HP 4142B Modular DC Source/Monitor

Operation Manual

SERIAL NUMBERS

This manual applies directly to instruments with serial numbers 2946J-
and above. With changes described in Appendix A, this manual
also applies to instruments with serial numbers 2716J- and 2839J-.

**HEWLETT
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CERTIFICATION

Hewlett-Packard Company certifies that this product met its published specifications at the time of shipment from the factory. Hewlett-Packard further certifies that its calibration measurements are traceable to the United States National Institute of Standards and Technology (formerly National Bureau of Standards), to the extent allowed by that organization's calibration facility, or to the calibration facilities of other International Standards Organization members.

WARRANTY

This Hewlett-Packard instrument product is warranted against defects in material and workmanship for a period of one year from the date of shipment. During the warranty period, Hewlett-Packard Company will, at its option, either repair or replace products which prove to be defective.

For warranty service or repair, this product must be returned to a service facility designated by HP. Buyer shall prepay shipping charges to HP and HP shall pay shipping charges to return the product to Buyer. However, Buyer shall pay all shipping charges, duties, and taxes for products returned to HP from another country.

HP warrants that its software and firmware designated by HP for use with an instrument will execute its programming instruction when property installed on that instrument. HP does not warrant that the operation of the instrument, or software, or firmware will be uninterrupted or error free.

LIMITATION OF WARRANTY

The foregoing warranty shall not apply to defects resulting from improper or inadequate maintenance by Buyer, Buyer-supplied software or interfacing, unauthorized modification or misuse, operation outside of the environment specifications for the product, or improper site preparation or maintenance.

NO OTHER WARRANTY IS EXPRESSED OR IMPLIED. HP SPECIFICALLY DISCLAIMS THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE.

EXCLUSIVE REMEDIES

THE REMEDIES PROVIDED HEREIN ARE BUYER'S SOLE AND EXCLUSIVE REMEDIES. HP SHALL NOT BE LIABLE FOR ANY DIRECT, INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES, WHETHER BASED ON CONTRACT, TORT, OR ANY OTHER LEGAL THEORY.

ASSISTANCE

Product maintenance agreements and other customer assistance agreements are available for Hewlett-Packard products.

For any assistance, contact your nearest Hewlett-Packard Sales and Service Office. Address are provided at the back of this manual.

Herstellerbescheinigung

Hiermit wird bescheinigt, daß das Gerät HP 4142B Modular DC Source/Monitor in Übereinstimmung mit den Bestimmungen von Postverfügung 1046/84 funkentstört ist.

Der Deutschen Bundespost wurde das Inverkehrbringen dieses Gerätes angezeigt und die Berechtigung zur Überprüfung der Serie auf Einhaltung der Bestimmungen eingeräumt.

Anm: Werden Meß- und Testgeräte mit ungeschirmten Kabeln und/oder in offenen Meßaufbauten verwendet, so ist vom Betreiber sicherzustellen, daß die Funk-Entstörbestimmungen unter Betriebsbedingungen an seiner Grundstücksgrenze eingehalten werden.

Manufacturer's Declaration

This is to certify that this product, the HP 4142B Modular DC Source/Monitor, meets the radio frequency interference requirements of directive 1046/84. The German Bundespost has been notified that this equipment was put into circulation and was granted the right to check the product type for compliance with these requirements.

Note: If test and measurement equipment is operated with unshielded cables and/or used for measurements on open setups, the user must insure that under these operating conditions, the radio frequency interference limits are met at the border of his premises.

SAFETY SUMMARY

The following general safety precautions must be observed during all phases of operation, service, and repair of this instrument. Failure to comply with these precautions or with specific **WARNINGS** given elsewhere in this manual violates safety standards of design, manufacture, and intended use of the instrument. **The Hewlett-Packard Company assumes no liability for the customer's failure to comply with these requirements.**

GROUND THE INSTRUMENT
To minimize shock hazards, the instrument chassis and cabinet must be connected to an electrical ground. The instrument is equipped with a three-conductor AC power cable. The power cable must be plugged into an approved three-contact electrical outlet or used with a three-contact to two-contact adapter with the grounding wire (green) firmly connected to an electrical ground (safety ground) at the power outlet. The power jack and the mating plug of the power cable meet International Electrotechnical Commission (IEC) safety standards.

DO NOT OPERATE IN AN EXPLOSIVE ATMOSPHERE
Do not operate the instrument in the presence of flammable gasses or fumes. Operation of any electrical instrument in such an environment constitutes a safety hazard.

KEEP AWAY FROM LIVE CIRCUITS
Operating personnel must not remove instrument covers. Component replacement and internal adjustments must be made by qualified maintenance personnel. Do not replace components with power cable connected. Under certain conditions, dangerous voltages may exist even with the power cable removed. To avoid injuries, always disconnect power and discharge circuits before touching them.

DO NOT SERVICE OR ADJUST ALONE
Do not attempt internal service or adjustment unless another person, capable of rendering first aid and resuscitation, is present.

DO NOT SUBSTITUTE PARTS OR MODIFY INSTRUMENT
Because of the danger of introducing additional hazards, do not substitute parts or perform unauthorized modifications to the instrument. Return the instrument to a Hewlett-Packard Sales and Service Office for service and repair to ensure the safety features are maintained.

DANGEROUS PROCEDURE WARNINGS
WARNINGs, such as the example below, precede potentially dangerous procedures throughout this manual. Instructions contained in the warnings must be followed.

| WARNING |

DANGEROUS VOLTAGES, CAPABLE OF CAUSING DEATH, ARE PRESENT IN THIS INSTRUMENT. USE EXTREME CAUTION WHEN HANDLING, TESTING, AND ADJUSTING THIS INSTRUMENT.

SAFETY SYMBOLS

General Definitions of Safety Symbols Used On Equipment or In Manuals.

Instruction manual symbol: the product will be marked with this symbol when it is necessary for the user to refer to the instruction manual in order to protect against damage to the instrument.

Indicates dangerous voltage (terminals fed from the interior by voltage exceeding 1000 volts must be so marked).
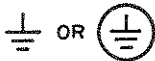
Protective conductor terminal. For protection against electrical shock in case of a fault. Used with wiring terminals to indicate the terminal which must be connected to ground before operating equipment.

Low-noise or noiseless, clean ground (earth) terminal. Used for a signal common, as well as providing protection against electrical shock in case of fault. A terminal marked with this symbol must be connected to ground in the manner described in the installation (Operating) manual, and before operating the equipment.
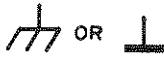
Frame or chassis terminal. A connection to the frame (chassis) of the equipment which normally includes all exposed metal structures.

Alternating current (power line).

Direct current (power line).

Alternating or direct current (power line).

A **WARNING** denotes a hazard. It calls attention to a procedure, practice, condition or the like, which, if not correctly performed or adhered to, could result in injury or death to personnel.

A **CAUTION** sign denotes a hazard. It calls attention to a procedure, practice, condition or the like, which, if not correctly performed or adhered to, could result damage to or destruction of part or all of the product.

NOTE

A **NOTE** denotes important information. It calls attention to a procedure, practice, condition or the like, which is essential to highlight.

PREFACE

This manual contains installation information, and operating and programming information for the HP 4142B. The manual consists of the following chapters and appendixes:

Chapter 1 Installation

Contains initial inspection and installation information necessary to know before applying ac power.

Chapter 2 Getting Started

Shows product overview, how to send commands to the HP 4142B, how to force and measure voltage and current, and how to retrieve measurement data. This chapter will help you quickly learn to operate the HP 4142B.

Chapter 3 Test Device Connections

Shows how to connect the test device to the HP 4142B.

Chapter 4 Measurement Modes

Describes the types of measurements, such as spot, sweep, and pulsed measurements.

Chapter 5 Measurement Functions

Describes the functions that can be used in measurements, such as ranging, compliance, measurement averaging, automatic sweep abort function, and program memory.

Chapter 6 Miscellaneous Functions

Describes the functions that are not directly related to the measurements, such as the front and rear panels, query commands, and the functions at power-on.

Appendix A Manual Changes

Contains the information needed to use this manual with an HP 4142B that was manufactured before the printing date of this manual.

Appendix B Specifications

Contains the specification and reference data of the HP 4142B.

Appendix C Accessories and Options

Contains the accessories and options lists.

This manual does not contain detailed descriptions of each HP 4142B command, measurement data output format, and error messages. Refer to the *HP-IB Command Reference Manual* for more detailed information on these topics.

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CHAPTER 1

INSTALLATION

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INTRODUCTION

This chapter provides HP 4142B installation information. Included is information on initial inspection and damage claims, installing your HP 4142B, installing and removing plug-in units, storage and shipment, and repair service.

INITIAL INSPECTION

Each HP 4142B is carefully inspected before it leaves the factory. Upon receipt and before unpacking the HP 4142B, inspect the shipping container for damage. If there is any evidence of damage or mishandling, retain all packing materials and notify both the shipping carrier and the nearest Hewlett-Packard office.

When you unpack the HP 4142B, verify that the following accessories are included.

- Operation Manual (this manual)
- HP-IB Command Reference Manual
- Power Cable

If the shipment is incomplete, or if the contents show any sign of mechanical damage or other defects (scratches, dents, broken switches, etc.), notify the nearest Hewlett-Packard office (see the list at the back of this manual). HP arranges for repair or replacement without waiting for the claim settlement.

When you unpack the HP 4142B, retain all packing materials for future use. If it becomes necessary to reship the HP 4142B, repack it in the original packing materials and shipping carton.

INSTALLING THE HP 4142B

Installing the Blank Panel

CAUTION

To prevent thermal damage to HP 4142B units, be sure that Blank Panels (part number 04142-60012) are installed in all unused slots.

Installing the Front Panel

The front panel of the HP 4142B is packed separately from the mainframe. Before you connect a power cable to the HP 4142B, attach the front panel to the mainframe as instructed in the following procedure.

1. Connect the flat cable connector of the front panel to the mainframe unit connector.

2. Insert the metal flanges on the upper right and left sides of the front panel into their corresponding slots on the mainframe. With a slotted screwdriver, tighten the two screws in the lower left and right corners of the front panel.

Line Power Requirements

The HP 4142B requires a 48 to 66 Hz, single phase power source of 100, 120, or 220 VAC ±10%, or 240 VAC -10% + 5%. Maximum power consumption is 750 VA (Volt-Amps).

WARNING

IF THE HP 4142B IS TO BE ENERGIZED VIA AN EXTERNAL AUTO TRANS-FORMER FOR VOLTAGE REDUCTION, BE SURE THE COMMON TERMINAL IS CONNECTED TO THE NEUTRAL POLE OF THE POWER SOURCE.

Line Voltage and Fuse Selection

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CAUTION
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Before connecting the HP 4142B to an ac power source, verify that the LINE VOLTAGE SELECTOR switch is set to the correct line voltage. Be sure the correct fuse is installed for the selected line voltage.

Setting the Line Voltage Switches:
Disconnect the HP 4142B line power cable before changing the ac line voltage selection switches. With a small flatblade screwdriver, move the LINE VOLTAGE SELECTOR switch to the 100V/120V or the 220V/240V position in accordance with the ac line voltage of your area.

Installing the Line Power Fuse:
To install a fuse, make sure the HP 4142B power cable is disconnected. With a small flatblade screwdriver, turn the fuse holder cap counterclockwise until it pops out. The correct fuse type for each line voltage is shown in the following table. Insert one end of the correct fuse into the fuse cap.

Line Voltage Fuse

Line Voltage	Fuse Rating	Part No.
100V/200V	8 A Normal Blow	2110-0342
220V/240V	4 A Normal Blow	2110-0055

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CAUTION
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Use only replacement fuses of the correct current rating and of the specified type. Do not use mended fuses, and do not short circuit the fuse holder.

Insert the fuse/cap assembly into the fuse holder. Push in on the fuse cap with the screwdriver and rotate it clockwise.
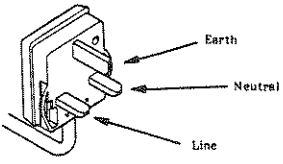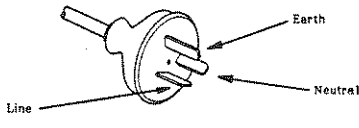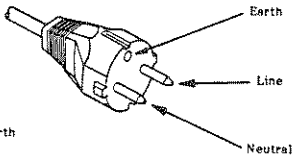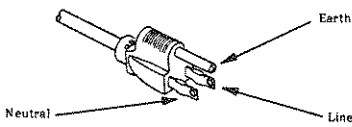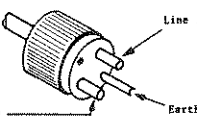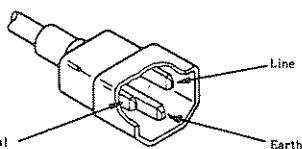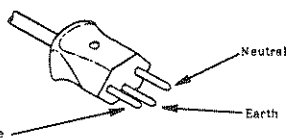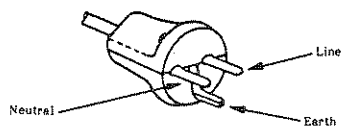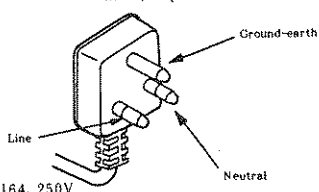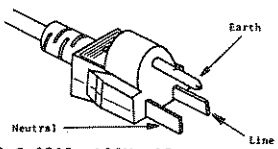
The HP 4142B is shipped from the factory with the LINE VOLTAGE SELECTOR switch set to the line voltage used in the geographic area to which the HP 4142B is shipped, and with the corresponding fuse installed.

Setting the Line Frequency FILTER Switch

To minimize the effects of line frequency noise during measurements, set the FILTER switch on the HP 4142B rear panel to the ac line frequency.

Power Cables

The following figure shows the power plugs used in various countries, and provides available power cable/plug information. Also included is ordering information. If you need assistance in determining the power cable you need, contact the nearest Hewlett-Packard office.

OPTION 906 United Kingdom	OPTION 901 Australia/New Zealand
Earth Neutral Line Plug: BS 1363A, 250V Cable: HP 8120-1351	Earth Neutral Line Plug: NZSS 198/AS C112, 250V Cable: HP 8120-1369
OPTION 902 European Continent	OPTION 903 U.S./Canada
Earth Line Earth Neutral Plug: CEE-VII, 250V Cable: HP 8120-1689	Earth Neutral Line Plug: NEMA 5-15P, 125V, 15A Cable: HP 8120-1378
OPTION 904 U.S./Canada	OPTION 905* Any country
Line 1 Line 2 Earth Plug: NEMA 6-15P, 250V, 15A Cable: HP 8120-0698	Line Neutral Earth Plug: CEE 22-VI, 250V Cable: HP 8120-1396
OPTION 906 Switzerland	OPTION 912 Denmark
Neutral Earth Line Plug: SEV 1011.1959-24507 Type 12, 250V Cable: HP 8120-2104	Line Neutral Earth Plug: DHCR 107, 220V Cable: HP 8120-2956
OPTION 917 India/Republic of S.Africa	OPTION 918 Japan
Ground-earth Line Neutral Plug: SABS 164, 250V Cable: HP 8120-4211	Earth Neutral Line Plug: JIS C 8303, 125V, 15A Cable: HP 8120-4753
NOTE: Each option number includes a 'family' of cords and connectors of various materials and plug body configurations (straight, 90° etc.).	* Plug option 905 is frequently used for interconnecting system components and peripherals.

Power Cables

Grounding Requirements

The HP 4142B is equipped with a three-conductor ac power cable. When plugged into the appropriate power line outlet, the cable grounds the HP 4142B cabinet, thereby protecting the user from possible shock hazards. To preserve this protection feature, the power cable must be connected to an approved three-contact electrical outlet that has its ground conductor connected to an electrical ground (safety ground).

If operating the HP 4142B from a two-contact outlet, use a three-prong to two-prong adapter, and connect the green grounding tab of the adapter to power line ground.

The HP 4142B power jack and the supplied power cable meet International Electrotechnical Commission (IEC) safety standards.

WARNING

FOR PROTECTION FROM ELECTRICAL SHOCK, THE POWER CABLE GROUND MUST NOT BE DEFEATED.

Changing the HP-IB Address

Every device on the HP-IB bus must have a unique address. If you need to change the HP-IB address of the HP 4142B, make sure the HP 4142B is turned off. With a small flatblade screwdriver, set the **HP-IB ADDRESS Switch** on the rear panel to the new address (0 to 30). The new HP-IB address is only recognized at power on.
The HP 4142B leaves the factory with the HP-IB address set to 17.

Connecting the HP-IB Cable

To connect the HP 4142B with a computer or peripheral device via HP-IB (IEEE Std. 488), connect an HP-IB cable between the HP-IB connector on the HP 4142B rear panel and the HP-IB connector on the peripheral device.

A total of 15 devices can be connected on the same HP-IB bus. The length of the HP-IB cables must not exceed 20 meters (65 feet) total, or 2 meters (6.5 feet) per device, whichever is less.

Mounting the HP 4142B

The HP 4142B comes equipped with four feet which allow it to be used as a bench instrument. There are also two retractable stands mounted on the bottom cover so you can tilt the HP 4142B. To use the stands, pull each one away from the bottom cover until it locks into position.

The HP 4142B can be rack-mounted into a cabinet. Use Option 907 to install front handles on your HP 4142B. If you're going to mount your HP 4142B into a rack, remove the retractable stands and install either Option 908 or 909. The following figure provides front handle and rack-mount flange installation information.

CAUTION

Install the HP 4142B horizontally within ±20° when you turn on and use the HP 4142B.

Option	Description	Kit Part Number
907	Handle Kit	5062-3991
908	Rack Flange Kit	5062-3979
909	Rack Flange & Handle Kit	5062-3985

Before installing the desired option, remove the adhesive-backed trim strips (1) from the right and left front sides of the HP 4142B.

HANDLE INSTALLATION (Option 907):
Attach the front handles (3) to the right and left front sides of the HP 4142B with the screws provided. Attach the trim (4) to the handles.

NOTE

To install either Option 908 or 909, remove the feet from the bottom cover by lifting the bar at the inner side of each foot and sliding the foot towards the bar.
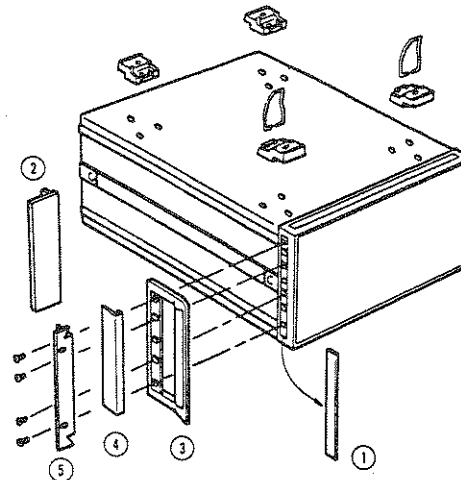
RACK FLANGE INSTALLATION (Option 908): Attach the rack-mount flanges (2) to the right and left front sides of the HP 4142B with the screws provided.

HANDLE & RACK FLANGE INSTALLATION (Option 909): Attach the front handles (3) and the rack-mount flanges (5) to the right and left front sides of the HP 4142B with the screws provided.

Front Handle and Rack-Mount Flange Installation

Operating Environment

To maintain the proper operating environment, operate your HP 4142B within the following limits:

Temperature: 5°C to 40°C.
Humidity: 5% to 80% RH.

Protect the HP 4142B from temperature extremes to prevent condensation from forming inside the HP 4142B.

INSTALLING AND REMOVING PLUG-IN UNITS

All HP 4142B plug-in units can be easily installed and removed. Each plug-in unit can be installed in any slot between slot #1 and #8, and all units can be retrofitted. The following procedure explains plug-in unit installation and removal.

1. Set the **POWER ON/OFF switch** or **LINE ON/OFF switch** to OFF.

CAUTION

To prevent damage to HP 4142B units, be sure to turn your HP 4142B OFF and wait at least 10 seconds before you remove or install units.

2. With a slotted screwdriver, loosen the two screws located in the lower left and right corners of the front panel. Swing the front panel slightly upward, then down, until it comes loose. Disconnect the flat cable that connects the front panel to the mainframe from the mainframe unit connector.

3. **Installing units:**

   Align the unit with the upper and lower slot guide rails. Push the unit into the slot until you feel the unit seat firmly into its mainframe connector. Turn the upper and lower quick-disconnect screws clockwise until they lock.

   Removing units:

   Turn the upper and lower quick-disconnect screws 90° counterclockwise to unlock the unit. Gently pull the unit free from its mainframe connector and remove the unit.

CAUTION

To prevent thermal damage to HP 4142B units, be sure that Blank Panels (part number 04142-60012) are installed in all unused slots.

4. Reconnect the front panel flat cable to the mainframe connector, and reinstall the front panel.

STORAGE AND SHIPMENT

Environment

The HP 4142B should be stored or shipped in environments within the following limits:

Temperature: -40°C to 70°C.
Humidity: Up to 90% RH at 65°C.

Protect the HP 4142B from temperature extremes to prevent condensation from forming inside the HP 4142B.

Original Packaging

When you unpack the HP 4142B, retain all packing material for future use. If it becomes necessary to reship the HP 4142B, repack it in the original packing material and shipping carton. Containers and material identical to those used in factory packaging are available from Hewlett-Packard.

Other Packaging

If you choose to package the HP 4142B in commercially available material, observe the following general instructions.

1. Wrap the HP 4142B in heavy paper or plastic.

2. Use a strong shipping container. A double-walled carton made of 159 kg (350 lb.) test material is adequate.

3. Use enough shock absorbing material, a 76 to 102 mm (3 to 4 in) layer, around all sides of the HP 4142B to provide a firm cushion and to prevent movement inside the container. Protect the front panel with cardboard.

4. Seal the shipping container securely and mark it FRAGILE to ensure careful handling.

5. In any correspondence with HP, refer to the instrument by model and serial number.

REPAIR SERVICE

You can have the HP 4142B repaired at an HP service center whether it is under warranty or not. Contact the nearest HP Sales Office for shipping instructions prior to returning the instrument. A list of Sales and Service Offices is located in the back of this manual.

Serial Number

Hewlett-Packard uses a two-serial-number system to identify the HP 4142B and each HP 4142B plug-in unit. The HP 4142B (mainframe) serial number is stamped on the serial number plate attached to the rear panel of the HP 4142B. The individual serial number of each unit is stamped on the serial number plate attached to the side panel of each unit. The HP 4142B serial number identifies the mainframe; unit serial numbers identify each individual unit. In any correspondence with Hewlett-Packard, be sure to include the serial numbers of both the HP 4142B and the unit.

CHAPTER 2

GETTING STARTED

CONTENTS

NOTES

INTRODUCTION

This chapter teaches you the fundamentals of operating your HP 4142B and how to make measurements. Included are discussions on basic function, and operating and measurement procedures.

PRODUCT INTRODUCTION

HP 4142B

The HP 4142B is a high performance DC parametric measurement instrument with plug-in unit architecture designed for:

- Wide Measurement Range (10 A, 200 V)
- High Resolution (20 fA, 4 µV)
- High Speed (Force I or V: 4 ms, Measure I or V: 4 ms)
- High Accuracy (V: 0.05%, I: 0.2%)

All HP 4142B operations--measurement set up and execution, and measurement data receipt--are computer-controlled via the Hewlett-Packard Interface Bus (HP-IB). Up to 1023 measurement data (4095 for binary data format) can be stored in internal memory.
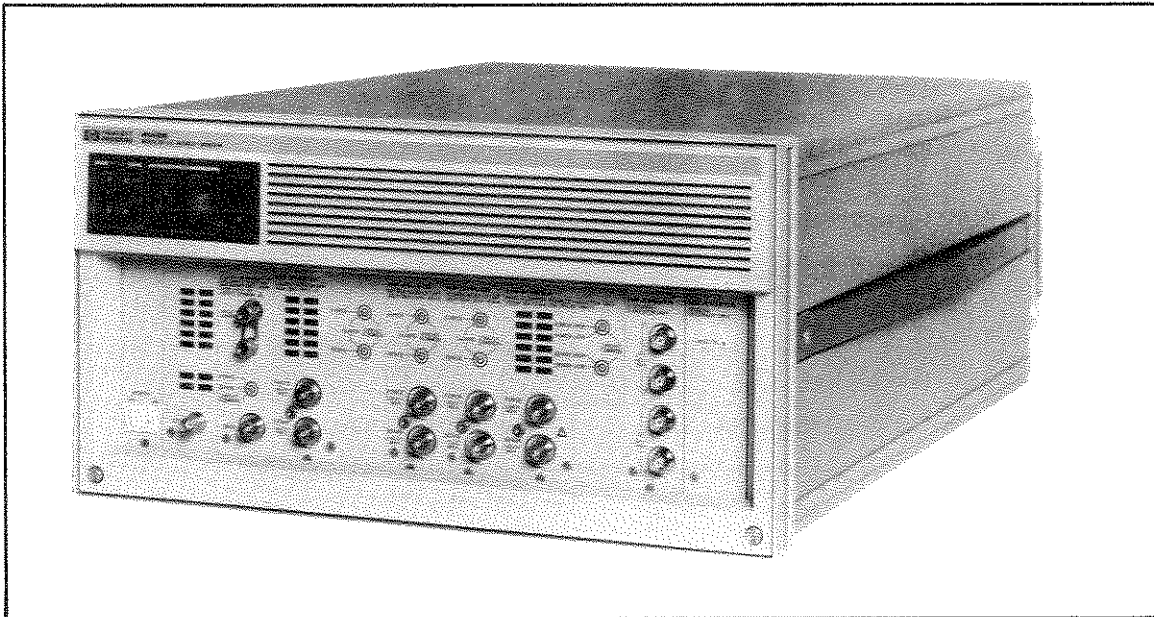
HP 4142B Modular DC Source/Monitor

As a measurement unit, the following five types of plug-in units are available, in addition to a built-in, 0 V source Ground Unit (GNDU). The plug-in units can be built-in to up to eight slots.

- HP 41420A Source/Monitor Unit, 40μV-200V/20fA-1A (High Power SMU, HPSMU). Occupies 2 slots.
- HP 41421B Source/Monitor Unit, 40μV-100V/20fA-100mA (Medium Power SMU, MPSMU). Occupies 1 slot.
- HP 41422A High Current Source/Monitor Unit, 40μV-10V/20nA-10A (HCU). Occupies 2 slots.
- HP 41424A Voltage Source/ Voltage Monitor Unit (VS/VMU). Occupies 1 slot.
- HP 41425A Analog Feedback Unit (AFU). Occupies 1 slot. No more than one HP 41425A per mainframe.

The following figure shows the output and measurement range of plug-in units.
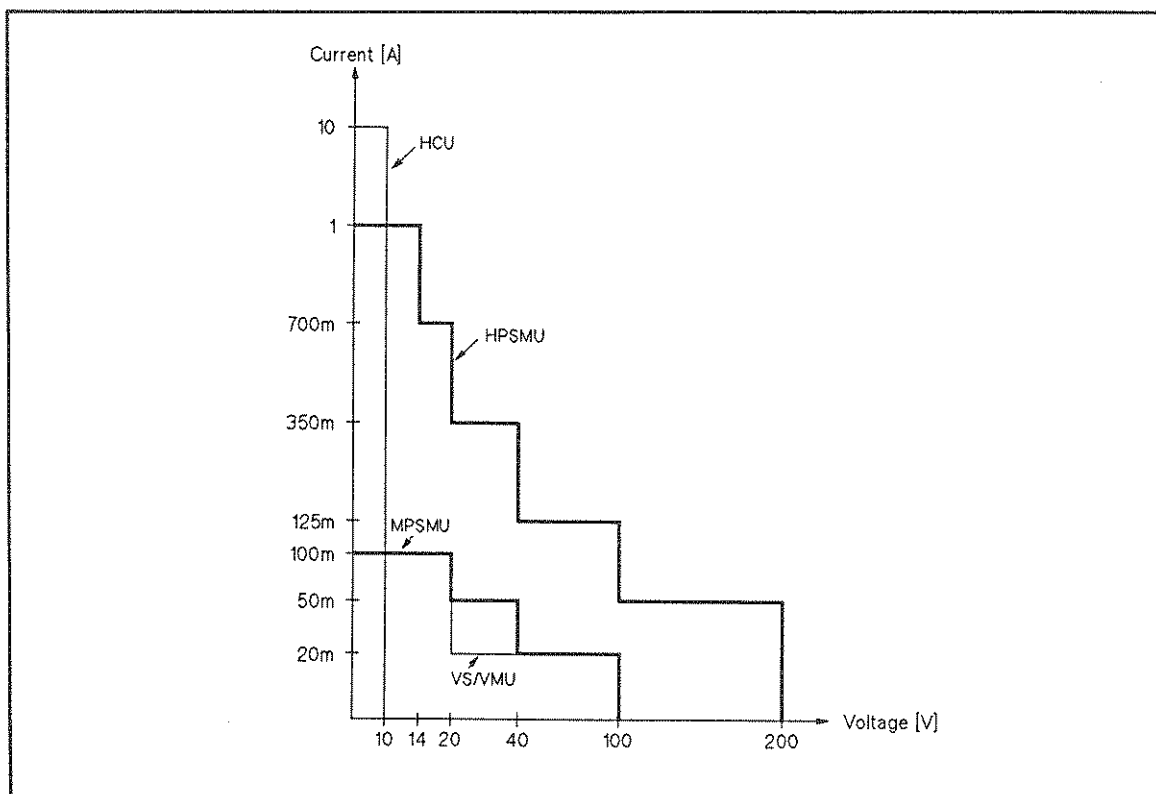
Output and Measurement Range of Plug-in Units

Ground Unit (GNDU)

The Ground Unit (GNDU) is a 0 V constant source that provides a measurement ground reference, and can sink up to ±1.6 A. The following figure shows a simplified GNDU circuit diagram.
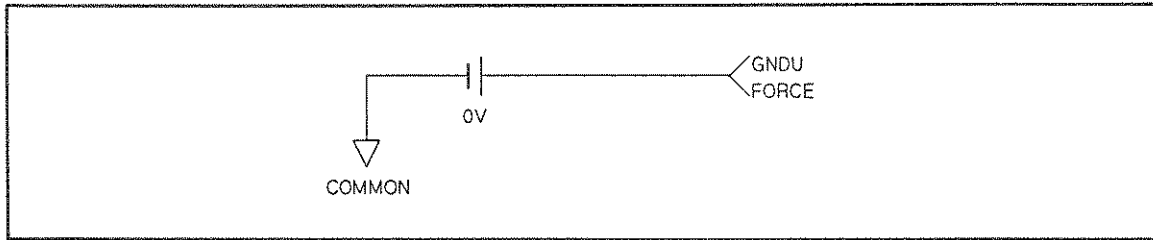
Simplified GNDU Circuit Diagram

HP 41420A HPSMU and HP 41421B MPSMU

The HP 41420A Source/Monitor Unit (High Power SMU: HPSMU) can force and measure up to ±200 V or ±1 A (maximum power: 14 W).
The HP 41421B Source/Monitor Unit (Medium Power SMU: MPSMU) can force and measure up to ±100 V or ±100 mA (maximum power: 2 W).
Each SMU functions in either of the following two modes:

- V source (constant or pulse) and I monitor
- I source (constant or pulse) and V monitor
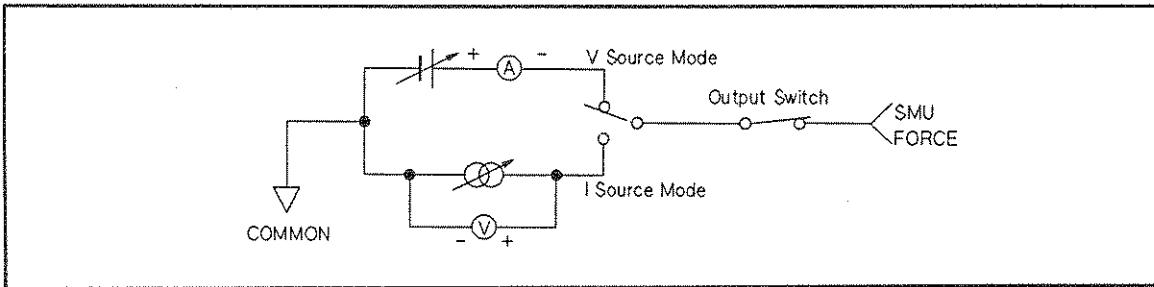
Simplified SMU Circuit Diagram

In High speed spot measurements and Analog search measurements (described later), the SMU functions in the following two modes in addition to the above two modes:

- V source (constant only) and V monitor
- I source (constant only) and I monitor
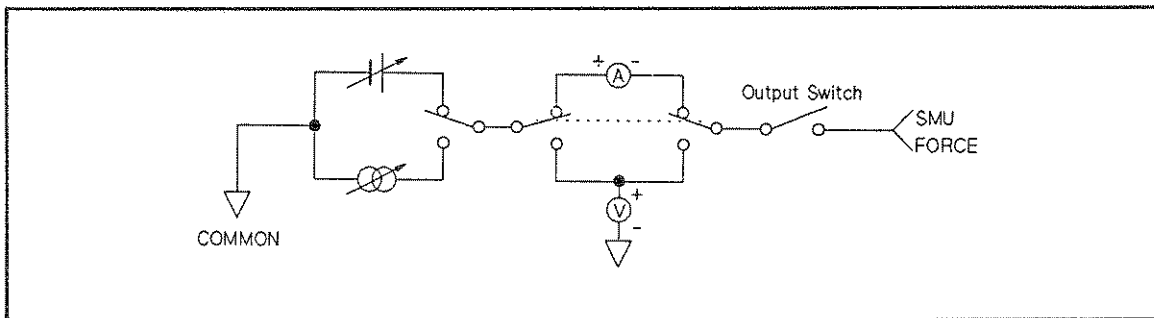
SMU Circuit Diagram

The following figure and table list HPSMU/MPSMU output and measurement ranges.

HPSMU/MPSMU Output and Measurement Ranges
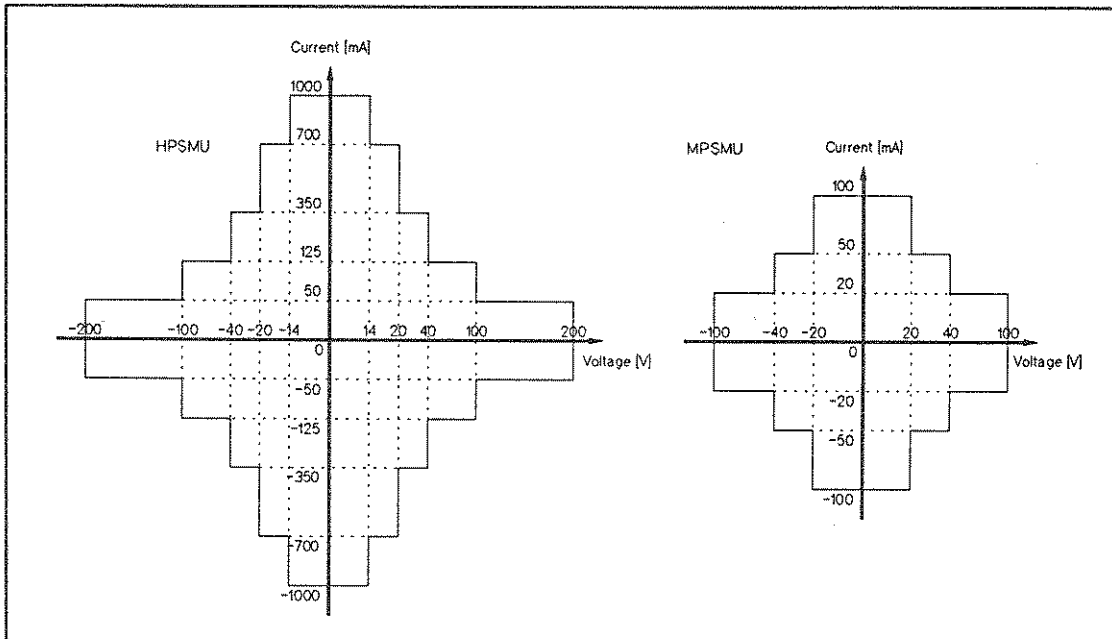
Range	Output/Measurement Value	Resolution [1] Output/Meas.	Maximum Output	
			HPSMU	**MPSMU**
2 V	$0 \leq |V| \leq 2$ V	100μV/40μV	±1 A	±100 mA
20 V	$0 \leq |V| \leq 14$ V	1mV/400μV	±1 A	±100 mA
	14 V $< |V| \leq 20$ V	1mV/400μV	±700 mA	±100 mA
40 V	$0 \leq |V| \leq 40$ V	2mV/800μV	±350 mA	±50 mA
100 V	$0 \leq |V| \leq 100$ V	5mV/2mV	±125 mA	±20 mA
200 V	$0 \leq |V| \leq 200$ V	10mV/4mV	±50 mA	---
1 nA [2]	$0 \leq |I| \leq 1.15$ nA	50fA/20fA	±200 V	±100 V
10 nA [3]	$0 \leq |I| \leq 11.5$ nA	500fA/200fA	±200 V [4]	±100 V [4]
100 nA [3]	$0 \leq |I| \leq 115$ nA	5pA/2pA	±200 V [4]	±100 V [4]
1 μA [3]	$0 \leq |I| \leq 1.15$ μA	50pA/20pA	±200 V [4]	±100 V [4]
10 μA [3]	$0 \leq |I| \leq 11.5$ μA	500pA/200pA	±200 V [4]	±100 V [4]
100 μA	$0 \leq |I| \leq 115$ μA	5nA/2nA	±200 V	±100 V
1 mA	$0 \leq |I| \leq 1.15$ mA	50nA/20nA	±200 V	±100 V
10 mA	$0 \leq |I| \leq 11.5$ mA	500nA/200nA	±200 V	±100 V
100 mA	$0 \leq |I| \leq 20$ mA	5μA/2μA	±200 V	±100 V
	20 mA $< |I| \leq 50$ mA	5μA/2μA	±200 V	±40 V
	50 mA $< |I| \leq 115$ mA [5]	5μA/2μA	±100 V	±20 V
1 A	$0 \leq |I| \leq 50$ mA	50μA/20μA	±200 V	---
	50 mA $< |I| \leq 125$ mA	50μA/20μA	±100 V	---
	125 mA $< |I| \leq 350$ mA	50μA/20μA	±40 V	---
	350 mA $< |I| \leq 700$ mA	50μA/20μA	±20 V	---
	700 mA $< |I| \leq 1$ A	50μA/20μA	±14 V	---

[1] Output Resolution: 1/20000, Measurement Resolution: 1/50000
[2] The 1 nA range cannot force and measure pulse current.
[3] When the pulse voltage output is in the 20 V through 200 V range, 10 nA through 10 μA measurement ranges cannot be used.
[4] When the pulse current output is in the 100 nA through 10 μA range, the maximum voltage is 2 V.
[5] For MPSMU, 100 mA

Pulse parameters are:

Pulse width: 1 ms to 50 ms
Pulse period: 10 ms to 500 ms
Maximum pulse duty (pulse width/ pulse period): 50%

Each SMU includes a compliance feature that limits output voltage or current to prevent damage to your device. When the SMU forces voltage, you can specify I compliance. When the SMU forces current, you can specify V compliance. You can specify V or I compliance with the same resolution as the output voltage or current within the maximum output.

HP 41422A HCU

HP 41422A High Current Source/Monitor Unit (HCU) can force and measure up to 10 A and 10 V, and functions in either of the following two modes:

- Pulsed V source and I monitor
- Pulsed I source and V monitor

The HCU can force pulsed voltage or pulsed current, but cannot force constant voltage or constant current. When the HCU does not force a pulse value, the HCU functions as 0 V source. (Maximum current: 0.1% of the current range value. 10 mA maximum at the 10 A range.)

The following figure shows a simplified HCU circuit diagram. Although the HCU is a floating source/monitor, the LOW line of the HCU must be connected to the GNDU and fixed to 0 V. Therefore, HCU circuit (including GNDU) is equivalent to the SMU circuit.

You cannot connect an SMU or VS in place of the GNDU.
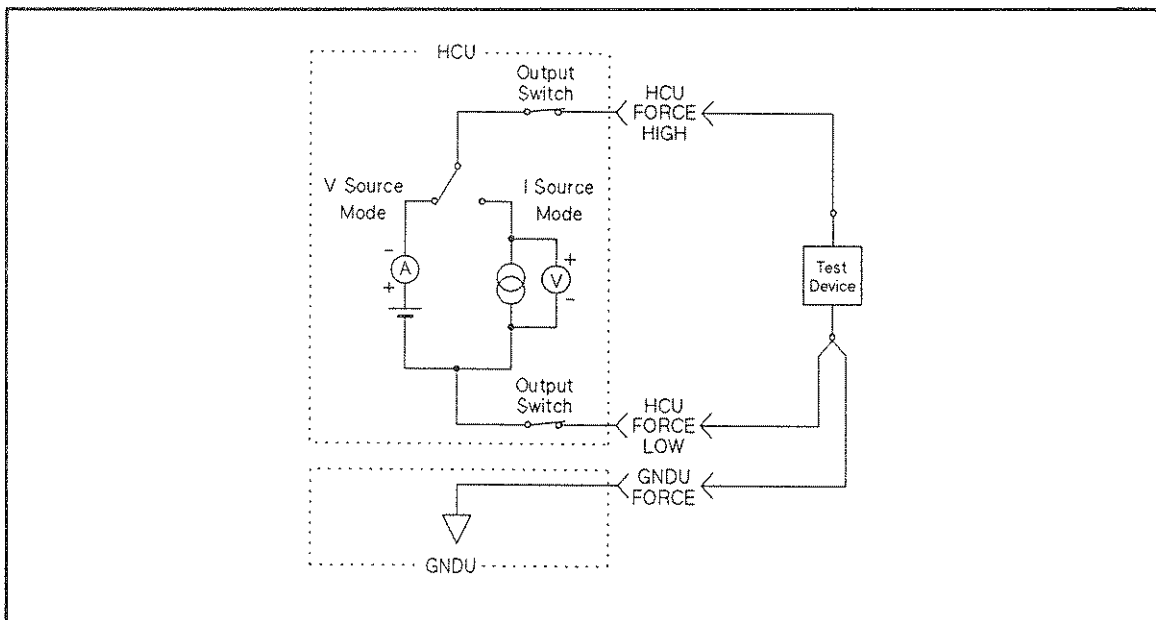
Simplified HCU Circuit Diagram

The following table shows the HCU output and measurement ranges. The HCU is a unipolar source, that is, voltage and current output are limited to the same polarity.

HCU Output/Measurement Ranges

Range	Output/Measurement Value	Resolution[1] Output/Meas.	Max. Output[2]
2 V	$0 \leq |V| \leq 2$ V	200µV/40µV	+10 A or -10 A
20 V	$0 \leq |V| \leq 10$ V	2mV/400µV	+10 A or -10 A
1 mA	$0 \leq |I| \leq 1.15$ mA	100nA/20nA	+10 V or -10 V
10 mA	$0 \leq |I| \leq 11.5$ mA	1µA/200nA	+10 V or -10 V
100 mA	$0 \leq |I| \leq 115$ mA	10µA/2µA	+10 V or -10 V
1 A	$0 \leq |I| \leq 1.15$ A	100µA/20µA	+10 V or -10 V
10 A	$0 \leq |I| \leq 10$ A	1mA/200µA	+10 V or -10 V
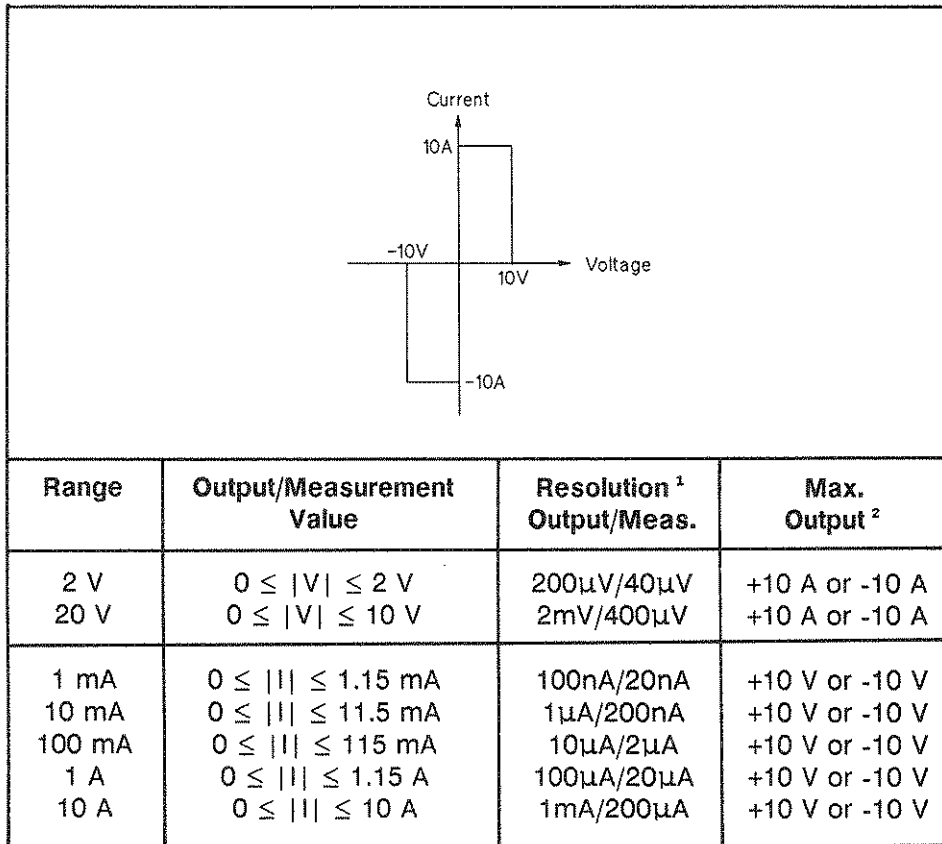
[1] V/I Output Resolution: 1/10000, V/I Measurement Resolution: 1/50000
[2] The polarity of maximum output is positive if the output value is positive, and negative if the output value is negative.

Pulse parameters are:

Pulse width: 100 µs to 1 ms
Pulse period: 10 ms to 500 ms
Maximum pulse duty (pulse width/ pulse period):
      10% (if output current or I compliance is 1 A or less.)
      1% (if output current or I compliance is more than 1 A.)

An HCU includes a compliance feature that limits output voltage or current to prevent damage to your device (same as the HPSMU/MPSMUs).

HP 41424A VS/VMU

The HP 41424A V Source/V Monitor Unit (VS/VMU) provides:

- V source (constant or pulse) and I monitor (VS), 2ch
- V monitor (VM), 2ch for grounded measurement, or 1ch for differential measurement

The current monitoring function of VS can be used only while performing High speed spot measurements (described later).

The differential voltage measurement function of VM cannot be used while performing measurements with pulsed source.
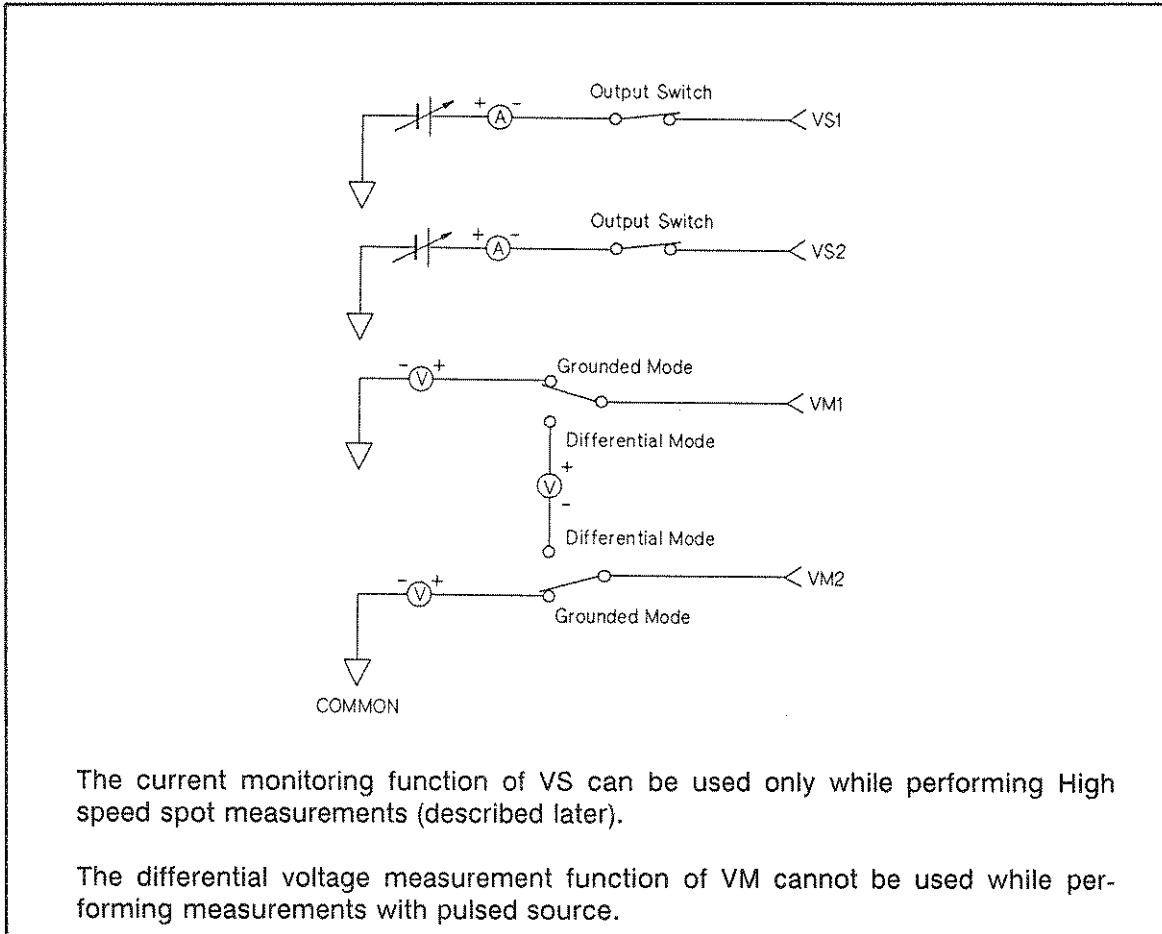
Simplified VS/VMU Circuit Diagram

VS can force up to 40 V, and VM can measure up to 40 V. The following tables show the V output range and I measurement range of VS, and the V measurement range of VM.

