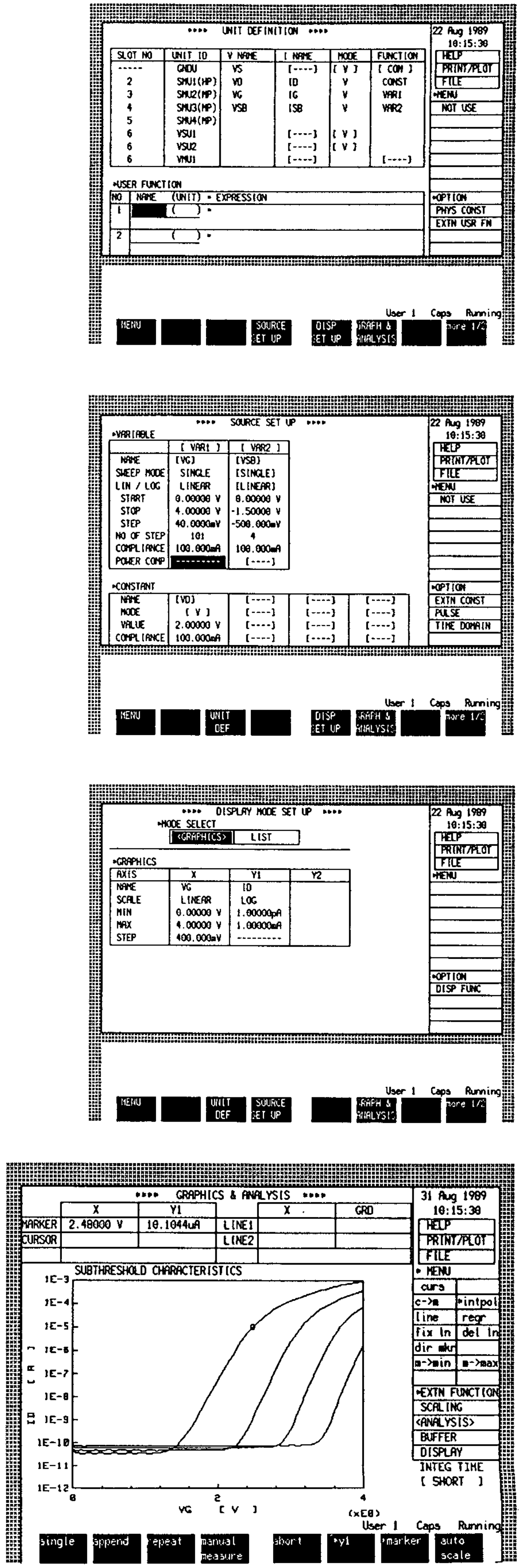


Figure 19

Application Example 9
Measuring Threshold Voltage (Vth) of MOSFETs 2

A frequently used method of measuring threshold voltage of a MOSFET is to bias the device so that the gate and drain are always the same potential. The characteristics are measured in the saturation region.
Drain current in the saturation region is calculated as:

$$I_D = \beta(V_G - V_{th})^2$$

β: gain factor (= $-\frac{1}{2}$ ($\mu \varepsilon_{ox} W/L$) t_{ox})
By taking the square root of both sides of the I_D equation, we find that the relationship between $\sqrt{I_D}$ and V_G is linear. A slope of $\sqrt{I_D}$ crossing the x-aixs is the threshold voltage. Thus,

$$\sqrt{I_D} = \sqrt{\beta}\,(V_G - V_{th})$$

The connection is shown in Figure 20. On the UNIT DEFINITION page, to insure that the gate and drain voltages are equal throughout the measurement, set VAR1′ as the gate bias and set VAR1 as the drain bias. Specify VAR1′ as the ratio of 1 in the VARIABLE′ AREA, which is displayed in the SOURCE SET UP page. On the UNIT DEFINITION page, define the user function as follows:

SQR _ ID = SQRT (ID)
PEAK = DELTA (SQRT(ABS(ID)))/DELTA (VG)

The later expresses the differential coefficient of $\sqrt{I_D}$ vs. V_G. Define the display function in the DISPLAY MODE SET UP page as follows:

BETA = CO1^2

Measurement results are shown in Figure 21. To obtain Vth and β, draw a regression line around point A. The X intercept is Vth. The β is shown directly above the plot area. We use this display data again in Example 12 (as in Example 8), so store this information to the disk as "B_VTH".
We also use this measurement setup in Section 4, so store it on the disk as "P_VTH".

