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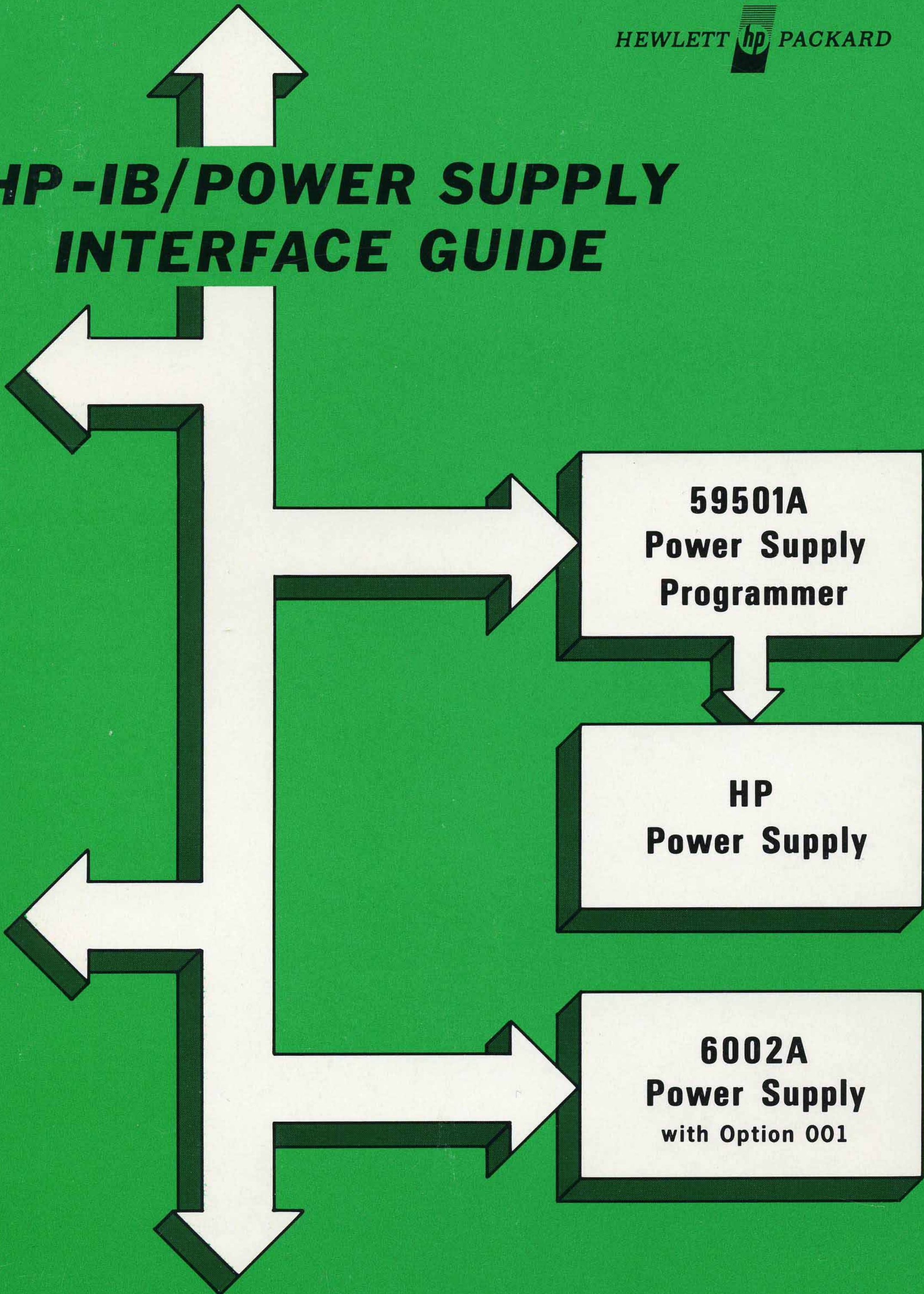
HP-IB/POWER SUPPLY INTERFACE GUIDE



APPLICATION NOTE 250-1

HP-IB/POWER SUPPLY INTERFACE GUIDE

5952-3990 April, 1977

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CHAPTER I
INTRODUCTION

1-1 There has always been a need for DC power supplies in automatic measuring and testing systems. The Hewlett-Packard Interface Bus (HP-IB)* provides an ideal means for interconnecting and controlling various instruments in automatic measurement and test systems. There are many applications where interactive instruments coupled with a computing controller can provide superior, error-free results as compared with conventional manual methods.

1-2 SCOPE

1-3 This introductory chapter briefly describes four different HP-IB/power supply interfaces that are currently available (see Figure 1-1). The remaining chapters are devoted to two of these interfaces: the 59501A power supply programmer and the 6002A-Option 001 power supply. The 59501A and 6002A-001 are designed specifically to allow power supplies to be controlled on the HP-IB. Chapters II and III describe the basic equipment configurations and programming format which allow HP-IB control of the 59501A and 6002A-001. Chapter IV provides details on using the 59501A with various power supplies while Chapter V covers the 6002A-001 supply. Also, several actual applications using a 59501A/power supply combination and a 6002A-001 power supply are provided in Appendix A.

1-4 Detailed descriptions of the multiprogrammer system and digitally controlled power sources with Option J99 are beyond the scope of this guide. The brief descriptions that follow, list additional documentation concerning the use of these interfaces on the HP-IB. The HP power supplies that can be used in the multiprogrammer system are listed in Appendix B in this guide.

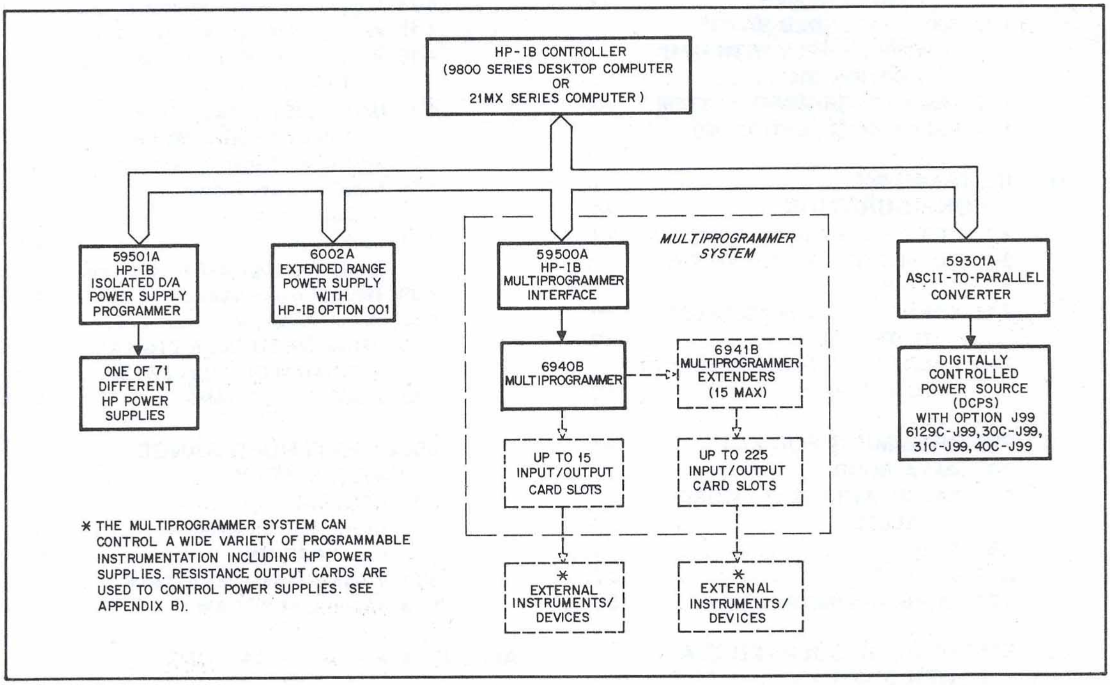
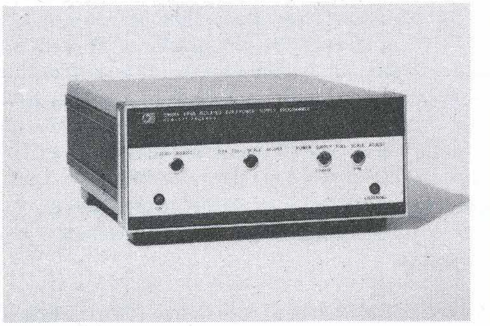


Figure 1-1. HP-IB/Power Supply Interface Capabilities

* Hewlett-Packard's implementation of IEEE Std. 488-1975 "Standard Digital Interface for Programmable Instrumentation."

1-5 59501A HP-IB ISOLATED D/A POWER SUPPLY PROGRAMMER

1-6 The 59501A unit can interface more different types of HP power supplies than any of the other interfacing methods. Moreover, it is the only means of interfacing laboratory and industrial type power supplies of over 100 volts to the HP-IB. Model 59501A can control any one of 71 different power supplies, placing a wide variety of power supply output rating, accuracies, and programming speeds at the users disposal. A tabular listing of the 71 different supplies that can be used with the 59501A is provided in Chapter IV.



59501A HP-IB Isolated D/A, Power Supply Programmer

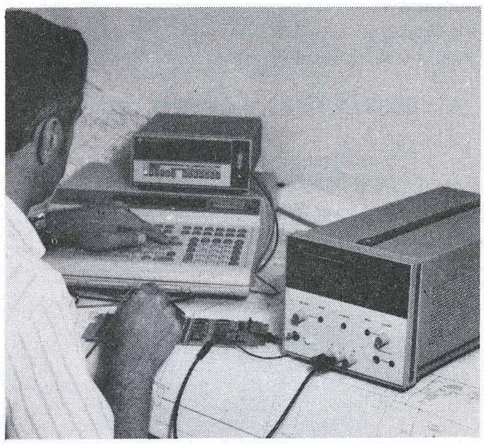
1-7 Model 59501A is a low-complexity, output type device that performs a LISTEN only function on the bus. Its individual address is set by switches on the rear of the unit so that it can be selectively accessed by the HP-IB controller. The unit is essentially a digital-to-analog (D/A) converter that is isolated to keep the power supply circuits separated from all other bus connected instruments. The output of the 59501A is available in two programmable ranges with the lower range providing better resolution and accuracy. The unit can provide either a unipolar or bipolar output with high range outputs of zero to +9.99 volts (unipolar) or –10 to +9.98 volts (bipolar). The bipolar output is used only for programming HP's line of Bipolar Power Supply/Amplifiers (Models 6824A-6827A). Power supply programming is accomplished by first making the appropriate connections (two or three wires) between the 59501A's rear terminals and the voltage programming terminals on the supply. After a simple calibration procedure is performed to match the particular power supply to the 59501A, the output voltage (or current) of the supply can be programmed from zero to full rated output. The 59501A includes front panel adjustments for calibrating the particular 59501A/power supply combination. This eliminates the need for the user to provide external circuitry.

1-8 Model 59501A is a unidirectional, single-channel device. Each 59501A can control either the voltage or current of one power supply. Thus, if it is required to program two supplies or both the voltage and current of one supply, two 59501A's must be employed. Of course, each 59501A that you employ must be set to a different address and will use up one of the 14 available HP-IB instrument ports associated with each bus.

1-9 Programming the unit is accomplished through the transmission of four consecutive digits of data. The first digit determines the output range and the next three digits determine the magnitude of the output within the selected range. Programming format is described in Chapter III. Detailed specifications for the 59501A are listed in Technical Data Sheet 5952-3989.

1-10 6002A EXTENDED RANGE POWER SUPPLY WITH HP-IB OPTION 001

1-11 The 6002A is an ideal power supply for operating in an HP-IB system. As a power source it is compact and it can deliver up to 200 watts. It is versatile by being able to produce 50V at 4A or 20V at 10A and any other 200W combination in between. Thus, one 6002A power supply can supply many 200-watt voltage and current combinations which would normally require a number of different supplies. In addition, the 6002A is the only supply with a self-contained HP-IB interface. The HP-IB option, designated Option 001, allows direct HP-IB control of the 6002A supply's output voltage or output current with a single cable to the controller.