VS Output and Measurement Ranges

Current [mA]
100
20
-40 -20   20   40
0
Voltage [V]
-20
-100

Range	V Output Value	Reso. [1]	Max. Output	I Measurement Value	Reso.
20 V	$0 \leq |V| \leq 20$ V	1 mV	100 mA	$0 \leq |I| \leq 100$ mA	100 µA
40 V	$0 \leq |V| \leq 40$ V	2 mV	20 mA	$0 \leq |I| \leq 20$ mA	20 µA
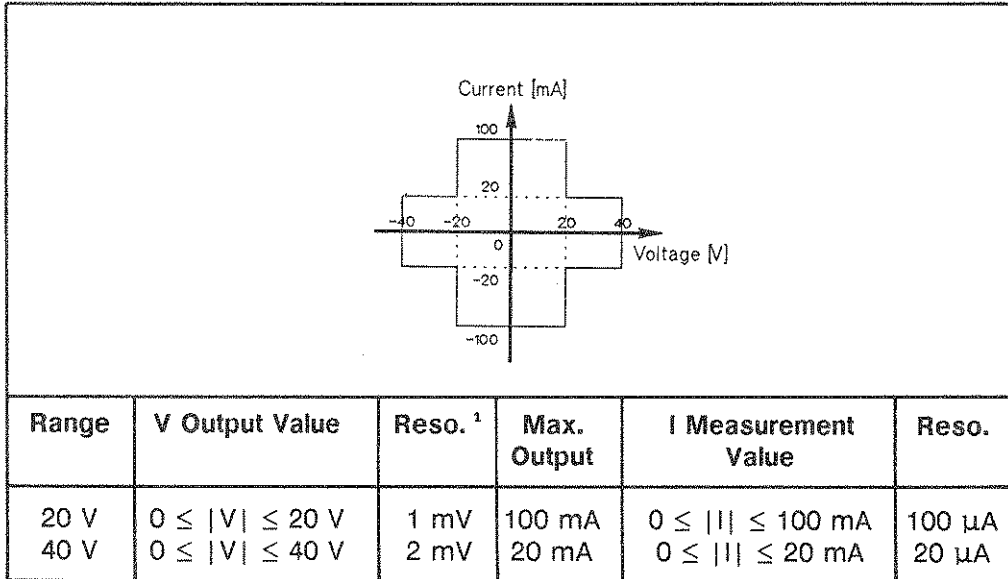
[1] V Output Resolution: 1/20000, I Measurement Resolution: 1/1000

VM Measurement Ranges

Grounded Measurement

Differential Measurement

-40   -2.3   0   2.3   40   Voltage [V]

Mode	Range	Measurement	Resolution [1]
Grounded Measurement	2 V	$0 \leq |V| \leq 2.3$ V	40 µV
	20 V	$0 \leq |V| \leq 23$ V	400 µV
	40 V	$0 \leq |V| \leq 40$ V	800 µV
Differential Measurement [2]	0.2 V	$0 \leq |V| \leq 0.23$ V	4 µV
	2 V	$0 \leq |V| \leq 2.3$ V	40 µV
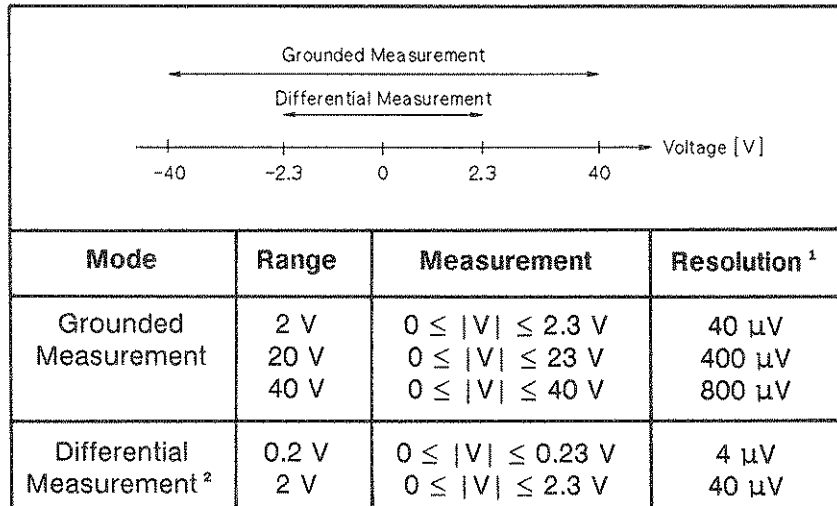
[1] V Measurement Resolution: 1/50000
[2] Each voltage of differential input must be within ±40 V.

Pulse parameters are the same as the SMU:

    Pulse width: 1 ms to 50 ms
    Pulse period: 10 ms to 500 ms
    Maximum pulse duty (Pulse width/ Pulse period): 50%

The VS has a current limiter. The limiter value is automatically determined by the output voltage range. If the output range is 20 V, then the current limit is 100 mA. If the output range is 40 V, then the current limit is 20 mA.

HP 41425A AFU

The HP 41425A Analog Feedback Unit (AFU) controls the output voltage of one SMU (HPSMU or MPSMU, called the search SMU), and set the monitor value of another SMU (HPSMU or MPSMU, called the sense SMU) to the specified value. The monitor value is current if the sense SMU is set to V source, and it is voltage if the sense SMU is set to I source. The SMUs specified for use are automatically connected internally to the AFU. The following figure shows a simplified AFU operational diagram.

The major applications of the AFU are:

- Bipolar transistor hFE measurement at the specified collector voltage and collector current.
- MOSFET Vth measurement at the specified drain voltage and drain current.
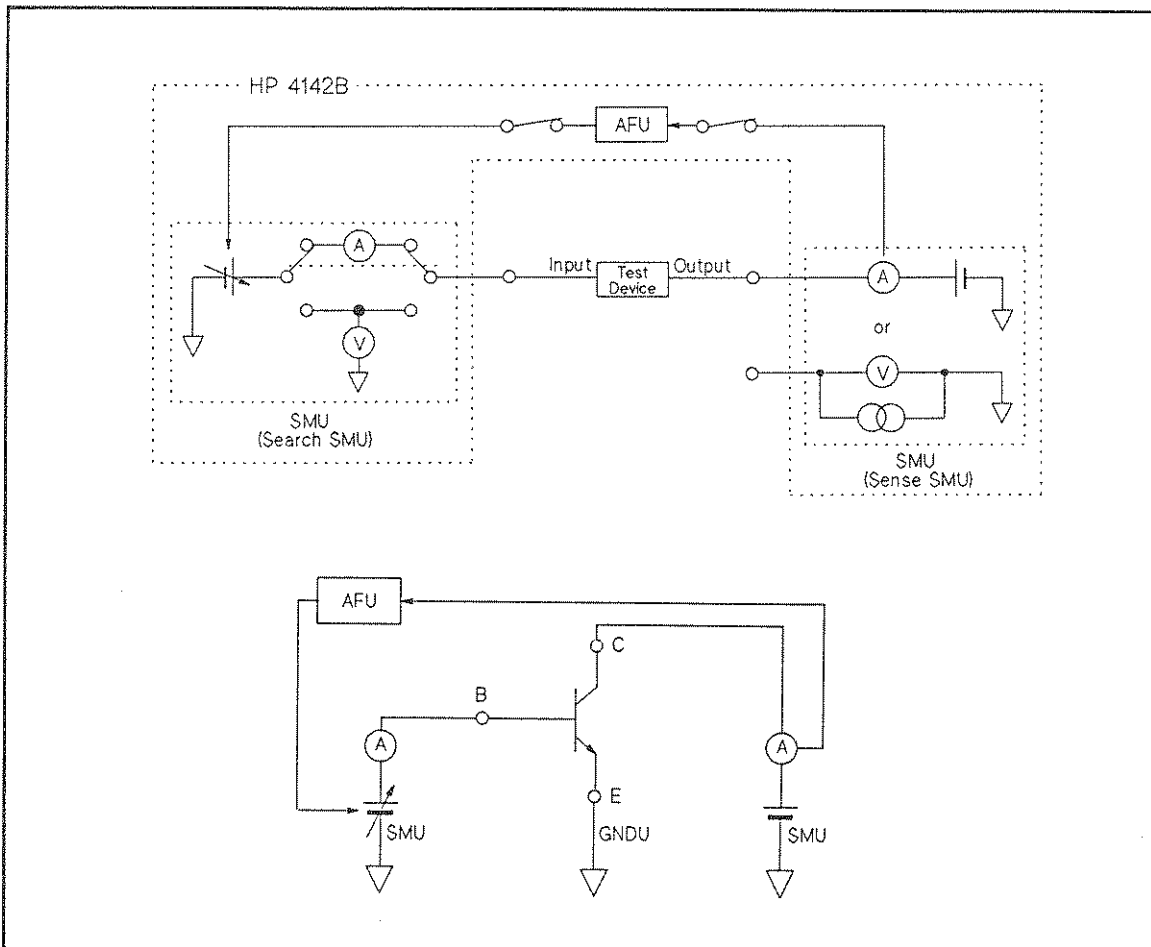
Simplified AFU Operational Diagram

Measurement Modes

By using the measurement units, you can perform the following nine types of measurements. The output waveform and available units are shown for each measurement mode in the following figure. The explanation number below corresponds to the No. in the figure.

1) Spot measurements

Up to 16 sources force constant voltages and currents, and up to 8 monitors measure the outputs.

2) Staircase sweep measurements

One source sweeps constant V or I, while up to 8 monitors measure the outputs. Or two sources sweep constant voltages or currents at the same time, while up to 8 monitors measure the outputs.

3) 1ch pulsed spot measurements

One source forces pulsed V or I, and one monitor measures the output.

4) Pulsed sweep measurements

One source sweeps pulsed V or I, while one monitor measures the output.

5) Staircase sweep with pulsed bias measurements

One source sweeps constant V or I, and another source forces pulsed V or I with synchronized sweep output, while one monitor measures the output.

6) Analog search measurement

Searches for a specified current or voltage on one SMU by controlling the voltage output of another SMU.
The AFU is required.

7) 2ch pulsed spot measurements

Two sources force pulsed outputs at the same time, and one monitor measures the output.
At least one pulsed source must be an HCU.

8) Pulsed sweep with pulsed bias measurement

One source sweeps pulsed V or I, and another source forces pulsed V or I with synchronized sweep pulsed output, while one monitor measures the output.
At least one pulsed source must be an HCU.

9) High speed spot measurement

Up to 16 sources force constant voltages and currents, and one monitor measures the outputs. You can perform the measurement with fewer commands than spot measurement.

Available Units in Each Measurement Mode

No.	Output Waveform	Source SMU (V/I)	Source HCU (V/I)	Source VS (V)	Monitor SMU (V/I)	Monitor HCU (V/I)	Monitor VS (I)	Monitor VM (V^1)	Monitor VM (VD^2)	AFU
1	(DC level)	●		●	●			●	●	
2	(staircase)	●		●	●			●	●	
2	(staircase, dual)	● / ●		● / ●	●			●	●	
3	(single pulse)	●	●	●	●	●		●		
4	(pulse train)	●	●	●	●	●		●		
5	(staircase)	●		●	●	●		●		
5	(pulsed staircase)	●	●	●						
6	(ramp)	● / ●			●					●
7	(pulse)	●	●		●	●		●		
7	(pulse)		●							
8	(pulse train)	●^{3}	●		●	●		●		
8	(pulse train)	●^{3}	●							
9	(DC level)	●		●	●		●	●	●	

^{1} Grounded measurement mode
^{2} Differential measurement mode
^{3} At least one pulsed source must be an HCU.

Total Power Limitation of Plug-in Units

Total SMU, HCU, and VS power consumption must not exceed 32 W. If you do not have an HPSMU, an HCU, or more than six VS/VMUs, total power consumption can not reach 32 W. Your HP 4142B is not limited by the total power of the units. Power consumption depends on the output settings for voltage and current, and is calculated as follows. Note that when the output switch of the unit is set to OFF, the power of that unit is 0 W.

Unit	Power [1]
SMU	2 V, 20 V range [2]: 20(Iset [3]) [W] 40 V range: 40(Iset) [W] 100 V range: 100(Iset) [W] 200 V range: 200(Iset) [W]
HCU	20(Iset)(pulse duty [4])+10 [W]
VS	20 V range: 2.2 [W] 40 V range: 0.88 [W]

[1] Output switch set to OFF: 0 W
The power of each unit is rounded down to the nearest hundredth. For example, if the calculation result is 1.057 W, then power = 1.05 W. If 0.002 W, then power = 0 W.

[2] If the SMU is the I source mode, voltage range is the lowest range that includes the voltage compliance value. For example, if you set the voltage compliance to 5 V, voltage range is 20 V.

[3] Iset is the specified output current value at I source mode, and is the specified current compliance value at V source mode.

[4] The pulse duty is defined: (pulse duty) = (pulse width/ pulse period).

Maximum value of power consumption for these units is as follows.

    HPSMU: 20 W
    MPSMU: 2 W
    HCU: 12 W
    VS/VMU: 4.4 W

For example, if you have two HPSMUs, total maximum power consumption is 40 W (20 W + 20 W) and exceeds 32 W. You cannot force the maximum output of each unit at the same time. The maximum current of the two units is limited to 1.6 A (32W/20V).

PANEL OVERVIEW

The following figures point out important locations on the HP 4142B. The name of each part is referenced in this manual.

HP-IB Status Indicators LOCAL/SELF TEST Key ERROR/FAILURE Display HIGH VOLTAGE Lamp MEASURING Lamp

CIRCUIT COMMON Terminal

Shorting-bar

CHASSIS GROUND Terminal

Slot Numbers

Slots

POWER ON/OFF Switch INTLK Terminal GNDU Terminal Slot#1 Slot#2 ... Slot#8

ZERO CHECK Terminal

Blank Panel

Retractable Stands
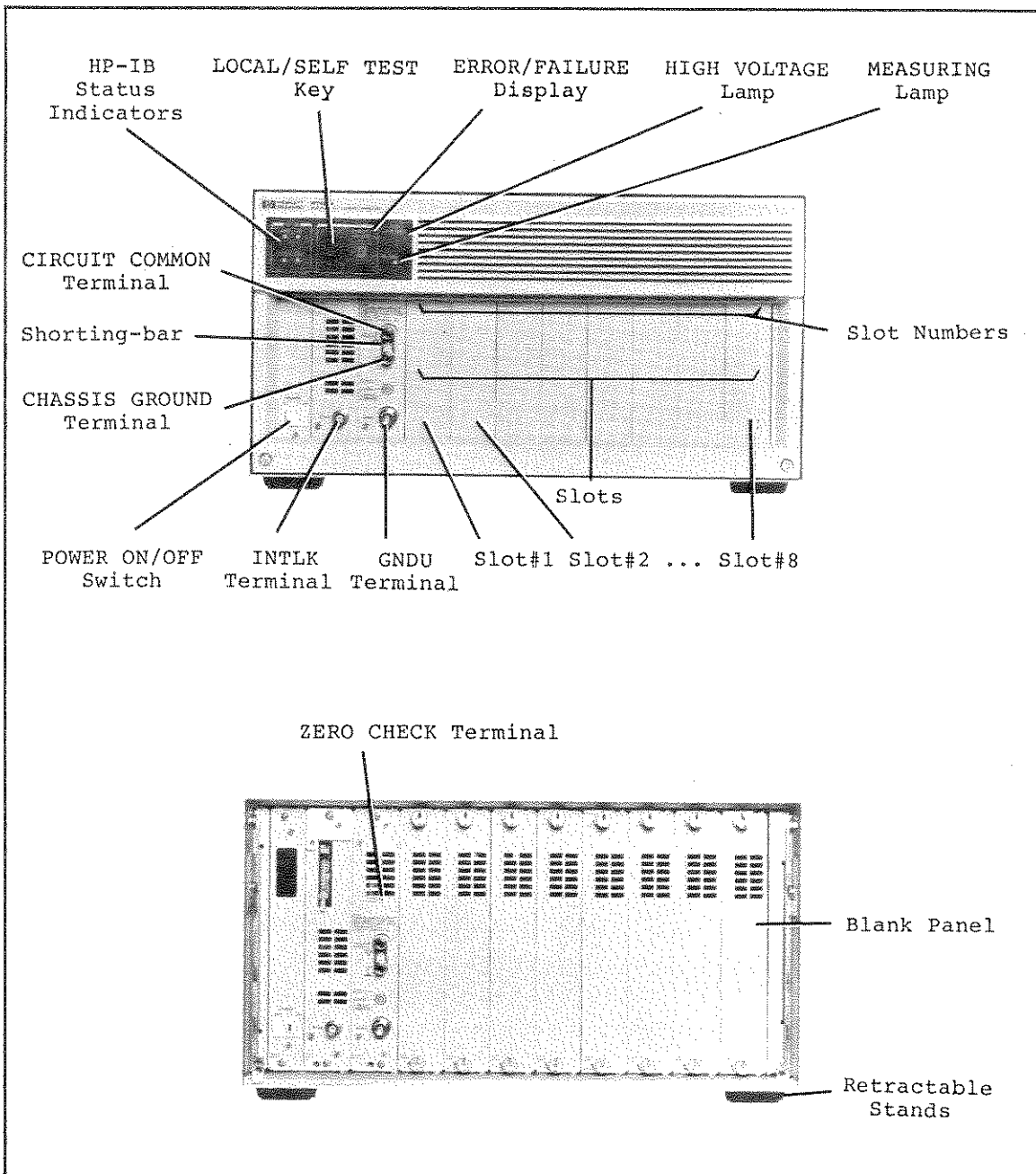
HP 4142B Panel Overview (1 of 2)

HP 41420A
High Power SMU
(HPSMU)

HP 41421B
Medium Power SMU
(MPSMU)

HP 41422A
HCU

HP 41424A
VS/VMU

HP 41425A
AFU

MONITOR Port

VS Terminals

FORCE Terminals

VM Terminals

SENSE Terminals

HP-IB ADDRESS
Switch

HP-IB Connector

FILTER Switch

LINE ON/OFF
Switch

LINE FUSE
Holder

LINE VOLTAGE
SELECTOR
Switch

LINE INPUT
Receptable

TRIGGER OUTPUT
Terminal

TRIGGER INPUT
Terminal

HP 4142B Panel Overview (2 of 2)

BEFORE APPLYING POWER

Before you apply power, confirm the following:

- The HP 4142B is installed horizontally, ±20° maximum.

- Line voltage is within the specified tolerance.

- The **LINE VOLTAGE SELECTOR** switch is set correctly.

- The correct fuse is installed.

- The line frequency **FILTER** switch is set correctly.

- Blank panels (part number 04142-60012) are installed in all unused slots.

- Front panel is correctly installed on the HP 4142B.

- **HP-IB ADDRESS Switch** on the rear panel is set to the desired value between 0 to 30 (it is set to 17 when shipped from the factory). The new HP-IB address is recognized only at power on.

If you have any questions above, refer to Chapter 1.

APPLYING POWER

To turn on the HP 4142B, perform the following procedure.

1. Set the front panel **POWER ON/OFF** switch to **ON**.

2. Set the rear panel **LINE ON/OFF** switch to **ON**.

   All front panel indicators light momentarily, **C** (performing the Self-Test or Self-Calibration) is displayed in the **ERROR/FAILURE** display, and Self-Test and Self-Calibration starts. The Self-Test and Self-Calibration takes about 30 seconds.

   Self-Test: This test verifies that the HP 4142B is operating but does not verify that the output and measurement will be accurate.

   Self-Calibration: This improves short-term accuracy for output and measurement functions, but is not a substitute for periodic calibration (adjustment) of the HP 4142B.

   When Self-Test and Self-Calibration are finished, the **LOCAL/SELF TEST** key indicator light goes out and a **0** (No error) is displayed in the **ERROR/FAILURE** display.

3. Confirm that **ERROR/FAILURE** display indicates **0** (No error). If anything other than **0** is displayed, see Chapter 6, "Front Panel" for details.

<div align="center">NOTE</div>

To simplify turning the HP 4142B on or off, keep the **POWER ON/OFF Switch** setting to **ON** at all times, and turn it on or off with the **LINE ON/OFF Switch.**

Line power is applied to the HP 4142B if the rear panel **LINE ON/OFF** switch is set to **ON**, even if the front panel **POWER ON/OFF** switch is set to **OFF**. To completely power down the HP 4142B, set the rear panel **LINE ON/OFF** switch to **OFF**, regardless of the **POWER ON/OFF Switch** setting.

To satisfy the specifications of the HP 4142B, allow the HP 4142B to warm-up for a minimum of 40 minutes before you begin performing measurements.

SENDING THE HP-IB COMMAND

Output/Input Statement

The statements used to operate the HP 4142B depend on the computer and its language. In particular, you need to know the statements the computer uses to output and input information. For example, the output statement for the HP 9000 Series 200/300 BASIC language is **OUTPUT**. The input statement is **ENTER**.

Read your computer manuals to find out which statements you need to use. The examples in this manual use HP 9000 Series 200/300 BASIC language. To use the examples, load the binary (BIN) files: HPIB, IO, GRAPH, and ERR.

Sending an HP-IB Command

To send the HP 4142B an HP-IB command, combine the output statement of the computer with the HP-IB select code, the HP 4142B address, and finally, the HP 4142B HP-IB command. For example, to make the HP 4142B perform Self-Calibration, send:

OUTPUT 717;"CA"

Notice that the **REM** and **LSTN** indicators of the front panel are illuminated. This means the HP 4142B is in the remote mode and has been addressed to listen (received a command).

Each HP-IB command syntax is described in the *HP-IB Command Reference Manual*.

Getting Data from the HP 4142B

The HP 4142B is capable of sending measurement data and responses to query commands. As an example, have the HP 4142B generate a response to a query command by sending:

OUTPUT 717;"*IDN?"

The HP 4142B sends the response to its output buffer. The output buffer is a register that holds a query response or measurement data until it is read by the computer. Use the input statement of the computer to get the response from the output buffer. For example, the following program reads the response (HEWLETT PACKARD, 4142B, 0, *ROM_version_number*) and prints it.

```
10  DIM A$[30]
20  ENTER 717;A$
30  DISP A$
40  END
```

The output format of response data to each query command and measurement data are described in the *HP-IB Command Reference Manual*.

IF AN ERROR OCCURS

The HP 4142B indicates errors in the following manner.

1. The HP 4142B displays an **A, E, F, H, P,** or **1** to **8** in the **ERROR/FAILURE** display, which indicates the following error conditions. For more information, see Chapter 6, "Front Panel."

    E: Syntax error or out of the parameter range.
    F: Incorrect input command sequence.
    H: Overvoltage or overcurrent occurred. Output switches of all units are discon-
    nected to prevent the HP 4142B damage.
    1 to 8, A, P:
    Self-Test failed.
    (**C:** Performing the Self-Test or Self-Calibration)

2. The HP 4142B sets Bit 5 of the status byte to one. If you remove the mask of that bit, the HP 4142B asserts the SRQ. Use this function when you handle the error in your programs. For more information, see Chapter 6, "Status Byte."

If an error occurs, you can get the error message. Refer to the next paragraph, "Reading the Error Register."

NOTE

In case of momentary power loss, overvoltage, or overcurrent, the HP 4142B may automatically turn off, keeping **LINE ON/OFF** and **POWER ON/OFF** switches **ON**, to prevent damage. If this occurs, set **LINE ON/OFF** switch to **OFF** and wait for more than 10 seconds, then set the switch to **ON**. The HP 4142B will function properly.

Reading the Error Register

Whenever an error occurs, a record of errors is stored in the error register as the error code. To read the error record, send the **ERR?** command to transfer the error codes from the error register to the output data buffer as shown below.

```
10    DIM A$[23]
20    OUTPUT 717;"ERR?"
30    ENTER 717;A$
40    PRINT A$
50    END
```

The first four error codes are printed in the order of their occurrence. For example:

    120, 100, 0, 0

For error code descriptions, see *HP-IB Command Reference Manual*, "Error Messages." If no error occurs, the error register returns "0, 0, 0, 0."

When you execute the **ERR?** command, the error register and **ERROR/FAILURE** display are initialized (set to "0, 0, 0, 0" and 0).

RESETTING THE HP 4142B

Many times during operation, you may wish to return to the power-on initial settings. The *RST or the HP BASIC **CLEAR** command returns you to the initial settings. To reset the HP 4142B (HP 4142B mainframe and all plug-in units), send:

OUTPUT 717;"*RST"

or

CLEAR 717

For initial settings information, see Chapter 6, "Initial Settings".

SENDING A COMMAND TO THE UNIT

Channel Numbers (*Ch#*) are used to identify the plug-in units installed in the HP 4142B. To control each unit, you must specify the channel number of the unit. For example, to make *ch*#5 of the unit perform Self-Calibration, send:

OUTPUT 717;"CA5"

Channel Numbers (Ch#)

Channel numbers are determined by the slot number that the unit is installed as follows. The slot number is displayed on the front panel.

HP 41420A HPSMU
HP 41422A HCU:
　　Ch# is the slot number that is the greater of the two slots occupied by the unit.
　　Example: In slot#1 and slot#2, *Ch#* is 2.

HP 41421B MPSMU:
　　Ch# is the slot number in which the MPSMU is installed.
　　Example: In slot#3, *Ch#* is 3.

HP 41424A VS/VMU:
　　1) VS1 and VM1:
　　　　Ch# is 1*n* or *n*, where *n* is the slot number in which the VS/VMU is installed.
　　　　Example: In slot#8, *Ch#* is 18 or 8.

　　2) VS2 and VM2:
　　　　Ch# is 2*n*, where *n* is the slot number in which the VS/VMU is installed.
　　　　Example: In slot#8, *Ch#* is 28.

　　3) Differential Voltmeter using VM1 and VM2:
　　　　Ch# is *n*, 1*n*, or 2*n*, where *n* is the slot number in which the VS/VMU is installed.
　　　　Example: In slot#8, *Ch#* is 8, 18, or 28.

FORCING AND MEASURING

This paragraph explains the operation of measurements using a bipolar transistor as a test device.

Connect the units to the test device as follows. Refer to Chapter 3 for information on how to connect.

    Emitter: GNDU
    Base: SMU (HPSMU or MPSMU)
    Collector: SMU (HPSMU or MPSMU)

Setting the Output Switch of the Unit to ON

Before you make the SMUs/HCUs/VSs force or measure voltage/current, you must set the internal output switch of the unit to ON.
Even if a physical connection by a cable exists, these units are not electrically connected to a test device, because the output switches are set to OFF at power-on. To set the output switches to ON, and to connect the units to the test device electrically, send **CN** command. The syntax is:

    CN [ch#] [,ch#] [,ch#] [,ch#] [,ch#] [,ch#] [,ch#] [,ch#]

Where the brackets [ ] mean optional parameter. If you connect three units of ch#2, ch#3, and ch#8:

    OUTPUT 717;"CN";2,3,8

If you connect all units:

    OUTPUT 717;"CN"

When the output switch is set to ON, 0 V is forced to the test device.
For VMs, GNDU and AFU, you do not need this operation because these units do not have output switches.

Setting the Output Switch of the Unit to OFF

To set the output switches to OFF, and to disconnect the units from the test device, send **CL** command. The syntax is:

    CL [ch#] [,ch#] [,ch#] [,ch#] [,ch#] [,ch#] [,ch#] [,ch#]

If you disconnect three units of ch#2, ch#3, and ch#8:

    OUTPUT 717;"CL";2,3,8

If you disconnect all units:

    OUTPUT 717;"CL"

Forcing Constant Voltage

The **DV** command forces the specified constant voltage. Constant voltage can be forced from SMUs or VSs. The syntax of **DV** command is:

> For SMUs:
> > DV *ch#, output range, output voltage, I compliance*
> For VSs:
> > DV *ch#, output range, output voltage*

If you force 1 V from the SMU of ch#2 with Auto ranging (*output range* = 0), and set the current compliance to 10 mA:

> OUTPUT 717;"CN";2
> OUTPUT 717;"DV";2,0,1,10E-3

Forcing Constant Current

The **DI** command forces the specified constant current. Constant current can be forced from SMUs. The syntax of **DI** command is:

> DI *ch#, output range, output current, V compliance*

If you force 10 uA from the SMU of ch#3 with Auto ranging (*output range* = 0), and set the voltage compliance to 2 V:

> OUTPUT 717;"CN";3
> OUTPUT 717;"DI";3,0,10E-6,2

The current polarity is positive if current flows from the HP 4142B, and negative if it flows into the HP 4142B.

If you use an SMU as no output (open) or a voltage monitor only, set current output to 0 A.

Setting the Output to 0 V

To stop forcing voltage and current, send the **DZ** command. The **DZ** command sets the specified unit(s) output to 0 V. You can send this command more easily than the **DV** command. The **DZ** command syntax is:

> DZ [*ch#*] [,*ch#*] [,*ch#*] [,*ch#*] [,*ch#*] [,*ch#*] [,*ch#*] [,*ch#*]

If you specify three units of ch#2, ch#3, and ch#8:

> OUTPUT 717;"DZ";2,3,8

If you specify all units:

> OUTPUT 717;"DZ"

Performing the Measurement

To specify the measurement mode and measurement channel, send the **MM** command. The syntax is:

MM *measurement mode, ch#* [*,ch#*] [*,ch#*] [*,ch#*] [*,ch#*] [*,ch#*] [*,ch#*] [*,ch#*]

When the measurement unit is an SMU or HCU, an SMU/HCU set to V source mode per-forms an I measurement--even if output value is 0 V, and an SMU/HCU set to I source mode performs a V measurement--even if output value is 0 A.
Measurements are performed in the order in which you specify them with the **MM** command.

Send the measurement trigger command **XE** to start a measurement. Measurement results are stored in the HP 4142B output data buffer in ASCII format. Transfer measurement data to your computer using the **ENTER** statement.

The following program forces collector voltage (1 V) and base current (10 µA) and measures the collector current with the spot measurement (*measurement mode* = 1).

```
10   Base=3       ! Base: ch#3, Collector: ch#2, Emitter: GNDU
20   Collector=2
30   Ib=10E-6
40   Vc=1
50   OUTPUT 717;"*RST"
60   OUTPUT 717;"CN";Base,Collector
70   OUTPUT 717;"DV";Collector,0,Vc,10E-3
80   OUTPUT 717;"DI";Base,0,Ib,2
90   OUTPUT 717;"MM";1,Collector
100  OUTPUT 717;"XE"
110  OUTPUT 717;"DZ";Base,Collector
120  OUTPUT 717;"CL";Base,Collector
130  ENTER 717;A$
140  PRINT A$
150  END
```

The measurement data *A$* is printed as shown below:

NBI+02.1808E-03

The first three characters (NBI) are the measurement data status, which indicates measure-ment condition. The remainder (+02.1808E-3) is the measurement value, 2.1808 mA. For more information about the measurement data format, see the *HP-IB Command Reference Manual*.

NOTE

The HP 4142B output data buffer can store up to 1023 measurement data (4095 for binary data format). See "Measurement Data Memory" in Chapter 5 for more information. The data buffer sends measurement data in the order in which it was stored. Therefore, if you transfer the measurement data after you perform the measurement twice, the first measurement data is transferred from the HP 4142B first. Use the **BC** command to clear the output data buffer. The output data buffer is also cleared when you turn the HP 4142B on and when you execute an *RST command.

Performing the Staircase Sweep Measurement

You can perform staircase sweep measurements easily by using the sweep command **WV** (for voltage sweep) or **WI** (for current sweep). The following is the syntax for each:

> WV *ch#, sweep mode, output range, start voltage, stop voltage,*
> *number of steps* [, *I compliance*]
>
> WI *ch#, sweep mode, output range, start current, stop current,*
> *number of steps* [, *V compliance*]

The following program forces collector voltage (0 to 1 V, 21 steps, linear sweep (*sweep mode* = 1)) and base current (10 µA) and measures the collector current with the staircase sweep measurement (*measurement mode* = 2).

```
10   Base=3        ! Base: ch#3, Collector: ch#2, Emitter: GNDU
20   Collector=2
30   Ib=10E-6
40   Vcstart=0
50   Vcstop=1
60   No_step=21
70   DIM A$[400]
80   OUTPUT 717;"*RST"
90   OUTPUT 717;"CN";Base,Collector
100  OUTPUT 717;"WV";Collector,1,0,Vcstart,Vcstop,No_step,10E-3
110  OUTPUT 717;"DI";Base,0,Ib,2
120  OUTPUT 717;"MM";2,Collector
130  OUTPUT 717;"XE"
140  OUTPUT 717;"DZ";Base,Collector
150  OUTPUT 717;"CL";Base,Collector
160  ENTER 717;A$
170  PRINT A$
180  END
```

The measurement data *A$* is printed as shown below:

```
NBI-09.9696E-06,NBI+08.5332E-06,NBI+0.12334E-03,NBI+0.61556E-03,
NBI+01.4284E-03,NBI+01.9058E-03,NBI+02.0858E-03,NBI+02.1426E-03,
NBI+02.1612E-03,NBI+02.1648E-03,NBI+02.1672E-03,NBI+02.1680E-03,
NBI+02.1700E-03,NBI+02.1722E-03,NBI+02.1728E-03,NBI+02.1744E-03,
NBI+02.1756E-03,NBI+02.1764E-03,NBI+02.1778E-03,NBI+02.1780E-03,
NBI+02.1808E-03
```

For the above program, measurement data is displayed after all steps of measurements are complete. If you want to display the measurement data immediately after each step of measurements, change program lines 140 through 180 to the following:

```
140  FOR Step=1 TO No_step
150     ENTER 717 USING "#,3A,12D,X";I$,I
160     PRINT I$,I
170  NEXT Step
180  ENTER 717 USING "#,X"
190  OUTPUT 717;"DZ";Base,Collector
200  OUTPUT 717;"CL";Base,Collector
210  END
```

The measurement data I and $I\$$ is printed as shown below:

```
NBI  -9.9636E-6
NBI  8.5332E-06
NBI  .00012334
NBI  .00061556
NBI  .0014284
NBI  .0019058
  :        :
  :        :
NBI  .002178
NBI  .0021808
```

Specifying the Measurement Range

If you specify a measurement ranging mode or range, specify that before sending the measurement trigger command **XE**. The measurement range of each unit can be specified as follows:

SMU/HCU Current Measurement Range:
> **RI** sets $Ch\#$ and I measurement range. Default I measurement range at power on is Auto.

SMU/HCU Voltage Measurement Range:
> Set automatically, depending on the V compliance setting, to the lowest range that includes the value of V compliance. For example, if you set the V compliance of the SMU to 5 V, the 20 V measurement range is set.

VM (voltage) Measurement Range:
> **RV** sets $Ch\#$ and V measurement range. Default V measurement range at power on is Auto.

See "Measurement Ranging Mode" in Chapter 5 for details.

Measurement Program Flow

The following figure shows the basic measurement program flow. The HP-IB commands for each step are listed in parentheses.

```
                        ┌─────────┐
                        │  START  │
                        └─────────┘
  ┌─────────────────────────────────────────────────────────────┐
  │  1.  Initialize the HP 4142B.  (*RST)                        │
  └─────────────────────────────────────────────────────────────┘
  ┌─────────────────────────────────────────────────────────────┐
  │  2.  Set the output switch of the source unit to ON.  (CN)   │
  └─────────────────────────────────────────────────────────────┘
  ┌─────────────────────────────────────────────────────────────┐
  │  3.  Specify V or I Source mode; force V or I.  (DV, DI, WV, WI, PV, PI, etc.) │
  └─────────────────────────────────────────────────────────────┘
  ┌─────────────────────────────────────────────────────────────┐
  │  4.  Specify the measurement mode and measurement unit.  (MM)│
  └─────────────────────────────────────────────────────────────┘
  ┌─────────────────────────────────────────────────────────────┐
  │  5.  Specify the measurement range.  (RI and RV)            │
  └─────────────────────────────────────────────────────────────┘
  ┌─────────────────────────────────────────────────────────────┐
  │  6.  Perform measurement.  (XE)                             │
  └─────────────────────────────────────────────────────────────┘
  ┌─────────────────────────────────────────────────────────────┐
  │  7.  Set the output to 0 V.  (DZ)                           │
  └─────────────────────────────────────────────────────────────┘
  ┌─────────────────────────────────────────────────────────────┐
  │  8.  Set the output switch of the source unit to OFF.  (CL) │
  └─────────────────────────────────────────────────────────────┘
  ┌─────────────────────────────────────────────────────────────┐
  │  9.  Transfer the measurement data.                         │
  └─────────────────────────────────────────────────────────────┘
                        ┌─────────┐
                        │   END   │
                        └─────────┘
```

Basic Measurement Program Flow

In flow number 3 of above figure, the main commands for specifying measurement conditions for Sweep, Pulsed, and Analog Search measurement are listed below.

- Staircase Sweep measurements (1ch sweep): **WV** and **WI**

- Staircase Sweep measurements (2ch sweep): **WV**, **WI**, **WSV**, and **WSI**

- 1ch Pulsed Spot measurements: **PV** and **PI**

- Pulsed Sweep measurements: **PWV** and **PWI**

- Staircase Sweep with Pulsed Bias measurements: **WV**, **WI**, **PV**, and **PI**

- Analog Search measurements: **ASV**, **AVI**, and **AIV**

- 2ch Pulsed Spot measurements: **PV**, **PI**, **PDV**, and **PDI**

- Pulsed Sweep with Pulsed Bias measurements: **PWV**, **PWI**, **PDV**, and **PDI**

WAITING FOR TIME

You can pause command execution until the specified *wait time* has elapsed. The command is **PA**, and the syntax is:

PA *wait time*

The *wait time* setting area is from 0 to 99.9999 s (100 µs resolution).

If you wait for 1 ms between output and measurement, send as follows:

```
:
80   OUTPUT 717;"MM";1;Collector
90   OUTPUT 717;"DI";Base,0,Ib,2      ! Current output
100  OUTPUT 717;"PA";1E-3
110  OUTPUT 717;"XE"                   ! Measurement Trigger
:
```

PERFORMING SELF-CALIBRATION

Self-Calibration improves short-term accuracy for output and measurement functions. To perform Self-Calibration, send:

OUTPUT 717;"CA"

or press the **LOCAL/SELF TEST** key.

After a minimum 40 minute warm-up period and before you begin to use your HP 4142B, perform Self-Calibration. Self-Calibration should be performed every 30 minutes or if the ambient temperature changes by more than 3°C (6°F).

PERFORMING SELF-TEST

Self-Test verifies that the HP 4142B is operating. To perform the Self-Test, press the **LOCAL/SELF TEST** key. If no errors occur, 0 is displayed in the **ERROR/FAILURE** display.

If you perform Self-Test by the program, send:

```
10    OUTPUT 717;"*TST?"
20    ENTER 717;A$
30    PRINT A$
40    END
```

If no error occurs, $A\$$ is 0.

If you keep the HP 4142B turned on more than 1 day, we recommend that you perform Self-Test one time per one day.

When the HP 4142B performs Self-Test, the HP 4142B also performs Self-Calibration.

CHAPTER 3

TEST DEVICE CONNECTIONS

CONTENTS

NOTES

INTRODUCTION

This chapter explains test device connection considerations and methods, and provides procedures to obtain optimum measurement results.
Be sure to observe all WARNINGs, CAUTIONs, and NOTEs to ensure your safety and to maintain the integrity of the HP 4142B.

BEFORE CONNECTING TEST DEVICES

Before you connect the test devices to the source or monitor unit, perform the following steps.

Enclose the Test Device with a Shielding Box

When you perform measurements, enclose the test device (wafer prober or user-fabricated test fixture) with a box to prevent the operator from receiving an electric shock from the output voltage or current of the HP 4142B. Use a grounded shielding box to minimize the effects of environmental noise and ambient light. To ground the shielding box, connect it to the chassis ground of the HP 4142B by using the CHASSIS GROUND ($\perp$) terminal or the outer conductor of the INTLK terminal.

Connect the INTLK Terminal

To prevent an operator from receiving an electric shock from the high voltage (more than ±42 V), connect the INTLK (interlock) terminal to a switch that turns on when the shielding box access door is closed, and that turns off when the shielding box access door is opened.

The HPSMU output can be as high as ±200 V and the MPSMU output can be as high as ±100 V. If the door is opened (INTLK terminal is open), the output is limited to ±42 V. When a unit output is more than ±42 V and if the door is opened, the HP 4142B immediately drops all output down to 0 V. Conversely, if the door is closed (INTLK terminal is shorted, that is, the INTLK center conductor is set to the chassis ground), the SMU output can be more than ±42 V.

To ground the shielding box, connect it to the outer conductor (chassis ground) of the INTLK terminal.

WARNING

SHORTING THE INTLK TERMINAL ENABLES SMU OUTPUT TO EXCEED ±42 V. DANGEROUS VOLTAGES MAY BE PRESENT AT FORCE, SENSE AND GUARD LINES OF THE SMU OUTPUT CONNECTORS WHEN THE INTLK TERMINAL IS SHORTED.

Shorting Circuit Common and Chassis Ground Terminals

Short the **CIRCUIT COMMON** (∇) and **CHASSIS GROUND** ($\perp$) terminals together with the shorting-bar installed on the **CHASSIS GROUND** terminal.

WARNING

A POTENTIAL SHOCK HAZARD EXISTS IF THE CIRCUIT COMMON (∇) TER-
MINAL IS NOT TIED TO CHASSIS GROUND ($\perp$) (SHORTING-BAR DISCONNECT-
ED FOR FLOATING MEASUREMENTS). DO NOT TOUCH ANY FRONT PANEL
CONNECTORS OF THE HP 4142B AT ANY TIME WHILE A FLOATING MEASURE-
MENT IS IN PROGRESS.

If you disconnect the shorting-bar, see "If the Test Device is Externally Grounded (Floating Measurement)" in this chapter.

CONNECTING THE TEST DEVICES

The following paragraphs discuss test device connection considerations and methods, and provide procedures for obtaining optimum measurement results.

GNDU Connections

GNDU can be connected to test devices using kelvin connections. The following figure shows and describes several GNDU/test device connection methods: one for kelvin connections, and one for non-kelvin connections.

WARNING

DO NOT USE TRIAXIAL CABLE PART NUMBERS 16058-61603 OR 04145-61622 TO CONNECT GNDU TO A TEST DEVICE. THE GNDU CAN SINK UP TO 1.6 A, AND THE MAXIMUM CURRENT RATING OF THESE CABLES IS 1 A.

For kelvin connections: Use a low-noise coaxial cable (part number 8120-3674) from the connector plate to the test device (Device Under Test: DUT). Connect the center conductor of the cable to SENSE, and outer conductor (shield) to FORCE. To cancel the effects of cable resistance, connect the SENSE line as close as possible to the terminal of the test device.
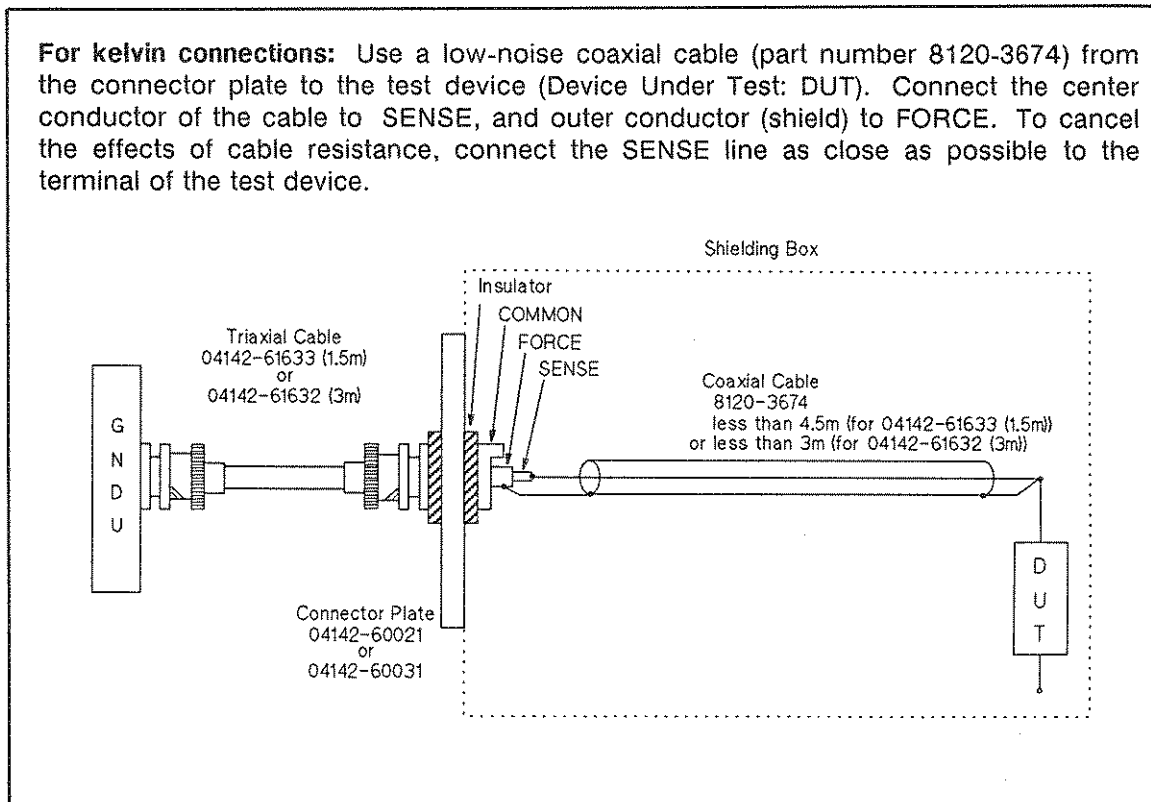
GNDU Example Connections (1 of 2)

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For non-kelvin connections: Short SENSE and FORCE at the connector plate as shown. Use AWG 24 single-strand insulated wire (part number 8150-0447) from the connector plate to the test device (DUT). Measurement results include the residual resistance of the connection wire.
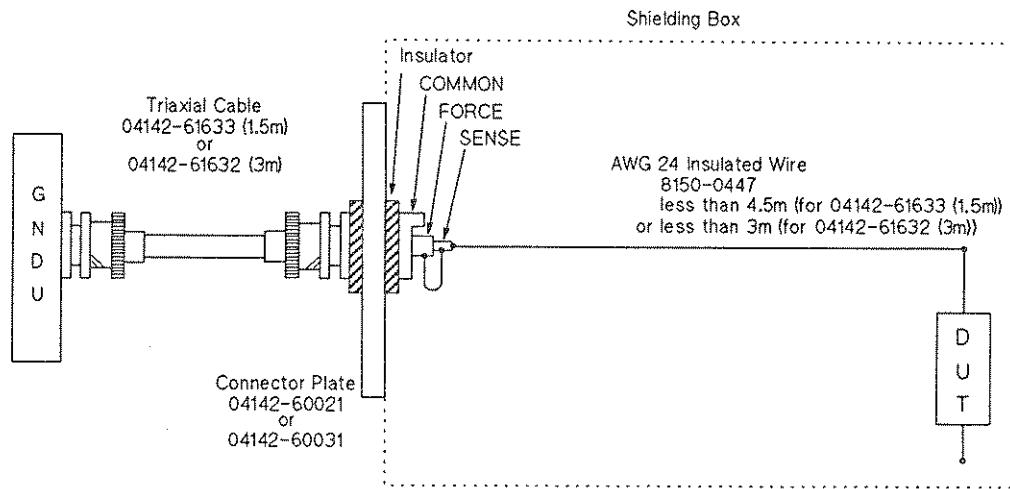
NOTE

To easily connect GNDU for a measurement in which the accuracy is not important, connect only FORCE to the test device (DUT), without shorting SENSE and FORCE.

GNDU Example Connections (2 of 2)

HPSMU and MPSMU Connections

The HPSMU and MPSMU can be connected to test devices using kelvin connections. For highly accurate current forcing and measurements while minimizing leakage, the FORCE and SENSE terminals are surrounded by a GUARD terminal that has the same potential as the output. The following figure shows and describes several SMU/test device connections.

WARNING

VOLTAGES UP TO ±200 V (±100 V FOR MPSMU) MAY BE PRESENT AT THE FORCE, SENSE, AND GUARD TERMINALS. DO NOT TOUCH THESE TERMINALS IF THE FRONT PANEL HIGH VOLTAGE LAMP IS LIT.
NOTE THAT SMU GUARD TERMINAL POTENTIAL IS EQUAL TO THE OUTPUT.

TO PREVENT POTENTIAL SHOCK HAZARDS WHEN INTERCONNECTING THE HP 4142B TO OTHER DEVICES (E.G., A WAFER PROBER OR USER-FABRICATED TEST FIXTURE), DO NOT EXPOSE THE SMU OUTPUT LINES.

CAUTION

NEVER connect the GUARD terminal of any SMU to any output, including CIRCUIT COMMON ($\triangledown$), CHASSIS GROUND ($\perp$), or the GUARD terminal of any other SMU. Doing so will result in SMU damage.

For kelvin connections: Use a low-noise coaxial cable (part number 8120-3674) from the connector plate to the test device. Connect the center conductor of one of the cables to FORCE, the center conductor of the other cable to SENSE, and the outer conductors (shields) of both cables to GUARD. To cancel the effects of cable resistance, connect the SENSE line as close as possible to the terminal of the test device. To prevent oscillations when making dc measurements, do not use cables longer than 1.5 m (for using 04142-61632 3 m cable) or 2.5 m (for using 04142-61633 1.5 m cable). For highly accurate current forcing and measurements while minimizing leakage, surround all FORCE and SENSE lines on the SMU by a GUARD as far as possible.
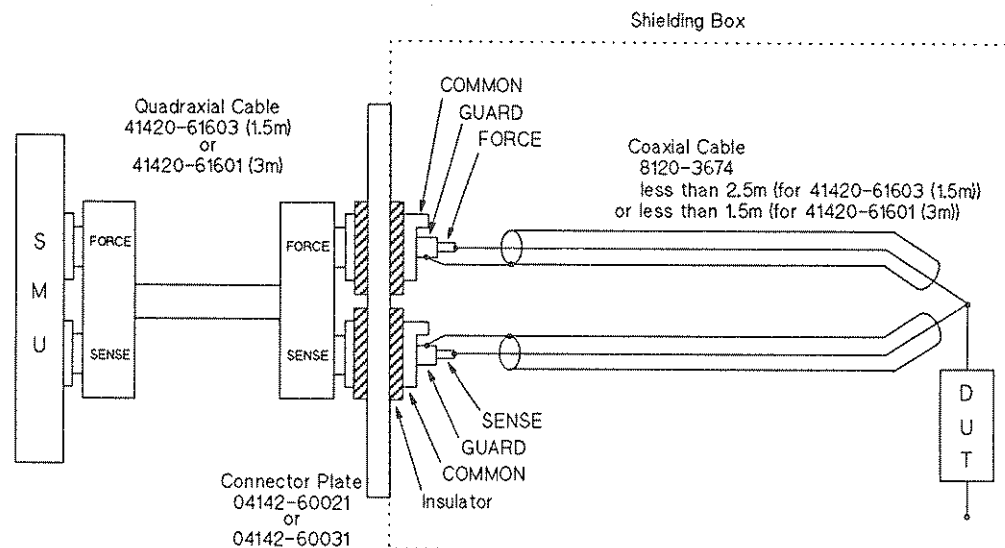
NOTE

One quadraxial cable can be replaced by two triaxial cables. If you use the 1.5 m triaxial cable (part number 16058-61603), make the length of the coaxial cable less than 1.5 m. If you use the 3 m triaxial cable (part number 04145-61622), make the length of the coaxial cable less than 35 cm.

