Agilent 75000 Series B

Agilent E1328A
4-Channel D/A Converter Module

User's Manual and SCPI Programming Guide

Where to Find it - Online and Printed Information:

System installation (hardware/software)............. VXIbus Configuration Guide*
Agilent VIC (VXI installation software)*

Module configuration and wiring........................ This Manual
SCPI programming... This Manual
SCPI example programs...................................... This Manual
SCPI command reference .... This Manual
Register-Based Programming .... This Manual

VXI*plug&play* programming .... VXI*plug&play* Online Help
VXI*plug&play* example programs...................... VXI*plug&play* Online Help
VXI*plug&play* function reference .... VXI*plug&play* Online Help
Soft Front Panel information............................... VXI*plug&play* Online Help

VISA language information .... Agilent VISA User's Guide

Agilent VEE programming information .... Agilent VEE User's Manual

**Supplied with Agilent Command Modules, Embedded Controllers, and VXLink.*

Agilent Technologies

Manual Part Number: E1328-90005
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Agilent E1328B User's Manual

Notes

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Agilent E1328A 4-Channel D/A Converter Module User's Manual
Edition 5 Rev 2

Printing History

The Printing History shown below lists all Editions and Updates of this manual and the printing date(s). The first printing of the manual is Edition 1. The Edition number increments by 1 whenever the manual is revised. Updates, which are issued between Editions, contain replacement pages to correct the current Edition of the manual. Updates are numbered sequentially starting with Update 1. When a new Edition is created, it contains all the Update information for the previous Edition. Each new Edition or Update also includes a revised copy of this printing history page. Many product updates or revisions do not require manual changes and, conversely, manual corrections may be done without accompanying product changes. Therefore, do not expect a one-to-one correspondence between product updates and manual updates.

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Safety Symbols

Instruction manual symbol affixed to product. Indicates that the user must refer to the manual for specific WARNING or CAUTION information to avoid personal injury or damage to the product.

Indicates the field wiring terminal that must be connected to earth ground before operating the equipment—protects against electrical shock in case of fault.

or Frame or chassis ground terminal—typically connects to the equipment's metal frame.

Alternating current (AC).

Direct current (DC).

Indicates hazardous voltages.

WARNING Calls attention to a procedure, practice, or condition that could cause bodily injury or death.

CAUTION Calls attention to a procedure, practice, or condition that could possibly cause damage to equipment or permanent loss of data.

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The following general safety precautions must be observed during all phases of operation, service, and repair of this product. Failure to comply with these precautions or with specific warnings elsewhere in this manual violates safety standards of design, manufacture, and intended use of the product. Agilent Technologies assumes no liability for the customer's failure to comply with these requirements.

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DO NOT operate the product in an explosive atmosphere or in the presence of flammable gases or fumes.

For continued protection against fire, replace the line fuse(s) only with fuse(s) of the same voltage and current rating and type.
DO NOT use repaired fuses or short-circuited fuse holders.

Keep away from live circuits: Operating personnel must not remove equipment covers or shields. Procedures involving the removal of covers or shields are for use by service-trained personnel only. Under certain conditions, dangerous voltages may exist even with the equipment switched off. To avoid dangerous electrical shock, DO NOT perform procedures involving cover or shield removal unless you are qualified to do so.

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According to ISO/IEC Guide 22 and CEN/CENELEC EN 45014

Manufacturer's Name: Agilent Technologies, Incorporated

Manufacturer's Address: *Measurement Product Generation Unit*
815 14th ST. S.W.
Loveland, CO 80537 USA

Declares, that the product

Product Name: 4 Channel D/A Converter
Model Number: E1328A
Product Options: *This declaration covers all options of the above product(s).*

Conforms with the following European Directives:

The product herewith complies with the requirements of the Low Voltage Directive 73/23/EEC and the EMC Directive 89/336/EEC and carries the CE Marking accordingly

Conforms with the following product standards:

EMC	Standard	Limit
	IEC 61326-1:1997+A1:1998 / EN 61326-1:1997+A1:1998	
	CISPR 11:1997 +A1:1997 / EN 55011:1998	*Group 1 Class A [1]*
	IEC 61000-4-2:1995+A1:1998 / EN 61000-4-2:1995	*4kV CD, 8kV AD*
	IEC 61000-4-3:1995 / EN 61000-4-3:1995	*3 V/m, 80-1000 MHz*
	IEC 61000-4-4:1995 / EN 61000-4-4:1995	*0.5kV signal lines, 1kV power lines*
	IEC 61000-4-5:1995 / EN 61000-4-5:1995	*0.5 kV line-line, 1 kV line-ground*
	IEC 61000-4-6:1996 / EN 61000-4-6:1996	*3V, 0.15-80 MHz*
	IEC 61000-4-11:1994 / EN 61000-4-11:1994	*I cycle, 100%*
	Canada: ICES-001:1998	
	Australia/New Zealand: AS/NZS 2064.1	

Safety *IEC 61010-1:1990+A1:1992+A2:1995 / EN 61010-1:1993+A2:1995*
Canada: CSA C22.2 No. 1010.1:1992
UL 3111-1:1994

Supplemental Information:

[1] The product was tested in a typical configuration with Agilent Technologies test systems.

September 5, 2000
Date

Jim White
Name

Quality Manager
Title

For further information, please contact your local Agilent Technologies sales office, agent or distributor.
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Notes

Notes

Notes

Chapter 1
Getting Started with the Agilent E1328A

Using This Chapter

This chapter describes the Agilent E1328A 4-Channel D/A Converter module, and contains information on how to program it using SCPI (Standard Commands for Programmable Instruments) commands. This chapter contains the following sections:

D/A Converter Description

The Agilent E1328A 4-Channel D/A Converter provides four independent, 16-bit isolated digital-to-analog channels configurable for either DC voltage or DC current output. Figure 1-1 shows a block diagram for one of the four

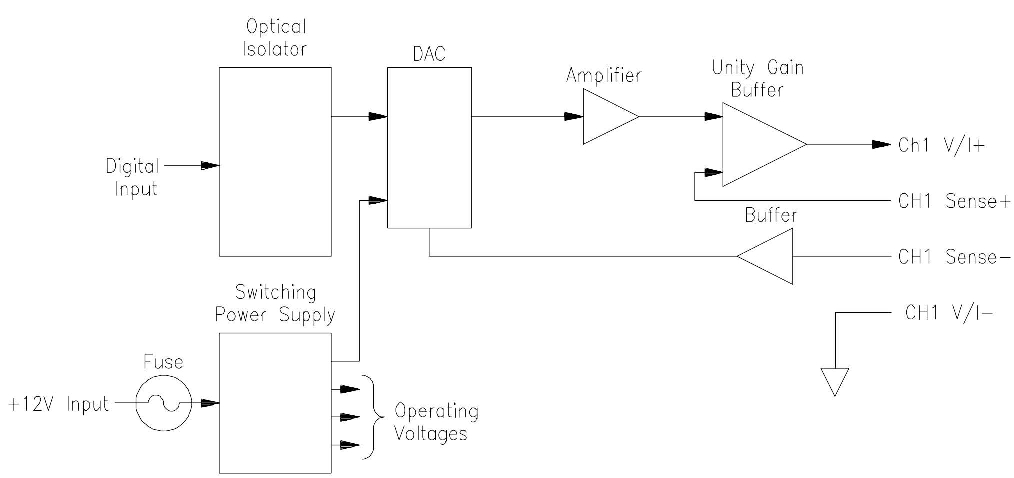

Figure 1-1. D/A Converter Block Diagram

Agilent E1328A channels. All four channels have the same block diagram.

General Description

Each of the four channels can be programmed to output voltage or current in one of the two operating modes.

– **Calibrated mode:** output voltage range is ±10.922 Vdc and output current range is ±21.84 mAdc.

– **Non-calibrated mode:** output range is typically ±12 Vdc and ±24 mAdc.

In the calibrated mode, output accuracy is dependent on the date of the last electronic adjustment performed (see Appendix A). This accuracy is maintained by use of stored adjustment constants in memory. Each channel has independent adjustment constants for both voltage and current, which are updated by performing the appropriate electronic adjustment procedure (see Chapter 3).

The electronic adjustment procedures used to update the channel's stored voltage and/or current adjustment constant in memory requires only a multimeter (5½-digit, 0.015% of reading + 1 mV accuracy) to complete. If a system multimeter is used, the electronic adjustment procedures can also be automated.

The four channels are electrically isolated from each other, and from chassis ground. This allows the usable output range (voltage and/or current) to be expanded by linking multiple channels. For example, the output voltage range can be expanded to 48 Vdc by linking channels in series, and the output current range can be expanded to 96 mAdc by linking channels in parallel.

Both voltage and current outputs on all channels are provided with output short circuit protection. Additionally, each channel configured for outputting voltage has no-fault remote-sensing capability to ensure accurate voltages at the load. If one of the sense leads become disconnected, the D/A Converter will automatically revert to local sensing.

The AC FAIL line (from the mainframe) is constantly monitored by the D/A Converter. If power fails, the D/A Converter channels are shut down to conserve power and provide greater hold-up time for the mainframe power supplies.

Instrument Definition

Agilent plug-in modules installed in an Agilent mainframe are treated as independent instruments, each having a unique secondary GPIB address. Each instrument is also assigned a dedicated error queue, input and output buffers, status registers and, if applicable, dedicated mainframe memory space for readings or data. An instrument may be composed of a single plug-in module (such as a counter) or multiple plug-in modules (for a switchbox or scanning voltmeter instrument).

Programming the D/A Converter

To program the D/A Converter using Standard Commands for Programmable Instruments (SCPI), you must select the controller language, interface address, and SCPI commands to be used. See *Installing the Agilent E1300B/E1301B Mainframe and Plug-In Modules Configuration Guide* for interface addressing and controller language information.

Note This discussion applies to SCPI programming. See Appendix B for details on register-based programming.

Selecting SCPI Commands

A SCPI command consists of a keyword, such as the source command [SOURce:]VOLTage*n* <*level*>. *n* defines the channel to be configured (for voltage in this case). Most keywords require that you specify the channel (1, 2, 3, or 4) you want to act on. If no channel is specified, the default is channel 1.

Some keywords must be followed by a value to set a parameter to a specific value (for example, voltage *level*, [SOURce:]VOLTage1 10.00000). "10.00000" outputs +10.00000 Vdc on channel 1 if properly configured for voltage. Additionally, some keywords must be followed by a value to set a parameter to a specific state (for example, calibration on/off CAL:STAT 1). The "1" sets the D/A Converter channel 1 mode to ON (calibration).

Note Implied commands are those which appear in square brackets (**[ ]**) in the command syntax. The brackets are not part of the command and are not sent to the instrument. [SOURce:] is an implied command and, therefore, is not required. See page 40 for more information about implied commands.

Notes

Chapter 2
Configuring the Agilent E1328A

Using This Chapter

This chapter shows how to connect external wiring to the 4-Channel D/A Converter module inputs, and how to configure the module for voltage and current output. This chapter contains the following sections:

Warnings and Cautions

WARNING **SHOCK HAZARD. Only service-trained personnel who are aware of the hazards involved should install, remove, or configure the D/A Converter module. Before you remove any installed module, disconnect AC power from the mainframe and field wiring.**

CAUTION **MAXIMUM VOLTAGE.** The maximum voltage that may be applied between any two terminals within the same channel is 15 Vdc. Do not apply voltage between any pair of terminals if the D/A Converter is turned off.

STATIC ELECTRICITY. Static electricity is a major cause of component failure. To prevent damage to the electrical components in the D/A Converter module, observe anti-static techniques whenever removing a module from the mainframe or whenever working on a module.

Setting the Logical Address Switch

The address switch (LADDR) factory setting is 72. You may have changed the setting during module installation. Valid address values are from 0 to 255. If the D/A Converter module is used in a Agilent E1300/E1301 Mainframe, refer to *Installing the Agilent E1300B/E1301B Mainframe and Plug-In Modules Configuration Guide* for addressing information. Otherwise, use Figure 2-1 to change the setting.

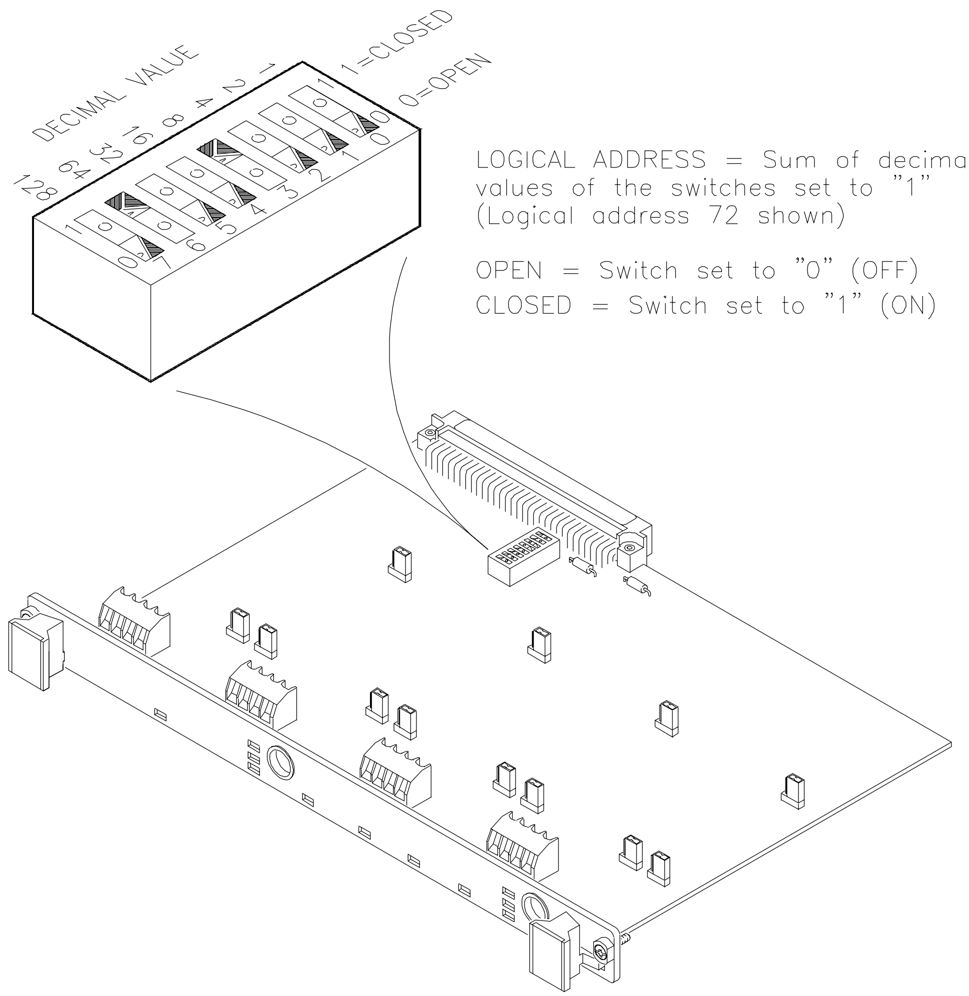

Figure 2-1. Locate and Set the Logical Address Switch

Selecting Voltage or Current Output

Each of the four D/A Converter channels is capable of providing either a voltage or current output. Voltage or current can be selected for each channel independently. Figure 2-2 shows the jumper location for each channel and highlights the jumpers for Channel 1. Figure 2-2 also shows the correct position for the desired output. Note that each channel contains three jumpers, and that all jumpers for a channel must be changed to the desired output.

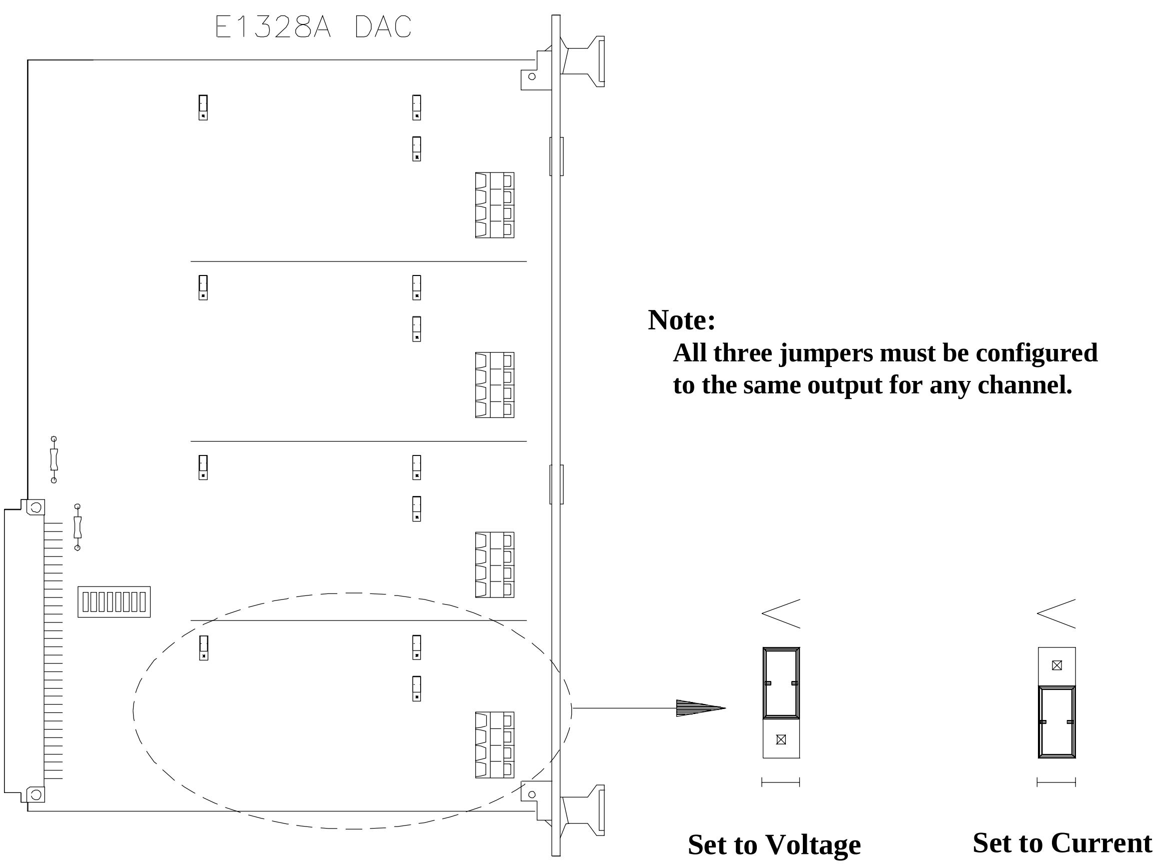

Figure 2-2. Voltage/Current Output Selection

CAUTION **Moving the V/I jumpers with power applied to the D/A Converter could cause improper operation or damage.**

Connecting Field Wiring

Figure 2-3 shows the input terminals for the D/A Converter output and sense terminals. Use the following guidelines for wire connections.