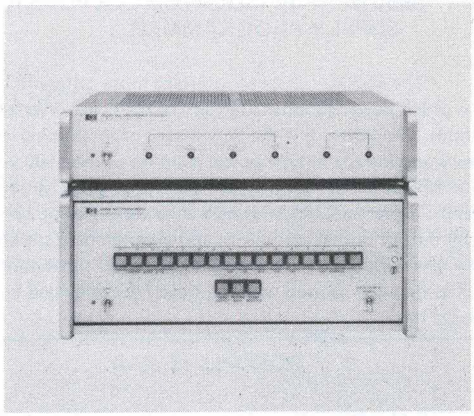


Using 6002A-001 on the HP-IB

A mode switch, included with the option, allows easy change-over from local to HP-IB control. In addition, since Option 001 is dedicated to the 6002A power supply, it is factory calibrated (there are no front panel adjustments associated with the HP-IB option). Like the 59501A, the Option 001 performs a LISTEN only function on the bus and is a uni-directional, single-channel device. The programming format is also the same as described for the 59501A. Detailed specifications for the 6002A-001 supply are listed in Technical Data Sheet 5952-3987.

1-12 MULTIPROGRAMMER SYSTEM

1-13 The 59500A/6940B/6941B multiprogrammer system allows a wide variety of devices including power supplies to be controlled via the HP-IB. The output voltage (up to 100V) and current (up to 1000A) of 40 different HP power supplies may be controlled with this system. The 59500A unit is used to interface the system to the bus and uses one of the 14 available HP-IB instrument ports. The multiprogrammer system's address is selected by address switches on the rear of the 59500A. The 59500A/6940B/6941B multiprogrammer performs talk and listen functions on the HP-IB and is a bi-directional data link between the controller and up to 240 individually software addressable plug-in card slots. Different types of cards are available for various applications. Certain types of plug-in cards provide programmable outputs in the form of resistance, voltage, current, contact closures, and logic levels. To program power supplies and bipolar power supply/amplifiers, the applicable resistance output cards must be installed in the system (see Appendix B). A detailed description of the multiprogrammer system is beyond the scope of this guide. Details about multiprogrammer products including descriptions of software, sample programs, applications and User's Guides are available from your local HP field engineer. In addition, a Technical Brochure (5952-3982) is available.

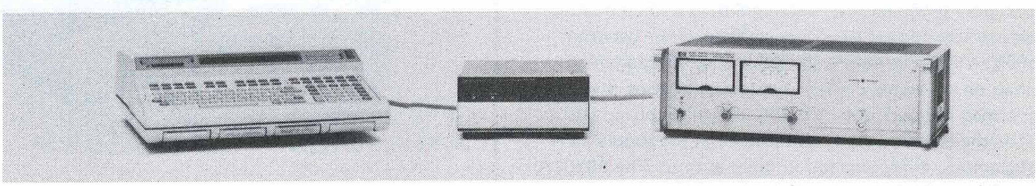


59500A (upper unit) and 6940B Multiprogrammer

1-14 59301A/DCPS – OPTION J99

1-15 This configuration allows digitally controlled power sources (DCPS's) 6129C-6131C, and 6140C to be programmed via the HP-IB. Models 6129C-6131C are digitally controlled voltage sources while Model 6140A is a digitally controlled current source. All models provide isolation between the digital input and analog output and digital storage of programmed inputs.

1-16 A DCPS equipped with Option J99 has a BCD data format compatible with the Model 59301A ASCII-to-Parallel Converter. This interface option allows the DCPS to be programmed by an HP-IB controller. One or more HP-IB equipped measuring instruments can then be added to the HP-IB bus that connects the controller with the 59301A to form a multi-instrument automatic test system. (Option J99 includes the Model 14539A-P02 cable that connects the DCPS to the 59301A and a J99 interface. To complete the basic system, the controller, the appropriate controller HP-IB Interface kit, and the Model 59301A ASCII-to-Parallel Converter must be ordered separately. Additional Option J99 DCPS's can be programmed from one controller by using an additional 59301A to interface each one. Each 59301A used must be set to a different address and will use one of the 14 available HP-IB instrument ports. Additional information concerning the operation of DCPS's on the HP-IB is provided in Technical Data Sheet 5959-3996.



Controller/59301A/DCPS-J99

CHAPTER II
INSTRUMENT CONFIGURATION

2-1 This chapter lists the controller requirements and also describes the connections between the controller and the 59501A and 6002A-001 HP-IB interfaces.

2-2 CONTROLLER REQUIREMENTS

2-3 If an HP 9800 series desktop computer is used as the HP-IB controller, it must be equipped with the applicable HP-IB I/O card package as listed below.

Desktop Computer	I/O Card Package	ROM
9815A	98135A HP-IB I/O	
9820A	59405A Option 020* HP-IB I/O	
9821A	59405A Option 021* HP-IB I/O	
9825A	98034A HP-IB I/O	General I/O Extended I/O
9830A	59405A Option 030* HP-IB I/O	

* Includes appropriate ROM and Users Guide.

2-4 If an HP-21MX series computer is used as the HP-IB controller, the 59310B HP-IB Computer Interface card is required.

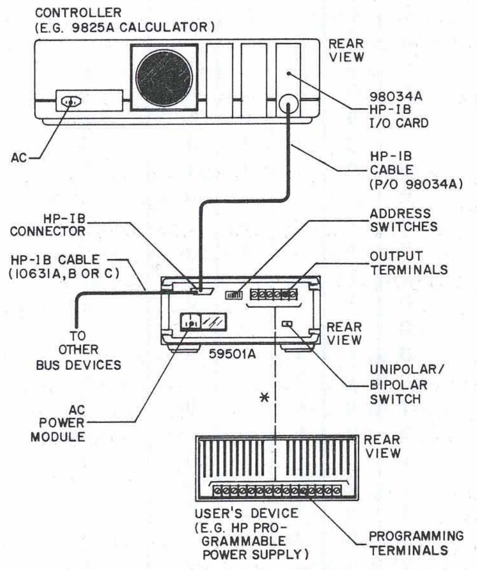
2-5 One HP-IB cable is supplied with each HP computer and calculator I/O card package. Extra cables may be ordered separately as follows:

HP-IB Cable Model No.	Cable Length
10631A	1m (3.3 ft)
10631B	2m (6.6 ft)
10631C	4m (13.2 ft)

2-6 The HP-IB cables use the same piggyback connector on both ends. Up to three connectors may be stacked one upon another. As many as 15 instruments (including the controller) may be connected to the same HP-IB.

2-7 CONNECTING 59501A TO THE HP-IB

2-8 Figure 2-1 illustrates a controller (e. g. a 9825A)



* CONNECTIONS BETWEEN THE 59501A'S OUTPUT TERMINALS AND THE PROGRAMMING TERMINALS OF TYPICAL HP PROGRAMMABLE POWER SUPPLIES ARE DESCRIBED IN CHAPTER IV.

Figure 2-1. 59501A Connections

and a 59501A unit connected to the HP-IB. In this case, the 98034A HP-IB interface card provides HP-IB capability for the 9825A calculator and is installed in any one of the three slots in the rear of the calculator. The 98034A card is equipped with the proper cable and connector to mate with the HP-IB connector on the rear of the 59501A. Note that specific connections between the 59501A's output terminals and the user's device (e. g. programmable power supply), are not illustrated on Figure 2-1. These connections depend upon the particular power supply being programmed and the type of control desired (output voltage or current). Typical connections are described in Chapter IV.

2-9 The listen address for the 59501A is selected by address switches on the rear of the unit. The switches are factory set to the suggested listen address of "&" (ASCII character) when the unit is shipped from the factory. Note that "&" is the suggested listen address and is one of 31 listen address possibilities. The address switch settings for each of the 31 listen address possibilities are listed in Table 2-1.

Table 2-1. Listen Addresses and Switch Settings

Address Switches					Listen Address Character
5	4	3	2	1	
0	0	0	0	0	SP
0	0	0	0	1	!
0	0	0	1	0	"
0	0	0	1	1	#
0	0	1	0	0	$
0	0	1	0	1	%
0	0	1	1	0	&
0	0	1	1	1	'
0	1	0	0	0	(
0	1	0	0	1	)
0	1	0	1	0	*
0	1	0	1	1	+
0	1	1	0	0	,
0	1	1	0	1	—
0	1	1	1	0	.
0	1	1	1	1	/
1	0	0	0	0	Ø
1	0	0	0	1	1
1	0	0	1	0	2
1	0	0	1	1	3
1	0	1	0	0	4
1	0	1	0	1	5
1	0	1	1	0	6
1	0	1	1	1	7
1	1	0	0	0	8
1	1	0	0	1	9
1	1	0	1	0	:
1	1	0	1	1	;
1	1	1	0	0	<
1	1	1	0	1	=
1	1	1	1	0	>

2-10 The UNIPOLAR/BIPOLAR mode switch is a push-in, push-out type switch located on the rear of the unit beneath the output terminal strip. In the UNIPOLAR mode (switch is in), the 59501A provides an output range of 0 to 0.999V or 0 to 9.99V. In the BIPOLAR mode (switch is out) the 59501A provides an output range of −1V to +0.998V or −10V to +9.998V.

2-11 CONNECTING THE 6002A-001 TO THE HP-IB

2-12 Figure 2-2 illustrates a controller (e. g. 9830A) and a 6002A-001 power supply connected to the HP-IB. The address switches on the rear of the 6002A-001 are factory set to the suggested listen address of "%". The LOCAL/CV/CC mode switches are set to CV or CC to program the CV or CC output of the 6002A supply as desired. The mode switches allow programming either the CV or CC output via the HP-IB but not both at the same time. If both CV and CC programming are required via the HP-IB, Option 001 can program one function (CV) and the 59501A can be used to program the other (CC).

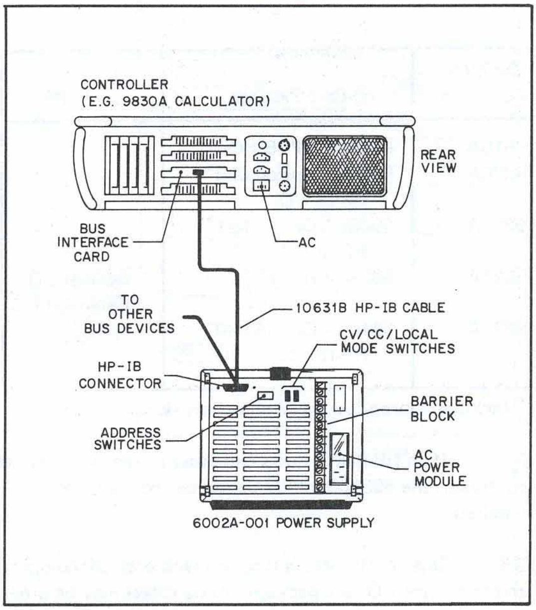


Figure 2-2. 6002A-001 Connections

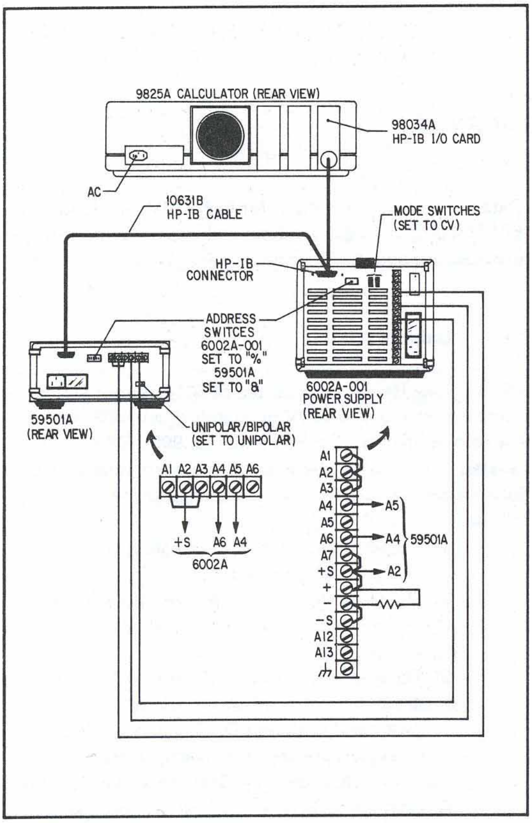


Figure 2-3. 6002A-001/59501A Connections

2-13 CONNECTING 6002A-001/59501A TO THE HP-IB

2-14 Figure 2-3 illustrates the connections and switch settings required to program both the CV and CC output of a 6002A supply on the HP-IB. A controller (e. g. 9825A), a 6002A-001, and a 59501A are shown connected to the HP-IB. The 6002A-001 mode switch is set to CV allowing the 9825A to program the CV output using the Option 001 circuitry. The 59501A output terminals are connected to the 6002A's remote programming terminals allowing the 9825A to program the CC output using the 59501A. The UNIPOLAR/BIPOLAR switch on the 59501A is set to UNIPOLAR for this application.

2-15 The address switches on the 6002A-001 and the 59501A must be set to different addresses. If both switches were set to the same address, the CV and CC outputs would be simultaneously programmed which is not usually desired. The most common use of the configuration, shown in Figure 2-3, is to operate the supply in the CV mode and program the current to a safe limit in case the load is shorted.

