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MODEL PCIe-DA16-6 Analog Output Multifunction Board

USER MANUAL

FILE: PCIe-DA16-6.A3a

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Table of Contents

Chapter 1: Introduction

Features

- 6-, 4- and 2 channel, 16- or 12-bit digital-to-analog outputs PCI Express card
- Software / Hardware compatible with PCI-DA12-6, 4 & 2, >125k conversions per channel
- Dip-switch selectable analog output ranges of 2.5V, 5V, 10V, ±2.5V, ±5V, ±10V, 4-20mA
- Individual or simultaneous update of the DACs
- DACs restricted at power-on to prevent spurious outputs
- 16-bits of digital I/O
- VCCIO voltage available to the user via 0.5A resettable fuse
- 12V available to the user via 0.2A resettable fuse
- RoHS Available
- Wind River VxWorks support available

Applications

Optical Networking, Instrumentation, Multichannel Data Acquisition and system monitoring, Automatic Test Equipment, Process Control and Industrial Automation, Power line simulation and stimulation. light control, motion control, and more.

Functional Description

Analog Outputs

These cards are 6.6” x 3.875” and can be installed in any PCI Express slot. They contain either six, four, or two double-buffered digital-to-analog converters (DACs) that provide independent analog output channels of 12- or 16-bit resolution. Each analog output channel can be configured for ranges of:

0V to +2.5V
0V to +5V
0V to +10V
-2.5V to +2.5V
-5V to +5V
-10V to +10V
4mA to 20mA sink

The analog output channels have a double-buffered input for single-step update and each is addressed at its own I/O location. Type DAC80504 quad DAC chips are used. Data is transferred to the FPGA's local registers a byte or word at a time and then transferred to the DAC buffer registers a word at a time. The analog outputs can then be updated by transferring this data to the DAC active registers either independently or simultaneously by command.

In order to prevent excessive voltage output to external circuits, the card contains automatic circuits that set D/A outputs to 0V at system power-on. Upon power-up, the card is in the Simultaneous Update mode. After all DACs have been loaded with the desired values, a software command can be used to switch the reference voltage to its normal value.

Digital I/O Lines

These cards provide 16 bits of parallel digital input/output. They can be programmed as inputs or outputs on the two 8-bit ports designated Ports A and B.

Each I/O line is buffered by a type 74LVC8T245 buffer transceiver capable of sourcing or sinking 32mA (w/ 5V VCCIO), or 24mA (w/ 3.3V VCCIO). Pull-ups on the card assure that there are no erroneous outputs at power up. The lines initialize in the input mode.

