

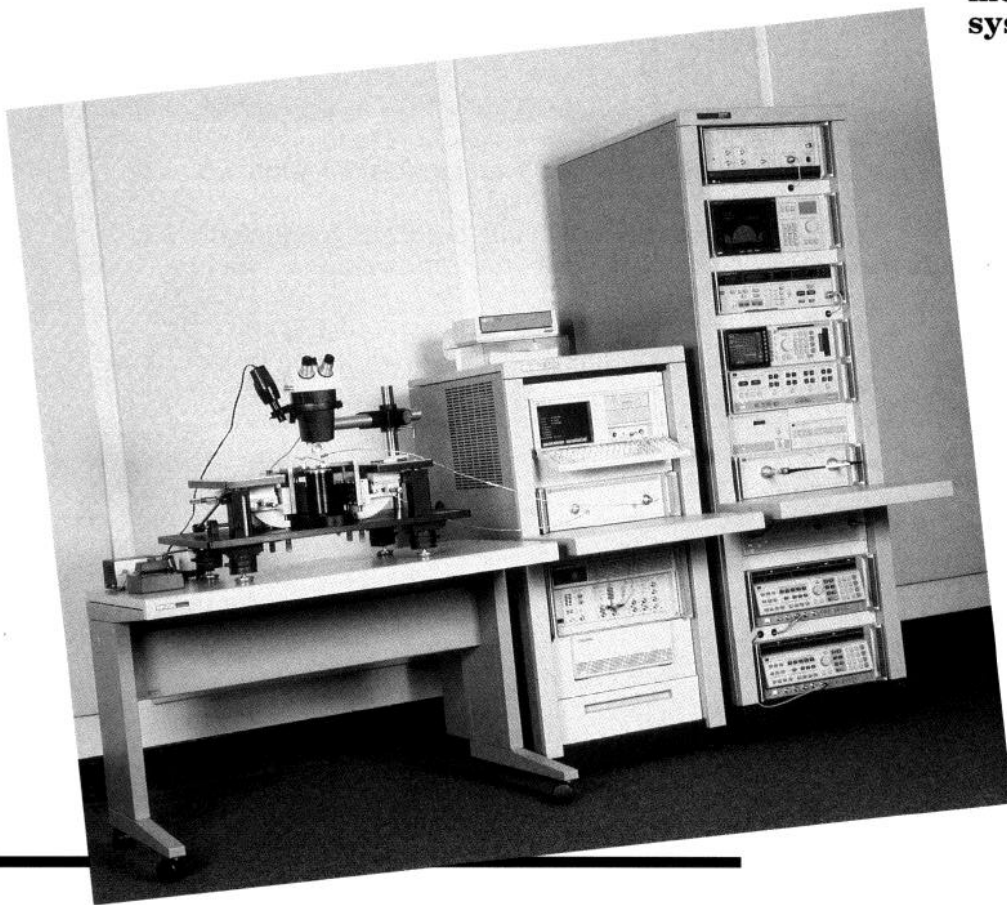
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# Efficient Microwave Bias and Test Using the HP 4142B Modular DC Source/Monitor

Application Note 1205

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**Improve microwave  
semiconductor device  
quality while reducing  
test costs by integrating  
precision DC measure-  
ments into MMIC test  
systems.**



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**Cover photo:**

Shown is a configurable MMIC test system available from Hewlett-Packard Company. DC/RF wafer evaluation is possible with a single connection.

## Overview

The ability to provide DC and RF in both continuous and pulsed modes are important for testing gallium arsenide (GaAs) and other microwave devices. For test system efficiency it is necessary for DC hardware to first provide DC functional test and then act as bias supplies during RF testing. This is particularly true with the emerging monolithic microwave integrated circuit (MMIC). High test costs continues to be a predominant barrier to high volume utilization of MMIC technology.

DC instrumentation is required which is designed to integrate well with automated RF instrumentation. Conventional power supplies and voltmeters provide awkward solutions which can damage high frequency devices or produce erroneous results if not carefully used.

The precision DC parametric measurement capability and flexible configuration of the HP 4142B make it ideal for comprehensive MMIC DC characterization and production test. Design features of the source/monitor unit (SMU) make it particularly well suited for testing microwave devices which can be easily damaged by static or power supply overshoot and glitches. Wide measurement ranges, excellent sensitivities in both current and voltage modes, and high throughput are just a few reasons the HP 4142B is the instrument of choice for MMIC applications.

Chapter 1 describes why the HP 4142B SMUs provide the best total solution for DC testing microwave devices. A complete MMIC test station is proposed which integrates precision DC test with RF test for single touch-down wafer characterization.

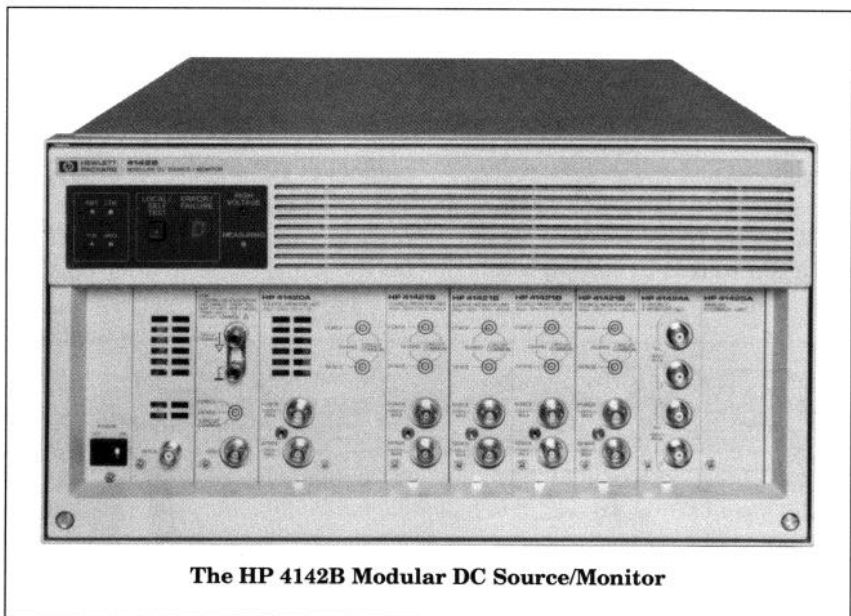
Chapter 2 extends concepts of using SMUs for precision microwave test by providing application details. A high-volume benchtop test system is described, capable of measuring 10,000 units per hour for both DC and AC limits.

## The HP 4142B Modular DC Source/Monitor

The HP 4142B is a high speed, highly accurate computer-controlled DC parametric

instrument capable of complete characterization of today's premier semiconductor devices such as GaAs MMICs. 5-digit precision voltage and current measurements are obtainable over a wide range from 4  $\mu$ V-400 V/20 fA-20 A. Pulsed bias, synchronized staircase sweeps, and very high speed spot measurements are features which make the HP 4142B ideal for testing GaAs and silicon devices.

For the basic principles of HP 4142B operation, refer to application note "High Speed DC Characterization of Semiconductor Devices for Sub pA to 1 A" (Application Note 356). Further detail is found in "Techniques and Applications for High Throughput and Stable Characterization" (Application Note 356-1).



The HP 4142B Modular DC Source/Monitor

It's modular SMU design is particularly well-suited for multi-pin MMIC applications.

## 1.1 Special Testing Needs of GaAs and Microwave Bipolar Devices

The performance of high-frequency active devices is primarily due to extremely low junction capacitances (sub pF) and small transit times between device terminals (<10 ps). To obtain low capacitances, the control electrodes are significantly reduced in size compared to conventional lower frequency devices. In the case of GaAs FETs, sub-micron fabrication technologies keep the gate contacts to the active device region confined to as small an area as possible. With GHz Ft bipolar devices, the base region is kept extremely thin using very shallow ion-implanted diffusions.

These scaled down devices make DC testing a particular challenge. First of all, the small sizes reduce current and voltage handling capabilities, making microwave devices extremely sensitive to electrostatic damage. Breakdown voltages between terminals can be as low as 10 volts. Extreme care must be taken to test in completely

anti-static environments, and then to bias the device "gently" without any voltage or current "glitching." Even non-catastrophic damage may occur due to improper DC biasing. In this case, the device may be weakened so as to fail upon subsequent testing, or worse yet, result in a field failure. Although individual transistor bias conditions may be modest, when combined to form ICs, bias currents can rise quickly.