CHAPTER III
PROGRAMMING FORMAT

3-1 The 59501A and 6002A-001 are capable of receiving and ignoring, but are not capable of sending information on the HP-IB. In order for the 59501A (or 6002A-001) to receive information, it must be addressed to "listen" and the controller (e. g. calculator) must be addressed to "talk". In order to make the 59501A (or 6002A-001) ignore programming information being sent to other instruments on the HP-IB, it must be unaddressed. While unaddressed, it will remain insensitive to information being sent to other instruments in the system.

3-2 DATA WORD

3-3 The 59501A and 6002A-001 are programmed by a data word comprised of four ASCII characters (digits) received in the order shown below. The first digit specifies range and the next three digits specify the desired output within the selected range. The range digit must be the number 1 to specify low range or the number 2 to specify high range. The magnitude digits can be any number from 000 to 999. An output voltage is automatically produced as soon as the four digits are received. Each data word must be exactly four digits long (one digit for range and three digits for magnitude). If more than four digits are received, the desired output will not be produced.

D1	D2 D3 D4
Range 1 or 2	Magnitude 000-999

3-4 CALCULATING DATA WORD VALUES

3-5 59501A

3-6 The 59501A is programmed by the magnitude digits in BCD to produce the desired output voltage. In the unipolar mode, 000 equals 00.0% of full range, 500 equals 50.0% of full range, and 999 equals 99.9% of full range. In the bipolar mode, 000 equals the maximum negative voltage output, 500 equals 0V output, and 999 equals the maximum positive voltage output. The following paragraphs describe the data word value calculations required to program the output of the 59501A. Similar calculations are required when programming power supply outputs using the 59501A. The programmable output range depends, of course, upon the power supply model being programmed. The desired output range of the particular power supply must be calibrated for programming with the 59501A. Power supply calibration procedures are described in Chapter IV.

Data word value calculations for high (10V) and low (1V) 59501A output ranges are described below. Calculations are provided for both the unipolar and bipolar output modes.

3-7 Unipolar Mode

3-8 Low Range. The desired 59501A output voltage values are from 0 to 0.999V programmable in 999 steps. The resolution in this range is equal to .999V/999, or 1mV per step. To calculate the correct data word value to produce the desired output within this range, proceed as follows:

1. The resolution in the low range is 1mV,
   Let D = .001
2. The range digit is 1 for the low range, so add 1 to the left of the 3 magnitude digits,
   Let R = 1000
3. The magnitude portion (M) is calculated by dividing the desired output voltage (V) by the least significant digit D. The magnitude portion must be rounded off to exactly 3 digits,
   M = INTEGER (V/D+0.5) = 3 magnitude digits
4. Combine range and rounded off magnitude portion to obtain the correct data word value (N),
   N = R + M

Example, desired voltage = 0.5123V

D = .001
R = 1000
M = INT (0.5123/.001 + 0.5)
M = INT (512.8)
N = 1000 + 512
N = 1512 = data word value

In this example, the desired output voltage is 0.5123 volts but the actual output is 0.512V because the resolution is 1mV (least significant digit equals .001):

V = M x D
V = 512 x .001
V = 0.512

3-9 High Range. The desired 59501A output voltage values are from 0 to 9.99V. The calculations are the same as for the low range, except resolution is 10mV and the high range is used. For the high range,

Let D = .01
and R = 2000

3-10 Bipolar Mode. The 59501A provides a bipolar output when the switch on the rear panel is set to BIPOLAR. Figure 3-1 illustrates the output of the 59501A as a function of the range and magnitude digits in the bipolar mode. Note that zero output occurs whenever the magnitude digits are 500 regardless of the range digit (1 or 2). Data word value calculations for the bipolar mode are described below.

3-11 Low Range. The desired 59501A output voltage values are from –1V to +0.998V programmable in 999 steps. For a –1V output, the magnitude digits are 000 and for a +0.998V output, the magnitude digits are 999. A 0V output is obtained when the magnitude digits are 500. Resolution in this range is equal to 1.998/999, or 2mV. To calculate the correct data word value to produce the desired positive or negative output voltage within this range, proceed as follows:

1. The resolution in the –1V to 0.998V range is 2mV,
   Let D = .002
2. The range digit is 1 for the low range, so add 1 to the left of the three magnitude digits,
   Let R = 1000
3. The magnitude portion (M) is calculated by adding 1 to the desired negative or positive output voltage (V) and dividing this sum by the least significant digit D. The magnitude portion must be rounded off to exactly 3 digits.
   M = INT (V + 1)/D + 0.5)
4. Combine range and rounded off magnitude pottion to obtain the correct data word value (N),
   N = R + M

Example, desired voltage = –0.5123V
D = .002
R = 1000
M = INT (–5.123 + 1)/.002 + 0.5)
M = INT (+0.4877/.002 + 0.5)
M = INT (243.85 + 0.5)
M = INT (244.35)
N = 1000 + 244 = 1244

In this example, the desired output voltage is –0.5123V but the actual output is –0.512V because the resolution is 2mV (.002):

V = (M x D) –1
V = (244 x .002) – 1
V = 0.488 – 1
V = –0.512V

3-12 High Range. The desired output voltage values are from –10V to +9.98V. Calculations are similar to those for the low range, except resolution is 20mV on the high range, and 10 must be added to desired positive or negative output voltage in order to calculate the correct magnitude digits. For this range, the equation for the magnitude portion (M) of the data word value is:

M = INT ((V + 10)/D + 0.5)

Example, desired voltage = –5.123V
D = .02
R = 2000
M = INT ((–5.123 + 10)/D + 0.5)
M = INT (243.85 + 0.5)
M = INT (244.35) = 244
N = 2000 + 244 = 2244

In this example, the desired output voltage is –5.123V but the actual output is –5.12V because the resolution is 20mV (.002):

V = (M x D) –10
V = (244 x .02) – 10
V = 4.88 – 10
V = –5.12V

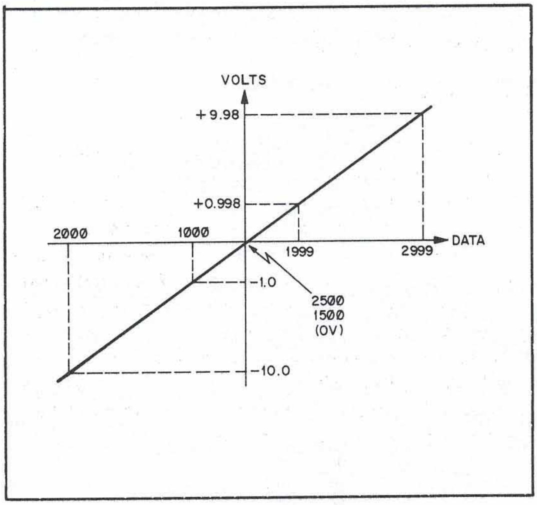


Figure 3-1. 59501A Bipolar Output Ranges

3-13 6002A-001

3-14 The 6002A-001 is programmed by the magnitude digits in BCD in such a way that 000 equal 00.0% of full range, 500 equals 50.0% of full range, and 999 equals 99.9% of full range. Since 999 is the maximum value for the magnitude digits, the programmable output ranges are as follows:

Low Range CV – 0 to 9.99V (99.9% of 10V)
High Rance CV – 0 to 49.95V (99.9% of 50V)
Low Range CC – 0 to 1.998A (99.9% of 2A)
High Range CC – 0 to 9.99A (99.9% of 10A)

3-15 Data word value calculations for the 10V, 50V, 2A and 10A output ranges are described below. Note that each data word must be exactly four digits long (one digit for range and three digits for magnitude). A sample program is provided in Chapter V.

3-16 10V Range. The desired output voltage values are from 0V to 9.99V. To convert the desired output voltage into a data word representing a percentage of the output range, proceed as follows:

1. The resolution in the 10V range is 10mV,
   Let D = .01
2. The range digit is 1 for the 10V range, so add 1 to the left end of the 3 magnitude digits,
   Let R = 1000
3. The magnitude portion (M) is calculated by dividing the desired output voltage (V) by the least significant digit D. The magnitude portion must be rounded off to exactly 3 digits,
   M = INT(V/D) + 0.5) = 3 magnitude digits
4. Combine range and rounded off magnitude portion to obtain the correct data word value (N).
   N = R + M

Example, desired voltage = 5.1234 volts

D = .01
R = 1000
M = INT (5.1234/0.01 + 0.5)
M = INT (512.34 + 0.5)
M = INT (512.84)
N = 1512 = data word value

In this example, the desired output voltage is 5.1234 volts but the actual power supply output is 5.12V because the resolution is 10mV (least significant digit equals .01).

3-17 50V Range. The desired output voltage values are from 0V to 49.95V. The calculations are the same as for the 10V range, except resolution is 50mV and the high range is used. For the 50V range,

Let D = .05
and R = 2000

3-18 2A Range. The desired output current values are from 0A to 1.998A. The calculations are the same as for the 10V range, except resolution is 2mA and substitute 1 for V where 1 = desired output current. For the 2A range,

Let D = .002,
and R = 1000

3-19 10A Range. The desired output current values are from 0 to 9.99A. The calculations are the same as for the 10V range, except resolution is 10mA, the high range is used, and substitute I for V, where I = desired output current. For the 10A range,

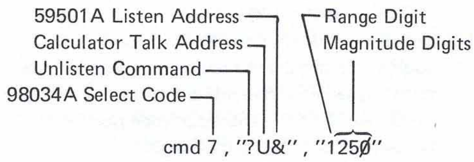
Let D = .01
and R = 2000

3-20 PROGRAMMING EXAMPLES

3-21 Before a data word is sent, a command must be issued establishing the controller as the "talker" and the 59501A (or 6002A-001) as the "listener". The following examples assume that the controller (9825A calculator) has been assigned its standard talk and listen addresses of "U" and "5" respectively, and the 59501A has been assigned a listen address of "&". The 6002A-001 has an assigned listen address of "%".

3-22 Example 1 illustrates a command statement issued by a 9825A Calculator for the 59501A. Note that in addition to the calculator talk address "U" and the 59501A listen address "&", the select code of the HP-IB Interface Card (98034A) must be included. It is assumed that the interface card has been assigned its standard select code of "7". The 9825A command statement also includes data word "1250" which is sent to the 59501A. To send data word "1250" to the 6002A-001, change the listen address from "&" to "%".

Example 1. Sending a Fixed Data Word (9825A Command Statement)



3-23 Command statements can only be used to send fixed data word values. This involves programming with literals, where a literal is defined as any character(s) within a quote field (e. g. "125Ø"). Write statements can also be used to send fixed data word values but must be used to send variable data word values.

3-24 Example 2 illustrates a write statement (9825A calculator) which can also be used to address the 59501A to listen and send a data word. The 59501A listen address of "&" corresponds to an address of "Ø6" as defined in the 9825A General I/O ROM Manual (09825-90024) Chapter 4. Note the format statement (line Ø) used in Example 3. The "c" specifies a character field, while the "z" is used to suppress carriage return/line feed codes at the end of the write statement. Suppression of the carriage return/line codes is essential when programming the 59501A (or 6002A). If they are not suppressed, they will be processed as data. Operation of the 59501A (and 6002A-001) is such that its output is changed after every fourth digit is received. This means that if extra digits (such as CR/LF codes) are sent by mistake, they will be processed causing an incorrect value to appear at the output. To send data word "125Ø" to the 6002A-001 using a write statement, change line 1 to read: wrt 7Ø5.1 "125Ø".

3-25 Example 3 illustrates how a write statement (9825A) is used to send variable data to the 59501A. If variable N in line 1 were equal to 125Ø, this example would program the same output as the previous examples. Format specification f4.Ø deletes leading spaces and specifies a field width of four digits with no decimal places. The "z" suppresses carriage return/line feed codes at the end of the write statement. If leading spaces are not deleted and the CR/LF codes are not suppressed, they will be processed as data resulting in an undesired output. To send variable data to the 6002A-001, change line 1 to read:

wrt 7Ø5.1, N.

3-26 Sample programs, using the examples described above, are included in Chapters IV and V for the 59501A and 6002A-001, respectively.

