Measurement of Power Devices Using External DC Power Supply

Application Note 4156-5

Agilent 4155C/4156C Semiconductor Parameter Analyzer

Introduction

If used in combination with an external DC power supply, the Agilent 4155C/4156C semiconductor parameter analyzer can easily evaluate the DC characteristics of a power device that requires a current of several amperes. This application note describes how to connect the highly cost-effective Agilent E3615A DC power supply to the 4155C and to use the Agilent 4155C's automatic analysis functions to automatically calculate threshold voltage (Vth).

Power Transistor Measurement

Curve tracers are widely used for power transistor measurement, but have few analysis functions and have difficulty in extracting transistor parameters. They also have the disadvantage of being difficult to automate in order to improve productivity.

The 4155C/4156C offers a wide range of analysis functions including log sweep measurement functions, tangent line, regression line, and marker Min/Max. It also has built-in Agilent Instrument BASIC, which allows the control and automation of all measurements
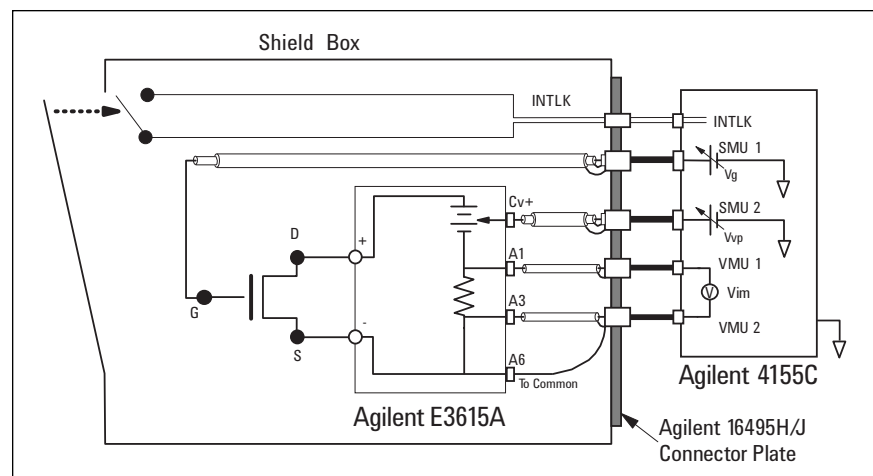

Figure 1. Diagram of Connections for Power Transistor Measurement

without any external controller, and offers major improvements in productivity from device development and design to incoming inspection. The dedicated expander (Agilent 41501B) gives a measurement range of up to 1 A/200 V, and, using an external DC power supply that can be remotely controlled, allows further expansion of the measurement range.

The Agilent E3615A can be remotely controlled by applying a voltage to its control terminal, and current can be monitored remotely via its sense resistor. This paper describes how this function can be used to increase the output power and expand the current measurement range of the 4155C. Our example uses the Agilent E3615A, which provides a maximum of 60 W and 3 A/20 V, but the Agilent E3614A (6 A/8 V) or the Agilent E3617A (1 A/60 V) are also suitable.

Connections
The 4155C and E3615A are connected as shown in Figure 1. SMU2 is connected to the control terminal Cv+ to control output voltage, and the voltage measurement units (VMU1 and VMU2) are connected to sense resistor terminals A1 and A3 to monitor output current. To give the E3615A a circuit common potential, terminal Cv- is connected to the common terminal which is the outer shield of VMU2. These connections are made using the Agilent 16495H/J option 002 connector plate.[1]

Agilent 4155C Settings and Results of Measurements
Figures 2 to 4 show the 4155C setup screens for the drain characteristic measurements. On the CHANNEL DEFINITION page (Figure 2), SMU1, which is connected to the gate, is set to pulse output. Driving the gate using a pulse voltage reduces the average output current, so thermal drift is reduced. VMU1 and VMU2 are set to differential mode and the potential difference (Vim) is measured.

