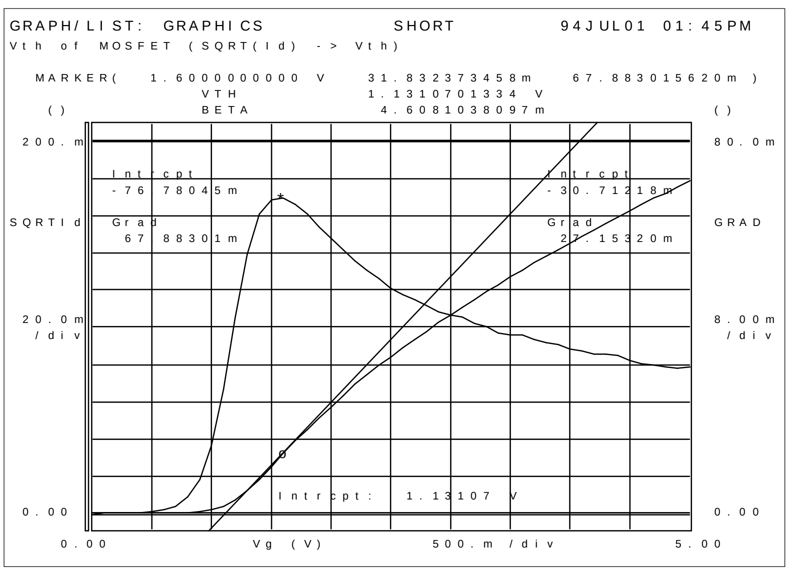
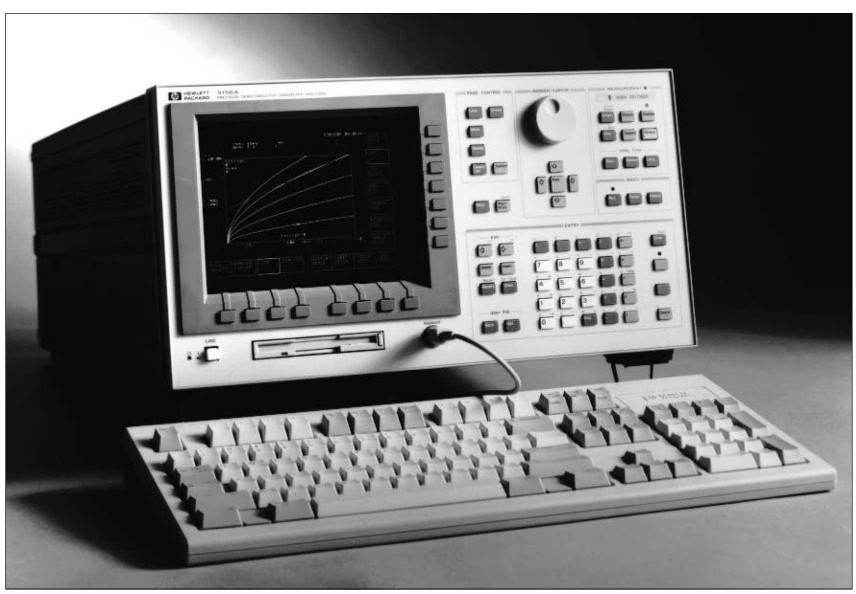
Automated Extraction of Semiconductor Parameters Using the HP 4155A/4156A

Application Note 4156-2

HP 4155A/4156A Semiconductor Parameter Analyzer





Introduction

To improve the efficiency of process evaluation and characterization of semiconductor devices, automation of semiconductor test is required. However, analysis of the measured data and extraction of important parameters are difficult to automate. This application note shows you how to automate extraction of parameters using the unique auto analysis function of the HP 4155A/4156A semiconductor parameter analyzers, using the measurement of threshold voltage as an example.