Wiring Guidelines

- It is recommended that each channel wire be identified (color coded or marked) as the connection is not visible when the D/A Converter module is installed.
- Be sure that wires make good connections on the screw terminals.
- Maximum wire size is 16 AWG. Wire ends should be stripped 6 mm (≈0.234 inch) and tinned to prevent single strands from shorting adjacent terminals.
- The other end may have any connection the user determines necessary.
- Do not connect the channel's SENSE terminals if they will not be used (for example, channel is being configured for a current output, or a voltage output without remote sensing).

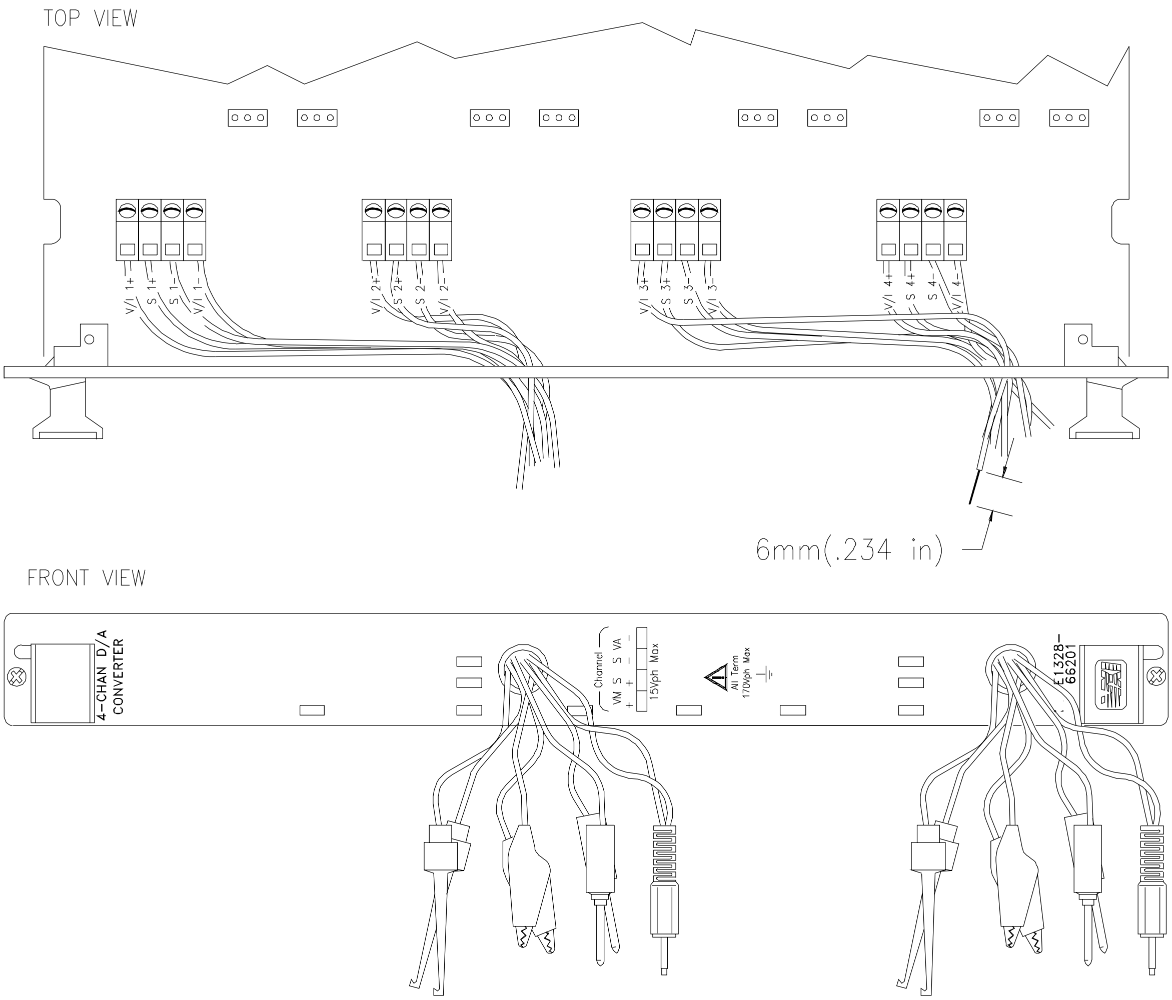

Figure 2-3. D/A Converter Terminals

Chapter 3
Using the Agilent E1328A

Using This Chapter

This chapter uses typical examples to show how to use the 4-Channel D/A Converter. Refer to Chapter 4, "Understanding the Agilent E1328A", for more information. This chapter contains the following:

D/A Converter Commands

Table 3-1. D/A Converter Commands Used in Chapter 3

Command **	Description
CAL:CURR*n z*,*z*,*z*	Used during the current electronic adjustment procedure to update a channel's stored adjustment constants in memory.
CAL*n*:STAT *y*	Selects calibrated (ON | 1) or non-calibrated mode (OFF | 0).
CAL:VOLT*n z*,*z*,*z*	Used during the voltage electronic adjustment procedure to update a channel's stored adjustment constants in memory.
[SOURce:]CURR*n xxx*	Causes the D/A Converter to output a specific current. Channel must be configured for current output (refer to page 17). Range is dependent on the mode selected.
[SOURce:]VOLT*n xxx*	Causes the D/A Converter to output a specific voltage. Channel must be configured for voltage output (refer to page 17). Range is dependent on the mode selected.
*RST	Sets the hardware and software to a known state.

** *n* = channel number, *xxx* = desired value, *y* = ON (1) or OFF (0), and *z*,*z*,*z* = measured minimum, default (0), and maximum values. [SOURce:] is a command that is implied (not required), but if it is used, delete the brackets and send as SOURce:.

Reset Conditions

When the D/A Converter is switched on or *RST (reset), all four channels are set to 0 Vdc/0 mAdc output (±100 ms.) and the calibrated mode is selected for all channels. Refer to Chapter 4 for more information.

Electronic Voltage Adjustment

The electronic voltage adjustment is used to update the stored voltage constants for each channel, and should be performed:

– on initial set-up;

– periodically (24 hours or 90 days) to maintain desired output accuracy (see Appendix A);

– when a ±5°C change in temperature from last adjustment performed has occurred;

– when the type of load is changed;

– or anytime accuracy is in doubt.

The adjustment procedure is performed for each channel as follows:

1. Configure the desired channel(s) for voltage output (see page 17).
2. Connect the load to the desired D/A Converter channel. Connect a voltmeter (external or system) to measure voltage at the load.
3. Set the D/A Converter channel to the non-calibrated mode.

Note The electronic adjustment ***must*** be performed in the ***non-calibrated mode*** (step 3), or errors in the adjustment constant will occur.

---

4. Set the channel's output to minimum (–12 volts). Measure and record to 5½-digits the actual output at the load.
5. Set the channel's output to default (0 volts). Measure and record to 5½-digits the actual output at the load.
6. Set the channel's output to maximum (+12 volts). Measure and record to 5½-digits the actual output at the load.
7. Record minimum, default, and maximum values and send them to the module as arguments of the CALibration command. New adjustment constants will be automatically calculated and stored from the entered measurement values.
8. Repeat steps 2 through 7 for all desired channels.

Example: Electronic Voltage Adjustment Using a System Voltmeter

Figure 3-1 shows how to connect channel 1 output terminals to the load and system voltmeter (Agilent E1326B/E1411B). The D/A Converter must be physically configured to provide voltage output on channel 1 (refer to page 17), and then instructed to perform the adjustment. For the example, use:

- An GPIB select code of 7, primary address of 09, and secondary address of 09 for the D/A Converter.
- An GPIB select code of 7, primary address of 09, and secondary address of 03 for the system voltmeter.
- An HP Series 200/300 Computer with BASIC.

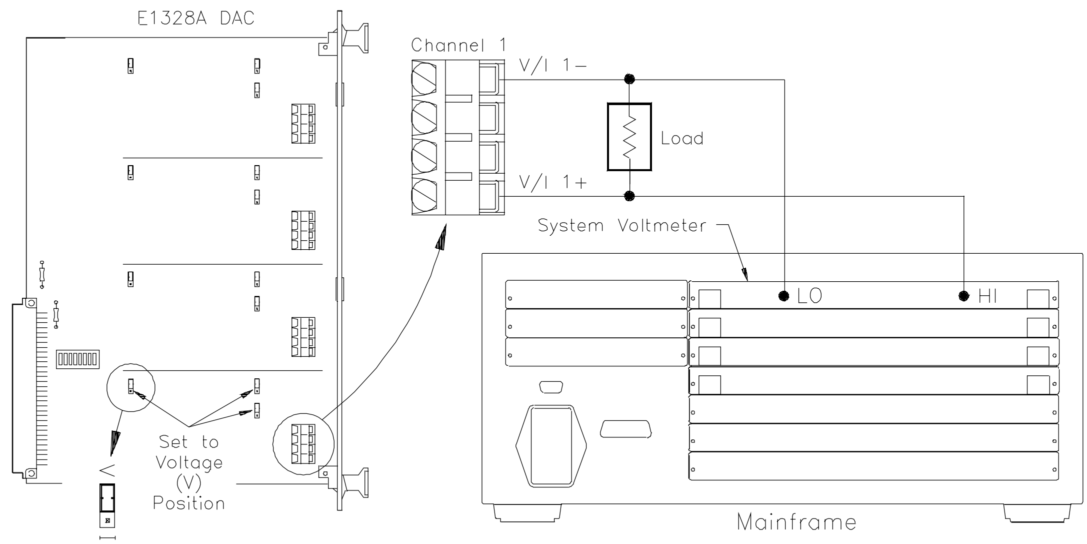

Figure 3-1. Electronic Voltage Adjustment

Execute:

```
10    REAL  A,B,C
20    OUTPUT  70909;"*RST"                 !Reset the D/A Converter to its
                                            default state; perform self-test.
30    OUTPUT  70909;"CAL1:STAT  OFF"       !Configure channel 1 to the
                                            non-calibrated mode.
40    OUTPUT  70909;"VOLT1  MIN"           !Configure channel 1 to output
                                            the minimum voltage (-12 volts).
50    OUTPUT  70909;"*OPC?"                !Hold program execution until
                                            the first output is complete. When
                                            done, generate an operation
                                            complete flag.
60    ENTER  70909;D                       !Dummy variable holds
                                            operation complete flag.
70    OUTPUT  70903;"MEAS:VOLT:DC?"        !Configure the system voltmeter to
                                            make a DC voltage measurement.
80    ENTER  70903;A                       !Store minimum voltage reading.
90    OUTPUT  70909;"VOLT1  DEF"           !Configure channel 1 to output
                                            the default voltage (0 volts).
100   OUTPUT  70903;"MEAS:VOLT:DC?"        !Configure the system voltmeter to
                                            make a DC voltage measurement.
```

```
110   ENTER 70903;B                   !Store default voltage reading.
120   OUTPUT 70909;"VOLT1 MAX"        !Configure channel 1 to output
                                      the maximum voltage (+12 volts).
130   OUTPUT 70903;"MEAS:VOLT:DC?"    !Configure the system voltmeter
                                      for a DC voltage measurement.
140   ENTER 70903;C                   !Store maximum voltage reading.
150   OUTPUT 70909;"CAL1:VOLT" ;A;B;C !Enter the measured minimum,
                                      default, and maximum values.
                                      New adjustment constants are
                                      calculated and stored for
                                      channel 1.
```

Comments

- **Test Hook-up.** If possible, calibrate to the same load (and leads) that the D/A Converter will be providing the voltage output to. Connect the voltmeter leads as close as possible to the load.

- **Voltmeter.** Any 5½-digit voltmeter with accuracy of at least (0.015% of reading +1mV) can be used when performing the adjustment. Agilent recommends using the Agilent E1326B/E1411B 5½-Digit Multimeter for a system voltmeter, or the Agilent 3457 for an external voltmeter (recommended for current).

- **Electronic Current Adjustment.** If a channel is only to be used for voltage output, it is not necessary to perform the current adjustment.

Outputting Voltage

- Will output voltage on channels 1, 2, 3, and/or 4.
- Range is 10.922 Vdc in calibrated mode and 12 Vdc in non-calibrated mode per channel.
- Range can be increased to a maximum of 43.600 Vdc in calibrated mode and 48 Vdc in non-calibrated mode by connecting all four channels in series.
- Remote sensing is available to ensure the selected voltage is available at the load.

Example: Voltage Output in Calibrated Mode

Figure 3-2 shows how to connect channel 1 output terminals to the load. The D/A Converter must be physically configured to provide voltage output on channel 1 (refer to page 17), and then instructed to output +10.00000 Vdc on channel 1 in the calibrated mode.

Execute:

CAL1:STAT ON	*Sets channel 1 to calibrated mode.*
VOLT1 10.00000	*Configures channel 1 for voltage and sets output at terminals to 10.00000 Vdc.*

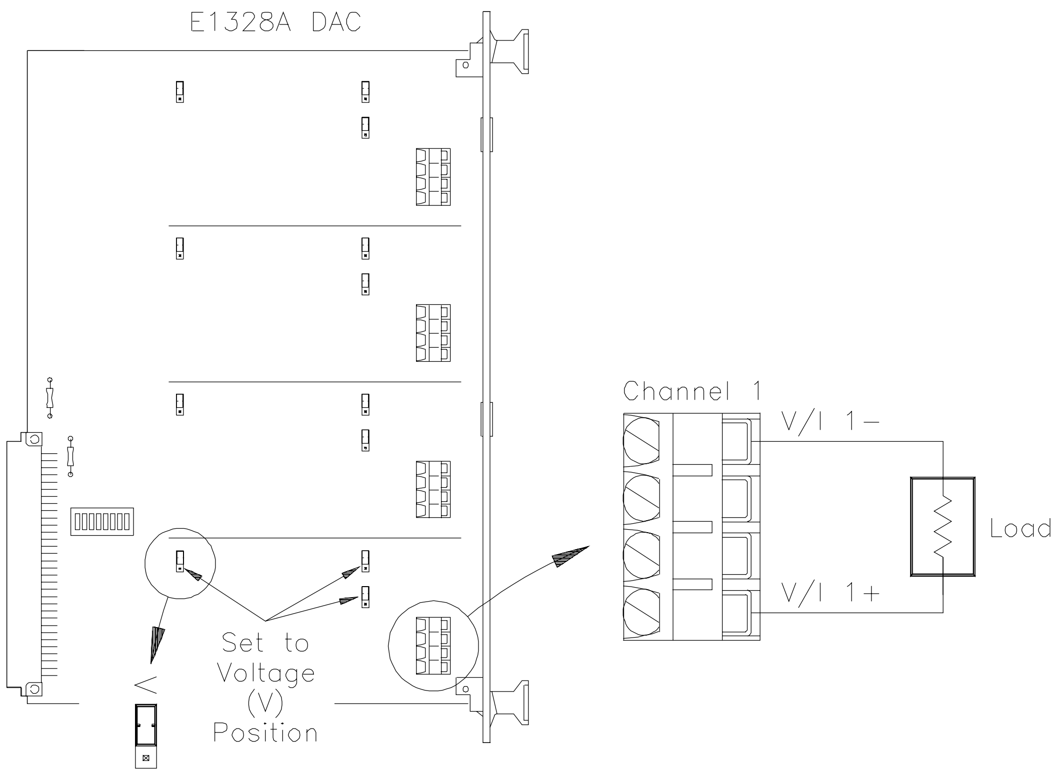

Figure 3-2. One Channel Voltage Output

Example: Voltage Output in Calibrated Mode with Remote Sensing

Figure 3-3 shows how to connect the sensing terminals to the load. The D/A Converter physical configuration and instructions are identical to those described earlier.