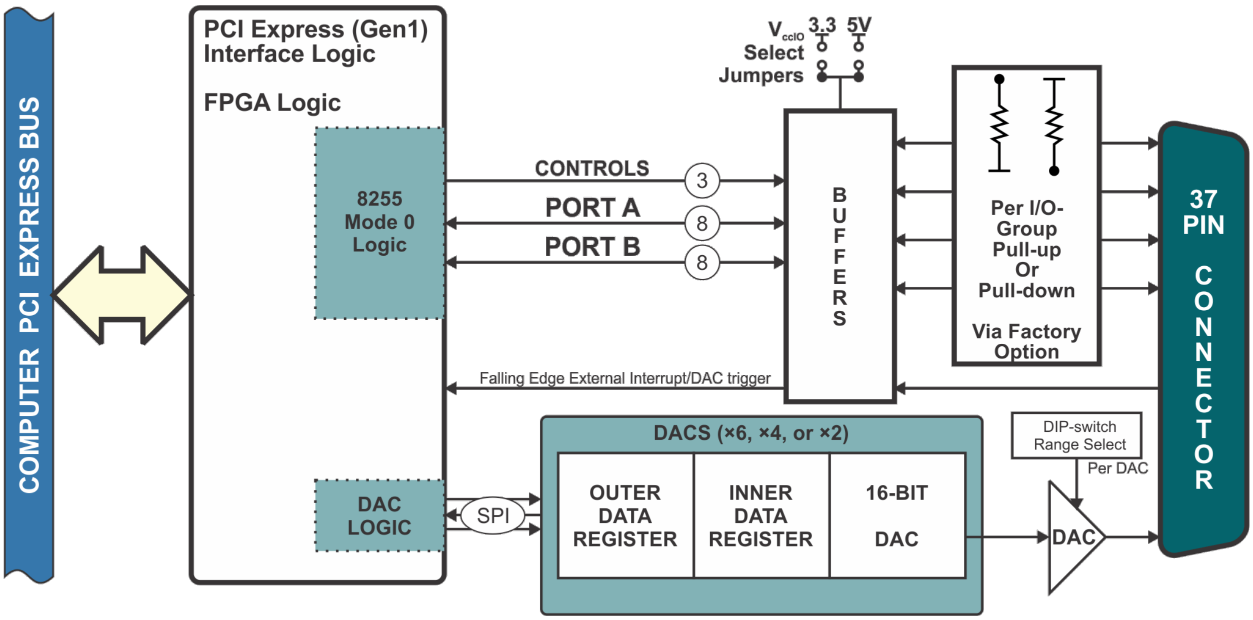


Figure 1-1: Block Diagram

Ordering Guide

- PCIe-DA16-6 Six 16-Bit Analog Outputs
- PCIe-DA16-4 Four 16-Bit Analog Outputs
- PCIe-DA16-2 Two 16-Bit Analog Outputs
- PCIe-DA12-6 Six 12-Bit Analog Outputs
- PCIe-DA12-4 Four 12-Bit Analog Outputs
- PCIe-DA12-2 Two 12-Bit Analog Outputs

Model Options

- -RoHS RoHS compliant version
- -T Extended operating temperature -40 to +85C

Included with your board

The following components are included with your shipment. Please take time now to ensure that no items are damaged or missing.

PCIe-DA1x-x Board

Optional Accessories

ADAP37F-MINI	Direct Plug Spring Cage Terminal Adaptor
STB-37	Screw Terminal Board
CAB37-18	Ribbon Cable Accessory, 18”

Chapter 2: Installation

The software provided with this board is available to download via the product page for free and must be installed onto your hard disk prior to use.

Windows

1. Visit the product web page at https://accesio.com/PCIe-DA16-6
2. Download the Software Package from the Manuals / Software tab
3. Run the Install program and follow the on-screen prompts to install the software for this board

Linux

1. Please visit https://github.com/accesio for information on installing under Linux.

Caution! * ESD ***A single static discharge can damage your card and cause premature failure! Please follow all reasonable precautions to prevent a static discharge such as grounding yourself by touching any grounded surface prior to touching the card.***

Hardware Installation

1. Make sure to set switches and jumpers from either the Option Selection section of this manual or from the suggestions of the Settings Program.
2. Do not install card into the computer until the software has been fully installed.
3. Turn OFF computer power AND unplug AC power from the system.
4. Remove the computer cover.
5. Carefully install the card in any available PCI Express expansion slot (you may need to remove a backplate first).
6. Inspect for proper fit of the card and tighten the mounting bracket screw. Make sure that the card mounting bracket is properly screwed into place and that there is a positive chassis ground.
7. Install an I/O cable (or an ADAP37F-MINI) onto the card’s bracket-mounted male connector.
8. Replace the computer cover and turn ON the computer which should auto-detect the card (depending on the operating system) and automatically finish installing the drivers.
9. Run AIOWDMFind.exe to complete installing the card into the registry (for Windows only) and to determine the assigned resources.
10. Run one of the provided sample programs that was copied to the newly created card directory to test and validate your installation.

If the card is not detected, go to Device Manager and check for the card showing up as an unknown "PCI Device" in “Other devices”; if you find it, right-click and "Update Driver" and search automatically; this should resolve any issues.

Chapter 3: Option Selection

Voltage output ranges are determined by switch settings as described in the following paragraphs. The method to update D/A outputs is software programmable as described in Chapter 5, Programming.

Output Ranges

There is a four-position slide switch (OFF = DOWN position / ON = UP position) with each individual position slide notated with 1, 2, 3 or 4. Each four-position slide switch is associated with each DAC channel to make voltage range selection: switches S1 (Channel 0) through S6 (Channel 5) as depicted in the following table.

