Fast fT-Ic Measurement Using the Agilent B2900A Series

Technical Overview

B2900A Series Precision Source/Measure Unit

B2901A Precision SMU, 1ch, 100fA resolution, 210V, 3A DC/10.5A pulse
B2902A Precision SMU, 2ch, 100fA resolution, 210V, 3A DC/10.5A pulse
B2911A Precision SMU, 1ch, 10fA resolution, 210V, 3A DC/10.5A pulse
B2912A Precision SMU. 2ch, 10fA resolution, 210V, 3A DC/10.5A pulse

Introduction

The cutoff frequency (f_T) is an important parameter to understand the operating frequency range of a bipolar transistor. To measure f_T, a DC bias must be applied to place the transistor at the correct operating point while simultaneously using a network analyzer to measure its frequency characteristics.

The Agilent B2900A Series of Precision Source/Measure Units are compact and cost-effective benchtop Source/Measure Units (SMUs) that supplies precise sourcing and measurement capability at a very reasonable price. In addition, the B2900A Series supports enhanced trigger functions that enable each step of a bias sweep it performs to be synchronized with a frequency sweep performed by a network analyzer. These capabilities allow you to evaluate and plot parameters such as f_T versus I_c very quickly and efficiently.

For all of these reasons, the B2900A Series are the ideal bias source to use with network analyzers for the evaluation of transistor DC and RF characteristics. This technical overview explains the key features of B2900A Series in detail and shows how it can help to determine the f_T-I_c characteristics of bipolar transistors.

System Configuration

Figure 1 shows a system configuration to perform f_T-I_c measurement using the B2902A or B2912A dual channel SMU in conjunction with a network analyzer (such as one from the Agilent ENA or PNA series). The bipolar transistor is connected through a bias-T (either built-in to the network analyzer or external) to the RF ports of the network analyzer and to the DC output terminals of B2900A Series.

The B2900A Series' DC bias voltage or current is applied to the DUT through the bias-T.

A PC can control the B2900A Series and the network analyzer using GPIB, Local Area Network (LAN) or USB communication protocols. In addition, the B2900A Series and network analyzer's external trigger inputs and outputs are connected to each other, and the trigger signals are used to improve overall system performance.

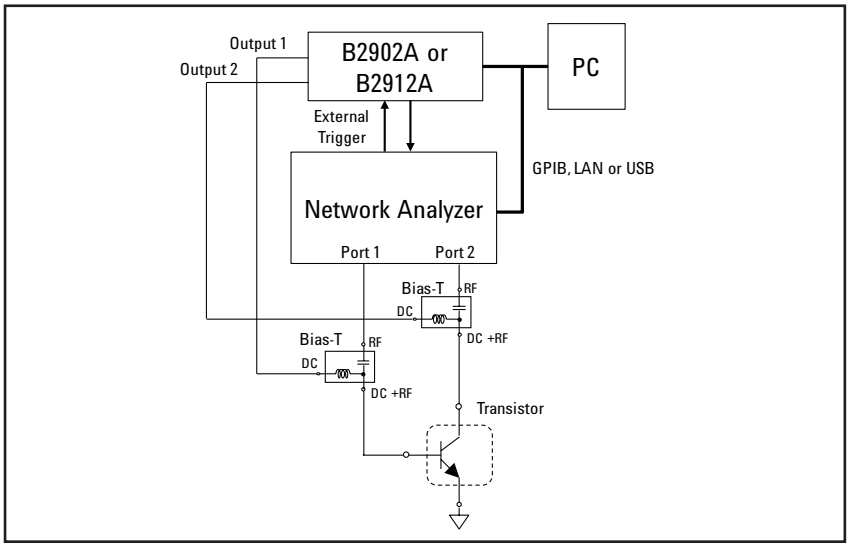

Figure 1. System configuration of a fast F_t-I_c measurement system using the Agilent B2900A Series

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What is the B2900A Series SMU?

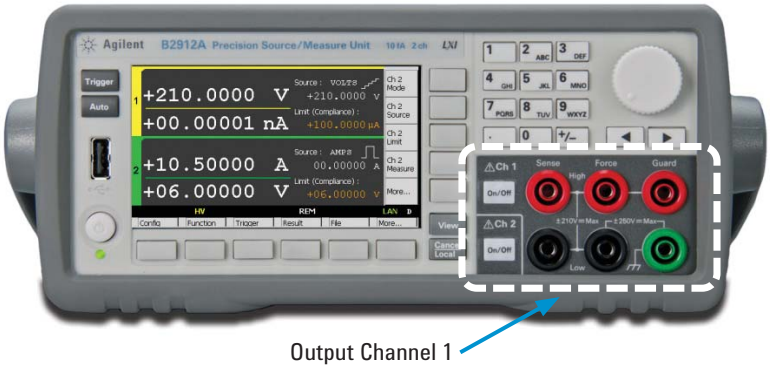
An SMU combines the capabilities of a current source, a voltage source, a current meter and a voltage meter along with the capability to switch easily between these various functions in a single instrument. This gives it the ability to evaluate the IV characteristics of devices easily across all four quadrants without any additional equipment.