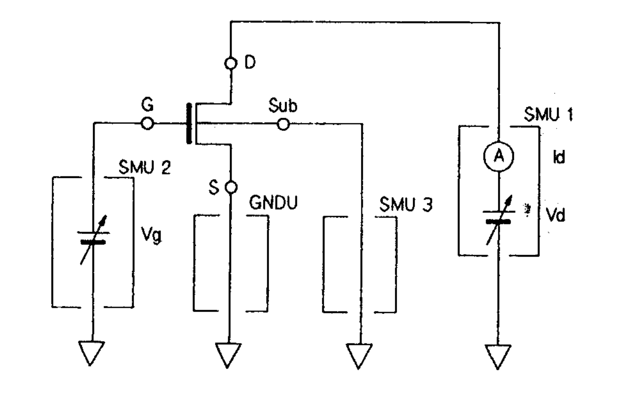


Figure 20

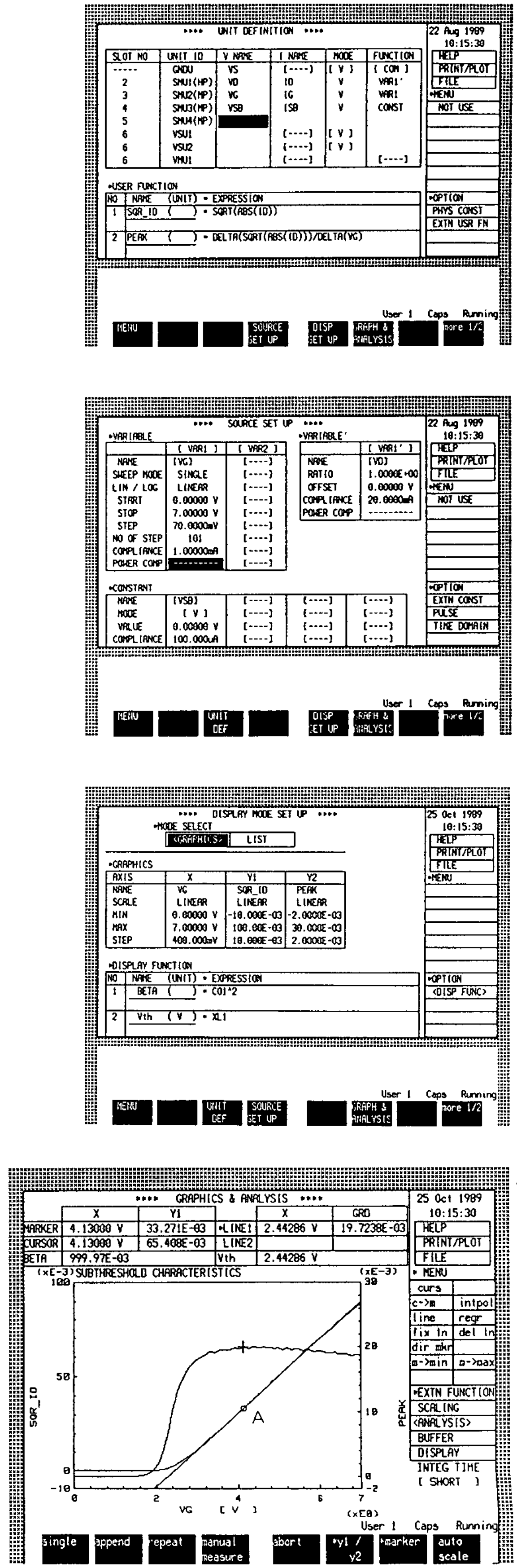


Figure 21

Application Example 10
Measuring Transconductance (gm) of MOSFETs

The transconductance of a MOSFET is defined as the ability of the device to vary drain current (output) in response to gate voltage (input) variations, with drain-source voltage constant. In equation form:

$$gm = \left.\frac{\Delta I_D}{\Delta V_G}\right|_{V_D}$$

In this example, we measure I_D at five different values of drain voltage and use the user function to calculate and plot gm.

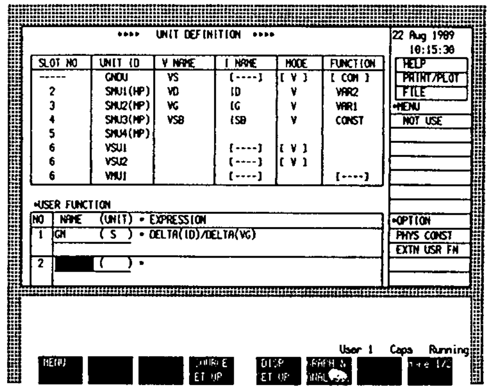
gm is measured sweeping drain voltage ranging from 0.5V to 2.5V by 0.5V steps. It is plotted along the Y-axis and the drain voltage is plotted along the X-axis.