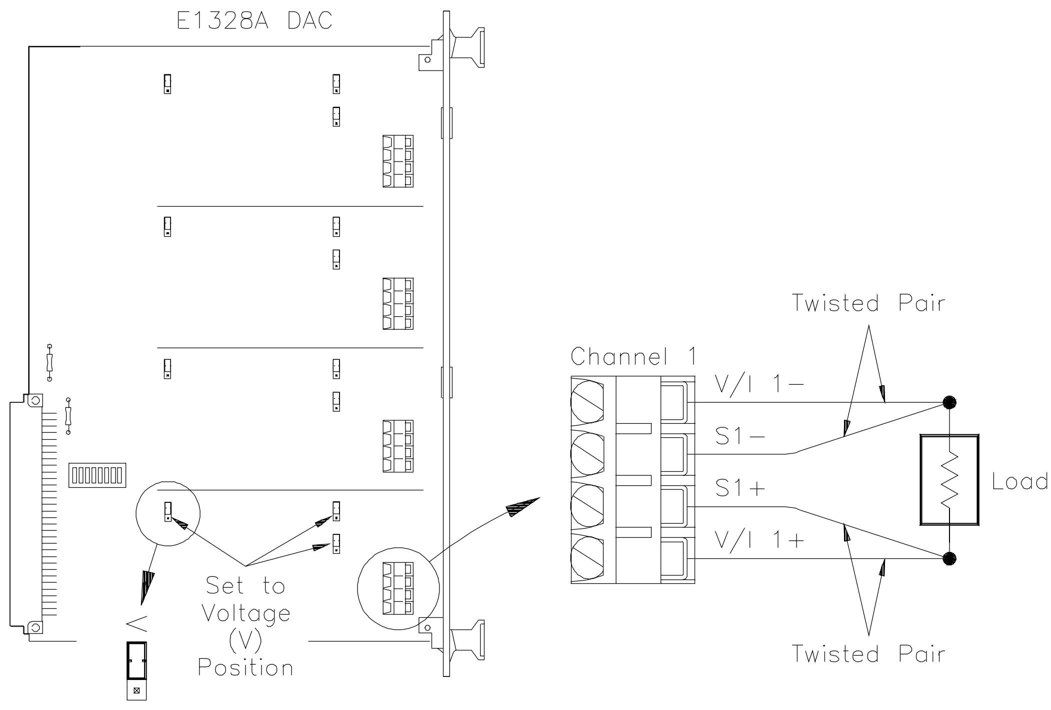

Figure 3-3. One Channel Voltage Output with Remote Sensing

Example: Expanding Voltage Output Range in the Calibrated Mode with Remote Sensing

Figure 3-4 shows how to configure channel 1 and 2 output terminals in series to increase the range, connecting the sense terminals, and connecting to the load. The D/A Converter must be physically configured to provide voltage output on channels 1 and 2 (refer to page 17), and then instructed to output a specific voltage on channels 1 and 2 in order to obtain a total of +20.00000 Vdc in the calibrated mode. For the example, use:

- an GPIB select code of 7, primary address of 09, and secondary address of 09 for the D/A Converter;
- an HP Series 200/300 computer with BASIC.

Execute:

10	OUTPUT 70909;"*RST"	*!Reset the D/A Converter to its default state.*
20	OUTPUT 70909;"VOLT1 10.00000"	*!Configure channel 1 for voltage and sets output at terminals to +10.00000 V in the calibrated (default) mode.*
30	OUTPUT 70909;"VOLT2 10.00000"	*!Configure channel 2 for voltage and sets output at terminals to +10.00000 V in the calibrated (default) mode.*

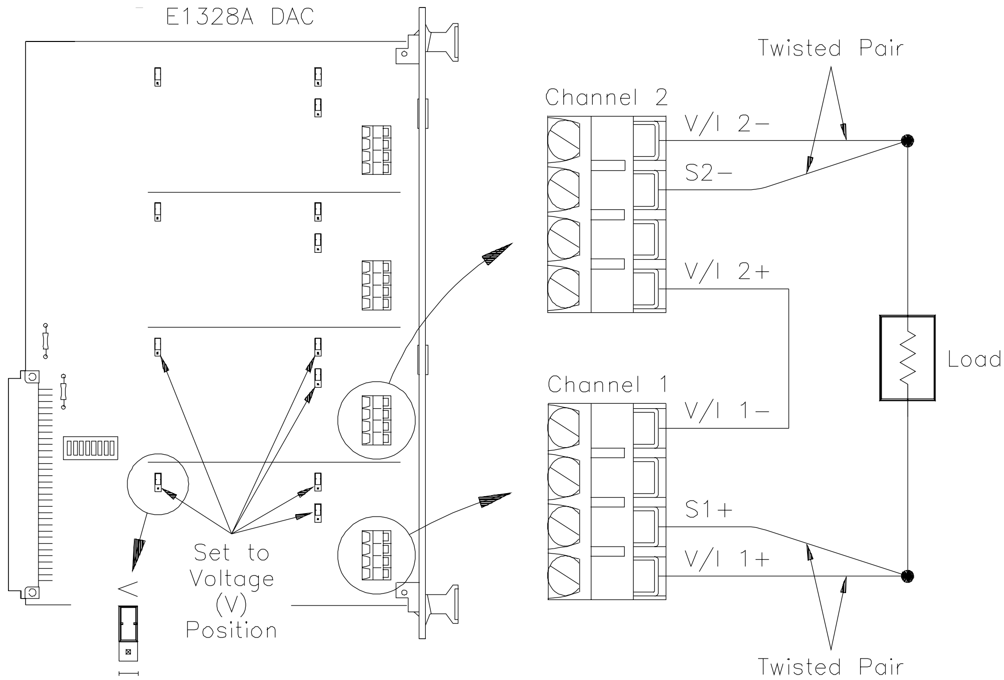

Figure 3-4. Extending Voltage Output Range

Comments

- **Sense Terminals.** Use of remote sensing is recommended to compensate for voltage drops in the test leads. This ensures an accurate voltage is present at the load. If not in use, do not make any connection to the SENSE terminals.

- **Compliance Current.** The maximum current available when outputting a voltage is 24 mAdc. This means, that at 12 Vdc, the load resistance should be at least 500Ω. See Chapter 4 for further explanation on compliance current and load resistance.

- **Isolation.** Channel-to-channel or channel-to-chassis isolation is rated at 250 Vrms (350 Vdc/ac peak).

WARNING

Do not exceed the rated isolation voltage. Damage may result if channels of the same D/A Converter are connected to separate phases of 3-phase power lines.

- **Incorrect Jumper Setting.** If a channel is configured for current and instructed to output voltage, an error will be generated.

Electronic Current Adjustment

The electronic current adjustment is used to update the stored current constants for each channel, and should be performed:

- on initial set-up;
- periodically (24 hours or 90 days) to maintain desired output accuracy (see Appendix A);
- when a ±5°C change in temperature from last adjustment performed has occurred;
- when the type of load is changed;
- or anytime accuracy is in doubt.

The adjustment procedure is performed for each channel as follows:

1. Configure the desired channel(s) for current output (refer to page 17).
2. Connect the load to the desired D/A Converter channel. Connect a multimeter to measure current at the load.
3. Set the D/A Converter channel to the non-calibrated mode.

Note The electronic adjustment ***must*** be performed in the ***non-calibrated mode*** (step 3), or errors in the adjustment constant will occur.

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4. Set the channel's output to minimum (–24 mAdc). Measure and record to 5½-digits the actual output at the load.
5. Set the channel's output to default (0 mAdc). Measure and record to 5½-digits the actual output at the load.
6. Set the channel's output to maximum (+24 mAdc). Measure and record to 5½-digits the actual output at the load.
7. Record the minimum, default, and maximum values and send them as parameters to the CALibration command. New adjustment constants will be calculated and stored from the entered values.
8. Repeat steps 2 through 7 for all desired channels.

Example: One Channel Electronic Current Adjustment Using an External Multimeter

Figure 3-5 shows how to connect channel 1 output terminals to the load and external multimeter (Agilent 3457A). The D/A Converter must be physically configured to provide current output on channel 1 (refer to page 17), and then instructed to perform the adjustment. For the example, use:

- An GPIB select code of 7, primary address of 09, and secondary address of 09 for the D/A Converter.
- An HP Series 200/300 computer with BASIC.

Execute:

```
10    REAL  A,B,C,                          !Define variables used to store
                                            measured values.
20    OUTPUT  70909;"*RST"                  !Reset the D/A Converter to its
                                            default state and performs a
                                            self-test.
30    OUTPUT  70909;"CAL1:STAT  OFF"        !Configure channel 1 to the
                                            non-calibrated mode.
40    OUTPUT  70909;"CURR1  MIN"            !Configure channel 1 to output the
                                            minimum current (–24 mAdc).
50    PRINT "RECORD AS MINIMUM"             !Message on screen instructs to
                                            record the measurement on the
                                            multimeter as minimum.
60    INPUT "ENTER RECORDED MIN: ",A        !Message on screen instructs to
                                            enter the recorded minimum
                                            value.  Enter and press RETURN.
70    OUTPUT  70909;"CURR1  DEF"            !Configure channel 1 to output
                                            the default current (0 mAdc).
80    PRINT "RECORD AS DEFAULT"             !Message on screen instructs to
                                            record the measurement on the
                                            multimeter as default.
90    INPUT "ENTER RECORDED DEF: ",B        !Message on screen instructs to
                                            enter the recorded default value.
                                            Enter and press RETURN.
100   OUTPUT  70909;"CURR1  MAX"            !Configure channel 1 to output the
                                            maximum current (+24 mAdc).
110   PRINT "RECORD AS MAXIMUM"             !Message on screen instructs to
                                            record the measurement on the
                                            multimeter as maximum.
120   INPUT "ENTER RECORDED MAX: ",C        !Message on screen instructs to
                                            enter the recorded maximum
                                            value.  Enter and press RETURN.
130   OUTPUT  70909; "CAL1:CURR ";A;B;C,    !Enter the measured minimum,
                                            default, and maximum values.
                                            New adjustment constants are
                                            then calculated and stored for
                                            channel 1.
```

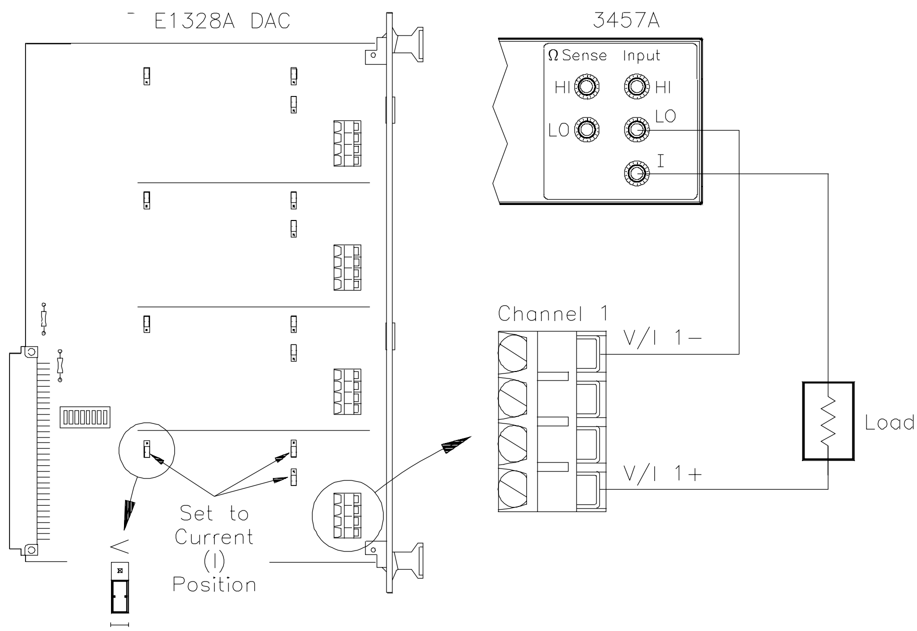

Figure 3-5. Electronic Current Adjustment

Comments

- **Test Hook-up.** If possible, calibrate to the same load (and leads) that the D/A Converter will be providing the current output to. Connect the multimeter leads as close as possible to the load.
- **Multimeter.** Any 5½-digit (or greater) multimeter with DC current, with an accuracy of at least (0.02% of reading +1A) can be used when performing the adjustment. Agilent recommends using the Agilent 3457A.
- **Electronic Voltage Adjustment.** If a channel is only to be used for current output, it is not necessary to perform the voltage adjustment.

Outputting Current

- Will output current on channels 1, 2, 3, and/or 4.
- Range is 21.844 mAdc in calibrated mode and 24 mAdc in non-calibrated mode per channel.
- Range can be increased to a maximum 87.376 mAdc in calibrated mode and 96 mAdc in non-calibrated mode by connecting all four channels in parallel.

Example: One Channel Current Output in Calibrated Mode

Figure 3-6 shows how to connect channel 1 output terminals to the load. The D/A Converter must be physically configured to provide current output on channel 1 (refer to page 17), and then instructed to output +20.00000 mAdc on channel 1 in the calibrated mode.

Execute:

CAL1:STAT ON	*Sets channel 1 to calibrated mode.*
CURR1 0.020000	*Configures channel 1 for current and sets output at terminals to 20.000 mAdc.*

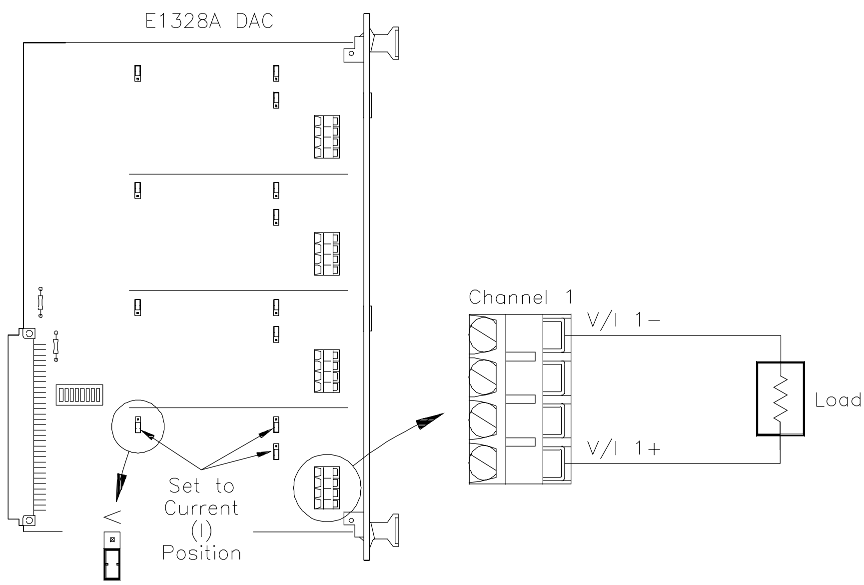

Figure 3-6. One Channel Current Output

Example: Expanding Current Output Range in the Non-Calibrated Mode

Figure 3-7 shows how to configure channel 1 and 2 output terminals in parallel to increase the range, and how to connect to the load. The D/A Converter must be physically configured to provide current output on channels 1 and 2 (refer to page 17), and then instructed to output a specific current on channels 1 and 2 in order to obtain a total of +48.00000 mAdc in the non-calibrated mode. For the example, use:

- An GPIB select code of 7, primary address of 09, and secondary address of 09 for the D/A Converter.
- An HP Series 200/300 computer with BASIC.

Execute:

10	OUTPUT 70909;"*RST"	*!Reset the D/A Converter to its default state.*
20	OUTPUT 70909;"CAL1:STAT OFF"	*!Configure channel 1 to the non-calibrated mode.*
30	OUTPUT 70909;"CAL2:STAT OFF"	*!Configure channel 2 to the non-calibrated mode.*
40	OUTPUT 70909;"CURR1 MAX"	*!Configure channel 1 for current and sets output at terminals to maximum (+24 mAdc) in non-calibrated mode.*
50	OUTPUT 70909;"CURR2 MAX"	*!Configure channel 2 for current and sets output at terminals to maximum (+24 mAdc) in non-calibrated mode.*

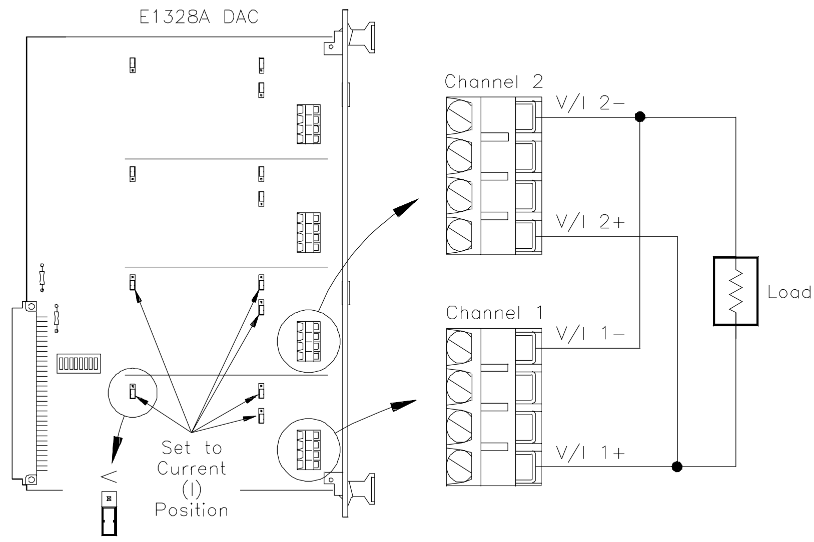

Figure 3-7. Extending Current Output Range

Comments

- **Sense Terminals.** Do not make any connection to the SENSE terminals when outputting current.
- **Compliance Voltage.** The maximum voltage available when outputting a current from one channel is 13 Vdc. This means that at 24 mAdc, the load resistance should not exceed 541. See Chapter 4 for further explanation on compliance voltage and load resistance.
- **Isolation.** Channel-to-channel or channel-to-chassis isolation is 250 Vrms (350 Vdc/ac peak).