Voltage Range	**1**	**2**	**3**	4	**Range Code**
0 to +2.5V	OFF	ON	ON	OFF	1
0 to +5V	OFF	OFF	OFF	OFF	0
0 to +10V	OFF	OFF	ON	OFF	2
-2.5V to +2.5V	ON	ON	ON	OFF	4
-5V to +5V	ON	OFF	OFF	OFF	3
-10V to +10V	ON	OFF	ON	OFF	5
4 mA to 20 mA	OFF	OFF	OFF	ON	6

Table 3-1: Range Switches and Codes

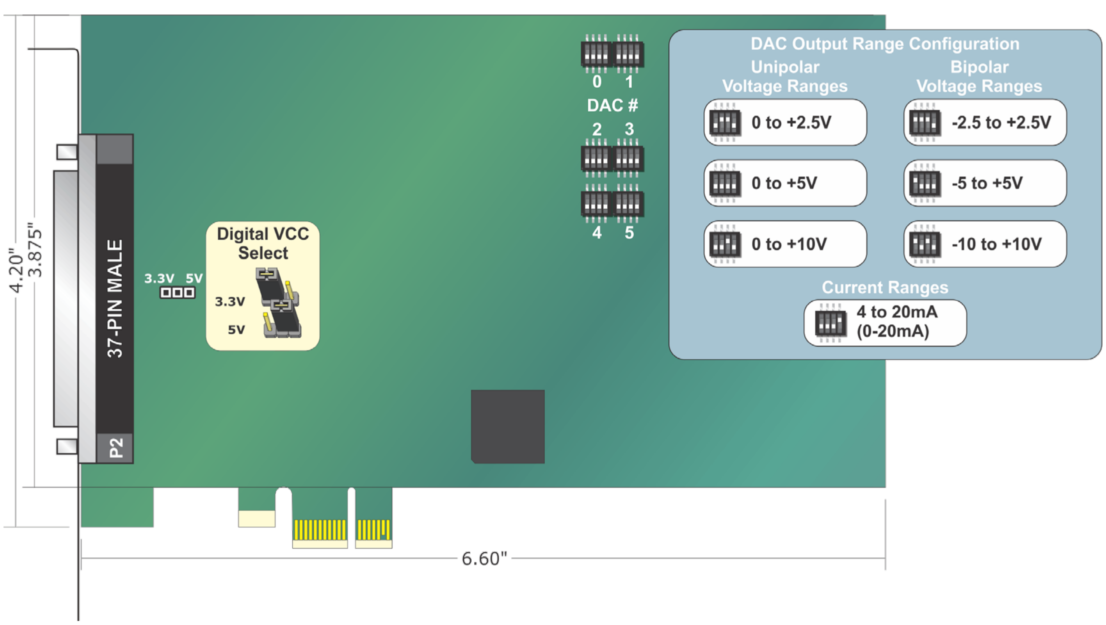


Figure 3-1: Option Selection Map

Chapter 4: Address Selection

These cards use three address spaces. These are defined in the Port Address Selection Table in the Programming section of this manual.

PCI Express architecture is inherently plug-and-play. This means that the BIOS or Operating System determines the resources assigned to PCI Express cards rather than you selecting those resources with switches or jumpers. As a result, you cannot set or change the card's base address or IRQ level. You can only determine what the system has assigned.

To determine the base address that has been assigned, run the AIOWDMFind.EXE utility program provided. This utility will display a list of all of the cards detected on the PCI Express bus, the addresses assigned to each function on each of the cards, and the respective IRQs.

Alternatively, some operating systems can be queried to determine which resources were assigned. In these operating systems, you can use either AIOWDMFind or the Device Manager utility from the System Properties Applet of the control panel. The card is installed in the Data Acquisition class of the Device Manager list. Selecting the card, clicking Properties, and then selecting the Resources Tab will display a list of the resources allocated to the card.

If you want to determine the base address and IRQ yourself, use the following information.

The Vendor ID for these cards is 494F. (ASCII for "IO")

The Device ID for the 16-bit 6 channel card is 48e0h.
The Device ID for the 16-bit 4 channel card is 48d8h.
The Device ID for the 16-bit 2 channel card is 48d0h.
The Device ID for the 12-bit 6 channel card is 48a0h.
The Device ID for the 12-bit 4 channel card is 4898h.
The Device ID for the 12-bit 2 channel card is 4890h.