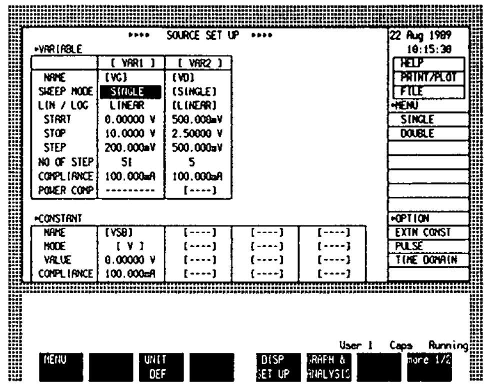
Define the user function as:

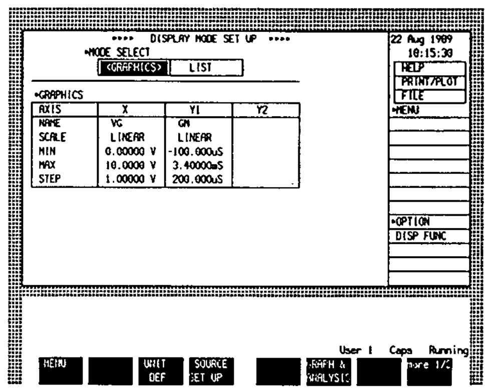
GM = DELTA (ID)/DELTA (VG)

The connection is shown in Figure 20. Measurement results are shown in Figure 22. The marker can be used to obtain a direct read-out of gm at any bias point. The threshold voltage, Vth, can be obtained by drawing the line shown in Figure 22 and reading the X intercept value.

As in Example 8 and 9, store this information on the disk as "B_MOS3".







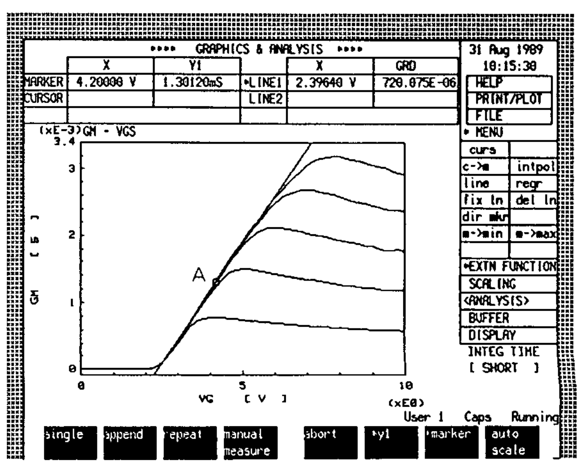


Figure 22

Application Example 11
Measuring Channel Conductance (Gds) of MOSFETs

Channel conductance is one of most important parameters used in the design of MOSFET analog switching circuits. In a MOSFET biased for linear operation, Gds is defined as the ratio of drain current ID to drain voltage VD when VD is near zero. In equation form:

$$Gds = \left.\frac{I_D}{V_D}\right|_{V_D \to 0} = 2\beta (V_G - Vth)$$

During measurement, the drain must be held at 50mV in order to operate the device in the linear region. Gate voltage V and substrate voltage Vs is swept, and drain current ID is measured. Define the user function as:

GDS = ID/VD

The connection is shown in Figure 20.
The measurement results are shown in Figure 23. The marker can be used to obtain direct read-out of channel conductance at any value of gate voltage. For example, moving the marker along the V_{SB} = 0V curve until V_G = 8V obtains a Gds of 4.93mS.

As with Examples 8 and 10, store the information on the disk as "B_MOS4".