WARNING **Damage may result if channels of the same D/A Converter are connected to separate phases of 3-phase power lines. Do not exceed the rated isolation voltage.**

Chapter 4
Understanding the Agilent E1328A

Using This Chapter

This chapter explains techniques to output voltage and current levels using the 4-Channel D/A Converter. This chapter contains the following sections:

Commands for D/A Converter Operation

Outputting voltages and currents from the D/A Converter consists of configuring the hardware for the type of output desired, then selecting the output type, level, and mode. When necessary, an electronic adjustment is performed to maintain calibrated mode output accuracy.

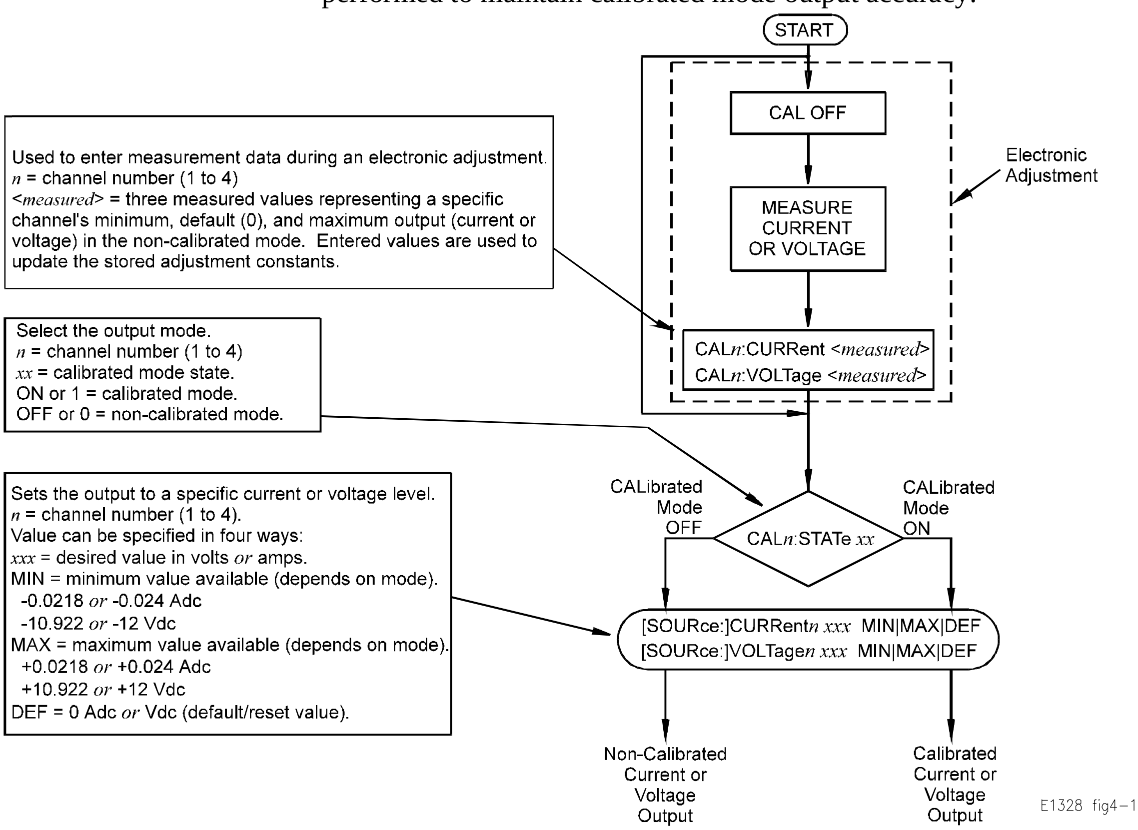

Figure 4-1. D/A Converter Commands

Voltage Output

The proper sequence of operation for outputting a voltage from the D/A Converter is provided below. Refer, as necessary, to Chapters 2 and 3 for additional operating information.

1. Determine the number of voltage outputs required, and configure the necessary channel jumpers for voltage (refer to page 17).
2. Connect the output leads to the correct channel V/I + and - terminals (refer to page 18). If extending the output range, connect the required number of channels in series to obtain the desired output (refer to pages 24–25).
3. If remote sensing will be used, connect leads to the S + and - terminals (refer to pages 24–25). If remote sensing will not be used, leave the SENSE terminals disconnected.
4. Verify that the compliance current will not be exceeded by calculating the total circuit resistance using Figure 4-2.
5. Install the D/A Converter in the mainframe and connect the output leads to the load (refer to Chapter 3).
6. Determine if an electronic voltage adjustment is necessary (refer to page 20).
7. Enter and execute the proper instructions to output the desired voltage(s), and the desired mode (refer to pages 23–25).

Compliance Current (Ic) is the maximum amount of current from the V/I+ terminal to the V/I− terminal. Maximum Ic is 24mA for each channel.

Minimum allowable total circuit resistance can be calculated using the following formula:
 Rt=Vout/0.024
Where:
 Rt=total circuit resistance (R1+R2+R3)
 Vout is selected output voltage
For example, if 12Vdc is selected, the maximum total circuit resistance should be at least 500Ω.

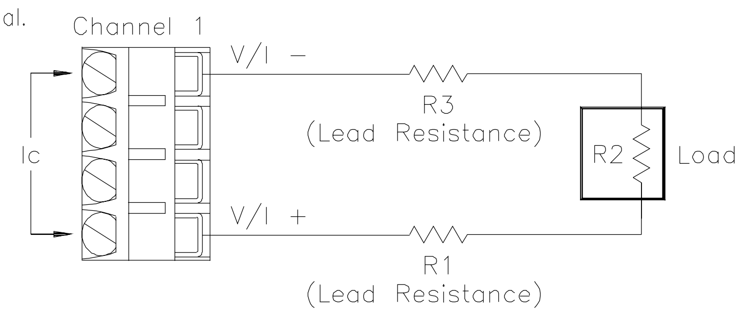

Figure 4-2. Output Voltage Compliance Current

Remote Sense

In remote sense mode, the D/A Converter measures the actual voltage delivered at the load, then compensates for any difference between the measured value and the selected value. The equivalent output circuit for the D/A Converter using remote sense is shown in Figure 4-3.

Note Remote sense operation is available for voltage output only. During current output, the SENSE terminals must remain disconnected.

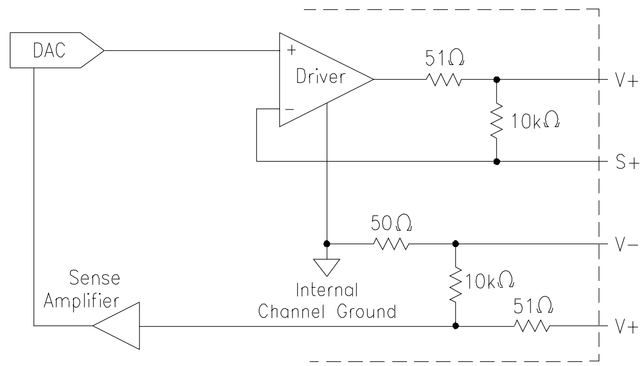

Figure 4-3. Remote Sense Operation

Maximum Lead Resistance

When using the D/A Converter to output voltage using remote sensing (refer to pages 24–25), the maximum allowable lead resistance is calculated using the following procedure (refer to Figure 4-3):

1. The driver amplifier's maximum output voltage is less than 19 V (17 V typical) when the load resistance is infinite.

2. The maximum output current available is 24 mA.

3. The maximum load voltage ($V_{L(max)}$) is normally 10.92 V, and never exceeds approximately 12 V. The maximum load voltage is calculated as follows:

   $$V_{L(max)} \le (24mA)(R_{load})$$

4. The maximum voltage drop allowed across the resistance of the leads ($V_{drop\ (max)}$) is calculated as follows:

   $$V_{drop(max)} = 17 - V_{L(max)} - (101\Omega)\left[\frac{V_{L(max)}}{R_{load}}\right]$$

5. Therefore the maximum allowable lead resistance (R_{lead}) is:

   $$R_{lead} \le \frac{V_{drop(max)}}{V_{L(max)}} R_{load}$$

Operation with Fixed Voltage Sources in Series

If a fixed voltage must be placed in series with the load, connect the voltage source to the V+ lead for the most accurate output. An example of this type of application is shown in Figure 4-4. The emitter follower configuration increases the total available output current.

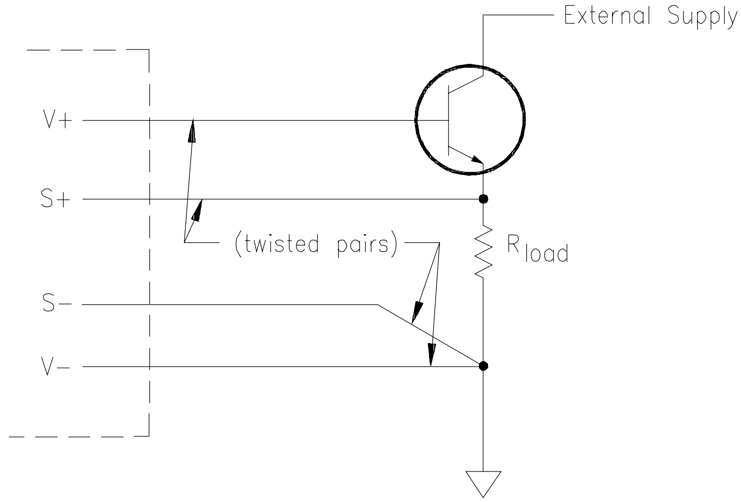

Figure 4-4. Emitter Follower Configuration

If the fixed voltage source is placed in the V- lead, a small error will occur in the output voltage. An output error of approximately 0.05% of the voltage between V- and S- occurs due to the 51Ω protection resistor in series with the S- terminal. This error does not occur if the voltage between V- and S- is due solely to lead resistance, provided that an electronic adjustment has been performed with the same load and lead configuration as under actual operating conditions.

Adjustment Under Actual Lead and Load Conditions

Whenever possible, perform electronic adjustments with the D/A Converter connected to the leads and load to be used in operation. An electronic adjustment performed under actual operating conditions provides the best output accuracy.

If an electronic adjustment is performed with a different V- lead resistance than that encountered under actual operating conditions, small errors will occur in the output voltage due to the effect of the 51Ω protection resistor mentioned in the preceding section, "Operation with Fixed Voltage Sources in Series".

As an example, suppose there was a difference of 100Ω between the lead resistances used for the electronic adjustment and those encountered under actual operating conditions. This would cause the voltage between V- and S- during electronic adjustment to be different than the voltage between V- and S- under actual operating conditions. The output error produced can be understood by referring to the example shown in Figure 4-5 and the following explanation.

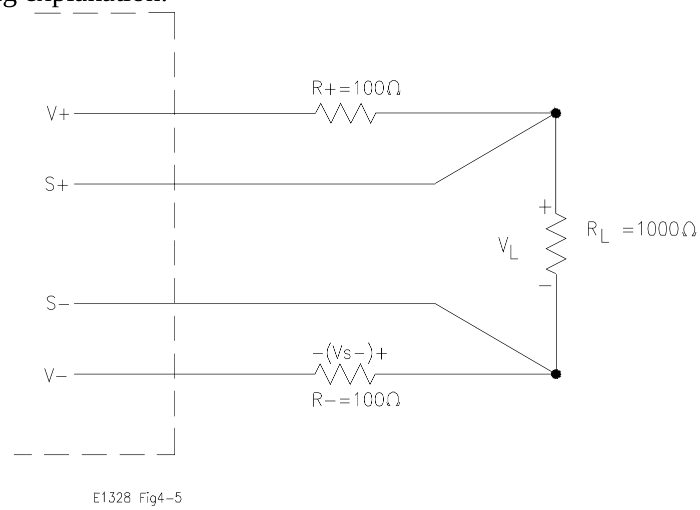

Figure 4-5. Lead Resistance and Electronic Adjustment

R- is the change in lead resistance. The difference in voltage drop across R- between the electronic adjustment and actual operating conditions is as follows:

$$V_{S-} = V_L \frac{R-}{R_L}$$

This difference in voltage drop across R- is also the change in voltage between V- and S- for electronic adjustment versus actual operating conditions. As discussed in the preceding section, this change in the voltage between V- and S- produces an output error of approximately 0.05% of the voltage between V- and S-. In this case:

$$\begin{aligned} \text{Output Error} &= (0.0005)(V_{S-}) \\ &= (0.0005)\, V_L \frac{R-}{R_L} \end{aligned}$$

For the circuit shown in Figure 4-5, the additional output error (caused by the change in lead resistance after electronic adjustment) is 0.005% of the load voltage.

Current Output

The proper sequence of operation for outputting a current from the D/A Converter is provided below. Refer, as necessary, to Chapters 2 and 3 for additional operating information.

1. Determine the number of current outputs required, and configure the necessary channel jumpers for current (refer to page 17).
2. Connect the output leads to the correct channel V/I + and - terminals (refer to page 18). Do not connect anything to the S + and - terminals. If extending the output range, connect the required number of channels in parallel to obtain the desired output (refer to page 29).
3. Verify that the compliance voltage will not be exceeded by calculating the total circuit resistance using Figure 4-6.
4. Install the D/A Converter in the Mainframe and connect the output leads to the load (refer to Chapter 3).
5. Determine if an electronic current adjustment is necessary (refer to page 26).
6. Enter and execute the proper instructions to output the desired current(s), and the desired mode (refer to pages 29–30).

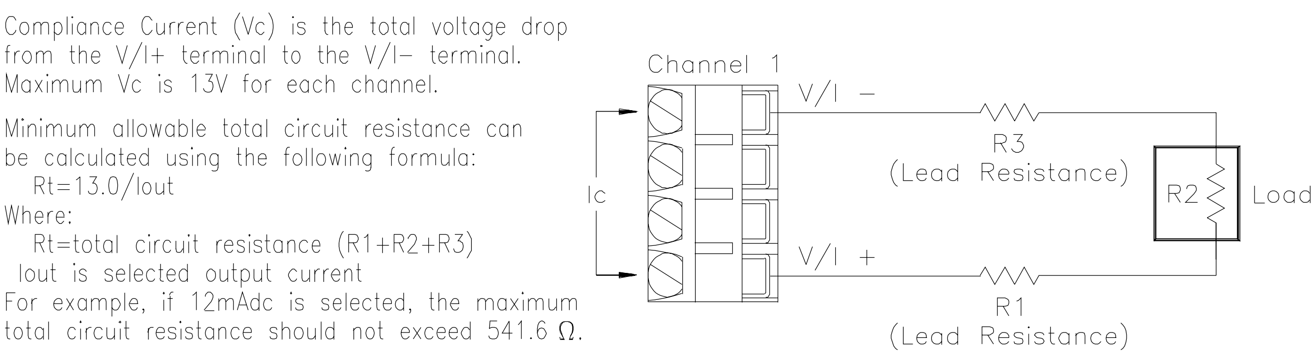

Figure 4-6. Output Current Compliance Voltage

Note The compliance current is 24 mA. The maximum short circuit current (e.g. R2 = 0 in Figure 4-6) is limited to ≤30 mA by the Agilent E1328A.

Querying the D/A Converter

This section summarizes the query commands you can use to determine the configuration or state of the D/A Converter. All commands end with the "?" which puts the data into the output buffer where you can retrieve it.

Calibration mode state:	CALibrate*n*:STATe? (*n* = channel number)
Current output level:	SOURce:CURRent*n*? (*n* = channel number)
Display channel selected:	DISPlay:MONitor:CHANnel?
Display present output setting:	DISPlay:MONitor:STRing?
System error:	SYSTem:ERRor?
V/I jumper position:	SOURce:FUNC*n*? (*n* = channel number)
Voltage output level:	SOURce:VOLT*n*? (*n* = channel number)

Notes

Chapter 5
Agilent E1328A Command Reference

Using This Chapter

This chapter describes Standard Commands for Programmable Instruments (SCPI) commands and summarizes IEEE 488.2 Common (*) Commands applicable to the 4-Channel D/A Converter.

Command Types

This manual covers two types of commands: IEEE 488.2 Common and SCPI Commands.

Common Command Format

The IEEE 488.2 standard defines the common commands that perform functions like reset, self-test, and so on. Common commands are four or five characters in length, always begin with the asterisk character (*), and may include one or more parameters. The command keyword is separated from the first parameter by a space character. Two common commands are:

*RST *and* *TST?

SCPI Command Format

SCPI commands perform functions like selecting output level, selecting output mode, and querying data. A subsystem command structure is a hierarchical structure that usually consists of a top level (or root) command, one or more lower level sub commands, and their parameters. The following example shows an excerpt from a typical subsystem:

```
[SOURce:]
    VOLTagen <level>
```

[SOURce:] is the root command, VOLTage*n* is the second-level sub command (where *n* is replaced by the channel number in the range of 1 to 4), and <*level*> is a parameter.

Command Separator

A colon (**:**) always separates one command from the next lower-level command as shown below:

DISPlay:MONitor[:STATe] <*mode*>

Abbreviated and Short Commands

The command syntax shows most commands as a mix of upper and lower case letters. The upper case letters indicate the abbreviated spelling for the command. For shorter program lines, send only the abbreviated form. For better program readability, you may send the entire command. The instrument accepts either the abbreviated form or the entire command.

For example, if the command reference syntax shows the command SOURce, then SOUR and SOURce are both acceptable forms. Other forms of SOURce, such as SOURC, will generate an error. You may use upper case and lower case letters; SOURCE, source, and SoUrCe are acceptable.

Implied Commands

Implied commands are those which appear in square brackets (**[ ]**) in the command syntax. **(Note that the brackets are not part of the command and are not sent to the instrument)**. Suppose you send a second-level command but do not send the preceding implied command. In this case, the instrument assumes you intend to use the implied command and it responds as if you had sent it. Examine an excerpt from the [SOURce:] subsystem shown below:

```
[SOURce:]
    VOLTagen?
```

The root command [SOURce:] is an implied command. To query the instrument about a voltage level set on channel 1, send either of the following commands:

SOUR:VOLT1? *or* VOLT1?