SMU Example Connections (1 of 3)

For non-kelvin connections: The total connection cable length can be increased to 6 m by shorting SENSE and FORCE at the connector plate, as shown below. Measurement results include residual resistance from the connection wire. To enable highly accurate current forcing and measurements while minimizing leakage, surround all FORCE lines on the SMU by a GUARD as far as possible.
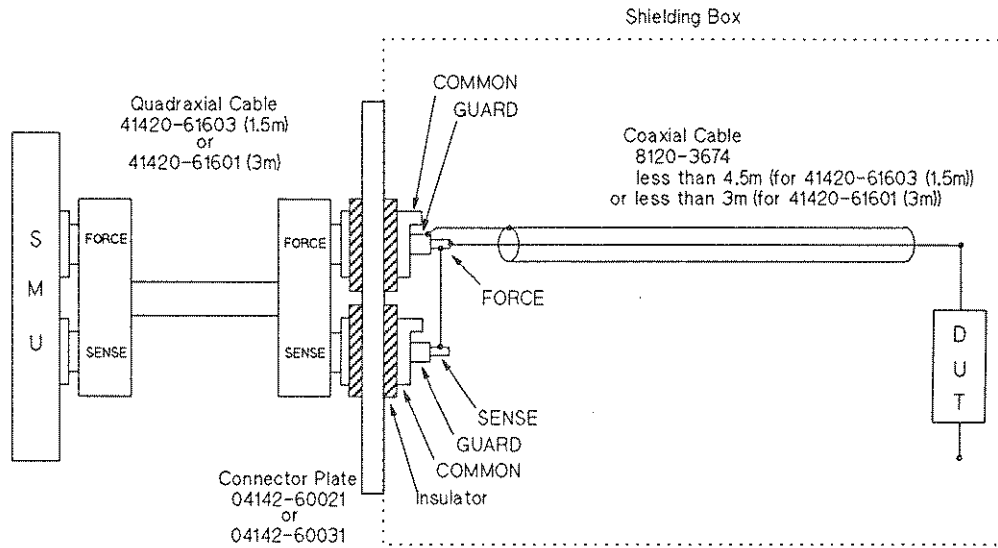
NOTE

One quadraxial cable can be replaced two triaxial cables. If you use the 1.5 m triaxial cable (part number 16058-61603), make the coaxial cable length less than 3 m. If you use the 3 m triaxial cable (part number 04145-61622), make the coaxial cable length less than 70 cm.

SMU Example Connections (2 of 3)

For non-kelvin connections: When current flow is minimum, i.e., the connection cable residual resistance is unimportant, the following connection method can be used. To use this method, be sure to connect a triax cover (part number 1250-1708) to the SENSE terminal of the SMU to provide shielding. For highly accurate current forcing and measurements while minimizing leakage, surround the FORCE line of the SMU with a GUARD as far as possible.
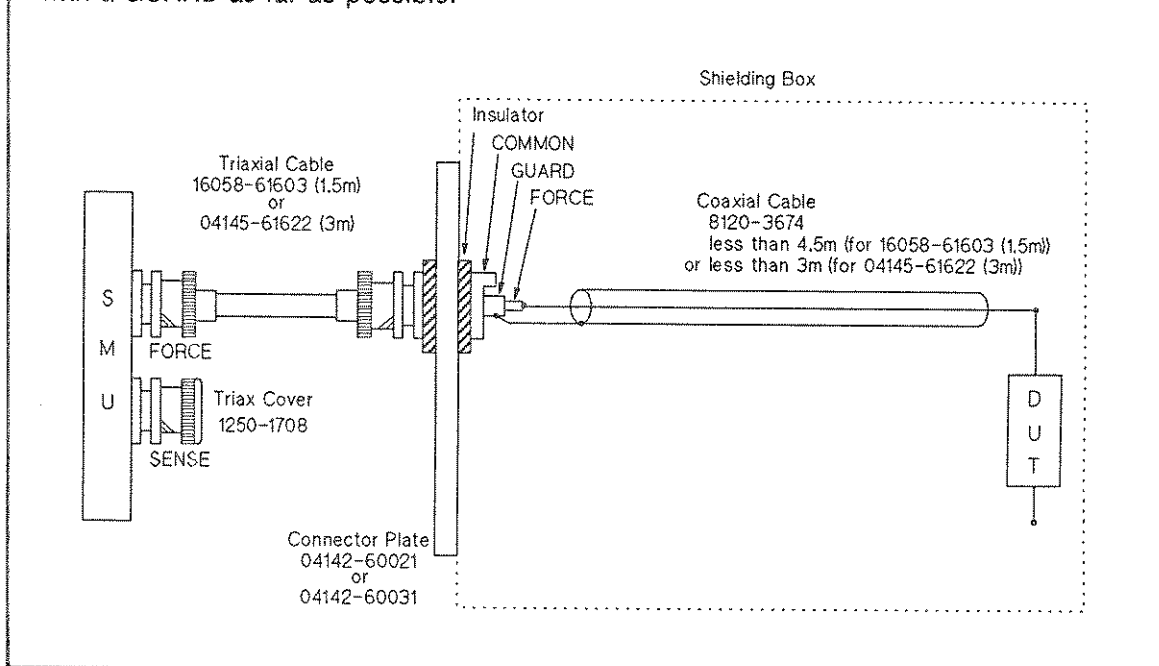
SMU Example Connections (3 of 3)

Connecting the SMU by another method

If you connect the SMU by a method that is not shown in the above figure, please note the following.

To prevent SMU oscillation, make the guard capacitance of the wiring cable less than 500 pF. The guard capacitance is the total cable capacitance between the FORCE and GUARD lines and between the SENSE and GUARD lines. Refer to the following guard capacitance data. For quadraxial cables, the following data is total guard capacitance.

    41420-61603   1.5 m Quadraxial Cable: 150 pF
    41420-61601   3 m Quadraxial Cable: 300 pF
    16058-61603   1.5 m Triaxial Cable: 120 pF
    04145-61622   3 m Triaxial Cable: 240 pF
    8120-3674   Coaxial Cable: 77 pF/m

Do not use the GNDU cables (04142-61632 and 04142-61633) because guard capacitance is too large.

HCU Connections

The HCU can be connected to test devices using kelvin connections. The following figure shows several HCU/ connections.

NOTE

You can not use the HCU as a normal floating source. Whenever you use the HCU, connect GNDU to the FORCE LOW line of the HCU, and fix FORCE LOW to 0 V. Do not connect the SMU or VS instead of the GNDU because the SMU or VS will not operate correctly.
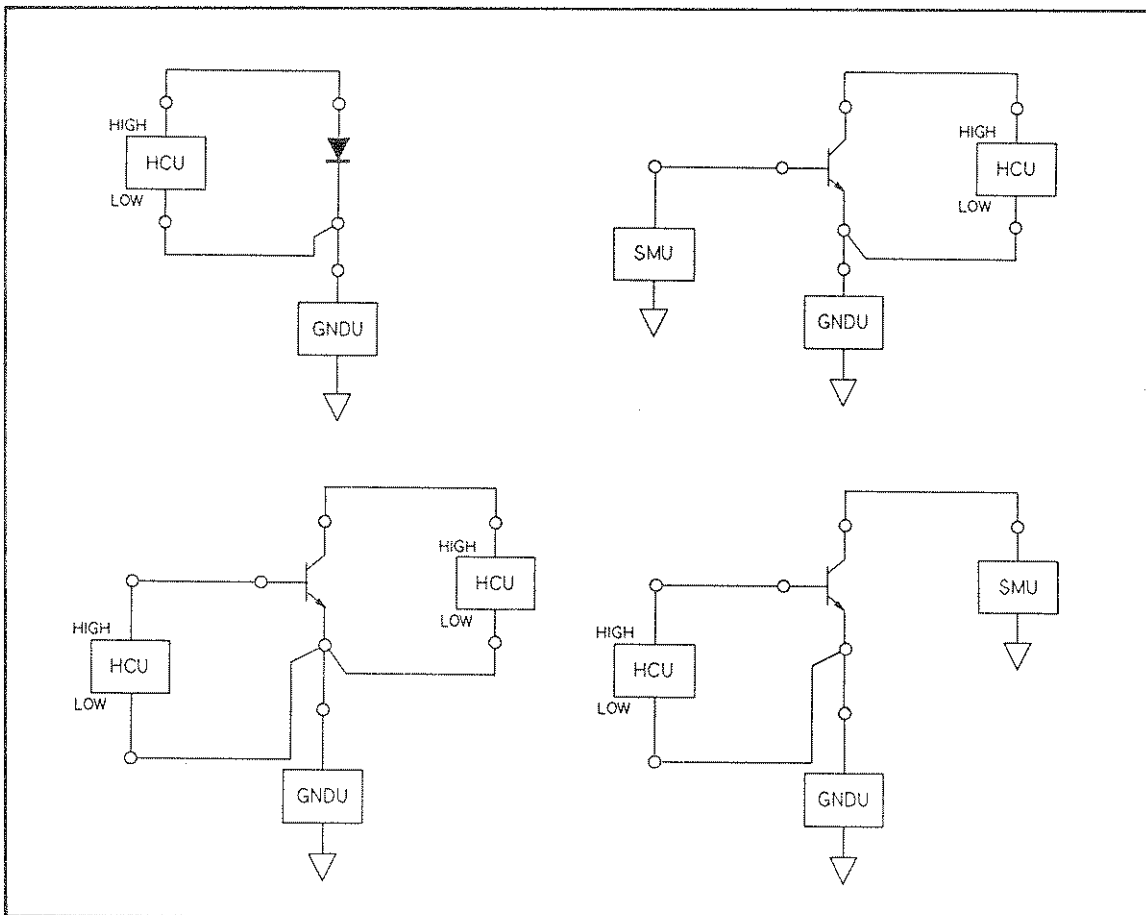
HCU Example Connection (1 of 2)

For the FORCE line connection, use an AWG 16 (1.29 mm in diameter) single-strand insulated wire (part number 8150-2605) from the connector plate to the test device. Make the wire length less than 1 m if you use 3 m wire (41422-61601), and less than 2.5 m if you use 1.5 m wire (41422-61602). Twist the FORCE HIGH and FORCE LOW lines together to prevent the increase of settling time and the occurrence of overshoot and noise from wire inductance. If the wire length is too short to twist the wires, tie the two wires together with string, as shown in the figure below.

For the SENSE line connection, use an AWG 24 (0.511 mm diameter) single-strand insulated wire (part number 8150-0447) from the connector plate to the test device. Make the length of the wire less than 3 m. Twist the SENSE HIGH and SENSE LOW lines together or tie the two wires together with string. To cancel the effects of residual resistance from the wire, connect the SENSE HIGH and SENSE LOW lines as close as possible to the test device.

Connect the FORCE and SENSE lines of GNDU to the same terminal of the test device (DUT) in which you connected the FORCE LOW and SENSE LOW lines of the HCU.
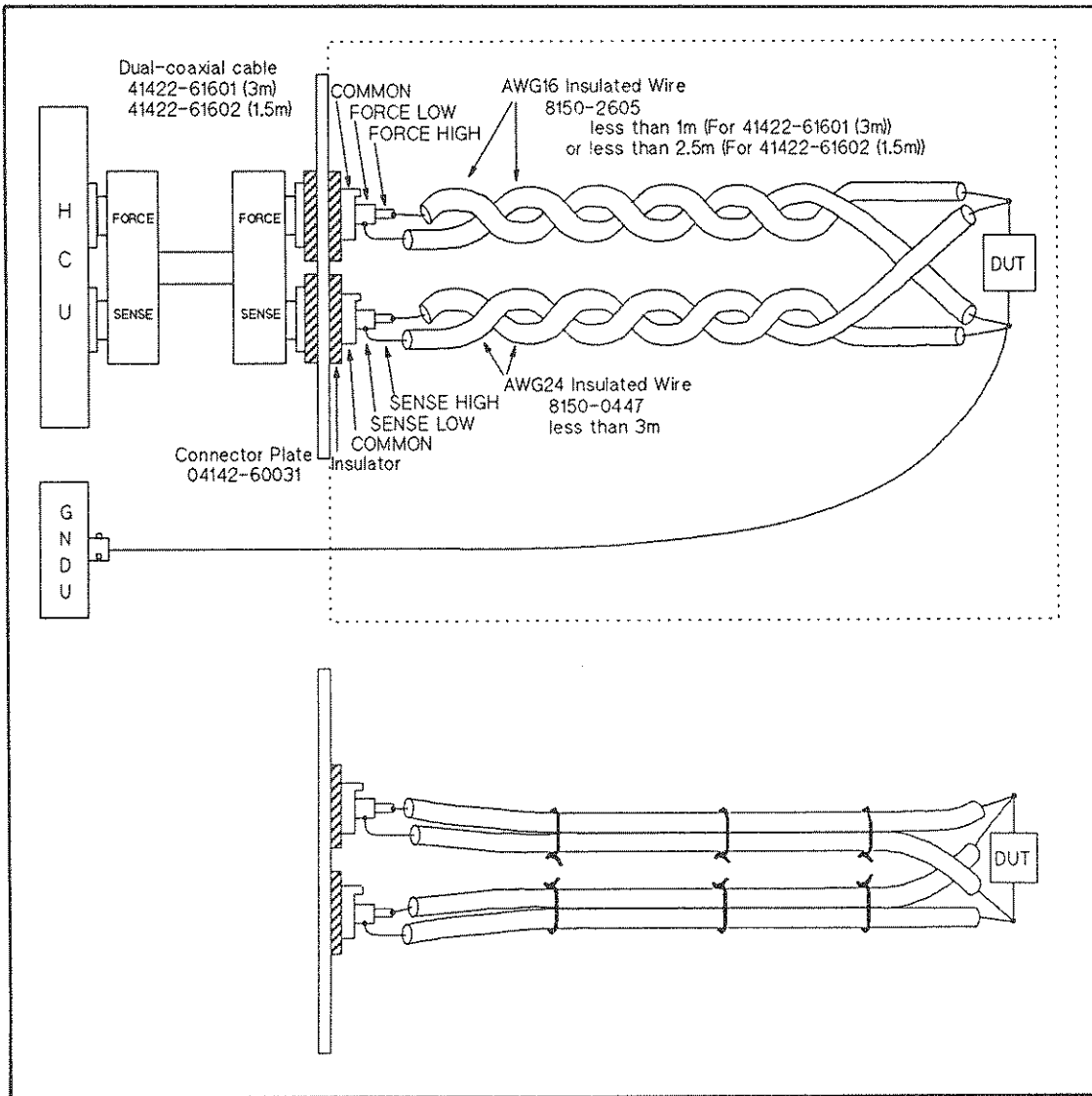
HCU Example Connection (2 of 2)

Connecting the HCU by another method

If you connect the HCU by a method that is not shown in the above figure, note the following.

● FORCE Wiring Resistance

The wiring resistance between the HCU FORCE HIGH terminal and the test device, and the wiring resistance between the HCU FORCE LOW terminal and the test device must be less than 150 mΩ, respectively. Refer to the following FORCE wiring resistance data. When you use the HP 16088A Test Fixture, do not use a 3 m dual-coaxial cable (part number 41422-61602) because the wiring resistance exceeds 150 mΩ.

> 41422-61601 3 m Dual-coaxial Cable
> 110 mΩ
> 41422-61602 1.5m Dual-coaxial Cable
> 65 mΩ
> 8150-2605 AWG16 (1.290 mm in diameter) insulated wire
> 14 mΩ/m
> 8150-2890 AWG18 (1.024 mm in diameter) insulated wire
> 22 mΩ/m
> 8150-0005 AWG22 (0.634 mm in diameter) insulated wire
> 56 mΩ/m
> 8150-0447 AWG24 (0.511 mm in diameter) insulated wire
> 89 mΩ/m
> Contact resistance between the Dual-coaxial cable (41422-61601 or 41422-61602) and connector plate (41422-60031)
> 5 m to 10 mΩ
> HP 16088A Test Fixture (from HCU connector of the the HP 16088A rear panel to the test device, for using the 16088-60007 to -60009 Socket boards)
> 75 mΩ

If the wiring resistance exceeds 150 mΩ, the usable output area of the HCU is limited. The limitation depends on the wiring resistance value. The following figure shows the output limitation when the wiring resistance of FORCE HIGH line R is same as that of FORCE LOW line.
If the wiring resistance value R is 0.5 ohm, maximum output current is limited to 8 A and output voltage is limited to 5 V (at 8 A) and 7 V (at 5 A). You cannot use the HCU outside of this limitation. If you specify a value that exceeds the limitation, the HCU output is not the specified value, and the actual output voltage or current value includes a large error.
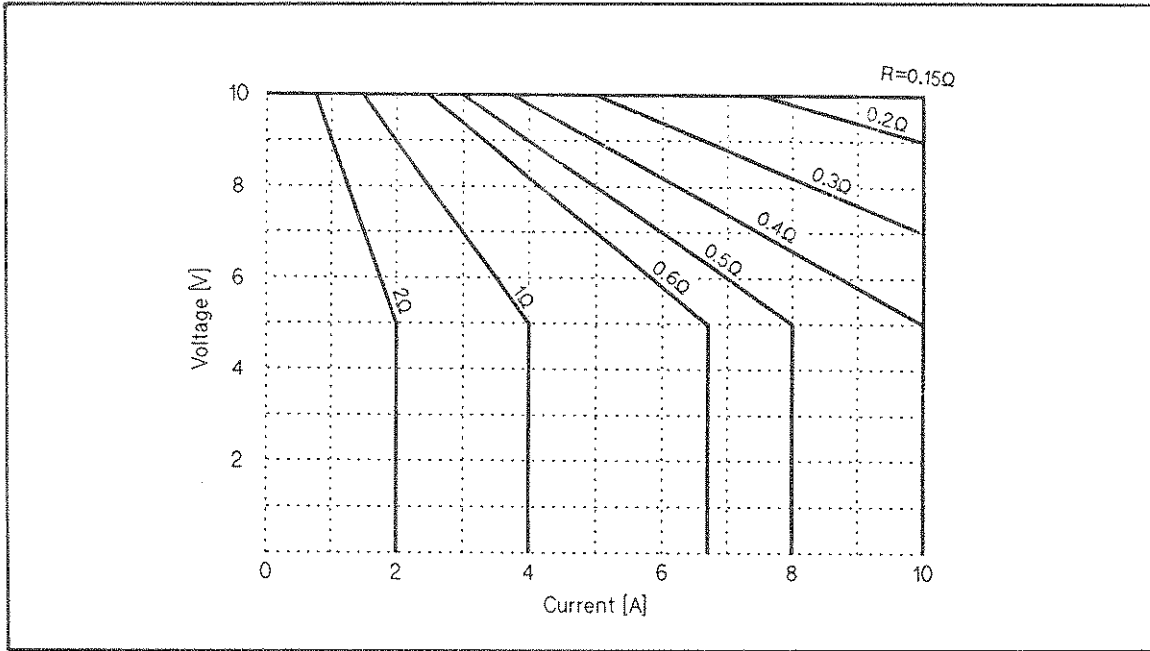
Output Limitation by Wiring Resistance

Apply the larger wiring resistance value of the FORCE HIGH and LOW lines in the above figure, if both values are different. To calculate the exact output limitation, use the following equations.

$$1) \ V \leq 13 - (R1+R2)I$$
$$2) \ I \leq 4/R1$$
$$3) \ I \leq 4/R2$$
$$4) \ I \leq 10$$
$$5) \ V \leq 10$$

where:

- V: Voltage across the test device. If the HCU forces voltage, it is the specified voltage value.
- I: Current through the test device. If the HCU forces current, it is the specified current value.
- R1: Wiring resistance of FORCE LOW
- R2: Wiring resistance of FORCE HIGH

Equation 1 is the limitation of maximum voltage between FORCE HIGH and FORCE LOW at the front output connectors, which is 13 V. Equation 2 and 3 are the limitations of maximum voltage between FORCE HIGH and SENSE HIGH or between FORCE LOW and SENSE HIGH at the front output connectors, which is 4 V. Equation 4 and 5 are the limitations of the maximum voltage and current of HCU across the test device.

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• FORCE Wiring Inductance

To prevent slow pulsed output settling, output overshoot, and noise, make the wiring inductance of the FORCE line less than 300 nH. The FORCE wiring inductance is the wiring inductance from the FORCE HIGH terminal of the HCU to the FORCE LOW terminal of the HCU, when both lines are shorted at the test device. Refer to the following FORCE wiring inductance.

    41422-61601 3 m Dual-coaxial Cable: 200 nH
    41422-61602 1.5 m Dual-coaxial Cable: 100 nH

Twist the FORCE HIGH and FORCE LOW lines from the connector plate to the test device so that wiring inductance decreases.

VS/VMU Connections

The following figure shows an example of a connection between VS1, VS2, VM1, or VM2 and a test device. Use AWG 24 single-strand insulated wire (part number 8150-0447) to connect the connector plate and the test device.
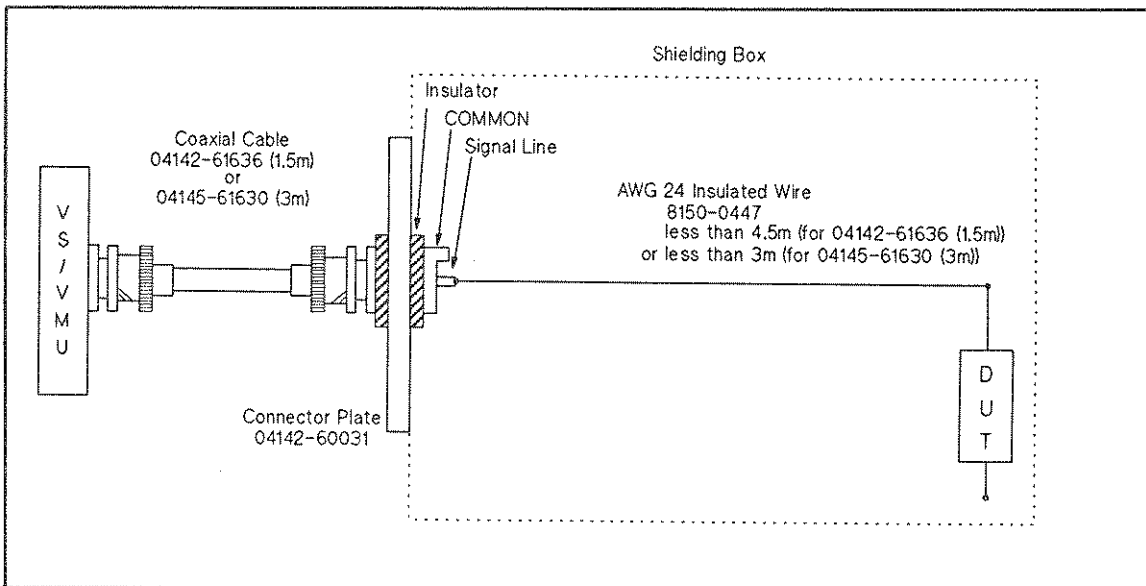
VS/VMU Example Connection

USING THE CONNECTION ACCESSORIES

Using Connector Plate Part Number 04142-60021

Connector Plate part number 04142-60021, one of the available accessories for the HP 4142B, interconnects 4 (for kelvin) to 8 (for non-kelvin) SMUs, GNDU and **INTLK** to test devices and a switch for **INTLK** via a shielding box. The following figure shows the connector assignments and connector plate dimensions.

The plate is electrically connected to the outer conductor of the **INTLK** connector, and is insulated from the outer conductors of the SMU and GNDU connectors for floating measurements.

To install the connector plate, drill holes to mount the connector plate onto the shielding-box, install the connector plate on the shielding-box, and ensure that there is good electrical contact between the connector plate and the shielding box.

NOTE

This connector plate cannot connect the HCU cable (41422-61601 or 41422-61602) because the location of the screw is different from the SMU cable (41420-61601 or 41420-61603).
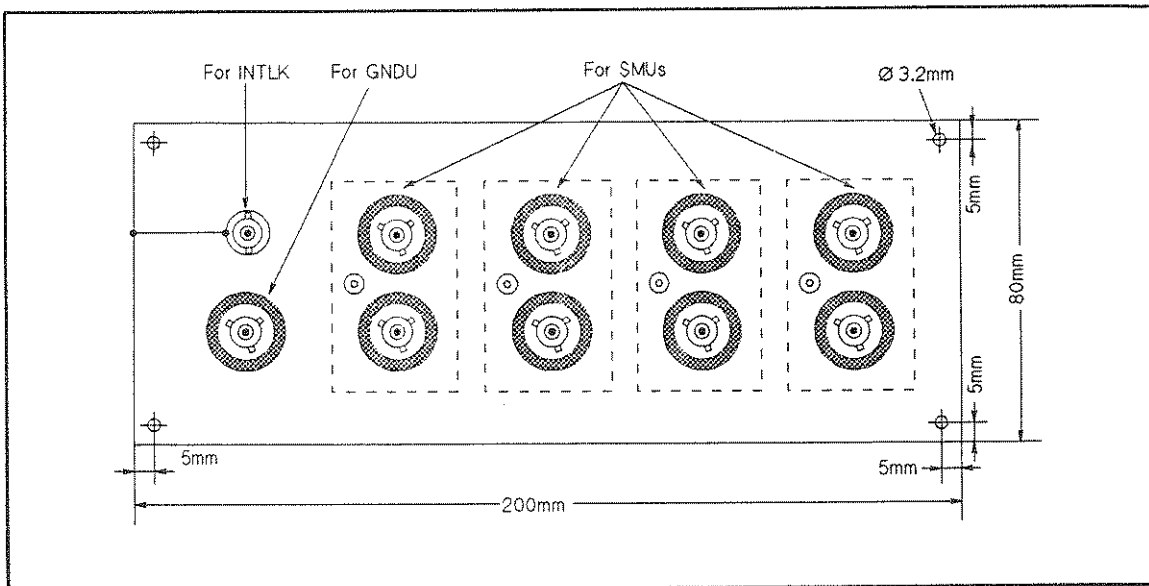
Connector Plate Part Number 04142-60021

Using Connector Plate Part Number 04142-60031

Connector Plate part number 04142-60031, one of the available accessories for the HP 4142B, interconnects two HCUs, VS/VMU, GNDU, INTLK, and two AUXs (two coaxial connectors) to test devices and a switch for INTLK via a shielding box. The following figure shows the connector assignment and connector plate dimensions.

The plate is electrically connected to the outer conductor of the INTLK connector, and is insulated from the outer conductors of other connectors for floating measurements.

To install the connector plate, drill holes to mount the connector plate onto the shielding-box, and install the connector plate on the shielding-box. Ensure that there is good electrical contact between the connector plate and the shielding box.

NOTE

The connector plate cannot connect the SMU cable (41420-61601 or 41420-61603) because the location of the screw is different from the HCU cable (41422-61601 or 41422-61602).
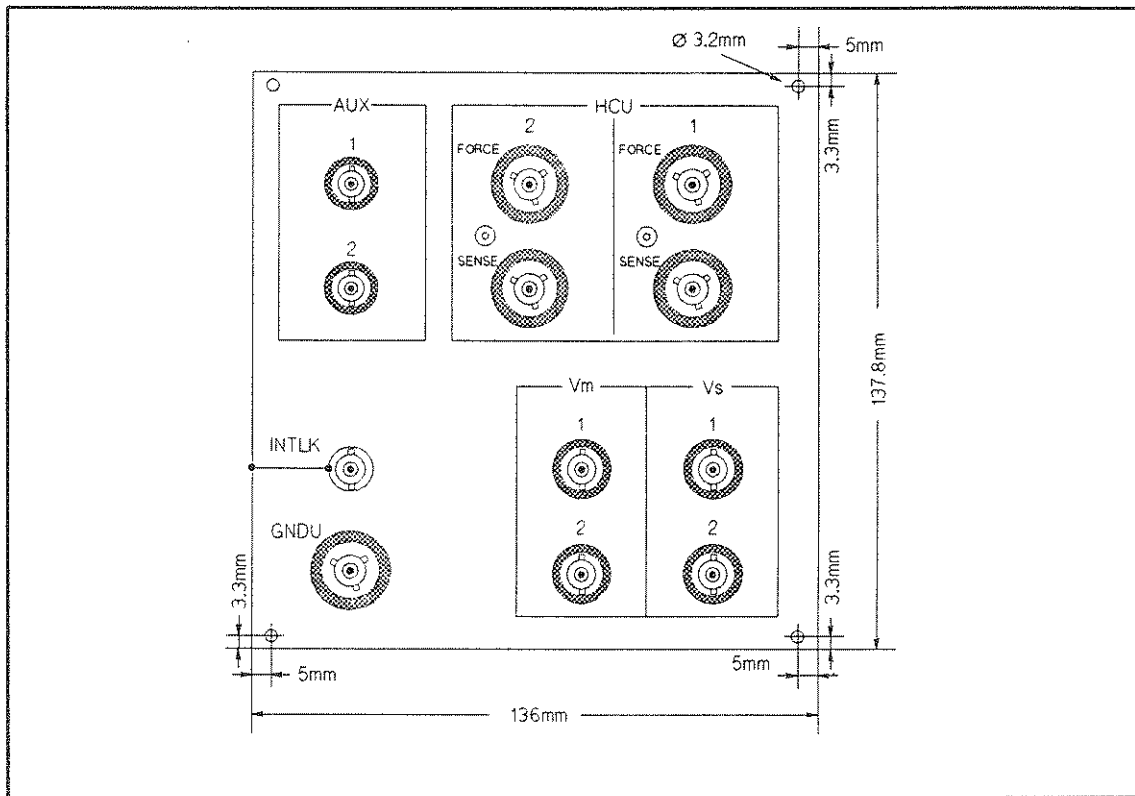
Connector Plate Part Number 04142-60031

Using the HP 16088A Test Fixture

The HP 16088A Test Fixture connects packaged test devices, such as transistors and ICs, to between four (for kelvin) and eight (for non-kelvin) SMUs, 2 HCUs, 2 VSs, 2 VMs, GNDU, and 2 AUXs. Eleven interchangeable DUT Socket Boards are available. The following figure shows the connector assignments of the HP 16088A.

You can use the following cables to connect the HP 4142B and HP 16088A.

> For GNDU:
> 04142-61633 1.5 m Triaxial Cable
> 04142-61632 3 m Triaxial Cable
>
> For SMUs:
> 41420-61603 1.5 m Quadraxial Cable
> 41420-61601 3 m Quadraxial Cable
> 16058-61603 1.5 m Triaxial Cable
> 04145-61622 3 m Triaxial Cable
>
> For HCUs:
> 41422-61602 1.5 m Dual-coaxial Cable
>
> For VSs,VMs, INTLK, or AUXs:
> 04142-61636 1.5 m Coaxial Cable
> 04145-61630 3 m Coaxial Cable

NOTE

When you connect the HCU and the HP 16088A Test Fixture, use 1.5 m Dual-coaxial cable, part number 41422-61602. Do not use 3 m Dual-coaxial cable, part number 41422-61601, because the wiring resistance of the FORCE line exceeds 150 mΩ.

You can also connect the VSs and VMs of the HP 4142B to the **AUX1** and **AUX2** coaxial terminals of the HP 16088A.

Because circuit common ($\triangledown$) and chassis ground ($\perp$) are connected inside the HP 16088A Test Fixture, floating measurements cannot be performed with the HP 16088A.
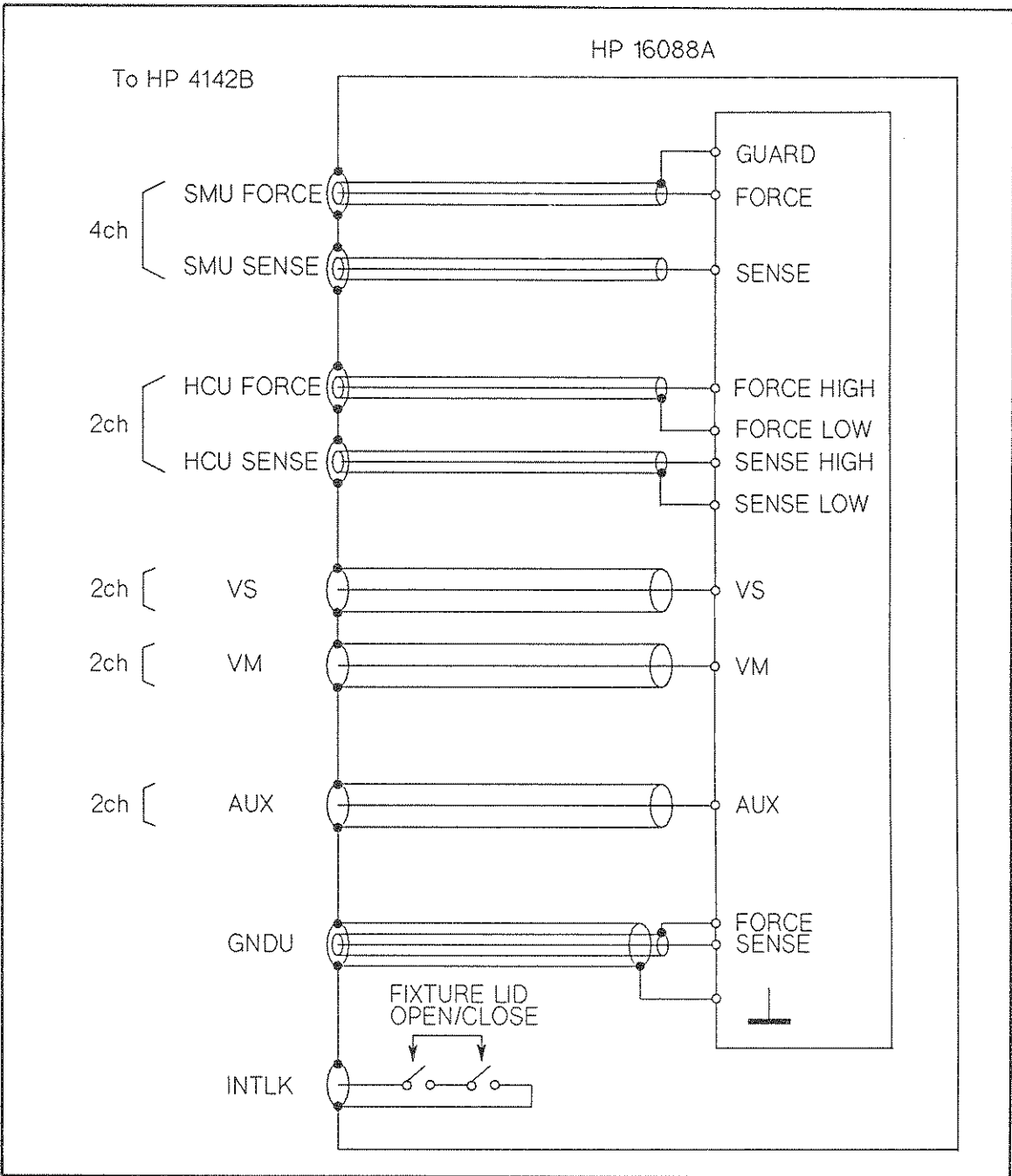
16088A Circuit Diagram

Using the HP 16058A Test Fixture

The HP 16058A Test Fixture connects packaged test devices, such as transistors and ICs, to the SMUs, VSs, and VMs of the HP 4142B. Eight interchangeable DUT Socket Boards are furnished with the HP 16058A. The following figure shows the interconnections between the HP 4142B and the HP 16058A.

NOTE

To use the GNDU with the HP 16058A, connect the GNDU to the desired HP 16058A SMU triaxial terminal, and connect the corresponding SMU **GD** (FORCE) or **GD** and **SMU** (SENSE) terminals to test device.

You can also connect the VSs and VMs of the HP 4142B to the **HIGH** and **LOW** coaxial terminals of the HP 16058A.

Because circuit common ($\bar{\lor}$) and chassis ground ($\perp$) are connected inside the HP 16058A Test Fixture, floating measurements cannot be performed with the HP 16058A.
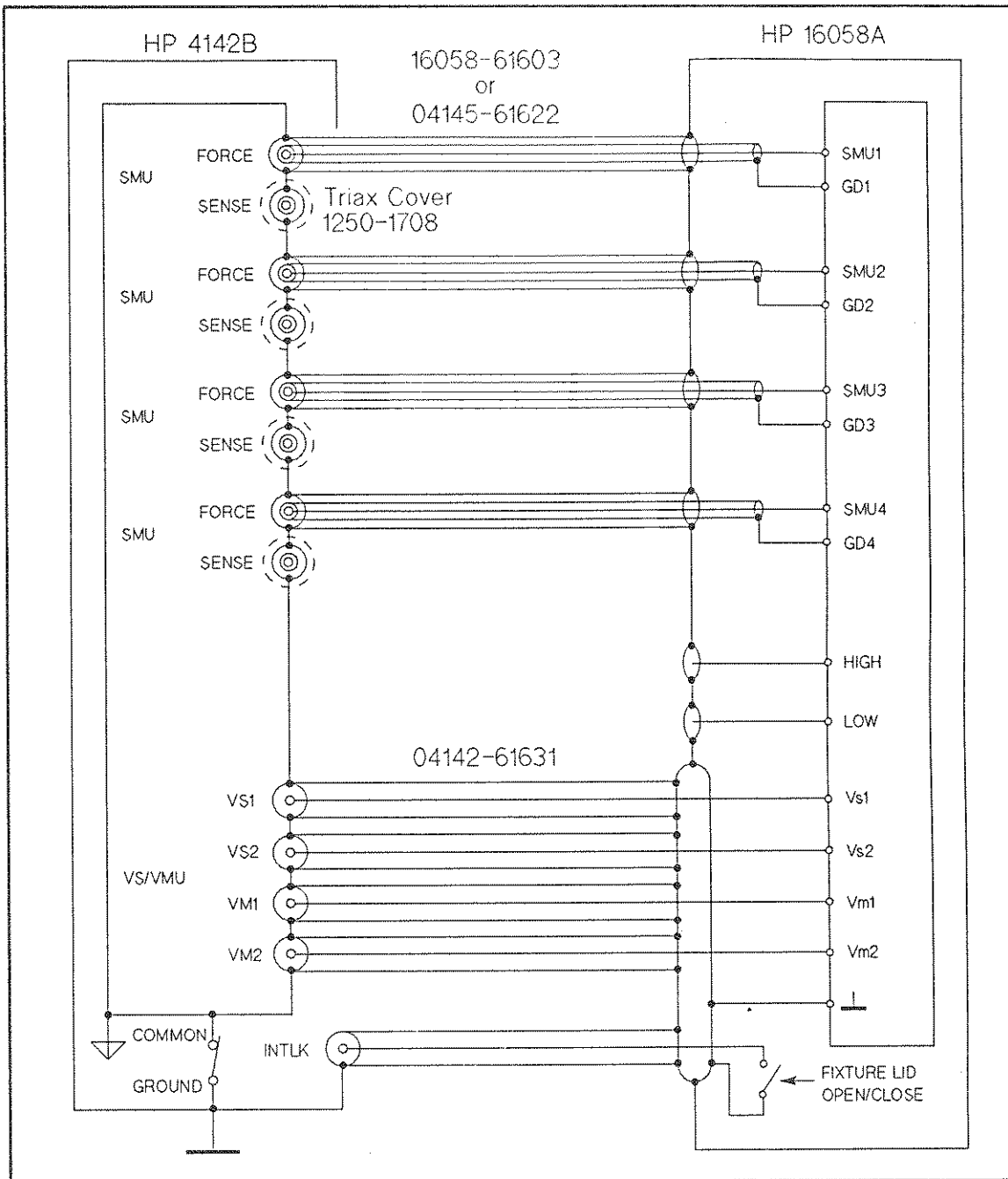
HP 4142B/16058A Interconnections Example

ADVANCED CONNECTION INFORMATION

For High Current Measurements (Kelvin Connection)

If you perform high-current measurements using the GNDU, SMU or HCU, use the SENSE terminal for the kelvin connection, as shown in one of the following sections in this chapter: "GNDU Connections," "HPSMU and MPSMU Connections," and "HCU Connections."

The wiring between the source unit and the test device has residual resistance from the cable and contact residual resistance from the connector. For example, if you do not use the kelvin connection and you force 1 A through a cable that has a residual resistance of 100 mΩ, as shown in the following figure, the voltage drop is 100 mV. This voltage (Verror) is included in the measurement result, and the measurement result (Vmeas) becomes:

Vmeas = Vdut + Verror   where Vdut is the voltage at device terminal.

To eliminate the effect of residual resistance (Verror) from the FORCE line, connect the SENSE terminal as close as possible to the test device terminal. This way, V monitor is directly connected to the test device.
Because the input impedance of V monitor is high, current does not flow into the SENSE line. Therefore, measurement error does not occur if the SENSE line has a residual resistance of 10Ω or less.

The kelvin connection is effective even when voltage is forced, because the voltage drop by wiring residual resistance is fed back to the voltage source through the SENSE line, thereby ensuring the specified voltage output at the sense point where the FORCE and SENSE lines intersect.
Because the input impedance of SENSE line is high, current does not flow into the SENSE line. Therefore, output error does not occur if the SENSE line has a residual resistance of 10Ω or less.

I source /V monitor Mode

Non-kelvin: Vmeas = Vdut+IRf $\langle$FORCE$\langle$ —— Rf —— Vdut

DUT

Kelvin: Vmeas = Vdut $\langle$SENSE$\langle$ —— Rs ——
$\langle$FORCE$\langle$ —— Rf —— Vdut

DUT

V source /I monitor Mode

Non-kelvin: X1 (A) $\langle$FORCE$\langle$ —— Rf —— Vdut = Vset-IRf
Vset Vset

DUT

Kelvin: $\langle$SENSE$\langle$ —— Rs ——
X1 (A) $\langle$FORCE$\langle$ —— Rf —— Vdut = Vset
Vset

DUT
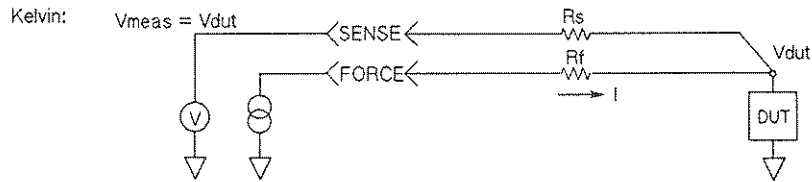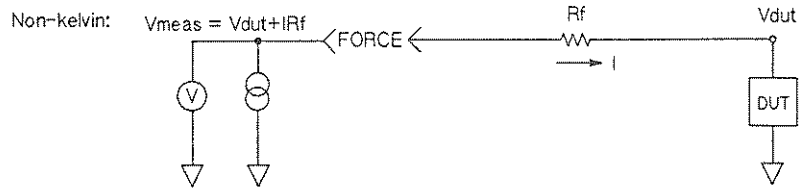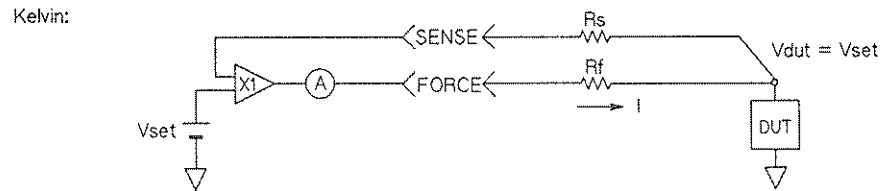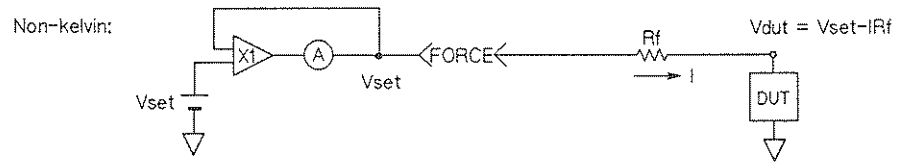
Kelvin Connection and Non-kelvin Connection Comparisons

For Low Current Measurements (Using the GUARD Terminal)

If you perform low-current measurements using an SMU, surround all FORCE and SENSE lines with the potential of GUARD as far as possible, as shown in the following figure, to minimize leakage current from the FORCE and SENSE lines. The potential of the Guard terminal is the same as FORCE and SENSE terminal voltage (the maximum difference is 1 mV).

By using GUARD, there is no potential difference between the FORCE or SENSE lines and GUARD line. Therefore, the leakage current from the FORCE and SENSE lines can not flow. The leakage current from GUARD does not affect the measurement result because it does not flow into the SMU ammeter (I monitor).

WARNING

SMU GUARD TERMINAL POTENTIAL IS EQUAL TO THE OUTPUT. DO NOT TOUCH THE SMU OUTPUT CONNECTORS DURING VOLTAGE OR CURRENT OUTPUT.

CAUTION

NEVER connect the GUARD terminal of any SMU to any other output, including CIRCUIT COMMON ($\triangledown$), CHASSIS GROUND ($\perp$), or the GUARD terminal of any other SMU. Doing so results in damage to the SMU.
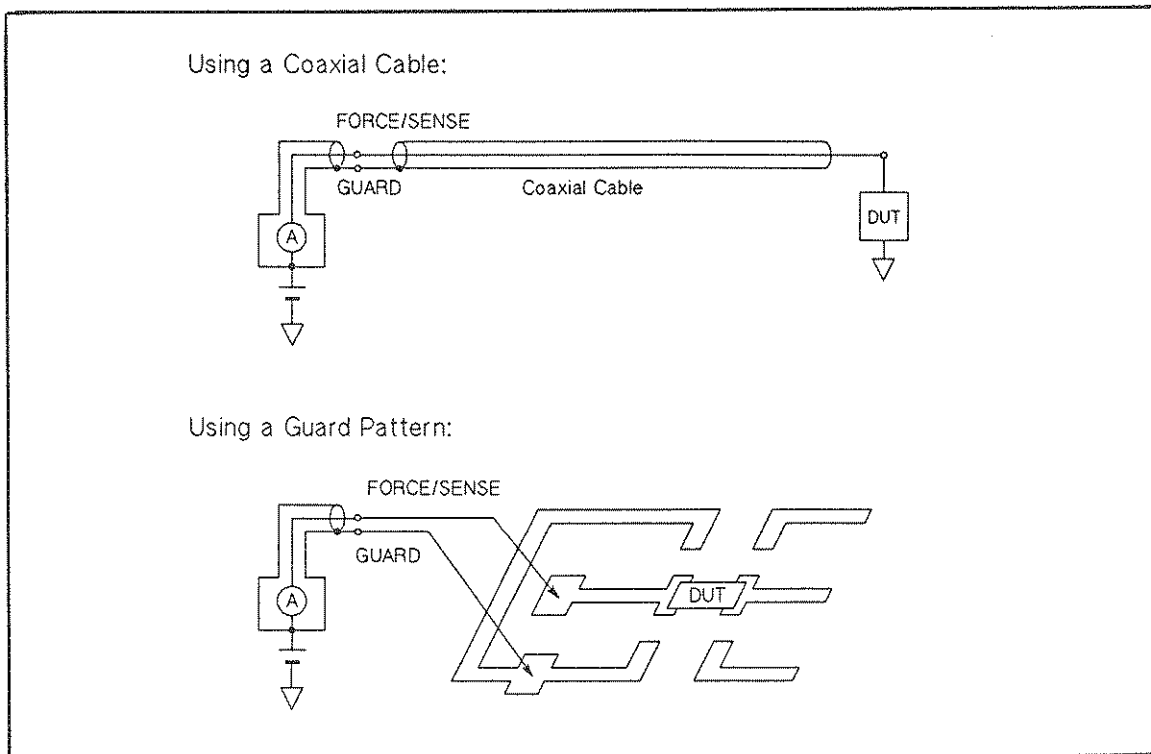
Example of GUARD Use

If the Test Device is Externally Grounded (Floating Measurement)

When the test device is grounded by the prober or is forced by the external V or I sources, the noise of ground loops may affect measurement results. To prevent this, perform the floating measurement as shown in the following procedure.

1) Disconnect the **CIRCUIT COMMON** (⩔) terminal and **CHASSIS GROUND** (⊥) terminal by removing the shorting-bar.

2) Connect the external ground to the **CIRCUIT COMMON** terminal. To do this, use the **CIRCUIT COMMON** terminals of the source and monitor units (GNDU, SMUs, HCUs, VSs, and VMs) on the connector plate, as shown in the following figure.

The **CIRCUIT COMMON** terminal is connected to the outer conductors of the GNDU, SMU, HCU, VS, and VM connectors. The **CHASSIS GROUND** terminal is tied to the HP 4142B chassis. With the above procedure, the HP 4142B (GNDU, SMUs, HCUs, VSs and VMs) forces and measures voltage or current referenced to external ground.

WARNING

A POTENTIAL SHOCK HAZARD EXISTS IF THE CIRCUIT COMMON (⩔) TERMINAL IS NOT TIED TO CHASSIS GROUND (⊥) (SHORTING-BAR DISCONNECTED FOR FLOATING MEASUREMENTS). DO NOT TOUCH ANY OF THE HP 4142B FRONT PANEL CONNECTORS AT ANY TIME WHILE A FLOATING MEASUREMENT IS IN PROGRESS.

DO NOT FLOAT THE CIRCUIT COMMON TERMINAL AT VOLTAGES GREATER THAN ±42 V REFERENCED TO CHASSIS GROUND. FAILURE TO HEED THIS WARNING MAY RESULT IN DAMAGE TO YOUR HP 4142B.

NOTE

Because circuit common (⩔) and chassis ground (⊥) are connected inside the HP 16088A and HP 16058A Test Fixtures, floating measurements cannot be performed with the HP 16088 or 16058A, even if the **CIRCUIT COMMON** (⩔) and **CHASSIS GROUND** (⊥) terminals of the HP 4142B are not connected (shorting-bar removed).

If the **CIRCUIT COMMON** terminal is open without connecting the **CIRCUIT COMMON** terminal to the **CHASSIS GROUND** terminal or the external ground, the noise can affect the accuracy of the measurements.
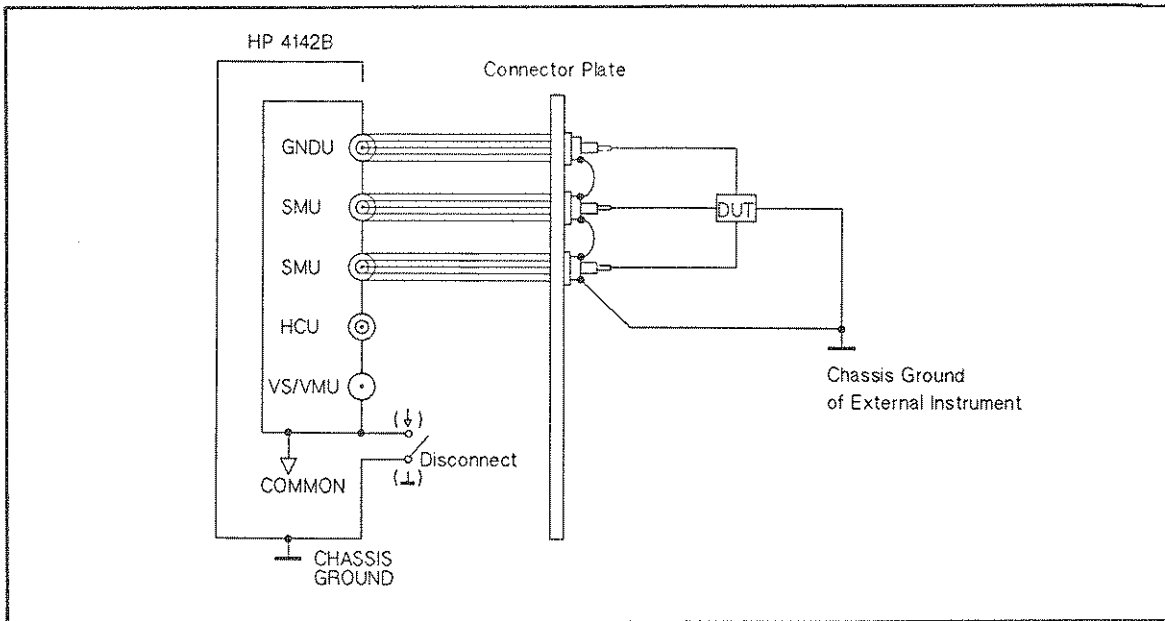
Floating Measurement Example

If the Test Device has Negative Resistance

If the test device has negative resistance characteristics (tunnel diodes or unijunction transistors), a source unit may oscillate at frequencies of 300 kHz or less because the source unit operates as a negative feedback amplifier.

The HPSMUs or the MPSMUs can detect this oscillation. An "X" is indicated in data status of measurement data if the HPSMU or MPSMU detects oscillation.