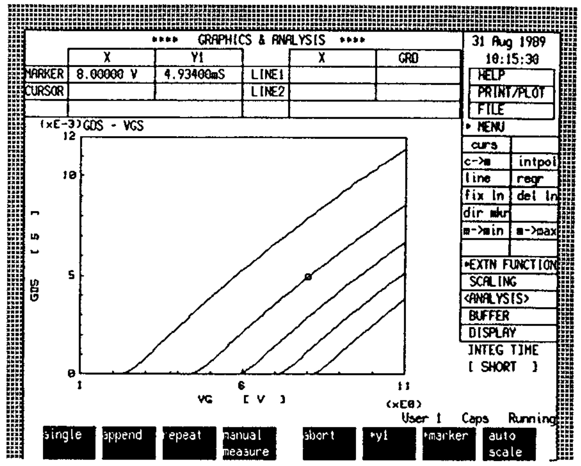
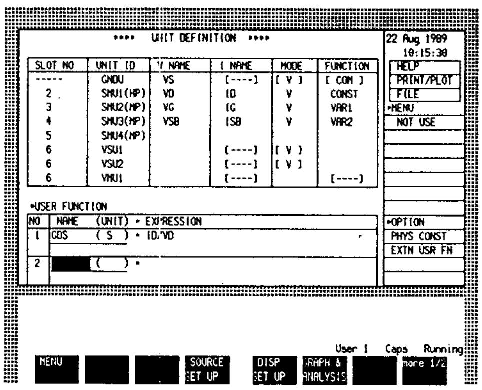
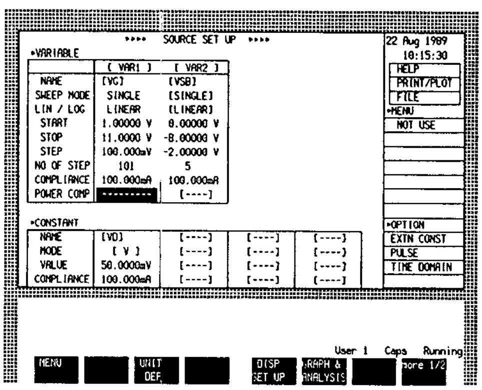
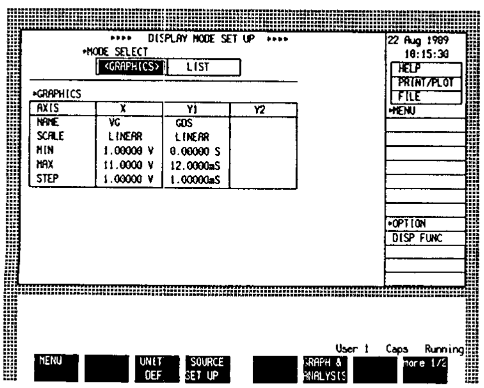


Figure 23







Application Example 12
Buffer Operation

Up to four measurement results can be displayed at the same time using the HP IMA buffer. In this example, we display the measurement results of Example 8-11 at the same time.
First, enter the following sequence to recall the data which is stored in Example 11, and store it to the buffer. Enter the following sequence to store B_MOS4 (the data of Example 11) to buffer 4.

[FILE] [GET] [B] [_] [M] [O] [S] [4] [↵] [BUFFER]
[STORE] [4] [↵]

Next, recall the data in B_MOS3, which you stored in Example 10. Store it the same way as B_MOS4 was stored. Recall the data in B_MOS2 and B_MOS1 and store it to buffer 2 and buffer 1. Then, enter the following sequence.

[DISPLAY] [part display]

The results are shown in Figure 24. If you use the buffer operation and user function at the same time, you can analyze a lot of information from only one measurement.

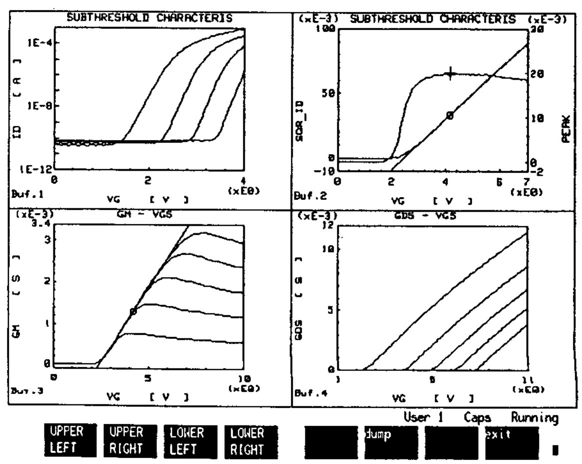


Figure 24

4.3 Evaluating a Photocoupler

In advanced electrical devices, photocouplers are being used more and more as isolators for I/O interfaces or in power supplies.

In this example, input current vs. output current and CTR (Current Transfer Ratio: = Io/If × 100%) characteristics, which correspond to the gain of the photocoupler, are evaluated.

Input current (If) is plottted along the X-axis, output current (Io) is plotted along the Y1-axis. CTR is plotted along the Y2-axis. The connection is shown in Figure 25 and the measurement results are shown in Figure 26.