Example 2. Sending a Fixed Data Word (9825A Write Statement)

```
                               ┌─ Suppresses CR/LF Codes
0: fmt 1, c, z
1: wrt 7Ø6.1, "125Ø"
98034A Select Code ──┘  └──── 59501A Address
```

Example 3. Sending Variable Data (9825A Write Statement)

```
Ø: fmt 1, f4.Ø, z
1: wrt 7Ø6.1, N
```

CHAPTER IV
59501A HP-IB ISOLATED D/A POWER SUPPLY PROGRAMMER

4-1 INTRODUCTION

4-2 The 59501A is basically a digital-to-analog converter (DAC) that provides an output voltage in response to digital data received from an HP-IB controller. Since the 59501A is designed primarily for programming power supplies, it is essential that the power supply outputs are electrically isolated from the controller and other instrumentation connected to the HP-IB. To accomplish this, photo-isolators within the 59501A provide 600 volts isolation between the HP-IB lines and the 59501A output terminals.

4-3 Two programmable 59501A output ranges (1V and 10V) are available in the selected output mode (unipolar or bipolar). The unipolar mode provides a 0 to +0.999V or a 0 to +9.99V output range. The bipolar mode provides a −1 to 0.998V or a −10 to +9.98V output range. Power supply programming is accomplished through use of the 59501A's programmable output voltage and the controls on the 59501A front panel. Any one of 71 different power supplies (up to 600Vdc) can be programmed using a 59501A. Power supplies are normally programmed with the 59501A set to the unipolar mode. The bipolar mode is used to program bipolar power supply/amplifiers such as the 6827A for bipolar output voltages up to 200 volts peak-to-peak.

4-4 The uses for the 59501A are numerous. Besides being used as a power supply programmer, it can be used as a stand-alone DAC to provide voltages for testing various analog and digital devices. The following paragraphs provide a block diagram description of the 59501A and also describe the basic uses of a 59501A as a power supply programmer and as a digital-to-analog converter. The information includes typical 59501A/power supply connections, the methods employed in programming the CV and CC power supply outputs, calibration, timing considerations, and a list of the 71 power supplies that can be programmed with the 59501A.

4-5 BLOCK DIAGRAM DESCRIPTION

4-6 Figure 4-1 is a block diagram illustrating the major circuit groups within the 59501A. The basic operation of each circuit group is described below.

4-7 Digital Processing Circuits

4-8 The 59501A responds to the ATN (attention) and IFC (interface clear) control signals as well as the data on lines (DI01-DI07). The 59501A also receives the DAV (data valid) handshake signal from the bus and sends the NRFD (not ready for data) and NDAC (data not accepted) handshake signals to the bus. A 3-wire handshake sequence is used to control the transfer of each character on the bus. This process allows devices with different input/output speeds to be interconnected to the HP-IB. The character transfer rate automatically adjusts to the slowest device. The acceptor handshake circuit implements the 3-wire handshake cycle that occurs with each command or data character received on data lines DI01-DI07. The 59501A transfer rate is approximately 20μsec per character. The 59501A is programmed by a data word consisting of four consecutive characters (digits), thus, a data word is transferred to the 59501A in approximately 80μsec.

4-9 Data lines DI01-DI07 accommodate the 7-bits (1-character) of the ASCII code. Each character is transferred onto the bus one at a time. The state of the ATN line determines how the data lines are interpreted. The ATN line is constantly monitored by the 59501A and all other bus devices. When ATN is true, the bus devices interpret the data as instructions (commands) from the controller. The 59501A recognizes two commands: its listen address (suggested listen address is "&") and the unlisten command "?".

4-10 When ATN is true and the 59501A's listen address is placed on data lines DI01-DI07, the 59501A is enabled to function as a "listener". As shown in Figure 4-1, the data lines are applied to the address comparator and to the listen logic. The address comparator decodes the 59501A's listen address when the levels on lines DI01-DI05 match the address switch settings on the rear of the 59501A. In this case, the address switches are set to "&" (one of 31 possible address codes) which distinguishes the 59501A from the other devices connected to the bus. Thus, when the 59501A's listen address is decoded and ATN is true (command mode), the listen logic is set. For this condition, the LISTENING indicator is turned-on and the clock generator is enabled allowing the 59501A to process subsequent data words received on the bus. If the ATN line is true and an unlisten command "?" is received, the listen logic is reset. For this condition, the LISTENING indicator is turned off and the clock generator is disabled inhibiting the 59501A from processing data words. Note that the IFC signal also resets the listen logic. The IFC signal is used by the controller to terminate activity on the HP-IB.

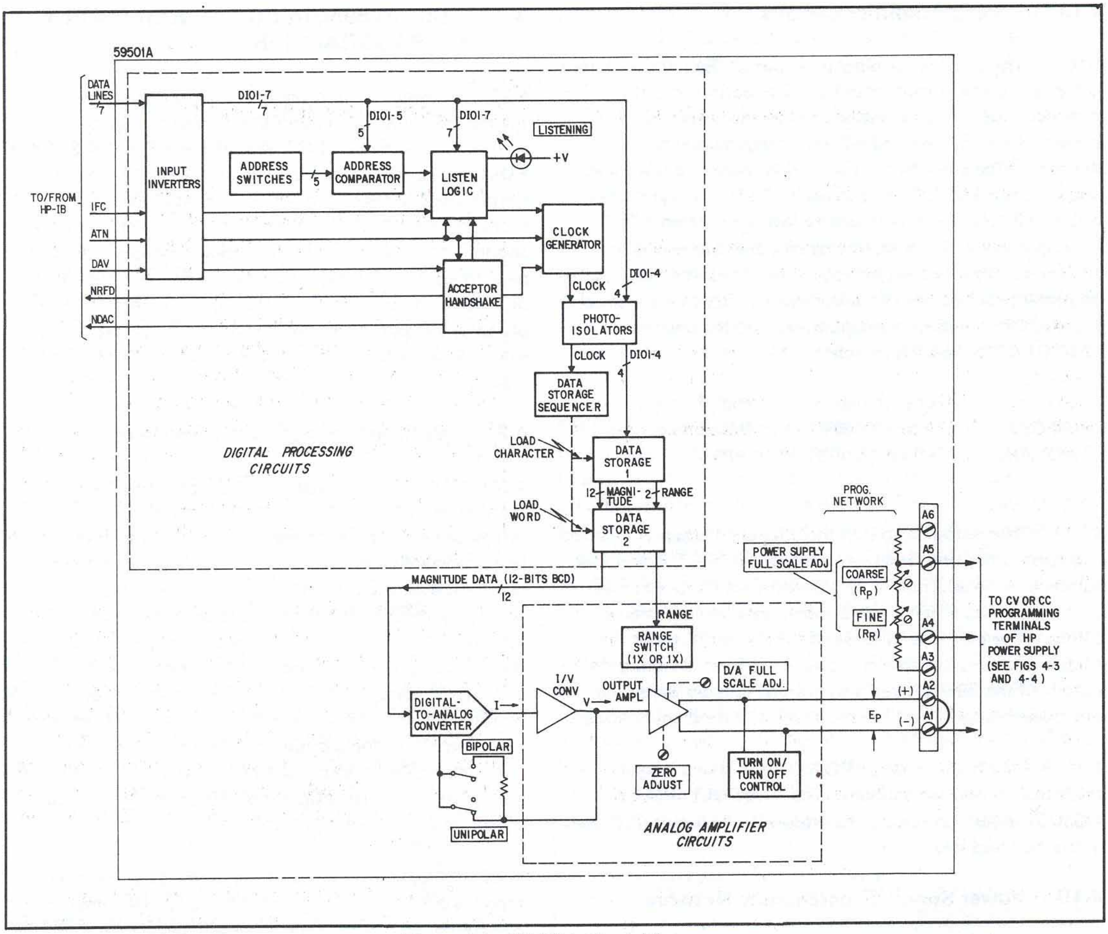


Figure 4-1. 59501A Block Diagram

4-11 When the ATN line is false and the 59501A is "listening" (listen logic is set), the digital processing circuits will store a data word comprised of four digits (characters) transmitted consecutively. The first digit specifies the output range (low or high) and the next three digits specify the magnitude of the output voltage within the selected range. Each digit, represented by bits DI04 (MSB)-DI01 (LSB), is transferred into data storage 1 (via input inverters and photo-isolators) during the accompanying 3-wire handshake cycle. The photo-isolators provide 600Vdc isolation between the HP-IB data lines and the 59501A's output voltage terminals (A1 and A2).

4-12 A clock pulse, generated during each handshake cycle, gates the data storage sequencer which in turn loads each digit (1-range, 3-magnitude) into the proper storage 1 latch position. After the fourth digit is loaded into data storage 1 all four digits (data word) are automatically transferred into the data storage 2 latches. The three magnitude digits are then sent to the digital-to-analog converter (DAC) while the range digit is sent to the analog amplifier circuits. The data storage 2 latches will retain this data until a new data word is transferred.

4-13 Digital-to-Analog Converter (DAC)

4-14 The DAC converts the three magnitude digits (12 bits, BCD) into an output current. The DAC output range, 0-2mA (nominal), corresponds to the BCD input range of ØØØ-999. The DAC output current is applied to the current-to-voltage (I/V) converter in the analog amplifier circuits. The UNIPOLAR/BIPOLAR switch on the rear of the 59501A changes the feedback path between the DAC and the I/V converter so that the I/V converter provides an output range from 0 to +2.5V (nominal) in the unipolar mode and from −2.5V to +2.5V (nominal) in the bipolar mode.

4-15 Analog Amplifier Circuits

4-16 The unipolar or bipolar output of the I/V converter is applied to the output amplifier. The output amplifier provides either a high range or a low range output voltage between terminals A1 and A2. The range switch controls the gain of the amplifier so that a high range or a low range output is produced. The range switch is set to high range when a "2" is programmed and to low range when a "1" is programmed. The high low range capability provides a ten to one improvement in resolution. Thus, the output amplifier provides one of the following output ranges depending upon the range digit programmed and the position of the UNIPOLAR/BIPOLAR switch:

	Low Range	High Range
UNIPOLAR:	0 to +0.999V	0 to 9.99V
BIPOLAR:	−1 to +0.998V	−10 to +9.98V

4-17 The output amplifier includes overvoltage protection and current limiting circuits to protect the 59501A and user equipment. In addition, a turn-on/turn-off control circuit clamps the output terminals at a low level when power is turned on or off. The purpose of this circuit is to prevent transients at power turn-on and turn-off from affecting the output of the 59501A and also prevent random programming of a power supply prior to receipt of valid programming data.

4-18 The front panel ZERO ADJUST allows a zero (±250mV) output adjustment. The D/A FULL SCALE ADJUST allows setting the maximum 59501A output (±5%) in the high and low ranges.

4-19 Power Supply Programming Network

4-20 When the 59501A is used as a power supply programmer, the POWER SUPPLY FULL SCALE ADJUST potentiometers (COARSE and FINE) allow the user to set the maximum power supply output when the 59501A is programmed to its maximum output. Power supply programming is accomplished by connecting the 59501A's output terminals to the power supply's voltage programming terminals. Figure 4-1 illustrates the connections required to program the output voltage of a typical HP power supply. In this case, a jumper is connected between terminals A2 and A3, and terminals A1, A4, and A5 are connected to the voltage programming terminals of the power supply. The method of programming and the connections required to program the output voltage or current of HP supplies are described in subsequent paragraphs. When the 59501A is used as a DAC (low level dc signal source), only terminals A1 and A2 are normally connected to the user's device.

4-21 USING 59501A AS A POWER SUPPLY PROGRAMMER

4-22 Power supply programming is accomplished using the digitally controlled output voltage of the 59501A in conjunction with the ZERO ADJUST and POWER SUPPLY FULL SCALE ADJUST controls on the 59501A front panel. Connections between the two units consist of two or three wires and are made via the rear terminals on each unit. After connecting the units, a simple calibration procedure must be performed to match the power supply to the 59501A. This procedure allows the output voltage (or current) of the supply to be programmed from zero to the calibrated full scale value. This method of programming is called voltage programming with gain.

4-23 Voltage Programming With Gain

4-24 HP programmable power supplies have certain features in common. These features include: an internal reference (either a fixed regulated voltage or a fixed regulated constant current source), voltage and current comparators with their input terminals, and front panel controls (voltage and current) with connections at the rear panel terminals. A power supply can be controlled by making the appropriate connections on the rear panel and applying an external voltage (or in some cases current). For example, by disconnecting the internal reference voltage from the input circuits of the constant voltage comparator and replacing it with an external voltage source, the output voltage of the power supply is programmed by the value of the external voltage source.

4-25 Figure 4-2 illustrates the method by which a power supply's constant voltage output can be programmed using an external voltage with a voltage gain dependent upon the ratio of R_P to R_R. Note that this method is no different from the circuit normally used for constant voltage control of the output except that an external reference (the programming voltage source) has been substituted for the internal reference. On most supplies, external terminals are available so that the connections shown in Figure 4-2 can be accomplished without any internal wiring changes. In all HP remotely programmable power supplies, the summing point S is made available, and the configuration of Figure 4-2 can always be accomplished using the external programming voltage source E_P and external precision wirewound resistors R_P and R_R. (R_R should not exceed 10k.) As indicated by the equation in Figure 4-2, R_P can be selected so that the resulting voltage gain is either less or greater than unity. It is possible to use the front panel control on the supply as the voltage gain control R_P.