Designs usually are optimized for controlled impedance loading (50 ohm) and useful RF output may be only a small percentage of bias power applied. MMICs may typically require heat sinking to dissipate 10 watts or greater. To reduce heating effects, DC pulsed biasing is highly desirable, or in some cases, mandatory.

GaAs and microwave bipolar semiconductor performance is quite sensitive to parasitic capacitances, stray inductances, and lead resistances. Computer models of RF transistors emphasize DC parasitics which can have dramatic effects on RF performance. It is usually

necessary to separate the intrinsic transistor characteristics from extrinsic packaging or probing environment to understand device behavior. Precision DC parametric extractions are required to verify initial models used in circuit simulations. Special attention must be given to eliminate residual resistances (kelvin contacts), residual capacitances (driven guards), and to properly isolate device terminals from one another.

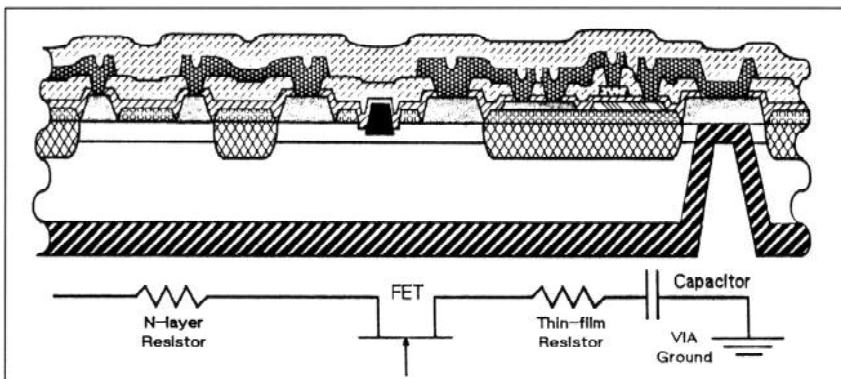
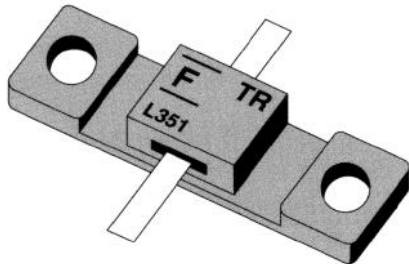


Figure 1. Shallow junction depths enhance microwave performance but make MMICs particularly susceptible to static and biasing damage.

And finally, many microwave devices must be tested both at DC and RF at the wafer level. The end product may be a hybrid involving many discrete chips. Cost to remove bad chips from hybrid packages may be in the hundreds of dollars. Thorough screening is now possible using special microwave probe stations. This allows end users to integrate chips into cost effective hybrids which require no-rework.



**Figure 2. Power GaAs FETs require fast pulse testing to avoid heating failure.**

For more information on the special testing needs of microwave GaAs and bipolar semiconductor devices, refer to the application note "Role of DC Parametric Test in High Speed Digital and Microwave Semiconductor Component Manufacturing" (Application Note 339-20).

## 1.2 Versatile SMU Simplifies Test Setups

We will now take a closer look at how the modular SMU architecture of the HP 4142B make it particularly well-suited for MMIC applications.

### Chose the Right Performance

MMICs may require eight or more pins biased simultaneously and measured over widely different current or voltage ranges. The open architecture of the HP 4142B accommodates a complete family of modules. Select up to eight modules per mainframe to build a cost effective tester. Chose from 5 digit, 20 fA and 4  $\mu$ V resolution for low level characterization such as electrode resistances, resistivities, leakage currents, etc. Extract high power parameters using the HPSMU (1 A high power SMU) or HCU (10 A high current unit). See Table 1 for specifications.

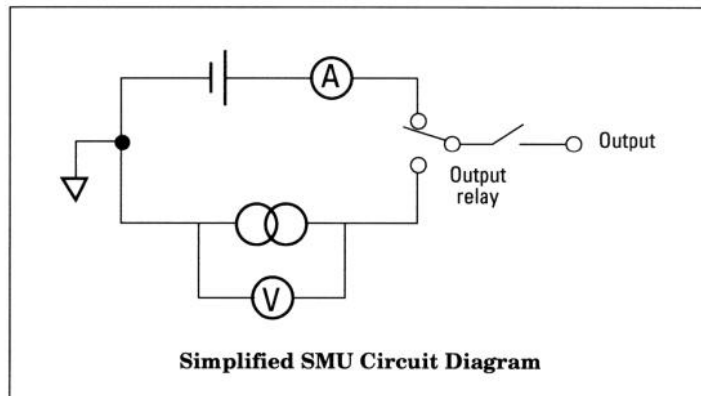
Minimize thermal drift with the HP 4142B's pulsed output. Perform quick analog current or voltage searches using two SMUs and the AFU (analog feedback unit).

## HP 4142B Modules

### Four Instruments in One

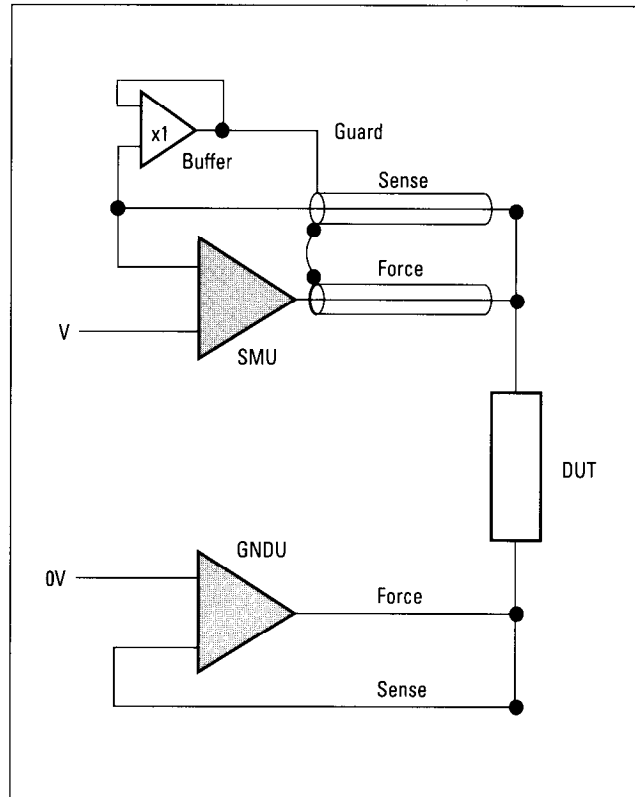
A SMU combines all of the instrumentation required to make constant or pulsed I-V measurements on a wide variety of semiconductor devices. Figure 3 shows a simplified circuit diagram of a SMU. A SMU acts simultaneously as a current source and voltage monitor or as a voltage source and current monitor. Switching between the two modes is done programmatically. You don't have to change your fixture wiring to switch from one test configuration to the next. With an SMU attached to each electrode of an active device, virtually any DC parametric test may be performed with one device insertion. This increases test throughput and test integrity. Test development time is also reduced because the engineer is freed from worrying about integrating source and measurement functions. Simple force/measure commands take care of ranging, compliance, wait times, and synchronizing more than one SMU.

**Figure 3. The equivalent of four instruments, SMUs can source voltage and measure current or source current and measure voltage.**



## Guarded Kelvin Connections and Stable Ground Reference

SMUs have separate force and sense terminals which calibrate out residual cable resistances. This is critical when making low voltage or high current MMIC measurements. Significant error would occur if cabling, bias network, and network analyzer DC line resistances were not taken into consideration. In addition, active guarding is used to minimize effects of cable capacitances and noise when making very low level current measurements. The HP 4142B mainframe contains a special Ground Unit (GNDU) which is a high current SMU set to 0 volts. This further eliminates noise by referencing all measurements to an active ground terminated as close as possible to the device under test (DUT). RF system ground is usually very noisy and can produce significant DC parametric errors of >10 mV. The GNDU is built into the HP 4142B's mainframe. This saves you from sacrificing one regular SMU as a stable ground reference.