You can quickly evaluate changes in CTR and read the input current of CTR by using the marker function.

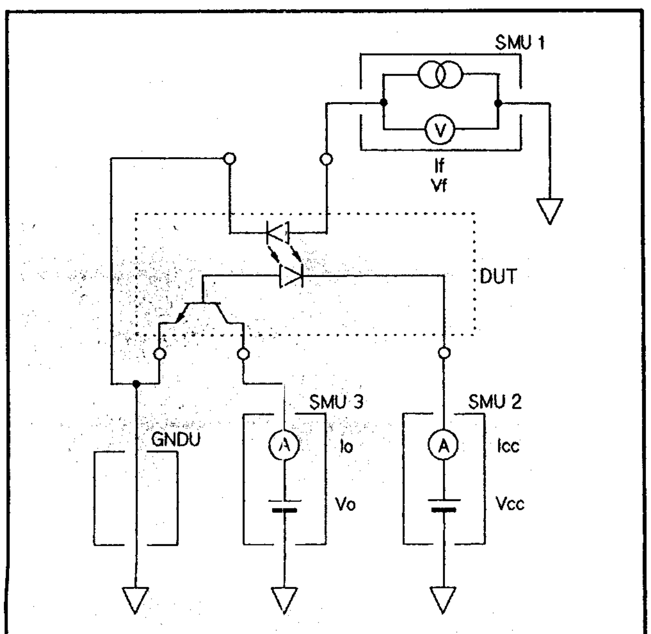


Figure 25

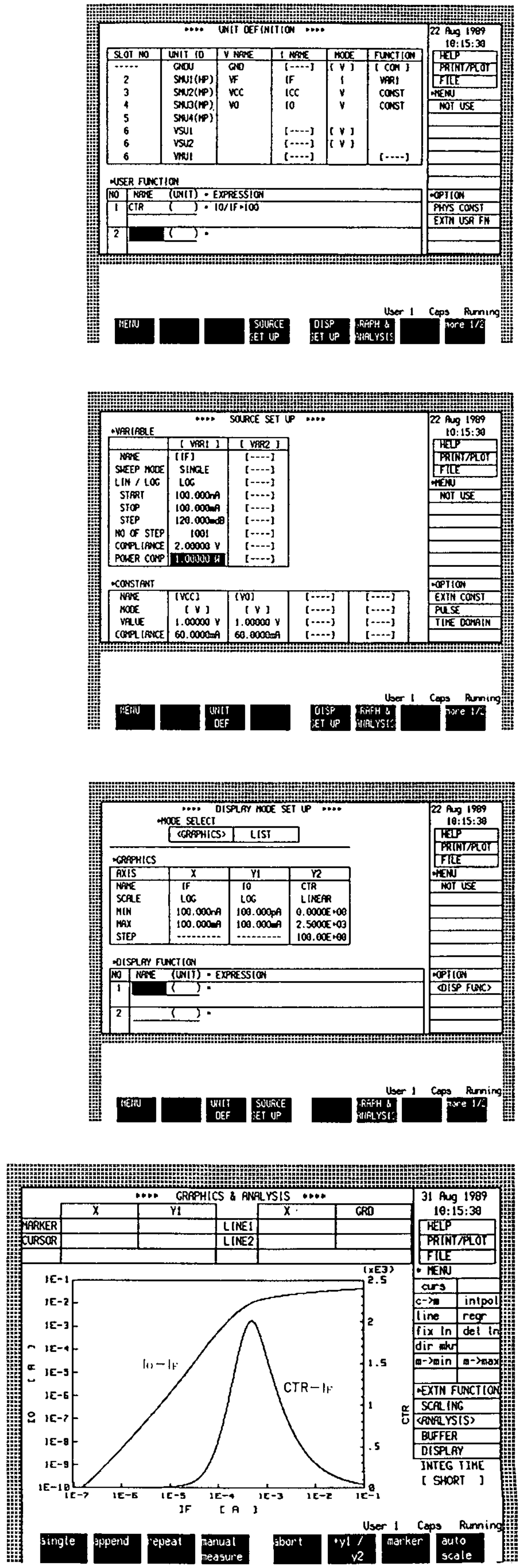


Figure 26

5. Analysis Instruction Set (AIS)

You can easily create a fully automated measurement and analysis system by combining custom code with AIS subroutines. On this page, we examine the sample program shown in Figure 27, which picks up Vth automatically from the $\sqrt{I_D}$-V_G characteristics of a MOSFET.