Parameters

Parameters are enclosed in greater than/less than symbols (**< >**) in the command syntax. When more than one parameter is allowed, the parameters are separated by a vertical line (**|**).

Parameter Types. The following table contains explanations and examples of parameter types you might see later in this chapter. Parameters *must* always be separated from the keywords by a space.

Parameter Type	Explanations and Examples
Numeric	Accepts all commonly used decimal representations of numbers including optional signs, decimal points, and scientific notation. 123 or 123E2; -123 or -1.23E2; .123, 1.23E-2, or 1.23000E-01. Special cases include MINimum, MAXimum, and DEFault.
Boolean	Represents a single binary condition that is either true or false. 1 or ON; 0 or OFF.

Linking Commands

Linking IEEE 488.2 Common Commands with SCPI Commands. Use a semicolon (;) between the commands. For example:

```
*RST;VOLT1?
```

Linking Multiple SCPI Commands. Use both a semicolon (;) and a colon (:) between the commands. For example:

```
VOLT1?;:CURR2?
```

SCPI Command Reference

The following sections describe the Standard Commands for Programmable Instruments (SCPI) commands for the Agilent E1328A 4-Channel D/A Converter Module. Commands are listed alphabetically by subsystem and within each subsystem. A command guide is printed in the top margin of each page. The guide indicates the current subsystem on that page.

The CALibration subsystem selects the mode of operation (calibrated or non-calibrated) under which a specific channel will operate, and is also used to enter updated adjustment constants during electronic adjustment procedures.

Subsystem Syntax

CALibration*n*
  :CURRent <*measured* | MIN | MAX | DEF>
  :STATe <*mode*>
  :STATe?
  :VOLTage <*measured* | MIN | MAX | DEF>

CALibration*n*:CURRent

CALibration*n*:CURRent <*measured* | MIN | MAX | DEF> is used to enter a channel's measurement data obtained during an electronic current adjustment. These values are used to update the stored adjustment constants. The three measured values are MINimum (-24mA), DEFault (0mA), and MAXimum (+24mA).

Note During an electronic adjustment, the output current must be measured with the channel configured in the non-calibrated mode (CALibration*n*:STATe OFF). If the output current is measured in the calibrated mode (CALibration*n*:STATe ON), and these measured values are entered using the CALibration*n*:CURRent command, output current errors will result when the channel is used in the calibrated mode.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Values
CALibration*n*	keyword	1, 2, 3, or 4	1
<*measured*>	numeric	-0.030 to -0.015 -0.005 to +0.005 +0.015 to +0.030	Amps

Comments

- **Channel Number:** Select only one channel at a time.
- **Related Commands:** [SOURce:]CURRent*n*, CALibration*n*:STATe
- **Measured Values:** Three values (MIN | DEF | MAX) are measured in the non-calibrated mode, then entered to 5½-digits. Once entered, the D/A Converter calculates and stores new adjustment constants. These stored constants are used to maintain the channel's accuracy in the output current calibrated mode.

Example **Entering Channel 4 Measurement Data.**

This command enters the minimum, default, and maximum measured values channel 4 output during an electronic adjustment procedure.

```
CAL4:CURR  -0.02359,  0.00012,  +0.02405
```

CALibration*n*:STATe

CALibration*n*:STATe <*mode*> enables or disables the calibrated mode for a specific channel.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Values
CALibration*n*	keyword	1, 2, 3, or 4	1
<*mode*>	boolean	0 | 1 | ON | OFF	1 | ON

Comments

- **Channel Number:** Select only one channel at a time.
- **Related Commands:** CALibration*n*:CURRent, CALibration*n*:VOLTage, [SOURce:]VOLTage*n*, [SOURce:]CURRent*n*
- ***RST Condition:** CALibration:STATe 1

Example **Setting Channel 3 to Non-Calibrated Mode.**

CAL3:STAT OFF — *Set channel 3 mode to non-calibrated output.*

CALibration*n*:STATe?

CALibration*n*:STATe? queries a specific channel about the currently selected mode of operation. `1` (one) indicates operating under calibrated mode, and `0` (zero) indicates operating under non-calibrated mode.

CALibration*n*:VOLTage

CALibration*n*:VOLTage <*measured* | MIN | MAX | DEF> is used to enter a channel's measurement data obtained during an electronic voltage adjustment. These values are used to update the stored adjustment constants. The three measured values are MINimum (-12V), DEFault (0V), and MAXimum (+12V).

Note During an electronic adjustment, the output voltage must be measured with the channel configured in the non-calibrated mode (CALibration*n*:STATe OFF). If the output voltage is measured in the calibrated mode (CALibration*n*:STATe ON), and these measured values are entered using the CALibration*n*:VOLTage command, output voltage errors will result when the channel is used in the calibrated mode.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Values
CALibration*n*	keyword	1, 2, 3, or 4	1
<*measured*>	numeric	-15.0 to -8.0 -1.0 to +1.0 +8.0 to +15.0	Volts

Comments

- **Channel Number:** Select only one channel at a time.
- **Related Commands:** CALibration*n*:STATe, [SOURce:]VOLTage*n*
- **Measured Values:** Three values (MIN | DEF | MAX) are measured in the non-calibrated mode, then entered to 5½-digits. Once entered, the D/A Converter calculates and stores new adjustment constants. These stored constants are used to maintain the channel's accuracy in the output voltage calibrated mode.

Example

Entering Channel 2 Measurement Data.

This command enters the minimum, default, and maximum measured values channel 2 output during an electronic adjustment procedure.

```
CAL2:VOLT  -12.00346,  0.00352,  +11.98342
```

The DISPlay subsystem monitors the channel state of a selected module in a mainframe. This command operates with mainframes that have a display, such as the Agilent E1301B Mainframe.

Subsystem Syntax

```
DISPlay
    :MONitor
        :CHANnel  <channel | MIN | MAX | DEF | AUTO>
        :CHANnel?  <channel>
        [:STATe]  <mode>
        :STRing?
```

DISPlay:MONitor:CHANnel

DISPlay:MONitor:CHANnel <*channel* | MIN | MAX | DEF | AUTO> selects the channel to be monitored when the monitor mode is enabled.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Values
<*channel*>	numeric	1 to 4 | DEF | MIN | MAX | AUTO	1

Comments

- **Selecting Monitor Channel Values:** When using the DISPlay:MONitor:CHANnel command, numbers 1 to 4 select a specific channel to be monitored. In addition to selecting a specific channel, four other values can be entered. DEFault and MINimum selects channel 1, MAXimum selects channel 4, and AUTO activates the automatic mode where the last channel changed is displayed.

- **Monitor Mode on an Agilent 1301B Mainframe Display:** Selecting the channel causes the information to be displayed on the mainframe's front panel. The DISPlay:MONitor:STRing? command must be used to display the information on the computer. The following shows the monitor mode display string on the display of an Agilent E1301B Mainframe:

```
CHAN1 10.00000E01 VOLT, CAL 1
```

The example above shows channel 1, 10 Vdc, in the calibrated mode.

- **Related Commands:** DISPlay:MONitor[:STATe]

Example

Selecting Channel 1 for Monitoring.

```
DISP:MON:CHAN 1
```

DISPlay:MONitor:CHANnel?

DISPlay:MONitor:CHANnel? <*channel*> performs two different functions dependent on if the parameter (<*channel*>) is used.

If <*channel*> is not used (blank): queries which channel will be displayed when the monitor mode is enabled. -1 indicates operating in automatic mode (displays the last channel changed). 1 through 4 indicates which specific channel will be displayed.

If <*channel*> is used (DEF | MIN | MAX): queries available channel information. DEFault and MINimum always returns 1, and MAXimum always returns 4.

DISPlay:MONitor[:STATe]

DISPlay:MONitor[:STATe] <*mode*> turns the monitor mode on or off.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Values
<*mode*>	boolean	0 | 1 | ON | OFF	0 | OFF

Comments

- The [:STATe] parameter is optional. Therefore, either of the following command statements is valid:

  DISP:MON:STAT ON *or* DISP:MON ON

- **Monitoring Module Channels:** DISPlay:MONitor:STATe ON or DISPlay:MONitor:STATe 1 turns the monitor mode on to show the selected channel state. DISPlay:MONitor:STATe OFF or DISPlay:MONitor:STATe 0 turns the monitor mode off.

- **Selecting the Channel to be Monitored:** Use the DISPlay:MONitor:CHANnel command to select the channel.

- ***RST Condition:** DISPlay:MONitor[:STATe] OFF

Example

Enabling the Monitor Mode.

This command selects monitor mode to on.

```
DISP:MON:STAT 1
```

DISPlay:MONitor:STRing?

DISPlay:MONitor:STRing? queries the channel for output information. Channel is selected by the DISPlay:MONitor:CHANnel command, and enabled by the DISPlay:MONitor[:STATe] command. Display string is two 25-character fields separated by a comma.

The [SOURce:] subsystem selects a channels output type (voltage or current), and level.

Subsystem Syntax

```
[SOURce:]
    CURRentn <level>
    CURRentn?
    FUNCtionn?
    VOLTagen <level>
    VOLTagen?
```

[SOURce:]CURRent*n*

[SOURce:]CURRent*n* <*level* | MIN | MAX | DEF> configures the D/A Converter to output current on a specified channel (*n*) at a specified level.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Values
n	numeric	1, 2, 3, or 4	1
<*level*>	numeric	-0.024 to +0.024 | MIN | MAX | DEF	0

Comments

- **Channel Number:** Select only one channel at a time.
- **If a "Settings Conflict" Error Occurs:** See "Selecting Voltage or Current Output" on page 17.
- **Related Commands:** CALibration*n*:STATe
- ***RST Condition:** [SOURce:]CURRent 0

Example

Setting Channel 2 to Current Output at +20 mAdc.

```
SOUR:CURR2 .020
```

[SOURce:]CURRent*n*?

[SOURce:]CURRent*n*? queries a specific channel about the currently selected current level on the channel specified by *n*. If the specified channel is configured for voltage, an error will be generated. Output format is as follows:

SDDDDDDDESDDD

Where: S = + or -
D = 0 to 9 with floating decimal point
E = base 100 exponent delimiter

[SOURce:]FUNCtion*n*?

[SOURce:]FUNCtion*n*? queries a specific channel about the configuration of the specified V/I jumper in the channel's digital section. Does not indicate V/I jumper position of the two jumpers in the analog section. Returns `CURR` if the jumper is in the "I" position or `VOLT` if the jumper is in the "V" position.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Values
n	numeric	1, 2, 3, or 4	1

Comments

- **Channel Number:** Select only one channel at a time.

[SOURce:]VOLTage*n*

[SOURce:]VOLTage*n* <*level* | MIN | MAX | DEF> configures the D/A Converter to output voltage on a specified channel at a specified level.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Values
n	numeric	1, 2, 3, or 4	1
<*level*>	numeric	-12 to +12 | MIN | MAX | DEF	0

Comments

- **Channel Number:** Select only one channel at a time.
- **If a "Settings Conflict" Error Occurs:** See "Selecting Voltage or Current Output" on page 17.
- **Related Commands:** CALibration*n*:STATe, CALibration*n*:VOLTage
- ***RST Condition:** [SOURce:]VOLTage 0

Example

Setting Channel 1 to Voltage Output at +10.000000 Volts.

```
VOLT1 10.000000
```

[SOURce:]VOLTage*n*?

[SOURce:]VOLTage*n*? queries a specific channel about the currently selected voltage level on the channel specified by *n*. If the specified channel is configured for current, an error will be generated. Output format is as follows:

`SDDDDDDDESDDD`

Where: `S = + or -`
`D` = 0 to 9 with floating decimal point
`E` = base 100 exponent delimiter

The SYSTem subsystem returns the error numbers and error messages in the error queue, and returns the types of modules (cards).

Subsystem Syntax

```
SYSTem
    :ERRor?
```

SYSTem:ERRor?

SYSTem:ERRor? returns the error numbers and error messages in the error queue. See Appendix C for a listing of the error numbers and messages.

Comments

- **Error Numbers/Messages in the Error Queue:** Each error generated by the D/A Converter stores an error number and corresponding error message in the error queue. Each error message can be up to 255 characters long.

- **Clearing the Error Queue:** An error number/message is removed from the queue each time the SYSTem:ERRor? command is sent. The errors are cleared first-in, first-out. When the queue is empty, each SYSTem:ERRor? command returns "0, No error". To clear all error numbers/messages in the queue, execute the *CLS command (see the mainframe operating manual).

- **Maximum Error Numbers/Messages in the Error Queue:** The queue holds a maximum of 30 error numbers/messages for the D/A Converter. If the queue overflows, the last error number/message in the queue is replaced by "-350, Too many errors". The least recent error numbers/messages remain in the queue and the most recent are discarded.

Example **Reading the Error Queue.**

This command queries the error queue, reads and prints the numbers/message.

```
SYST:ERR?
```

IEEE-488.2 Common Command Quick Reference

The following table lists the IEEE 488.2 Common (*) Commands that can be executed by the D/A Converter Module. For more information on Common Commands, refer to the *Agilent E1300B/E1301B User's Manual*, the *Agilent E1406A Command Module User's Manual*, or the *ANSI/IEEE Standard 488.2-1987*.

Command	Title	Description
*IDN?	Identification Query	Returns Identification String of the D/A Converter.
*RST	Reset	Performs a 5-second self-test, places 0Vdc/0mAdc on all channels, and then sets the mode of all channels calibrated (ON).
*TST?	Self-Test Query	Returns 0 unless self-test fails.
*OPC	Operation Complete	(See note below).
*OPC?	Operation Complete Query	Returns a 1 if previous operation is complete.
*WAI	Wait to Complete	(See note below).
*CLS	Clear Status Register	Clears all Status Register (see SYSTem:ERRor?).
*ESE	Event Status Enable	(See note below).
*ESE?	Event Status Enable Query	(See note below).
*ESR?	Event Status Register Query	(See note below).
*SRE	Service Request Enable	(See note below).
*SRE?	Service Request Enable Query	(See note below).
*STB?	Read Status Byte Query	(See note below).
*RCL <*n*>	Recall Saved State	Recalls previously stored D/A Converter Module configuration. <*n*> indicates location in memory from 0 to 9.
*SAV <*n*>	Save State	Stores the current D/A Converter Module configuration in memory. <*n*> indicates location in memory from 0 to 9.

Note These commands have little or no effect on D/A Converter operation. Refer to the *Agilent E1300B/E1301B Mainframe User's Manual*, the *Agilent E1406A Command Module User's Manual*, or the *ANSI/IEEE Standard 488.2-1987* for more information.

Agilent E1328A Command Quick Reference

The following table summarizes SCPI Commands for the Agilent E1328A.

SCPI Commands Quick Reference

Command Subsystem	Command/Parameter	Description
CALibration*n*	:CURRent <*measured*>	Enters three measured values to update the channel's stored current adjustment constant.
	:STATe <*mode*>	Selects mode to calibrated (1) or non-calibrated (0).
	:STATe?	Returns mode channel is currently operating under.
	:VOLTage <*measured*>	Enters three measured values to update the channel's stored voltage adjustment constant.
DISPlay	:MONitor:CHANnel <*channel*>	Enters the desired channel number to be viewed when in monitor mode (1 to 4 or auto).
	:MONitor:CHANnel? <*channel*>	Returns the presently selected channel number to be viewed when in monitor mode (1 to 4 or auto); or the DEFault, MINimum, or MAXimum available channel number.
	:MONitor[:STATe] <*mode*>	Selects monitor mode to on (1) or off (0).
	:MONitor:STRing?	Returns the selected channel number (1 to 4), output configuration (voltage or current), output level, and mode (calibrated or non-calibrated).
[SOURce:]	:CURRent*n* <*level*>	Sets the specified channel (*n*) to output the specific current level.
	:CURRent*n*?	Returns the current level the specified channel (*n*) is currently set to output.
	:FUNCtion*n*?	Returns the present position of the V/I jumper in the specified channel's (*n*) digital section.
	:VOLTage*n* <*level*>	Sets the specified channel (*n*) to output the specific voltage level.
	:VOLTage*n*?	Returns the voltage level the specified channel (*n*) is currently set to output.
SYSTem	:ERRor?	Returns the error number/message in the error queue.

Notes

Appendix A
Agilent E1328A Specifications

DC Voltage

Range: ± 10.92 V (cal on)
± 12 V (cal off)

Resolution:
333 µV programming interval (cal on)
16-bit resolution (cal off)
Monotonic to 2 mV at 25°C

Accuracy: ± (% of output + volts)
Conditions: cal on, within ± 5°C of cal temperature and same load as at calibration.

24-hour:	± (0.05% of output + 3.3 mV)*
90-day:	± (0.15% of output + 29 mV)
1 year:	± (0.30% of output + 110 mV)

Temperature Coefficient: ± (.01% + 0.667 mV)/°C
*(For loads ≥ 500 Ω, the maximum additional error due to using a load different than that used for calibration is ± 0.02% of output.)

Output Current:
Compliance current: 24 mA
Short circuit current: ≤ 30mA

Differential Ripple and Noise:
< 2 mV_{rms} in Agilent 75000 mainframe
(20 Hz – 250 kHz, 1 kΩ load)

Common Mode Noise
(V/I to chassis, 1 kΩ**):**
<30 mV in Agilent 75000 Mainframe

DC Current

Range: ± 21.8 mA (cal on)
± 24.0 mA (cal off)

Resolution:
667 nA programming interval (cal on)
16-bit resolution (cal off)
Monotonic to 4 µA at 25°C

Accuracy: ± (% of output + amps)
Conditions: Cal on, within ± 5°C of cal temperature and same load as at calibration.