**Figure 4. The stable ground reference (GNDU) and force-sense-guard SMU configuration eliminate system noise and cable errors**

**Table 1. HP 4142B plug-in modules**

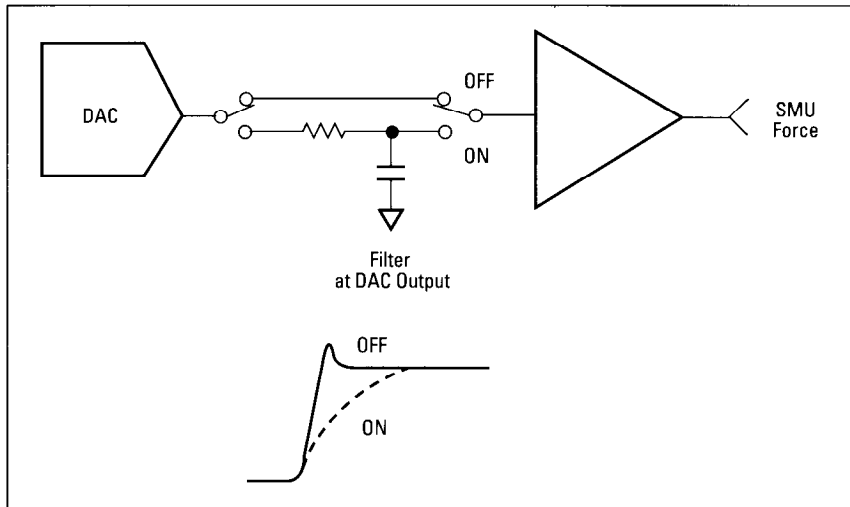
Model number	Voltage range	Current range	Measurement resolution	Accuracy	
				V	I
HP 41420A HPSMU	$\pm 100 \mu\text{V}$ to $\pm 200 \text{V}^*$	$\pm 50 \text{fA}$ to $\pm 1 \text{A}$	$40 \mu\text{V}$ , $20 \text{fA}$	0.05%	0.2%
HP 41421B MPSMU	$\pm 100 \mu\text{V}$ to $\pm 100 \text{V}$	$\pm 50 \text{fA}$ to $\pm 100 \text{mA}$	$40 \mu\text{V}$ , $20 \text{fA}$	0.05%	0.2%
HP 41424A VS/VMU	$\pm 1 \text{mV}$ to $\pm 40 \text{V}$	$\pm 20 \text{mA}$ to $\pm 100 \text{mA}$	$4 \mu\text{V}$ , $20 \mu\text{A}$	0.05%	0.3%
HP 41422A HFU	$\pm 200 \mu\text{V}$ to $\pm 10 \text{V}$	$\pm 100 \text{nA}$ to $\pm 10 \text{A}^*$	$40 \mu\text{V}$ , $20 \text{nA}$	0.5%	0.5%
HP 41425A ACU	Searches for a specified current or voltage on one SMU by controlling the voltage output of another SMU.				

\*Note: 400V max using two HPSMU channels or 20A max using two HCU channels

## Flexible Compliance and Filtering

SMUs are inherently well suited for testing MMIC devices which are easily weakened or damaged by excessive bias conditions. SMUs are multi-range instruments with up to 10 current ranges and 5 voltage ranges. Compliance resolutions are the same as setting resolutions. And programming the measurement range automatically sets the compliance range. There is no need to coordinate these two functions as with separate sources and monitors.

Each SMU provides a low-pass filter at the DAC output. This further limits the possibility of damaging the device and increases source setting accuracy. The filter (optionally programmed ON or OFF) reduces current or voltage overshoot to less than .03% of the maximum range value. SMU settling time is only slightly longer so for most MMIC applications the filter switch should be set to ON.



**Figure 5. The DAC output filter limits voltage or current spikes when changing value to 1/30 of unfiltered value.**

## Wide variety of sweep conditions

SMUs can provide all of the sweeps expected of a semiconductor curve tracer, and much more. Table 2 illustrates a few of the variety of waveforms easily programmed by the HP 4142B. Sweeps include single fixed-level sweeps, linear or logarithmic staircase sweeps, and single and double pulsed sweeps. Command software is tailored for synchronizing SMUs for typical semiconductor applications. For example, the double pulsed mode allows rapid plotting of family curves where measurements from two device electrodes are required. Programmable hold and delay times ensure that your source/measurement sequence is coordinated exactly as you desire.

**Table 2. Output Waveform available**

Output Waveform	Source		
	SMU	HCU	VS
	●		●
	●		●
	●		●
	●	●	●
	●	●	●
	●	●	●
	●		
	●	●	

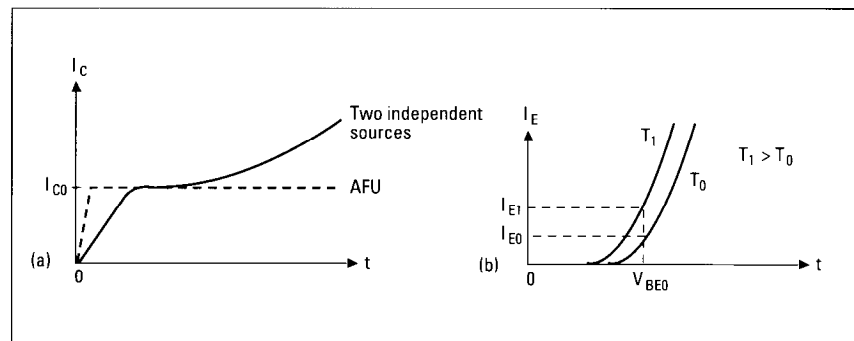
### 1.3 Using the AFU for Active Biased S-Parameter Measurements

Small signal S-parameter measurements using network analyzers is the industry method of choice for evaluating RF performance of microwave devices. Active devices such as GaAs FETs or BJTs require “glitch-free” and stable DC biasing during RF measurement. Using two independent sources, such as linear power supplies, for external bias during S-parameter test can result in inaccuracy and even damage the device under test. Thermal heating causes bias point drift which can lead to runaway destruction of sensitive microwave devices.

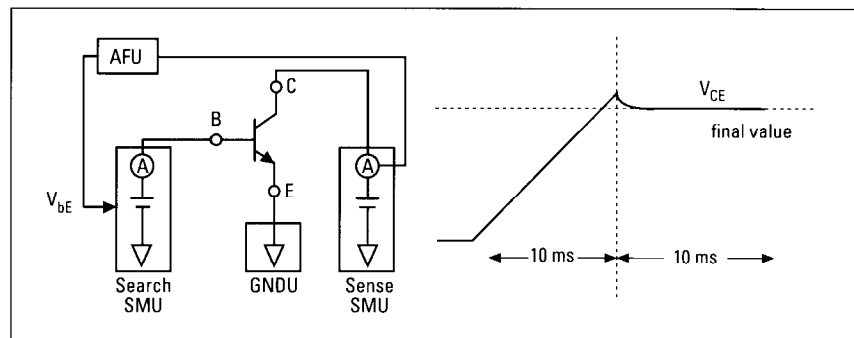
This section shows how active feedback may be placed between two SMUs of the HP 4142B to precisely and safely hold bias conditions during S-parameter measurement. The Analog Feedback Unit (AFU) modulates the output voltage of one SMU while monitoring the current or voltage of the second. Target currents or voltages are found using rapid ramp integrations (10 ms) and precision analog searches (10 ms typically). Control over the slew rate of the search ramp can be used to eliminate overshoot, a common way discrete and MMIC devices are damaged.

The AFU is a modular plug-in for the HP 4142B which requires no user connection. Internal connections allow it to be programmatically placed within the feedback paths of two specified SMUs. Figure 6 shows how the AFU would be used to set bias conditions for a bipolar device. S-parameters, in this case, are

usually specified at a constant collector current. The AFU monitors collector current and ramps the DUT base voltage from a specified start voltage and ramp rate. Negative feedback is used to reliably settle the collector current to the precise target value after the ramp integration. See figure 7.



**Figure 6.** Thermal drift during bias. The active feedback unit (AFU) holds collector voltage and current constant.

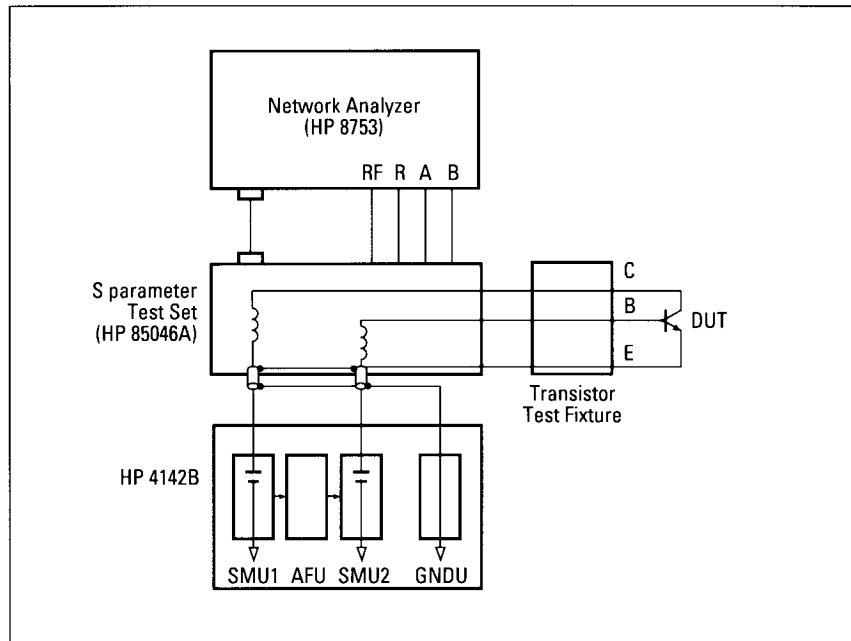


**Figure 7.** Simplified AFU Operation. A programmable ramp followed by an analog search applies bias quickly and safely.