Create the program in edit mode, link[*1] subprograms, and press **RUN** . The measurements and analysis are automatically made.

The sample is explained briefly here.

1) Recalls the program stored as "P_VTH" and makes measurements and analysis four times.

2) Connects a device, makes a measurement, and changes the scale to the optimum scale.

3) Writes the display title, selects the measurement curve to analyze, and checks the gate voltage for a 10 mA drain current.

4) Finds the point where the gradient of the I_D is maximum, draws a regression line from that point, and picks up Vth from the cross point of graident lire and x-axis.

5) Stores the measurement results and analysis data to the disks and dumps the analysis display to a printer or plotter.

6) Displays the four measurement results in four screen divisions and halts the procedure.

---

*1 There are two ways to link subprograms:

1. Without a hard disk.

After creating the program, press **LINK AIS** .

2. With a hard disk. (This is the quickest way).

After creating the program, run the following commands:

LOADSUB ALL FROM "IMA_SYSTEM"

LOADSUB ALL FROM "AIS"

(Make an "IMA_SYSTEM" file in advance. Refer to the operation manual.)

```
10    OPTION BASE 1
20    K=4
30    DIM Vth(4),D_ana(14)
40    Set_printer(701,2)
50    Init_ais
60    Get_f("P_VTH:,700,1")
70    !                                                        (1)
80    FOR Dut=1 TO K
90      INPUT "MEASUREMENT START, CONNECT DUT THEN PRESS RETURN",Ok$
100     Measure                                                (2)
110     Auto_scale
120     Disp_graph(0,"Vth MEASUREMENT"&VAL$(Dut))
130     Select_curve(1)                                        (3)
140     Search_data(2,SQRT(1.0E-5),Vg,Y)
150     !
160     Loop_p=0
170     Gradl=0
180     Reg_coef=0
190     Step_v=.05
200     LOOP
210       Draw_regress(1,Vg+Step_v*Loop_p,3)
220       Vth(Dut)=D_ana(5)                                    (4)
230       Get_ad(D_ana(*))
240     EXIT IF D_ana(7)<Gradl
250       Gradl=D_ana(7)
260       Reg_coef=D_ana(13)
270       Loop_p=Loop_p+1
280     END LOOP
290   !
300     Save_f("B_VTH"&VAL$(Dut))
310     Store_buf(1,5-Dut)
320     !
330     NEXT Dut                                               (5)
340     !
350     FOR J=1 TO K
360       OUTPUT 701;"Vth"&VAL$(J);" ";PROUND(Vth(J),-3);"(V)"
370     NEXT J
380     !
390     Disp_graph(1)                                          (6)
400     !
410     END
```

Figure 27

HEWLETT PACKARD

For more information, call your local HP sales office listed in your telephone directory or an HP regional office listed below for the location of your nearest sales office.

United States:
Hewlett-Packard Company
4 Choke Cherry Road
Roickville, MD 20850
(301) 670-4300

Hewlett-Packard Company
5201 Tollview Drive
Rolling Meadows, IL 60008
(312) 255-9800

Hewlett-Packard Company
5161 Lankershim Blvd.
No. Hollywood, CA 91601
(818) 505-5600

Hewlett-Packard Company
2015 South Park Place
Atlanta, GA 30339
(404) 955-1500

Canada:
Hewlett-Packard Ltd.
6877 Goreway Drive
Mississauga, Ontrario L4V1M8
(416) 678-9430

Australia/New Zealand:
Hewlett-Packard Australia Ltd.
31-41 Joseph Street
Blackburn, Victoria 3130
Melbourne, Australia
(03) 895-2895

Europe/Africa/Middle East:
Hewlett-Packard S.A.
Central Mailing Department
P.O. Box 529
1180 AM Amstelveen
The Netherlands
(31) 20/547 9999

Far East:
Hewlett-Packard Asia Ltd.
22/F Bond Centre
West Tower
89 Queensway
Central, Hong Kong
(5) 8487777

Japan:
Yokogawa-Hewlett-Packard Ltd.
29-21, Takaido-Higashi 3-chome
Suginami-ku, Tokyo 168
(03) 331-6111

Latin America:
Latin American Region Headquarters
Monte Pelvoux Nbr. 111
Lomas de Chapultepec
11000 Mexico, D.F. Mexico
(905) 596-79-33

December 1, 1989
Printed in Japan
5950-2396