24-hour:	± (0.05% of output + 7 µA)
90-day:	± (0.15% of output + 59 µA
1 year:	± (0.3% of output + 220 µA)

Temperature Coefficient: ± (0.01% + 1.33 µA)/°C

Output Voltage:
Compliance voltage: 13 V
Max open circuit voltage: ≤ 19V
Typical output impedance: > 25 MΩ

Differential Ripple and Noise:
< 4 μA_{rms} in Agilent 75000 mainframe
(20 Hz – 250 kHz, into 100 Ω)

General

Settling Time:
Conditions: single channel, to rated accuracy
750 µs (cal on), 500 µs (cal off)

Isolation:
250 V_{rms}, 350 Vdc/ac peak
(channel-to-channel or chassis)
15 Vdc/ac, peak (channel-to-sense)

Max wire size: 16AWG

Module Size/Device Type: B, register-based

Connectors Used: P1

No. Slots: 1

VXIbus Interface Capability: Slave, A16, D16

Interrupt Level: None

Power Requirements:

Voltage:	+ 5	+ 12
Peak module current, IPM (A):	0.40	0.50
Dynamic module current, IDM (A):	0.02	0.01

Watts/Slot: 6.5

Cooling/Slot:
0.11 mm H_2O @ 0.52 liter/sec.

Humidity: 65%, 0 to 40°C

Operating Temperature: 0 to 55°C

Storage Temperature: -40 to 75°C

EMC, RFI, Safety:
meets FTZ 1046/1984, CSA 556B,
IEC 348, UL 1244

Net Weight (kg): 0.7

Appendix B

Agilent E1328A Register-Based Programming

Using This Appendix

The contents of this appendix are:

Addressing the Registers

To access a specific register for either read or write operations, the address of the register must be used. Register addresses for the plug-in modules are found in an address space known as VXI A16. The exact location of A16 within a VXIbus master's memory map depends on the design of the VXIbus master you are using; for the Agilent E1300/1301 Mainframe and Agilent E1405/E1406 Command Module, the A16 space location starts at $1F0000_{16}$[1].

The A16 space is further divided so that the modules are addressed only at locations above $1FC000_{16}$ within A16. Further, every module is allocated 64 register addresses (40_{16}). The address of a module is determined by its logical address (set by the address switch on the module) times 64 (40_{16}). In the case of the D/A Converter module, the factory default address setting is 72 or 48_{16}.

Register addresses for register-based devices are located in the upper 25% of VXI A16 address space. Every VXI device (up to 256) is allocated a 64-byte block of addresses.

Figure B-1 shows the register address location within A16. Figure B-2 shows the location of A16 address space in the Agilent E1405/E1406 Command Module.

1 The "16" at the end of the address indicates a hexadecimal base number.

The Base Address

When you are reading or writing to a module register, a hexadecimal or decimal register address is specified. This address consists of a base address plus a register offset. The base address used in register-based programming depends on whether the A16 address space is outside or inside the Agilent E1405/06 Command Module.

A16 Address Space Outside the Command Module (on the VXIbus)

When the Agilent E1405/06 Command Module is not part of your VXIbus system (Figure B-1), the Agilent E1328's base address is computed as:

$C000_{16}$ + $(LADDR * 64)_{16}$

or (decimal)

49,152 + (LADDR * 64)

where $C000_{16}$ (49,152) is the starting location of the register addresses, LADDR is the module's logical address, and 64 is the number of address bytes per VXI device. For example, the Agilent E1328's factory set logical address is 72 (48_{16}), therefore it will have a base address of:

$C000_{16}$ + $(72 * 64)_{16}$ = $C000_{16}$ + 1200_{16} = $\mathbf{D200_{16}}$

or (decimal)

49,152 + (72 * 64) = 49,152 + 4,608 = **53,760**

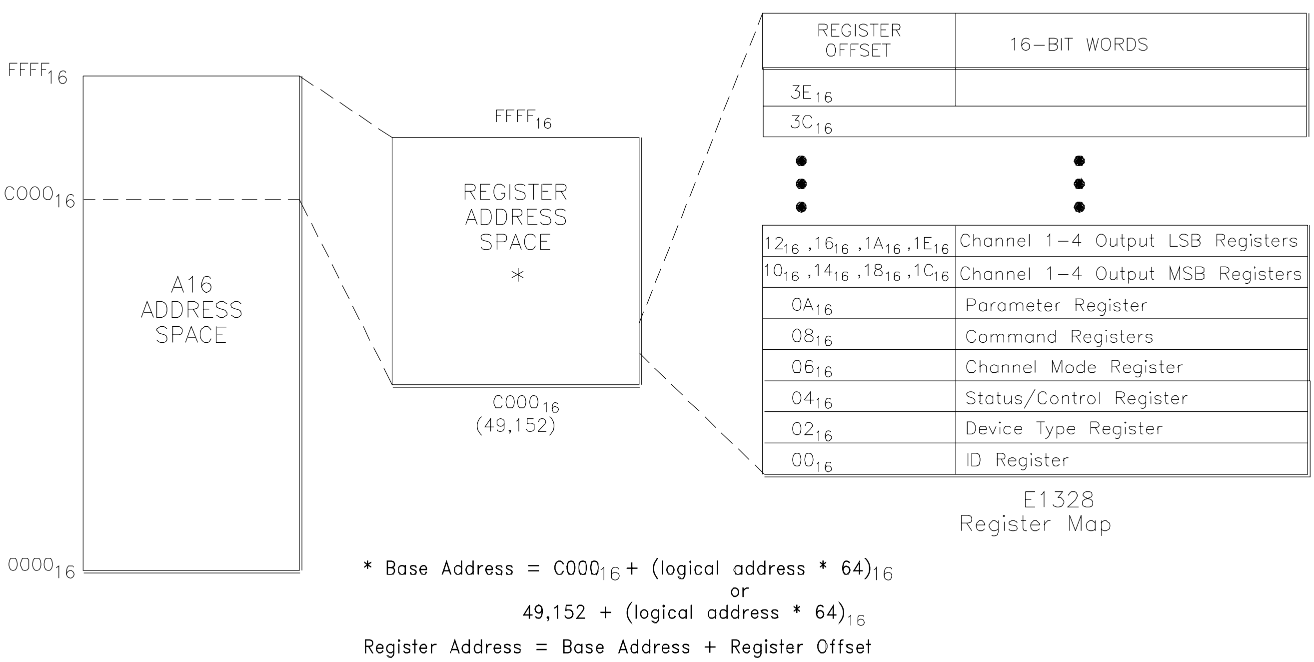

Figure B-1. Register Address Location within A16 Address Space

A16 Address Space Inside the Agilent E1405/06 Command Module or Agilent E1300/01 Mainframe

When the A16 address space is inside the Agilent E1405/E1406 Command Module (Figure B-2, the module's base address is computed as:

$1FC000_{16}$ + (LADDR * 64)$_{16}$

or

2,080,768 + (LADDR * 64)

where $1FC000_{16}$ (2,080,768) is the starting location of the VXI A16 addresses, LADDR is the module's logical address, and 64 is the number of address bytes per register-based device. Again, the Agilent E1328's factory set logical address is 72. If this address is not changed, the module will have a base address of:

$1FC000_{16}$ + (72 * 64)$_{16}$ = $1FC000_{16}$ + 1200_{16} = **$1FD200_{16}$**

or

2,080,768 + (72 * 64) = 2,080,768 + 4608 = **2,085,376**

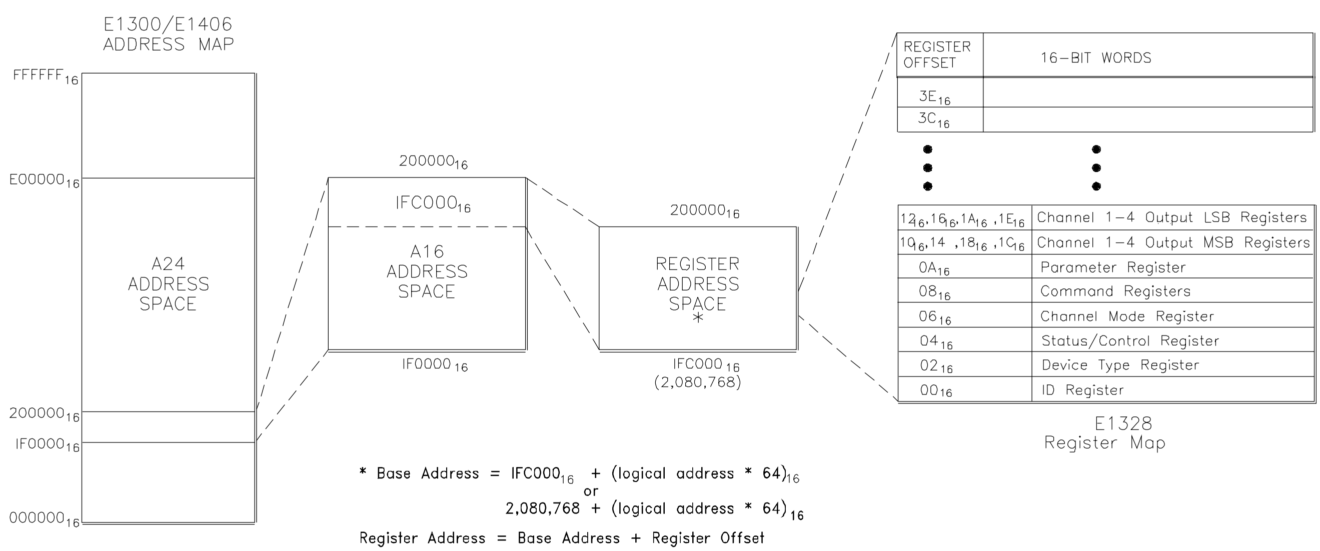

Figure B-2. Address Space in the Mainframe and Command Module

Register Offset

The register offset is the register's location in the block of 64 address bytes that belong to the module. For example, the module's Status/Control Register has an offset of 04_{16}. When you write a command to this register, the offset is added to the base address to form the register address:

$D200_{16} + 04_{16} =$ **$D204_{16}$** $1FD200_{16} + 04_{16} =$ **$1FD204_{16}$**

or

53,760 + 4 = **53,764** 2,085,376 + 4 = **2,085,380**

Table B-1 shows the general programming method for accessing the Agilent E1328A registers using different computers.

Table B-1. Accessing the Agilent E1328A Registers

Computer	Programming Method	Base Address
E1300/01 IBASIC (Absolute Addressing) (select code 8)	READIO (-9826, Base_addr + offset) WRITEIO -9826, Base_addr + offset; data (positive select code = byte read or write negative select code = word read or write) READIO (8, Base_addr + reg number) WRITEIO 8, Base_addr + reg number; data	Base_addr = $1FC000_{16}$ + $(LADDR * 64)_{16}$ or = 2,080,768 + (LADDR * 64) offset = register offset (Figure B-2) Base_addr = LADDR * 256 reg number = register offset (Figure B-2)/2
External Computer (over GPIB to Agilent E1300/E1301 Mainframe or Agilent E1405/E1406 Command Module)	VXI:READ? logical_address, offset VXI:WRITE logical_address, offset, data DIAG:PEEK? Base_addr + offset, width DIAG:POKE Base_addr + offset, width, data	Module logical address setting (LADDR) offset = register offset (Figure B-2) Base_addr = $1FC000_{16}$ + $(LADDR * 64)_{16}$ or = 2,080,768 + (LADDR * 64) offset = register offset (Figure B-2)
V/382 Embedded Computer (C-Size system)	READIO (-16, Base_addr + offset) WRITEIO -16, Base_addr + offset; data (positive select code = byte read or write negative select code = word read or write)	Base_addr = $C000_{16}$ + $(LADDR * 64)_{16}$ or = 49,152 + (LADDR * 64) offset = register offset (Figure B-1)
Agilent RADI-EPC7 Embedded Computer with SICL	iwpeek((unsigned short *) (base_addr + offset)) iwpoke((unsigned short *) (base_addr + offset),data)	INST device_name; device_name = iopen ("vxi, logical address"); base_addr = imap (device_name, I_MAP_VXIDEV,0,1,NULL);
LADDR: Agilent E1328A logical address = 72 $(LADDR * 64)_{16}$: Multiply quantity then convert to a hexadecimal number (e.g. $(72 * 64)_{16} = 1200_{16}$) When using DIAG:PEEK? and DIAG:POKE, the width (number of bits) is either 8 or 16.		

Register Definitions

Table B-2 lists the registers on the Agilent E1328A 4-Channel D/A Converter Module and whether you can read or write to the registers.

Table B-2. Register Map

Register Offset	Definition	High Byte	Low Byte
$1E_{16}$	Channel 4 LSB Output (write only)	ignored	Channel 4 Least Significant Byte (LSB)
$1C_{16}$	Channel 4 MSB Output (write only)	ignored	Channel 4 Most Significant Byte (MSB)
$1A_{16}$	Channel 3 LSB Output (write only)	ignored	Channel 3 LSB
18_{16}	Channel 3 MSB Output (write only)	ignored	Channel 3 MSB
16_{16}	Channel 2 LSB Output (write only)	ignored	Channel 2 LSB
14_{16}	Channel 2 MSB Output (write only)	ignored	Channel 2 MSB
12_{16}	Channel 1 LSB Output (write only)	ignored	Channel 1 LSB
10_{16}	Channel 1 MSB Output (write only)	ignored	Channel 1 MSB
$0E_{16}$		reserved	reserved
$0C_{16}$		reserved	reserved
$0A_{16}$	Parameter Register (read or write to lower byte)	ignored	Parameter Register
08_{16}	Command Register (read or write to lower byte)	ignored	Command Register
06_{16}	Channel Mode Register (read only)	FF_{16}	Channel Mode Register
04_{16}	Status/Control Register (read or write to lower byte)	Status/Control Register	Status/Control Register
02_{16}	Device Type Register (read only)	Device Type Register	Device Type Register
00_{16}	Manufacture ID Register (read only)	ID Register	ID Register

Register Descriptions

The following pages detail register descriptions for the Agilent E1328A 4-Channel D/A Converter Module.

Manufacturer ID Register

Reading this register returns $FFFF_{16}$. This shows Agilent Technologies as the manufacturer and that the module is an A16 register based device.

Manufacturer ID Register (Read Only)

Base + 00_{16}	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Write	Undefined															
Read*	Manufacturer ID															

*Returns $FFFF_{16}$ = Agilent Technologies A16 only register-based.

Device Type Register

Reading this register returns $FF7F_{16}$. This shows that the device is an Agilent E1328A 4-Channel D/A Converter Module.

Device Type Register (Read Only)

Base + 02_{16}	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Write	Undefined															
Read	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1

Status/Control Register

Eleven 1-bit fields provide information on equipment and operational status. Refer to the register definitions and the following explanation for Status/Control Register information.

Status/Control Register (Read/Write)

Base + 04_{16}	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Write	-	-	-	-	-	-	-	-	-	-	-	-	-	-	SFI	SR
Read	1	1	1	1	S4	S3	S2	S1	DON	ER*	IE*	CF*	READY	PAS	1	C/P RDY

C/P RDY: (Ready **-** bit 0). A one (1) in this field indicates that the D/A Converter's data buffer is empty and that data may be written to registers 08_{16} through $1E_{16}$. Note: This bit was formerly called RDY.

Note This bit must be checked before writing to registers 08_{16} through $1E_{16}$ (except the RESTART command).

Status Bit Precedence

In addition to bit 0 indicating the DAC ready condition, bit 0 also determines the validity of bits 6 - 11. When bit 0 is cleared (0), bits 6 - 11 may be invalid. Therefore, when monitoring bits 6 - 11, that bit AND bit 0 must both be true.

PAS: (Passed - bit 2). A zero (0) in this field indicates that the D/A Converter is either executing, or has failed a self test. A one (1) indicates that the self test has successfully completed.

READY: (Ready - bit 3). A zero (0) in this field in combination with a one (1) in the PAS field indicates that the D/A Converter is executing an extended self test. Note: This bit was formerly called EX* (Extended (not)).

CF*: (Checksum-failure (not) - bit 4). A zero (0) in this field indicates that the D/A Converter's stored adjustment constants did not have the correct checksum, and may be incorrect.

Note If CF* is asserted, it is recommended that each channel be calibrated in both voltage and current modes before using the D/A Converter in the calibrated mode.

IE*: (Internal-exception (not) - bit 5). A zero (0) in this field indicates that the D/A Converter has encountered an error in executing its program. To clear the error, perform the steps below.

1. Write correct CAL-ON/CAL-OFF commands to each channel.
2. Write correct output data to each channel (ignore the state of the settle bits).
3. Issue a RESTART command.
4. When IE* is one (1), repeat steps 1 and 2.
5. If this procedure fails, perform a soft reset.

Note Performing a soft reset (SR) will zero all outputs, cause the D/A Converter to execute a self-test, and assert the SYSFAIL line. Therefore, it is recommended that the SFI bit be set before performing a soft reset to avoid halting mainframe operations.

ER*: (Error (not) - bit 6). A zero (0) in this field indicates that an error has occurred in executing a command. The error condition is cleared on receipt of another command. The recommended way of clearing the error condition is by sending the NULL command. Channel output operations have no effect on this bit.

DON: (Done - bit 7). A one (1) this field indicates that the previous command has been completed. Writing to the Command Register (08_{16}) when this bit is zero (0) may abort the command in progress. Channel output operations have no effect on this bit.

