



HP 4145B Semiconductor Parameter Analyzer

Technical Information

PREVENTING SMU OSCILLATION WHEN MAKING DC PARAMETRIC MEASUREMENTS WITH THE HP 4145B

1. INTRODUCTION.

The HP 4145B Semiconductor Parameter Analyzer features high speed, high resolution, and high gain Source Monitor Units (SMUs) necessary for evaluating semiconductor processes and devices. However, this combination of high gain and high speed creates oscillation problems under certain load conditions. The DC characterization of semiconductors is adversely affected by these oscillations. Oscillation problems and the methods to prevent and stop them are presented in this note.

2. CAUSES OF OSCILLATION

There are two modes of oscillation, one mode caused by the SMU or the DUT, and the other mode caused by connection leads. A low-pass guard filter is included in the SMUs to obtain stable operation when in the very low current ranges, however, SMUs are high-speed, high-gain amplifiers, and will oscillate under certain load conditions.

(1) SMU Induced Oscillation

Oscillations caused by the SMU occur when an inductive load is connected to the SMU's output. The SMU often has an inductive load because the output impedance of the SMU is inductive during V-mode operation and usually several SMUs are connected together through the DUT. For example, in Figure 1 the SMUs connected to the MOSFET's gate and drain are operating in the V-mode, so these SMUs appear to be inductive, thus making this configuration equivalent to a Hartley oscillator.

Figure 2 shows a simplified drawing of an SMU output circuit. C_g is the capacitance between the center conductor and the inner shield of the triaxial output cable. To prevent oscillation, the SMU

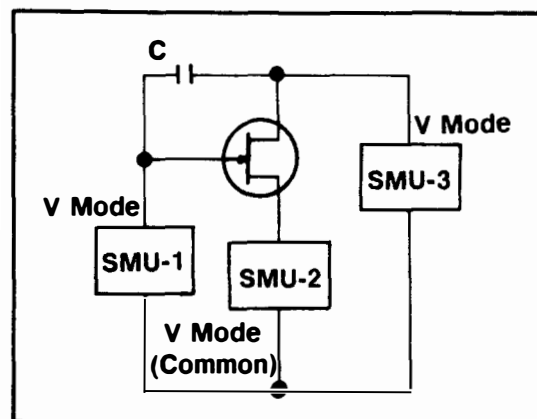


Figure 1. Test Configuration

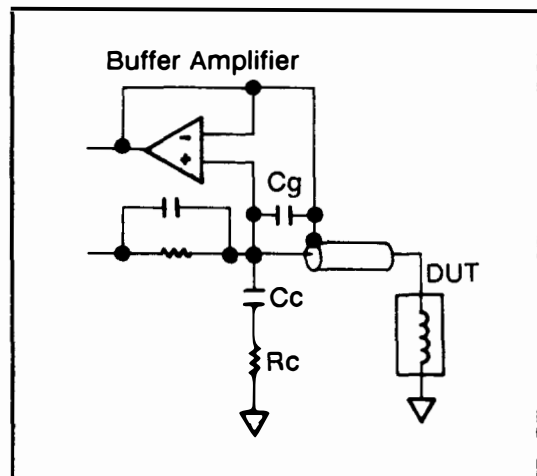


Figure 2. SMU Output Circuit

uses a network consisting of C_c and R_c to compensate for the output inductive reactance. However, the value of C_c cannot be increased enough to make the output impedance capacitive because the settling time would become too long.

Therefore, the SMU may oscillate if an unusually large inductance is connected to it. This could occur if the DUT is a superbeta transistor ($h_{FE} > 3000$) and the SMU connected to the emitter is set to one of the low current ranges.

(2) Oscillation due to strays.

The test sample itself may also oscillate due to the residual inductance and stray capacitance of the connection cables, test fixture or probe card. Superbeta, wide bandwidth bipolar transistors are especially susceptible to oscillation.

3. OSCILLATION COUNTERMEASURES

The type of devices which tend to cause oscillation are:

- (1) Superbeta (High h_{FE}) bipolar transistors
- (2) High g_m MOSFETs
- (3) Devices which have large stray capacitance
- (4) Devices operated at very high frequency
- (5) Negative resistance devices

Some effective methods for eliminating oscillations are:

For (1), (2), (3), and (4) above, position ferrite beads as close as possible to the DUT to kill high frequency oscillations, and to kill low frequency oscillations, insert a resistor as shown in Figure 3. In some instances it may be necessary to use more than one ferrite bead.

Figure 4 shows two methods of stopping a SMU from oscillating when measuring (5) of negative resistance devices.