The following figure shows several examples of measurements made on negative devices.

Voltage controlled negative resistance devices

Connect G in parallel with your test device to cancel negative resistance. To obtain an output I-V curve, use the following equation.

$$I_Y = I - G \times V$$

Current controlled negative resistance devices

Connect R in series with your test device to cancel negative resistance. To obtain an output I-V curve, use the following equation.

$$V_Z = V - R \times I$$

Negative Resistance Measurements

Preventing Oscillation from the Test Device

The test device itself may oscillate at high frequencies (more than 3 MHz) due to stray capacitances and residual inductances of connection cables, probe card, and test fixture. Bipolar transistors, which have a high hfe (forward current transfer ratio) and a wide frequency range, and Field Effect Transistors (FETs), which have a high gm (transconductance) and a wide frequency range, are especially likely to oscillate, and produce measurement results similar to those shown in the following figure.
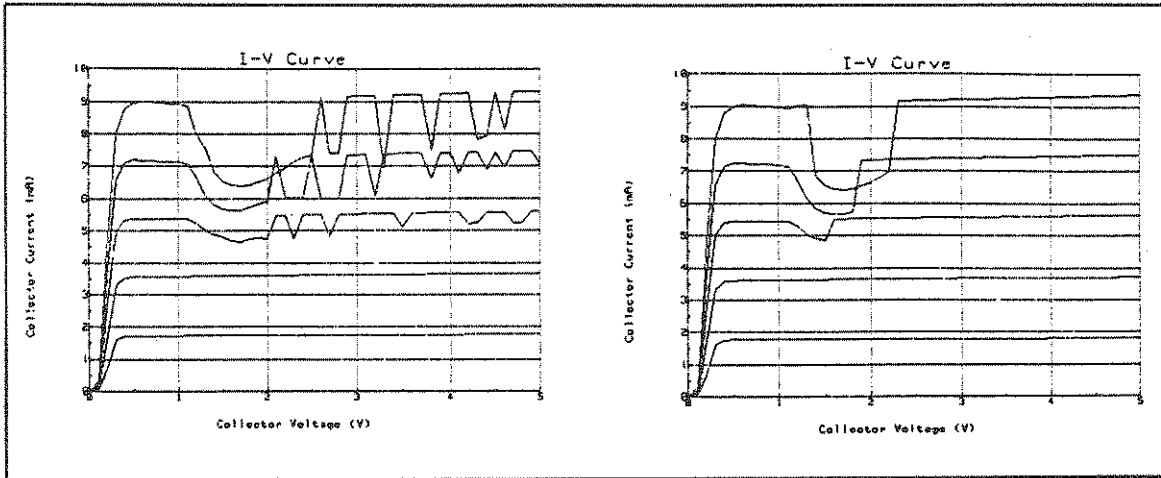
Example of an Oscillating Test Device Output I-V Curves

To prevent test device oscillation, install a ferrite bead (part number 9170-0029) to the test device leads as shown in the following figure.

Install the ferrite bead as close as possible to the test device. You may need to install more than one bead or change to a bead with a different diameter to prevent oscillation. Installing the ferrite bead to the base lead of bipolar transistors and to the gate lead of FETs is generally most effective to stop oscillation.
To minimize leakage current, do not short the ferrite beads to the case of the device, to other leads, or to the ferrite beads of other lines.
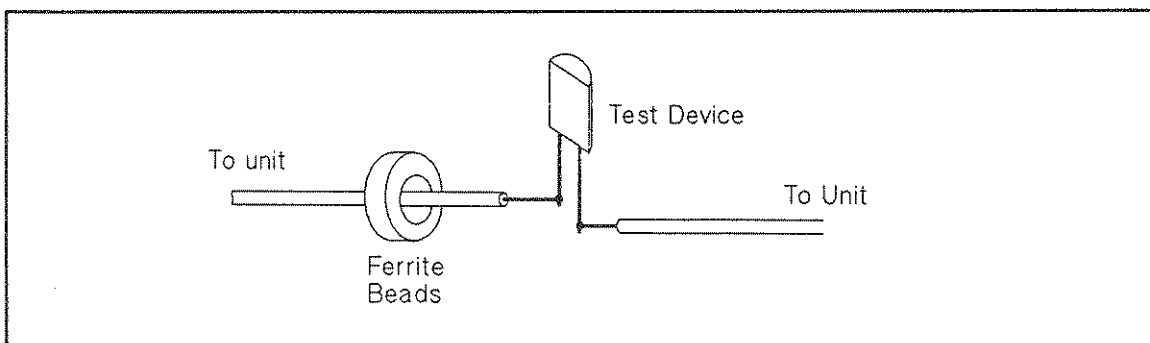
Preventing Test Device Oscillation

Below are more suggestions to stop oscillation:
- Shorten the length of the connection cable.
- Enclose the test device with a shielding box.
- For the SMU, surround the FORCE and SENSE lines by GUARD.

This type of oscillation (more than 3 MHz) does not come from the source and monitor units. It comes from a combination of the test device and stray parameters around the test device. Oscillation of 5 MHz or more cannot be detected by the SMU.

NOTES

CHAPTER 4

MEASUREMENT MODES

CONTENTS

NOTES

INTRODUCTION

This chapter explains all nine measurement modes of the HP 4142B. Included in the description of each measurement mode are measurement method, allowable units, allowable number of source and measurement channels, HP-IB commands, and a sample program.

SPOT MEASUREMENTS

Spot measurements are performed as follows: up to 16 sources force constant voltages and currents and up to 8 monitors measure the outputs. The **DV** and **DI** commands set *output voltage* and *output current*. When using an SMU as a voltage monitor, set the *output current* of the unit to 0 A using the **DI** command. The following table and figure show HP 4142B spot measurement specifics, and an example spot measurement using two channels, respectively.

Spot Measurement Specifics

Output Mode	No. of Source Ch.	Source Mode	Source Setup Command	Allowable Units	Allowable Monitor Mode	Meas. Setup Command	No. of Meas. Ch.
Constant	0¹ to 16	V	DV	HPSMU MPSMU	I	MM	1 to 8
				VS	---		
		I	DI	HPSMU MPSMU	V		
No Output	---	---	---	VM	V DIF. V	MM VM	

¹ When using a VM to make an measurement only.

```
                Output Voltage
                  or Current
                              Settling Time
  Specified ┤                  ┌─────────────────────── Ch#1
    Value    │                 │
  Previous   │                 │
    Value    │_____│      ┌──── Measurement Time ────┐
             │                        
  Specified ┤                    ┌─────────────────────── Ch#2
    Value    │                   │
  Previous   │                   │
    Value    │_____│
             └──────────────────────────────────────── Time
                    ↑      ↑        ↑     ↑
                    DV     DV    Trigger  │
                    /DI    /DI        Completion
```
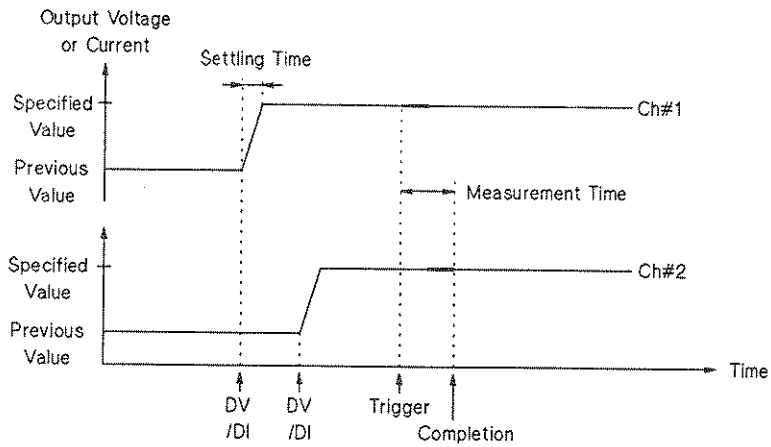
1) When the HP 4142B receives a **DV** or **DI** command, the source unit forces the *output voltage* or *current*.

2) When the HP 4142B receives a trigger, the measurement starts. When using more than one channel, measurements are performed in the order specified in the **MM** command. If the trigger is received during the settling time of the source unit, the measurement is performed after the settling time.

3) After the measurement is complete, the source unit continues to force the *output voltage* or *current*.

Spot Measurement Using Two Channels

Commands and Parameters

The following table lists the commands and parameters for spot measurements.

Spot Measurement Commands and Parameters

Function	Command [1]	Parameters [1]
Constant V Source	DV	*ch#, output range, output voltage,* [*I compliance*], [*compliance polarity mode*]
Constant I Source	DI	*ch#, output range, output current,* [*V compliance*], [*compliance polarity mode*]
Measurement	MM	*measurement mode, ch#*
	[RI]	*ch#, I measurement range*
	[RV]	*ch#, V measurement range*
	[VM]	*ch#, VM operation mode*
	[AV]	*number,* [*averaging mode*]
Trigger	XE	-----

[1] Brackets ([   ]) denote optional commands and parameters.

Information

Measurement Data Output Format is explained in the *HP 4142B HP-IB Command Reference Manual*.

Output and Measurement Ranging Mode and **Averaging** are explained in chapter 5.

Spot Measurement Sample Program

The following is a sample program that measures collector saturation voltage (Vce(sat)) and base saturation voltage (Vbe(sat)) of a 2N3904 bipolar transistor by using the spot measurement function. A description of key program lines follows the program list.

Measurement Conditions

DUT Terminal	Unit	Output	Measurement
Base Collector Emitter	SMU Ch#3 SMU Ch#2 GNDU	Ib = 1 mA Ic = 10 mA Ve = 0 V	Vbe Vce ---

Program List

```
10    ! Vce(sat) and Vbe(sat) Measurement using Spot Function
20    !
30    INTEGER B_ch, C_ch
40    DIM A$[31]
50    ASSIGN @Hp4142 TO 717
60    OUTPUT @Hp4142;"*RST"
70    !                                    Emitter    : GNDU
80    B_ch=3                            !  Base       : Ch#3
90    C_ch=2                            !  Collector  : Ch#2
100   Ib=1.E-3
110   Ic=1.E-2
120   !
130   OUTPUT @Hp4142;"CN";B_ch, C_ch
140   OUTPUT @Hp4142;"DI";B_ch, 0, Ib, 2
150   OUTPUT @Hp4142;"DI";C_ch, 0, Ic, 2
160   OUTPUT @Hp4142;"MM";1, C_ch, B_ch
170   OUTPUT @Hp4142;"XE"
180   OUTPUT @Hp4142;"CL"
190   !
200   ENTER @Hp4142;A$
210   PRINT "Vce(sat)= ";A$[4, 15];"[V]"
220   PRINT "Vbe(sat)= ";A$[20, 31];"[V]"
230   END
```

Result

```
Vce(sat)= +0.06764E+00[V]
Vbe(sat)= +0.74692E+00[V]
```
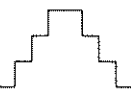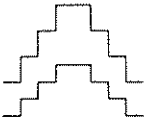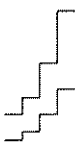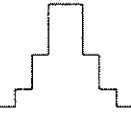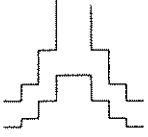
Description

40	Defines the string variable, $A\$$, for storing measurement data.
60	Initializes the HP 4142B.
130	Sets the SMU output switches to ON.
140	Forces 1 mA to the base.
150	Forces 10 mA to the collector
160	Sets the spot measurement mode and the measurement channels.
170	Sends a trigger to start the measurement.
180	Sets the SMU output switches to OFF.
200	Enters the measurement data into the string variable, $A\$$.
210-220	Displays the measurement results.

STAIRCASE SWEEP MEASUREMENTS

Staircase sweep measurements are performed as follows: one source sweeps constant voltage or current, while up to 8 monitors measure the output for each sweep step. Or two sources sweep constant voltages or currents at the same time, while up to 8 monitors measure the outputs for each sweep step. Measurement data for each sweep step is stored in the output data buffer. The following table lists the staircase sweep measurement modes and provides an illustration of each.

Staircase Sweep Measurement Modes

Sweep Mode	Output Waveform	
	1 Channel Sweep	2 Channel Synchronous Sweep[1]
Linear Single Staircase Sweep		
Linear Double Staircase Sweep		
Log Single Staircase Sweep		
Log Double Staircase Sweep		

[1] To perform sweep measurements using two sweep source channels, both source channels must be set to the same source mode (V source or I source).

The following table and figure show HP 4142B staircase sweep measurement specifics, and an example of a linear single staircase sweep measurement, respectively.

Staircase Sweep Measurement Specifics

Output Mode	No. of Source Ch.	Source Mode	Source Setup Command	Allowable Units	Allowable Monitor Mode	Meas. Setup Command	No. of Meas. Ch.
Staircase Sweep	1 to 2 [1]	V	1ch: **WV** 2ch: **WV** **WSV**	HPSMU MPSMU	I	MM	1 to 8
				VS	---		
		I	1ch: **WI** 2ch: **WI** **WSI**	HPSMU MPSMU	V		
Constant	0 to 15	V	**DV**	HPSMU MPSMU	I		
				VS	---		
		I	**DI**	HPSMU MPSMU	V		
No Output	---	---	---	VM	V DIF. V	MM VM	

[1] To perform sweep measurements using two sweep source channels, both source channels must be set to the same source mode (V source or I source).

Output Voltage
or Current

Ts : Settling Time
Th : Hold Time
Td : Delay Time
Tm : Measurement Time
N : No. of Steps

Stop Value

Th+Td Tm Td

Ts

N

3

2

Previous Value

Start Value

1

Time

Trigger

Completion

1) When the HP 4142B receives a trigger, the sweep source forces the *start* value.
2) The HP 4142B waits the specified *hold time* and *delay time*.
3) The measurement unit measures voltage or current. For multi-channel measurements, measurements are performed in the order set by the **MM** command.
4) The sweep source forces the next step value.
5) The measurement unit measures voltage or current after the *delay time*.
6) Steps 4 and 5 repeat until the specified *stop* value is reached.
7) When the measurement finishes, the HP 4142B forces the *start* (default value) or *stop* value, as specified by the **WM** command.

Linear Single Staircase Sweep Measurement

If you specify a *hold time* or *delay time* that is less than the settling time of the source unit, *hold time* or *delay time* is set to equal the settling time.

For linear staircase sweep, output values are calculated using the following equation.

kth output value = *start* value + $(k-1)$(step value)

where step value = (*stop* value - *start* value)/(*number of steps* - 1)

For log staircase sweep, output values are calculated using the following equation. *Start* and *stop* values must have the same polarity, and must not be zero.

kth output value = (*start* value)(step value)$^{(k-1)}$

where step value = EXP[(ln(*stop* value/*start* value))/(*number of steps* - 1)]

The following figure shows an example of a linear double staircase sweep measurement. The sweep source output is swept from the *start* value to the *stop* value, then from the *stop* value to the *start* value. The number of sweep steps is determined by the *number of steps* specified between the *start* and *stop* values. The measurement sequence is the same as a single staircase sweep. You can use the **WM** command to set the value (*start* or *stop* value) that is forced after the measurement is complete.
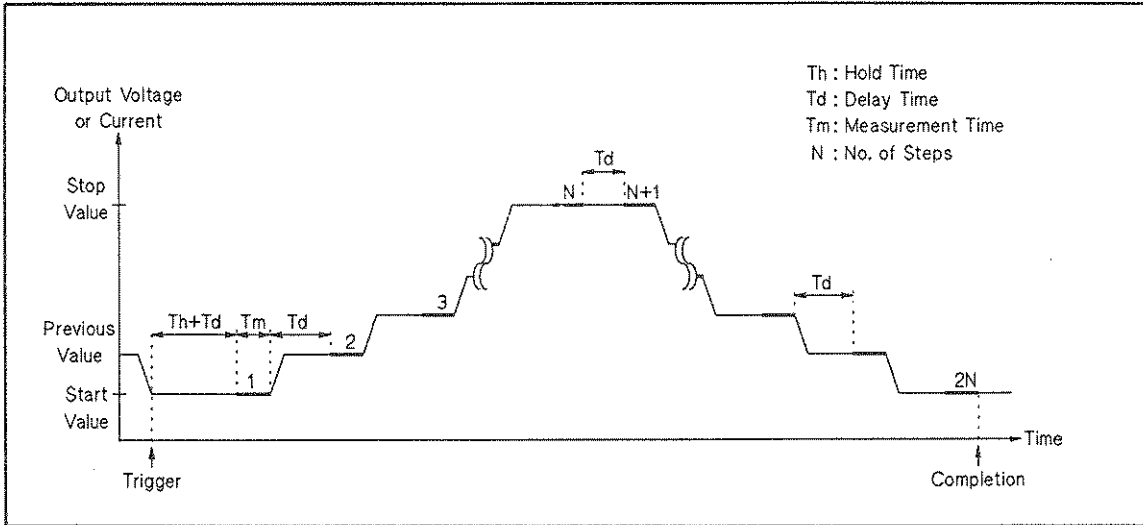
Linear Double Staircase Sweep Measurement

Commands and Parameters

The following table lists the commands and parameters for staircase sweep measurements. To perform a synchronous sweep measurement, set the main sweep source using the **WV** or **WI** commands, and set the synchronous sweep source using the **WSV** or **WSI** commands. Both sweep sources must be set to the same source mode (V source or I source).

Staircase Sweep Measurement Commands and Parameters

Function	Command [1]	Parameters [1]
Sweep V Source	WV	*ch#, sweep mode, output range, start voltage, stop voltage, number of steps, [I compliance], [power compliance]*
Sweep I Source	WI	*ch#, sweep mode, output range, start current, stop current, number of steps, [V compliance], [power compliance]*
Synchronous Sweep V Source	WSV	*ch#, output range, start voltage, stop voltage, [I compliance], [power compliance]*
Synchronous Sweep I Source	WSI	*ch#, output range, start current, stop current, [V compliance], [power compliance]*
Sweep Conditions	[WT]	*hold time, delay time*
	[WM]	*automatic sweep abort function, [output after sweep]*
Constant Source	DV	*ch#, output range, output voltage, [I compliance], [compliance polarity mode]*
	DI	*ch#, output range, output current, [V compliance], [compliance polarity mode]*
Measurement	MM	*measurement mode, ch#*
	[RI]	*ch#, I measurement range*
	[RV]	*ch#, V measurement range*
	[VM]	*ch#, VM operation mode*
	[AV]	*number, [averaging mode]*
Trigger	XE	-----
Abort	AB	-----

[1] Brackets ([ ]) denote optional commands and parameters.

Information

Measurement Data Output Format is explained in the *HP 4142B HP-IB Command Reference Manual*.

Output and **Measurement Ranging Mode, Averaging, Automatic Sweep Abort Function,** and **Power Compliance** are explained in chapter 5.

Staircase Sweep Measurement Sample Program

The following is a sample program that measures static collector characteristics of a 2N3904 npn bipolar transistor by using the HP 4142B staircase sweep measurement function. This program sweeps the collector voltage while holding the base current constant, then changes the base current as a second variable. The program executes the real-time sweep measurement that plots the measurement result whenever the measurement at each sweep step is performed. A description of key program lines follows the program list, along with an example graphics display of measurement results.

This sample program minimizes range changes to optimize measurement speed.

Measurement Conditions

DUT Terminal	Unit	Output	Measurement
Base	SMU Ch#3	Ib = 10 µ, 20 µ, 30 µA	---
Collector	SMU Ch#2	Vc = 0 to 1 V, 101 steps	Ic
Emitter	GNDU	Ve = 0 V	---

Program List

```
10      ! Ic-Vce Measurement using Staircase Sweep Function
20      !
30      OPTION BASE 1
40      INTEGER B_ch, C_ch, Vc_no_step, Ib_no_step, Var1, Var2
50      REAL Vc(101)
60      ASSIGN @Hp4142 TO 717
70      OUTPUT @Hp4142;"*RST"
80      OUTPUT @Hp4142;"FMT";S
90      !                              Emitter    : GNDU
100     B_ch=3                       ! Base       : Ch#3
110     C_ch=2                       ! Collector  : Ch#2
120     Vc_start=0
130     Vc_stop=1
140     Vc_no_step=101
150     Ic_comp=.01
160     Ib_start=1.E-5
170     Ib_step=1.E-5
180     Ib_no_step=3
190     !
```

```
200   Vc_step=(Vc_stop-Vc_start)/(Vc_no_step-1)
210   FOR Var1=1 TO Vc_no_step
220     Vc(Var1)=Vc_start+(Var1-1)*Vc_step
230   NEXT Var1
240   CALL Icvc_graph(Vc_start, Vc_stop, 0, 1.E-2)
250   !
260   OUTPUT @Hp4142;"CN";B_ch, C_ch
270   OUTPUT  @Hp4142;"WV";C_ch,  1,  0,  Vc_start,  Vc_stop,  Vc_no_step,
Ic_comp
280   OUTPUT @Hp4142;"MM";2, C_ch
290   OUTPUT @Hp4142;"RI";C_ch, 18
300   FOR Var2=1 TO Ib_no_step
310     Ib=Ib_start+(Var2-1)*Ib_step
320     OUTPUT @Hp4142;"DI";B_ch, 0, Ib, 2
330     OUTPUT @Hp4142;"XE"
340     !
350     FOR Var1=1 TO Vc_no_step
360       ENTER @Hp4142 USING "#, 3X, 2D, X";Ic
370       PLOT Vc(Var1), Ic
380     NEXT Var1
390     PENUP
400   NEXT Var2
410   OUTPUT @Hp4142;"CL"
420   END
430   !
440   SUB Icvc_graph(X_axis_min, X_axis_max, Y_axis_min, Y_axis_max)
450     !
460     GINIT
470     GRAPHICS ON
480     CONTROL CRT, 12;1
490     PRINT CHR$(12)
500     !
510     Xmax=100*MAX(1, RATIO)
520     Ymax=100*MAX(1,1/RATIO)
530     !
540     LORG 6
550     MOVE Xmax/2, Ymax
560     LABEL "COLLECTOR CHARACTERISTICS"
570     DEG
580     LDIR 90
590     CSIZE 4.5
600     MOVE 0, Ymax/2
610     LABEL "Ic(A)"
620     LORG 4
630     LDIR 0
640     MOVE Xmax/2, 0
650     LABEL "Vce(V)"
660     !
670     VIEWPORT .16*Xmax, .91*Xmax, .15*Ymax, .9*Ymax
680     !
690     FRAME
700     WINDOW X_axis_min, X_axis_max, Y_axis_min, Y_axis_max
710     AXES(X_axis_max-X_axis_min)/10,(Y_axis_max-Y_axis_min)/10,
X_axis_min, Y_axis_min
720     CLIP OFF
730     CSIZE 4, .5
740     LORG 6
```

```
750        FOR I=X_axis_min TO X_axis_max STEP (X_axis_max-X_axis_ min)/2
760          MOVE I, Y_axis_min
770          LABEL I
780        NEXT I
790        CSIZE 3.8, .5
800        LORG 8
810        FOR I=Y_axis_min TO Y_axis_max STEP (Y_axis_max-Y_axis_ min)/2
820          MOVE X_axis_min, I
830          LABEL USING "#, MD.DE";I
840        NEXT I
850        CLIP ON
860        !
870     SUBEND
```

Result
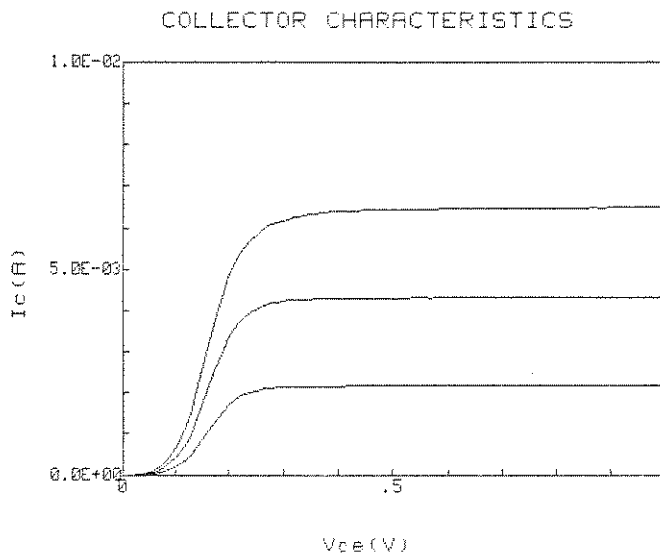
COLLECTOR CHARACTERISTICS

Description

30-50	Defines the variables.
70	Initializes the HP 4142B.
80	Sets the data output format to ASCII with header and comma (,) as a terminator.
100-180	Assigns the constants.
200-230	Calculates collector voltage value for each step, and stores these values in an array variable.
240	Calls subprogram to display graphics frame.
260	Sets the SMU output switches to ON.
270	Sets the *ch#2* SMU voltage sweep parameters.
280	Sets the measurement mode to staircase sweep function.
290	Sets the measurement range to 10 mA.
310-320	Sets the *ch#3* SMU current output parameters as a second sweep source.
330	Sends a trigger to start a voltage sweep measurement.

350-390	Enters the measurement data into the variable Ic, and displays measurement data in the graphics frame.
400	Sets the source base current to the next value.
410	Sets the SMU output switches to OFF.
440-870	Subprogram for displaying graphics frame.

1CH PULSED SPOT MEASUREMENTS

1 Channel Pulsed spot measurements are performed as follows: one source forces pulsed voltage or current, and one monitor measures the output. The following table lists HP 4142B pulsed spot measurement specifics. The following two figures show an example of a typical pulsed spot measurement (when *pulse period* is not specified), and an example of a repeated pulsed spot measurement (when *pulse period* is specified), respectively.

Pulsed Spot Measurement Specifics

Output Mode	No. of Source Ch.	Source Mode	Source Setup Command	Allowable Units	Allowable Monitor Mode	Meas. Setup Command	No. of Meas. Ch.
Pulse	1	V	PV	HPSMU MPSMU HCU	I	MM	1
				VS	---		
		I	PI	HPSMU MPSMU HCU	V		
Constant	0 to 15	V	DV	HPSMU MPSMU	I		
				VS	---		
		I	DI	HPSMU MPSMU	V		
No Output	---	---	---	VM	V [1]		

[1] Differential voltage measurements cannot be performed for pulsed measurements.

1) When the HP 4142B receives a trigger, the pulse source forces the *base* value.
2) The HP 4142B waits for the specified *hold time*. If the *hold time* is less than the settling time of the source unit, *hold time* is set equal to the settling time.
3) The pulse source forces the *pulse* value.
4) The measurement unit measures V or I before the end of pulse.
5) The pulse source forces the *base* value.

Pulsed Spot Measurement

Output Voltage
or Current

Th : Hold Time
Tp : Pulse Period
W : Pulse Width
Tm : Measurement Time

Th   Tp   Tp   Tp

W   W   W

Pulse Value3

Tm

Pulse Value2
Pulse Value1

Base Value

Previous Value

Time

Trigger   PV/PI   Trigger   PV/PI   Trigger   Completion
                 (Pulse Value2)   (Pulse Value3)

1) For the first pulse, the HP 4142B performs steps 1 through 5 in the previous figure.
2) The HP 4142B receives the next pulse settings. If these pulse settings are not received, the first pulse settings apply.
3) The HP 4142B receives a trigger.
4) After the first *pulse period* (Tp), the pulse source forces the next pulse.
5) The measurement unit measures V or I before the end of the pulse.
6) Steps 2 through 5 repeat for the remaining pulses.
7) If the HP 4142B does not receive a trigger for a succeeding pulse within the specified *pulse period*, the HP 4142B considers the measurement finished. To perform repeated pulse measurements at constant intervals, the following condition must be satisfied.

hold time < pulse period - pulse width

Repeated Pulsed Spot Measurement

NOTE

When using an SMU as a pulse source, set the Filter to OFF (Filters set to ON at power on) with the **FL** command.

The HP 4142B can receive and execute commands during the *base* value output of pulsed spot measurements with *pulse period*, but other types of measurements cannot be performed until the pulsed spot measurement is complete.

For SMU current pulses, the *pulse current* and *base current* values must have the same polarity.

For HCU voltage pulses, the base voltage can be specified only as 0 V. For HCU current pulses, during HCU base value output, the HCU output is 0 V and no current.

Commands and Parameters

The following table lists the commands and parameters for 1ch pulsed spot measurements. To specify a voltage pulse source, use the **PV** command. To specify a current pulse source, use the **PI** command.

1ch Pulsed Spot Measurement Commands and Parameters

Function	Command[1]	Parameters[1]
Pulsed Source[2]	PV	*ch#, output range, base voltage, pulse voltage,* [*I compliance*]
	PI	*ch#, output range, base current, pulse current,* [*V compliance*]
	[FL]	*filter,* [*ch#*]
Pulse Conditions	[PT]	*hold time, pulse width,* [*pulse period*]
Constant Source	DV	*ch#, output range, output voltage,* [*I compliance*], [*compliance polarity mode*]
	DI	*ch#, output range, output current,* [*V compliance*], [*compliance polarity mode*]
Measurement	MM	*measurement mode,* [*ch#*]
	[RI]	*ch#, I measurement range*
	[RV]	*ch#, V measurement range*
Trigger	XE	-----
Abort	AB	-----

[1] Brackets ([ ]) denote optional commands and parameters.
[2] When using SMUs, set Filter to OFF.

Information

Measurement Data Output Format is explained in the *HP 4142B HP-IB Command Reference Manual*.

Output and Measurement Ranging Mode and **Filter** are explained in chapter 5.

1ch Pulsed Spot Measurement Sample Program

The following is the sample program for measuring the collector saturation voltage (Vce(sat)) of a 2N3904 npn bipolar transistor by using the 1ch pulsed spot measurement function. A description of key program lines follows the program list.

Measurement Conditions

DUT Terminal	Unit	Output	Measurement
Base	SMU Ch#3	Ib = 5 mA	---
Collector	SMU Ch#2	Ic = 50 mA	Vce
Emitter	GNDU	Ve = 0 V	---

Program List

```
10    ! Vce(sat) Measurement using 1ch Pulsed Spot Function
20    !
30    INTEGER B_ch, C_ch
40    DIM A$[15]
50    ASSIGN @Hp4142 TO 717
60    OUTPUT @Hp4142;"*RST"
70    !                                    Emitter    :  GNDU
80    B_ch=3                            !  Base       :  Ch#3
90    C_ch=2                            !  Collector  :  Ch#2
100   Ib=5.E-3
110   Ic=5.E-2
120   !
130   OUTPUT @Hp4142;"CN";B_ch, C_ch
140   OUTPUT @Hp4142;"FL";0, B_ch
150   OUTPUT @Hp4142;"PI";B_ch, 0, 0, Ib, 2
160   OUTPUT @Hp4142;"PT";0, 1.E-3
170   OUTPUT @Hp4142;"DI";C_ch, 0, Ic, 2
180   OUTPUT @Hp4142;"MM";3, C_ch
190   OUTPUT @Hp4142;"XE"
200   OUTPUT @Hp4142;"CL"
210   !
220   ENTER @Hp4142;A$
230   PRINT "Vce(sat)= ";A$[4, 15]
240   END
```

Result

Vce(sat)= +0.10800E+00
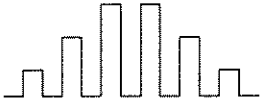
Description

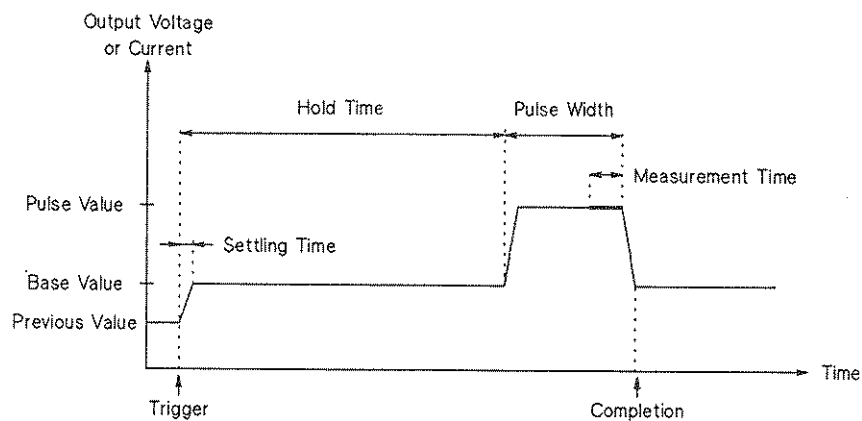|	
60	Initializes the HP 4142B.
80-110	Assigns the constants.
130	Sets the SMU output switches to ON.
140	Sets the SMU Filter to OFF.
150	Sets the *ch#3* SMU current pulse parameters.
160	Sets the output pulse waveform.
170	Forces 50 mA to the collector.
180	Sets the measurement mode to 1ch pulsed spot function.
190	Sends a trigger to start the measurement.
200	Sets the SMU output switches to OFF.
220	Enters the measurement data into the string variable, $A\$$.
230	Displays the measurement results.

PULSED SWEEP MEASUREMENTS

Pulsed sweep measurements are performed as follows: one source sweeps pulsed voltage or current, while one monitor measures the output for each sweep step. Measurement data for each pulse sweep step is stored in the output data buffer. The following two tables list the pulsed sweep measurement modes and provide an illustration of each, and list the HP 4142B pulsed sweep measurement specifics, respectively.

Pulsed Sweep Measurement Modes

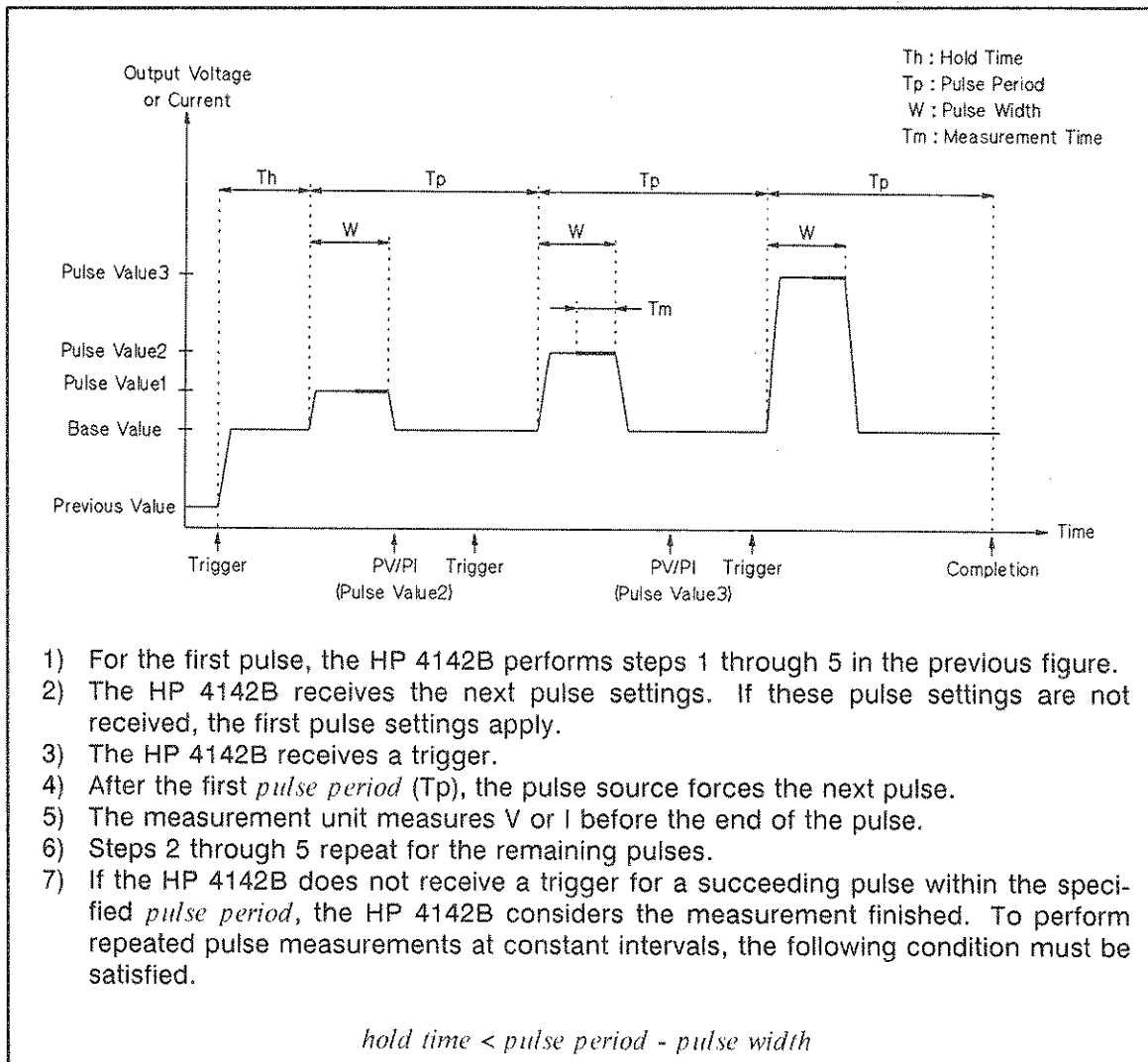| Sweep Mode	Output Waveform
Single Pulsed Sweep	
Double Pulsed Sweep	

Pulsed Sweep Measurement Specifics

Output Mode	No. of Source Ch.	Source Mode	Source Setup Command	Allowable Units	Allowable Monitor Mode	Meas. Setup Command	No. of Meas. Ch.
Pulsed Sweep	1	V	PWV	HPSMU MPSMU HCU	I	MM	1
				VS	---		
		I	PWI	HPSMU MPSMU HCU	V		
Constant	0 to 15	V	DV	HPSMU MPSMU	I		
				VS	---		
		I	DI	HPSMU MPSMU	V		
No Output	---	---	---	VM	V [1]		

[1] Differential voltage measurements cannot be performed for pulsed measurements.

The following figure shows an example of a pulsed single sweep measurement.

1) When the HP 4142B receives a trigger, the pulse source forces the *base* value.
2) The HP 4142B waits the specified *hold time*. If the *hold time* is less than the settling time of the source unit, *hold time* is set to equal settling time.
3) The pulse source forces the *start pulse* value.
4) The measurement unit measures V or I before the end of the pulse.
5) The pulse source forces the *base* value.
6) The pulse source forces the next pulse after the specified *pulse period* (Tp).
7) The measurement unit measures V or I before the end of the pulse.
8) The pulse source forces the *base* value.
9) Steps 6 through 8 repeat until the *stop pulse* value is reached.

Pulsed Single Sweep Measurement

The *k*th pulse value is calculated using the following equation.

*k*th pulse value = *start pulse* value + (*k*-1)(step value)

where step value = (*stop pulse* value - *start pulse* value)/(*number of steps* - 1)

The following figure shows an example of a pulsed double sweep measurement. Pulse sweep source output is swept from *start pulse* to *stop pulse* value, then from *stop pulse* to *start pulse*, as shown. The measurement sequence is the same as a pulsed single sweep measurement.
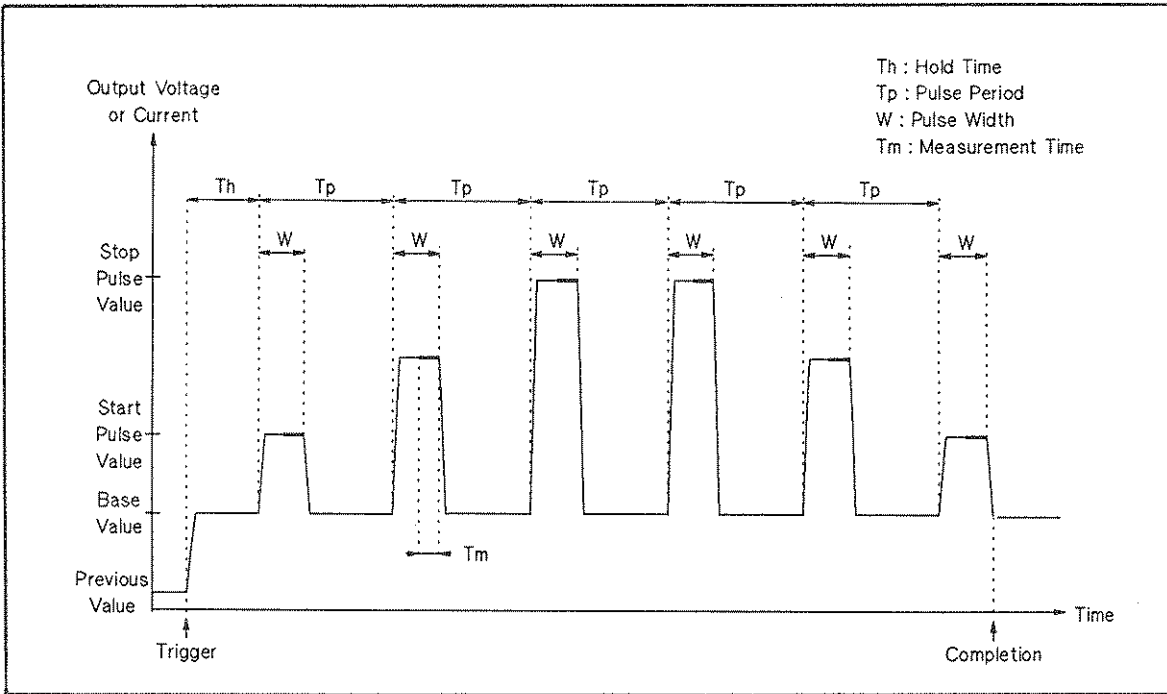
Th : Hold Time
Tp : Pulse Period
W : Pulse Width
Tm : Measurement Time

Output Voltage or Current

Th   Tp   Tp   Tp   Tp   Tp

W   W   W   W   W   W

Stop Pulse Value

Start Pulse Value

Base Value

Previous Value

Tm

Time

Trigger

Completion

Pulsed Double Sweep Measurement

NOTE

When using an SMU as a pulse source, set the Filter to OFF (SMU Filters set to ON at power-on) by using FL command.

If you set *start pulse* value = *stop pulse* value, all pulses are the same height.

For current pulse sweep measurements, *base*, *start pulse*, and *stop pulse* values must have the same polarity.

For HCU voltage pulses, the base voltage can be specified only as 0 V. For HCU current pulses, while the HCU output is a base value, the HCU output is 0 V and no current.

Commands and Parameters

The following table lists the commands and parameters for pulsed sweep measurements. To specify a voltage pulse sweep source, use the **PWV** command. To specify a current pulse sweep source, use the **PWI** command.

Pulsed Sweep Measurement Commands and Parameters

Function	Command [1]	Parameters [1]
Pulsed Sweep Source [2]	**PWV**	*ch#, sweep mode, output range, base voltage, start pulse voltage, stop pulse voltage, number of steps, [I compliance]*
	PWI	*ch#, sweep mode, output range, base current, start pulse current, stop pulse current, number of steps, [V compliance]*
	[FL]	*filter, [ch#]*
Pulse Conditions	**[PT]**	*hold time, pulse width, [pulse period]*
Sweep Conditions	**[WM]**	*automatic sweep abort function*
Constant Source	**DV**	*ch#, output range, output voltage, [I compliance], [compliance polarity mode]*
	DI	*ch#, output range, output current, [V compliance], [compliance polarity mode]*
Measurement	**MM**	*measurement mode, ch#*
	[RI]	*ch#, I measurement range*
	[RV]	*ch#, V measurement range*
Trigger	**XE**	-----
Abort	**AB**	-----

[1] Brackets ([   ]) denote optional commands and parameters.
[2] To use an SMU as a pulsed sweep source, set the Filter to OFF.

4-25

Information

Measurement Data Output Format is explained in the *HP 4142B HP-IB Command Reference Manual*.

Output and Measurement Ranging Mode, Automatic Sweep Abort Function, and Filter are explained in chapter 5.

Pulsed Sweep Measurement Sample Program

The following is a sample program that measures the forward characteristics of a pn junction diode by using the pulsed sweep measurement function. A description of key program lines follows the program list.

Measurement Conditions

DUT Terminal	Unit	Output	Measurement
Cathode	SMU Ch#2	Vf = 0 to 0.9 V	If
Anode	GNDU	0 V	---

Program List

```
10     ! Diode If-Vf Measurement using Pulsed Sweep Function
20     !
30     INTEGER A_ch, No_step, Var1
40     ASSIGN @Hp4142 TO 717
50     OUTPUT @Hp4142;"*RST"
60     OUTPUT @Hp4142;"FMT";5
70     !                               ! Cathode : GNDU
80     A_ch=2                          ! Anode   : Ch#2
90     Pv_start=0
100    Pv_stop=.9
110    No_step=91
120    If_comp=.1
130    !
140    CALL Ifvf_graph(Pv_start, 1, 0, If_comp)
150    Pv_step=(Pv_stop-Pv_start)/(No_step-1)
160    !
170    OUTPUT @Hp4142;"CN";A_ch
180    OUTPUT @Hp4142;"FL";0, A_ch
190    OUTPUT @Hp4142;"PWV";A_ch, 1, 0, 0, Pv_start, Pv_stop, No_step,
If_comp
200    OUTPUT @Hp4142;"PT";0, 1.E-3, 1.E-2
210    OUTPUT @Hp4142;"MM";4, A_ch
220    OUTPUT @Hp4142;"RI";A_ch, -19
230    OUTPUT @Hp4142;"XE"
240    OUTPUT @Hp4142;"CL"
250    !
```

```
260    FOR Var1=1 TO No_step
270       ENTER @HP4142 USING "#, 3X, 12D, X";If
280       Vf=Pv_start+(Var1-1)*Pv_step
290       PLOT Vf, If
300    NEXT Var1
310    PENUP
320    END
330    !
340    SUB Ifvf_graph(X_axis_min, X_axis_max, Y_axis_min, Y_axis_max)
350       !
360       GINIT
370       GRAPHICS ON
380       CONTROL CRT, 12;1
390       PRINT CHR$(12)
400       !
410       Xmax=100*MAX(1, RATIO)
420       Ymax=100*MAX(1, 1/RATIO)
430       !
440       LORG 6
450       MOVE Xmax/2, Ymax
460       LABEL "If-Vf Curve"
470       DEG
480       LDIR 90
490       CSIZE 4.5
500       MOVE 0, Ymax/2
510       LABEL "If(A)"
520       LORG 4
530       LDIR 0
540       MOVE Xmax/2, 0
550       LABEL "Vf(V)"
560       !
570       VIEWPORT .16*Xmax, .91*Xmax, .15*Ymax, .9*Ymax
580       !
590       FRAME
600       WINDOW X_axis_min, X_axis_max, Y_axis_min, Y_axis_max
610       AXES(X_axis_max-X_axis_min)/10.,(Y_axis_max-Y_axis_min)/10.,
X_axis_min, Y_axis_min
620       CLIP OFF
630       CSIZE 4, .5
640       LORG 6
650       FOR I=X_axis_min TO X_axis_max STEP (X_axis_max-X_axis_min)/2
660          MOVE I, Y_axis_min
670          LABEL I
680       NEXT I
690       CSIZE 3.8, .5
700       LORG 8
710       FOR I=Y_axis_min TO Y_axis_max STEP (Y_axis_max-Y_axis_min)/2
720          MOVE X_axis_min, I
730          LABEL USING "#, MD.DE";I
740       NEXT I
750       CLIP ON
760       !
770    SUBEND
```

Result

If–Vf Curve
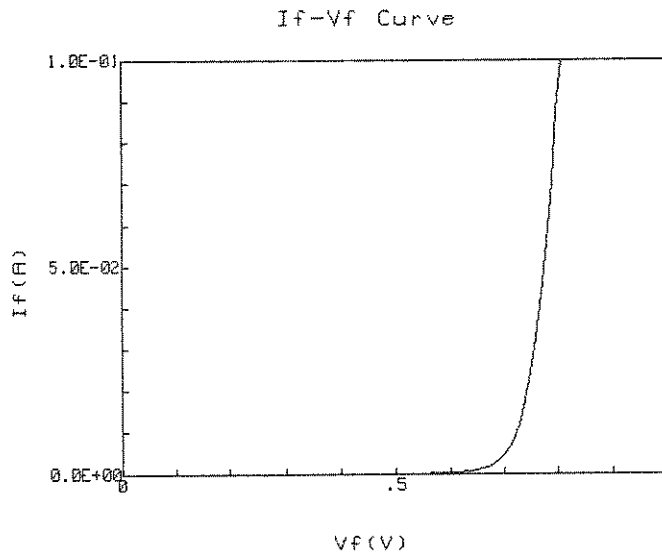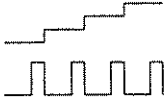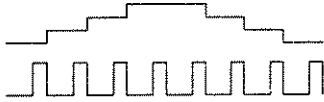
Description

30	Defines the variables.
50	Initializes the HP 4142B.
60	Sets the data output format to ASCII with header and comma (,) as a terminator.
80-120	Assigns the constants.
140	Calls subprogram to display graphics frame.
150	Calculates the pulse sweep step value.
170	Sets the SMU output switch to ON.
180	Sets the SMU Filter to OFF.
190	Sets the *ch#2* SMU voltage pulse sweep parameters.
200	Sets the output pulse sweep waveform.
210	Sets the measurement mode to pulsed sweep function.
220	Sets the current measurement range to 100 mA.
230	Sends a trigger to start measurement.
240	Sets the SMU output switch to OFF.
260-310	Enters the measurement data into variable *If*, and displays measurement data in the graphics frame.
340-770	Subprogram for displaying graphics frame.

STAIRCASE SWEEP WITH PULSED BIAS MEASUREMENTS

Staircase sweep with pulsed bias measurements are performed as follows: one source sweeps constant voltage or current, another source forces pulsed voltage or current with synchronized sweep output, while one monitor measures the output for each sweep step. Measurement data for each sweep step is stored in the output data buffer. The following two tables list the staircase sweep with pulsed bias measurement modes and provides an illustration of each, and HP 4142B staircase sweep with pulsed bias measurement specifics, respectively.

Staircase Sweep with Pulsed Bias Measurement Modes

Sweep Mode	Output Waveform
Linear Single Staircase Sweep with Pulsed Bias	
Linear Double Staircase Sweep with Pulsed Bias	

Staircase Sweep with Pulsed Bias Measurement Specifics

Output Mode	No. of Source Ch.	Source Mode	Source Setup Command	Allowable Units	Allowable Monitor Mode	Meas. Setup Command	No. of Meas. Ch.
Staircase Sweep	1	V	WV	HPSMU MPSMU	I	MM	1
				VS	---		
		I	WI	HPSMU MPSMU	V		
Pulse	1	V	PV	HPSMU MPSMU HCU	I		
				VS	---		
		I	PI	HPSMU MPSMU HCU	V		
Constant	0 to 14	V	DV	HPSMU MPSMU	I		
				VS	---		
		I	DI	HPSMU MPSMU	V		
No Output	---	---	---	VM	V [1]		

[1] Differential voltage measurements cannot be performed for pulsed measurements.

The following figure shows an example of a single staircase sweep with pulsed bias measurement.

```
                                                        Ts : Settliing Time
                                                        Th : Hold Time
        Output Voltage                                  Tp: Pulse Period
         or Current                                     W : Pulse Width
                                                        Tm: Measurement Time

                    Th        Tp          Tp          Tp

                          W           W          W           W

Pulse Value

Base Value
Previous Value
                                              Tm

Stop Value

Previous Value    Ts
Start Value
                                                                    Time

              Trigger                                Completion
```

1) When the HP 4142B receives a trigger, the pulse source forces the *base* value, and the sweep source forces the *start* value.
2) The HP 4142B waits the specified *hold time*. If the *hold time* is less than the settling time of the source unit, *hold time* is set to equal the settling time.
3) The pulse source forces the *pulse* value.
4) The measurement unit performs a measurement just before the end of the pulse.
5) The pulse source forces the *base* value, and the sweep source outputs the value of the next step.
6) The pulse source forces the next pulse value after the specified *pulse period* (Tp).
7) The measurement unit performs a measurement just before the end of the pulse.
8) Steps 5 through 7 repeat until the output reaches the *stop* value.
9) When the measurement finishes, the pulse source forces the *base* value and the sweep source forces the *start* (default value) or *stop* value, as specified.