S1 through S4: (Settle Flags - bits 8 to 11). A one (1) in one of these fields indicates that the corresponding channel output is stable. A zero (0) indicates that the channel output is or will be changing. Writing to a channel when its settle flag is low (0) could corrupt the output data.

SR: (Soft Reset - bit 0). Writing a one (1) causes the D/A Converter to enter a reset state. Channel output data will be lost and all pending commands will be terminated. Registers 08_{16} through $1E_{16}$ cannot be accessed when Soft Reset is set. The D/A Converter will be held in the reset condition until a zero (0) is written to the SR bit, at which time the power-on self test and start-up sequence will be executed. It is recommended that the SR bit remain high for **>**200 msec.

CAUTION Only perform a soft reset if the "RESTART" command fails (see "Command and Parameter Registers" later in this appendix). This is because when the D/A Converter is soft reset, power is removed from the output channels, and the output state during power-down is indeterminate.

SFI: (SysFail Inhibit - bit 1). Writing a one (1) inhibits the assertion of the SYSFAIL line on the backplane.

Channel Mode Registers

V1 through V4 (bits 0 to 3). A one (1) in any of these bits indicates that the corresponding channels digital section V/I jumper is configured to operate in voltage output mode. A zero (0) indicates current output mode. Configuration of the channel's two analog section V/I jumpers are not indicated; therefore, it is essential that all three V/I jumpers match for each channel.

Channel Mode Register (Read Only)

Base + 06_{16}	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Write	Undefined															
Read	1	1	1	1	1	1	1	1	1	1	1	1	V4	V3	V2	V1

Channel Output Registers

Eight registers (two per channel) allow output value to be set. Two writes are required to set each channel. Refer to the register definitions and the following explanation for Channel Output Register information.

Channel Output MSB Registers (Write Only)

Base + *	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Write	Ignored								MSB value							
Read	Undefined															

*base + 10_{16} for channel 1, base + 14_{16} for channel 2, base + 18_{16} for channel 3, or base + $1C_{16}$ for channel 4.

Channel Output LSB Registers (Write Only)

Base + *	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Write	Ignored								LSB value							
Read	Undefined															

*base + 12_{16} for channel 1, base + 16_{16} for channel 2, base + $1A_{16}$ for channel 3, or base + $1E_{16}$ for channel 4.

The procedure for setting or changing an output level is as follows:

1. Determine the output data. The required value is a 16-bit number in offset binary. $FFFF_{16}$ represents positive full scale, 0000_{16} is negative full scale, and 8000_{16} is zero. Calibrated output modes provide "3 counts per 1 mV" or "3 counts per 2µA" (1.5 counts per 1µA) resolution.

   For example, to program 100mV, multiply 100 by 3 (= 300 decimal, or $12C_{16}$). Add this to 8000_{16} to get the output data ($812C_{16}$). For negative output values, subtract from 8000_{16} instead of adding. Or, to program 2500µA, multiply 2500 by 1.5 and add 8000_{16}.

2. Poll the Status/Control Register until C/P RDY is one (1).

3. Verify that the selected channel's Status/Control Register settle bit is one (1).

4. Write the selected channel's Most Significant Byte (MSB) in bits 0-7 (register 10_{16}, 14_{16}, 18_{16}, or $1C_{16}$).
5. Poll the Status/Control Register until C/P RDY is one (1).
6. Write the selected channel's Least Significant Byte (LSB) in bits 0-7 (register 12_{16}, 16_{16}, $1A_{16}$, or $1E_{16}$). Writing to an LSB Register will cause the corresponding channel to be updated.

Note The output is not changed until the LSB is received. If the MSB has not changed from the previous entry, you need only send the LSB.

For example, to program +100 mVdc on channel 4:

1. Multiply 100 by 3 (= 300 decimal, or $12C_{16}$). Add this to 8000_{16} to get the output data (= 33068 decimal, 100 0001 0010 1100 binary, or $812C_{16}$).
2. Enter MSB (1000 0001 binary, 81_{16}) in channel 4 MSB Register $1C_{16}$ low byte.
3. Enter LSB (0010 1100 binary, $2C_{16}$) in channel 4 LSB Register $1E_{16}$ low byte.

Command and Parameter Registers

Seven commands control equipment operation using the 08_{16} register. Three of these commands have parameters used to enter data in the $0A_{16}$ register. Refer to the register definitions and the following explanation for Command and Parameter Register information.

Command Register (Write)

Base + 08_{16}	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Write	Ignored								Null, Cal-on/off, Calibrate, Checksum, Zero-all, Restart							
Read	Undefined															

Parameter Register (Write)

Base + $0A_{16}$	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Write	Ignored								Calibrate, Checksum, and Restart							
Read	Undefined															

The procedure for sending a command is as follows:

1. Poll the Status/Control Register until both DON and RDY are asserted (1).
2. Write the Command byte to the Command Register (08_{16}). If the command is invalid (and DONE is true again), ER* will be zero (0). The command will not be executed until all required parameters (if any) have been received. If the command is CALIBRATE, CHECKSUM or RESTART, enter parameters as follows:
3. Poll the Status/Control Register until C/P RDY is asserted (1).
4. Write a Parameter byte to the Parameter Register ($0A_{16}$).
5. Repeat steps 3 and 4 as required to send all parameters.

Note The D/A Converter channel number physical markings and SCPI commands are numbered from 1 to 4, but for register-based programming the channels are numbered 0 to 3, respectively.

Commands referencing higher channel numbers than 3 will be ignored, and the ER* bit will be set to one (1) after receipt of the final parameter. In the command formats given, **xxx** = don't care, **cccc** = channel number from 0 to 3, **b** = binary, and $_{16}$ = hex.

NULL: Resets the ER* bit of the Status/Control Register and terminates any pending command. The NULL command does not have a parameter. Command format is as follows:

$0000xxxx_b$ *or* $0x_{16}$.

CAL-OFF: Disables gain and offset adjustment for the indicated channel, providing greater speed and output range, but less accuracy. The CAL-OFF command does not have a parameter. Command format is as follows:

$0010cccc_b$ *or* $2c_{16}$

For example, the command 00100000_b or 20_{16} sets channel 1 mode to non-calibrated (CAL-OFF).

CAL-ON: Enables gain and offset adjustment for the indicated channel, providing greater accuracy, but less speed and output range. The CAL-ON command does not have a parameter. Command format is as follows:

$0011cccc_b$ *or* $3c_{16}$

For example, the command 00110001_b or 31_{16} sets channel 2 mode to calibrated (CAL-ON).

CHECKSUM: Checksums the stored adjustment constants for the specified channel, and sets the ER* bit accordingly. ER* is asserted (low) if checksum is bad, and deasserted (high) if good. The CHECKSUM parameter bit (m) is 0 to check current mode constants, and 1 to check voltage mode constants. The state of the D/A Converter module's V/I jumpers is ignored. Command format (register 08_{16}) is as follows:

$0101cccc_b$ *or* $5c_{16}$

Parameter format (register $0A_{16}$) is as follows (m is parameter):

$0000000m_b$ *or* $0m_{16}$

For example, the Command 01010010_b or 52_{16} (08_{16} Register) and Parameter 00000001_b or 01_{16} ($0A_{16}$ Register) performs a checksum on the adjustment constant for channel 3 voltage.

ZERO-ALL: Writes (uncalibrated) zero to all channels as quickly as possible. The ZERO-ALL command does not have a parameter. Command format is as follows:

10101010_b *or* AA_{16}

RESTART: This command is used to recover from AC FAIL and IE* conditions. Command format is as follows:

11110000_b *or* $F0_{16}$

Parameter format is as follows (fixed parameter):

11110111_b *or* $F7_{16}$

CALIBRATE: Used to change a channel's stored voltage and/or current adjustment constant. The state of the channel's V/I jumpers determines which constant is entered. These constants are used by the D/A Converter to maintain the required output accuracy when in the calibrated mode.

The CALIBRATE command and parameter are used to enter new offset, gain, and checksum values. These values are calculated from actual channel output measurements, then entered into the Parameter Register.

Command format (register 08_{16}) is as follows:

0100cccc$_b$ *or* 4c$_{16}$

Parameter format (register $0A_{16}$) consists of seven bytes as follows:

- Offset high byte
- Offset low byte
- Gain high byte
- Gain second byte
- Gain third byte
- Gain low byte
- Checksum byte

The procedure to perform an electronic adjustment on a channel is as follows:

1. Configure the selected channel's V/I jumpers to voltage or current as required (refer to page 17).
2. Connect the load and a precision multimeter to the selected channel's V/I output terminals. Configure the multimeter for voltage or current as required.
3. Change the selected channel mode to CAL-OFF.
4. Output the value 0000_{16} (minimum) and measure the resulting voltage or current. Record the measured value as ym.
5. Output the value 8000_{16} (default or reset) and measure the resulting voltage or current. Record the measured value as yo.
6. Output the value $FFFF_{16}$ (maximum) and measure the resulting voltage or current. Record the measured value as yp.
7. Calculate the offset (J) and gain (K) constants using the equations given below. The equations must be calculated using double precision floating point arithmetic. (A sample program (in C) to compute the J, K, and checksum (steps 7 to 8) is listed below.) If the sample program is used, proceed to step 9.

   Calculate b_o and b_1 as follows:

   $$b_o = \frac{ad - eq}{dp - cq} \quad \text{and} \quad b_1 = \frac{ep - ac}{dp - cq}$$

where:

w = 3.65
ym = measured value in step 4
yo = measured value in step 5
yp = measured value in step 6
a= (ym) + (w)(yo) + (2^{16} - 1)(yp)
p= w+2
c=q= (2^{15})(w) + 2^{16} - 1
d= (2^{30})(w) + 2^{32} - 2^{17} + 1

Calculate J and K as follows:

$$k = 2^{32}\left[1 - \frac{R}{(2^{15}-1)(b_1)}\right]$$

$$J = \frac{-bo}{b1} + \frac{k}{2^{17}} - 2^{15}$$

where: R= 10.92233 for volts
0.02184467 for current

K should be rounded to a 32 bit unsigned integer. Use the rounded value of K to compute J. Round J to the nearest integer and express in 8-bit two's complement form.

NOTE: For maximum speed, precompute the actual output data using the following equation, and operate the Agilent E1328A in uncalibrated mode:

$$y = J + x - \left\{\frac{k \times x}{2^{32}}\right\}$$

where: x = desired output code (calculated as shown under "Channel Output Registers" on page 63) and y = value actually sent to the Agilent E1328A.

8. Compute a checksum by adding the 6 bytes representing J and K (on an 8-bit wide basis) and taking the two's complement of the result. (Checksum is defined to be that number which causes all seven bytes to sum to zero in byte-wide arithmetic.)

   For example (in hex), if offset (J) is 0B 7C and gain (K) is 16 F8 F2 1A (as calculated in step 6), then checksum would be 5F.

9. Use the CALIBRATE command and parameter to load J, K and the checksum into the D/A Converter's memory.

   For example (using hex example values in step 8), entering the following calculated offset (J), gain (K), and checksum for channel 4 is as follows:

00110011_b *or* 33_{16} (register 08_{16})

instructs channel 4 to accept the following data entries.

The seven parameters (register $0A_{16}$) are entered as follows:
$0B_{16}$ is high 8 bits of calculated offset (J).
$7C_{16}$ is low 8 bits of calculated offset (J).
16_{16} is high 8 bits of calculated gain (K).
$F8_{16}$ is second 8 bits of calculated gain (K).
$F2_{16}$ is third 8 bits of calculated gain (K).
$1A_{16}$ is low 8 bits of calculated gain (K).
$5F_{16}$ is calculated check sum.

10. Change the selected channel mode to CAL-ON.

11. If desired, check that the constants have been loaded correctly by outputting 8000_{16} and verifying that the channel output is zero 24 hour accuracy for voltage or current (see Appendix A).

Sample Program

The following is a sample program written in C to calculate J, K, and checksum. "ym, yo, and yp" (from steps 4-6 on page 67) are measured and entered. Note, the program does not prompt for the value of *w*, the default value of 3.65 is used.

```
/* This program demonstrates a weighted least-squares approach to determining DAC calibration
constants.
ym = (uncalibrated) negative full-scale output value
yp = positive full-scale output
y0 = uncalibrated zero
w = weighting factor for relative importance of zero
        w = 3.65 is the recommended weighting factor
        w = 1 yields conventional least-squares algorithm
The DAC characteristic is modeled as y = b1*x + b0.
The coefficients b1 and b0 are used to calculate the actual calibration constants, J and K. */
dac_line(yp, y0, ym, w, b1, b0)
double yp, y0, ym, w, *b1, *b0;
{
double u[2], M[2][2], N[2][2], d;
u[0] = ym + w * y0 + yp;
u[1] = w * 0x8000 * y0 + 0xFFFF * yp;
M[0][0] = w + 2;
M[0][1] = 0x8000 * w + 0xFFFF;
M[1][0] = M[0][1];
M[1][1] = w * (double)(0x8000) * 0x8000 + (double)(0xFFFF) * 0xFFFF;
d = M[0][0]*M[1][1] - M[0][1]*M[1][0];
N[0][0] = M[1][1] / d;
N[0][1] = - M[0][1] / d;
```

```
N[1][0] = - M[1][0] / d;
N[1][1] = M[0][0] / d;
*b0 = N[0][0]*u[0] + N[0][1]*u[1];
*b1 = N[1][0]*u[0] + N[1][1]*u[1];
return;
}
main()
int i, Jint;
double yp, y0, ym, b1, b0, w, J, K, Rx;
unsigned long Kint, checksum;
char string[81];
w=3.65;                                                   /* may be changed if desired */
printf("\nEnter yp, y0, ym (in Volts or Amps)\n");        /* prompt for data */
gets(string);
sscanf(string,"%lf, %lf, %lf",&yp,&y0,&ym);
dac_line(yp,y0,ym,w,&b1,&b0);                              /* find best fit line */
printf("\nCoefficients of best-fit line, using w = %g:\n",w);
printf("\tb1 = %g\n",b1);
printf("\tb0 = %g\n",b0);
/* compute cal constants from best fit line */
if(yp=1) Rx = 10.92233;                                   /* voltage case */
else Rx = .02184467;                                      /* current case */
K = 1.0 - ( Rx /( 0x7fff * b1));
K *= 4.0 * 0x8000 * 0x8000;                               /* mult by 2^32 */
Kint = K + .5;                                            /* round to integer */
J = -b0/b1 - 0x8000;
J += ((double)Kint)/(4.0*(double)0x8000);                 /* divisor is 2^17 */
if(J=(double)0.0) Jint = J +.5;                           /* round to integer */
else      Jint = J -.5;                                   /* J is negative */
/* compute an eight bit checksum */
checksum = Jint & 0xff;
checksum += Jint>8 & 0xff;
for(i=0;i<=3;i++)  checksum += ( Kint>(i*8) ) & 0xff;
checksum ^= -1; checksum += 1;                            /* two's complement */
checksum &= 0xff;                                         /* truncate to eight bits */
printf("\nCalibration constants are as follows for Rx = %g:\n",Rx);
printf("\tJ = %04x h\n",Jint); printf("\tK =  %8lx h\n",Kint);
printf("\tchecksum = %02lx h\n",checksum);
}
```

A Register-Based Algorithm

The following algorithm describes the procedure you would use to program the registers on the Agilent E1328A D/A Converter module to output either a voltage or a current.

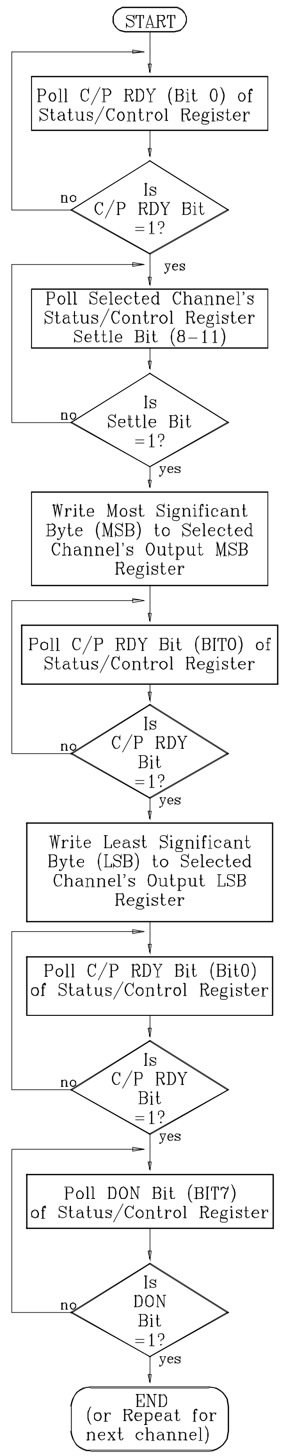

Figure B-3. Register-Based Programming Algorithm

Programming Examples

The examples in this section demonstrate how to program the module at the register level. The programs follow the algorithm described in a previous section. The examples include:

- Resetting the Module
- Reading the ID, Device Type, and Status Registers
- Outputting a Voltage or Current

System Configuration

The following example programs were developed with the module at logical address 72.

- The BASIC programs were developed using the Agilent E1300 mainframe Series B IBASIC language.
- The C language programs were developed on an HP Vectra PC (IBM PC compatible) using Borland's Turbo C++® programming language, the Agilent 82335 GPIB Interface and GPIB Command Library. The last C language programming example was developed on the Agilent RADI-EPC7 Embedded Controller.

Resetting the Module

The following program resets the Agilent E1328A D/A Converter module. The process is as follows:

1. Write a "2" to the Status/Control Register to set SFI high.
2. Write a "3" to the Status/Control Register to keep the SFI bit high and set the reset bit.
3. Wait 200 mS.
4. Write a "2" to the Status/Control Register to keep the SFI bit high and zero the reset bit.
5. Wait 100 mS.
6. Write a "0" to the Status/Control Register.