The USER FUNCTION DEFINITION page (Figure 3) is used to calculate the Vd and Id variables. Vd is the SMU2 output voltage (Vvp) multiplied by a factor depending on the DC power supply (2/3 for the E3615A). The sense resistance is 0.2 W for the E3615A, so Id = Vim/0.2. So, you set the user functions as follows:

Vd = Vvp * (2/3)

Id = Vim / 0.2

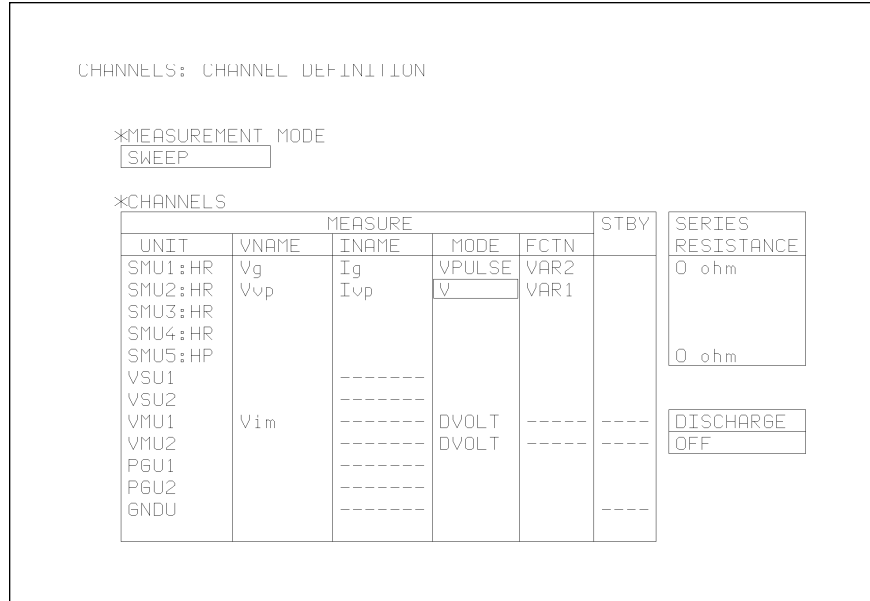For other DC power supplies, see [2] at the end of this note.

Figure 2. CHANNEL DEFINITION Page

The SWEEP SETUP page (Figure 4) is used to set the sweep conditions for SMU1 and SMU2, and the pulse output for SMU1. In this example, to reduce the number of measurements in the high voltage range and prevent heating, SMU2 is set to log sweep. Pulse width and pulse period are set so that pulse of SMU1 has a duty cycle of 10%. The measurement results of drain characteristics are shown in Figure 5.

Automatic Extraction of Transistor Parameters
The 4155C/4156C can automatically extract parameters after measurements.[3] Figure 6 shows the automatic extraction of threshold voltage from the "drain current versus the gate voltage" characteristics graph. Before measurement, you set up the ANALYSIS SETUP page to extract desired parameters. After measurement, 4155C/4156C automatically extracts the parameters.

In this example, the 4155C finds maximum Gm, then draws tangent to Id curve of this point. The x-intercept of this tangent line is Vth, which is automatically displayed. Measurement productivity, repeatability, and speed are all significantly improved.

Tips on Maximizing Measurement Accuracy
To obtain the highest possible accuracy of measurement, you should observe the following points:

• Instead of calculating Vd by user functions, directly connect one SMU to drain and one SMU to source, and subtract voltage difference between the drain and the source. This will eliminate the error caused by remote programming and the voltage loss caused by the cables.