Single Staircase Sweep with Pulsed Bias Measurement

The following figure shows an example of a double staircase sweep with pulsed bias measurement. Sweep source output is swept from *start* to *stop* value, then from *stop* to *start* value, as shown. The measurement sequence is the same as a single staircase sweep measurement.
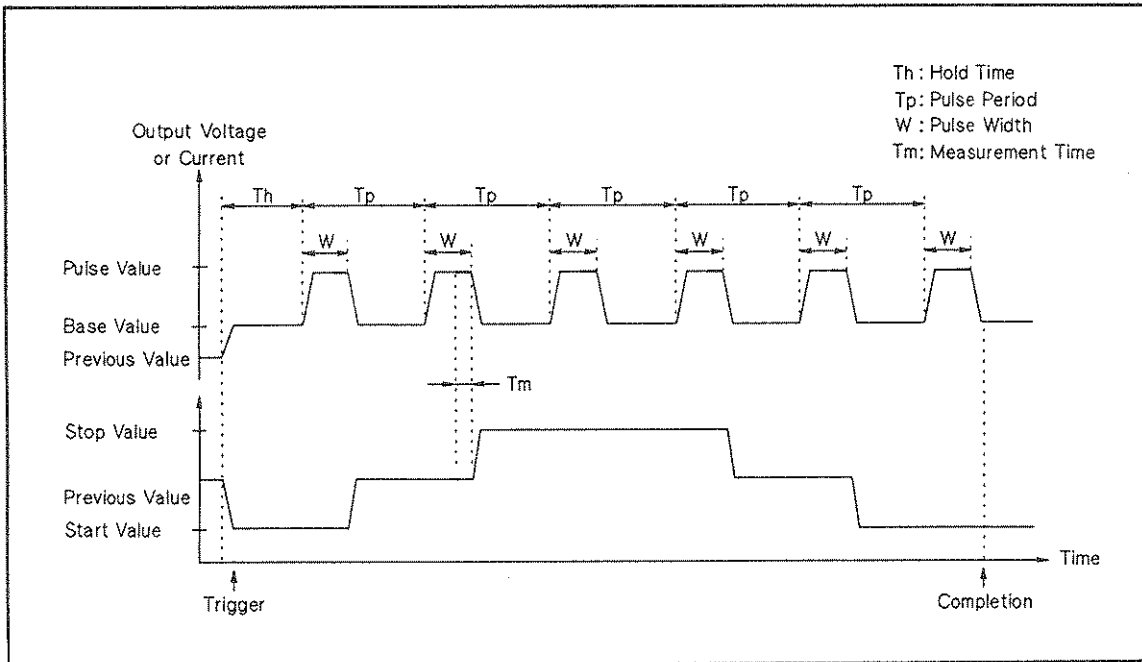
Double Staircase Sweep with Pulsed Bias Measurement

NOTE

When using an SMU as a pulse source, set the Filter to OFF (Filters set to ON at power-on) with the FL command.

For SMU current pulses, the *pulse current* and *base current* values must have the same polarity.

For HCU voltage pulses, the base voltage can be specified only as 0 V. For HCU current pulses, while the HCU output is a base value, the HCU output is 0 V and no current.

Commands and Parameters

The following table lists the commands and parameters for staircase sweep with pulsed bias measurements. To specify the staircase sweep source, use the **WV** or **WI** command. To specify the pulse source, use the **PV** or **PI** command.

Staircase Sweep with Pulsed Bias Measurement Commands and Parameters

Function	Command [1]	Parameters [1]
Voltage Sweep Source	**WV**	*ch#, sweep mode, output range, start voltage, stop voltage, number of steps, [I compliance]*
Current Sweep Source	**WI**	*ch#, sweep mode, output range, start current, stop current, number of steps, [V compliance]*
Sweep Conditions	[WM]	*automatic sweep abort function, [output after sweep]*
Pulse Source [2]	**PV**	*ch#, output range, base voltage, pulse voltage, [I compliance]*
	PI	*ch#, output range, base current, pulse current, [V compliance]*
	[FL]	*filter, [ch#]*
Pulse Conditions	[PT]	*hold time, pulse width, [pulse period]*
Constant Source	**DV**	*ch#, output range, output voltage, [I compliance], [compliance polarity mode]*
	DI	*ch#, output range, output current, [V compliance], [compliance polarity mode]*
Measurement	**MM**	*measurement mode, [ch#]*
	[RI]	*ch#, I measurement range*
	[RV]	*ch#, V measurement range*
Trigger	**XE**	-----
Abort	**AB**	-----

[1] Brackets ([   ]) denote optional commands and parameters.
[2] When using SMUs, set Filter to OFF.

Information

Measurement Data Output Format is explained in the *HP 4142B HP-IB Command Reference Manual*.

Output and **Measurement Ranging Modes**, **Automatic Sweep Abort Function**, and **Filter** are explained in chapter 5.

Staircase Sweep with Pulsed Bias Measurement Sample Program

The following is a sample program that measures the static collector characteristics of a 2N3904 bipolar transistor by using the HP 4142B staircase sweep with pulsed bias measurement function. A description of key program lines follows the program list.

Measurement Conditions

DUT Terminal	Unit	Output	Measurement
Base	SMU Ch#3	I_b = 200 μ, 300 μ, 400 μA	---
Collector	SMU Ch#2	V_c = 0 to 20 V, 101 steps	Ic
Emitter	GNDU	V_e = 0 V	---

Program List

```
10      ! Ic-Vce Measurement using Sweep with Pulsed Bias Function
20      !
30      OPTION BASE 1
40      INTEGER B_ch, C_ch, Vc_no_step, Ib_no_step, Var1, Var2
50      REAL Vc(101)
60      ASSIGN @Hp4142 TO 717
70      OUTPUT @Hp4142;"*RST"
80      OUTPUT @Hp4142;"FMT";5
90      !                                   Emitter      :  GNDU
100     B_ch=3                          !   Base         :  Ch#3
110     C_ch=2                          !   Collector    :  Ch#2
120     Vc_start=0
130     Vc_stop=20
140     Vc_no_step=101
150     Ic_comp=.1
160     Ib_start=2.E-4
170     Ib_step=1.E-4
180     Ib_no_step=3
190     !
200     Vc_step=(Vc_stop-Vc_start)/(Vc_no_step-1)
210     FOR Var1=1 TO Vc_no_step
220        Vc(Var1)=Vc_start+(Var1-1)*Vc_step
230     NEXT Var1
240     CALL Icvc_graph(Vc_start, Vc_stop, 0, Ic_comp)
250     !
260     OUTPUT @Hp4142;"CN";B_ch, C_ch
270     OUTPUT @Hp4142;"WV";C_ch, 1, 0, Vc_start, Vc_stop, Vc_no_ step,
Ic_comp
280     OUTPUT @Hp4142;"FL";0, B_ch
```

```
290    OUTPUT @Hp4142;"PT";0, 1.E-3, 5.0E-2
300    OUTPUT @Hp4142;"MM";5, C_ch
310    OUTPUT @Hp4142;"RI";C_ch, -19
320    FOR Var2=1 TO Ib_no_step
330       Ib=Ib_start+Ib_step*(Var2-1)
340       OUTPUT @Hp4142;"PI";B_ch, 0, 0, Ib, 2
350       OUTPUT @Hp4142;"XE"
360       !
370       FOR Var1=1 TO Vc_no_step
380          ENTER @Hp4142 USING "#, 3X, 12D, X";Ic
390          PLOT Vc(Var1), Ic
400       NEXT Var1
410       PENUP
420    NEXT Var2
430    OUTPUT @Hp4142;"CL"
440    END
450    !
460    SUB Icvc_graph(X_axis_min, X_axis_max, Y_axis_min, Y_axis_ max)
470       !
480       GINIT
490       GRAPHICS ON
500       CONTROL CRT, 12;1
510       PRINT CHR$(12)
520       !
530       Xmax=100*MAX(1, RATIO)
540       Ymax=100*MAX(1, 1/RATIO)
550       !
560       LORG 6
570       MOVE Xmax/2, Ymax
580       LABEL "COLLECTOR CHARACTERISTICS"
590       DEG
600       LDIR 90
610       CSIZE 4.5
620       MOVE 0, Ymax/2
630       LABEL "Ic(A)"
640       LORG 4
650       LDIR 0
660       MOVE Xmax/2, 0
670       LABEL "Vce(V)"
680       !
690       VIEWPORT .16*Xmax, .91*Xmax, .15*Ymax, .9*Ymax
700       !
710       FRAME
720       WINDOW X_axis_min, X_axis_max, Y_axis_min, Y_axis_max
730       AXES(X_axis_max-X_axis_min)/10,(Y_axis_max-Y_axis_min)/10,
X_axis_min, Y_axis_min
740       CLIP OFF
750       CSIZE 4, .5
760       LORG 6
770       FOR I=X_axis_min TO X_axis_max STEP (X_axis_max-X_axis_min)/2
780          MOVE I, Y_axis_min
790          LABEL I
800       NEXT I
810       CSIZE 3.8, .5
820       LORG 8
830       FOR I=Y_axis_min TO Y_axis_max STEP (Y_axis_max-Y_axis_ min)/2
840          MOVE X_axis_min, I
```

```
850       LABEL USING "#, MD.DE";I
860      NEXT I
870      CLIP ON
880       !
890   SUBEND
```

Result

COLLECTOR CHARACTERISTICS

Description

30-50	Defines the variables.
70	Initializes the HP 4142B.
80	Sets the data output format to ASCII with header and comma as a terminator.
100-180	Assigns the constants.
200-230	Calculates collector voltage value for each step, and stores these values in an array variable.
240	Calls subprogram to display graphics frame.
260	Sets the SMU output switches to ON.
270	Sets the $ch\#2$ SMU voltage sweep parameters.
280	Sets the SMU filter to OFF.
290	Sets the output pulse waveform.
300	Sets the measurement mode to staircase sweep with pulsed bias function.
310	Sets the current measurement range to 100 mA.
320-340	Sets the $ch\#3$ SMU current pulsed source parameters.
350	Sends a trigger to start a voltage sweep measurement.
370-410	Enters the measurement data into variable Ic, and displays measurement data in the graphics frame.
420	Sets the base current to the next value.
430	Sets the SMU output switches to OFF.
460-890	Subprogram for displaying graphics frame.

ANALOG SEARCH MEASUREMENTS

Analog search measurements are performed with the Analog Feedback Unit (AFU) and two SMUs. The AFU provides precision control between the specified SMUs via a feedback loop to obtain a previously specified *target* value. The SMUs specified for use are automatically connected internally to the AFU. The following figure shows the basic analog search measurement circuit.
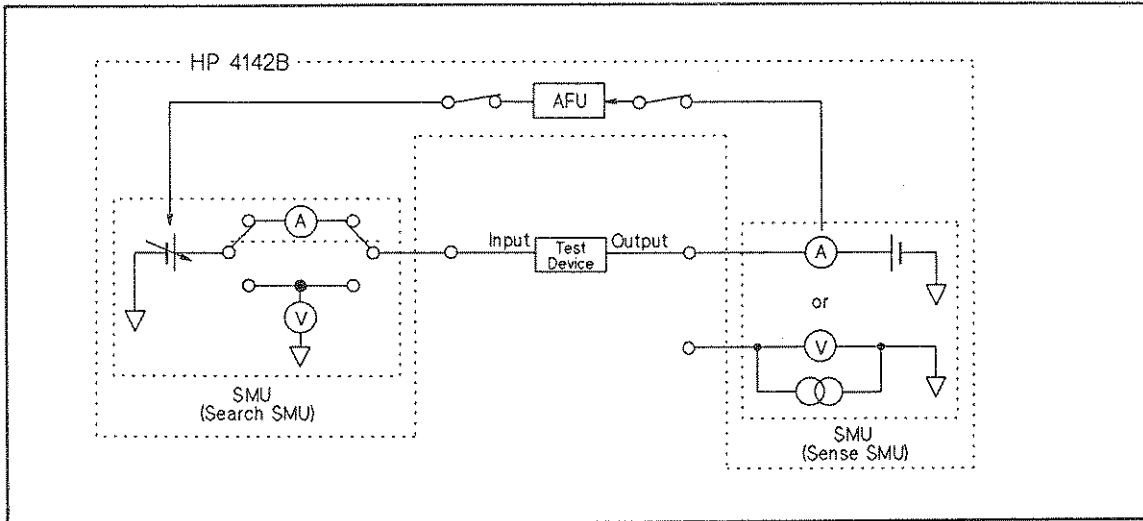
Basic Analog Search Measurement Circuit

One SMU (the search SMU) connects to the input of a test device, and sources voltage. The other SMU (the sense SMU) connects to the output of the test device, and monitors the output voltage (I source mode) or current (V source mode), depending on the specified *target* value. An error amplifier in the AFU detects the difference between the monitored test device output and the *target* value. The AFU then sends a control voltage, in proportion to the difference value, to the search SMU. This control voltage adjusts the voltage output from the search SMU to the test device, thereby adjusting test device output. This feedback process continues until the monitored test device output equals the *target* value and the specified measurements are complete.

The following figure shows the basic analog search measurement timing sequence and provides a brief description of the sequence of events.

Labels in figure:
- Search SMU Output Voltage
- Th: Hold Time
- dV/dT: Ramp Rate
- Tf: Feedback Search Time
- Td: Delay Time
- Tm: Measurement Time
- Stop Value
- Previous Value
- 0
- Start Value
- Sense SMU Output Voltage or Current
- Specified Value
- Previous Value
- Time
- Trigger
- Search Completion
- Search Measurement Completion
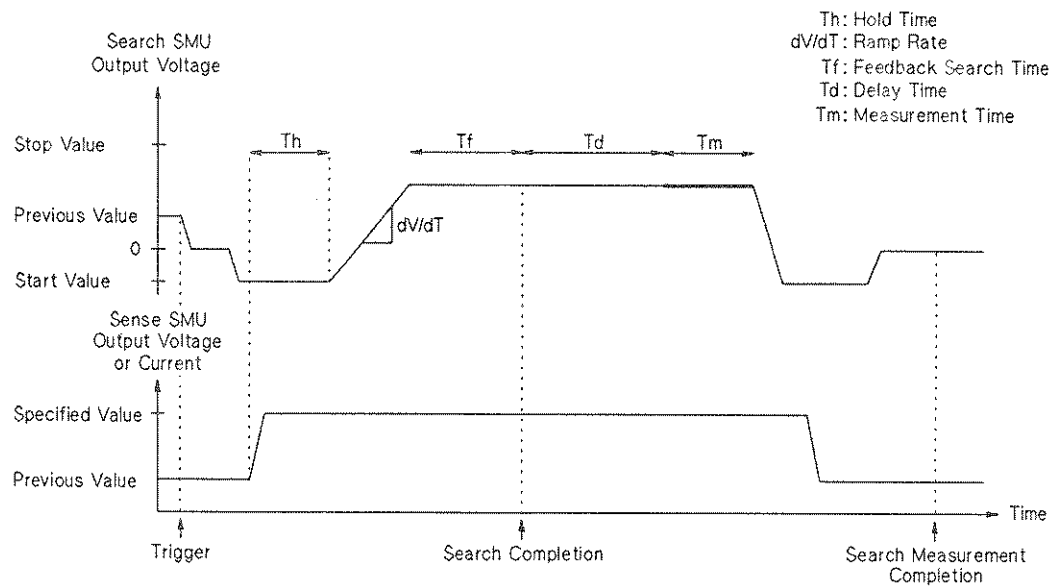
1) When the HP 4142B receives a trigger, the search SMU forces 0 V. The search and sense SMUs are then automatically connected to the AFU.

2) The AFU forces the *search start* value via the search SMU.

3) The sense SMU forces the *output* value specified in the **AIV** or **AVI** command. If the output range, *output*, and *compliance* values are the same as before the trigger, this step is not performed.

4) After the sense SMU starts to force the *output* value, the HP 4142B waits the *hold time*.

5) The AFU forces the ramp voltage with the specified *ramp rate* via the search SMU to start the search.

6) The AFU converges the output of test device (DUT) to the specified *target* value.
   For feedback searches, negative or positive feedback begins when DUT output is approximately equal to the *target* value, and continues until measurements are performed. After feedback begins, the HP 4142B waits the feedback search time Tf, and the *delay time Td*, before performing the measurements. Tf is either the *feedback integration time* or 100 μs, whichever is longer, and is valid for feedback searches only. The time constant in which the AFU converges the output is directly proportional to the *feedback integration time*. If the *feedback integration time* is set larger, the time constant becomes larger.
   For ramp searches, the HP 4142B waits the *delay time Td* after the search is complete, then performs the measurements.

7) The HP 4142B performs the measurements according to the *search measurement mode*.

8) The search SMU forces 0 V, and the sense SMU forces the same value as before the trigger. The search and sense SMUs are then automatically disconnected from the AFU.

Analog Search Measurement Sequence

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The following table lists HP 4142B analog search measurement specifics.

Analog Search Measurement Specifics

Output Mode	No. of Source Ch.	Source Mode	Source Setup Command	Allowable Units	Allowable Monitor Mode	Meas. Setup Command	No. of Meas. Ch.
Search	1	V	ASV	HPSMU MPSMU	V, I	MM ASM	1
Sense	1	V	AVI	HPSMU MPSMU	I	MM ASM	0 to 1
		I	AIV	HPSMU MPSMU	V		
Constant	0[1] to 10	V	DV	HPSMU MPSMU VS	---	---	---
		I	DI	HPSMU MPSMU	---	---	---

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Search Operation Modes

The AFU can perform four types of search operations: two feedback-type searches, and two ramp-wave-type searches. Feedback search operations are for performing highly accurate search measurements, where measurement speed is not as important. Ramp wave search operations are for performing high speed search measurements, where measurement accuracy is not as important.

These four search operation modes are described in the following paragraphs. Each paragraph number corresponds to the *search operation mode* number you must specify in your measurement program. The following table lists the four search operation modes and shows the basic input and output waveforms for each mode.

(1) Negative Feedback Search:
Use this search mode for measuring DUTs in which the inputs and outputs are directly related, i.e., a positive-going input causes a positive-going output, and a negative-going input causes a negative-going output.

As the measurement begins, the AFU forces a ramp voltage via the search SMU, and compares the *target* and DUT output values. When the *target* and DUT output values are nearly the same, a negative feedback search begins. If DUT output is greater than the *target* value, AFU output decreases, and vice versa. Feedback continues until the *target* value is reached, then the specified measurements are performed.

(2) Positive Feedback Search:
Use this search mode for measuring DUTs in which the inputs and outputs are inversely related, i.e., a positive-going input causes a negative-going output, and a negative-going input causes a positive-going output.

As the measurement begins, the AFU forces a ramp voltage via the search SMU, and compares the *target* and DUT output values. When the *target* and DUT output values are nearly the same, a positive feedback search begins. If DUT output is less than the *target* value, AFU output decreases, and vice versa. Feedback continues until the *target* value is reached, then the specified measurements are performed.
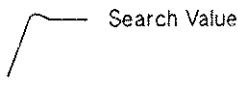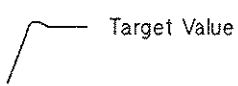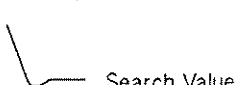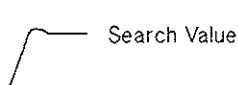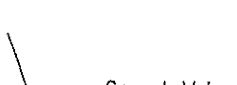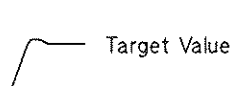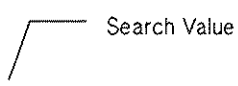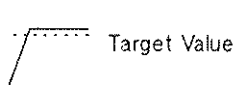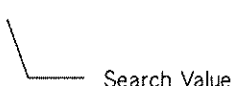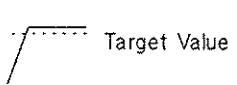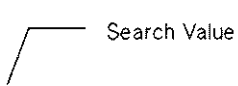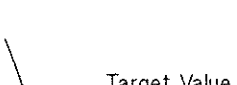
(3) Ramp Wave Search (search until DUT output > target):
The AFU forces ramp voltage to the DUT input via the search SMU. Immediately after the DUT output is greater than the *target* value, the AFU keeps the DUT input voltage constant, then performs the specified measurements.

(4) Ramp wave search (search until DUT output < target):
The AFU forces ramp voltage to the DUT input via the search SMU. Immediately after the DUT output becomes less than the *target* value, the AFU keeps the DUT input voltage constant, then performs the specified measurements.

Search Operation Modes

Search Operation Mode	DUT Input and Output Waveform	
	$\left(\dfrac{search\ start}{voltage}\right) < \left(\dfrac{search\ stop}{voltage}\right)$	$\left(\dfrac{search\ start}{voltage}\right) > \left(\dfrac{search\ stop}{voltage}\right)$
Negative Feedback Search	Input Waveform: ⎽⎽⎽ Search Value Output Waveform: ⎽⎽⎽ Target Value	Input Waveform: ⎽⎽⎽ Search Value Output Waveform: ⎽⎽⎽ Target Value
Positive Feedback Search	Input Waveform: ⎽⎽⎽ Search Value Output Waveform: ⎽⎽⎽ Target Value	Input Waveform: ⎽⎽⎽ Search Value Output Waveform: ⎽⎽⎽ Target Value
Ramp Wave Search (search until DUT output > *target*)	Input Waveform: ⎽⎽⎽ Search Value Output Waveform: ⎽⎽⎽ Target Value	Input Waveform: ⎽⎽⎽ Search Value Output Waveform: ⎽⎽⎽ Target Value
Ramp Wave Search (search until DUT output < *target*)	Input Waveform: ⎽⎽⎽ Search Value Output Waveform: ⎽⎽⎽ Target Value	Input Waveform: ⎽⎽⎽ Search Value Output Waveform: ⎽⎽⎽ Target Value

Search Measurement Modes

After the *target* value is reached, the HP 4142B performs the measurements in accordance with the measurement mode you specified. The following table lists the four measurement modes.

Search Measurement Modes

Search Measurement Mode#	Number of Measurement Channels	V or I Measurement	
		Search SMU (DUT Input)	Sense SMU (DUT Output)
1	1	V	-
2	1	I	-
3	2	V	V (if *target* value is V)
			I (if *target* value is I)
4	2	I	V (if *target* value is V)
			I (if *target* value is I)

Commands and Parameters

The following table lists the commands and parameters for analog search measurements. The search SMU is set by the **ASV** command. The sense SMU is set by **AIV** (if *target* value is voltage) or by **AVI** (if *target* value is current).

Analog Search Measurement Commands and Parameters

Function	Command [1]	Parameters [1]
Search SMU	**ASV**	*ch#, search start voltage, search stop voltage,* [*ramp rate*], [*I compliance*]
V Sense SMU	**AIV**	*ch#, output current, target voltage,* [*V compliance*]
I Sense SMU	**AVI**	*ch#, output voltage, target current,* [*I compliance*]
Search Conditions	**[ASM]**	*search operation mode, search measurement mode,* [*feedback integration time*]
	[AT]	*hold time, delay time*
Constant Source	**DV**	*ch#, output range, output voltage,* [*I compliance*], [*compliance polarity mode*]
	DI	*ch#, output range, output current,* [*V compliance*], [*compliance polarity mode*]
Measurement [2]	**MM**	*measurement mode*
	AV	*number,* [*averaging mode*]
Trigger	**XE**	---
Abort	**AB**	---

[1] Brackets ([   ]) denote optional commands and parameters.
[2] Measurement channels are specified by the *search measurement mode* parameter of the **ASM** command.

NOTE

When measuring hFE or Vth, suitable *ramp rate, feedback integration time,* and *delay time* values can be obtained by using the Control Software parameter calculation subprograms, **Para_hfe** and **Para_vth**.

AFU MONITOR Port

The AFU **MONITOR** port allows you to monitor DUT output, as monitored by the sense SMU, by providing a voltage proportional to DUT output. Maximum AFU **MONITOR** port voltage is ±8 V, as calculated using the following equations.

(1) If the target value is voltage:

AFU **MONITOR** Port V = DUT Output V/(Sense SMU V Measurement Range)(-8V)

where the sense SMU V measurement range is the lowest range that includes V *compliance*.

(2) If the target value is current:

AFU **MONITOR** Port V = DUT Output I/(Sense SMU I Measurement Range)(8V)

where sense SMU I measurement range is the lowest range that includes I *compliance*.

You can also observe DUT waveform patterns at the AFU **MONITOR** port using an oscilloscope to determine the validity of several analog search measurement parameters. The following table lists four waveform pattern symptoms and their related parameter(s). If you observe any of the waveform patterns listed in the following table, check the corresponding parameter(s).

AFU MONITOR Port Waveforms and Related Parameters

Waveform Pattern	Parameter To Check
If waveform does not settle before search starts	*hold time*
Excessive waveform overshoot at beginning of feedback search	*ramp rate*
Excessive waveform oscillation when a measurement is performed	*feedback integration time*
If waveform does not settle when a measurement is performed	*ramp rate, feedback integration time, delay time*

NOTE

If the sense current monitor range of the sense SMU is set to less than 10 μA range, no overshoot may be observed at the MONITOR port due to measurement circuit delay, even if overshoot occurs. Therefore, even if no overshoot is observed, do not set the *feedback integration time* too short or the *ramp rate* too high. The measurement circuit delay does not affect the measurement because it is corrected by the internal circuit of the AFU.

Information

Measurement Data Output Format is explained in the *HP 4142B HP-IB Command Reference Manual*.

Output and Measurement Ranging Mode, and **Averaging** are explained in chapter 5.

Analog Search Measurement Sample Program

The following figure shows a sample program that measures the hFE of a 2N3904 bipolar transistor by using the analog search measurement function. The base terminal is connected to the search SMU, and the collector terminal is connected to the sense SMU. The AFU senses the collector current via the sense SMU, and uses negative feedback to control the base voltage via the search SMU. A description of key program lines follows the program list.

Measurement Conditions

DUT Terminal	Unit	Output	Measurement
Base Collector Emitter	SMU Ch#3 SMU Ch#2 GNDU	Vb = 0 to 1 V Vc = 1 V, Ic = 1 mA Ve = 0 V	Ib Ic ---

Program List

```
10    ! hFE Measurement using Analog Search Function
20    !
30    INTEGER B_ch, C_ch
40    DIM A$[31]
50    ASSIGN @Hp4142 TO 717
60    CLEAR @Hp4142
70    !                              ! Emitter    : GNDU
80    B_ch=3                         ! Base       : Ch#3
90    C_ch=2                         ! Collector  : Ch#2
100   Vb_start=0
110   Vb_stop=1
120   Vb_rate=200
130   Ib_comp=1.15E-4
140   Vc=1
150   Ic_target=1.E-3
160   Ic_comp=1.15E-3
170   Integ_time=4.5E-4
180   Delay_time=1.E-4
190   !
200   OUTPUT @Hp4142;"CN";B_ch, C_ch
210   OUTPUT @Hp4142;"ASV";B_ch, Vb_start, Vb_stop, Vb_rate, Ib_comp
220   OUTPUT @Hp4142;"AVI";C_ch, Vc, Ic_target, Ic_comp
230   OUTPUT @Hp4142;"ASM";1, 4, Integ_time
240   OUTPUT @Hp4142;"AT";0, Delay_time
250   OUTPUT @Hp4142;"MM";6
260   OUTPUT @Hp4142;"XE"
270   OUTPUT @Hp4142;"CL"
280   !
290   ENTER @Hp4142;A$
300   Ib=VAL(A$[4, 15])
310   Ic_meas=VAL(A$[20, 31])
320   PRINT "Ib= ";Ib*1.E+6;"[uA]"
330   PRINT "Ic= ";Ic_meas*1.E+3;"[mA]"
340   Hfe=Ic_meas/Ib
350   PRINT "hFE= ";PROUND(Hfe, -2)
360   END
```

Result

```
Ib=    4.492 [uA]
Ic=    .99628 [mA]
hFE= 221.79
```

Description

40	Defines the string variable $A\$$ for storing measurement data.
60	Initializes the HP 4142B.
100-180	Assigns the constants.
200	Sets the SMU output switches to ON.
210	Sets the parameters for the search SMU.
220	Sets the parameters for the sense SMU.
230-240	Sets the parameters for the search operation and the measurement after search.
250	Sets the measurement mode to analog search measurement function.
260	Sends a trigger to start measurement.
270	Sets the SMU output switches to OFF.
290	Enters the measurement data into string variable $A\$$.
300-350	Displays the base current, collector current, and hFE.

2CH PULSED SPOT MEASUREMENTS

2 Channel Pulsed spot measurements are performed as follows: two sources force pulsed outputs at the same time, and one monitor measures the output. The following table lists 2 channel pulsed spot measurement specifics. The following two figures show an example of a typical 2 channel pulsed spot measurement (when *pulse period* is not specified), and an example of a repeated pulsed spot measurement (when *pulse period* is specified), respectively.

2ch Pulsed Spot Measurement Specifics

Output Mode	No. of Source Ch.	Source Mode	Source Setup Command	Allowable Units	Allowable Monitor Mode	Meas. Setup Command	No. of Meas. Ch.
Pulse	2	V	PDV[1] PV[1]	HPSMU[2] MPSMU[2] HCU[2]	I	MM	1
		I	PDI[1] PI[1]	HPSMU[2] MPSMU[2] HCU[2]	V		
Constant	0 to 10	V	DV	HPSMU MPSMU	I		
				VS	---		
		I	DI	HPSMU MPSMU	V		
No Output	---	---	---	VM	V[3]		

[1] Select one command from (**PDV** and **PDI**), and one command from (**PV** and **PI**).
[2] One of two pulsed sources must be an HCU.
[3] Differential voltage measurements cannot be performed for pulsed measurements.
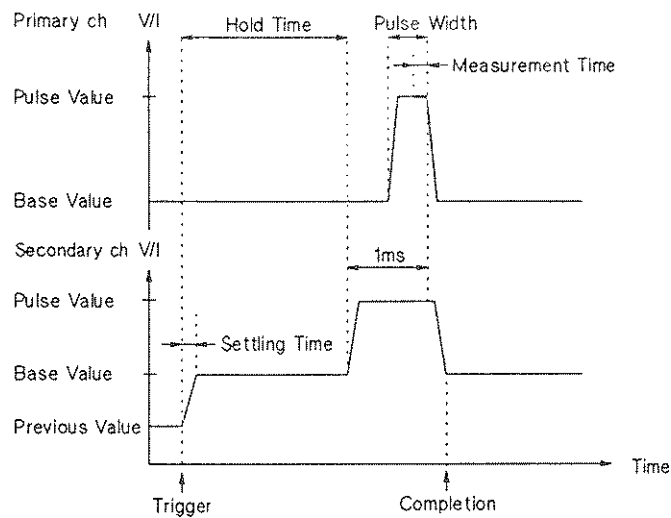
1) When the HP 4142B receives a trigger, the primary pulsed source forces the *base* value, and the secondary pulsed source forces the *base* value.

   The primary pulsed source is automatically set to the HCU (if you use two HCUs for both pulsed sources, the primary pulsed source is specified by **PDM** command), and forces a pulse with the specified *pulse width*. The pulse width of the secondary pulsed source is set to about 1 ms, regardless of the specified *pulse width*.

2) After the secondary pulsed source starts to force the *base* value, the HP 4142B waits for the specified *hold time*. If the *hold time* is less than the settling time of the source unit, *hold time* is set to equal the settling time.

3) The secondary pulsed source forces the *pulse* value.

4) The primary pulsed source forces the *pulse* value.

5) The monitor unit measures V or I before the end of pulse.

6) The primary pulsed source forces the *base* value, and the secondary pulsed source forces the *base* value.

2ch Pulsed Spot Measurement Output Waveform

Th: Hold Time
Tp: Pulse Period
W : Pulse Width
Tm: Measurement Time
Ts: Settling Time

1) For the first pulse, the HP 4142B performs steps 1 through 6 in the previous figure.
2) The HP 4142B receives the next pulse settings. If these pulse settings are not received, the first pulse settings apply.
3) The HP 4142B receives a trigger.
4) After the first *pulse period* (Tp), the pulse sources force the next pulses.
5) The measurement unit measures V or I before the end of the pulse.
6) Steps 2 through 5 repeat for the remaining pulses.
7) If the HP 4142B does not receive a trigger for a succeeding pulse within the specified *pulse period*, the HP 4142B considers the measurement finished. To perform repeated pulse measurements at constant intervals, the following condition must be satisfied.

hold time < pulse period - pulse width

Repeated 2 ch Pulsed Spot Measurement

NOTE

When using an SMU as a pulse source, set the Filter to OFF (Filters set to ON at power-on) by using the FL command.

The HP 4142B can receive and execute commands during *base* value output in pulsed spot measurements that *pulse period* specified, but other types of measurements cannot be performed until the pulsed spot measurement is complete.

For SMU current pulses, the *pulse current* and *base current* values must have the same polarity.

For HCU voltage pulses, the base voltage can be specified only as 0 V. For HCU current pulses, while the HCU output is a base value, the HCU output is 0 V and no current.

Commands and Parameters

The following table lists the commands and parameters for 2 channel pulsed spot measurements. To specify one pulsed source, use the **PDV** or **PDI** command. To specify another pulsed source, use the **PV** or **PI** command.

2ch Pulsed Spot Measurement Commands and Parameters

Function	Command [1]	Parameters [1]
Pulsed Sources [2]	PDV	*ch#, output range, base voltage, pulse voltage,* *[I compliance]*
	PV	*ch#, output range, base voltage, pulse voltage,* *[I compliance]*
	PDI	*ch#, output range, base current, pulse current,* *[V compliance]*
	PI	*ch#, output range, base current, pulse current,* *[V compliance]*
	[FL]	*filter, [ch#]*
Pulse Conditions	PT	*hold time, pulse width, [pulse period]*
	[PDM]	*primary pulse ch#*
Constant Source	DV	*ch#, output range, output voltage,* *[I compliance], [compliance polarity mode]*
	DI	*ch#, output range, output current,* *[V compliance], [compliance polarity mode]*
Measurement	MM	*measurement mode, [ch#]*
	[RI]	*ch#, I measurement range*
	[RV]	*ch#, V measurement range*
Trigger	XE	-----
Abort	AB	-----

[1] Brackets ([ ]) denote optional commands and parameters.
[2] When using SMUs, set Filter to OFF.

Information

Measurement Data Output Format is explained in the *HP 4142B HP-IB Command Reference Manual*.

Output and Measurement Ranging Mode, and Filter are explained in chapter 5.

2ch Pulsed Spot Measurement Sample Program

The following is a sample program that measures the collector saturation voltage (Vce(sat)) of a 2SC3281 npn bipolar transistor by using the 2ch pulsed spot measurement function of the HP 4142B. A description of key program lines follows the program list.

Measurement Conditions

DUT Terminal	Unit	Output	Measurement
Base Collector Emitter	HPSMU Ch#2 HCU Ch#5 GNDU	Ib = 1 A Ic = 10 A Ve = 0 V	--- Vce ---

Program List

```
10    ! Vce(sat) Measurement using 2ch Pulsed Spot Function
20    !
30    INTEGER B_ch, C_ch
40    DIM Status$[3]
50    ASSIGN @Hp4142 TO 717
60    OUTPUT @Hp4142;"*RST"
70    !                                    Emitter    :  GNDU
80    B_ch=2                         ! Base       :  HPSMU Ch#2
90    C_ch=5                         ! Collector  :  HCU Ch#5
100   Ib=1
110   Ic=10
120   !
130   OUTPUT @Hp4142;"CN";B_ch, C_ch
140   OUTPUT @Hp4142;"FL";0, B_ch
150   OUTPUT @Hp4142;"PI";B_ch, 0, 0, Ib, 2
160   OUTPUT @Hp4142;"PDI";C_ch, 0, 0, Ic, 5
170   OUTPUT @Hp4142;"PT";0, 1.E-4
180   OUTPUT @Hp4142;"MM";7, C_ch
190   OUTPUT @Hp4142;"XE"
200   OUTPUT @Hp4142;"CL"
210   !
220   ENTER @Hp4142 USING "#, 3A, 12D, 2X";Status$,Vce
230   PRINT "Vce(sat)= ";Vce;"V", "(Data status: ";Status$;")"
240   END
```

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Result

    Vce(sat)= .4336 V   (Data status: NEV)
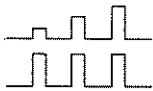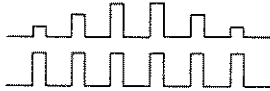
Description

60	Initializes the HP 4142B.
80-110	Assigns the constants.
130	Sets the output switches to ON.
140	Sets the SMU Filter to OFF.
150	Sets the *ch#2* HPSMU current pulse parameters.
160	Sets the *ch#5* HCU current pulse parameters.
170	Sets the output pulse waveform.
180	Sets the measurement mode to 2ch pulsed spot function.
190	Sends a trigger to start the measurement.
200	Sets the output switches to OFF.
220	Enters the measurement data.
230	Displays the measurement results.

PULSED SWEEP WITH PULSED BIAS MEASUREMENTS

Pulsed sweep with pulsed bias measurements are performed as follows: one source sweeps pulsed voltage or current, and another source forces pulsed voltage or current with synchronized sweep pulsed output, while one monitor measures the output for each sweep step. Measurement data for each sweep step is stored in the output data buffer. The following two tables list the pulsed sweep with pulsed bias measurement modes and provide an illustration of each, and HP 4142B pulsed sweep with pulsed bias measurement specifics, respectively.

Pulsed Sweep with Pulsed Bias Measurement Modes

Sweep Mode	Output Waveform
Linear Single Pulsed Sweep with Pulsed Bias	
Linear Double Pulsed Sweep with Pulsed Bias	

Pulsed Sweep with Pulsed Bias Measurement Specifics

Output Mode	No. of Source Ch.	Source Mode	Source Setup Command	Allowable Units	Allowable Monitor Mode	Meas. Setup Command	No. of Meas. Ch.
Pulsed Sweep	1	V	PWV	HPSMU [1] MPSMU [1] HCU [1]	I	MM	1
		I	PWI	HPSMU [1] MPSMU [1] HCU [1]	V		
Pulsed Bias	1	V	PDV	HPSMU [1] MPSMU [1] HCU [1]	I		
		I	PDI	HPSMU [1] MPSMU [1] HCU [1]	V		
Constant	0 to 10	V	DV	HPSMU MPSMU	I		
				VS	---		
		I	DI	HPSMU MPSMU	V		
No Output	---	---	---	VM	V [2]		

[1] One of the two pulsed sources must be an HCU.
[2] Differential voltage measurements cannot be performed for pulsed measurements.

The pulse period of one pulsed source (primary pulsed source) is set to the specified *pulsed width*, and the other pulsed source (secondary pulsed source) is set to about 1 ms. The following figure shows an example of a single pulsed sweep with pulsed bias measurement. Figure (a) shows the pulsed sweep source as the primary pulsed source, and the pulsed bias source as the secondary pulsed source. Figure (b) shows the pulsed sweep source as the secondary pulsed source, and the pulsed bias source as the primary pulsed source.

The primary pulsed source is automatically set to the HCU (if you use two HCUs for both pulsed sources, the primary pulsed source is specified by the **PDM** command). The secondary pulsed source is set to the other pulsed source.

(a) When pulsed sweep source is the primary pulsed source:

Th : Hold Time
Tp : Pulse Period
W : Pulse Width
Tm : Measurement Time
Ts : Settling Time
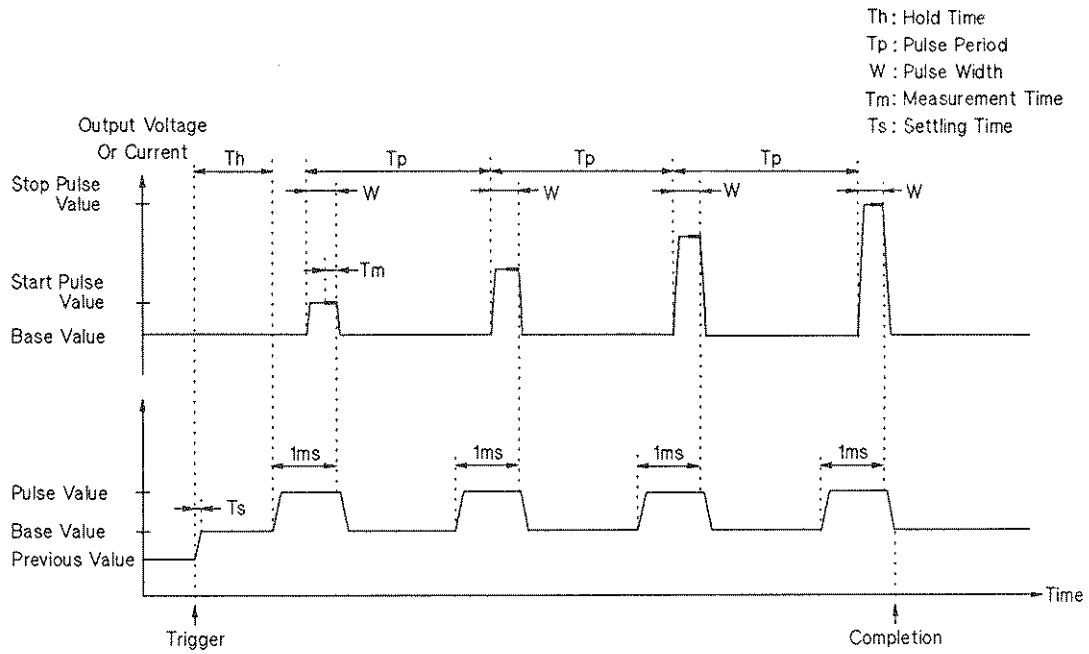
(b) When pulsed bias source is the primary pulsed source:
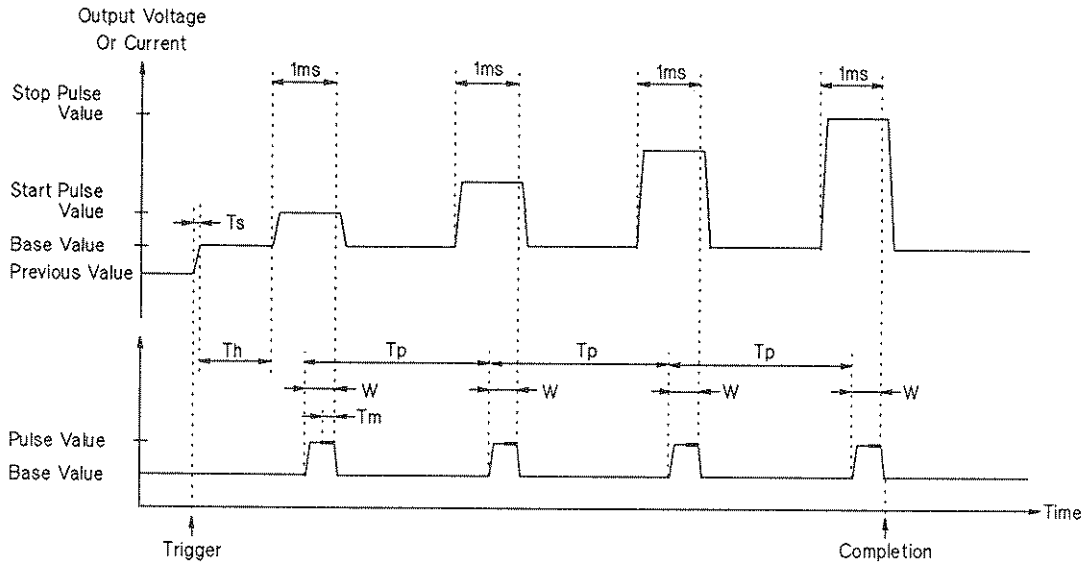
Pulsed Sweep with Pulsed Bias Measurement Output Waveform (1 of 2)

1) When the HP 4142B receives a trigger, the pulsed sweep source forces the *base* value, and the pulsed bias source forces the *base* value.
2) After the pulsed bias source starts to force the *base* value, the HP 4142B waits for the specified *hold time*. If the *hold time* is less than the settling time of the source unit, *hold time* is set to equal the settling time.
3) The secondary pulsed source forces the pulse, and the primary pulsed source forces the pulse.
4) The monitor unit measures V or I before the end of pulse.
5) The primary pulsed source forces the *base* value, and the secondary pulsed source forces the *base* value.
6) The secondary pulsed source forces the next pulse.
7) The primary pulsed source forces the next pulse after the specified *pulse period* (Tp).
8) The monitor unit measures V or I before the end of pulse.
9) Steps 5 through 8 repeat until the output reaches the *stop pulse* value. When the measurement finishes, both pulsed sources force the *base* value.

Pulsed Sweep with Pulsed Bias Measurement Output Waveform (2 of 2)

The following figure shows an example of a double pulsed sweep with pulsed bias measurement. Sweep source output is swept from *start* value to *stop* value, then from *stop* value to *start* value, as shown. The measurement sequence is the same as a single staircase sweep measurement.
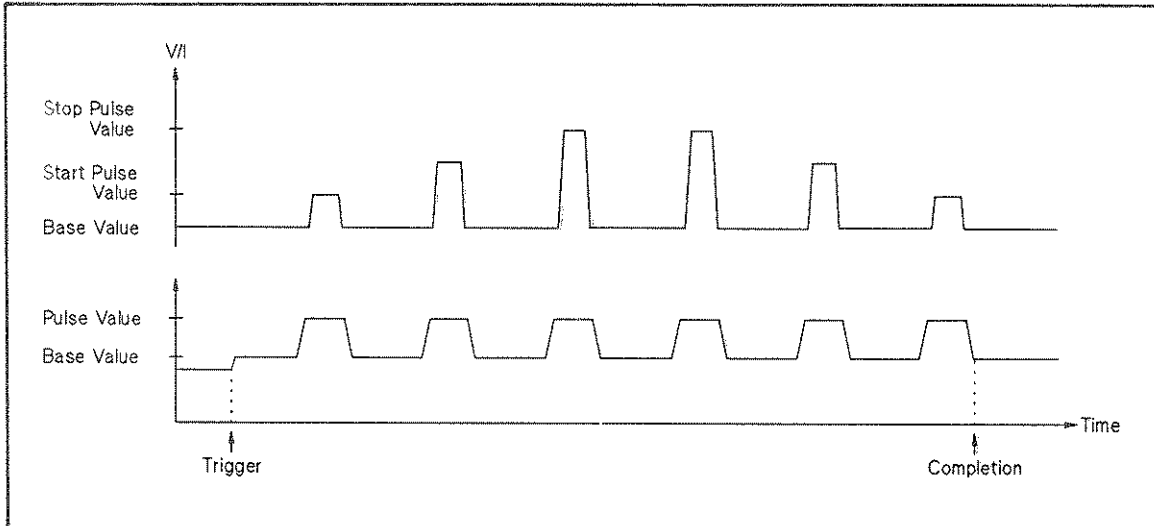
Pulsed Double Sweep Measurement

NOTE

When using an SMU as a pulse source, set the Filter to OFF (Filters set to ON at power-on) by using the **FL** command.

If you set *start pulse* value = *stop pulse* value, all pulses are the same height.

For current pulse sweep source, *base, start pulse*, and *stop pulse* values must have the same polarity. For current bias source, *base current* and *pulse current* must have the same polarity.

For HCU voltage pulses, the base voltage can be specified only as 0 V. For HCU current pulses, while the HCU output is a base value, the HCU output is 0 V and no current.

Commands and Parameters

The following table lists the commands and parameters for pulsed sweep with pulsed bias measurements. To specify the pulsed sweep source, use the **PWV** or **PWI** command. To specify the pulsed bias source, use the **PDV** or **PDI** command.

Pulsed Sweep with Pulsed Bias Measurement Commands and Parameters

Function	Command [1]	Parameters [1]
Pulsed Sweep Source [2]	PWV	*ch#, sweep mode, output range, base voltage, start pulse voltage, stop pulse voltage, number of steps, [I compliance]*
	PWI	*ch#, sweep mode, output range, base current, start pulse current, stop pulse current, number of steps, [V compliance]*
Pulsed Source [2]	PDV	*ch#, output range, base voltage, pulse voltage, [I compliance]*
	PDI	*ch#, output range, base current, pulse current, [V compliance]*
Pulse Enable [2]	[FL]	*filter, [ch#]*
Pulse Conditions	PT	*hold time, pulse width, [pulse period]*
	[PDM]	*primary pulse ch#*
Sweep Conditions	[WM]	*automatic sweep abort function*
Constant Source	DV	*ch#, output range, output voltage, [I compliance], [compliance polarity mode]*
	DI	*ch#, output range, output current, [V compliance], [compliance polarity mode]*
Measurement	MM	*measurement mode, [ch#]*
	[RI]	*ch#, I measurement range*
	[RV]	*ch#, V measurement range*
Trigger	XE	-----
Abort	AB	-----

[1] Brackets ([ ]) denote optional commands and parameters.
[2] When using SMUs, set the SMU Filter to OFF.

Information

Measurement Data Output Format is explained in the *HP 4142B HP-IB Command Reference Manual*.

Output and Measurement Ranging Mode, **Automatic Sweep Abort Function**, and **Filter** are explained in chapter 5.

Pulsed Sweep with Pulsed Bias Measurement Sample Program

The following is a sample program that measures the static collector characteristics of a 2SC3281 bipolar transistor by using the pulsed sweep with pulsed bias measurement function of the HP 4142B. A description of key program lines follows the program list.