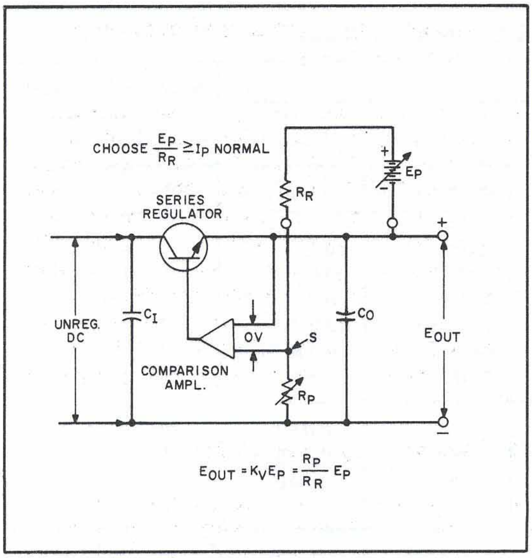


Figure 4-2. Voltage Programming with Gain.

4-26 59501A/Power Supply Capabilities

4-27 Table 4-1 lists the HP power supplies that can be programmed on the HP-IB using the 59501A and specifies if the supply's output voltage and/or current can be programmed with the 59501A. The table also lists the output voltage and current ratings for each supply and specifies whether the supply is a constant voltage (CV) /constant current (CC) type or a CV/CL (current limit) type. The 59501A is not capable of programming the current limit of CV/CL supplies. Specific connections for each 59501A/ power supply combination and any special instructions associated with a particular power supply are provided in Operating and Service Manual HP Part No. 59501-90001. Typical connections for programming output voltage and current are described below. Overall accuracy and timing considerations are described in subsequent paragraphs.

NOTE

One 59501A can only program a supply's output voltage or current. If it is desired to program both voltage and current on the HP-IB, two 59501A's are required with their address switches set to different addresses.

4-28 **Output Voltage.** Figure 4-3 illustrates the connections required for the 59501A to program the output voltage of a typical HP power supply. Note the similarities between Figures 4-2 and 4-3. The 59501A includes R_R (R76), R_P (COARSE and FINE POWER SUPPLY FULL SCALE ADJUST), and E_P (59501A output between terminals A1 and A2). The extra resistor (R77) between terminals A5 and A6 is used only when programming power supplies above 300 volts.

4-29 As shown in Figure 4-3, the supply's internal reference voltage ($+V_{REF}$) and VOLTAGE control are disconnected (dotted lines) and are replaced with the 59501A's output voltage and POWER SUPPLY FULL SCALE ADJUST. Note that in the unipolar mode, 59501A output terminal A1 is negative with respect to A2. This polarity must be complied with when making connections. The connections shown in Figure 4-3 are typical for most supplies. After the connections have been made the 59501A/ power supply combination must be calibrated (see para. 4-31).

4-30 **Output Current.** Figure 4-4 illustrates the connections required for the 59501A to program the output current of a typical HP power supply. Programming consists of replacing the internal reference with the output voltage from the 59501A and replacing the internal CURRENT control with the POWER SUPPLY FULL SCALE ADJUST controls on the 59501A. With these connections, the voltage developed across POWER SUPPLY FULL SCALE ADJUST (R_P) becomes the reference against which the voltage drop across the output current monitoring resistor (R_M) is compared. The relationship between E_P and the supply's output current depends upon the resistance ratio R_P/R_R and on the constant current programming coefficient (K_P) of the particular supply. The relationship between input voltage and output current is,

$$I_{OUT} = (E_P \times R_P) \div (K_P \times R_R)$$

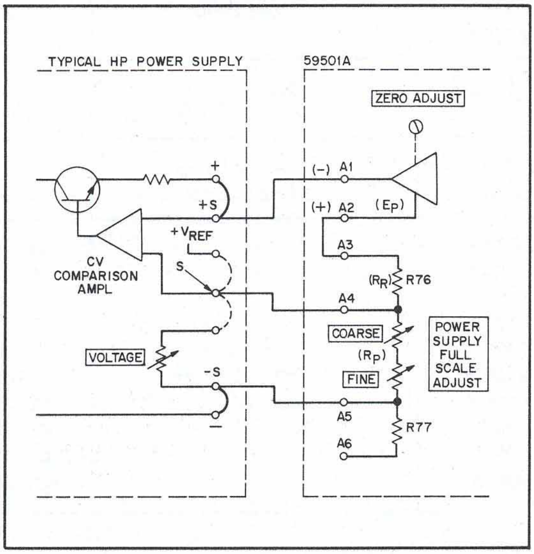


Figure 4-3. Typical 59501A/HP Power Supply Connections for Output Voltage Programming

Table 4-1. 59501A/Power Supply Capability Guide

HP Power Supply					59501 Programming Capabilities	
Model	Type	Operating Modes (Note 1)	Volts	Amps	Voltage	Current
6002A	Lab-Extended Range, 200W	CV/CC	0-50	0-10	Yes	Yes
6111A	Precision DC Power Supplies	CV/CL	0-20	0-1	Yes	No
6112A		CV/CL	0-40	0-0.5	Yes	No
6113A		CV/CL	0-10	0-2	Yes	No
6114A		CV/CC	0-20, 0-40	0-2, 0-1	Yes	Yes
6115A		CV/CC	0-50, 0-100	0-0.8, 0-0.4	Yes	Yes
6116A		CV/CL	0-100	0-0.2	Yes	No
6177C	Precision Current Sources	Constant Current/ Voltage Limit	0-50	0-0.50	No	Yes
6181C			0-100	0-0.25	No	Yes
6186C			0-300	0-0.10	No	Yes
6200B	Laboratory Bench Supplies	CV/CC	0-20, 0-40	0-1.5, 0-0.75	Yes	Yes
6201B		CV/CC	0-20	0-1.5	Yes	Yes
6202B		CV/CC	0-40	0-0.75	Yes	Yes
6203B		CV/CC	0-7.5	0-3	Yes	Yes
6204B		CV/CL	0-20, 0-40	0-0.6, 0-0.3	Yes	No
6205B		CV/CL	0-20, 0-40	0-0.6, 0-0.3	Yes	No
6206B		CV/CL	0-30, 0-60	0-1, 0-0.5	Yes	No
6207B		CV/CC	0-160	0-0.2	Yes	Yes
6209B		CV/CC	0-320	0-0.1	Yes	Yes
6220B	General Purpose Power Supplies	CV/CC	0-25, 0-50	0-1, 0-0.5	Yes	Yes
6224B		CV/CC	0-24	0-3	Yes	Yes
6226B		CV/CC	0-50	0-1.5	Yes	Yes
6227B	Dual Tracking Power Supplies	CV/CC	0-25	0-2	Yes	Yes
6228B		CV/CC	0-50	0-1	Yes	Yes
6253A	General Purpose Power Supplies	CV/CC	0-20	0-3	Yes	Yes
6255A		CV/CC	0-40	0-1.5	Yes	Yes
6256B	High Performance 120-2000 Watts (See Note 2)	CV/CC	0-10	0-20	Yes	Yes
6259B		CV/CC	0-10	0-50	Yes	Yes
6260B		CV/CC	0-10	0-100	Yes	Yes
6261B		CV/CC	0-20	0-50	Yes	Yes
6263B		CV/CC	0-20	0-10	Yes	Yes
6264B		CV/CC	0-20	0-20	Yes	Yes
6265B		CV/CC	0-40	0-3	Yes	Yes
6266B		CV/CC	0-40	0-5	Yes	Yes
6267B		CV/CC	0-40	0-10	Yes	Yes
6268B		CV/CC	0-40	0-30	Yes	Yes

Table 4-1. 59501A/Power Supply Capability Guide (Continued)

HP Power Supply					59501A Programming Capabilities	
Model	Type	Operating Modes (Note 1)	Volts	Amps	Voltage	Current
6269B	High Performance 120-2000 Watts (See Note 2)	CV/CC	0-40	0-50	Yes	Yes
6271B		CV/CC	0-60	0-3	Yes	Yes
6274B		CV/CC	0-60	0-15	Yes	Yes
6281A	General Purpose (See Note 2)	CV/CC	0-7.5	0-5	Yes	Yes
6282A		CV/CC	0-10	0-10	Yes	Yes
6284A		CV/CC	0-20	0-3	Yes	Yes
6286A		CV/CC	0-20	0-10	Yes	Yes
6289A		CV/CC	0-40	0-1.5	Yes	Yes
6291A		CV/CC	0-40	0-5	Yes	Yes
6294A		CV/CC	0-60	0-1	Yes	Yes
6296A		CV/CC	0-60	0-3	Yes	Yes
6299A		CV/CC	0-100	0-0.75	Yes	Yes
6427B	Industrial Performance Power Supplies (See Note 3)	CV/CC	0-20	0-15	Yes	No
6428B		CV/CC	0-20	0-45	Yes	No
6433B		CV/CC	0-36	0-10	Yes	No
6434B		CV/CC	0-40	0-25	Yes	No
6438B		CV/CC	0-60	0-5	Yes	No
6439B		CV/CC	0-60	0-15	Yes	No
6443B		CV/CC	0-120	0-2.5	Yes	No
6448B		CV/CC	1-600	.5-1.5	Yes	No
6453A		CV/CC	0-15	0-200	Yes	Yes
6456B		CV/CC	0-36	0-100	Yes	Yes
6459A		CV/CC	0-64	0-50	Yes	Yes
6464C		CV/CC	0-8	0-1000	Yes	Yes
6466C		CV/CC	0-16, 0-18	0-600, 0-500	Yes	Yes
6469C		CV/CC	0-36	0-300	Yes	Yes
6472C		CV/CC	0-64	0-150	Yes	Yes
6475C		CV/CC	0-110	0-100	Yes	Yes
6477C		CV/CC	0-220	0-50	Yes	Yes
6479C		CV/CC	0-300	0-35	Yes	Yes
6483C		CV/CC	0-440	0-25	Yes	Yes
6824A	Bipolar Power Supply/ Amplifiers	CV/CL	–50 to +50	0-1.0	Yes	No
6825A		CV/CC	–20 to +20 –5 to +5	0-2	Yes	Yes
6826A		CV/CC	–50 to +50 –5 to +5	0-1	Yes	Yes
6827A		CV/CC	–100 to +100 –10 to +10	0-0.5	Yes	Yes

NOTES: 1. A CV/CC power supply acts as a constant voltage (CV) source for comparatively large values of load resistance and as a constant current(CC) source for comparatively small values of load resistance. A CV/CL supply is similar to a CV/CC supply except for less precise regulation at low values of load resistance, i. e. in the current limiting region.

2. These supplies contain a special protection circuit which affects the down programming speed (see para. 4-47).

3. These supplies (except Models 6453C, 56B, 59B, and 64C) require a factory installed option when programming with the 59501A (see para. 4-37).

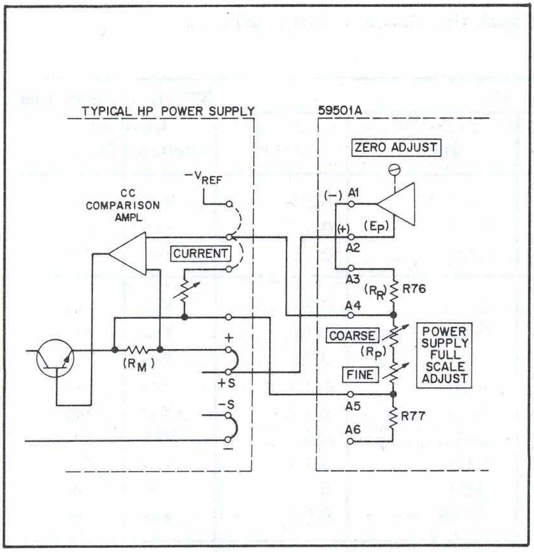


Figure 4-4. Typical 59501A/HP Power Supply Connections for Output Current Programming

4-31 Calibration

4-32 Before programming a 59501A/power supply combination, a simple two-step calibration procedure must be performed to match the particular power supply to the 59501A. A power supply is calibrated and programmed with the 59501A set to the unipolar mode. The bipolar mode is used when calibrating and programming a bipolar power supply/amplifier (BPS/A) with the 59501A.