• To minimize voltage loss in cables that carry a high current, use cables that are as short and thick as possible.
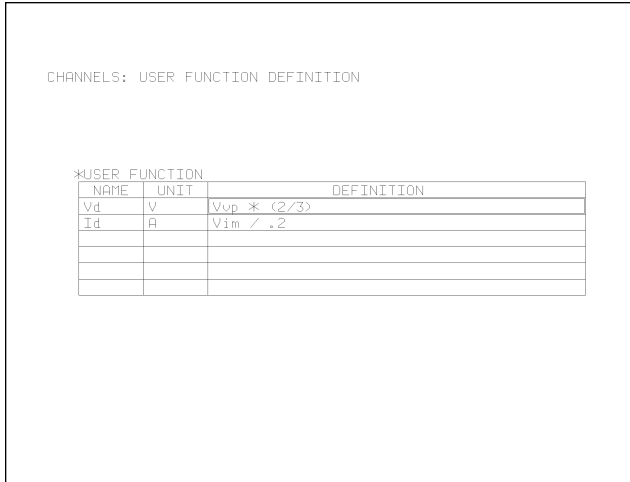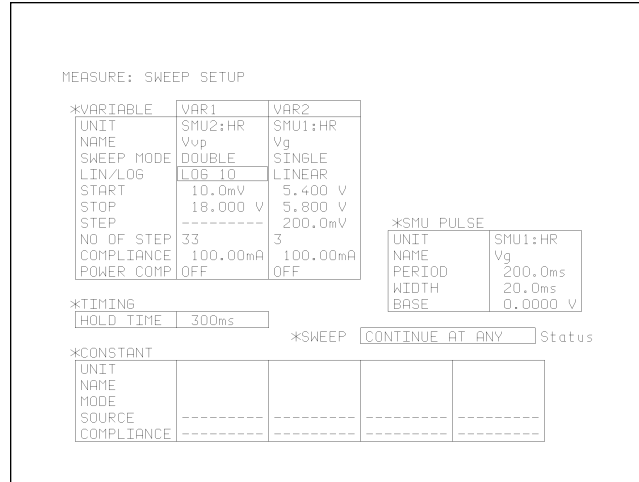
```
CHANNELS: USER FUNCTION DEFINITION


    *USER FUNCTION
    ┌──────┬──────┬───────────────────────────────────┐
    │ NAME │ UNIT │            DEFINITION             │
    ├──────┼──────┼───────────────────────────────────┤
    │ Vd   │ V    │ Vvp * (2/3)                       │
    │ Id   │ A    │ Vim / .2                          │
    ├──────┼──────┼───────────────────────────────────┤
    │      │      │                                   │
    ├──────┼──────┼───────────────────────────────────┤
    │      │      │                                   │
    ├──────┼──────┼───────────────────────────────────┤
    │      │      │                                   │
    └──────┴──────┴───────────────────────────────────┘
```

Figure 3. USER FUNCTION DEFINITION Page


```
MEASURE: SWEEP SETUP

  *VARIABLE   │ VAR1      │ VAR2
   UNIT       │ SMU2:HR   │ SMU1:HR
   NAME       │ Vvp       │ Vg
   SWEEP MODE │ DOUBLE    │ SINGLE
   LIN/LOG    │ LOG 10    │ LINEAR
   START      │ 10.0mV    │ 5.400 V
   STOP       │ 18.000 V  │ 5.800 V
   STEP       │ --------- │ 200.0mV      *SMU PULSE
   NO OF STEP │ 33        │ 3            │ UNIT   │ SMU1:HR
   COMPLIANCE │ 100.00mA  │ 100.00mA     │ NAME   │ Vg
   POWER COMP │ OFF       │ OFF          │ PERIOD │ 200.0ms
                                         │ WIDTH  │ 20.0ms
  *TIMING                                │ BASE   │ 0.0000 V
   HOLD TIME  │ 300ms
                          *SWEEP │ CONTINUE AT ANY │ Status
  *CONSTANT
   UNIT       │          │          │          │
   NAME       │          │          │          │
   MODE       │          │          │          │
   SOURCE     │ -------- │ -------- │ -------- │ --------
   COMPLIANCE │ -------- │ -------- │ -------- │ --------
```