Figure 8 shows a setup using the AFU biasing method with the HP 4142B for making reliable S-parameter measurements immune from thermal drift error. Later in the application note an improved circuit is shown which includes kelvin bias compensation to correct for voltage drops in series with the DUT terminals.

**Figure 8.**  
**S-Parameter**  
**measurement**  
**configuration**  
**using the**  
**HP 4142B AFU.**



#### 1.4 A complete MMIC DC/RF Wafer Probe Test System

Test costs can often be the single most prohibitive factor limiting availability of competitively priced MMICs. Tests are often exotic and manual in nature. Usually multiple test setups are required for each unit tested. There is an industry need for solutions which integrate DC and RF testing in an efficient manner, preferably at wafer level. Thorough testing early on in the MMIC process can help avoid costly or time consuming mistakes. More accurate test data is now being required to support simulation models during the design phase. In production, as chip volumes increase, reduction of high MMIC costs require faster (higher throughput) testing using integrated test systems.

Figure 9 shows an integrated test solution for MMIC test which is made possible, in part, by the robust feature set of the HP 4142B. Through the use of

bias “tees” and central test sets such as the HP 85110A shown, precise DC and RF characterization is performed with a single device connection. You benefit with this approach with,

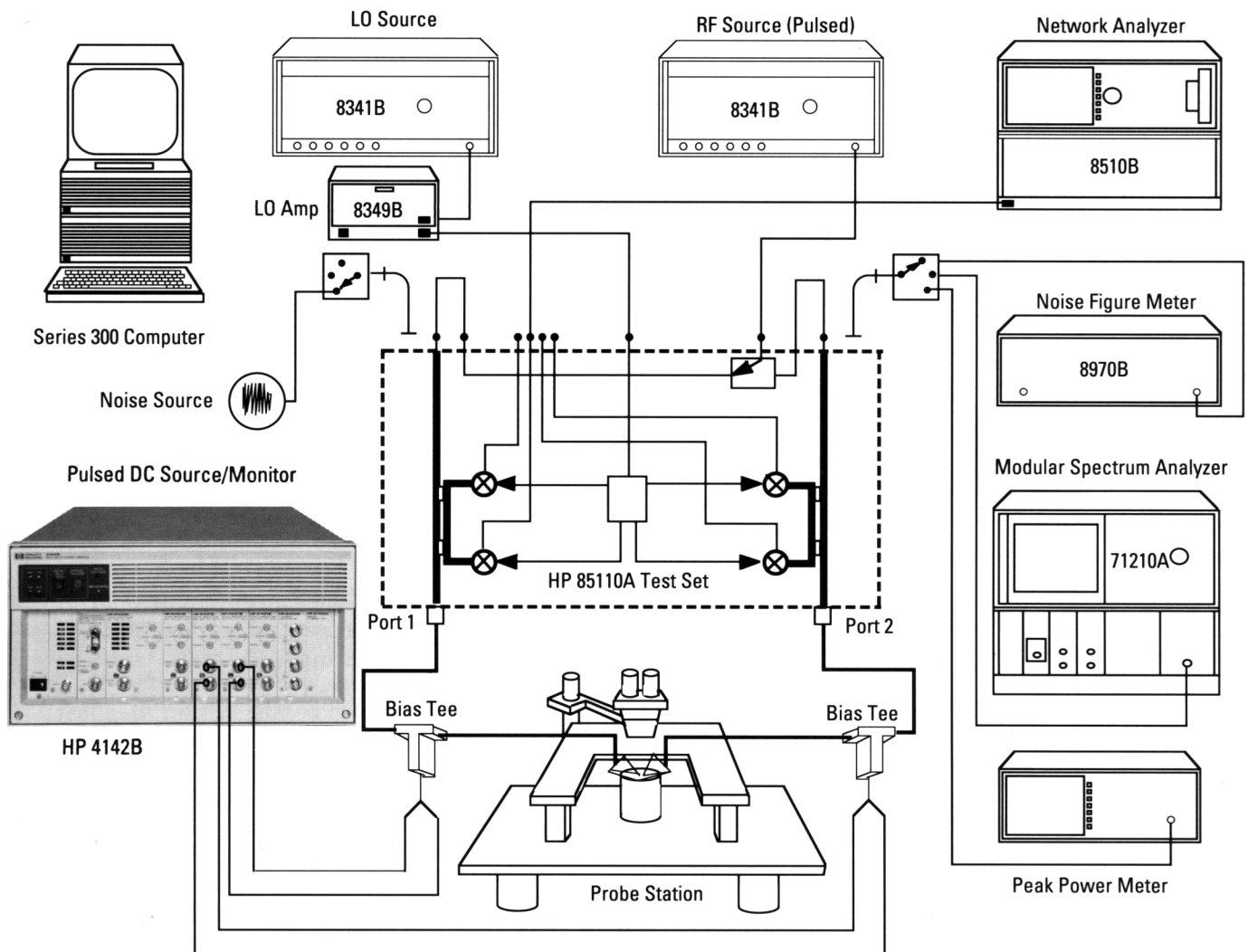
- Reduced setup and test times
- Eliminate pad damage due to multiple probing
- Increase correlation accuracy between DC and RF data
- Reduce test development and support costs

The test system shown provides DC test and S-parameter, noise figure, distortion, power, pulsed DC/RF and frequency translation measurement capability. Features of the HP 4142B which enhance this systems capabilities include,

- Precision extraction of DC parameters for modeling
- High throughput DC functional test in production
- Integration of up to 8 DC channels in one 11" high rack space

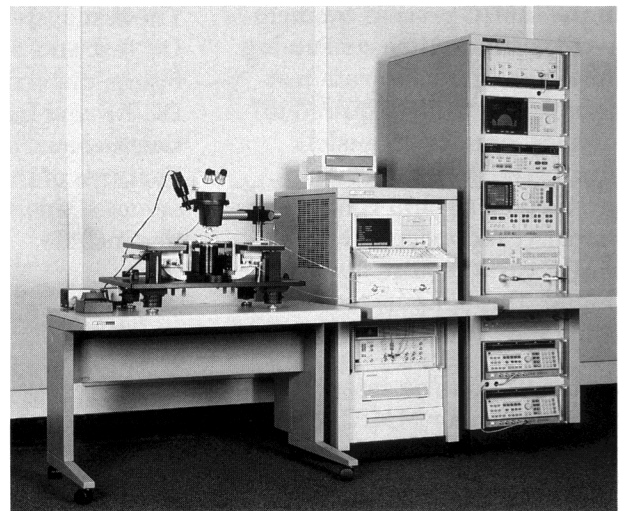
- SMU design eliminates matrix switching, complex fixturing
- External triggering and synch to RF test instrumentation
- Safe biasing using active feedback (AFU)
- Advanced DC waveforms like staircase sweeps and dual pulse

For more detailed information concerning multi-parameter MMIC test systems, refer to “A complete microwave test system integrated for you by Hewlett-Packard” (publication number 5952-1749). This solution is referred to as the SCMM (single connection multiple measurement) test system. Instrumentation is optionally tailored for your requirements. A test shell contains all instrument control software and provides a unified user interface for turnkey DC/RF test.



**Figure 9. Diagram of complete MMIC test system. The HP 4142B obtains all DC parameters and provides RF biasing for single connection testing.**

**Figure 10. HP offers integrated solutions. This system combines DC, network, spectrum and noise analysis to characterize and production test MMICs.**



**2.1 RF With Precision DC Bias Compensation**

As mentioned earlier, the ability to combine DC and RF test with a single connection is critical for production MMIC test. The HP 4142B with its flexible SMU architecture allows virtually any measurement to be made without re-connecting the device. Key to integrating DC with RF signals is the bias network (tee) and RF test set. This section will review techniques for increasing system accuracy and throughput by using kelvin (remote) sensing to compensate for bias tee and RF test set resistive losses.