4-33 Unipolar Mode. Calibrating a 59501A/power supply combination consists of two adjustments:

1. Use ZERO ADJ on 59501A to set the supply's output to 0V when the 59501A is programmed to zero "2ØØØ."
2. Use POWER SUPPLY FULL SCALE ADJ (COARSE and FINE) on 59501A to set the supply's output to a desired maximum value when the 59501A is programmed to maximum "2999."

4-34 The maximum desired power supply output can be set to any value within the rating of the particular supply. For example, if only 20V maximum is required for a model 6266B supply (40V rating), the 6266B output range should be calibrated for an output range of 0V to 20V. Since the 59501A is programmable in 999 steps (magnitude digits 000-999), resolution is 20/999 (about 20mV) in the high range and 2/999 (about 2mV) in the low range. If the supply is calibrated for the full 40V rating, the resolution is 40mV (approx.) even though the supply would never be programmed above 20V.

4-35 Note that for a 20V full scale output, it is usually better to calibrate the full scale setting to 99.9% of 20V or 19.98V. The reason for this is that the resolution will be 19.98/999 or exactly 20mV per step. However, if it is imperative to calibrate the output to exactly 20V, the resolution is 20/999, or 20.02002mV per step. Thus, the user must determine the importance of having a round number for resolution when writing programs.

4-36. Bipolar Mode. Calibration consists of using the front panel adjustments on the 59501A to set the BPS/A's desired bipolar output range when the 59501A is programmed to its maximum negative and positive limits. The desired bipolar range can be set to any value within the rating of the particular BPS/A. For example, the maximum output range of model 6826A is from −50V to +50V. To calibrate this range, the −50V output is calibrated with the 59501A programmed to "2ØØØ" and the +50V output is calibrated with the 59501A programmed to "2999". Since the 59501A is programmable in 999 steps, resolution is approximately 100mV (100/999). Note if it is desired to have a resolution equal to exactly 100mV, the positive limit is set to +49.9V instead of +50V. For this range (−50V to +49.9V), the resolution is exactly 100mV (99.9V/999).

4-37 Special Interfacing Considerations

4-38 Most power supplies can be connected directly to the 59501A; however, some of the high power (industrial performance) supplies require an additional circuit. This additional circuit, designated special Option J30, is required when programming the output voltage of models 6427B through 6448B and 6466C through 6483C. The Option J30 circuit is a voltage-to-current converter and is required because the 59501A is essentially a constant voltage source. The above supplies utilize current sources in their programming networks. The programmable 0 − 10V output of the 59501A is connected to the Option J30 input terminals (+ and −) on the rear of the supply as shown in Figure 4-5. One characteristic of the J30 converter is that if its input is open circuited, the output of the power supply will rise to about 25% of its rating. With the 59501A connected, the open circuit condition is prevented because a protection circuit in the 59501A presents a low impedance to the J30 input when ac power is removed from the 59501A.

4-39 Timing Considerations

4-40 All instruments have programming response times. Programming response time is defined as the time delay between a programming input and the desired output. The total response time (programming speed) of a controller/59501A/power supply combination depends upon the speed of each system component. Controller speed depends upon

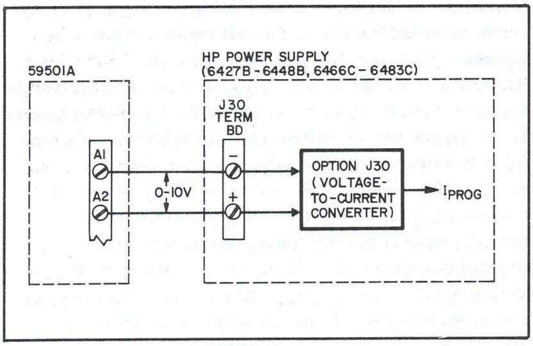


Figure 4-5. 59501A/Option J30 Connections

the particular controller's data transfer rate, the program, and the ROM's installed. The total response time of the 59501A is 250μsec. The programming speed of the power supply depends upon the particular model and load conditions.

4-41 **Controller/59501A Programming Speed.** The programming speed of a controller/59501A combination can best be explained using a typical program. The program example below is written for a 9825A calculator and will program the 59501A output from 0 to 9.99V in 1000 steps. The program includes a format statement, a for-next loop for 1000 (0-999) iterations, and a write statement.

```
0: fmt 1,f4.0,z
1: for N=0 to 999
2: wrt 706.1,2000+N
3: next N
*12253
```

4-42 This program will output 1000 (2000-2999) points to the 59501A in approximately 3.5 seconds (3.5 milliseconds per output). Each output requires (see Figure 4-6):
1170μsec (HP-IB setup time) + 230μsec (4 digits) + 2100μsec (time required for calculator/program to send the next output) = 3500μsec or 3.5msec.

4-43 **59501A/Power Supply Response Times.** Figure 4-7 illsutrates the response time of a 59501A/power supply combination. The 250μsec response time of the 59501A is the sum of data acceptance time (80μsec) and the analog slew time (170μsec). The data acceptance time is the minimum time required for the 59501A to accept the four digits from the controller. The analog slew time starts when the fourth digit is accepted and is the time required for the 59501A to reach 99% of the programmed value.

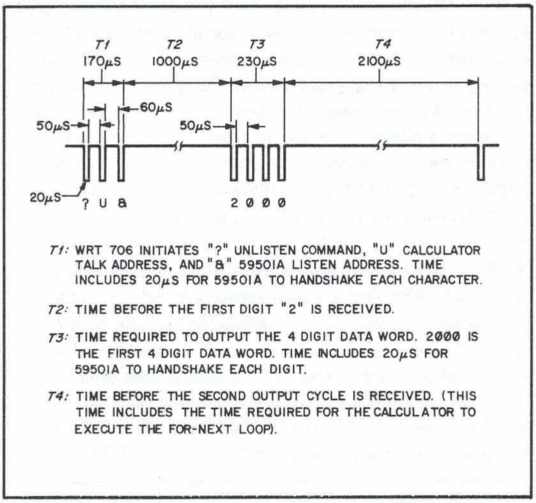


Figure 4-6. Typical 9825A/59501A Data Transfer, Timing Diagram

4-44 The programming speed of an HP power supply depends upon the particular model and load conditions. Programming speeds can vary from several milliseconds to a number of seconds (refer to the applicable power supply specifications sheet). Be sure to check the up and down programming speeds of the particular supply being considered for use in the HP-IB system. The longer programming response times usually occur when the supply is programmed down with little or no load current. The reason for the slower speed is that the supply's output capacitor discharges much more slowly without a load than with a load. If speed is important, it may be possible to program the power supply down before disconnecting the load.

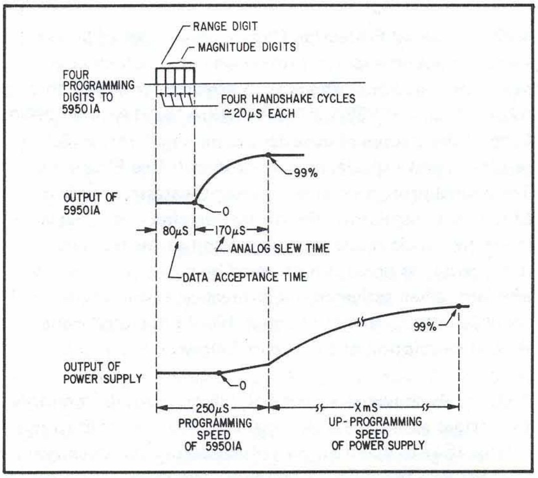


Figure 4-7. 59501A and Power Supply Response Times

4-45 Also, since the controller only waits for the 59501A to accept data and does not wait for the power supply to react, the user must consider whether or not a delay (wait period) is needed in the software. For example, if a controller programs a power supply to a particular voltage and then programs a digital voltmeter to read the supply's output voltage, then it is important to have the voltmeter wait until the output voltage has settled to its proper value before measuring it.

4-46 **BPS/A Response Time.** Bipolar power supply amplifiers (BPS/A's) are high speed instruments compared with power supplies and are well suited for use with the 59501A. Figure 4-8 illustrates the response time of a model 6827A BPS/A with respect to the analog slew time of the 59501A. The 6827A can be programmed through its full bipolar range (±100V) in 170μsec (max). This time does not include the data acceptance time of the 59501A.

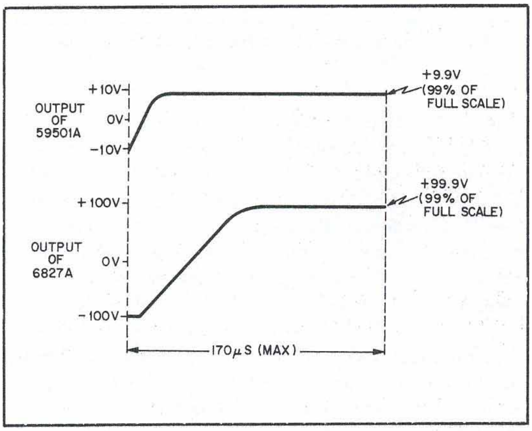


Figure 4-8. 59501A and 6827A Response Times

4-47 **Special Protection Circuit.** A number of power supplies contain a special protection circuit which affects programming speed. The models affected are 6256B through 6274B, 6282A, 6285A, 6286A, 6290A, 6291A, and 6296A. Each of these supplies includes a series regulator, an SCR preregulator, and a special protection circuit (see Figure 4-9) The special protection circuit prevents catastrophic failure of the series regulator. The protection circuit is activated if a short circuit is suddenly connected across the output or if the output is down programmed by more than a certain amount. When activated, the protection circuit limits the supply's output current to about 10% of the rated value. A brief description of the circuit follows.

4-48 As shown in Figure 4-9, the preregulator monitors the voltage across the series regulator and adjusts the input voltage (E_1) to maintain the voltage across the series regulator (E_2) below a few volts. Keeping E_2 low means low power dissipation and higher efficiency at high outputs. If a short circuit were suddenly placed across the output terminals, E_2 would tend to increase dangerously high. That is, with the output terminals shorted, E_{OUT} goes to zero volts and E_2 approaches E_1 (the voltage across the input filter capacitors). To prevent damage to the series regulator transistor when this condition occurs, the special protection circuit monitors E_2. Whenever E_2 reaches a predetermined value, the protection circuit turns on and causes the current comparison amplifier to limit the output current to about 10% of rated output current. At the same time the preregulator shuts off until E_1 bleeds down to yield a safe voltage across the series regulator. Output current will be limited to the 10% value until a safe voltage appears across the series regulator causing the protection circuit to reset. The reset time varies depending upon the particular model but can take from 400msec to 15 seconds. The output voltage of a particular power supply, such as the 6264B, takes only 80msec to go from 20V to 20mV, but it will take about 800msec before the circuit resets and full output current is supplied.

4-49 The protection circuit is also activated if the output voltage is programmed down by more than 4 volts (approx.). The actual value depends upon the particular power supply model. To prevent activating the circuit, the supply can be programmed down in small increments (e. g. 4V) with programming delays between increments.

4-50 Overall Accuracy

4-51 The discussion of timing illustrated that the total speed depended upon the speed of the individual system components. This same principal applies to temperature coefficient, drift, etc. In other words, the combination of a 59501A and a power supply exhibits an overall performance that is the sum of the characteristics of the two. Obviously the primary concern is that of overall accuracy. Accuracy includes every variable that could possibly affect the output setting such as:

Source Effect (Line Regulation)
Load Effect (Load Regulation)
Drift (Stability)
Temperature Coefficient

4-52 A worst case figure would be the sum of all these four variables. In reality the user can probably minimize some of these parameters. If it is known that the source (AC line) will remain within ±5% limits instead of ±10% limits then a 2:1 improvement is expected in this parameter. If the load impedance is constant, then this parameter may be subtracted from the accuracy specification. Drift usually cannot be improved by the user since its behavior is dependent upon such variables as stability of feedback networks, reference voltages, base currents in the input error amplifier, base-to-emitter voltage ratios and many others. These same

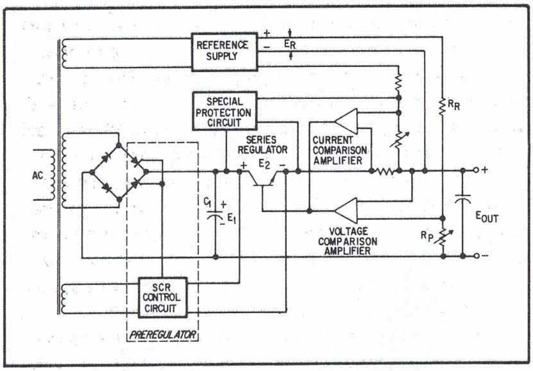


Figure 4-9. Simplified Schematic of Power Supply with Special Protection Circuit

variables not only contribute to drift but also to temperature coefficient. However, if the ambient temperature can be controlled closely, such as in a standards room, then the accuracy will be improved even further. Usually accuracy is specified at 23°C ±5°C which represents a normal laboratory environment. Factory calibration is performed at about 23°C. If the user were to operate the 59501A and the power supply at 45°C then it would probably make sense to recalibrate the units at this temperature especially if better accuracy were required. The composite system accuracy, then, is the sum of the 59501A accuracy plus the accuracy of the power supply. Accuracy specifications are provided in the 59501A data sheet and the individual power supply data sheets.