The B2900A Series members are single or dual channel SMU units that offer a wide range of IV measurement capability for a variety of two-terminal and three-terminal devices. They cover currents from 10 fA to 10.5 A and voltages from 100 nV to 210 V. In addition to their DC operation mode, the B2900A Series also has the ability to perform pulsed measurements in order to prevent device self-heating from distorting the measurement results.

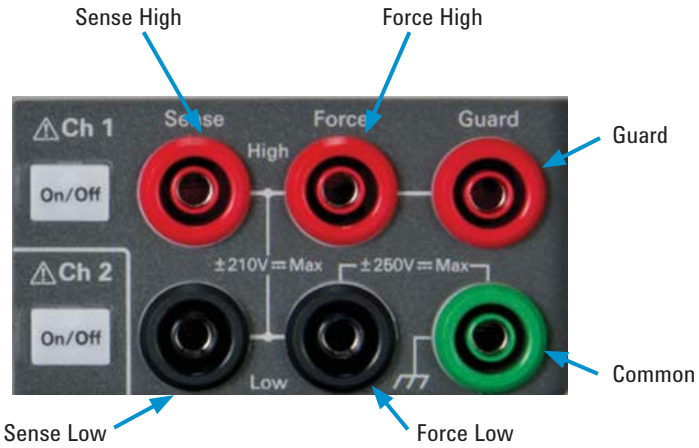
Figure 2 provides an overview of the B2900A Series. The B2900A Series' SMUs support both 2-wire and 4-wire measurements. A 4-wire measurement uses one pair of leads to force current and the other pair of leads to monitor (sense) voltage. This eliminates the voltage measurement error caused by residual cable resistance. The B2900A Series also supports a remote-sensing function that keeps the voltage applied to the sense point the same as the programmed voltage.

Agilent offers the 11612V Kelvin bias-T network to support 4-wire measurement. Performing a 4-wire measurement using the B2900A Series and the 11612V Kelvin bias-T network eliminates the voltage error caused by the residual bias-T resistance.

From this discussion it is clear that the B2900A Series can be used to perform both IV measurements and



(a) Front view (for the B2902A and B2912A, the channel 2 is located on the rear panel)



(b) Layout of output terminals

Figure 2. Overview of the B2900A Series and its output terminals

to act as a precision bias source in conjunction with a network analyzer. Conveniently, the B2900A Series also supports triggering functions that allow it to be easily synchronized with other measurement equipment (such as network analyzers).

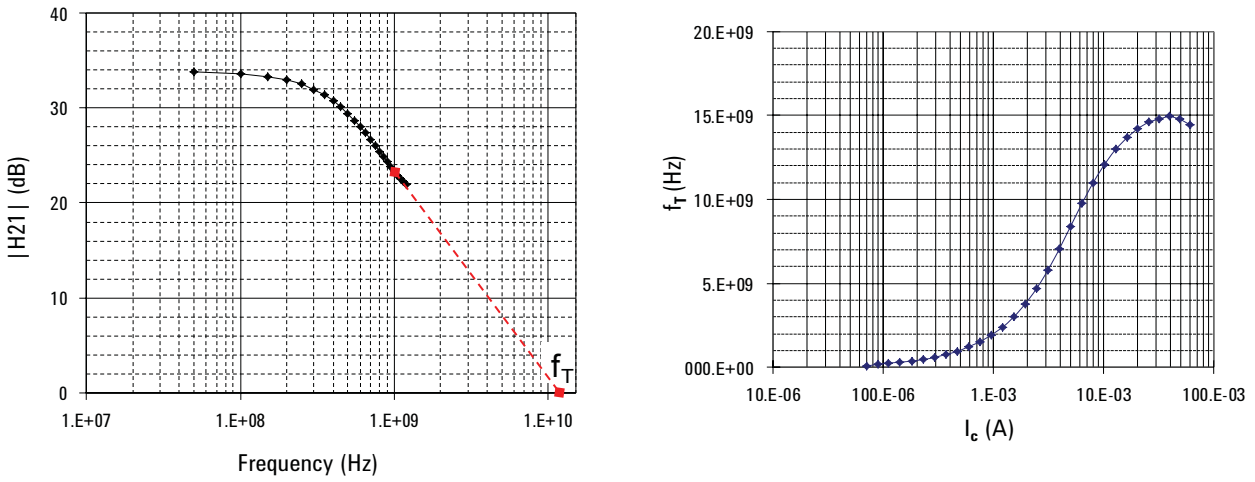
Measuring f_T-I_c Characteristics

The cutoff frequency (f_T) can be calculated from the H_{21} parameter, and the H parameters can be calculated from the measured S parameters. Figure 3(a) shows an example of f_T extraction using H parameters.