Figure 4. SWEEP SETUP Page


```
MARKER(  9.7222222222 V   1.6182300000 A
(A)
2.00


ID


200.m
/div



0.00
   0.00        VD (V)       1.00  /div      14.0
```
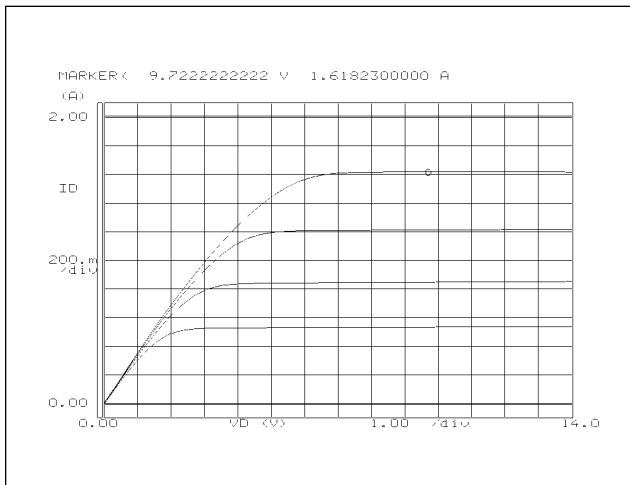
Figure 5. Examples of Drain Characteristic Measurements


```
MARKER(  6.1500000000 V   965.26000000mA   888.44000000m )
(A)            VTH          5.0635338346 V             ()
1.50                                                  900.m


ID                                                    GM


200.m                                                 120.m
/div                                                  /div



0.00                                                  0.00
   3.00      VG (V)      500.m /div      7.00
```
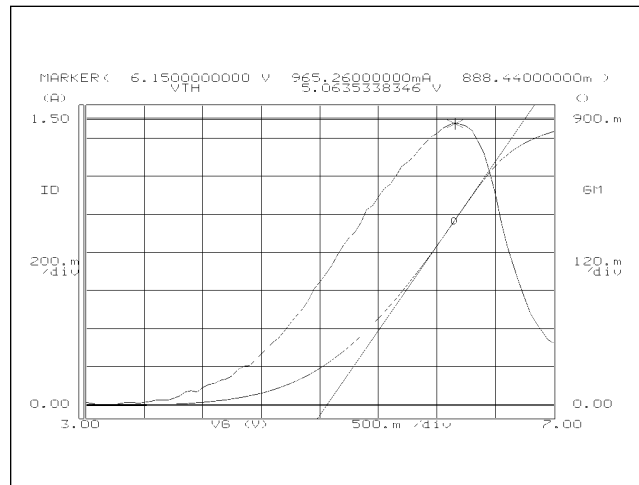
Figure 6. Drain Current versus Gate Voltage Characterisitcs to Obtain Vth

- After a sweep, when the drain voltage returns abruptly to zero, the Agilent E3615A may generate a spike. To eliminate this spike, use the double-staircase sweep mode.

- As much as possible, you should use a heat sink.

Conclusion
This application note described one example of how the Agilent 4155C can be used with the highly cost-effective Agilent E3615A DC power supply to extract power transistor parameters, which are difficult to extract using the conventional curve tracer method.

The 4155C/4156C's automatic analysis functions and built-in Instrument BASIC environment also allow 4155C/4156C to become an automatic test station.

Notes:

1. Please observe the following safety precautions when using the Agilent 4155C.

• Make sure that the wiring used with the connector plate and shield box has adequate capacity. The maximum output voltage and current of each external DC power supply are as follows:

Mode No.	Max. Output Voltage	Max. Output Current
Agilent E3614A	8 V	6 A
Agilent E3615A	20 V	3 A
Agilent E3616A	35 V	1.7 A
Agilent E3617A	60 V	1 A

• To protect yourself against electrical shocks when replacing the DUT, be sure to fit an INTLK switch and install the measurement system, including external DC power supply, in a shield box.

2. For other external DC power supplies, use the following user functions:

Agilent E3614A:
$Vd = Vvp * (4/9)$, $Id = Vim/0.1$

Agilent E3616A:
$Vd = Vvp * (7/9)$, $Id = Vim/0.6$

Agilent E3617A:
$Vd = Vvp * (6/7)$, $Id = Vim/0.89$

3. For a detailed explanation of automatic analytical functions, see *Application Note 4156-2, Automated Extraction of Semiconductor Parameters Using the Agilent 4155C/4156C* (Agilent publication number 5963-1249E).

Note: The information contained in this application note is also applicable to the Agilent 4155A/4156A and Agilent 4155B/4156B.

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