4-53 USING 59501A AS A DIGITAL-TO-ANALOG CONVERTER

4-54 Using the 59501A as a digital-to-analog converter (DAC) is quite versatile and easy. The output of the DAC is available at terminals A1 and A2. The unipolar mode provides a 0 to 9.99V output range and the bipolar mode provides a −10V to +9.98V range. Output terminals A1 and A2 are connected directly to the user's device and the programmable output is used as a low level dc signal source. The ZERO ADJUST and the D/A FULL SCALE ADJUST on the 59501A front panel are used to calibrate the 59501A output range.

4-55 In the unipolar mode, the two adjustments are used to set the zero and the maximum output. The ZERO ADJUST allows the output to be adjusted to zero (±250 millivolts) when the 59501A is programmed to zero (2ØØØ). The ability to actually set a finite zero is useful when compensating for a specific offset in an external amplifier. The D/A FULL SCALE ADJUST allows the output to be adjusted to 9.99V (±5%) when the 59501A is programmed to maximum (2999). This range results in a resolution of 9.99V/999 or 10mV per programming step.

4-56 In the bipolar mode, the two adjustments are used to set the negative and positive output limits. The ZERO ADJUST allows the negative limit to be set to −10V when the 59501A is programmed to zero (2ØØØ). The D/A FULL SCALE ADJUST allows the positive limit to be set to +9.98V when the 59501A is programmed to maximum (2999). This range results in a resolution of 19.98V/999 or 20mV per programming step.

4-57 SAMPLE PROGRAMS

4-58 Sample programs using the 9825A calculator are provided in examples 1 and 2. Example 1 is a sample program for controlling the output voltage of a 59501A/power supply combination. Example 2 generates a repetitive ramp output from the 59501A.

4-59 Power Supply Voltage Output

4-60 The sample program given in example 1 can be used to program the output voltage of any 59501A/power supply combination. The program contains calibration and setup routines and allows the operator to input specific voltage values on the keyboard. The program also includes automatic changing of ranges and error messages that indicate when the voltage requested by the operator exceeds the maximum value available or when a negative voltage is requested. A line-by-line explanation is given after the program. Programming fundamentals are provided in Chapter III.

4-61 The sample program requires use of the General I/O and Extended I/O ROM's. After keying in the program, press RUN on the calculator. All operations required to complete the program are given on the calculator display. After each operation is completed, press CONTINUE. The operator enters the maximum desired output voltage value (e. g. 20) when "Enter maximum output voltage" appears on the display. The program automatically uses 99.9% of this value (e.g. 19.98) to calibrate the supply (see paragraph 4-34). After connecting the load, the operator enters the desired output voltage (line 13) on the keyboard and presses CONTINUE. If it is desired to recalibrate the power supply (change the maximum desired output voltage) press STOP and then press RUN.

4-62 59501A Ramp Output

4-63 The program given in example 2 generates a repetitive ramp output from the 59501A. The ramp is programmed from 0 to +9.99V in 100mV steps. A 10 millisecond delay (line 7) is programmed between steps. This delay can be deleted if maximum speed is desired.

Example 1. 9825A Sample Program, Power Supply Voltage Output

```
0: "UNIPOLAR Power Supply Voltage Output":
1: dsp "Set 59501A to UNIPOLAR";stp
2: dsp "Turn PSFS ADJ fully CCW";stp
3: ent "Enter maximum output voltage",E
4: E/1000→D;E-D→E
5: cmd 7,"?U&","2999"
6: dsp "Set PSFS ADJ for",E;stp
7: cmd 7,"?U&","2000"
8: dsp "Set ZERO ADJ for 0.000";stp
9: cmd 7,"?U&","2999"
10: dsp "Adjust PSFS FINE ADJ for ",E;stp
11: cmd 7,"?U&","2000"
12: dsp "Connect load to supply";stp
13: ent "Enter desired output voltage",V
14: if V<0;dsp "No negative voltages";wait 3000;gto 13
15: if V>E;dsp "Voltage too high";wait 3000;gto 13
16: if V<=.1*E;1000+int(V/.1D+.5)→N;gto 18
17: 2000+int(V/D+.5)→N
18: fmt 1,f4.0;wrt 706.1,N;gto 13
19: end
*10217
```

Explanation:

1-2:	Setup instructions.
3:	User enters desired maximum output voltage on keyboard (e. g. 10, 20, 50, 100, etc.).
4:	Resolution is calculated and the maximum desired output is changed to 99.9% of voltage entered in line 3 (see paragraph 4-34).
5-10:	Calibration routine using ZERO ADJUST and POWER SUPPLY FULL SCALE ADJUST (COARSE and FINE) controls on 59501A front panel.
11-12:	Output is programmed to zero. Load is connected to power supply's output terminals (see applicable power supply Operating and Service manual).
13:	User inputs desired voltage on keyboard.
14-15:	If the voltage requested (line 13) is negative or too high, the appropriate error message appears on the display for three seconds and then the program returns to line 13.
16-17:	Proper range is selected and correct data word value (N) is calculated for the voltage requested.
18:	Data word (N) representing the desired output voltage is sent to the 59501A. Format f4.Ø deletes leading spaces and z suppresses the carriage return/line feed codes (see paragraph 3-25).

Example 2. 9825A Sample Program, 59501A Ramp Output

```
0: "RAMP Output 59501A UNIPOLAR Mode":
1: for J=1 to 100
2: (J-1)*10+2000→N[J]
3: next J
4: for J=1 to 100
5: fmt 1,f4.0,z
6: wrt 706.1,N[J]
7: wait 10
8: next J
9: gto 4
10: end
*1034
```

CHAPTER V
6002A EXTENDED RANGE POWER SUPPLY WITH OPTION 001

5-1 GENERAL

5-2 The 6002A is an ideal power supply for operation in an HP-IB system. It is a compact power source and can deliver up to 200 watts. It is versatile by being able to deliver 50 volts at 4 amps or 20 volts at 10 amps and any other 200 watt combination in between. Option 001 allows the 6002A power supply to be digitally controlled via the HP-IB. With this option, an HP-IB controller can program the constant voltage (CV) or constant current (CC) output of the power supply. Mode switches on the rear panel of the supply allow selecting any one of three modes of operation: Local, HP-IB constant voltage (CV), or HP-IB constant current (CC). When the mode switch is set to local, the 6002A's front panel VOLTAGE and CURRENT potentiometers (or remote programming resistance/voltage) control operation and there is no control via the HP-IB. The basic operation of the Option 001 circuitry is the same as described for the 59501A in paragraphs 4-5 through 4-17 with the following exceptions.

1. Option 001 does not provide a bipolar output.
2. Option 001 does not have an indicator to monitor its "Listening" status.
3. The programmable output (E_P) of Option 001 is applied directly to the 6002A supply's CV or CC comparison amplifiers through the mode switch.

5-3 The magnitude of E_P ranges from 0 to +6.20V (nominal) for high range programming codes (2ØØØ – 2999) and from 0 to +1.24V (nominal) for low range programming codes (1ØØØ – 1999). The 0 to +6.20V range programs the CV output of the supply from 0 to 49.95V or the CC output from 0 to 9.99A. The 0 to +1.24V range programs the CV output of the supply from 0 to 9.99V or the CC output from 0 to 1.998A.

5-4 CV/CC PROGRAMMING

5-5 Figure 5-1 illustrates the Option 001 amplifier output (E_P), the mode switches, and the CV and CC comparison amplifier circuits in the 6002A power supply. In the CV mode, $+E_P$ is substituted for the +6.2V internal reference and is applied to the summing point of the CV comparison amplifier through R_R. Also, the wiper of the VOLTAGE control (R_P) is open circuited making it a fixed resistor. The constant voltage output of the supply is programmed by E_P with a voltage gain dependent upon the ratio of R_P to R_R. This method of programming is called voltage programming with gain (see paragraph 4-23).

5-6 In the CC mode, $-E_P$ is substituted for the –6.2V reference in the CC comparison amplifier to program the supply's output current. Also, the wiper of the CURRENT control is open circuited making it a fixed resistor. Programmed changes in E_P will program the supply's output current to the desired value.

5-7 The mode switches allow programming either the CV or CC output via the HP-IB but not both at the same time. If both switches are inadvertently pushed in (CV and CC both selected), the output of the supply is held near zero and there is no control from either the front panel controls or the HP-IB.

5-8 If both CV and CC control is required via the HP-IB, Option 001 can program one function (e. g., CV) and the 59501A can program the other (CC). Hardware connections for this configuration are given in paragraph 2-13.

5-9 CALIBRATION

5-10 When shipped from the factory, the 6002A – Option 001 is calibrated (internal adjustments) for CV programming on the HP-IB. If it is desired to program the CC output on the HP-IB, the unit must be calibrated in accordance with procedures provided in the 6002A Operating and Service manual. There are no front panel adjustments associated with the Option 001 circuitry. Note, however, that when programming the CV output, the OVERVOLTAGE control on the 6002A front panel should be set one volt above the maximum voltage value that is to be programmed.

5-11 TIMING CONSIDERATIONS

5-12 The combined speed of the HP-IB controller and the Option 001 interface is the same as described for the 59501A (see paragraph 4-41) and is much faster than the response time of the 6002A power supply. Consequently, the 6002A is not useful in generating fast unipolar waveforms or rapid changes in output. The 6002A will respond in less than 100 milliseconds when programmed from 0 to 99.9% of maximum rated output voltage. This response is independent of load. For programming the supply down (100% to 0.1% of maximum rated output) the output takes approximately 400 milliseconds without any load and approximately 200 milliseconds with a full load. The slower time to program down is due to the supply's output capacitor which discharges much more slowly without a load than with a load.

5-13 SAMPLE PROGRAM

5-14 The following is an example of a simple program using the 9825A calculator. This program allows the user to program the 6002A power supply output voltage by simply entering the desired voltage on the keyboard. The program automatically selects the correct range, rounds off values to closest 3-digit magnitude, and also displays appropriate error statements for negative voltages and for values higher than 50 volts.

```
0: "VOLTAGE OUTPUT;6002A":
1: "INPUT IS IN VOLTS":
2: fmt 1,f4.0,z
3: ent "ENTER V IN VOLTS",V
4: if V=50;gto 13
5: if V>=0;gto 9
6: dsp "NO NEGATIVE VOLTAGES"
7: wait 3000
8: gto 3
9: if V<50;gto 14
10: dsp "VOLTAGE TOO HIGH"
11: wait 3000
12: gto 3
13: 49.95→V
14: if V>9.995;gto 17
15: int(V/.01)→D;1000→N
16: gto 18
17: int(V/.05)→D;2000→N
18: N+D→N
19: wrt 705.1,N
20: gto 2
21: end
*23349
```

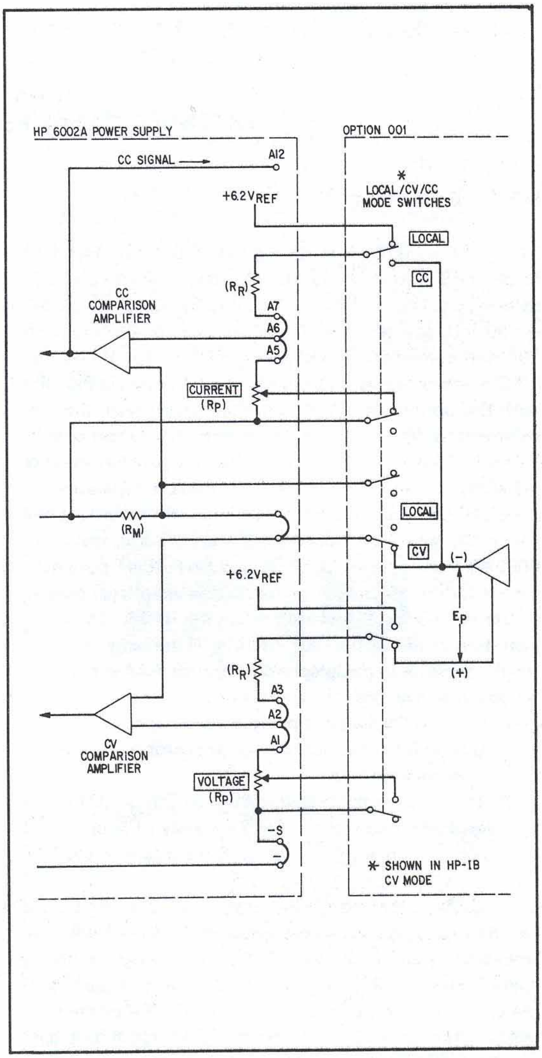


Figure 5-1. CV/CC Programming With Option 001

APPENDIX A
APPLICATIONS

A-1 RELAY TESTING

A-2 An HP-IB controlled relay test system is illustrated in Figure A-1. A 6002A-001 power supply provides the voltage to operate the relay. A 9825A calculator programs the 6002A-001 to produce a ramp output in 0.5V steps. The instant the armature of the relay pulls in, the calculator prints the voltage value. Next, the calculator ramps downward. At the moment the contacts open, the calculator records the dropout voltage. For a production quantity of relays, an entire set of data is available in the calculator for analysis. The calculator can print, or plot, the distribution of relay characteristics and the minimum and maximum pull-in and dropout voltages along with the mean and standard deviation. For life testing, a relay can be repeatedly cycled. Any changes in relay performance can be detected by changes in pull-in and dropout voltages.