**Bias Tees**

Bias tees are precision broadband components for supplying DC bias to the center conductor of a coaxial RF line which can be connected to the microwave DUT. A tee-junction is made to the DC source through a low pass filter, consisting of a loss choke and a bypass capacitor. See Figure 11. RF test sets are boxes containing RF coaxial switches and couplers which allow complete S-parameter characterization of a two port DUT with a single connection. A bias tee is included in each RF port.

**Compensating DC error**

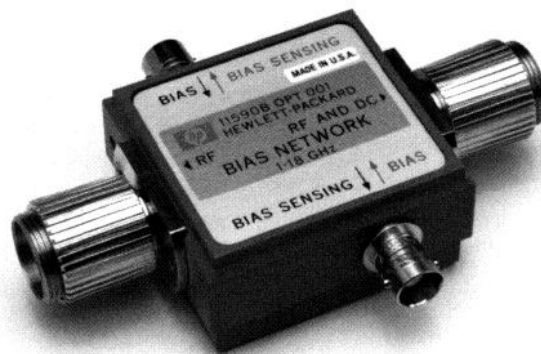
Bias tees and fuses in each test set channel can add >1 ohm of uncompensated series resistance to each DUT RF line making precision DC measurement impractical. For biasing of

MMICs above 500 mA both pulsed DC and remote sensing becomes mandatory to solve this problem. Overheating of bias tee coils and significant resistive channel drops of >100 mV error would otherwise occur.

Probe contact resistance during wafer evaluation can be another source of resistive error. In some cases multiple pad connections are available or designed in for remote sensing right down to the chip level.

Compensating for DC error with remote sensing not only improves system accuracy, but can increase test throughput by up to 5 or 10 fold. Kelvin remote sensing can eliminate the need for calibrating out fixture losses which can involve complicated look-up tables of correction factors.

**Figure 11. Bias network with two BNC ports used for DC force and DC sense.**



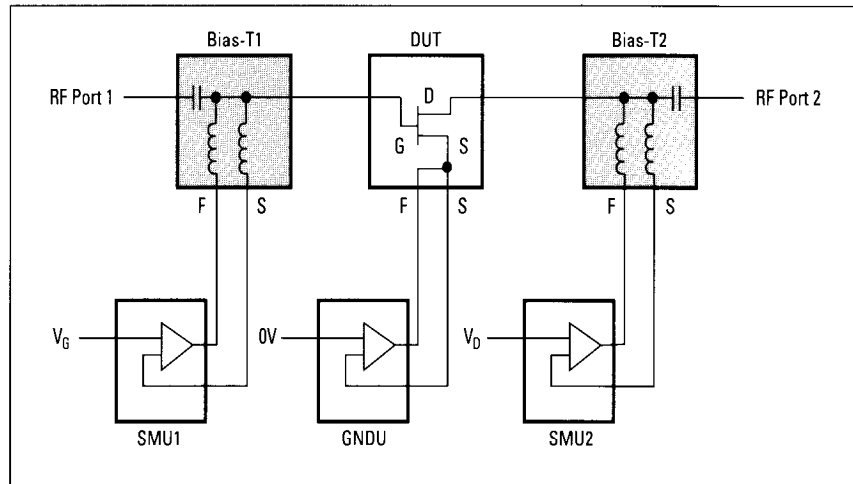
**Table 3. Bias Tee Specifications**

	Model HP 11590B	Model HP 11590B opt. 001	Model HP 116612A
Frequency Range	0.1 to 12.4 GHz	0.1 to 18 GHz	0.045 to 26.5 GHz
RF Connector	N-female	APC-7	APC-3.5
Impedance	50 ohms	50 ohms	50 ohms
Port Match (Min Return Loss)	19 dB	19 dB to 12.4 GHz 14 dB to 18 GHz	20 dB to 8 GHz 18 dB to 18 GHz 14 dB to 26.5 GHz
Insertion Loss (Max)	0.8 dB	1.2 dB	1.2 dB
Max Bias Voltage	100 VDC	100 VDC	100 VDC
Max Bias Current (Continuous)	500 mA	500 mA	500 mA
Bias Ports	2	2	1
DC Resistance (Bias to RF port)	3.0 ohms	3.0 ohms	3.0 ohms

## Kelvin Sensing with RF Test Sets

Ideally, a dual-coil (force/sense) bias tee is desirable, which can be placed at the DUT RF-in and RF-out connections. Table 3 lists several models of HP bias tees which can be used to bias the DUT external to the RF test set. Bias tees with two DC ports can be used as shown in figure 12. The high DC resistance of the bias choke coil in the force (F) line does not affect the programmed voltage monitored by the high impedance sense (S) line. By calibrating the network analyzer at the fixture interface, RF impedance error from the external bias tees can be removed during S-parameter measurement.

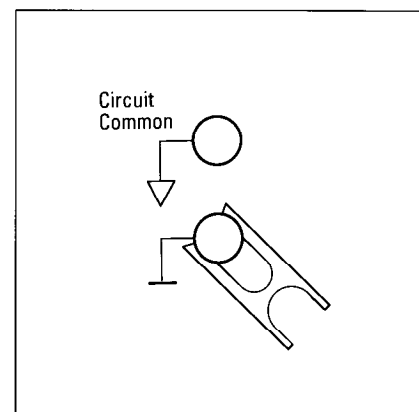
The GNDU (0 volt SMU) of the HP 4142B should also be connected with force/sense terminated as close as possible to the DUT. Proper use of the GNDU removes noise and resistive losses due to ground paths which can add up to >10 mV of typical system error. The point at which the GNDU force/sense lines are terminated becomes the reference point for all SMU measurements. Keeping this point at the DUT fixture is necessary to effectively reduce cable and instrumentation chassis ground losses. This is especially true for wafer probing applications.



**Figure 12.**  
Adding external bias tees to achieve full kelvin sensing at the DUT.

## Use of the HP 4142B Shorting Bar

Disconnect the shorting bar on the front of the HP 4142B when the GNDU is being used with a network analyzer. This floats the circuit common of the HP 4142B and prevents the GNDU from being grounded to the network analyzer chassis. It will also eliminate the possibility of any ground current loops flowing between the HP 4142B chassis and the network analyzer chassis.

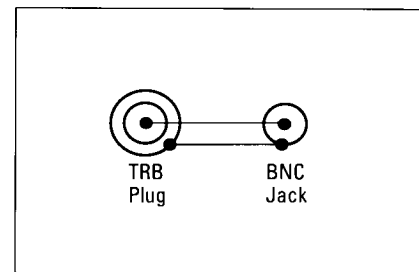


**Figure 13.**  
HP 4142B chassis shorting bar disconnected at the front panel.

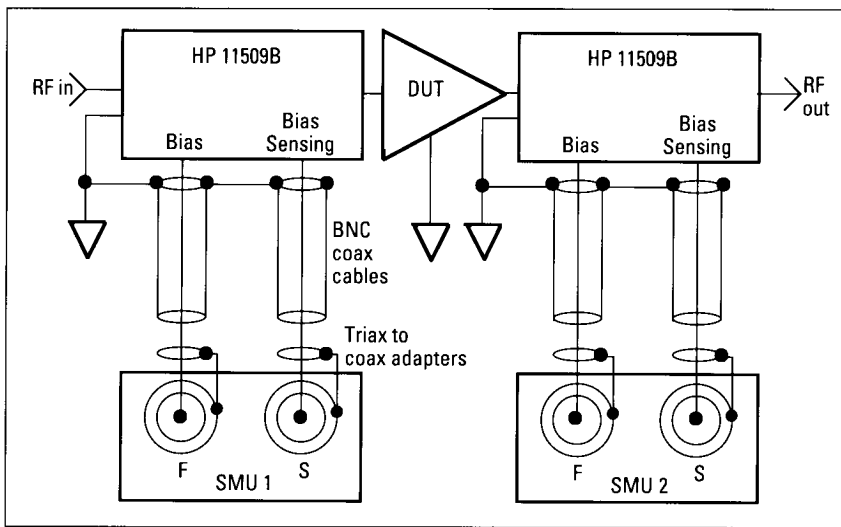
### Triax to Coax Adapters Simplify Bias Hookup

The driven guard connections used to insure accurate low current measurements ( $<1\text{nA}$ ) usually are not necessary in microwave applications. By using a triax to coax adapter which leaves the inner shield (guard) disconnected, simple SMU hookup is possible with standard 50 ohm BNC coaxial cables. Figure 14 shows a particularly convenient way to fixture to the DUT when using the HP 11509B bias network. Coaxial cables connect directly to the HP 11509B bias/bias sense terminals and serve as a solid ground return path to the SMU circuit common. The GNDU is not needed in this application due to the low impedance return and excellent shielding afforded by the coax cable.