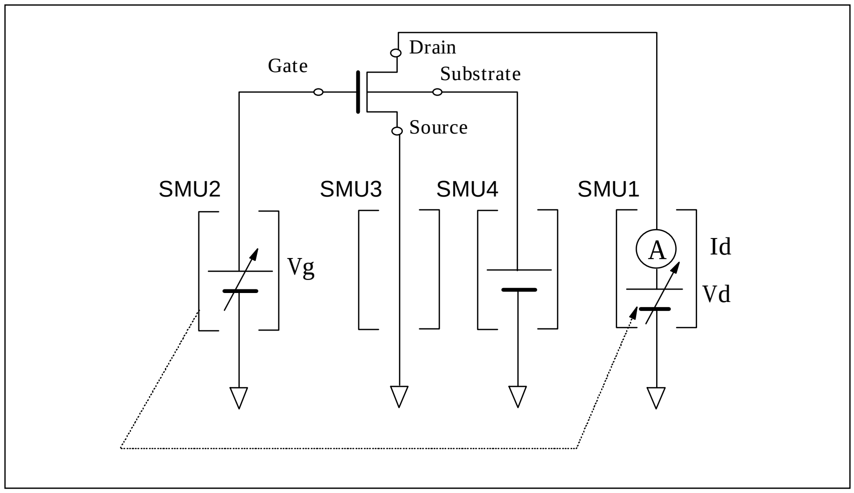


Figure 1. Connection Diagram

CHANNELS: CHANNEL DEFINITION 94JUL01 01:44PM
Vth of MOSFET (SQRT(Id) -> Vth)

* MEASUREMENT MODE
SWEEP

* CHANNELS

MEASURE					STBY
UNIT	VNAME	INAME	MODE	FCTN	
SMU1: MP	Vd	Id	V	VAR1'	
SMU2: MP	Vg	Ig	V	VAR1	
SMU3: MP	Vs	Is	COMMON	CONST	
SMU4: MP	Vsb	Isb	V	CONST	
SMU5: MP					
SMU6: MP					
VSU1		-------			
VSU2		-------			
VMU1		-------		-----	----
VMU2		-------		-----	----
PGU1		-------			
PGU2		-------			
GNDU		-------			----

SERIES RESISTANCE
0 ohm
0 ohm

Figure 2. CHANNEL DEFINITION Page

Current problems

Using the HP 4145B, you can sequentially make some measurements using ASP (auto sequence program). ASP simply executes one test after another without any breaks. To perform analysis on data after a test, you have to pause the ASP program, manually move the marker and cursors, draw lines, then continue the program.

Moreover, if you want to transfer analyzed data to a computer, you must spend time inputting the data manually. Or you may need to develop programs to control the instrument and analyze data.

Automation of data analysis using the HP 4155A/ 4156A

The HP 4155A/4156A semiconductor parameter analyzer provides the following new functions that let you analyze data and extract parameters automatically and efficiently:

User functions

You can specify up to 6 user functions. In the user defined functions, you can use 14 built-in math functions, measurement data, and read out functions for the calculation. Calculated variables can be displayed and analyzed the same as measured data.

For example, the calculation of transconductance (gm) of a MOSFET is expressed as the following simple expression:

gm [S] = DIFF(Id, Vg)

Id: Drain current

Vg: Gate voltage

DIFF: The function which returns the differential coefficient

The above equation means Delta (Id) divided by Delta (Vg).

Auto analysis function

With a simple setup, you can predefine exactly how the marker and lines will be automatically drawn on the measurement curve.

Read out function

The read out functions are for displaying various values related to the marker, cursors or lines. You can display parameters such as gradients, X and Y intercept of a line, and X and Y coordinates of the marker. You are not limited to displaying just parameters from the built-in display functions. You can use the read out functions in the user defined functions. You can also transfer those parameters to the internal HP Instrument BASIC or an external controller.