A-3 Relay contact resistance can also be measured at the same time. A 59501A is used to program a constant current source (HP Model 6181C) which is connected across a pair of relay contacts. A digital voltmeter (HP Model 3437A) monitors the voltage across the contacts. The calculator can plot or print the contact resistance as a function of relay coil voltage (which determines contact pressure) and calculate resistance changes as a function of cycling. This test may reveal production problems with the contacts or fatigue and distortion of the springs.

A-4 PRINTED CIRCUIT BOARD TESTING

A-5 In another application, a 6002A – Option 001 power supply is being controlled by a 9825A calculator to drive a group of printed circuit logic cards inside an environmental test chamber. While measuring several parameters on each card, the calculator varies the DC supply voltage on the cards at various operating temperatures. This data is later analyzed by the calculator to determine rejects. Certain irregularities could indicate changes needed in the design of the cards.

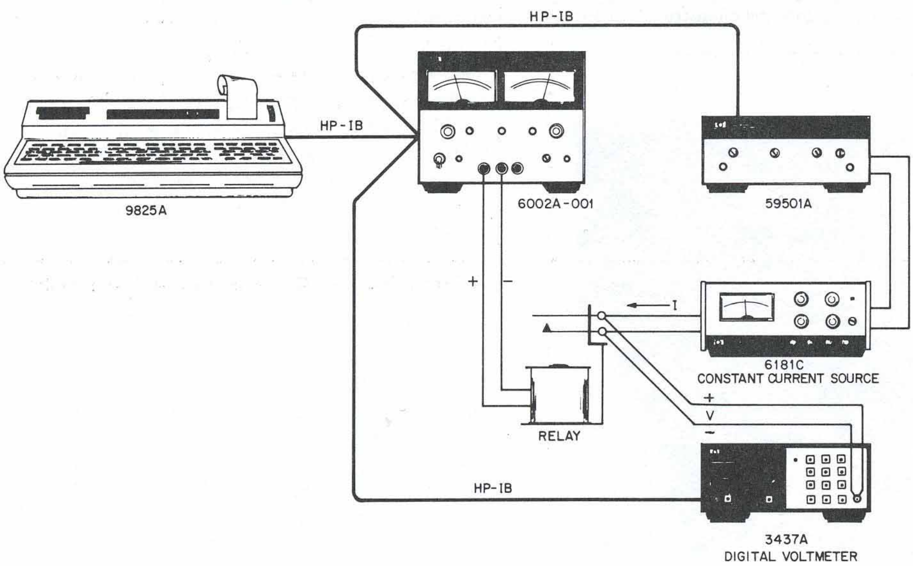


Figure A-1. HP-IB Controlled Relay Test System

APPENDIX B
MP RESISTANCE OUTPUT CARD/POWER SUPPLY SELECTION TABLES

B-1 To program HP power supplies and bipolar power supply/amplifiers, the applicable resistance output cards must be installed in the multiprogrammer (MP) system. These cards provide a programmed value of resistance as their output. Twelve magnetically shielded, mercury wetted, reed relays select the resistance values by modifying the value of a series string of high accuracy, binary weighted resistors. A maximum of 15 resistance output cards may be used in any one mainframe.

B-2 POWER SUPPLY AND RESISTANCE OUTPUT CARD SELECTION

B-3 Table B-1 lists the HP dc power supplies which have been tested with the applicable resistance output card for operation with the Multiprogrammer. Option number 040 is assigned to these power supplies. The option (as performed by the factory) consists of (1) special calibration, and (2) protection checkout. The former procedure insures (by addition of adjustment of calibration controls) that the power supply can be accurately set to zero and the maximum rated output voltage or current when programmed by the Multiprogrammer; the latter procedure insures (by modifications of internal circuitry, if necessary) that the power supply will not be damaged by the rapid, repetitive programming possible with the Multiprogrammer. Other HP power supplies under 100 volts, not listed in the table, are available with modifications equivalent to Option 040 on special order.

B-4 BPS/A AND RESISTANCE OUTPUT CARD SELECTION

B-5 Table B-2 lists the resistance output cards that can be used to control the gain, voltage, and current of Bipolar Power Supply/Amplifiers (BPS/A's), Models 6825A-6827A. The 69325A card controls the magnitude and polarity of the Bipolar Power Supply/Amplifier output voltage. During the period that the resistance output of the card is changing, a hold command from the card causes the BPSA voltage to remain relatively constant, and then make a smooth transition to the new output voltage. The 69326A or 69327A card is used to independently control the positive and negative current limits, and to monitor the status of the BPSA current limit. The 69328A programs the gain of the amplifier from zero (no gain) to the full gain value of X2, X4, X8, X20 or X40, depending on the particular model of HP BPSA being controlled.

Table B-1. HP Power Supply (Equipped with Option 040) and Resistance Output Card Selection Table

HP POWER SUPPLY			VOLTAGE PROGRAMMING			CURRENT PROGRAMMING §		
Volts	Amps	Model	Resistance Card	Volt/Step	Accuracy	Resistance Card	Amp/Step	Accuracy ‡
0-7.5	0-5	6281A	69501A	10mV	1% ± 20mV	69501A	10mA	10% ± 65mA
0-8	0-1000	6464C	69501A	10mV	1.0% ± 5mV	69501A	2A	1.0% ± 2A
0-10	0-2	6113A	69504A	10mV	0.1% ± 2mV	69512A	40mA	◇
0-10	0-10	6282A	69501A	10mV	1% ± 20mV	69501A	20mA	10% ± 65mA
0-10	0-20	6256B	69501A	10mV	1.0% ± 10mV	69510A	0.4A	10% ± 85mA
0-10	0-50	6259B	69501A	10mV	1.0% ± 8mV	69510A	1A	10% ± 65mA
0-10	0-100	6260B	69501A	10mV	1.0% ± 10mV	69510A	2A	10% ± 205mA
0-16 or 0-18	0-600 or 0-500	6466C	69501A	10mV	1.0% ± 5mV	69501A	3A	1.0% ± 2A
0-20 0-40 Dual Output; Dual Range	0-0.6 0-0.3	6205B	2 Each 69501A	10mV	1% ± 20mV	Current Limit Not Adjustable		
0-20	0-1	6111A †	69504A	10mV	0.1% ± 2mV	69512A	20mA	◇
0-20 0-40	0-2 0-1	6114A ††	69505A	10mV	.025% ± 1mV	69512A	40mA	2% ± 5mA
0-20	0-3	6284A	69501A	10mV	1% ± 20mV	69513A	60mA	10% ± 60mA
0-20	0-3	6253A *	2 Each 69501A	10mV	1% ± 20mV	69513A	60mA	10% ± 60mA
0-20	0-10	6263B	69501A	10mV	1.0% ± 9mV	69512A	0.2A	10% ± 50mA
0-20	0-20	6264B	69501A	10mV	1.0% ± 10mV	69510A	0.4A	10% ± 85mA
0-20	0-50	6261B	69501A	10mV	1.0% ± 8mV	69510A	1.0A	10% ± 65mA
0-24	0-3	6224B	69501A	10mV	1.0% ± 15mV	69513A	60mA	10% ± 35mA
0-25	0-1	6220B	69502A	25mV	1% ± 50mV	69512A	20mA	10% ± 20mA
0-25	0-2	6227B *	2 Each 69501A	10mV	1% ± 25mV	69512A	40mA	10% ± 15mA
0-36	0-300	6469C	69501A	10mV	1.0% ± 5mV	69501A	0.6A	1.0% ± 1A
0-40	0-0.5	6112A †	69504A	10mV	0.1% ± 2mV	69512A	10mA	◇
0-40	0-1.5	6289A	69501A	10mV	1% ± 20mV	69511A	30mA	10% ± 30mA
0-40	0-1.5	6255A*	2 Each 69501A	10mV	1% ± 20mV	69511A	30mA	10% ± 30mA
0-40	0-3	6265B	69501A	10mV	1.0% ± 7mV	69512A	60mA	10% ± 12mA
0-40	0-5	6266B	69501A	10mV	1.0% ± 8mV	69512A	0.1A	10% ± 20mA
0-40	0-10	6267B	69501A	10mV	1.0% ± 8mV	69512A	0.2A	10% ± 30mA
0-40	0-30	6268B	69501A	10mV	1.0% ± 8mV	69510A	0.60A	10% ± 40mA
0-40	0-50	6269B	69501A	10mV	1.0% ± 8mV	69510A	1.0A	10% ± 65mA
0-50	0-0.5	6220B	69502A	25mV	1% ± 25mV	69512A	10mA	10% ± 10mA
0-50 0-100	0-0.8 0-0.4	6115A ††	69506A	25mV	.025% ± 1mV	69511A	15mA	2% ± 5mA
0-50	0-1	6228B *	2 Each 69502A	25mV	1% ± 25mV	69512A	20mA	10% ± 15mA
0-50	0-1.5	6226B	69502A	25mV	1.0% ± 15mV	69511A	30mA	10% ± 18mA
0-60	0-1	6294A	69502A	25mV	1% ± 50mV	69512A	20mA	10% ± 20mA
0-60	0-3	6271B	69502A	25mV	1.0% ± 6mV	69512A	60mA	10% ± 12mA
0-60	0-15	6274B	69502A	25mV	1.0% ± 7mV	69512A	0,3A	10% ± 50mA
0-64	0-150	6472C	69502A	25mV	1.0% ± 25mV	69501A	0.3A	1.0% ± 1A
0-100	0-0.75	6299A	69502A	25mV	1% ± 15mV	69511A	15mA	10% ± 15mA

§ Each current programming card (models 69510A-69513A) provides two independent outputs, and thus can program the current output of two power supplies. The 69501A card has only one output and is used for current programming of certain high current supplies.

‡ The accuracy specification refers to the combination of the power supply and the programming card; it includes the effects of load related internal temperature changes in the supply.

◇ These supplies are constant voltage/current limit, rather than constant voltage/constant current.

† The 6111A and 6112A supplies have thumbwheel voltage controls.

†† No special option 040 modifications are necessary for these dual range supplies, 6114A and 6115A.

* Dual Output.

Table B-2. BPSA Control Card Selection Table

Bipolar Supply Model #	Voltage Programming			Current Programming			Gain Programming			
	Card	Resolution	Accuracy	Card	Resolution	Accuracy	Card	Resolution	Full Scale Gain	Accuracy
6825A ±20V,2A Range	69325A	10mV	0.1% ±4mV	69326A	32mA	2% ±2mA	69328A	8/4095	8	0.1%
±5V,2A Range	69325A	2.5mV	0.1% ±1mV	69326A	32mA	2% ±2mA	69328A	2/4095	2	0.1%
6826A ±50V,1A Range	69325A	25mV	0.1% ±10mV	69326A	16mA	2% ±1mA	69328A	20/4095	20	0.1%
±5V,1A Range	69325A	2.5mV	0.1% ±1mV	69326A	16mA	2% ±1mA	69328A	2/4095	2	0.1%
6827A ±100V, 0.5A Range	69325A	50mV	0.1% ±20mV	69327A	8mA	2% ±0.5mA	69328A	40/4095	40	0.1%
±10V, 0.5A Range	69325A	5mV	0.1% ±2mV	69327A	8mA	2% ±0.5mA	69328A	4/4095	4	0.1%

Rear terminals on the BPSA allow the range to be selected by remote contact closure if desired.

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