Use of the proper triax adapter is important. The recommended adapter for SMU force and sense connections is the Trompeter Elec. Inc. part no. ADBJ20-E2-PL75. This adapter connects the triax center lead and outer shield while leaving the inner shield floating, as shown in figure 15.



**Figure 15. Triax to coax adapter floats guard and simplifies SMU connections for MMIC applications.**



**Figure 14. Using RF ground as circuit common for the HP 4142B.**

## 2.2 Safely Applying Bias To Microwave Transistors

The following procedures provide the safest turn-on sequence for devices which are very sensitive to current and voltage spikes. These procedures are easily adopted in automated systems using several SMU channels of the HP 4142B.

### Bipolar Transistors

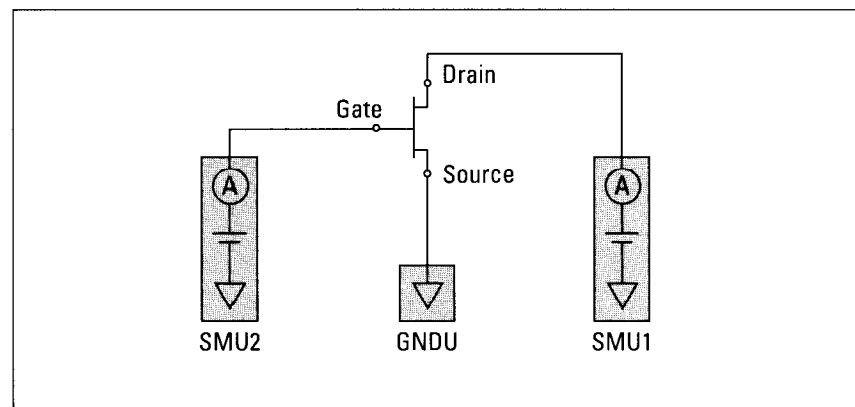
1. Ground the base to the emitter.
2. Apply desired collector-to-emitter bias with an SMU in voltage mode.
3. Apply base-to-emitter bias through an SMU in current mode to desired quiescent point.
4. Remove bias in the reverse order.

### GaAs FETs

1. Ground the gate to source.
2. Apply bias approximately equal to or less than the pinch-off voltage between gate and source. Some FETs are unable to handle  $I_{dss}$  without damage.
3. Apply the desired drain-to-source bias.
4. Decrease (N-channel) or increase (P-channel) gate

5. Remove bias in the reverse order.

Dual-gate FETs are biased by first applying forward bias to the second gate (closest to the drain). Next, apply reverse bias to the first gate. Lastly, bias the drain.



**Figure 16.**  
Measurement connections for GaAs FET.

```

10  ! Safe bias sequence for GaAs FET susceptible to Idss damage
20  !
30  LOADSUB ALL FROM "HP4142_DRV"
40  OPTION BASE 1
50  ASSIGN @Hp4142 TO 717
60  COM @Hp4142
70  INTEGER Gate,Drain
80  !
90  Drain=1
100 Gate=2
110 Vds=6.0
120 Vgs_pinch=-2.5
130 Vgs1=-.8
140 Vgs2=0
150 !
160 Init_hp4142
170 Ch_sw_on
180 Force_v(Gate,Vgs_pinch,0,.01)
190 Force_v(Drain,Vds,0,1)
200 Force_v(Gate,Vgs1)
210 Measure_i(Drain,Ids1)
220 Force_v(Gate,Vgs2)
230 Measure_i(Drain,Ids2)
240 Force_v(Gate,Vgs_pinch)
250 Force_v(Drain,0)
260 Zero_output
270 Ch_sw_off
280 Gm=(Ids2-Ids1)/(Vgs2-Vgs1)
290 END
! Source : GNDU
! Drain : Channel 1
! Gate : Channel 2
! Connect SMU channels to FET
! Vgs_pinch set with 10 mA compliance
! Set Vds after setting Vgs_pinch
! Raise Vgs above Vgs_pinch
! Return Vgs to Vgs-pinich
! Remove Drain bias before Gate bias
! Remove remaining bias
! Disconnect

```

**Figure 17.** Measurement program for safely biasing a GaAa FET.

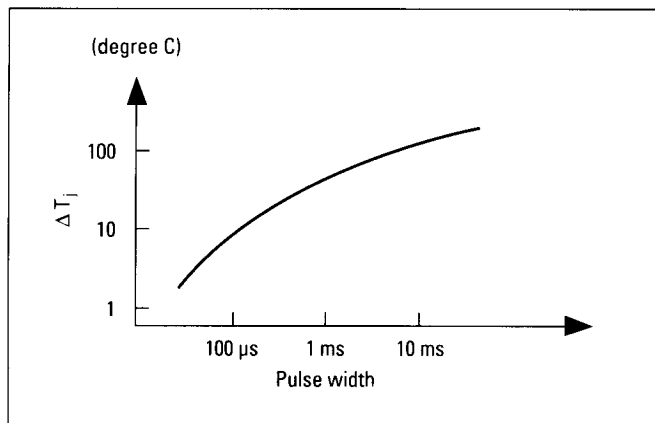
Figure 17 gives a programming example of a safe turn-on procedure for a microwave GaAs FET with very low gate and drain break down voltages. The HP 4142B control software includes easy-to-use commands which take care of all setup and measurement requirements.

### 2.3 Advantages of DC Pulsed Bias

The clean pulsed waveforms of the HPSMU (1 A max) and the HCU (10 A max) allow precision testing at high currents by reducing thermal drift in the DUT and overheating of bias tees (rated at 500 mA max continuous DC). The 100  $\mu$ s minimum pulse width of the HCU is still well within the cut-off response of the bias tee low-pass filter response to allow both accurate DC and RF characterization in one fixture.

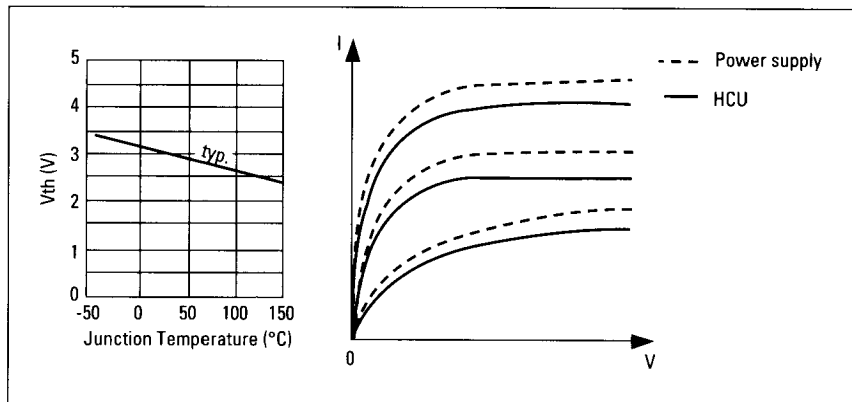
#### 100 $\mu$ s Pulse Width

Figure 18 illustrates how junction temperature can vary widely with different pulse widths. The HCU can operate down to 100  $\mu$ s pulse widths.



**Figure 18. Pulsed measurements improve system accuracy by reducing thermal drift.**

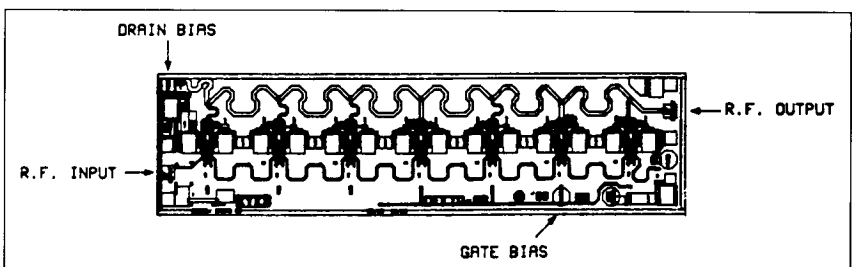
And with a 1% duty cycle, heating can be reduced to below 10 degrees C. This becomes significant with MMIC devices where heating can change electrical parameters such as HFE or  $V_{th}$  by 0.5% per degree C. Less device heating correlates to



**Figure 19. The HCU allows pulsed down to 100  $\mu$ s and 1% duty cycle to reduce device heating.**

### Synchronized Swept Pulsing

Figure 20 shows a MMIC traveling wave amplifier which electrical can be characterized as a high power FET. Synchronized dual pulse sweeps allow quick generation of family curves such as  $I_d$  vs  $V_{ds}$ . Notice the simplicity of software control statements. Use of supplied HP 4142B software driver routines simplifies development of custom MMIC test algorithms. See figure 21.