Measurement Conditions

DUT Terminal	Unit	Output	Measurement
Base	HPSMU Ch#2	Ib = 50 m,100 m,150 mA	---
Collector	HCU Ch#5	Vc = 0.1 to 10 V, 100 steps	Ic
Emitter	GNDU	Ve = 0 V	---

Program List

```
10     ! Ic-Vce Measurement using Pulsed Sweep with Pulsed Bias Function
20     !
30     OPTION BASE 1
40     INTEGER B_ch, C_ch, Vc_no_step, Ib_no_step, Var1, Var2
50     REAL Vc(100), Ic(3, 100)
60     COM Error$(100)[3], Error1(100), Error2(100), Error3(100), No_error
70     ASSIGN @Hp4142 TO 717
80     OUTPUT @Hp4142;"*RST"
90     OUTPUT @Hp4142;"FMT";5
100    !                              Emitter    : GNDU
110    B_ch=2                       ! Base       : HPSMU (Ch#2)
120    C_ch=5                       ! Collector  : HCU (Ch#5)
130    Vc_start=.1
140    Vc_stop=10
150    Vc_no_step=100
160    Ic_comp=10
170    Ib_start=5.0E-2
180    Ib_step=5.0E-2
190    Ib_no_step=3
200    !
210    Vc_step=(Vc_stop-Vc_start)/(Vc_no_step-1)
220    FOR Var1=1 TO Vc_no_step
230       Vc(Var1)=Vc_start+(Var1-1)*Vc_step
240    NEXT Var1
250    CALL Icvc_graph(0, Vc_stop, 0, Ic_comp)
260    !
```

```
270    OUTPUT @Hp4142;"CN";B_ch, C_ch
280    OUTPUT @Hp4142;"PWV";C_ch, 1, 0, 0, Vc_start, Vc_stop, Vc_no_ step,
Ic_comp
290    OUTPUT @Hp4142;"FL";0, B_ch
300    OUTPUT @Hp4142;"PT";0, 2.E-4, 2.0E-2
310    OUTPUT @Hp4142;"MM";8, C_ch
320    !
330    No_error=0
340    FOR Var2=1 TO Ib_no_step
350      Ib=Ib_start+Ib_step*(Var2-1)
360      OUTPUT @Hp4142;"PDI";B_ch, 0, 0, Ib, 2
370      OUTPUT @Hp4142;"XE"
380      !
390      FOR Var1=1 TO Vc_no_step
400        ENTER @Hp4142 USING "#, 3A, 12D, X";Status$, Ic(Var2, Var1)
410        PLOT Vc(Var1), Ic(Var2, Var1)
420        IF Status$[1;1]<>"N" THEN
430          No_error=No_error+1
440          Error$(No_error)=Status$
450          Error1(No_error)=Ib
460          Error2(No_error)=Vc(Var1)
470          Error3(No_error)=Ic(Var2, Var1)
480          DISP    "MEASUREMENT    ERROR",    Error$(No_error),    Er-
ror1(No_error), Error2(No_error), Error3(No_error)
490        END IF
500      NEXT Var1
510      PENUP
520    NEXT Var2
530    OUTPUT @Hp4142;"CL"
540    END
550    !
560    SUB Icvc_graph(X_axis_min, X_axis_max, Y_axis_min, Y_axis_ max)
570      !
580      GINIT
590      GRAPHICS ON
600      CONTROL CRT, 12;1
610      PRINT CHR$(12)
620      !
630      Xmax=100*MAX(1, RATIO)
640      Ymax=100*MAX(1, 1/RATIO)
650      !
660      LORG 6
670      MOVE Xmax/2, Ymax
680      LABEL "COLLECTOR CHARACTERISTICS"
690      DEG
700      LDIR 90
710      CSIZE 4.5
720      MOVE 0, Ymax/2
730      LABEL "Ic(A)"
740      LORG 4
750      LDIR 0
760      MOVE Xmax/2, 0
770      LABEL "Vce(V)"
780      !
790      VIEWPORT .16*Xmax, .91*Xmax, .15*Ymax, .9*Ymax
800      !
810      FRAME
```

```
820        WINDOW X_axis_min, X_axis_max, Y_axis_min, Y_axis_max
830        AXES(X_axis_max-X_axis_min)/10,(Y_axis_max-Y_axis_min)/10,
X_axis_min, Y_axis_min
840        CLIP OFF
850        CSIZE 4, .5
860        LORG 6
870        FOR I=X_axis_min TO X_axis_max STEP (X_axis_max-X_axis_min)/2
880           MOVE I, Y_axis_min
890           LABEL I
900        NEXT I
910        CSIZE 3.8, .5
920        LORG 8
930        FOR I=Y_axis_min TO Y_axis_max STEP (Y_axis_max-Y_axis_min)/2
940           MOVE X_axis_min, I
950           LABEL USING "#, MD.DE";I
960        NEXT I
970        CLIP ON
980        !
990    SUBEND
1000   SUB Error_disp
1010      COM Error$(*), Error1(*), Error2(*), Error3(*), No_error
1020      PRINT "STATUS", "Ib", "Vc", "Ic"
1030      FOR I=1 TO No_error
1040         PRINT Error$(I), Error1(I), Error2(I), Error3(I)
1050      NEXT I
1060   SUBEND
```

Result

COLLECTOR CHARACTERISTICS
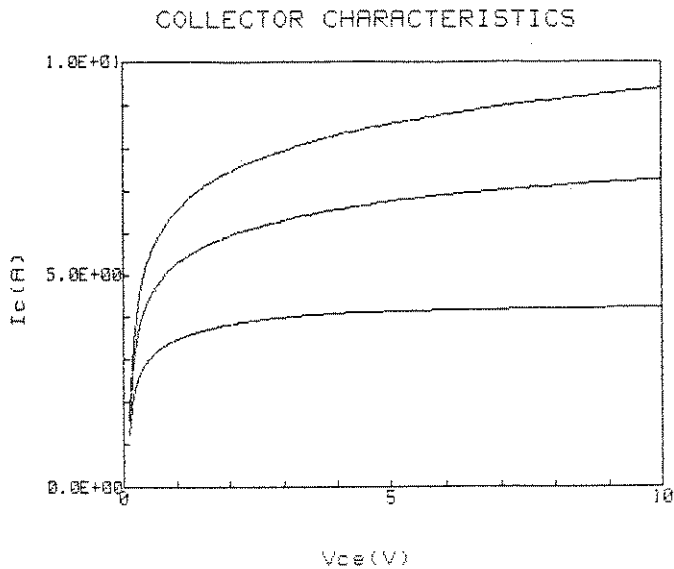
Description

30-60	Defines the variables.
80	Initializes the HP 4142B.
90	Sets the data output format to ASCII with header and comma as a terminator.
110-190	Assigns the constants.
210-240	Calculates collector voltage value for each step, and stores these values in an array variable.
250	Calls subprogram to display graphics frame.
270	Sets the output switches to ON.
280	Sets the *ch#5* HCU pulsed voltage sweep parameters.
290	Sets the SMU filter to OFF.
300	Sets the output pulse waveform.
310	Sets the measurement mode to pulsed sweep with pulsed bias function.
340-360	Sets the *ch#2* SMU current pulsed source parameters.
370	Forces a trigger to start a voltage swept measurement.
400-410	Enters the measurement data into variable *Ic*, and displays measurement data in the graphics frame.
420-490	Displays any measurement errors that may occur.
520	Sets the base current to the next value.
530	Sets the SMUs output switches to OFF.
560-990	Subprogram for displaying graphics frame.
1000-1060	Subprogram for displaying measurement errors.

HIGH SPEED SPOT MEASUREMENTS

You can make high speed spot measurements by using the **TV** or **TI** commands. These commands make a V or I measurement independently of the source mode setting (V or I). Measurements are faster because trigger, *measurement mode, measurement ch#,* and *measurement range* are all combined into one command. However, you are limited to one measurement channel. The **TV** command (for V measurements) is used instead of the **MM, RV,** and **XE** commands. The **TI** command (for I measurements) is used instead of the **MM, RI,** and **XE** commands. The following two tables list measurement functions that can only be performed using the high speed spot measurement function, and high speed spot measurement specifics, respectively.

High Speed Spot Measurement Special Functions

Measurement Function	Equivalent Circuit
VS current measurement	VS
Voltage measurement by SMU set to V source mode	SMU
Current measurement by SMU set to I source mode	SMU

High Speed Spot Measurement Specifics

Output Mode	No. of Source Ch.	Source Mode	Source Setup Command	Allowable Units	Allowable Monitor Mode	Meas. Setup Command	No. of Meas. Ch.
Constant	0¹ to 16	V	DV	HPSMU MPSMU	V, I	V: TV I: TI	1
				VS	I	TI	
		I	DI	HPSMU MPSMU	V, I	V: TV I: TI	
No Output	---	---	---	VM	V DIF. V	TV VM	

¹ When using a VM to make a measurement only.

Commands and Parameters

The following table lists high speed spot measurement commands and parameters.

High Speed Spot Measurement Commands and Parameters

Function	Command [1]	Parameters [1]
Constant Source	DV	*ch#, output range, output voltage,* *[I compliance], [compliance polarity mode]*
	DI	*ch#, output range, output current,* *[V compliance], [compliance polarity mode]*
Measurement and Trigger	TV	*ch#, [V measurement range]*
	TI	*ch#, [I measurement range]*
Measurement	[VM]	*ch#, VM operation mode*
	[AV]	*number, [averaging mode]*

[1] Brackets ([ ]) denote optional commands and parameters. Optional parameters and optional command parameters have default values.

Information

Measurement Data Output Format is explained in the *HP 4142B HP-IB Command Reference Manual*.

Output and Measurement Ranging Mode and **Averaging** are explained in chapter 5.

High Speed Spot Measurement Sample Program

The following is a sample program that measures collector current for two collector-to-emitter voltage values using the high speed spot measurement function. Saturation Ic-Vce values are then used to calculate Early Voltage. A description of key program lines follows the program list.

Measurement Conditions

DUT Terminal	Unit	Output	Measurement
Base	SMU Ch#3	Ib = 20 μA	---
Collector	SMU Ch#2	Vc = 2, 6 V	Ic
Emitter	GNDU	Ve = 0 V	---

Program List

```
10    ! Early Voltage Measurement using High Speed Spot Function
20    !
30    INTEGER B_ch, C_ch
40    DIM Ic1$[15], Ic2$[15]
50    ASSIGN @Hp4142 TO 717
60    OUTPUT Hp4142;"*RST"
70    !                                    Emitter    : GNDU
80    B_ch=3                            !  Base       : Ch#3
90    C_ch=2                            !  Collector  : Ch#2
100   Ib=2.E-5
110   Vc1=2
120   Vc2=6
130   !
140   OUTPUT @Hp4142;"CN";B_ch, C_ch
150   OUTPUT @Hp4142;"DI";B_ch, 0, Ib, 2
160   OUTPUT @Hp4142;"DV";C_ch, 0, Vc1, 1.E-2
170   OUTPUT @Hp4142;"TI";C_ch
180   ENTER @Hp4142;Ic1$
190   OUTPUT @Hp4142;"DV";C_ch, 0, Vc2
200   OUTPUT @Hp4142;"TI";C_ch
210   ENTER @Hp4142;Ic2$
220   OUTPUT @Hp4142;"CL"
230   !
240   Ic1=VAL(Ic1$[4, 15])
250   Ic2=VAL(Ic2$[4, 15])
260   Va=(Vc1*Ic2-Ic1*Vc2)/(Ic2-Ic1)
270   PRINT "Early Voltage= ";PROUND(Va, -2);"[V]"
280   END
```

Result

```
Early Voltage= -155.44[V]
```

Description

60	Initializes the HP 4142B.
100-120	Assigns the constants.
140	Sets the SMUs output switches to ON.
150	Forces 20 µA to the base.
160	Forces 2 V to the collector.
170	Measures the collector current.
180	Enters the measurement data into string variable $Ic1\$$.
190	Forces 6 V to the collector.
200	Measures the collector current.
210	Enters the measurement data into string variable $Ic2\$$.
220	Sets the SMUs output switches to OFF.
240-250	Converts the string expression into a numeric value to obtain the collector current values.
260	Calculates the Early Voltage value.
270	Displays the result.

CHAPTER 5

MEASUREMENT FUNCTIONS

CONTENTS

NOTES

INTRODUCTION

This chapter explains the functions that can be used in measurements, such as ranging, compliance, measurement averaging, automatic sweep about function and program memory.

OUTPUT RANGING MODE

Allowable Ranging Mode

The following table lists the allowable output ranging mode for each source.

Allowable Output Ranging Mode

Output Mode	Output Setup Command	Auto Ranging	Limited Auto Ranging
Constant V/I Source	DV/DI	YES	YES
Staircase Sweep V/I Source	WV/WI, WSV/WSI	YES	YES
Pulsed V/I Source	PV/PI, PDV/PDI	YES	YES
Pulsed Sweep V/I Source	PWV/PWI	YES	YES
Search	ASV	YES	---
V/I Sense (Constant I/V Source)	AVI/AIV	YES	---

Auto Ranging

For Auto ranging, the output of the source unit is forced at the lowest range that includes the Range Determination Value shown in the following table.

Range Determination Value

Output Setup Command	Range Determination Value [1]
DV	*output voltage*
DI	*output current*
WV	MAX(*start voltage, stop voltage*)[2] [3]
WSV	MAX(*start voltage, stop voltage*)[2] [3]
WI (For linear sweep)	MAX(*start current, stop current*)[2]
WI (For log sweep)	each step output current [4]
WSI (For linear sweep)	MAX(*start current, stop current*)[2]
WSI (For log sweep)	each step output current [4]
PV	MAX(*base voltage, pulse voltage*)
PI	MAX(*base current, pulse current*)
PWV	MAX(*base voltage, start pulse voltage, stop pulse voltage*)[2]
PWI	MAX(*base current, start pulse current, stop pulse current*)[2]
ASV	MAX(*search start voltage, search stop voltage, (search stop voltage - search start voltage)*)[2]
AVI	*output voltage*
AIV	*output current*

[1] Each parameter value means an absolute value.

[2] During a sweep, the output range does not change.

[3] However, if you specify *power compliance* for the SMU of the staircase sweep V source, and the I compliance value at some step (smaller value of (*power compliance*)/ (step output voltage) and *I compliance*) is greater than the maximum current for the V output range selected by the Auto ranging or Limited Auto ranging, then the V output range at this step is changed according to the output voltage, as follows. SMU output is momentarily set to 0 V if V range changing occurs.

[4] During a log I sweep, the output range changes so that each step current is forced at the lowest range that includes the step current.

Unit	Step Voltage	Output Range
SMU	$0\ V \leq V \leq 20\ V$	20 V
	$20\ V < V \leq 40\ V$	40 V
	$40\ V < V \leq 100\ V$	100 V

The following table lists the lowest output range that includes the Range Determination Value, that is, the range set by Auto ranging.

Output Range Set by Auto Ranging

Unit	Range Determination Value	Output Range
HPSMU MPSMU	$0 \leq |V| \leq 2$ V 2 V $< |V| \leq 20$ V 20 V $< |V| \leq 40$ V 40 V $< |V| \leq 100$ V 100 V $< |V| \leq 200$ V	2 V 20 V 40 V 100 V 200 V
HCU	$0 \leq |V| \leq 2$ V 2 V $< |V| \leq 10$ V	2 V 20 V
VS	$0 \leq |V| \leq 20$ V 20 V $< |V| \leq 40$ V	20 V 40 V
HPSMU MPSMU	$0 \leq |I| \leq 1.15$ nA 1.15 nA $< |I| \leq 11.5$ nA 11.5 nA $< |I| \leq 115$ nA 115 nA $< |I| \leq 1.15$ μA 1.15 μA $< |I| \leq 11.5$ μA 11.5 μA $< |I| \leq 115$ μA 115 μA $< |I| \leq 1.15$ mA 1.15 mA $< |I| \leq 11.5$ mA 11.5 mA $< |I| \leq 115$ mA 115 mA $< |I| \leq 1$ A	1 nA 10 nA 100 nA 1 μA 10 μA 100 μA 1 mA 10 mA 100 mA 1 A
HCU	$0 \leq |I| \leq 1.15$ mA 1.15 mA $< |I| \leq 11.5$ mA 11.5 mA $< |I| \leq 115$ mA 115 mA $< |I| \leq 1.15$ A 1.15 A $< |I| \leq 10$ A	1 mA 10 mA 100 mA 1 A 10 A

Limited Auto Ranging

For Limited Auto ranging, the output of the source unit is forced at the specified range, if this range includes the Range Determination Value described in "Auto Ranging." If not, the output is forced at the same range as Auto ranging.

MEASUREMENT RANGING MODE

Allowable Ranging Mode

The following table lists the allowable V measurement ranging mode for each monitor unit.

Unit	V/I Meas.	Allowable Ranging Mode [1] (Ranging Mode Setup Command)		
		Constant V/I Meas.	Pulsed V/I Meas.	Search Meas.
HPSMU MPSMU HCU	V Meas.	Comp [2]	Comp	Comp [2]
	I Meas.	Auto, Ltd, Fix, Comp [2] (RI, TI)	Comp, Fix (RI, TI)	Comp
VM	V Meas.	Auto, Fix (RV, TV)	Fix (RV, TV)	---
VS	I Meas.	[3]	---	---

[1] Auto: Auto ranging, Ltd: Limited Auto ranging, Comp: Compliance range, Fix: Fixed range
Constant Meas.: For Spot, Staircase sweep, or High speed spot measurements.
Pulse Used Meas.: 1ch pulsed spot, 2ch pulsed spot, Pulsed sweep, Pulsed sweep with pulsed bias, or staircase sweep with pulsed bias measurements.
Search Meas.: Analog search measurements

[2] If the unit is the V source and V monitor, or I source and I monitor, the measurement range is set to the same as output range, regardless of the shown ranging mode.

[3] If VS output range is set to 20 V, VS I measurement range is automatically set to the 100 mA range. If VS output range is set to 40 V, VS I measurement range is automatically set to the 20 mA range. VS I measurement is only available for High speed spot measurements.

Auto Ranging

The monitor unit measures at the range that provides the highest resolution. The range changes to the next higher range if the measurement value is greater than 114% of the present range. The range changes to the next lower range if the measurement value is less than 10% of the present range.

The following table lists the auto ranging measurement area for each range.

Auto Ranging Measurement Area

Unit	Range	Meas. Area	Auto Ranging Meas. Area
VM (Grounded measurement)	2 V 20 V 40 V	0 to ±2.3 V 0 to ±23 V 0 to ±40 V	$0\ V \leq |V| \leq 2.28\ V$ $2\ V \leq |V| \leq 22.8\ V$ $4\ V \leq |V| \leq 40\ V$
VM (Differential measurement)	0.2 V 2 V	0 to ±0.23 V 0 to ±2.3 V	$0 \leq |V| \leq 0.228\ V$ $0.2\ V \leq |V| \leq 2.3\ V$
HPSMU MPSMU	1 nA 10 nA 100 nA 1 µA 10 µA 100 µA 1 mA 10 mA 100 mA 1 A	0 to 1.15 nA 0 to 11.5 nA 0 to 115 nA 0 to 1.15 µA 0 to 11.5 µA 0 to 115 µA 0 to 1.15 mA 0 to 11.5 mA 0 to 115 mA [1] 0 to 1 A	$0\ A \leq |I| \leq 1.14\ nA$ $1\ nA \leq |I| \leq 11.4\ nA$ $10\ nA \leq |I| \leq 114\ nA$ $100\ nA \leq |I| \leq 1.14\ µA$ $1\ µA \leq |I| \leq 11.4\ µA$ $10\ µA \leq |I| \leq 114\ µA$ $100\ µA \leq |I| \leq 1.14\ mA$ $1\ mA \leq |I| \leq 11.4\ mA$ $10\ mA \leq |I| \leq 114\ mA$ [1] $100\ mA \leq |I| \leq 1\ A$

[1] For MPSMU, 100 mA

Limited Auto Ranging

The monitor unit measures at the range that provides the highest resolution in the specified range and higher. The range changes to the next higher range if the measurement value is greater than 114% of the present range. The range changes to the next lower range if the present range is higher than the specified range and the measurement value is less than 10% of the present range. If you do not need to measure at the lower I range, specify the higher range at this ranging mode. You can reduce the measurement time of Auto Ranging with Limited Auto Ranging because the number of range changes decreases.

However, if the specified range is greater than the lowest range that includes *I compliance*, the measurement range is not set by Limited Auto ranging and is set to Compliance range (see next paragraph, "Compliance Range"). Therefore, if you specify the 1 A Limited Auto ranging for HPSMU, and the 100 mA Limited Auto ranging for MPSMU, then the measurement range is always set to Compliance range regardless of *I compliance*.

Compliance Range

For V measurement, the monitor unit measures at the lowest range that includes V *compliance*. If you also specify *power compliance* for the SMU, the SMU measures at the lowest range that includes V *compliance*, or (*power compliance*)/(step output current), whichever range is lower.

For I measurement, the monitor unit measures at the lowest range that includes I *compliance*. If you also specify *power compliance* for the SMU, the SMU measures at the lowest range that includes I *compliance*, or (*power compliance*)/(step output voltage), whichever range is lower.

Compliance range performs measurements fastest because the ranging is performed when you set the compliance and the range does not change for each measurement.

The following table lists the measurement range for Compliance range.

NOTE

If you specify the 1 A Limited Auto ranging or 1 A fixed range for the HPSMU, and the 100 mA Limited Auto ranging or 100 mA fixed range for the MPSMU, then the measurement range is set to Compliance range.

Measurement Range for Compliance Range

Unit	*V compliance/ I compliance*	Measurement Range
HPSMU MPSMU	$0\ V \leq |V| \leq 2\ V$ $2\ V < |V| \leq 20\ V$ $20\ V < |V| \leq 40\ V$ $40\ V < |V| \leq 100\ V$ $100\ V < |V| \leq 200\ V$	2 V 20 V 40 V 100 V 200 V
HCU	$0\ V \leq |V| \leq 2\ V$ $2\ V < |V| \leq 10\ V$	2 V 20 V
HPSMU MPSMU	$0 \leq |I| \leq 1.15\ nA$ $1.15\ nA < |I| \leq 11.5\ nA$ $11.5\ nA < |I| \leq 115\ nA$ $115\ nA < |I| \leq 1.15\ \mu A$ $1.15\ \mu A < |I| \leq 11.5\ \mu A$ $11.5\ \mu A < |I| \leq 115\ \mu A$ $115\ \mu A < |I| \leq 1.15\ mA$ $1.15\ mA < |I| \leq 11.5\ mA$ $11.5\ mA < |I| \leq 115\ mA$ $115\ mA < |I| \leq 1\ A$	1 nA 10 nA 100 nA 1 µA 10 µA 100 µA 1 mA 10 mA 100 mA 1 A
HCU	$0 \leq |I| \leq 1.15\ mA$ $1.15\ mA < |I| \leq 11.5\ mA$ $11.5\ mA < |I| \leq 115\ mA$ $115\ mA < |I| \leq 1.15\ A$ $1.15\ A < |I| \leq 10\ A$	1 mA 10 mA 100 mA 1 A 10 A

Fixed Range

The monitor unit measures at the specified range only.

However, the I measurement range is set to the Compliance range if the specified range is greater than the lowest range that includes I compliance. For example, if you specify the 1 A range for HPSMU and the 100 mA range for MPSMU, then the measurement range is always set to the Compliance range, regardless of *I compliance*.

If the measurement value exceeds the specified measurement range, the measurement data is dummy data (199.999E+99).

V/I Compliance

Allowable Units:

HPSMU, MPSMU, HCU

To prevent damage to the test device due to overcurrent or overvoltage, you can set the HPSMU, MPSMU, and HCU to I or V compliance. I and V compliance are limiters that can be set with the same resolution and accuracy as output current or output voltage. When using a unit in the V source mode, specify *I compliance*. When using a unit in the I source mode, specify *V compliance*. The following tables list the compliance area and compliance resolution, respectively.
If an output reaches *I* or *V compliance*, that unit acts as a constant I or V source, respectively, and output is maintained at the specified compliance level.

To check whether a source unit reaches *I* or *V compliance* during a measurement, check the measurement data status byte. Refer to the *HP-IB Command Reference Manual* for more details.

When setting compliance, observe the following precautions:

- Do not set *I compliance* too low.
  The lower that *I compliance* is, the longer it takes for the settling time.

- Do not set *V compliance* too high, even if you think that damaging high voltage can not occur. A unit will reach *V compliance* if it cannot force the specified current by the following current limitations:

  1) Test device.
  2) Compliance/limiter of another unit.
  3) Limitation of maximum current at the I measurement range of another unit, if the I measurement range is lower than the compliance range. However, this limitation is momentary because the I measurement range automatically changes to the compliance range immediately after this limitation occurs.

- The V measurement range (that is, V measurement resolution) of the SMU or HCU is determined by *V compliance*, and set to the Compliance range.

V/I compliance **Setting Area**

Unit	Output Range	*V/I compliance*
HPSMU	2 V 20 V (0 ≤ |V| ≤ 14 V) 20 V (14 < |V| ≤ 20 V) 40 V 100 V 200 V	1 pA[1] to 1 A 1 pA[2] to 1 A 1 pA[2] to 700 mA 1 pA[2] to 350 mA 1 pA[2] to 125 mA 1 pA[2] to 50 mA
	1 nA[3] 10 nA to 10 µA 100 µA to 10 mA 100 mA (0 ≤ |I| ≤ 50 mA) 100 mA (50 mA ≤ |I| ≤ 115 mA) 1 A (0 ≤ |I| ≤ 50 mA) 1 A (50 mA < |I| ≤ 125 mA) 1 A (125 mA < |I| ≤ 350 mA) 1 A (350 mA < |I| ≤ 700 mA) 1 A (700 mA < |I| ≤ 1 A)	0 to 200 V 0 to 200 V[4] 0 to 200 V 0 to 200 V 0 to 100 V 0 to 200 V 0 to 100 V 0 to 40 V 0 to 20 V 0 to 14 V
MPSMU	2 V 20 V 40 V 100 V	1 pA[1] to 100 mA 1 pA[2] to 100 mA 1 pA[2] to 50 mA 1 pA[2] to 20 mA
	1 nA[3] 10 nA to 10 µA 100 µA to 10 mA 100 mA (0 ≤ |I| ≤ 20 mA) 100 mA (20 mA < |I| ≤ 50 mA) 100 mA (50 mA ≤ |I| ≤ 100 mA)	0 to 100 V 0 to 100 V[4] 0 to 100 V 0 to 100 V 0 to 40 V 0 to 20 V
HCU	2 V to 20 V	1 µA to 10 A
	1 mA to 10 A	0 to 10 V

[1] 2 nA when performing pulsed measurements.
[2] 20 µA when performing pulsed measurements.
[3] 1 nA range not available when performing pulsed measurements.
[4] 2 V when performing pulsed measurements.

V/I compliance Resolution

Unit	*V/I compliance*	Resolution
HPSMU MPSMU	0 $\|V\| \leq 2$ V 2 V $< \|V\| \leq 20$ V 20 V $< \|V\| \leq 40$ V 40 V $< \|V\| \leq 100$ V 100 V $< \|V\| \leq 200$ V	100 µV 1 mV 2 mV 5 mV 10 mV
	1 pA $\leq \|I\| \leq 1.15$ nA 1.15 nA $< \|I\| \leq 11.5$ nA 11.5 nA $< \|I\| \leq 115$ nA 115 nA $< \|I\| \leq 1.15$ µA 1.15 µA $< \|I\| \leq 11.5$ µA 11.5 µA $< \|I\| \leq 115$ µA 115 µA $< \|I\| \leq 1.15$ mA 1.15 mA$< \|I\| \leq 11.5$ mA 11.5 mA $< \|I\| \leq 115$ mA 115 mA $< \|I\| \leq 1$ A	50 fA 500 fA 5 pA 50 pA 500 pA 5 nA 50 nA 500 nA 5 µA 50 µA
HCU	0 $\|V\| \leq 2$ V 2 V $< \|V\| \leq 10$ V	200 µV 2 mV
	1 µA $< \|I\| \leq 1.15$ mA 1.15 mA $< \|I\| \leq 11.5$ mA 11.5 mA $< \|I\| \leq 115$ mA 115 mA $< \|I\| \leq 1$ A	100 nA 1 µA 10 µA 100 µA

NOTE

For HCUs, the specified V or I *compliance* is set only during pulse value output. While the HCU forces a base value, the output is fixed to 0 V and the I compliance is fixed to 0.1% of the range value of I range, regardless of the pulsed V or I source. The I range is the lowest range that includes the I *compliance* for pulsed V source, or is the I output range for the pulsed I source.

When the V or I compliance range is set to the unit, the V or I measurement range is set to the lowest range that includes the compliance. The I measurement range, however, changes during the measurement according to the specified ranging mode, if you do not specify compliance range.

Polarity of Compliance

The HP 4142B automatically sets I *compliance* polarity to the same polarity as the output voltage, regardless of the specified I *compliance* polarity.
The HP 4142B automatically sets V *compliance* polarity to the same polarity as the output current, regardless of the specified V *compliance* polarity.
The following figure shows the compliance and output area.

NOTE

The only time V/I compliance automatic polarity setting mode is not valid is when you set *compliance polarity mode* to MANUAL using the **DV** or **DI** command. See the following paragraph, "Manual Setting of Compliance Polarity."

For I compliance, current with the opposite polarity of I *compliance* is limited also. For HPSMU and MPSMU, this opposite polarity value is greater than $|I$ *compliance*$|$ by an amount that is 2% to 10% of the range value in the lowest range that includes I *compliance*. For HCU, the opposite polarity value is 0.1% of the range value for I range (maximum value is 10 mA at 10 A range). I range is the lowest range that includes I *compliance* for pulsed V source, or is the I output range for pulsed I source.
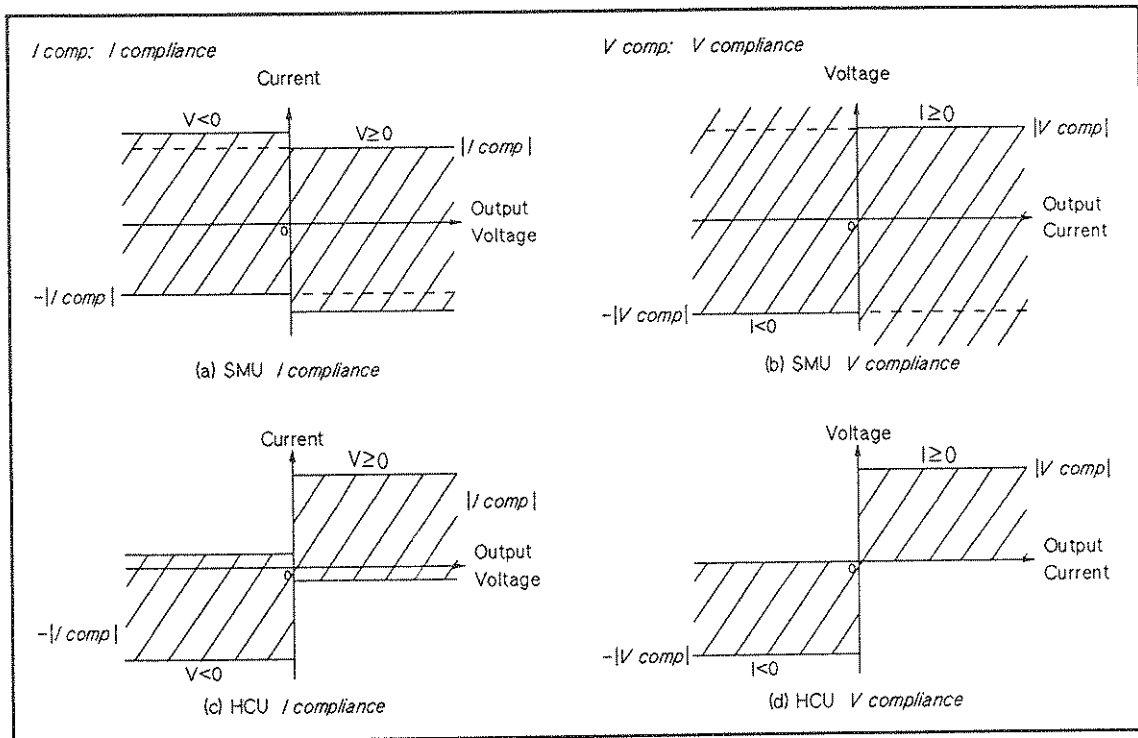
Output Area

The following table lists the compliance polarity for each command.

Compliance Polarity

Source	Setup Command	Compliance Polarity [1]
Constant	DV DI	Same as *output voltage* [2] Same as *output current* [2]
Staircase sweep	WV, WSV WI, WSI	Same as each step voltage Same as each step current
Pulse	PV, PDV PI, PDI	Same as *pulse voltage* Same as *pulse current* and *base current*
Pulsed sweep	PWV	SMU: Same as *start pulse voltage* HCU: Same as each step pulse voltage
	PWI	SMU: Same as *start pulse current* and *base current* HCU: Same as each step pulse current
Search	ASV	Same as *search stop voltage*
Sense	AVI AIV	Same as *output voltage* Same as *output current*

[1] If the parameter value(s) = 0, the compliance polarity is positive for the SMU, and the same as the previous polarity for the HCU.

[2] If you set *compliance polarity mode* to MANUAL, the I compliance polarity you specified is used, regardless of the polarity of the parameter. See the following paragraph, "Manual Setting of Compliance Polarity."

Manual Setting of Compliance Polarity

When you execute the **DI** or **DV** command for the HPSMU or the MPSMU, you can set compliance to the polarity of a specified V or I compliance, regardless of the output voltage polarity. Set the compliance polarity mode to MANUAL. The following figure shows the MANUAL mode compliance and output areas.

In figure (c), V *compliance* ≥ 0. If the specified *output current* < 0, then V *compliance* is the minimum allowed positive voltage. Negative voltages are not allowed. If the specified output current ≥ 0, then V *compliance* is the maximum allowed positive voltage. Negative voltages are not limited. In figure (d), V *compliance* < 0. If the specified *output current* < 0, then V *compliance* is the maximum allowed negative voltage. Positive voltage is not limited. If the specified *output current* ≥ 0, then V *compliance* is the minimum allowed negative voltage. Positive voltages are not allowed.

The following figure shows a measurement example using MANUAL mode.

I comp: I compliance

V comp: V compliance

(a) *I compliance (>0)*

(b) *I compliance (<0)*

(c) *V compliance(≥0)*
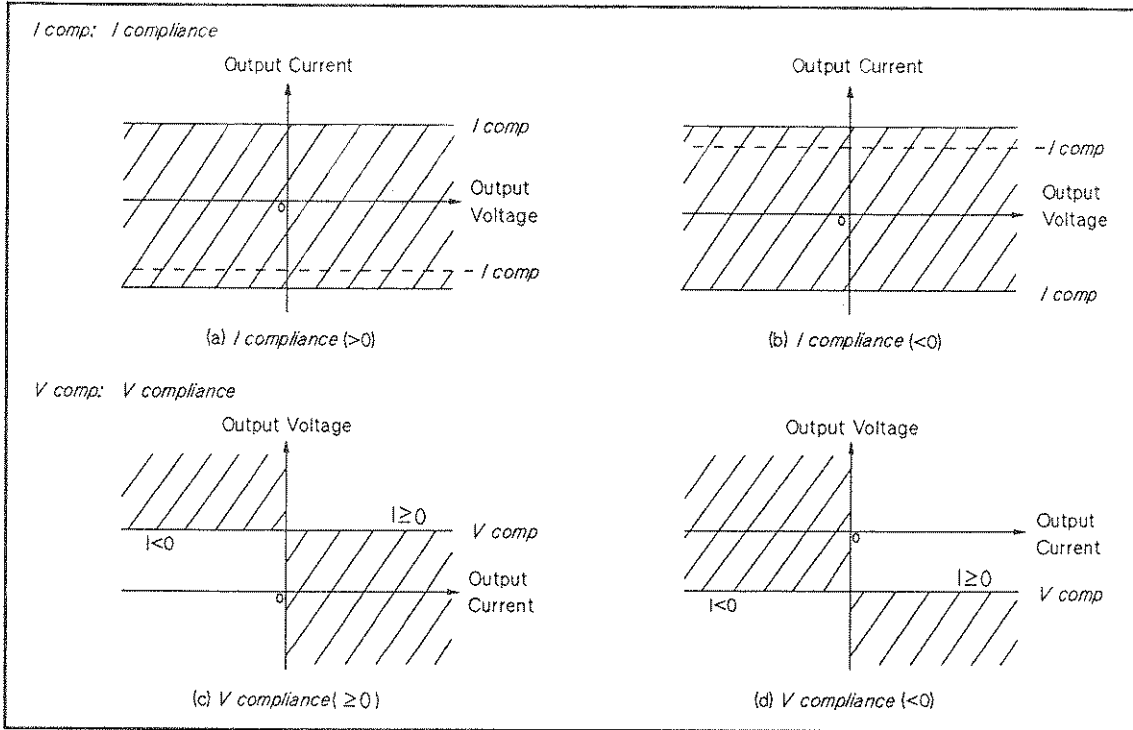
(d) *V compliance (<0)*

SMU Output Area for Manual Mode Compliance

In this example, the HIGH output voltage of a TTL inverter is measured when the output current is 1 mA. The *compliance polarity mode* is set to MANUAL mode, and the *V compliance* (+3 V) and *output current* (-1 mA) are opposite polarities. Thus, *V compliance* is the minimum allowed voltage, which protects the test device by preventing the HIGH output voltage from going below +3 V.
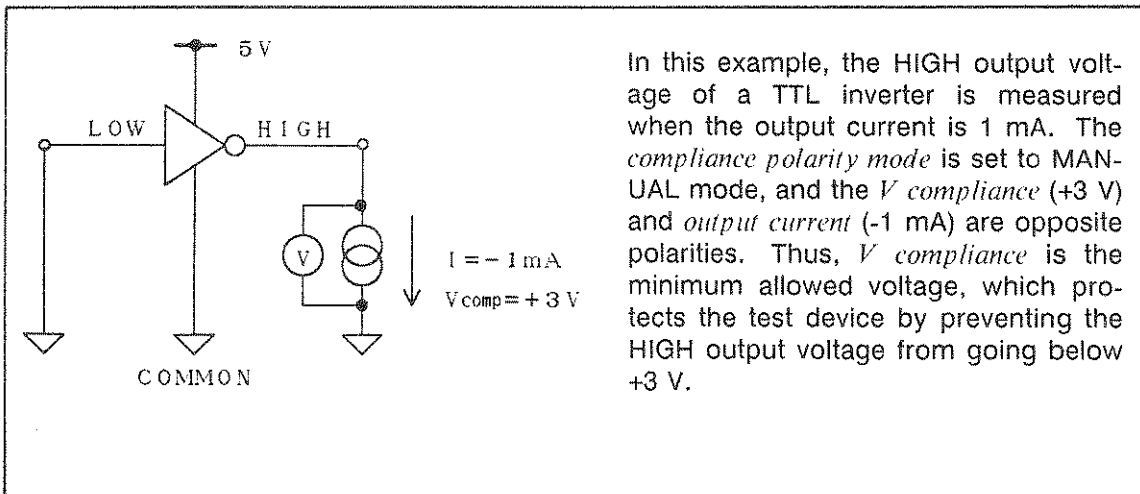
Compliance Polarity MANUAL Mode V Measurement Example

MANUAL MODE V COMPLIANCE CONSIDERATIONS

If you set the *compliance polarity mode* of the **DI** command to MANUAL, set *V compliance* (Vcomp) as follows. If *V compliance* is not set as follows, the SMU output may be an undesired opposite polarity current (Irev), instead of the desired *output current* (Iset).

1) If the specified Iset is positive or zero, set Vcomp more positive than Vrev.
2) If the specified Iset is negative, set Vcomp less positive than Vrev.

Vrev is the voltage that occurs at the SMU output terminal when Irev is forced to a test device. $|Irev| = |Iset| + |\Delta I|$, where ΔI is 2% to 10% range value of I output range.

The following figure shows the allowable *V compliance* values when the test device (DUT) is a resistor.
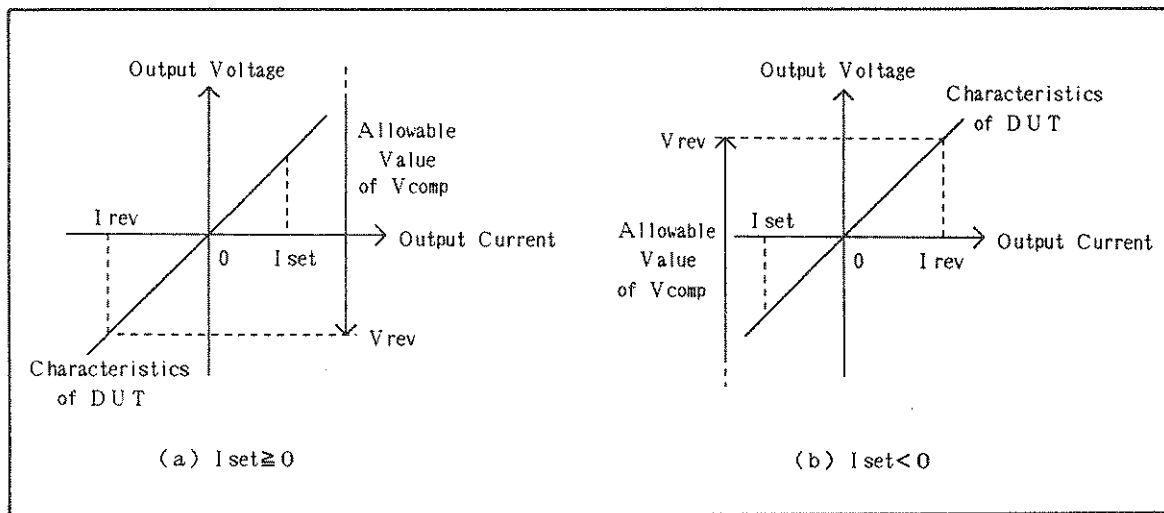
Allowable *V compliance* **Values**

In the I source mode, the I-V characteristics curve of an SMU is determined by the specified Iset and Vcomp, and consists of the Iset, Vcomp, and Irev lines as shown in the following figure. SMU output depends on the intersection of the I-V characteristic curves of the SMU and the DUT. An SMU forces Iset, Vcomp, or Irev depending on the intersection. To achieve the desired SMU output, specify Vcomp as shown in the above figure.

The following second figure shows how changing Vcomp affects the SMU output when the specified Iset is greater than 0, and the DUT is a resistor:

(1) If Vcomp > Vrev, and the intersection is on the Iset line, as shown in figure (a), the SMU forces Iset.
(2) If Vcomp > Vrev, and the intersection is on the Vcomp line, as shown in figure (b), the SMU forces Vcomp.
(3) If Vcomp < Vrev, and the intersection is on the Irev line, as shown in figure (c), the SMU forces undesirable current Irev.

(a) Iset≧0   (b) Iset< 0

SMU I-V Characteristics Curve

(a) Outputs Iset (Vcomp> Vrev)   (b) Outputs Vcomp (Vcomp≧ Vrev)

(c) Outputs Irev (Vcomp< Vrev)
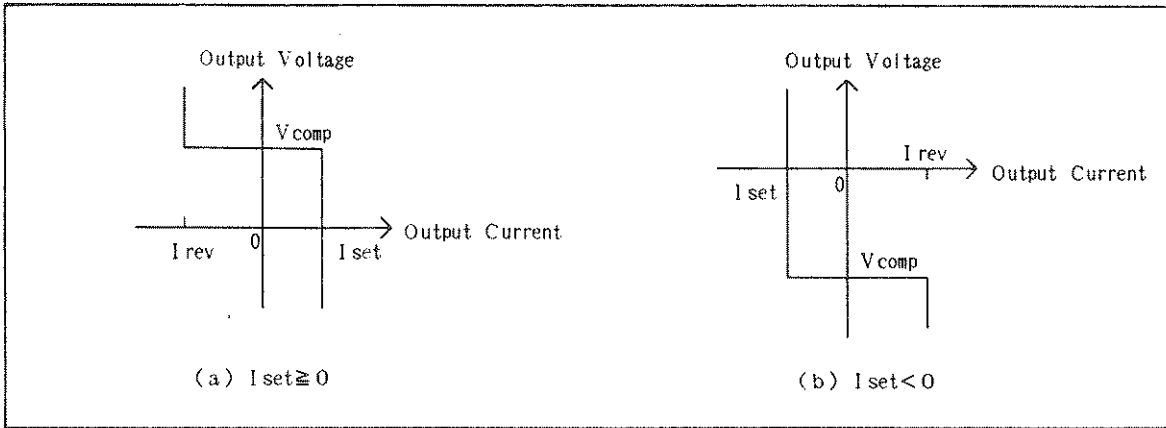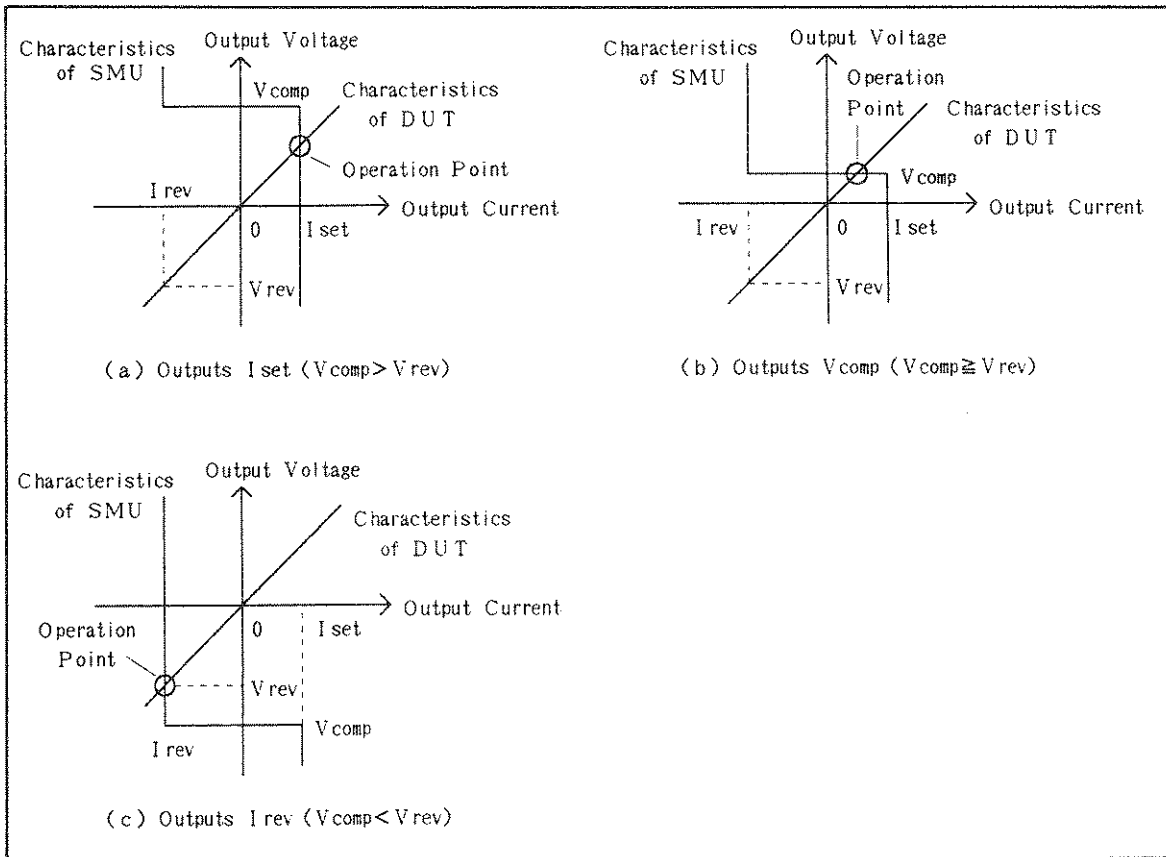
V compliance **and SMU Operation**

Power Compliance

Allowable Unit:

HPSMU, MPSMU

Allowable Measurement Mode:

Staircase sweep measurements

When using an SMU as a staircase sweep source, you can specify *power compliance* in addition to *V compliance* or *I compliance*.

If you specify *I compliance* and *power compliance* when using an SMU as a staircase sweep V source, the HP 4142B changes the I compliance at every voltage step. The I compliance is set to the smaller value of *I compliance* and *(power compliance)*/(step voltage), as shown in the following figure (a).

If you specify *V compliance* and *power compliance* when using an SMU as a staircase sweep I source, the HP 4142B changes the V compliance at every current step. The V compliance is set to the smaller value of *V compliance* and *(power compliance)*/(step current) as shown in figure (b).
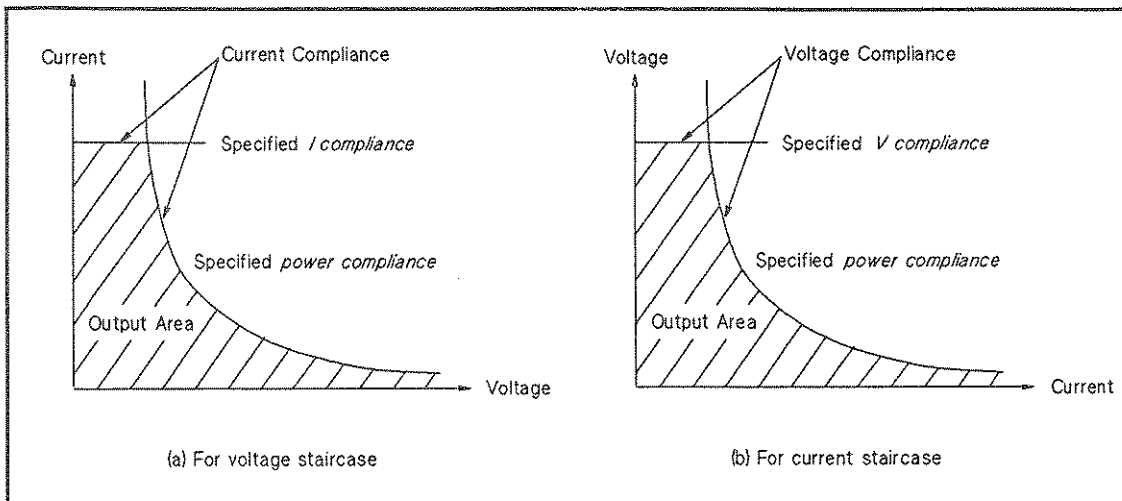
Staircase Sweep Source Power Compliance

If you specify *power compliance* and the staircase sweep source output reaches compliance during a sweep, the sweep stops, the specified *start* value is forced, and an F is displayed in the **ERROR/FAILURE** display. Dummy data (199.999E+99) is returned for measurement points not reached.

If the *(power compliance)*/(step value at a step) is greater than the maximum SMU output, compliance is set to the maximum SMU output.

If you specify *power compliance*, SMUs can be swept at their maximum output limits because the HP 4142B changes the V range during a V sweep. The following figure shows an example of the difference in SMU output when *power compliance* is set and when *power compliance* is not set.
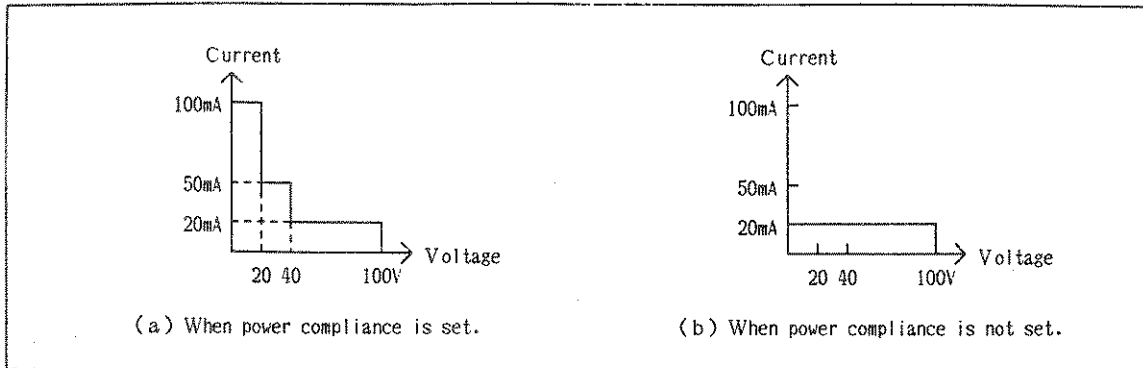
SMU Sweep I Source Output

NOTE

If you specify *power compliance*, the measurement time increases slightly because the HP 4142B adjusts V or I compliance for every sweep step to accommodate *power compliance*.

The SMU output is momentarily set to 0 V if V range changing occurs during a staircase sweep.

Limiter

Allowable Unit:

VS

The VS can be set to I limiter. The limiter value is automatically determined by the V output range. If output range = 20 V, then I limit = 100 mA. If the output range = 40 V, then I limit = 20 mA.