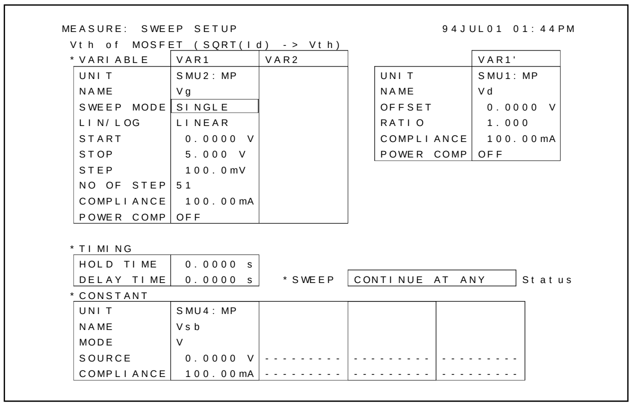


Figure 3. SWEEP SETUP Page

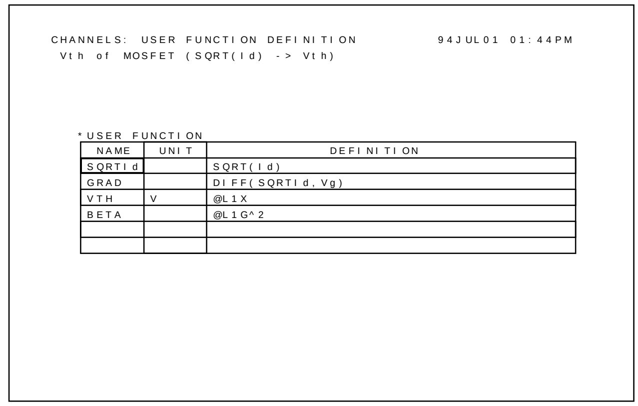


Figure 4. USER FUNCTION DEFINITION Page

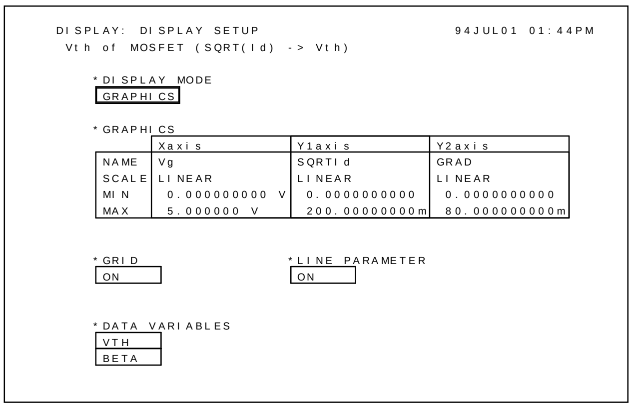


Figure 5. DISPLAY SETUP Page

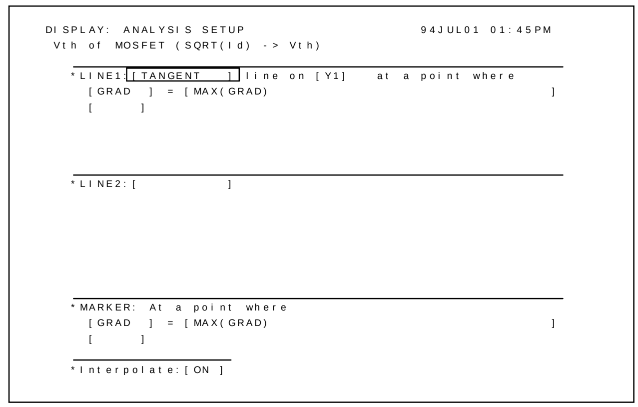


Figure 6. ANALYSIS SETUP Page

Automated extraction of threshold voltage using the HP 4155A/4156A

The following shows how to automatically extract the threshold voltage (Vth) of a MOSFET by using the built-in user functions and auto analysis functions. In addition, this describes how to transfer the extracted Vth into an HP Instrument BASIC program.

A frequently used method of measuring Vth 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:

$$Id = \beta (Vg - Vth)^2$$

Where β is the gain factor and expressed as
$-1/2 \times (\mu\varepsilon_{ox} W/L) \times t_{ox}$.

Therefore, if you take the square root of both sides of the equation,

$$\sqrt{Id} = \sqrt{\beta} \times (Vg - Vth)$$

$\sqrt{Id}$ is proportional to Vg and the slope is $\sqrt{\beta}$. At the point where $\sqrt{Id}$ is equal to 0, Vg is equal to Vth. The Vth measurement is performed with the connection shown in Figure 1.