**Figure 20. A MMIC travelling wave amplifier is tested as a power FET.**

```

10  ! High current pulsed sweep with synchronous pulsed bias
20  !
30  LOADSUB ALL FROM "HP4142_DRV"
40  OPTION BASE 1
50  ASSIGN @Hp4142 TO 717
60  COM @Hp4142
70  INTEGER Base_,Collector,Vc_steps
80  DIM Ic(101)
90  !
100 Base_=2                      ! Emitter : GNDU
110 Collector=5                  ! Base   : HPSMU Channel 2
120 Vc_start=.1                  ! Collector : HCU Channel 5
130 Vc_stop=10
140 Vc_steps=101
150 Ic_comp=10
160 Ib=5.E-2
170 !
180 Init_hp4142
190 Ch_sw_on
200 Set_piv(Collector,1,0,0,Vc_start,Vc_stop,Vc_steps,2.E-4,2.E-2,0,Ic_comp)
210                               ! Set pulsed voltage sweep source
220 Dpulse_i(Base_,0,0,Ib,2)     ! Set pulsed current bias source
230 Dsweep_piv(Collector,2,0,Ic(*)) ! Trigger both sources synchronously and
240                               ! store swept measurement data in Ic(*)
250 Zero_output
260 Ch_sw_off
270 END

```

Figure 21. The HCU operated in tandem with standard SMUs for synchronized pulsed testing.

## 2.4 Fixturing Considerations when Using the HCU

To allow full 10 A sinking of ground currents without resistive losses, a special active ground is supplied in each HCU channel. The HCU is really two SMUs in one box. Its floating design keeps ground currents internal to the HCU. The RF system ground and the DC ground reference (GNDU) are isolated from these currents, which increases noise immunity and extends the current sinking capability of the HP 4142B mainframe. See figure 22.

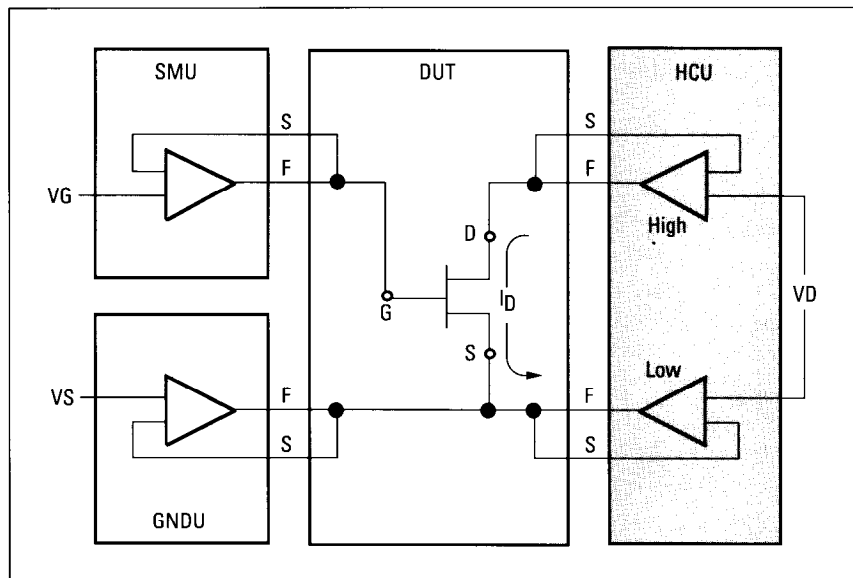


Figure 22. Its floating design allows the HCU to sink pulsed currents up to 10A.



### HP 16088A/B Test Fixtures

To simplify device hookup of packaged parts to the HCU, SMU or other HP 4142B channels, the HP 16088A/B test fixtures are recommended. These fixtures terminate all coax and triax channel cables properly in a dark shielded box. Standard and customizable sockets provide safe and accurate hookup to any device pin using quick, jumper-wire connections.

The 16088B supports an internal three-input matrix. This allows the full range of HP 4142B resources to be applied to a device pin.

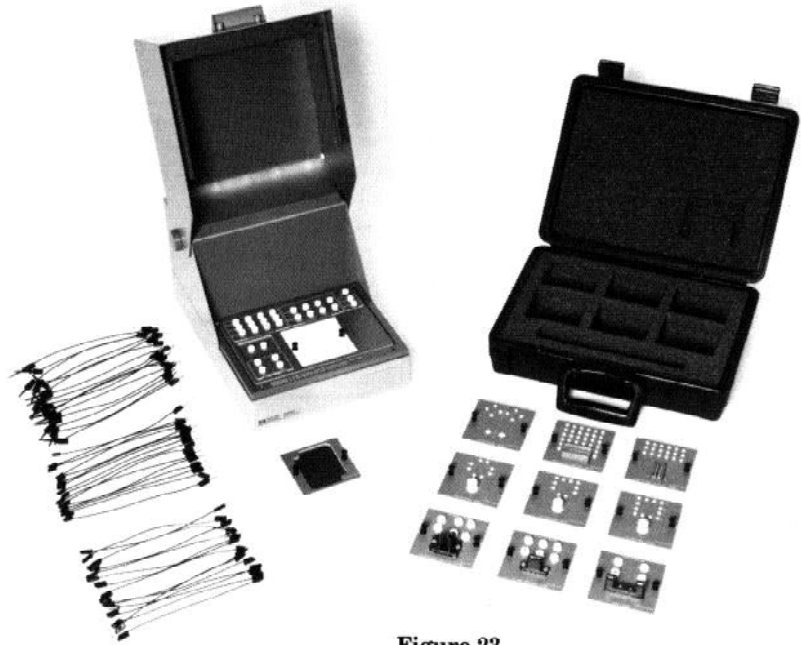


Figure 23.  
HP 16088A test  
fixture and  
accessories

### Low Inductance Cabling

Normal coaxial wiring capable of handling 10 amp currents would add  $5 \mu\text{H}$  inductance to the DUT. Oscillation would be very likely due to typical capacitive inputs of MMICs in the order of 1 pf. By coupling the high force and low force wires with a special twisted and shielded design, inductive effects cancel one another to allow  $<0.1 \mu\text{H}$  in a 1.5 m cable. Such specialized cabling is an integral factor allowing the HCU to retain the same 5-digit accuracy and resolution as the standard SMUs in the HP 4142B product family.

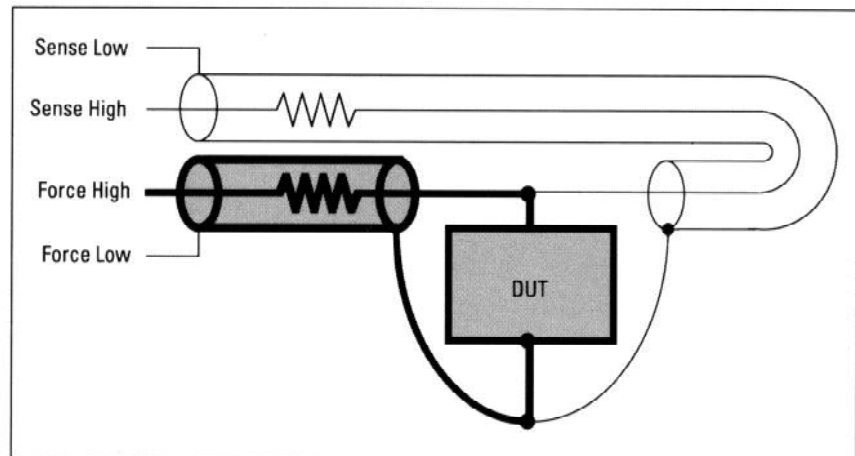


Figure 24.  
Coupling force  
high and force  
low currents in  
the same cable  
greatly reduces  
cable inductance.