AVERAGING

Allowable Unit:

HPSMU, MPSMU, HCU, and VM

Allowable Measurement Mode:

Spot / Staircase sweep / Analog search / High speed spot measurements

To minimize the possibility of reduced HP 4142B measurement accuracy due to line frequency noise or other environmental noise, use the **AV** command to perform averaging. The averaging function of the HP 4142B arithmetically averages the results of two or more samples (A/D conversions). The **AV** command provides three averaging modes--AUTO, MANUAL, or POWER LINE CYCLE--as described in the following paragraphs.

AUTO Mode:

In the AUTO mode, the actual number of samples taken and averaged for a measurement is determined by the following expression:

number of samples = (required minimum samples)(*averaging number*)

where *averaging number* is the value specified in the **AV** command, and the required minimum sample is the minimum number of samples required to assure an accurate HP 4142B measurement. If you specify 1 for the *averaging number*, the HP 4142B performs the required minimum samples. For V measurements, the required minimum samples is 1. For SMU I measurements, the required minimum samples depends on the V output range and I measurement range as listed in the following table. The initial settings for averaging are *averaging number* = 1, *averaging mode* = AUTO.

Measurement times increase approximately 240 μs for each additional sample.

Required Minimum Samples for SMU I Measurements

		V Output Range [1]		
		2 V, 20 V, 40 V	100 V	200 V
I Meas. Range	1 nA to 10 μA	4	10	25
	100 μA to 1 A	1	1	1

[1] If the SMU is in I source mode, the V output range is the lowest range that includes *V compliance*.

MANUAL Mode:

In the MANUAL mode, the number of samples taken and averaged for a measurement is determined by the following expression.

number of samples = *averaging number*

Where *averaging number* is the value specified in the **AV** command. If you specify 1 for the *averaging number*, only 1 sample is taken for the measurement. To assure an accurate HP 4142B measurement, the *averaging number* you specify should be greater than or equal to the required minimum samples defined by the AUTO mode.

In the AUTO or MANUAL mode, measurement times increase approximately 240 μs for each additional sample.

POWER LINE CYCLE (PLC) Mode:

In the PLC mode, 32 samples are taken for each line frequency period (50 Hz: 20 ms, 60 Hz: 16.67 ms) specified in the **AV** command. To set to this mode, specify the *averaging number* with a negative number. Number of power line cycles is determined by the following expression:

number of power line cycles = - (*averaging number*)

For example, if 3 periods are specified, 96 samples are taken and averaged for the measurement.

Before the measurements, make sure the **FILTER** switch on the rear panel is set to the correct line frequency.

NOTE

During sweep measurements, averaging settings can be changed using the **AV** command.

FILTER

Allowable Unit:

HPSMU and MPSMU

Each SMU provides a low-pass filter (LPF) at the digital-to-analog converter (DAC) output. When the DAC output changes, a spike occurs. DAC output changes when the output value, compliance value, or output range changes. If the filter is ON, the spike is reduced to 1/30 of its unfiltered value. Output overshoot becomes 0.03% (typically) of the maximum value in the range. However, the SMU settling time may be longer. If the filter is ON, the SMU settling time is 200 μs to 500 ms. If the filter is OFF, the SMU settling time is 10 μs to 500 ms. The settling time of each depends on output value, output range, and compliance. The initial setting of the filter is ON, and can be set to ON or OFF using the FL command.

When an SMU filter is ON, the output wait time is set to the SMU settling time (200 μs to 500 ms). When an SMU filter is OFF, the output wait time is set to the SMU settling time if the SMU settling time (10 μs to 500 ms) is 5 ms or less. If the SMU settling time is greater than 5 ms, the output wait time is set to 5 ms. When an SMU filter is set to OFF, wait for the settling time of the SMU before making a measurement. Setting multi-channel output is usually much faster when SMU filters are OFF because the maximum wait time between output settings is 5 ms versus 500 ms when the SMU filter is on.

NOTE

- When an SMU filter is set to OFF, the DAC output settling time is 1/40 of the filter ON value. However, the actual settling time at the output terminal is limited by the slew rate, and thus is greater than the DAC output settling time. The slew rate depends on the test device, output range, and compliance value. The filter OFF output terminal settling time is still less than the filter ON value. For example, if the two following conditions apply, the filter OFF value is less than 50% of the filter ON value.

Voltage difference:	less than 50 V
I Compliance:	greater than 1 mA

  If above conditions do not apply, the filter OFF value will be 50% to 100% of the filter ON value.

- When using an SMU as a pulse source, set the filter of that SMU to OFF (to enable pulse output). SMU filter initial setting is ON.

AUTOMATIC SWEEP ABORT FUNCTION

Allowable Measurement Mode:

Staircase sweep / Staircase sweep with pulsed bias / Pulsed sweep / Pulsed sweep with pulsed bias measurements

To reduce sweep time and to prevent damage to the test device during sweep measurements, the *automatic sweep abort function* parameter of the **WM** command aborts a sweep if any of the following conditions occur:

1) If SMU or HCU output reaches compliance.

2) If VS output reaches I limit.

3) If a measurement value exceeds the specified measurement range.

4) If an SMU oscillates.

If a sweep aborts, the staircase sweep source forces the specified *start value*, the pulsed source and pulsed sweep source force the specified *base* value. An F is displayed in the **ERROR/FAILURE** display, and dummy data (199.999E+99) is returned for measurement points not reached.

NOTE

For staircase sweep measurements: if you set *power compliance* and the output of the SMU that you set *power compliance* reaches *power compliance*, *V compliance*, or *I compliance*, the HP 4142B automatically stops the measurement, even if you do not specify *automatic sweep abort function*.

If the HP 4142B receives an abort (**AB**) command, only the measurement data obtained before the sweep was aborted is stored in the output data buffer (dummy data is not stored).

OUTPUT AFTER SWEEP

Allowable Measurement Mode:

Staircase sweep / Staircase sweep with pulsed bias measurements

After staircase sweep or staircase sweep with pulsed bias measurements, you can set the output of staircase sweep source to either *start* value or *stop* value by the *output after sweep* of the **WM** command.

However, if the sweep is stopped by *power compliance*, *automatic sweep abort function*, or **AB** command, the *start* value is forced regardless of the *output after sweep* setting.

MEASUREMENT DATA MEMORY

When the HP 4142B performs a measurement, measurement data are stored in the internal output data buffer. Output data buffer size is 16383 bytes. The maximum number of data that can be stored in the output data buffer depends on the data format specified by the FMT command as follows.

- ASCII data with header (15 bytes) and "CR/LF^EOI" terminator (2 bytes): (default)
  - Spot measurement: Max. 963 data
  - Sweep measurement: Max. 1023 data

- ASCII data without header (12 bytes) and "," terminator (1 byte):
  - Spot measurement: Max. 1023 data
  - Sweep measurement: Max. 1023 data

- ASCII data without header (12 bytes) and "CR/LF^EOI" terminator (2 bytes):
  - Spot measurement: Max. 1170 data
  - Sweep measurement: Max. 1260 data

- BINARY data (4 bytes) and "CR/LF^EOI" terminator (2 bytes):
  - Spot measurement: Max. 2730 data
  - Sweep measurement: Max. 4095 data

- BINARY data (4 bytes) and "^EOI" terminator (0 byte):
  - Spot measurement: Max. 4095 data
  - Sweep measurement: Max. 4095 data

For more information about measurement data format, see the *HP-IB Command Reference Manual*.

The data buffer sends measurement data in the order in which it was stored. Therefore, if you transfer the measurement data after you perform the measurement twice, first measurement data is transferred from the HP 4142B first. If there is an output data buffer overflow, new measurement data is not stored and existing measurement data is maintained. Clear the output data buffer with the BC command. You can also clear it with the FMT, *RST, Device Clear, or by turning the HP 4142B off.

PROGRAM MEMORY

HP-IB commands can be stored locally in the internal program memory of the HP 4142B. Program memory size is 5000 bytes, enabling you to store approximately 500 commands. The commands stored in program memory can be grouped into as many as 99 programs. Because the programs are stored locally in the HP 4142B instead of in the controller, the following steps are eliminated, thus increasing execution speed.

1) Command transmission:
   Transmission of commands from the controller to the HP 4142B.

2) Command validation:
   Checking the syntax and content of transmitted commands.

3) Internal code conversion:
   Conversion of commands to the internal code of the HP 4142B.

For example, **DV** command execution time can be reduced by about 1 ms if the **DV** command is stored in internal program memory. Also, if frequently used command strings are stored in internal program memory, bus/controller activity is reduced to a minimum.

The following table lists the HP-IB commands that can be stored in program memory, and the number of bytes required for each command.

HP-IB Command	Optional Parameters	No. of Bytes [1]
AIV	0	12
	1	14
ASM	0	4
	1	6
ASV	0	10
	1	12
	2	16
AT	---	6
AV	0,1	6
AVI	0	12
	1	14
BC	---	2
CL	0,2,4,6,8	$2+n$
	1,3,5,7	$2+(n+1)$
CN	0,2,4,6,8	$2+n$
	1,3,5,7	$2+(n+1)$
DI	0	8
	1	12
DO	0,2,4,6	$4+n$
	1,3,5,7	$4+(n-1)$
DV	0	8
	1	12
DZ	0,2,4,6,8	$2+n$
	1,3,5,7	$2+(n+1)$
FL	1,3,5,7	$4+(n-1)$
	0,2,4,6,8	$4+n$
FMT	0,1	4
IN	0,2,4,6,8	$2+n$
	1,3,5,7	$2+(n+1)$
MM	1,3,5,7	$4+(n-1)$
	0,2,4,6,8	$4+n$
OS	---	2
PA	0,1	6
PDM	0	2
	1	4
PDI	0	10
	1	14
PDV	0	10
	1	14

[1] Where n is the number of optional parameters used in the command.

HP-IB Command	Optional Parameters	No. of Bytes [1]
PI	0	10
	1	14
PT	0,1	8
PV	0	10
	1	14
PWI	0	14
	1	18
PWV	0	14
	1	18
RI	---	6
RU	---	4
RV	---	6
RZ	0,2,4,6,8	$2+n$
	1,3,5,7	$2+(n+1)$
TI	0,1	6
TM	---	4
TV	0,1	6
VM	---	4
WI	0	14
	1	18
	2	20
WM	0,1	4
WS	0,1	4
WSI	0	14
	1	18
	2	20
WSV	0	14
	1	18
	2	20
WT	---	6
WV	0	14
	1	18
	2	20
XE	---	2
*SRE	---	4

[1] Where n is the number of optional parameters used in the command.

Using Program Memory

The following paragraphs describe how to store, execute, list, and scratch programs using the program memory function. See *HP-IB Command Reference Manual* for details on each command.

Storing Programs

Use the **ST** and **END** commands to store a program. The **ST** command indicates the start of the program and assigns its program number (*program#* is an integer from 1 to 99). Following the **ST** command, enter the desired HP-IB commands in the order you want them executed. Use the **END** command to indicate the end of a program. The HP 4142B continues to store HP-IB commands until the **END** command is received or until a memory overflow.

NOTE

If program memory overflows while storing a program, an **F** displays on the **ER-ROR/FAILURE Display**.

Executing Programs

To execute a stored program, use the **RU** or **DO** command with the *program#*.

1) Use the **RU** command with *start program#* and *stop program#* to execute a series of programs. For example, if **RU1,5** is sent to the HP 4142B, *program#1* through *program#5* executes in sequence.

2) Use the **DO** command to execute programs in a specified order. For example, if **DO2,5,4** is sent to the HP 4142B, these programs execute in this order: *program#2*, *program#5*, and *program#4*. You can specify up to eight programs for each **DO** command.

Listing Programs

Use the **LST?** command with the *program#* to place a program list in the output buffer. You can then read the program list using the controller.

Scratching (Deleting) Programs

Use the **SCR** command with a *program#* to scratch a program from program memory. If you do not specify a *program#* with the **SCR** command, all programs in program memory are scratched. If you store a new program using the same *program#* as an existing program, the old program is scratched and the new program is stored.

NOTE

Program memory is cleared only by the **SCR** command and when the HP 4142B is turned OFF. *RST and Device Clear (HP BASIC **CLEAR**) commands do not clear program memory.

Program Memory Sample Program

The following is a sample program for using the program memory function. A description of key program lines follows the program list.

Program List

```
10    ! SAMPLE PROGRAM FOR PROGRAM MEMORY
20    !
30    OPTION BASE 1
40    INTEGER B_ch, C_ch
50    DIM A$(7)[15], Exit$[1]
60    ASSIGN @Hp4142 TO 717
70    OUTPUT @Hp4142;"*RST"
80    !                                    Emitter    :  GNDU
90    B_ch=3                             ! Base       :  Ch#3
100   C_ch=2                             ! Collector  :  Ch#2
110   !
120   OUTPUT @Hp4142;"ST";1
130   OUTPUT @Hp4142;"DV";B_ch, 0, -3, 1.E-7      ! Vb=-3V
140   OUTPUT @Hp4142;"DV";C_ch, 0, 30, 1.E-7      ! Vc=30V
150   OUTPUT @Hp4142;"TI";C_ch, 0                 ! Icev Measurement
160   OUTPUT @Hp4142;"TI";B_ch, 0                 ! Ibev Measurement
170   OUTPUT @Hp4142;"END"
180   !
190   OUTPUT @Hp4142;"ST";2
200   OUTPUT @Hp4142;"DI";C_ch, 0, 1.E-2, 2       ! Ic=10mA
210   OUTPUT @Hp4142;"DI";B_ch, 0, 1.E-3, 2       ! Ib=1mA
220   OUTPUT @Hp4142;"TV";C_ch                    ! Vce(sat) Measurement
230   OUTPUT @Hp4142;"TV";B_ch                    ! Vbe(sat) Measurement
240   OUTPUT @Hp4142;"END"
250   !
260   OUTPUT @Hp4142;"ST";3                       ! Early Voltage
Measurement
270   OUTPUT @Hp4142;"DI";B_ch, 0, 2.E-5, 2       ! Ib=20uA
280   OUTPUT @Hp4142;"DV";C_ch, 0, 2, 1.E-2       ! Vc1=2V
290   OUTPUT @Hp4142;"TI";C_ch                    ! Ic1 Measurement
300   OUTPUT @Hp4142;"DV";C_ch, 0, 6              ! Vc2=6V
310   OUTPUT @Hp4142;"TI";C_ch                    ! Ic2 Measurement
320   OUTPUT @Hp4142;"END"
330   !
340   OUTPUT @Hp4142;"ST";4
350   OUTPUT @Hp4142;"DI";B_ch, 12, 0, 2          ! Ib=0A
360   OUTPUT @Hp4142;"DI";C_ch, 0, 1.E-3, 70      ! Ic=1mA
370   OUTPUT @Hp4142;"TV";C_ch                    ! BVceo Measurement
380   OUTPUT @Hp4142;"END"
390   !
400   OUTPUT @Hp4142;"ST";5
410   OUTPUT @Hp4142;"DZ"
420   OUTPUT @Hp4142;"END"
430   !
```

```
440    OUTPUT @Hp4142;"CN";B_ch, C_ch
450    LOOP
460      OUTPUT @Hp4142;"RU";1, 5
470      ENTER @Hp4142 USING "#, 15A, 2X";A$(*)
480      PRINT "Icev=           ";A$(1)[4, 15]
490      PRINT "Ibev=           ";A$(2)[4, 15]
500      PRINT "Vce(sat)=       ";A$(3)[4, 15]
510      PRINT "Vbe(sat)=       ";A$(4)[4, 15]
520      Ic1=VAL(A$(5)[4, 15])
530      Ic2=VAL(A$(6)[4, 15])
540      Vc1=2
550      Vc2=6
560      Va=(Vc1*Ic2-Ic1*Vc2)/(Ic2-Ic1)
570      PRINT "Early Voltage=      "PROUND(Va, -2)
580      PRINT "BVceo=              "A$(7)[4, 15]
590      PRINT
600      !
610      INPUT "Set the next device and hit ""Return"" key to continue, or enter
""E"" to stop", Exit$
620    EXIT IF Exit$="E"
630    END LOOP
640    !
650    OUTPUT @Hp4142;"CL"
660    BEEP
670    END
```

Result

Icev=	+000.272E-09
Ibev=	-0.07796E-09
Vce(sat)=	+0.06760E+00
Vbe(sat)=	+0.74656E+00
Early Voltage=	-160
BVceo=	+058.368E+00

Description

|	
120-170	Stores *program#1* in HP 4142B memory.
190-240	Stores *program#2* in HP 4142B memory.
260-320	Stores *program#3* in HP 4142B memory.
340-380	Stores *program#4* in HP 4142B memory.
400-420	Stores *program#5* in HP 4142B memory.
440	Sets the output switches to ON.
460	Executes the the five programs.
470	Enters measurement data into the string array variable, *A$*.
480-590	Displays the measurement results.
610-620	Decides whether to exit or continue.
650	Sets the output switches to OFF.

USING THE HP 4142B WITH EXTERNAL INSTRUMENTS

The HP 4142B can perform measurements synchronized with external instruments, such as C meters, precision voltmeters/ammeters, probers, and handlers, via the rear panel **TRIGGER INPUT** and **TRIGGER OUTPUT** terminals. The following paragraphs describe how to synchronize external instruments with the HP 4142B to perform measurements.

Trigger Output and Input Function

You can trigger external instruments from the HP 4142B via the **TRIGGER OUTPUT** terminal. You can initiate HP 4142B operation via the **TRIGGER INPUT** terminal, as described in the following paragraphs. The following figure shows the connection of the HP 4142B and an external instrument. The figure also shows the trigger output waveform from the **TRIGGER OUTPUT** terminal, and the trigger input waveform conditions. For trigger input, the HP 4142B is triggered by a negative-going (HIGH to LOW) TTL level trigger.
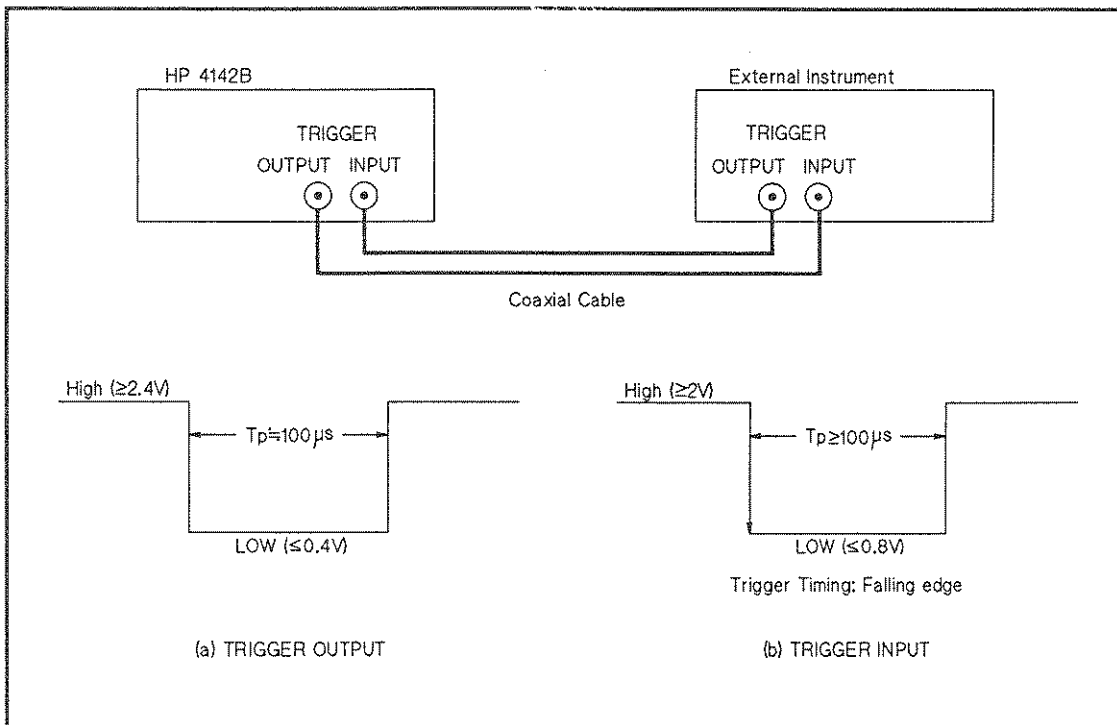
Trigger Output and Input

Triggering an External Instrument

To trigger an external instrument from the HP 4142B, execute the **OS** command. When the HP 4142B receives the **OS** command, the HP 4142B sends a trigger signal from **TRIGGER OUTPUT** terminal.

Externally Triggered HP 4142B Measurements

To externally trigger the HP 4142B to perform only measurements, set the *trigger mode* parameter of the **TM** command to **3**. The HP 4142B performs a measurement when it receives a negative-going (HIGH to LOW) TTL level trigger.

To pause program execution until the HP 4142B receives a trigger and completes measurements, include an **ENTER** statement of the HP BASIC in your measurement program. The **ENTER** statement pauses program execution until measurement data is entered into the measurement data buffer. Then, the **ENTER** statement reads the data, and program execution continues.

When an externally triggered HP 4142B measurement is complete, the HP 4142B automatically sends a trigger signal from the **TRIGGER OUTPUT** terminal.

Waiting for Trigger Signal from TRIGGER INPUT Terminal

The WAIT state (**WS**) command waits for a negative-going (HIGH to LOW) TTL level trigger signal via the **TRIGGER INPUT** terminal.
You can cause the execution of the commands following the **WS** (for example, V/I sourcing or measurement commands) to wait until an external instrument completes its operation and triggers the HP 4142B.

WS signals the HP 4142B CPU to check the software TRIGGER flag to determine whether an external trigger has been received (TRIGGER flag SET) or not (TRIGGER flag RESET). The TRIGGER flag is SET when the HP 4142B receives an external trigger. The TRIGGER flag is RESET when any of the following occur:

- If *RST or Device Clear executes.
- If **TM3** executes.
- If **TM** *trigger mode* is changed from **3** to another mode.
- If **OS** executes.
- After a **WS** WAIT state completes.
- If the trigger signal via the **TRIGGER INPUT** terminal triggers the measurements.

WS provides two WAIT states--*waiting mode* parameters **1** and **2**--as follows:

WS1 (default):
If the TRIGGER flag is SET when **WS1** is executed, the HP 4142B continues operation without waiting. If the TRIGGER flag is RESET, HP 4142B operation waits until an external trigger is received before continuing operation.

WS2:
When **WS2** executes, the HP 4142B operation waits--regardless of whether the TRIGGER flag is SET or RESET--and continues operation when the next external trigger is received.

Include the **WS** command in your measurement program immediately following the **OS** command. When **OS** executes, the HP 4142B triggers an external instrument to perform its operation. When the external instrument completes an operation, it triggers the HP 4142B, which is set to a WAIT state by **WS**, to perform its operation. Using **OS** and **WS** together, therefore, ensures that the HP 4142B and external instrument operations do not overlap.

If you want to end a WAIT state, execute the AB or *RST command. If you first send any other commands while the HP 4142B is in the WAIT state, the WAIT state ending commands are not effective because the command input buffer is full. In this case, use the Device Clear (CLEAR command in HP BASIC) to end the WAIT state.

NOTE

An external trigger can end a WAIT state independent of the *trigger mode* set by the **TM** command. To reduce programming complexity when using the **WS** command, set the **TM** command *trigger mode* to 1, 2, or 4. In **TM3**, WAIT state programming is complex because an external trigger signal can cause either of the following to occur:

Case 1--The HP 4142B is in a WAIT state when the external trigger is received. The HP 4142B ends the WAIT state.

Case 2--The HP 4142B is not in a WAIT state when the external trigger is received. The HP 4142B performs the measurement.

Waiting for Time or Trigger

Use the **PA** command to pause command execution or internal memory program execution. The pause lasts until the specified *wait time* has elapsed, or until a trigger is received (**XE** command, and **MM** command, HP BASIC **CLEAR** command, or the external trigger signal from **TRIGGER INPUT** terminal specified by the **TM** command). The trigger only releases the wait status and does not perform the measurements. The *wait time* setting area is from 0 to 99.9999s (100 μs resolution).

If you send the **PA** command without a *wait time* parameter, you can pause until a trigger is received.

Waiting for Command Execution Completion

Use the *OPC? query command to wait for the completion of the previous command execution before sending a command to the external instrument. This command tells the HP 4142B to return a 1 to the HP 4142B query buffer. The measurement program then reads the contents of the query buffer (via the **ENTER** statement). A 1 in the query buffer indicates that the HP 4142B has executed the *OPC? command, that is, the HP 4142B has completed the previous command execution. In effect, the *OPC? command serves to delay external instrument operation until the HP 4142B has completed its operation.

For example, refer to the following program segment and assume that you're forcing current from the HP 4142B, and measuring voltage via an external voltmeter, such as the HP 3457A. By including the *OPC? command immediately after the I forcing (**DI**) command, then by reading the contents of the query buffer with the **ENTER** statement, the measurement program waits until the query buffer is set to 1 before performing a measurement with the HP 3457A.

```
OUTPUT 717;"DI";1,0,1.0E-10,1
OUTPUT 717;"*OPC?"
ENTER 717; A$
OUTPUT Hpib;"DCV"
```

(Hpib: HP-IB address of the HP 3457A)
(**DCV** command: V measurement command of the HP 3457A)

NOTE

If you do not include the *OPC? command in your measurement program(s) to confirm HP 4142B operation completion, an external instrument may initiate operation prematurely.

CHAPTER 6

MISCELLANEOUS FUNCTIONS

CONTENTS

NOTES

INTRODUCTION

This chapter explains the functions that are not directly related to measurement. Included is information about front and rear panels, query commands, and the functions at power-on.

FRONT AND REAR PANELS

The following describes each key, indicator, and connector on the HP 4142B. See "Panel Overview" in chapter 2 for location on the panel of each item.

Front Panel

INTLK Terminal:

Used in conjunction with the INTERLOCK function of the HP 4142B. The HPSMU output can be as high as ±200 V, and the MPSMU output can be as high as ±100V. The voltages are also present at the GUARD conductors of the SMU output terminals. If the INTLK terminal is open, i.e., not shorted, SMU output is limited to ±42 V. Conversely, if you short the INTLK terminal (with a shorting switch or 0Ω termination), SMU output is enabled to the maximum output voltage of the unit.

For optimum measurement results when using the HP 4142B with a wafer prober or user-fabricated test fixture, use a grounded shielding box to minimize the effects of environmental noise and ambient light. Connect the INTLK terminal of the HP 4142B to a switch on the shielding box access door, so that when the door is open, voltage is limited to ±42 V.

WARNING

SHORTING THE INTLK TERMINAL ENABLES SMU OUTPUT TO EXCEED ±42 V. DANGEROUS VOLTAGES MAY BE PRESENT AT SMU OUTPUT CONNECTORS (CENTER CONDUCTORS AND INNER SHIELDS) WHEN THE INTLK TERMINAL IS SHORTED.

CIRCUIT COMMON (⩗) - CHASSIS GROUND (⏚) Terminals:

Used when making floating or grounded measurements. These terminals are shorted together for grounded measurements, and disconnected from each other (shorting-bar removed) for floating measurements. The **CIRCUIT COMMON** (⩗) terminal is connected to the outer conductors of the GNDU, SMU, HCU, VM, and VS connectors. The **CHASSIS GROUND** (⏚) terminal is tied to the HP 4142B chassis. If **CIRCUIT COMMON** is disconnected from **CHASSIS GROUND** and tied to external ground, the HP 4142B forces or measures voltage or current referenced to the external ground potential. For more information, see Chapter 3, "If the Test Device is Externally Grounded (Floating Measurements)."

WARNING

A POTENTIAL SHOCK HAZARD EXISTS IF THE CIRCUIT COMMON (⩗) TERMINAL IS NOT TIED TO CHASSIS GROUND (⏚) (SHORTING-BAR DISCONNECTED FOR FLOATING MEASUREMENTS). DO NOT TOUCH ANY OF THE HP 4142B FRONT PANEL CONNECTORS AT ANY TIME WHILE A FLOATING MEASUREMENT IS IN PROGRESS.

DO NOT FLOAT THE CIRCUIT COMMON TERMINAL AT VOLTAGES GREATER THAN ±42 V REFERENCED TO CHASSIS GROUND. FAILURE TO HEED THIS WARNING MAY RESULT IN DAMAGE TO YOUR HP 4142B.

HIGH VOLTAGE Lamp:

Indicates that the HP 4142B output is >±42 V.

WARNING

DO NOT TOUCH THE SMU OUTPUT CONNECTORS WHEN THE HIGH VOLTAGE LAMP IS LIT. THIS LAMP INDICATES THAT DANGEROUS VOLTAGES OF UP TO ±200 V MAY BE PRESENT AT THESE CONNECTORS.

Blank Panel:

For unused slots.

CAUTION

To prevent thermal damage to HP 4142B units, be sure that Blank Panels (part number 04142-60012) are installed in all unused slots.

ERROR/FAILURE Display:

The front panel **ERROR/FAILURE** Display indicates the status of the HP 4142B by displaying one of the following: 0 to 8, A, C, E, F, H, or P. See the descriptions below.

0: Displayed during normal operating conditions: The HP 4142B or specified plug-in unit(s) passed Self-Test or Self-Calibration.

C: The HP 4142B or specified plug-in unit(s) are now performing Self-Test or Self-Calibration.

E: The HP 4142B received an undefined command; all succeeding commands did not execute. Check for correct command syntax and out-of-range parameters.

F: Command execution not allowed due to present HP 4142B settings; normally caused by an incorrect input command sequence.

If **F** is displayed during a sweep measurement, one of the following occurred:
1) Measurement aborted: SMU reached *power compliance*.
2) Measurement aborted by *automatic sweep abort function*.
3) Output data buffer measurement data overflow.

H: All SMU, HCU, and VS outputs are disabled and output switches are disconnected to prevent SMU/HCU/VS damage due to an overvoltage or overcurrent, or a momentary power loss. Check for incorrect settings and check ac power. Reconnect the output switches by using the **CN** command.

1 to 8, A, P:
The HP 4142B failed. If a plug-in unit failed, 1 to 8 indicates the slot # of the failed unit. A indicates a failure in the HP 4142B analog-to-digital conversion (ADC) section; P indicates a failure in the HP 4142B central processing unit (CPU). If more than one failure occurs, the **ERROR/FAILURE** display indicates the last failure detected during Self-Test or Self-Calibration. Self-Test and Self-Calibration are performed in the following order.
1) CPU
2) ADC
3) All plug-in units by slot # (ascending), except the AFU.
4) AFU

To determine whether a multiple failure occurred, execute the *TST? command. This command performs the Self-Test again and displays test results on the controller.

If a plug-in unit fails, remove the failed unit from slot and use a known-good unit to perform your measurement. Contact the nearest Hewlett-Packard Sales and Service office for assistance.

If an **A, E, F, H, P,** or 1 to 8 is displayed, details about errors (error codes) are stored in the error register. Refer to *HP-IB Command Reference Manual* for error code descriptions.

The **ERROR/FAILURE** Display and error register are initialized (set to **0** and "0, 0, 0, 0", respectively) when the *RST, **ERR?**, or Device Clear (HPBASIC **CLEAR** statement) is executed. The error register is also initialized when **CA** or *TST? command execution begins.

POWER ON/OFF Switch:
>Secondary ac Line switch. Used in conjunction with the rear panel **LINE ON/OFF** switch. Both switches must be set to **ON** to operate the HP 4142B. To simplify turning the HP 4142B on or off, keep the **POWER ON/OFF** switch setting **ON** at all times, and use the **LINE ON/OFF** switch only.
>
>Line power is applied to the HP 4142B if the rear panel **LINE ON/OFF** switch is set to **ON**, even if the front panel **POWER ON/OFF** switch is set to **OFF**. To completely power down the HP 4142B, set the rear panel **LINE ON/OFF** switch to **OFF**, regardless of the **POWER ON/OFF** switch setting.
>
>If you install or remove a plug-in unit, either set the **POWER ON/OFF** switch to **OFF** or set the **LINE ON/OFF** switch to **OFF**, depending on which is most accessible.

LOCAL/SELF TEST Key:
>If the HP 4142B is in remote control, this key sets the HP 4142B to local control. If the HP 4142B is in local control, this key starts the HP 4142B Self-Test/Self-Calibration. If the HP 4142B is set to local lockout, this key is disabled.

MEASURING Lamp:
>Indicates that the HP 4142B is performing a measurement.

HP-IB Status Indicators:
>These LEDs indicate HP 4142B SRQ, LISTEN, TALK, and REMOTE HP-IB status. See "Status Byte" in this chapter for more information on SRQ.

GNDU Terminal:
>Triaxial GNDU output terminal. The GNDU terminal output is Circuit Common voltage (0 V). The GNDU maintains 0 V output while sinking up to ±1.6 A.

ZERO CHECK Terminal:
>Circuit Common reference terminal for checking HP 4142B output voltage.

SLOTS:
>For plug-in units. The slot number is 1 to 8 from left to right. The slot numbers indicate the number of slot for each plug-in unit.

FORCE and SENSE Terminals of the HP 41420A HPSMU:
Maximum output and input is 200V/1A.

```
WARNING
```

VOLTAGES UP TO ±200 V MAY BE PRESENT AT THE FORCE, SENSE, AND
GUARD TERMINALS. DO NOT TOUCH THESE TERMINALS IF THE FRONT PAN-
EL HIGH VOLTAGE LAMP IS LIT.

FORCE and SENSE Terminals of the HP 41421B MPSMU:
Maximum output and input is 100V/100mA.

```
WARNING
```

VOLTAGES UP TO ±100 V MAY BE PRESENT AT THE FORCE, SENSE, AND
GUARD TERMINALS. DO NOT TOUCH THESE TERMINALS IF THE FRONT PAN-
EL HIGH VOLTAGE LAMP IS LIT.

FORCE and SENSE Terminals of the HP 41422A HCU:
Maximum output and input is 10V/10A.

HP 41424A VS Terminal:
Maximum output is 40V/100mA.

HP 41424A VM Terminal:
Maximum input is 40 V.

MONITOR Port of the HP 41425A AFU:
See chapter 4, "Analog Search Measurements"

Rear Panel

LINE ON/OFF Switch:
> Main ac line switch. Used in conjunction with the front panel **POWER ON/OFF** switch. Both switches must be set to **ON** to operate the HP 4142B. Note that line power is applied to the HP 4142B if this switch is set to **ON**, even if the front panel **POWER ON/OFF** switch is set to **OFF**.

HP-IB ADDRESS Switch:
> For setting the HP-IB address (0 to 30) of the HP 4142B. The new HP-IB address is recognized only at power on.

HP-IB Connector:
> 24-pin connector for connecting the HP 4142B to HP-IB.

FILTER Switch:
> For setting measurement integration time to minimize the effects of line-frequency noise. Set to the ac line frequency.

TRIGGER INPUT Terminal:
> For triggering the HP 4142B. The HP 4142B is triggered (a measurement is performed) when a negative-going TTL level pulse (from HIGH--5 V to LOW--0 V) is applied. Trigger signals must be ≥ 100 µs. See chapter 5, "Using the HP 4142B with External Instruments" for more information.

TRIGGER OUTPUT Terminal:
> Sends a HIGH (5 V) TTL level signal. When the HP 4142B receives a trigger output command (**OS**), this terminal sends a LOW (0 V) TTL level pulse for approximately 100 µs. See chapter 5, "Using the HP 4142B with External Instruments" for more information.

LINE Input Receptacle:
> For connecting the HP 4142B ac line cord.

LINE VOLTAGE SELECTOR Switch:
> For setting the ac line voltage (100 V, 120 V, 220 V, or 240 V). See Chapter 1 for more information on power requirements.

LINE FUSE Holder:
> The HP 4142B line fuse is installed in this holder. See chapter 1 for more information on the line fuse.

QUERY COMMANDS

Query commands request HP 4142B operation status data, and return status results to the query buffer. This query data can then be read by the controller. The following table lists the query commands and output data associated with each command. Refer to the *HP-IB Command Reference Manual* for details about query command syntax and output data syntax.

The HP 4142B provides two separate buffers for query data and measurement data. When you perform a data buffer read, the query buffer is always checked first. If there is no query data, a read is performed on the measurement data buffer. Only query data for the most recent query command is stored in the query buffer. The query buffer is cleared by the **BC**, **FMT**, **∗RST**, or Device Clear (HP BASIC **CLEAR**) command.

Query Commands

Command	Query Command Output Data
ERR?	The first four error codes.
∗IDN?	Model number (HP 4142B) and ROM version.
LOP?	Plug-in unit operation status.
∗LRN?	Plug-in unit output and measurement settings.
LST?	Contents of program memory.
NUB?	Number of measurement data stored in data buffer.
∗OPC?	After ∗OPC? executes, a "1" is placed in the query buffer.
∗SRE?	Mask condition of the status byte.
∗STB?	Contents of the status byte.
∗TST?	Self-Test results.
UNT?	Model # and hardware version of installed plug-in units.
WNU?	Number of steps in sweep measurement.

NOTE

∗OPC? facilitates the synchronizing of HP 4142B and external instrument operations. See "Waiting for Command Execution Completion" in this chapter for details.

Query command output data is always stored in the query buffer in ASCII format regardless of the measurement data output format.

HP-IB CAPABILITY

The following table lists the HP-IB capabilities and functions of the HP 4142B. These functions provide the means for an instrument to receive, process, and transmit, commands, data, and status over the HP-IB bus.

HP-IB Interface Capability

Interface Function	Code	Description
Source Handshake	SH1	Complete capability
Acceptor Handshake	AH1	Complete capability
Talker	T6	Basic Talker: YES Serial Poll: YES Talk Only Mode: NO Unaddress if MLA (my listen address): YES
Listener	L4	Basic Listener: YES Unaddress if MTA (my talk address): YES Listen Only Mode: NO
Service Request	SR1	Complete capability
Remote/Local	RL1	Complete capability (with local lockout)
Parallel Poll	PP0	No capability
Device Clear	DC1	Complete capability
Device Trigger	DT1	Complete capability
Controller Function	C0	No capability
Driver Electronics	E1	Open Collector

The HP 4142B responds to the following HP BASIC statements:

- **ABORT** (IFC)
- **CLEAR** (DCL or SDC, same as *RST command)
- **LOCAL** (GTL)
- **LOCAL LOCKOUT** (LL0)
- **REMOTE**
- **SPOLL** (Serial Poll)
- **TRIGGER** (GET, same as **XE** command)

Status Byte Sample Program

The following is a sample program that uses Bit 3 (Interlock Open) and Bit 5 (Error) of the status byte, and a sample program that uses Bit 4 (Set Ready). A description of key program lines follows each program list.

Program List 1

```
10    ! BVceo Measurement using High Speed Spot Function
20    !
30    DIM A$[15], Err$[23]
40    ASSIGN @Hp4142 to 717
50    OUTPUT @Hp4142;"*RST"
60    !                                    Emitter   : GNDU
70    B_ch=3                            ! Base      : Ch#3
80    C_ch=2                            ! Collector : Ch#2
90    Ib=0
100   Ic=1.E-3
110   Vc_comp=70
120   !
130   ON INTR 7 GOTO Service
140   ENABLE INTR 7;2
150   OUTPUT @Hp4142;"*SRE";40
160   !
170   OUTPUT @Hp4142;"CN";B_ch, C_ch
180   OUTPUT @Hp4142;"DI";B_ch, 12, Ib, 2
190   OUTPUT @Hp4142;"DI";C_ch, 0, Ic, Vc_comp
200   OUTPUT @Hp4142;"TV";C_ch
210   OUTPUT @Hp4142;"CL"
220   !
230   ENTER @Hp4142;A$
240   PRINT "Bvceo= ";A$[4, 15];"[V]
250   DISABLE INTR 7
260   STOP
270   !
280 Service: !
290   OUTPUT @Hp4142;"CL"
300   Status_byte=SPOLL(@Hp4142)
310   IF BIT(Status_byte, 3)=1 THEN
320     DISP "NOT INTERLOCKED"
330   ELSE
340     OUTPUT @Hp4142;"ERR?"
350     ENTER @Hp4142;Err$
360     DISP "ERROR ";Err$
370   END IF
380   BEEP
390   END
```

Description 1

130	When an SRQ interrupt is received, go to line labeled "Service."
140	Enables the interrupt.
150	Removes masks from Bit3 and Bit5.
170	Sets the SMU output switches to ON.
180-200	Forces current and performs measurement.
210	Sets the SMUs output switches to OFF.
230-240	Enters and displays measurement data.
250	Disables the interrupt.
260	Stops the program.
290	Sets the SMU output switches to OFF.
300	Enters value of the status byte.
310-370	Displays the message.

STATUS BYTE

Status byte bits are turned off or on (0 or 1) to represent HP 4142B operation status. When you execute a Serial Poll (HPBASIC **SPOLL**) command, the controller reads the contents of the status byte, and responds accordingly. When an unmasked status bit is set to "1", the HP 4142B sends an SRQ to the controller, causing the controller to perform an interrupt service routine.

Status

The following table lists status byte contents.

Status Byte Contents

Bit 7 (128)	Bit 6 (64)	Bit 5 (32)	Bit 4 (16)	Bit 3 (8)	Bit 2 (4)	Bit 1 (2)	Bit 0 (1)
Shut Down	RQS	Error	Set Ready	Inter- lock Open	not used	Wait	Data Ready

( ): Decimal Value. Use this value when specifying a bit in a command.

A brief description of each bit follows:

Bit 0: Data Ready
This bit is set to "1" when measurement data or Query command response data is stored in the output data buffer. It is reset to "0" when all the stored data has been transferred to the controller, or when the HP 4142B receives a ***RST**, **BC**, **FMT**, or Device Clear (HP BASIC **CLEAR**) command.

Bit 1: Wait
This bit is set to "1" by the **PA** or **WS** command. It is reset to "0" when the waiting condition is complete, or when the HP 4142B receives a ***RST** or Device Clear command.

Bit 2: not used
This bit is always set to "0".

Bit 3: Interlock Open
This bit is set to "1" if either of the following occurs when the **INTLK** terminal is not terminated (open).
    1) The HP 4142B outputs a voltage that exceeds ±42 V.
    2) *V compliance* greater than ±42 V is specified.
This bit is reset to "0" when the HP 4142B receives a Serial Poll, ***RST**, or Device Clear command.

Bit 4:   Set Ready
          This bit is reset to "0" when any of the following occur, and set to "1" when the
          corresponding operation is complete.
          1) HP-IB command is received.
          2) The SELF-TEST Key on the front panel is pushed.
          3) A trigger signal is received at the TRIGGER INPUT Terminal.

Bit 5:   ERROR
          This bit is set to "1" when an error causes 1 to 8, A, E, F, H, or P to be displayed in
          the ERROR/FAILURE Display. It is reset to "0" when the HP 4142B receives a Serial
          Poll, *RST, ERR?, CA, *TST?, or Device Clear command. The ERROR/FAILURE
          Display is cleared to 0 by all these commands except the Serial Poll command.

Bit 6:   RQS (Request Service)
          This bit is set to "1" whenever any other unmasked bit is set to "1". This causes the
          HP 4142B to send an SRQ to the controller. It is reset to "0" when the HP 4142B
          receives a Serial Poll, *RST, or Device Clear command. This bit is the only non-
          maskable status bit.

Bit 7:   Shut Down
          This bit is set to "1" when an error causes H to be displayed in the ERROR/
          FAILURE Display. It is reset to "0" when the HP 4142B receives a Serial Poll, *RST,
          or Device Clear command. The ERROR/FAILURE Display is cleared to 0 by all
          these commands except the Serial Poll command.

NOTE

If Bit 3, Bit 5, or Bit 7 are masked, they are not reset to 0 by a Serial Poll com-
mand. Also, if these bits are masked, set to "1", then unmasked, a Serial Poll
command does not reset them to "0".

After a masked bit is set to "1", removing the mask does not set Bit 6 to "1". That
is, the HP 4142B does not send an SRQ to the controller. Therefore, if you re-
move a mask from a bit, it is usually best to do it at the beginning of the program.

Commands

The commands related to the status byte are listed below.
    (1)   *STB?
           This command sends the contents of the status byte to the controller. The status
           byte is not cleared by this command.
    (2)   *SRE
           This command removes the mask from the specified bits. All bits except Bit 6
           are masked in the initial setting. If parameter is 0, this command masks all bits.
    (3)   *SRE?
           This command outputs data about which bits of the status byte are masked.

Program List 2

```
10     ! Ic-Vce Measurement using Sweep with Pulsed Bias Function
20     !
30     OPTION BASE!
40     INTEGER B_ch, C_ch, Vc_no_step, Ib_no_step, Varl, Var2
50     INTEGER Data_no, Plot_no, X
60     DIM A$(3)[1615]
70     REAL Vc(101)
80     ASSIGN @Hp4142 TO 717
90     OUTPUT @Hp4142;"*RST"
100    !                                    Emitter    :  GNDU
110    B_ch=3                           !  Base      :  Ch#3
120    C_ch=2                           !  Collector :  Ch#2
130    Vc_start=0
140    Vc_stop=20
150    Vc_no_step=101
160    Ic_comp=.1
170    Ib_start=2.E-4
180    Ib_step=1.E-4
190    Ib_no_step=3
200    !
210    OUTPUT @Hp4142;"CN";B_ch, C_ch
220    OUTPUT @Hp4142;"WV";C_ch, 1, 0, Vc_start, Vc_stop, Vc_no
_step, Ic_comp
230    OUTPUT @Hp4142;"FL";0, B_ch
240    OUTPUT @Hp4142;"PT";0, 1.E-3, 5.E-2
250    OUTPUT @Hp4142;"MM";5, C_ch
260    OUTPUT @Hp4142;"RI";C_ch, -19
270    !
280    Data_no=1
290    ON INTR 7 GOSUB Service
300    ENABLE INTR 7;2
310    OUTPUT @Hp4142;"PI";B_ch, 0, 0, Ib_start, 2
320    OUTPUT @Hp4142;"*SRE16;XE"
330    !
340    CALL Icvc_graph(Vc_start, Vc_stop, 0, Ic_comp)
350    Vc_step=(Vc_stop-Vc_start)/(Vc_no_step-1)
360    FOR Var1=1 TO Vc_no_step
370      Vc(Var1)=Vc_start+(Var1-1)*Vc_step
380    NEXT Var1
390    !
400    Plot_no=1
410    FOR Plot_no=1 TO Ib_no_step
420      LOOP
430      EXIT IF Plot_no<Data_no
440      END LOOP
450      FOR Var1=1 TO Vc_no_step
460        Ic=VAL(A$(Plot_no)[16*(Var1-1)+4;12])
470        PLOT Vc(Var1), Ic
480      NEXT Var1
490      PENUP
500    NEXT Plot_no
510    !
520    OUTPUT @Hp4142;"CL"
530    STOP
540    !
```

```
550 Service:  !
560    Status_byte=SPOLL(@Hp4142)
570    OUTPUT @Hp4142;"*SRE0"
580    !
590    ENTER @Hp4142;A$(Data_no)
600    !
610    Data_no=Data_no+1
620    IF Data_no<=Ib_no_step THEN
630       Ib=Ib_start+(Data_no-1)*Ib_step
640       ENABLE INTR 7;2
650       OUTPUT @Hp4142;"PI";B_ch, 0, 0, Ib
660       OUTPUT @Hp4142;"*SRE16;XE"
670    END IF
680    RETURN
690    !
700    END
710    !
720    SUB Icvc_graph(X_axis_min, X_axis_max, Y_axis_min, Y_axis_max)
730       !
740       GINIT
750       GRAPHICS ON
760       CONTROL CRT, 12;1
770       PRINT CHR$(12)
780       !
790       Xmax=100*MAX(1, RATIO)
800       Ymax=100*MAX(1, 1/RATIO)
810       !
820       LORG 6
830       MOVE Xmax/2, Ymax
840       LABEL "COLLECTOR CHARACTERISTICS"
850       DEG
860       LDIR 90
870       CSIZE 4.5
880       MOVE 0, Ymax/2
890       LABEL "Ic(A)"
900       LORG 4
910       LDIR 0
920       MOVE Xmax/2, 0
930       LABEL "Vce(V)"
940       !
950       VIEWPORT .16*Xmax, .91*Xmax, .15*Ymax, .9*Ymax
960       !
970       FRAME
980       WINDOW X_axis_min, X_axis_max, Y_axis_min, Y_axis_max
990       AXES(X_axis_max-X_axis_min)/10,(Y_axis_max-Y_axis_min)/10,
X_axis_min, Y_axis_min
1000      CLIP OFF
1010      CSIZE 4, .5
1020      LORG 6
1030      FOR I=X_axis_min TO X_axis_max STEP (X_axis_max-X_axis_ min)/2
1040         MOVE I, Y_axis_min
1050         LABEL I
1060      NEXT I
```

```
1070    CSIZE 3.8, .5
1080    LORG 8
1090    FOR I=Y_axis_min TO Y_axis_max STEP (Y_axis_max-Y_axis_min)/2
1100      MOVE X_axis_min, I
1110      LABEL USING "#, MD.DE";I
1120    NEXT I
1130    CLIP ON
1140      !
1150  SUBEND
```

Description 2

110-260	Sets up the conditions for staircase sweep with pulsed bias measurements.
280	Sets sweep data # to 1.
290	When SRQ interrupt is received, go to "Service" subroutine. In this program, the SRQ is received after measurements are performed.
300	Enables the interrupt.
310	Sets up and forces the first Base current.
320	Removes mask from Bit 4 and performs measurements.
340	Calls subprogram to display a graphics frame.
350-380	Calculates Collector voltage for each step, and stores these values in an array variable.
400	Sets sweep data plot# to 1.
410-500	Plots the sweep data. Loops between line 420 and line 440 until sweep data is ready for plotting.
530	Stops the program.
560	Clears the SRQ (resets Bit 6).
570	Disables the SRQ (masks all bits).
590	Enters the measurement data.
610	Increments the sweep data#.
620-670	If not final Base current, sets up next base current, outputs base current, enables interrupt, removes mask from Bit 4, and performs measurement.
680	Returns to main program.
720-1150	Subprogram to display a graphics frame.

SELF-CALIBRATION

To minimize output drift and measurement fluctuations caused primarily by changes in the ambient temperature, the HP 4142B provides a Self-Calibration function. Self-Calibration is performed automatically when you turn your HP 4142B on. After a minimum 40 minute warm-up period and before you begin to use your HP 4142B, perform Self-Calibration again by pressing the **LOCAL/SELF TEST** key, or by executing the **CA** command. Self-Calibration should be performed every 30 minutes, or if the ambient temperature changes by more than 3°C (6°F).

Auto-Calibration

The Auto-Calibration function of the HP 4142B automatically performs Self-Calibration at 30 minute intervals after the output switches of all plug-in units have been set to OFF for 30 minutes. Use the **CM** command to enable or disable the Auto-Calibration function. Auto-Calibration is enabled when you turn the HP 4142B on.

SELF-TEST

The HP 4142B has a Self-Test function that automatically checks its basic operation when you turn your HP 4142B on.

You can also initiate the Self-Test at any time by pressing the **LOCAL/SELF TEST** key, or by executing the *TST? command.

When the HP 4142B starts Self-Test, a **C** is displayed in the **ERROR/FAILURE** display and the **LOCAL/SELF TEST** key indicator lights. When Self-Test is finished, the **LOCAL/SELF TEST** key indicator light goes out and a **0** (No error) is displayed.