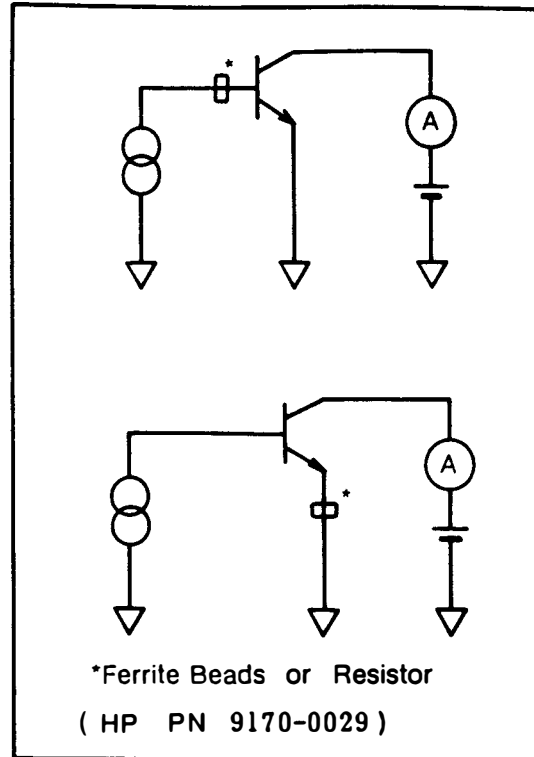


Figure 3. Preventing Transistor Oscillation

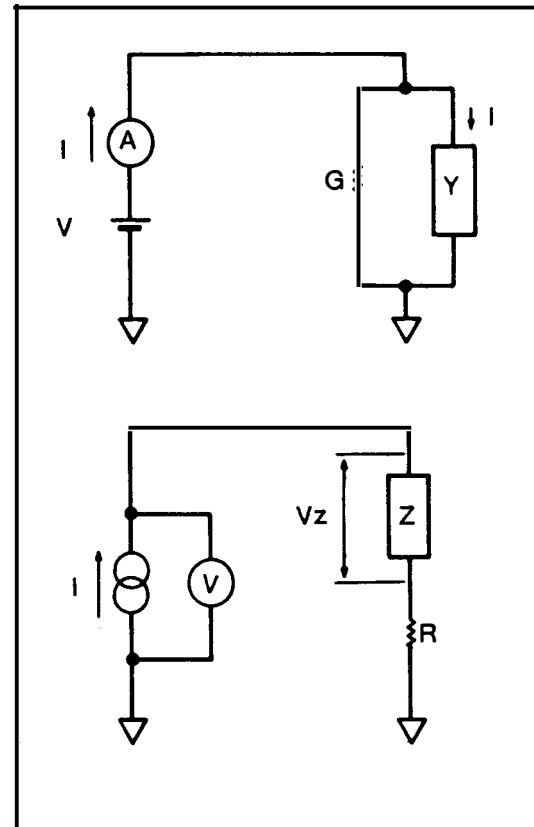


Figure 4. Negative Resistance Measurements

Voltage-Controlled Negative Resistance Measurement.

Parallel conductance (G), effectively cancels the negative resistance of test sample Y. If the value of G is known, you can use the following equation to calculate the current through the sample for any value of V. Use the User Function to display IY directly.

$$I_y = I - GV$$

Current-Controlled Negative Resistance Measurement.

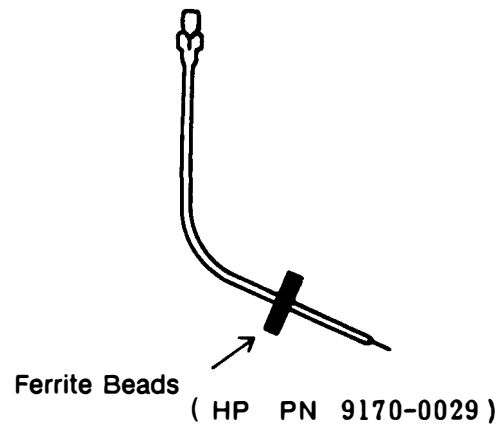
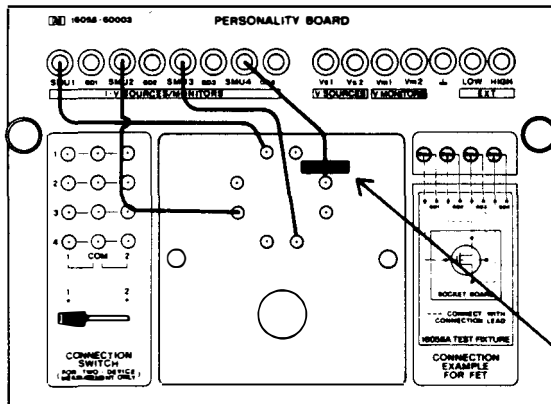
Series resistance (R), effectively cancels the negative resistance of test sample Z. If the value of R is known use the following equation to calculate the voltage across the sample for any value of I using the following equation. Use the User Function to display VZ directly.

$$V_z = V - RI$$

Oscillation can also occur if you use cable other than that listed in the operation manual to connect to the test fixture.