## 2.5 High Speed Testing of Monolithic Amplifiers

An application well suited to the HP 4142B modular DC source/monitor is high speed production testing of microwave components such as the HPMA-200 series of single stage bipolar gain blocks. Gains of 12 dB at 1 GHz and bandwidths of 3 GHz are typical. Such components are typically priced at less than \$1 each and must be 100% tested for DC functionality and RF gain/flatness specs. Automatic testing of up to 10,000 units/hour is required to make production economically feasible. This means DC bias, RF sweep and data gathering must be completed in as little as 200 ms.

### Features

- 3 dB bandwidth: DC to 2.4 GHz
- 11.6 dB gain at 1 GHz
- Cascadeable 50 ohm gain block
- Low cost surface mount plastic package

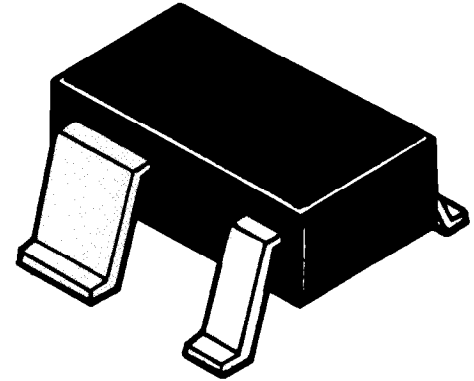


Figure 25.  
HPMA-0211  
Silicon  
Monolithic  
Amplifier

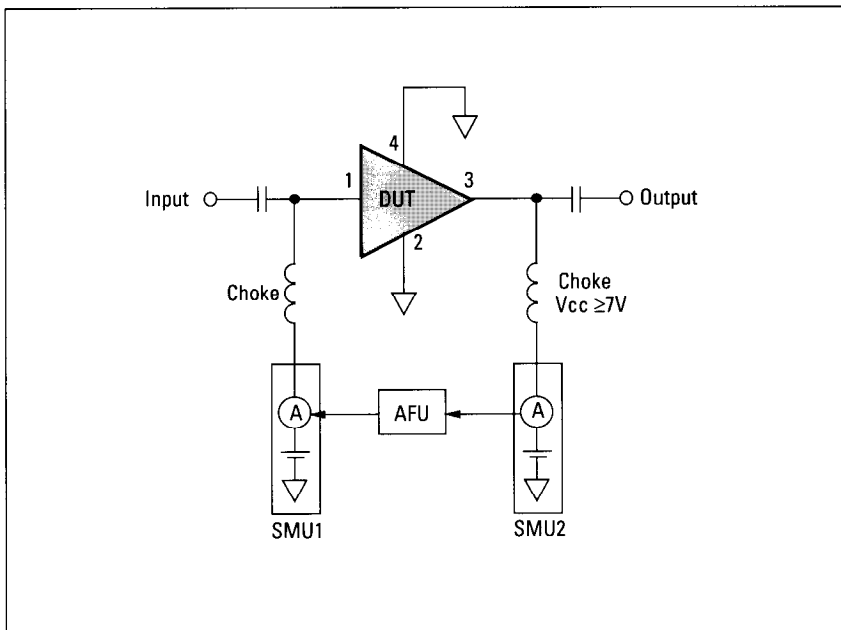


Figure 26. Typical amplifier bias configuration.

### The AFU Increases Test Speed and Stability

The automatic feedback unit (AFU) and two SMUs of the HP 4142B are designed to bias such high-frequency devices in as little as 25 ms without overshooting or spikes. As seen in figure 26, SMU2 monitors the amplifier current. The AFU controls SMU1 as determined by the monitored current. This method contributes to a stable bias point, free of thermal drift. The AFU slew rate is programmable from 0.5 V/sec to 50 kV/sec without spikes, thus controlling bias overshoot.

### Fully Automated High-volume Test Station

Using a bias tee such as the HP 11590B with bias sensing, reliable measurements to  $\pm 500$  mA are possible. And using a fast scalar analyzer such as the HP 8757, at least 10 RF readings are possible in less than 50 ms. A complete block diagram of a production-line bench test station is shown in figure 27. The DUT is packaged in a plastic four-lead surface mount configuration (SOT143). Commercially available handlers easily move the SOT package in and out of a strip-line fixture. This fixture is designed to test S-parameters over the required 3 GHz bandwidth of SOT amplifiers such as the HPMA-0211.

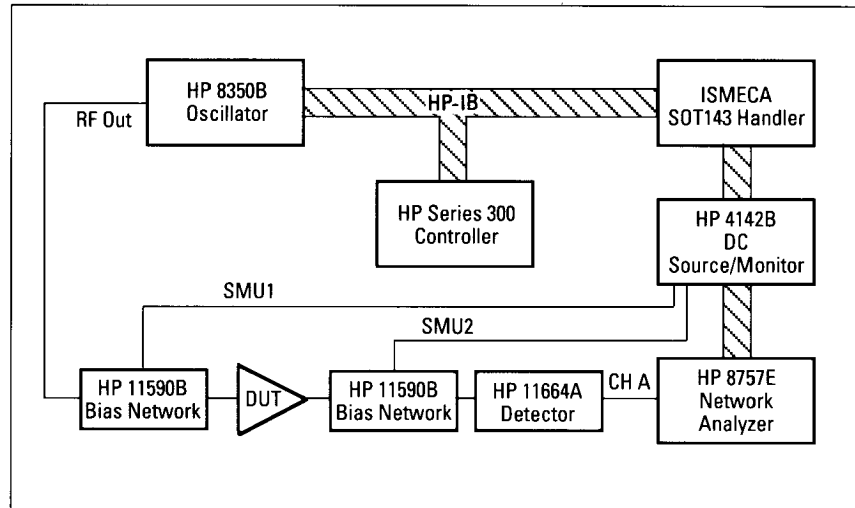


Figure 27. Using the HP 4142B to achieve 10,000 unit per hour throughput for DC and RF test.

### Programmed Memory Further Increases Test Speed

The sample code in figure 28 shows a testing sequence which quickly searches for the desired bias condition using the AFU. The HP 4142B then releases control of the HP-IB bus and allows the HP 8757 to apply RF input power over a range of frequencies and extract RF output power levels at channel A.

The HP 4142B has the ability to store entire test sequences in memory and then execute them on command, once for each new device tested. This eliminates the time that would be required to program the HP 4142B over the HP-IB bus each time a control command is issued.

```

10      ! Using programmed memory and analog feedback
20      ! to quickly bias an amplifier for RF test
21      !
30      OPTION BASE 1
40      ASSIGN @Hp4142 TO 717
50      ASSIGN @Hp8757 TO 714
60      OUTPUT @Hp4142;"*RST"
70      INTEGER Input,Output
80      DIM AS[31]
90      !
100     Input=1                ! Ground : RF Ground Plane
110     Output=2              ! Input : SMU channel 1
120     !                      ! Output : SMU channel 2
130     !                      ! Icc : Target output current
140     Icc=.05                ! Ibias : Input bias
150     Vcc=10
160     !
170     OUTPUT @Hp4142;"ST";1    ! Store program in memory
180     OUTPUT @Hp4142;"CN";Input,Output ! Connect channels
190     OUTPUT @Hp4142;"ASV";Input,0,2,100,.1 ! Set search SMU channel
200     OUTPUT @Hp4142;"AVI";Output,Vcc,Icc,.5 ! Set sense SMU channel
210     OUTPUT @Hp4142;"ASM";1,4,.0002 ! Neg feedback integ. time
220     OUTPUT @Hp4142;"MM";6    ! Analog search meas. mode
230     OUTPUT @Hp4142;"XE"     ! Trigger search
240     OUTPUT @Hp4142;"END"    ! End of program in memory
250     OUTPUT @Hp4142;"RU";1,1 ! Trigger program in memory
260     ENTER @Hp4142;AS
270     Ibias=VAL(AS[4,15])
280     OUTPUT @Hp4142;"DI";Input,16,Ibias ! Hold amplifier bias
290     OUTPUT @Hp4142;"DV";Output,12,Vcc ! settings for RF test
310     !
320     OUTPUT @Hp8757;"SC";Start_posn ! Begin RF Test, S21
330     OUTPUT @Hp8757;"OC"
340     ENTER @Hp8757;Value_a
350     S21(Start_freq*10)=Value_a

```

Using programmed memory can reduce test times below 300 ms for a complete DC and RF test of monolithic amplifiers. The test cycle includes DC leakage, DC current, RF gain and RF gain flatness tests.

Figure 28. Programming example of high-speed RF gain measurement.

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