The absolute value of H_{21} at 1 GHz is calculated, and a line is drawn at this point with a –6 dB/octave slope. The f_T is defined as the intercept of this line with the X- axis.

To find the maximum cutoff frequency f_{T_max}, the base current (I_b) is swept while measuring the collector current (I_c). At each step of the I_b sweep, S-parameters are measured and used to calculate the cutoff frequency, f_T.

Figure 3(b) shows an example of a measured f_T-I_c curve. The maximum cutoff frequency, f_{T_max}, can be determined from this curve. In this example, the f_{T_max} is 14.9 GHz when the collector current is approximately 40 mA.



(a) f_T extraction from H_{21} parameter

(b) Measured f_T-I_c characteristics

Figure 3. Example of f_T-I_c measurement

Handshaking the B2900A Series and a Network Analyzer

The B2900A Series has sophisticated triggering functions that enable it to perform complicated measurement sequences in synchronization with other instruments. For example, the start of each measurement step in a sweep can be initiated using an external trigger signal. This is opposed to using a single trigger signal to start the entire sweep measurement.

In addition, the B2900A Series can output trigger signals at the beginning and end of various measurement events, such as signal transition and data acquisition.

Figure 4 shows an example of some handshaking signals between the B2900A Series and a network analyzer to perform an f_T-I_c measurement. After incrementing the bias, the B2900A Series sends a trigger signal to the network analyzer to notify that it is ready for the frequency sweep. After receiving the trigger signal, the network analyzer initiates a frequency sweep to measure the S parameters.

After the network analyzer completes its data transfer, it sends a trigger signal to the B2900A Series and it measures the collector current. This process continues until the last voltage step has been reached.

Using this trigger-controlled handshake scheme, the f_T-I_c measurement speed is much faster than it would be if the B2900A Series and network analyzer were controlled programmatically using one of the supported communication protocols.

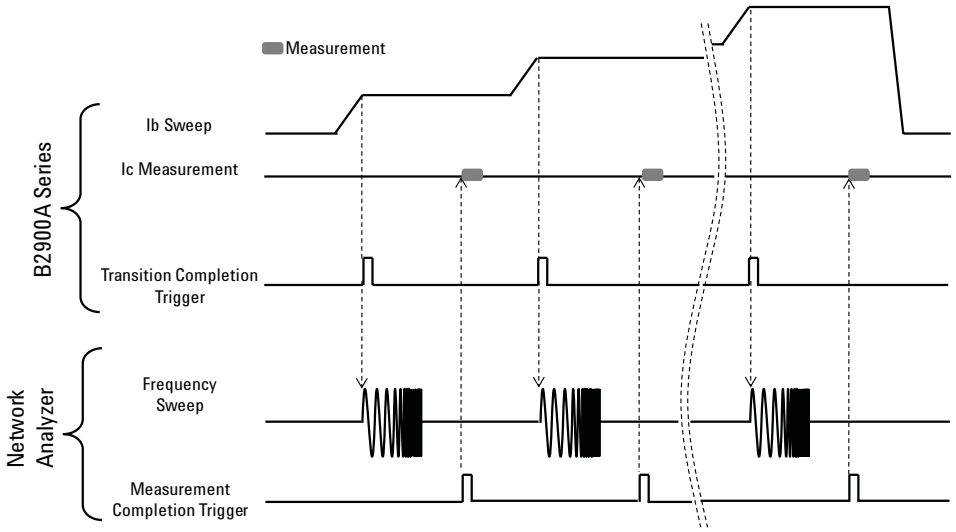


Figure 4. B2900 A Series and network analyzer triggering diagram example for fast f_T-I_c measurement

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Summary

The Agilent B2900A Series of Precision Source/Measure Units is a low-cost Source/Measure Unit (SMU) capable of supplying the DC voltages and currents to a bipolar transistor in conjunction with a network analyzer.

The B2900A Series covers wide current and voltage measurement ranges (from 100 fA/100 nV to 10.5 A/210 V). It also has a 4-wire measurement function with remote-sensing that allows you to measure the IV characteristics of bipolar transistors accurately through a bias-T by eliminating the influence of the residual resistance.

Moreover, its sophisticated triggering capabilities support fast f_T-I_c measurements by allowing the B2900A Series and network analyzer to be synchronized via handshaking trigger signals rather than by using commands sent over a communication protocol.

For all of these reasons, the B2900A Series is the most cost-effective solution for the evaluation of bipolar transistors in conjunction with network analyzers such as those in the Agilent ENA or PNA series.

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