How To Use Ferrite Beads

1. When making measurements using the 16058A test fixture, insert ferrite beads on the connection leads of the Personality Board, or on the back side of the Socket Board.
2. When making measurements using a manual prober, place ferrite beads at the tip of the probe needles, but be sure to insulate the beads from the signal and guard lines.



4. APPLICATION EXAMPLE

Figures 5 and 6 are plots of normal measurements and examples of measurements plagued by oscillations.

Example 1. GaAs (devices used for very high frequency operation). Figure 5a shows a plot of a normal measurement while Figure 5b is an example of a measurement with oscillation problems.

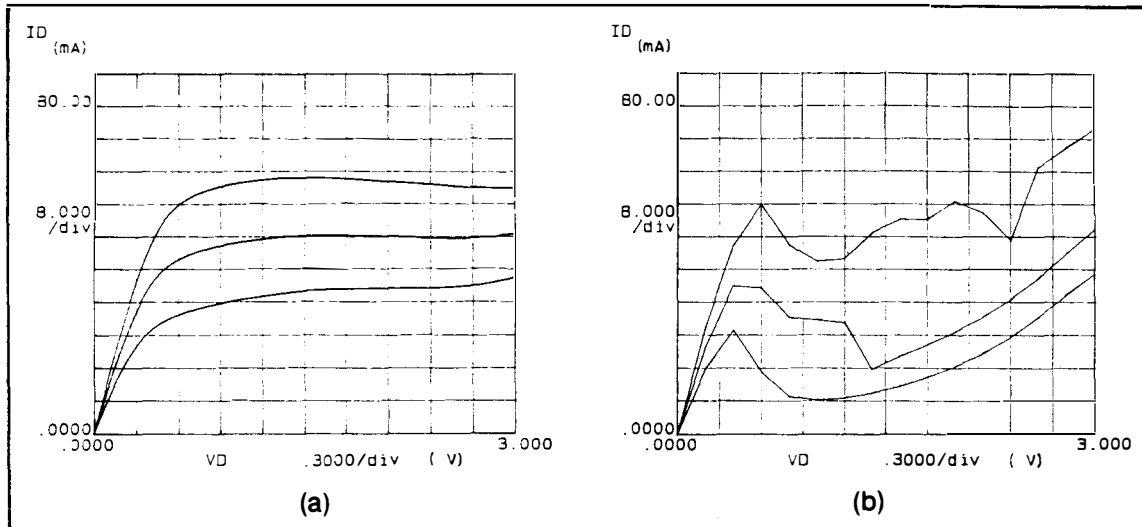


Figure 5. GaAs MESFET Measurement

Example 2. Bipolar Transistor (devices with large stray capacitance). Figure 6a is a plot of a normal measurement while Figure 6b is an example of a measurement with oscillation problems.

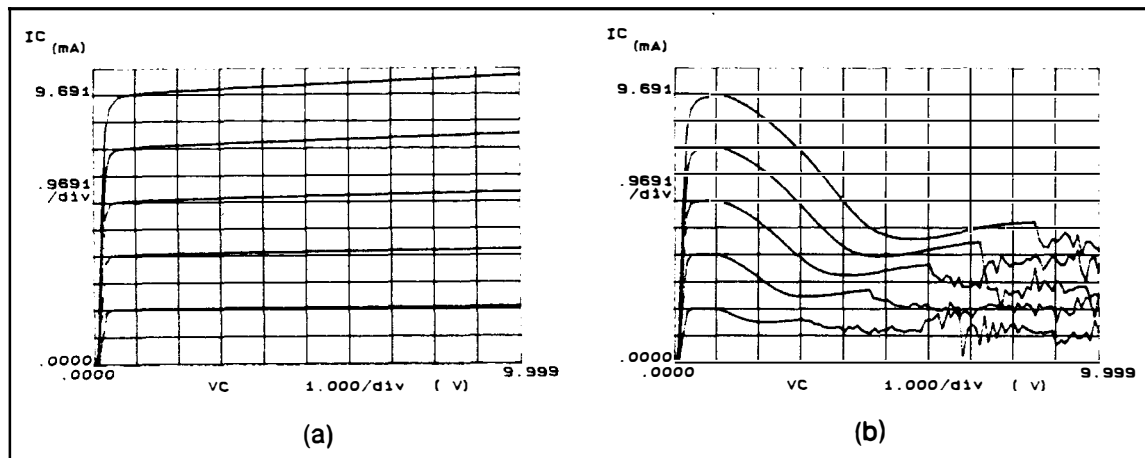


Figure 6. Transistor Measurement

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