The measurement conditions are defined in the CHANNEL DEFINITION page and SWEEP SETUP page shown in Figure 2 and Figure 3 respectively.

By this setup, Id-Vg characteristics are measured. In the USER FUNCTION DEFINITION page shown in Figure 4, the square root of Id (SQRTId), and differential coefficient (GRAD) of SQRTId versus Vg are defined. Also VTH and BETA are defined by using Read Out Functions. They are calculated using @L1X (the x intercept of Line 1) and @L1G (the slope of Line 1). Line 1 is drawn by setup of the ANALYSIS SETUP page which is described later.

In Figure 5, the DISPLAY SETUP page is set to plot two curves: SQRTId versus Vg and GRAD versus Vg. Also VTH and BETA are to be displayed in the data variables display area.

The auto analysis functions are defined in the ANALYSIS SETUP page shown in Figure 6. A tangent line (Line 1) is drawn on the SQRTId versus Vg curve (Y1) at the point where the GRAD is maximum. The marker is also moved to the point where the

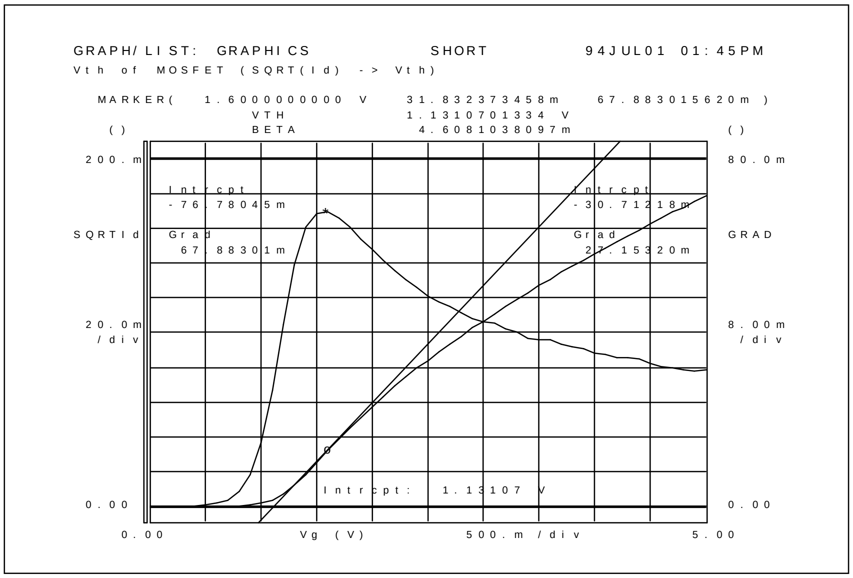


Figure 7. Measurement Result

```
10 ASSIGN @Hp415x to 800
20 OUTPUT @Hp415x;":TRAC? 'VTH'"  ! Read out Vth
30 ENTER @Hp415x;Vth_data         ! Enter Vth
40 OUTPUT @Hp415x;":TRAC? 'BETA'" ! Read out Beta
50 ENTER @Hp415x;Beta_data        ! Enter Beta
60 PRINT Vth_data, Beta_data
70 END
```

Figure 8. Example Program

GRAD is maximum.

If you execute a single measurement, as shown in Figure 7, two curves are drawn. Right after the measurement, a tangent line is drawn as specified in ANALYSIS SETUP page, and VTH and BETA are displayed.

By executing the simple program in Figure 8, you can transfer the VTH and BETA data to variables using the internal HP Instrument BASIC or an external controller.

Conclusion

You can automate data analysis and extraction of DC parameters using the auto analysis features of the HP 4155A/4156A. You can perform accurate analysis, free from error that may be caused by manual operations. It is easy to transfer extracted parameters to an HP Instrument BASIC program or external controller. Using this capability, full automation of complicated procedures, such as reliability tests, is easily implemented.

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