If a **1** to **8**, **A**, **P** is displayed, the HP 4142B failed Self Test. If a plug-in unit failed, **1** to **8** indicates the slot # of the failed unit. **A** indicates a failure in the HP 4142B analog-to-digital conversion (ADC) section; **P** indicates a failure in the HP 4142B central processing unit (CPU). If more than one failure occurs, the **ERROR/FAILURE** display indicates the last failure detected during Self-Test or Self-Calibration. Self-Test and Self-Calibration are performed in the following order:

    1) CPU
    2) ADC
    3) All plug-in units by slot # (ascending), except the AFU.
    4) AFU

To determine whether a multiple failure occurred, execute the *TST? command. This command performs the Self-Test again and displays the test results on the controller.
If Self-Test is performed by pressing the **LOCAL/SELF TEST** key, the test results are not returned.

If a plug-in unit fails, remove the failed unit from the slot and use a known-good unit to perform your measurement. Contact the nearest Hewlett-Packard Sales and Service office for assistance.

When the HP 4142B performs Self-Test, the HP 4142B also performs Self-Calibration.

NOTE

Units that fail Self-Test are disabled except *TST? command, and can only be enabled by the **RCV** command. However, the **RCV** command should be used only for servicing the HP 4142B. DO NOT use this command during normal operation.

INITIAL SETTINGS

The HP 4142B is initialized at power ON, or when an *RST or Device Clear (HP BASIC CLEAR) command executes. The following table lists the initial settings of the HP 4142B.

Initial Settings (1 of 3)

Setting Item	Initial Setting		Command
SMU/HCU/VS output	open		**CN** and **CL**
SMU/HCU/VS output switch	OFF		**CN** and **CL**
SMU filter	ON		**FL**
VM operation mode	grounded measurement		**VM**
I measurement range of SMU/HCU	spot staircase sweep analog search	Auto	**RI**
	1ch pulsed spot pulsed sweep sweep with pulsed bias 2ch pulsed spot pulsed sweep with p_bias	1	
V measurement range of VM	spot staircase sweep	Auto	**RV**
	1ch pulsed spot pulsed sweep sweep with pulsed bias	40V	
automatic sweep abort function	OFF		**WM**
output after sweep of staircase sweep source	start value		**WM**

1 Compliance range

Setting Item	Initial Setting		Command
hold time	staircase sweep	Os	WT
	1ch pulsed spot pulsed sweep sweep with pulse bias 2ch pulsed spot pulsed sweep with p_bias		PT
	analog search		AT
delay time	staircase sweep	Os	WT
	analog search		AT
pulse width	0.001 s		PT
pulse period	0.01 s		PT
primary pulse channel	unit specified by **PDV/PDI**		PDM
search operation mode	negative feedback search		ASM
search measurement mode	search SMU V measurement		ASM
feedback integration time	0.005 s		ASM
trigger	**XE, TV, TI,** or **GET** [1]		TM
averaging mode	Auto		AV
averaging number	1		AV
auto calibration	ON		CM
measurement data output format	ASCII (with header and CR/LF)		FMT
output data buffer	cleared		BC
program memory	cleared [2]		SCR
status byte	all bits masked except Bit 6		*SRE
ERROR/FAILURE display	displays **0**		---
error code register	cleared		ERR?

[1] GET is the HP-IB bus trigger command. For HP BASIC, use the **TRIGGER** command.

[2] Only at power ON. Program memory is not cleared by an *RST or Device Clear (HP BASIC **CLEAR**) command.

Setting Item	Initial Setting	Command
sweep source parameters	cleared	WV, WSV WI, WSI
pulse source parameters	cleared	PV, PI PDV, PDI
pulse sweep source parameters	cleared	PWV, PWI
search SMU parameters	cleared	ASV
sense SMU parameters	cleared	AVI, AIV

APPENDIXES

CONTENTS

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APPENDIX A

MANUAL CHANGES

HP 4142Bs may vary slightly, depending on the Serial Number and the version of the ROM-based firmware. The information in this manual applies directly to an HP 4142B with the serial number prefix listed on the title page of this manual. This appendix contains information for customizing this manual, so that all the information pertains to the HP 4142B that you are using.

To customize this manual for your HP 4142B, refer to the following table, and make all of the manual changes corresponding to the serial number of your HP 4142B and version of the ROM-based firmware.

To see the version of your HP 4142B ROM-based firmware, send:

```
10    OUTPUT 717;"*IDN?"
20    ENTER 717;A, B, Version
30    DISP Version
40    END
```

Manual Changes by Serial Number

Serial Prefix or Number	ROM Version	Make Manual Changes
2839Jxxxxx and below	2.52 and below	1
	Above 2.52	No changes

• Change 1

Throughout this manual, delete any descriptions referring to the HP 41422A HCU, and to the 40 V, 100 V, and 200 V range of the Search SMU in the Analog feedback measurements.

You cannot use your HP 4142B with the HP 41422A HCU, and cannot use the 40 V, 100 V, and 200 V range of the Search SMU in Analog feedback Measurements.

NOTES

NOTES

APPENDIX B

SPECIFICATIONS

The following two tables list complete HP 4142B specifications and supplemental performance characteristics. The specifications are the performance standards or limits against which the HP 4142B is tested. When the HP 4142B is shipped from the factory, it meets the specifications. The characteristics are not specifications but are typical characteristics included as additional information for the operator.

GENERAL INFORMATION

Basic Function:

Performs high speed DC parameter measurements.

Plug-in Units:

The HP 4142B provides eight plug-in unit slots, and any combination of units can be specified.* The five types of plug-in units available, and their slot requirements, are listed below.

HP 41420A Source/Monitor Unit (SMU), 40μV-200V/20fA-1A: 2 slots
HP 41421B Source/Monitor Unit (SMU), 40μV-100V/20fA-100mA: 1 slot
HP 41422A High Current Source/Monitor Unit (HCU),
                                    40μV-10V/20nA-10A: 2 slots
HP 41424A Voltage Source/Voltage Monitor Unit (VS/VMU): 1 slot
HP 41425A Analog Feedback Unit (AFU)*: 1 slot

* Only one AFU can be installed per HP 4142B.

Maximum Power Consumption:

Total SMU, HCU and VS/VMU power consumption must not exceed 32W. Power consumption for these units is calculated as follows.

SMUs (HP 41420A and HP 41421B):

V Source Mode:

Voltage Range	Power
2V	20Ic
20V	20Ic
40V	40Ic
100V	100Ic
200V	200Ic

where Ic is the current compliance setting.

I Source Mode:

Voltage Compliance	Power
$Vc \leq 20$	20Io
$20 < Vc \leq 40$	40Io
$40 < Vc \leq 100$	100Io
$100 < Vc \leq 200$	200Io

where Vc is the voltage compliance setting; Io is output current.

Output switch set to OFF: 0W

Maximum Power Consumption (continued):

  HCU (HP 41422A):

    V Source Mode:

      Power = 10 + 20Ic(pulse width/pulse period)

    where Ic is the current compliance setting.

    I Source Mode:

      Power = 10 + 20Io(pulse width/pulse period)

    where Io is the output current.

    Output switch set to OFF: 0 W

  VS/VMU (HP 41424A):

Voltage Range	Power
20 V	2.2 W
40 V	0.88 W

    Output switch set to OFF: 0 W

  AFU (HP 41425A): 0 W

Furnished Unit:
Ground Unit (GNDU), 0 V Output, Maximum Sink Current: 1.6 A

Measurement Modes:
Spot, Staircase Sweep, 1 ch Pulsed Spot, 2ch Pulsed Spot, Pulsed Sweep, Staircase Sweep with Pulsed Bias, Pulsed Sweep with Pulsed Bias, and Analog Search Measurements

Measurement and Output Accuracy Conditions:
Measurement and output accuracies are specified at the front panel connector terminals, referenced to the ZERO CHECK terminal (except for the HCU) under the following conditions:

1. $23°\pm5°$C--accuracies double from $5°$ - $17°$C, and $29°$ - $40°$C.
2. After a minimum 40 minute warm-up period.
3. After performing Self-calibration.
4. Averaging mode: AUTO; Averaging number: 1
5. SMU Filter: ON (For SMUs)
6. Kelvin connection (For SMU, HCU, and GNDU voltage accuracy)

Accuracies for the HCU are specified between the high and low sense terminals on the front panel of the HCU.

HP 4142B Modular DC Source/Monitor

Ground Unit (GNDU): 1 channel (Kelvin connection)
    Maximum Sink Current: 1.6A
    Output Voltage: 0V ±500μV

Maximum Voltage Between Common and Ground: ≤42V

Plug-in Unit Control Functions:
    Spot Measurement Mode: Outputs and measures voltage and current.

    Staircase Sweep Measurement Mode: Outputs and measures sweep voltage and current. One channel can sweep current or voltage while up to 8 channels can measure current or voltage. A second channel can be slaved to the first channel (dual synchronous sweep). Linear or log sweeps can be performed.
        Number of Steps: 2 - 1001
        Hold Time: 0 - 655.35s, 10ms resolution.
        Delay Time: 0 - 65.535s, 1ms resolution.

    1ch Pulsed Spot Measurement Mode: Outputs and measures V and I pulses.
        Pulse Width: 1ms to 50ms, 100μs steps (SMU or VS).
                   100μs to 1ms, 100μs steps (HCU).
        Pulse Period: 10ms to 500ms, 100μs steps.

    2ch Pulsed Spot Measurement Mode: Outputs and measures V and I pulses in synchronization with a pulse of another channel.
        Pulse Width: 100μs to 800μs, 100μs steps
                  pulse width of another channel is set to about 1ms.
        Pulse Period: same as 1ch Pulsed Spot

    Pulsed Sweep Measurement Mode: Outputs and measures V and I sweep pulses.
        Number of Steps and Hold Time: same as Staircase Sweep Measurement Mode.
        Pulse Width and Pulse Period: same as 1ch Pulsed Spot Measurement Mode.

    Staircase Sweep with Pulse Bias Measurement Mode: Outputs sweep V or I and performs measurements in synchronization with a periodic pulse of another channel.
        Number of Steps and Hold Time: same as Staircase Sweep Measurement Mode.
        Pulse Width and Pulse Period: same as 1ch Pulsed Spot Measurement Mode.

    Pulsed Sweep with Pulsed Bias Measurement Mode: Outputs pulsed sweep V or I and performs measurements in synchronization with a periodic pulse of another channel.
        Number of Steps and Hold Time: same as Staircase Sweep Measure ment Mode.
        Pulse Width and Pulse Period: same as 1ch Pulsed Spot Measurement Mode.
        Analog Search Measurement Mode: Performs measurements using the HP 41425A Analog Feedback Unit.

HP 4142B Modular DC Source/Monitor (continued)

Pulse Measurement Restrictions (for SMU):
Current Output Range [1]: 10nA to 1A
Maximum Voltage for 10nA to 10µA Range [1]: 2V
Current Measurement Range:
    10nA to 1A Range (when voltage output range is 2V)
    100µA to 1A Range (when voltage output range is 20V to 200V)
Current Limit (Compliance) Minimum Setting Value [1]:
    2nA (when voltage output range is 2V)
    20µA (when voltage output range is 20V to 200V)
SMU filter: OFF
Averaging Function: Not available

[1] Not applicable if an SMU is set to constant source and does not perform measurements.

Pulse Measurement Restrictions (for HCU):
Maximum Pulse Duty: 1% (when current range is 10A)
                       10% (when current range is 1mA to 1A)

Memory Function:
Data Memory: Measurement results can be stored. Maximum number of data are 4095 (binary) or 1023 (ASCII).
Program Memory: Program code can be stored.

Input/Output Functions:
External Trigger Input: TTL-level Negative Logic; pulse width must be > 100µs. For continuing a paused program when using the HP 4142B's internal program memory.
External Trigger Output: TTL-level Negative Logic; pulse width is approximately 100µs. For controlling peripherals when using the HP 4142B's internal program memory.
HP-IB Function: The HP 4142B may be interfaced to any HP-IB capable computer or instrument.
HP-IB Interface: SH1, AH1, T6, L4, SR1, RL1, PP0, DC1, DT1, C0, E1.

HP 41420A Source/Monitor Unit (SMU) 40µV-200V/20fA-1A

Measures current when operating as a voltage source; measures voltage when operating as a current source. Kelvin connections can be used. The HP 41420A's source and measurement ranges, resolution, and accuracy specifications are listed in the following table.

Voltage Range	Setting Resolution	Measurement Resolution	Accuracy	Maximum [1] Current
±2V	100µV	40µV	±0.05%±1mV	1A
±20V	1mV	400µV	±0.05%±10mV	1A ($|V_o| \leq 14V$)
				700mA ($14V < |V_o|$)
±40V	2mV	800µV	±0.05%±20mV	350mA
±100V	5mV	2mV	±0.05%±50mV	125mA
±200V	10mV	4mV	±0.05%±100mV	50mA

Current Range	Setting Resolution	Measurement Resolution	Accuracy [1], [2]	Maximum Voltage
±1nA	50fA	20fA	±1%±(0.1+0.2Vo/100)%±5pA	200V
±10nA	500fA	200fA		
±100nA	5pA	2pA	±0.5%±(0.1+0.2Vo/100)%	
±1µA	50pA	20pA		
±10µA	500pA	200pA		
±100µA	5nA	2nA		
±1mA	50nA	20nA	±0.2%±(0.1+0.2Vo/100)%	
±10mA	500nA	200nA		

[1] Vo is output voltage.
[2] ±n% of specified output or measurement value, ±n% of range value.

	HP 41420A Source/Monitor Unit (SMU) 40µV-200V/20fA-1A (continued)			
Current Range	Setting Resolution	Measurement Resolution	Accuracy [1],[2]	Maximum [3] Voltage
±100mA	5µA	2µA	±0.2%±(0.1+0.2Vo/100)%	200V (|Io|≤50mA)
				100V (50mA<|Io|)
±1A	50µA	20µA	±0.5%±(0.1+0.2(Vo/100)%	200V (|Io|≤50mA)
				100V(50mA <|Io|≤125mA)
				40V(125mA <|Io|≤350mA)
				20V(350mA <|Io|≤700mA)
				14V (700mA<|Io|)

[1] ±n% of specified output or measurement value, ±n% of range value.
[2] Vo is output voltage.
[3] Io is output current.

Current Over-Range:
15% of Range (0% at 1A range)

Current/Voltage Limiting (Compliance):
Limit Setting Range:
Current Limit: 1pA to maximum current for each voltage range.
Voltage Limit: 0V to maximum voltage for each current range.

Limit Setting Accuracy: same as V/I Setting Accuracy.

Current Limit Setting Accuracy for Opposite Polarity:
1nA to 10nA Range: V/I setting accuracy ±10% of range
100nA to 1A Range: V/I setting accuracy ±2% of range.

HP 41421B Source/Monitor Unit (SMU) 40µV-100V/20fA-100mA

Measures current when operating as a voltage source; measures voltage when operating as a current source. The following table lists the HP 41421B's source and measurement ranges, resolution, and accuracy specifications.

Voltage Range	Setting Resolution	Measurement Resolution	Accuracy	Maximum Current
±2V	100µV	40µV	±0.05%±1mV	100mA
±20V	1mV	400µV	±0.05%±10mV	
±40V	2mV	800µV	±0.05%±20mV	50mA
±100V	5mV	2mV	±0.05%±50mV	20mA

Current Range	Setting Resolution	Measurement Resolution	Accuracy [1,2]	Maximum [3] Voltage
±1nA	50fA	20fA	±1%±$(0.1+0.2V_o/100)$%±5pA	100V
±10nA	500fA	200fA		
±100nA	5pA	2pA	±0.5%±$(0.1+0.2V_o/100)$%	
±1µA	50pA	20pA		
±10µA	500pA	200pA	±0.2%±$(0.1+0.2V_o/100)$%	
±100µA	5nA	2nA		
±1mA	50nA	20nA		
±10mA	500nA	200nA		
±100mA	5µA	2µA		100V ($|I_o| \leq 20$mA)
				40V (20mA $< |I_o| \leq 50$mA)
				20V (50mA $\leq |I_o|$)

[1] ±n% of specified output or measurement value, ±n% of range value.
[2] V_o is output voltage.
[3] I_o is output current.

HP 41421B Source/Monitor Unit (SMU) 40µV-100V/20fA-100mA (continued)

Current Over-Range:
15% of Range (0% at 100mA Range)

Current/Voltage Limiting (Compliance):
Limit Setting Range:
Current Limit: 1pA to maximum urrent for each voltage range.
Voltage Limit: 0V to maximum voltage for each current range.

Limit Setting Accuracy: same as V/I Setting Accuracy.

Current Limit Setting Accuracy for Opposite Polarity:
1nA to 10nA Range: V/I setting accuracy ±10% of range
100nA to 100mA Range: V/I setting accuracy ±2% of range.

HP 41422A High Current Source/Monitor Unit (HCU)

Measures current when operating as a pulsed voltage source; measures voltage when operating as a pulsed current source. Kelvin connections should be used and low terminals of the HCU should be connected the GNDU. The HP 41422A's source and measurement ranges, resolution, and accuracy specifications are listed in the following table.

Voltage Range	Maximum Voltage	Setting Resolution	Measurement Resolution	Accuracy [1]	Maximum [3] Current
±2V	2V	200µV	40µV	±0.5%±10mV	
±20V	10V	2mV	400µV	±0.5%±100mV	10A

Current Range	Setting Resolution	Measurement Resolution	Accuracy [1,2]	Maximum [3] Voltage
±1mA	100nA	20nA		
±10mA	1µA	200nA	±0.5%±(0.2+0.2Vo/20)%	
±100mA	10µA	2µA		10V
±1A	100µA	20µA	±1%±(0.2+0.2Vo/20)%	
±10A	1mA	200µA	±2%±(0.2+0.2Vo/20)%	

[1] ±n% of specified output or measurement value, ±n% of range value.
[2] Vo is output voltage.
[3] Polarity of the current and voltage must be same (see below).
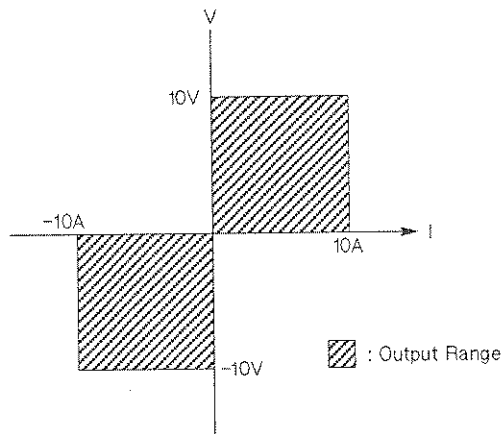
HP 41422A High Current Source/Monitor Unit (HCU)

Current Over-Range:
   15% of Range (0% at 10A Range)

Current/Voltage Limiting (Compliance):
   Limit Setting Range:
      Current Limit: 1µA to maximum current for each voltage range.
      Voltage Limit: 0V to maximum voltage for each current range.

   Limit Setting Accuracy: same as V/I Setting Accuracy.

HP 41424A Voltage Source/Voltage Measurement Unit (VS/VMU)

Provides two voltage source (VS) channels that can monitor current, and two voltage monitor (VM) channels. When used as a differential voltmeter, the two voltage monitor channels (VM1 and VM2) are used together as one channel. The HP 41424A's ranges, resolutions, and accuracies are listed in the following table.

Voltage Source:

Voltage Range	Setting Resolution	Accuracy	Maximum Current
20V	1mV	±0.1%±10mV	100mA
40V	2mV	±0.1%±20mV	20mA

VS Current Measurement:

Current Range	Measurement Resolution	Accuracy
20mA	20µA	±3%±200µA
100mA	100µA	±3%±1mA

Voltage Monitor:

Voltage Range	Measurement Resolution	Accuracy
2V	40µV	±0.05%±1mV
20V	400µV	±0.05%±10mV
40V	800µV	±0.05%±20mV

Differential Voltmeter:

Voltage Range	Measurement Resolution	Accuracy [1]	Max. Common Voltage
0.2V	4µV	$\pm0.2\%\pm2.5\times10^{-6}\,Vin\pm0.4mV$	40V
2V	40µV	$\pm0.1\%\pm25\times10^{-6}\,Vin\pm2mV$	

[1] Vin is the input voltage of VM2.

VM Over-Range:
    15% of Range (0% at 40V Range)

HP 41425A Analog Feedback Unit (AFU)

Converges current or voltage on one SMU (Sense SMU) to a specified target value by controlling the output voltage of another SMU (Search SMU).

Maximum Target Voltage:
HP 41420A: 180V
HP 41421B: 90V

Maximum Target Current:
HP 41420A: 900mA
HP 41421B: 90mA

Target Value Setting Resolution:
Same as sense SMU measurement range setting resolution

Target Value Setting Over-Range:
Current: 0%
Voltage: -10%

Target Value Convergence Accuracy: (Sense SMU measurement accuracy)
±(0.1% of Setting Value) ±(0.1% of sense SMU measurement range)

Search Voltage Range:
2V,20V,40V,100V, and 200V (HP 41420A only)

Search Start Voltage Accuracy:
(0.5% of Setting) ±(0.5% of Voltage Range)

Search Stop Voltage Accuracy:
3% of Voltage Range

HP 41425A Analog Feedback Unit (continued)

Ramp Rate Ranges and Resolution:

Search Voltage Range			
2V		20V	
Ramp Rate	Resolution	Ramp Rate	Resolution
0.5 - 5V/s	0.05V/s	5.5 - 50V/s	0.5V/s
5.5 - 50V/s	0.5V/s	55 - 500V/s	5V/s
55 - 500V/s	5V/s	550 - 5kV/s	50V/s
550 - 5kV/s	50V/s	5.5k - 50kV/s	500V/s

Search Voltage Range (continued)			
40V		100V	
Ramp Rate	Resolution	Ramp Rate	resolution
10 - 50V/s	1V/s	25 - 50V/s	2.5V/s
55 - 100V/s	5V/s	55 - 250V/s	5V/s
110 - 500V/s	10V/s	275 - 500V/s	25V/s
550 - 1kV/s	50V/s	550 - 2.5kV/s	50V/s
1.1k - 5kV/s	100V/s	2.75k - 5kV/s	250V/s
5.5k - 10kV/s	500V/s	5.5k - 25kV/s	500V/s
11k - 50kV/s	1000V/s	27.5k - 50kV/s	2500V/s
55k - 100kV/s	5000V/s	55k - 100kV/s	5000V/s

Search Voltage Range (continued)	
200V	
Ramp Rate	Resolution
55 - 500V/s	5V/s
550 - 5kV/s	50V/s
5.5k - 50kV/s	500V/s
55k - 100kV/s	5000V/s

HP 41425A Analog Feedback Unit (continued)

Feedback Integration Time Ranges and Resolution:

Search Voltage Range			
2V		20V	
Integ. Time	Resolution	Integ. Time	Resolution
50μ - 450μs	50μs	5μ - 45μs	5μs
500μ - 4.5ms	500μs	50μ - 450μs	50μs
5m - 45ms	5ms	500μ - 4.5ms	500μs
50m - 450ms	50ms	5m - 45ms	5ms

Search Voltage Range (continued)			
40V		100V	
Integ. Time	Resolution	Integ. Time	Resolution
2.5μ - 4.5μs	0.5μs	1.0μ - 4.5μs	0.5μs
5μ - 45μs	5μs	5μ - 45μs	5μs
50μ - 450μs	50μs	50μ - 450μs	50μs
500μ - 4.5ms	500μs	500μ - 4.5ms	500μs
5m - 25ms	5ms	5m - 10ms	5ms

Search Voltage Range (continued)	
200V	
Integ. Time	Resolution
0.5μ - 4.5μs	0.5μs
5μ - 45μs	5μs
50μ - 450μs	50μs
500μ - 4.5ms	500μs
5m	-

GENERAL SPECIFICATIONS

Self-Test Function:
At power on, the HP 4142B automatically verifies its own operational status. Self-test can be performed at any time via HP-IB.

Maximum Installation Inclination Angle:
±20° from horizontal (during operation)

Warm-up Time:
Allow the HP 4142B to warm-up for at least 40 minutes before performing measurements.

Operating Temperature Range:
5°C to 40°C

Operating Humidity Range:
5% to 80%RH

Storage Temperature Range:
-40°C to 70°C

Storage Humidity Range:
≤90%RH at 65°C

Power Requirements:
100/120/220V±10%; 240V-10%+5%, 48-66Hz (maximum 750VA)

Dimensions (in mm):
426W by 235H by 676D (approximately)

Weights (approximate):
HP 4142B Mainframe: 23kg   HP 41422A: 2.2kg
HP 41420A: 3kg   HP 41424A: 2kg
HP 41421B: 2kg   HP 41425A: 2kg

Safety Considerations:
The HP 4142B compliies with UL-1244, CSA bulletin 556B, and IEC-348 safety standards, and is shipped from the factory in a safe condition.

The following supplemental performance characteristics are not guaranteed specifications but are typical characteristics included as additional operation information.

HP 4142B Modular DC Source/Monitor

Ground Unit (GNDU):
Capacitance Load: $\leq 10\mu F$
Cable Impedance: $\leq 1\Omega$ (Force side), $\leq 10\Omega$ (Sense side)

Plug-in Unit Control Functions:
Hold Time Setting Accuracy: 0.5% + 1ms
Delay Time Setting Accuracy: 0.5% + 1ms
Pulse Width Accuracy: 0.5% + 100µs (SMU or VS)
                         0.5% + 20µs (HCU)
Pulse Period Accuracy: 0.5% + 100µs

where the pulse width is defined as below;

Pluse Width
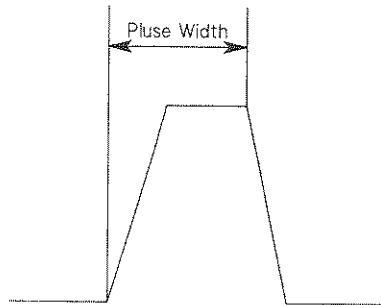
Memory Function:
Program Memory: Can store approximately 500 program steps; up to 99 separate programs. Programs can be executed individually.

HP 41420A and 41421B SMUs

Capacitance Load: $\leq 1000pF$

Guard Capacitance: $\leq 900pF$

Shield Capacitance: $\leq 5000pF$

NOTE

When connecting cables or test devices with capacitance values greater than the allowable Capacitance Load, Guard, and Shield capacitance values, SMUs may oscillate.

HP 41420A and 41421B SMUs (continued)

Cable Impedance:
Force side: $\leq 0.7\Omega$ (when forcing 1A), $\leq 10\Omega$ (when forcing 100mA)
Sense side: $\leq 10\Omega$

NOTE

If cable impedance is greater than the allowable value when performing a measurement and using a Kelvin connection, measurement results may be invalid.

Voltage Measurement Input Resistance: $\geq 10^{12}\Omega$

Guard Voltage Offset: ± 1mV

Noise Characteristics: (typical, with SMU Filter ON)
Voltage Source Noise: 0.01% of Range (rms)
Current Source Noise: 0.1% of Range (rms)
Voltage Monitor Noise: 0.02% of Range (p-p value)
Current Monitor Noise: 0.2% of Range (p-p value)

Voltage/Current Output Overshoot:
0.03% of Range (typical, with SMU Filter ON)

Maximum Slew Rate: 0.2V/µs (with SMU Filter ON)

Range Switching Transient Noise: (typicallly, with SMU Filter ON)
Voltage Range Switching: 250mV
Current Range Switching: 10mV

Residual Impedance when not using Kelvin connection: 0.2Ω (typical)

Measurement Time:
Force (Current or Voltage): Approximately 3.5ms
Measurement (Current or Voltage): Approximately 4ms
(When using an HP 9000 Series 300 Model 310 computer. Including data transfer time when set to the 20V and 100mA ranges.)

HP 41422A HCU

Current Limit Setting for Opposite Polarity: 0.1% of current range

Capacitance Load: ≤3.5 nF

Inductance Load: ≤1 μH

Cable Resistance:
Force side: ≤150 mΩ (High and low when forcing 10 V and 10 A, respectively. See below for details.)
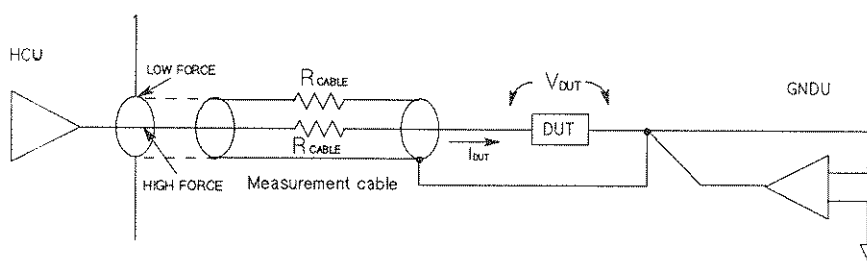
$$R_{CABLE} \leq \frac{13 - V_{DUT}}{2 * I_{DUT}}$$

$$R_{CABLE} \leq \frac{4}{I_{DUT}}$$

$$I_{DUT} \leq 10$$

$$V_{DUT} \leq 10$$
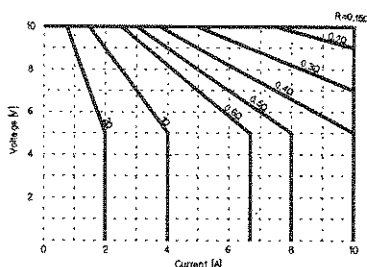
Cable resistance should be satisfied above conditions.

Sense side: ≤10 Ω (high and low, respectively)

NOTE

If the cable resistance is greater than the allowable value when performing a measurement and using a kelvin connection, the measurement results may be invalid.

Noise Characteristics: (typical)
Voltage Source Noise: 0.01% of Range (rms)
Current Source Noise: 0.1% of Range (rms)
Voltage Monitor Noise: 0.02% of Range (p-p value)
Current Monitor Noise: 0.2% of Range (p-p value)

Maximum slew rate: 0.3V/μs (typical)

HP 41424A VS/VMU

Voltage Source:
Output Impedance: 0.2Ω (typical)
Capacitance Load: $\leq 10\mu F$
Slew Rate: $0.2V/\mu s$
Current Limit Accuracy: +20% of Limit
Noise: (typically) 0.005% of Range (rms)

Voltage Monitor:
Input Impedance: $\geq 100M\Omega$
Leakage Current: $\leq 2nA$ (when measuring 0V)
Noise: 0.01% of Range (p - p value)
Differential Voltage Monitor Noise: 0.02% of Range (p - p value)

Measurement Time: (same as SMU measurement times, except for ranging)
Voltage Force: Approximately 3.5ms (at 20V Range)
Voltage Monitor: Approximately 4ms (at 20V Range)
Differential Voltage Monitor: Approximately 5.5ms (at 2V Range)

HP 41425A AFU

Ramp Rate Setting Accuracy:
0.5 to 5V/s: 30% of setting $\pm 0.5V/s$
5.5 to 50V/s: 30% of setting $\pm 5V/s$
55 to 500V/s: 30% of setting $\pm 50V/s$
550 to 5kV/s: 30% of setting $\pm 500V/s$
5.5k to 50kV/s: 30% of setting $\pm 5kV/s$

Feedback Integration Time Setting Accuracy: 30% of setting

Ramp Voltage Stop Delay Time: $5\mu s$ (typical)

Measurement Time:
Approximately 12ms* for detecting MOSFET threshold voltage (Vth) when the specified drain current is $1\mu A$, under optimum measurement setting conditions.

* From the time a measurement is triggered, until measurement results are stored in the output data buffer.

General Characteristics

Auto Calibration:
Automatically calibrates for offset errors (all units) every 30 minutes,.

Allowable Temperature Drift after Calibration: $\pm 3°C$ ($\pm 6°F$)

APPENDIX C

ACCESSORIES AND OPTIONS

ACCESSORIES

The following table shows the available accessories for the HP 4142B.

HP 4142B Available Accessories

Description	Model or Part Number
Interactive Measurement and Analysis (IMA) Software	HP 16276A/L
Test Fixture	HP 16088A
Connector Plate (for GNDU, SMUs and INTLK)	04142-60021
Connector Plate (for GNDU, HCUs, VS/VMU and INTLK)	04142-60031
Triaxial Cable (3 m for GNDU)	04142-61632
Triaxial Cable (1.5 m for GNDU)	04142-61633
Quadraxial Cable (3 m for SMU)	41420-61601
Quadraxial Cable (1.5 m for SMU)	41420-61603
Triaxial Cable (1.5 m for SMU)	16058-61603
Triaxial Cable (3 m for SMU)	04145-61622
Triax Cover (for SMU)	1250-1708
Dual-coaxial Cable (3 m for HCU)	41422-61601
Dual-coaxial Cable (1.5 m for HCU)	41422-61602
Coaxial Cable (1.5 m for VS/VMU, or INTLK)	04142-61636
Coaxial Cable (3 m for VS/VMU, or INTLK)	04145-61630
Adaptor Cable (for INTLK/VS/VMU - HP 16058A)	04142-61631

HP 16276A/L Interactive Measurement Analysis (IMA) Software
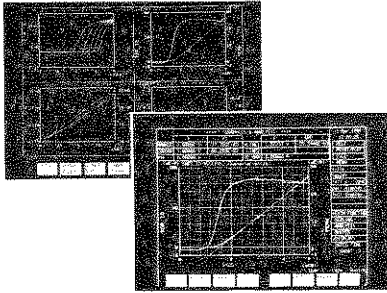
This software turns the HP 4142B into a fully automatic semiconductor dc parameter analyzer by providing an interactive, softpanel user interface. Without having to program, you can quickly make measurements in several different applications.

Besides the softpanel operation, you can easily perform automated measurements and analysis using the Analysis Instruction Set (AIS), which is a subprogram library.

This software operates on HP BASIC.

HP 16088A Test Fixture
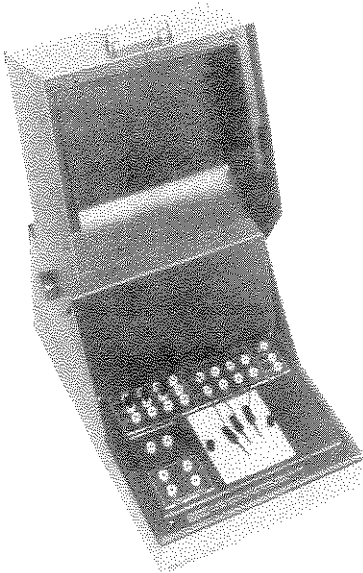
Shielded test fixture for packaged test devices. Equipped with the following two interchangeable socket boards for test device:

16058-60004 Blank Teflon Board
16088-60010 Universal Socket Board

The following socket boards are available (not furnished with HP 16088A):

16088-60001 4-pin TO-package Socket Board
16088-60002 28-pin Dual-in-line Socket Board
16088-60003 18-pin Dual-in-line Socket Board
16088-60004 8-pin TO-package Socket Board
16088-60005 10-pin TO-package Socket Board
16088-60006 12-pin TO-package Socket Board
16088-60007 TO-3/TO-66 Socket Board (kelvin connection)
16088-60008 3-pin In-line Socket Board (kelvin connection)
16088-60009 Axial Lead Socket Board (kelvin connection)

This fixture can be connected the following units:

SMU: 4 (for kelvin) to 8 (for non-kelvin) channels
HCU: 2 channels
VS or VM: 4 channels
GNDU: 1 channel
INTLK: 1 channel
AUX: 2 channels
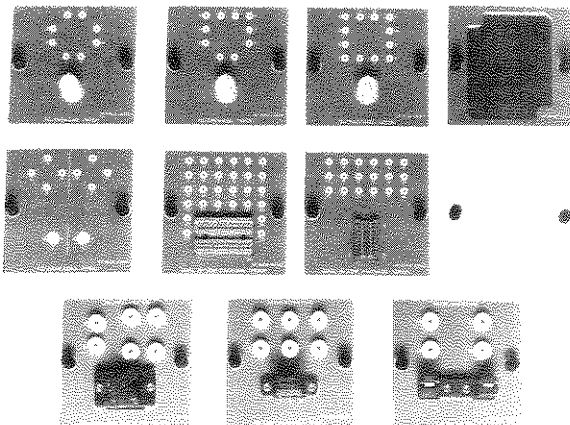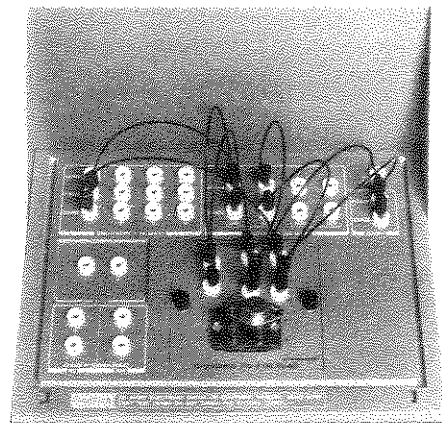
Socket Boards   **Interconnections Example**

HP 16088A Circuit Diagram
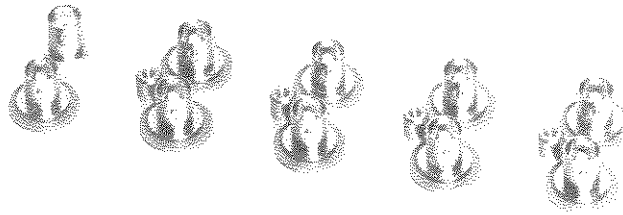
Front View

Rear View

For interfacing the HP 4142B with a wafer prober. The connector assignments are:

04142-60031 Connector Plate
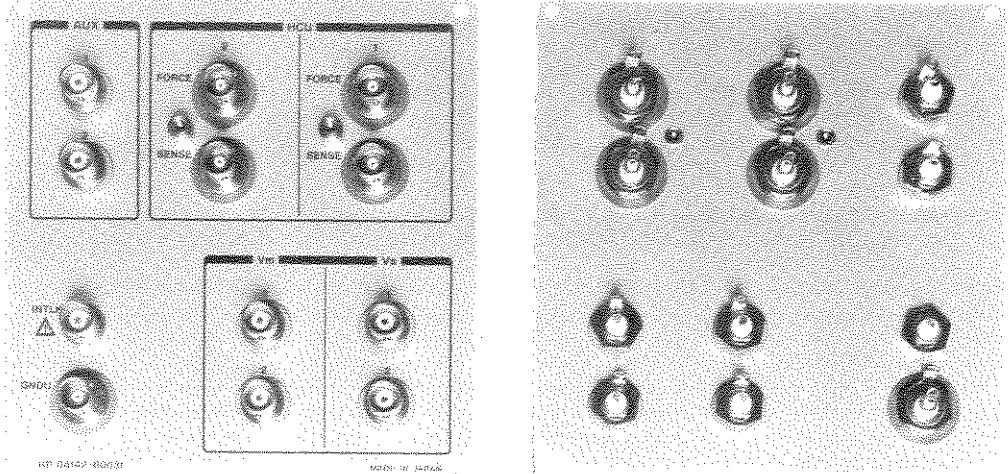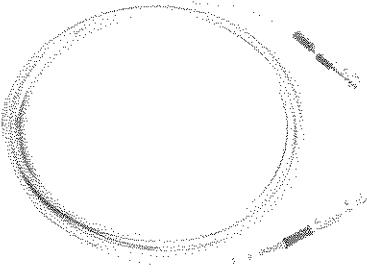

Front View   Rear View

For interfacing the HP 4142B with a wafer prober. The connector assignments are:
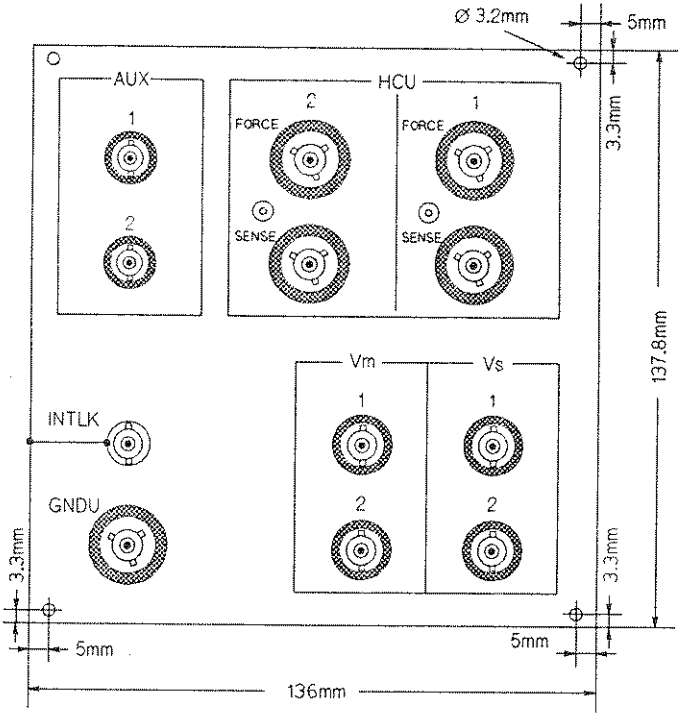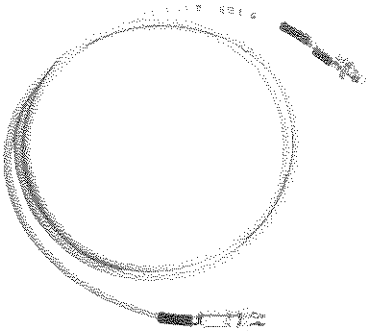
04142-61632 GNDU Triaxial Cable (3 m)

For connecting the HP 4142B GNDU. Reference data is:

Capacitance between FORCE and COMMON lines: 1100 pF
Resistance of FORCE line: 150 mΩ
Capacitance between FORCE and SENSE lines: 700 pF

04142-61633 GNDU Triaxial Cable (1.5 m)

For connecting the HP 4142B GNDU. Reference data is:

Capacitance between FORCE and COMMON lines: 550 pF
Resistance of FORCE line: 80 mΩ
Capacitance between FORCE and SENSE lines: 350 pF
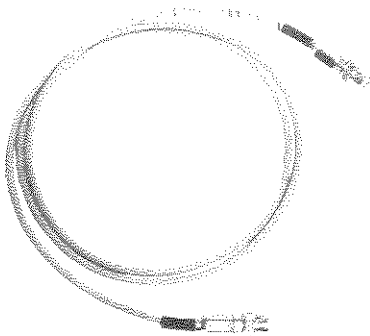
41420-61601 SMU Quadraxial Cable (3 m)
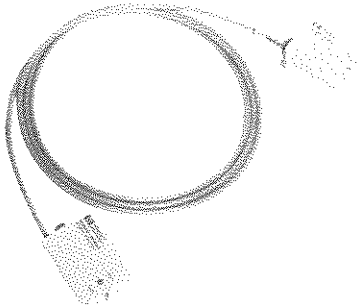
For connecting the HPSMU or MPSMU. Reference data is:

Capacitance between GUARD and FORCE lines (guard capacitance): 300 pF
Capacitance between GUARD and COMMON lines: 2400 pF
Resistance of FORCE line: 300 mΩ

41420-61603 SMU Quadraxial Cable (1.5 m)
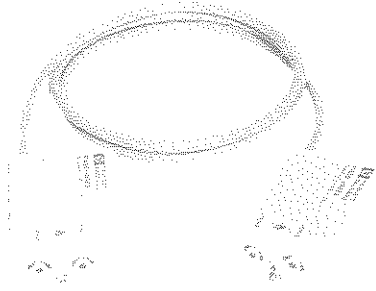
For connecting the HPSMU or MPSMU. Reference data is:

Capacitance between GUARD and FORCE lines (guard capacitance): 150 pF
Capacitance between GUARD and COMMON lines: 1200 pF
Resistance of FORCE line: 150 mΩ

16058-61603 SMU Triaxial Cable (1.5 m)

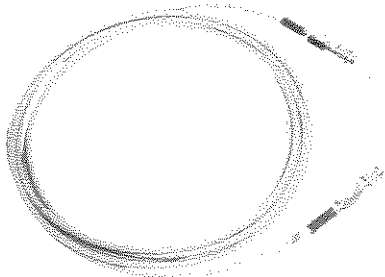For connecting the HPSMU or MPSMU. Reference data is:

Capacitance between GUARD and FORCE (or SENSE) lines (guard capacitance): 120 pF
Capacitance between GUARD and COMMON lines: 900 pF
Resistance of FORCE line: 160 mΩ
Maximum current: 1 A

04145-61622 SMU Triaxial Cable (3 m)

For connecting the HPSMU or MPSMU. Reference data is:

Capacitance between GUARD and FORCE (or SENSE) lines (guard capacitance): 240 pF
Capacitance between GUARD and COMMON lines: 1800 pF
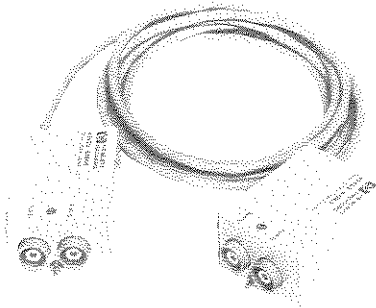Resistance of FORCE line: 320 mΩ
Maximum current: 1 A

1250-1708 Triax Cover

For shielding the HPSMU or MPSMU SENSE terminal.

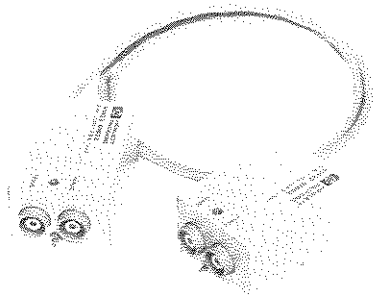## 41422-61601 HCU Dual-coaxial Cable (3 m)

For connecting the HCU. Reference data is:

Capacitance between FORCE HIGH and FORCE LOW lines: 3000 pF
Capacitance between SENSE HIGH and SENSE LOW lines: 350 pF
Inductance between FORCE HIGH and FORCE LOW lines: 200 nH
Resistance of FORCE HIGH line: 70 mΩ
Resistance of FORCE LOW line: 110 mΩ

41422-61602 HCU Dual-coaxial Cable (1.5 m)

For connecting the HCU. Reference data is:

Capacitance between FORCE HIGH and FORCE LOW lines: 1500 pF
Capacitance between SENSE HIGH and SENSE LOW lines: 200 pF
Inductance between FORCE HIGH and FORCE LOW lines: 100 nH
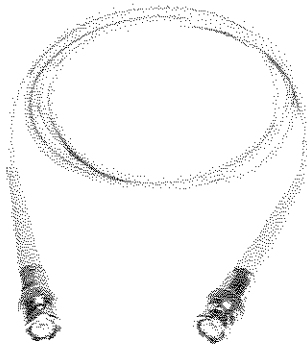Resistance of FORCE HIGH line: 40 mΩ
Resistance of FORCE LOW line: 65 mΩ

04145-61630 Coaxial Cable (3 m)
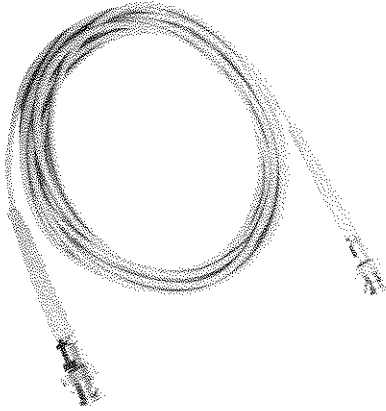
For connecting the VS, VM, or INTLK. Reference data is:

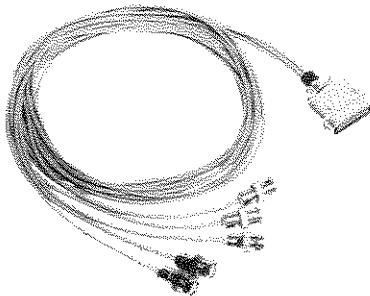Capacitance: 330 pF
Resistance of center line: 400 mΩ

04142-61636 Coaxial Cable (1.5 m)

For connecting the VS, VM, or INTLK. Reference data is:

Capacitance: 160 pF
Resistance of center line: 220 mΩ

04142-61631 Adaptor Cable (1.5 m)

For connecting the VS/VMU and INTLK to the HP 16058A Test Fixture.

OPTIONS

The following tables list the options available for the HP 4142B.

HP 4142B Options Available (1 of 2)

Option Number	Description	Model or Part Number
001	INTLK/VS/VMU - HP16058A Adapter Cable (1.5 m)	04142-61631
002	GNDU and INTLK cables (3 m) and Connector Plate	---
	Triaxial Cable (3 m for GNDU)	04142-61632
	Coaxial Cable (3 m for INTLK or VS/VMU)	04145-61630
	Connector Plate (for GNDU, SMUs and INTLK)	04142-60021
003	GNDU and INTLK Cables (1.5 m)	---
	Triaxial Cable (1.5 m for GNDU)	04142-61633
	Coaxial Cable (1.5 m for INTLK or VS/VMU)	04142-61636
022	Connector Plate (for GNDU, HCUs, VS/VMU, and INTLK)	04142-60031
050	Line frequency filter switch is set to 50 Hz.	---
060	Line frequency filter switch is set to 60 Hz.	---
100	Line voltage switch setting and fuse for 100V/120V.	---
220	Line voltage switch setting and fuse for 220V/240V.	---
400	HP 41420A SMU (occupies 2 slots)	HP 41420A
401	SMU Cable (1.5 m) and Triax Cover	---
	Triaxial Cable (1.5 m for SMU)	16058-61603
	Triax Cover (for SMU)	1250-1708
402	Quadraxial Cable (3 m for SMU)	41420-61601
403	Quadraxial Cable (1.5 m for SMU)	41420-61603
410	HP 41421B SMU (1 slot)	HP 41421B
411	SMU Cable (1.5 m) and Triax Cover	---
	Triaxial Cable (1.5 m for SMU)	16058-61603
	Triax Cover (for SMU)	1250-1708
412	Quadraxial Cable (3 m for SMU)	41420-61601
413	Quadraxial Cable (1.5 m for SMU)	41420-61603
420	HP 41422A HCU (occupies 2 slots)	HP 41422A
422	Dual-coaxial Cable (3 m for HCU)	41422-61601
423	Dual-coaxial Cable (1.5 m for HCU)	41422-61602

Option Number	Description	Model or Part Number
440	HP 41424A VS/VMU (1 slot)	HP 41424A
442	Four Coaxial Cables (3 m for VS/VMU or INTLK)	1
443	Four Coaxial Cables (1.5 m for VS/VMU or INTLK)	2
450	HP 41425A AFU (1 slot--1 per 4142B)	HP 41425A
560	Interactive Measurement and Analysis (IMA) Software	HP 16276A/L
561	License-to-Use the HP 16276A	HP 16276L
907	Front Handle Kit	5062-3991
908	Rack Flange Kit	5062-3979
909	Front Handle and Rack Flange Kits	5062-3985
910	Extra Manuals (English)	
	Operation Manual	
	HP-IB Command Reference Manual	
	Control Software Programming Manual	
J10	Extra Manuals (Japanese)	
	Operation Manual (Japanese)	
	HP-IB Command Reference Manual (Japanese)	
	Control Software Programming Manual (English)	
W03	90 day On-site Service	

1 Four 04145-61630s
2 Four 04142-61636s

Options Available for the HP 4142B Plug-in Units

Model and Option	Description / Part Number
HP 41420A Option 401	Same as HP 4142B Option 401
Option 402	Same as HP 4142B Option 402
Option 403	Same as HP 4142B Option 403
Option W03	90 day On-site Service
HP 41421B Option 411	Same as HP 4142B Option 411
Option 412	Same as HP 4142B Option 412
Option 413	Same as HP 4142B Option 413
Option W03	90 day On-site Service
HP 41422A Option 422	Same as HP 4142B Option 422
Option 423	Same as HP 4142B Option 423
Option W03	90 day On-site Service
HP 41424A Option 442	Same as HP 4142B Option 442
Option 443	Same as HP 4142B Option 443
Option W03	90 day On-site Service
HP 41425A Option W03	90 day On-site Service