IBASIC Version

```
10    Base_addr = DVAL("1FD200",16)     !Logical Address 72.
20    Reg_addr = 04   ! Offset for Status Control Register.
30    ! Write a 2 then a 3 to the Status Register.
40    WRITEIO -9826, Base_addr + Reg_addr; 2
50    WRITEIO -9826, Base_addr + Reg_addr; 3
60    WAIT .2  ! wait 200 mS.
70    WRITEIO -9826, Base_addr + Reg_addr; 2
80    WAIT .1   ! wait 100 mS.
90    WRITEIO -9826, Base_addr + Reg_addr; 0
100   END
```

C Version

```
/* reset the module */
#include <stdio.h>
#include <chpib.h>
#include <dos.h>

#define LOG_ADDR 72                          /* Agilent E1328A Logical
                                             Address */
#define BASE_ADDR (long) ((0x1FC000) + (64 * LOG_ADDR))

/* function to send values to the Status Register */
void send_value (int base_address, int data_value)
{
    float   send_data[3], read;
    char    state[2] = {13,10};
    send_data[0] = base_address + 4;         /* Status Register offset */
    send_data[1] = 16;                       /* base 16 */
    send_data[2] = data_value;               /* data value sent to the register */

    IOEOI (7L, 0);   IOEOL (7L, " ", 0);     /* GPIB library call */
    IOOUTPUTS (70900L, "DIAG:POKE ", 10);/* GPIB library call */
    IOEOI (7L, 1);   IOEOL (7L, state,0);    /* GPIB library call */
    IOOUTPUTA (70900L, send_data, 3);        /* GPIB library call */
}

main ()
{
        send_value(BASE_ADDR, 2);
        send_value(BASE_ADDR, 3);
        delay (200);                         /* wait 200 mS (delay is unique
                                             to Borland Turbo C++) */
        send_value(BASE_ADDR, 2);
        delay (100);                         /* wait 100 mS */
        send_value(BASE_ADDR, 0);
return 0;
}
```

Reading the ID, Device Type, and Status Registers

The following examples read the ID, Device Type, and Status/Control Registers.

IBASIC Version

```
10   !***********************************************************
20   !*****                 READREG                        *****
30   !***********************************************************

40   ! OPTION BASE 0 is default.
50   ! Set up arrays to store register names and addresses.
60   DIM Reg_name$(0:2)[32], Reg_addr(0:2)
70   !
80   ! Read register names and addresses into the arrays.
90   READ Reg_name$(*)
100  READ Reg_addr(*)
110  !
120  ! Set base Address variable.
130  Base_addr = DVAL ("1FD200",16)
140  !
150  ! Map the A16 address space.
160  !
170  ! CONTROL 16,25;2  ! used only with V360 Controller.
180  ! Call the subprogram Read_regs.
190  Read_regs(Base_addr, Reg_name$(*),Reg_addr(*))
200  !
210  DATA Identification Register, Device Register, Status Register
220  DATA 00, 02, 04
230  END
240  ! This subprogram reads each register and prints its contents.
250  SUB Read_regs(Base_addr, Reg_name$(*),Reg_addr(*))
260  FOR Number = 0 to 2
270  Register = READIO(-9826,Base_addr + Reg_addr(number))
280  PRINT Reg_name$(number);" = "; IVAL$(Register, 16)
290  NEXT Number
300  SUBEND
```

This program returns:

ID Register = FFFF
Device Type Register = FF7F
Status/Control Register = *(dependent on current status, default is FFFF)*

C Version

```
#include <stdio.h>
#include <chpib.h>
#include <cfunc.h>

#define LOG_ADDR 72
#define BASE_ADDR (long) ((0x1FC000) + (64 * LOG_ADDR))

main()
{
    int  reg_addr;
    float   send_data[3], read;
    char state[2] = {13,10};
    send_data[1] = 16;
    send_data[2] = 0;

    /* Read ID Register */
    send_data[0] = BASE_ADDR + 0;
    IOEOI (7L, 0); IOEOL (7L, , 0);                /* GPIB library call */
    IOOUTPUTS (70900L, "DIAG:PEEK? ", 11);/* GPIB library call */
    IOEOI (7L, 1); IOEOL (7L, state, 2);          /* GPIB library call */
    IOOUTPUTA (70900L, send_data, 2);              /* GPIB library call */
    IOENTER(70900L, &read);                        /* GPIB library call */
    printf(\nIdentification Register = %0x,(int)read);/* print ID Register */
    /* Read Device Type Register */
    send_data[0] = BASE_ADDR + 2;
    IOEOI (7L, 0); IOEOL (7L, , 0);                /* GPIB library call */
    IOOUTPUTS (70900L, "DIAG:PEEK? ", 11);/* GPIB library call */
    IOEOI (7L, 1); IOEOL (7L, state, 2);          /* GPIB library call */
    IOOUTPUTA (70900L, send_data, 2);              /* GPIB library call */
    IOENTER(70900L, &read);                        /* GPIB library call */
    printf(\nDevice Register = %0x,(int)read); /* print Device Register */
    /* Read Status Register */
    send_data[0] = BASE_ADDR + 4;
    IOEOI (7L, 0); IOEOL (7L, " ", 0);             /* GPIB library call */
    IOOUTPUTS (70900L, "DIAG:PEEK? ", 11);/* GPIB library call */
    IOEOI (7L, 1); IOEOL (7L, state, 2);          /* GPIB library call */
    IOOUTPUTA (70900L, send_data, 2);              /* GPIB library call */
    IOENTER(70900L, &read);                        /* GPIB library call */
    printf("\nStatus Register = %0x",(int)read);/* print Status Register */
return o;
}
```

Outputting a Voltage or Current

For specific information on setting or changing the output levels, see the sections titled "Channel Output Registers" on page 63 and "A Register-Based Algorithm" on page 71. Voltage or current mode is jumper selected on the module; it is not possible to select either the voltage or current mode by register programming. Ensure the proper mode is selected before writing data to the module.

The following examples set the D/A Converter Channel 1 to output +100mVdc. First determine the output data. The required value is a 16-bit number in offset binary. $FFFF_{16}$ represents positive full scale, 0000_{16} is negative full scale, and 8000_{16} is zero. Calibrated output modes are arranged to provide "3 counts per 1 mV" resolution.

For our example, to program 100 mV, multiply 100 by 3 (= 300 decimal, or $12C_{16}$). Add this to 8000_{16} to get the output data ($812C_{16}$). (For negative output values, subtract from 8000_{16} instead of adding). 81_{16} is the MSB and $2C_{16}$ is the LSB. Writing to the LSB Register causes the corresponding channel to output the specified voltage or current.

IBASIC Version

```
10   Base_addr = DVAL("1FD200",16)
20   Msb_addr = DVAL("10",16)              ! Channel 1 MSB Register offset.
30   Lsb_addr = DVAL("12",16)              ! Channel 1 LSB Register offset.
40   ! Poll Status Register Bit 0 (RDY).
50   REPEAT
60   UNTIL BIT (READIO (-9826, Base_addr + 4),0)
70   ! Verify that Channel settle bit is 1.
80   REPEAT
90   UNTIL BIT (READIO (-9826, Base_addr + 4),8)
100  ! Write the MSB.
110  WRITEIO -9826, Base_addr + Msb_addr; DVAL ("81",16)
120  ! Poll Status Register Bit 0 (RDY).
130  REPEAT
140  UNTIL BIT (READIO (-9826, Base_addr + 4),0)
150  ! Write LSB.
160  WRITEIO -9826, Base_addr + LSB_addr; DVAL("2C",16)
170  ! Poll Status Register Bit 0 (RDY).
180  REPEAT
190  UNTIL BIT (READIO (-9826, Base_addr + 4),0)
200  ! Poll Status Register Bit 7 (DON).
210  REPEAT
220  UNTIL BIT (READIO (-9826, Base_addr + 4),7)
230  END
```

C Version

```
/* Output a Voltage */
#include <stdio.h>
#include <chpib.h>
#include <dos.h>.h

#define LOG_ADDR 72                                    /* E1328 Logical Address */
#define BASE_ADDR (long) ((0x1FC000) + (64 * LOG_ADDR))

float   send_data[3], read;                            /* Output data array */
int     msb_addr = 0x10;                               /* MSB Register address */
int     lsb_addr = 0x12;                               /* LSB Register address */
char    state[2] = {13,10};                            /* CR/LF for data */


/*Function to poll Status Register to make certain channel is ready */
void poll_status_register (base_address)
{
    long    bit_number;
    float   send_data[3], read;
    send_data[0] = base_address + 4;                   /* Status Register address */
    send_data[1] = 16;                                 /* hex base */
    send_data[2] = 0;                                  /* no value because reading the
                                                          register */
    IOEOI (7L, 0);   IOEOL (7L, " ", 0);               /* GPIB library call */
    IOOUTPUTS (70900L, "DIAG:PEEK? ", 11); /* GPIB library call */
    IOEOI(7L,0);     IOEOL(7L, " ",0);                 /* GPIB library call */
    IOOUTPUTA (70900L, send_data,2);                   /* GPIB library call */
    while (bit_number != 0x0101)                       /* wait until bits 0 and 8
                                                          (channel 1) are ready */
        {
        IOENTER(70900L, &read);                        /* GPIB library call */
        bit_number = ((long)(read));
        }
}

main ()
{
    /* Poll Status Register to ensure channel ready */
    poll_status_register(BASE_ADDR);

    /* Send Channel MSB */
    send_data[0] = BASE_ADDR + msb_addr;/* set MSB address */
    send_data[2] = 0x81;                               /* MSB data */
```

```
        IOEOI (7L, 0);    IOEOL (7L, " ", 0);          /*  GPIB library call  */
        IOOUTPUTS (70900L, "DIAG:POKE ", 10);/*  GPIB library call  */
        IOEOI (7L, 1);    IOEOL (7L, state,0);         /*  GPIB library call  */
        IOOUTPUTA (70900L, send_data, 3);      /*  GPIB library call  */

        /* Poll Status Register to ensure channel ready */
        poll_status_register(BASE_ADDR);

        /* Send Channel LSB */
        send_data[0] = BASE_ADDR + lsb_addr;/*  set LSB address  */
        send_data[2] = 0x2C;                           /*  LSB data  */

        IOEOI (7L, 0);    IOEOL (7L, " ", 0);          /*  GPIB library call  */
        IOOUTPUTS (70900L, "DIAG:POKE ", 10);/*  GPIB library call  */
        IOEOI (7L, 1);    IOEOL (7L, state,0);         /*  GPIB library call  */
        IOOUTPUTA (70900L, send_data, 3);      /*  GPIB library call */

    return 0;
    }
```

Using an Embedded Agilent RADI-EPC7 Computer

The following C language program was developed on the Agilent RADI-EPC7 embedded computer using the Standard Instrument Control Library (SICL) for DOS. As listed, the program sets channel 1 to output -2.00V. The program can be used to set the output voltage or current on any DAC channel.

```
/* E1328_VO.CPP - This program sets D/A Converter to output -2.00V */
/* on channel 1. The program can also be used to set the output voltage or */
/* output current on any channel. Note that the channel mode (voltage or */
/* current) must be set using the jumpers on the Agilent E1328A module. */

#include <sicl.h>
#include <stdio.h>
#include <stdlib.h>
#include <conio.h>
#include <dos.h>

/* define macros to monitor D/A status in the Status Register */

#define READY (iwpeek((unsigned short *)(base_addr + 0x04)) & 0x01)
#define DONE ((iwpeek((unsigned short *)(base_addr + 0x04)) & 0x81) == 0x81)
#define SETTLE1 (iwpeek((unsigned short *)(base_addr + 0x04)) & 0x100)
#define SETTLE2 (iwpeek((unsigned short *)(base_addr + 0x04)) & 0x200)
#define SETTLE3 (iwpeek((unsigned short *)(base_addr + 0x04)) & 0x400)
#define SETTLE4 (iwpeek((unsigned short *)(base_addr + 0x04)) & 0x800)
#define PASS_FAIL (iwpeek((unsigned short *)(base_addr + 0X04)) & 0x04)

/* Function prototypes */
void setup_dtoa(char *base_addr, int mode, int channel, float level);
void reset_dtoa(char *base_addr);
void main(void)
{
        char *base_addr;
        /* create and open a device session */
      INST e1328a;
        e1328a = iopen("vxi,72");

        /* map the Agilent E1328A registers into user memory space */
        base_addr = imap(e1328a, I_MAP_VXIDEV, 0, 1, NULL);

        /* function call to reset the D/A converter */
        reset_dtoa(base_addr);

        /* function call to set up the D/A converter; send base address, */
        /* mode (voltage = 1, any other number = current), channel (1-4), */
        /* and level (in volts or amps) */

        setup_dtoa(base_addr, 1, 1, -2.00);     /* outputs -2.0V on channel 1 */
        /* close session */
      iclose(e1328a);
}
```

```
/*******************************************************************************/
void setup_dtoa(char *base_addr, int mode, int channel, float level)
{
/* This function sets up the D/A converter to output voltages or currents */
/* on the specified channels. */

        unsigned short level_word = 0, msbyte = 0, lsbyte = 0;
        /* convert voltage or current level to binary number */
        if (mode == 1)                          /* convert voltage */
        {
            level_word = (unsigned short)(level * 3000) + 0x8000;
            msbyte = level_word >> 8;
            lsbyte = level_word & 0xFF;
        }
        else                                    /* convert current */
        {
            level_word = (unsigned short)(level * 1500000) + 0x8000;
            msbyte = level_word >> 8;
            lsbyte = level_word & 0xFF;
        }

        /* wait for the D/A ready bit and the channel's settle bit = 1, */
        /* and then write msbyte of voltage */

        switch (channel)
        {
                case 1:     while(!READY);          /* channel 1 */
                            while(!SETTLE1);
                            iwpoke((unsigned short *)(base_addr + 0x10),msbyte);

        /* wait for D/A ready bit = 1, and then write lsbyte of voltage */

                while (!READY);
                iwpoke((unsigned short *)(base_addr + 0x12),lsbyte);
                break;
                case 2:     while(!READY);          /* channel 2 */
                            while(!SETTLE2);
                            iwpoke((unsigned short *)(base_addr + 0x14),msbyte);
        /* wait for D/A ready bit = 1, and then write lsbyte of voltage */

                            while (!READY);
                            iwpoke((unsigned short *)(base_addr + 0x16),lsbyte);
                            break;

                case 3:     while(!READY);          /* channel 3 */
                            while(!SETTLE3);
                            iwpoke((unsigned short *)(base_addr + 0x18),msbyte);

        /* wait for D/A ready bit = 1, and then write lsbyte of voltage */

                            while (!READY);
                            iwpoke((unsigned short *)(base_addr + 0x1A),lsbyte);
                            break;
```

```
                    case 4:     while(!READY);          /* channel 4 */
                                while(!SETTLE4);
                                iwpoke((unsigned short *)(base_addr + 0x1C),msbyte);

        /* wait for D/A ready bit = 1, and then write lsbyte of voltage */

                                while(!READY);
                                iwpoke((unsigned short *)(base_addr + 0x1E),lsbyte);
                                break;

                default:    exit(EXIT_FAILURE);
                            break;
        }

        /* wait for command to complete before setting next output */
        while(!READY);
        while(!DONE); }

/*******************************************************************************/
void reset_dtoa(char *base_addr)
{
/* This function resets the D/A converter by disabling the Status/Control */
/* Register 'SYSFAIL' bit (bit 1), by writing a '1' to the soft reset bit */
/* (bit 0), and then by writing a '0' to bit 0. After the reset, the 'SYSFAIL'*/
/* bit is re-enabled. */

        iwpoke((unsigned short *)(base_addr + 0x04),2);     /* disable 'SYSFAIL' */
        iwpoke((unsigned short *)(base_addr + 0x04),3);
        delay (200);                                        /* Borland C++ function */
        iwpoke((unsigned short *)(base_addr + 0x04),2);     /* turn off reset */
        while (!PASS_FAIL);                                 /* wait for the reset to complete */
        iwpoke((unsigned short *)(base_addr + 0x04),0);     /* enable 'SYSFAIL' */
 }
```

Notes

Appendix C
Agilent E1328A Error Messages

Table C-1 lists the error messages associated with the 4-Channel D/A Converter module programmed by SCPI. See the appropriate mainframe manual for a complete list of error messages.

Table C-1. 4-Channel D/A Converter Error Messages

No.	Title	Potential Cause(s)
–350	Too many errors	The error queue is full as more than 30 errors have occurred.
–330	Self-test Failure	Module malfunction.
–240	Hardware Failure	Module malfunction.
–221	Jumper Settings	Channel’s V/I jumper in incorrect position.
+2801	Channel 1 current checksum error	Channel 1 stored adjustment constant (current) is corrupted.
+2802	Channel 2 current checksum error	Channel 2 stored adjustment constant (current) is corrupted.
+2803	Channel 3 current checksum error	Channel 3 stored adjustment constant (current) is corrupted.
+2804	Channel 4 current checksum error	Channel 4 stored adjustment constant (current) is corrupted.
+2805	Channel 1 voltage checksum error	Channel 1 stored adjustment constant (voltage) is corrupted.
+2806	Channel 2 voltage checksum error	Channel 2 stored adjustment constant (voltage) is corrupted.
+2807	Channel 3 voltage checksum error	Channel 3 stored adjustment constant (voltage) is corrupted.
+2808	Channel 4 voltage checksum error	Channel 4 stored adjustment constant (voltage) is corrupted.

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