Chapter 5: Programming

The cards' DACs and Digital I/O use 18 I/O addresses. Programming these cards is very straightforward as there are only two operating modes and four range-selection switches per channel. The basic operation of a Digital-to-Analog card is to write a 16-bit value to a Digital to Analog Converter (DAC) where it is buffered and loaded by an update command to a DAC active register. Outputs of that register control a "ladder" network which produces the analog output. The output voltage range is defined by settings of the range-selection switches for that channel. For example:

```
double spanVolts = 10.0;  // for ±5V; use "20.0" for ±10
double offsetVolts = spanVolts / 2; //use "0.0" for all unipolar ranges.
double targetVolts = 1.3; // change to any desired output voltage
counts = (targetVolts + offsetVolts) / spanVolts * 65536.0;
RelOutport(DeviceIndex, DAC * 2, counts);
```

Upon power-up, or hardware reset, the DAC registers are restricted to a safe value and the card is set in Simultaneous Update mode.

Simultaneous Update Mode is the power-up or default mode of operation for the DAC card. When a value is written to a DAC address the output does not change until an output update is commanded via a read from Base Address+8. (Alternatively, a read of Base Address+A will update the DAC registers and switch the board to Automatic Update Mode.) While in Simultaneous Update Mode, a single read will load all DAC registers with the value waiting in the pre-load registers, causing all outputs to be updated and changed simultaneously. In other words, the outputs of all D/As may be updated simultaneously by first enabling simultaneous updating for all outputs, preloading the low and high bytes of each DAC, and then initiating a simultaneous update by software command or external update falling edge.

Automatic Update Mode is the configuration that changes a DAC output immediately after the high-byte of the new value is written to the DAC address.
(Each channel is updated individually when new data are written to the related high-byte base address)
If the card is in Simultaneous Update Mode a read of Base Address+2 will change the card back to Automatic Update Mode without updating the outputs. A read of Base Address+A will update all outputs simultaneously and then place the card in Automatic Update Mode.

Restrict-Output-Voltage limits the output of all DAC channels to 0V and is active at power-up. Since the pre-load register defaults to its min-scale value, known values can be written to the preload registers before using a "Clear Restrict-Output-Voltage" command. Those written values will then be output to the connector when a "Clear Restrict-Output-Voltage" command is issued by a read of Base Address +F.

External Trigger Update Mode allows a negative level at pin 25 of the I/O connector to cause the DACs to be updated. A read of Base Address +5 will enable this mode, a read of Base Address +6 will disable it. Note that this pin is shared with the External Interrupt signal.

External Interrupt is a negative edge at pin 25 and is latched until cleared by a read of Base Address +4. The interrupt is enabled by a read of Base Address+3 and powers up disabled. After being cleared the interrupt must be re-enabled.

Address hex	Write	Read
Base + 0	DAC 0 Low Byte	Place card in Simultaneous Mode without updating outputs.
Base + 1	DAC 0 High Byte	
Base + 2	DAC 1 Low Byte	Release card from Simultaneous Mode without updating outputs.
Base + 3	DAC 1 High Byte	Enable Interrupts
Base + 4	DAC 2 Low Byte	Disable Interrupts
Base + 5	DAC 2 High Byte	Enable Timer Initiated DAC Update
Base + 6	DAC 3 Low Byte	Disable Timer Initiated DAC Update
Base + 7	DAC 3 High Byte	
Base + 8	DAC 4 Low Byte	Update all outputs and place card in Simultaneous Mode.
Base + 9	DAC 4 High Byte	
Base + A	DAC 5 Low Byte	Update all outputs and release card from Simultaneous Mode.
Base + B	DAC 5 High Byte	
Base + E		Restrict-Output-Voltage (Disables voltage reference)
Base + F		Clear Restrict-Output-Voltage (Allows full operating output voltage).
Base + 20	Digital I/O Port A, Output	Digital I/O Port A, Input
Base + 21	Digital I/O Port B, Output	Digital I/O Port B, Input
Base + 23	Digital I/O Control Byte	

Table 5-1: Register Map

Restrict-Output-Voltage limits the output of all DAC channels and is active at power-up.

BIT	D7	D6	D5	D4	D3	D2	D1	D0
Low Byte	B7	B6	B5	B4	B3	B2	B1	B0
High Byte	*B15	*B14	*B13	*B12	B11	B10	B9	B8

Table 5-2: DAC Data Format

* B15->B12 are ignored by 12-bit models

For Unipolar ranges, data is in true binary form.

```
            0000  0000  0000  0000   =  Zero (Low Scale)
            1000  0000  0000  0000   =  ½ Scale
            1111  1111  1111  1111   =  Full Scale
            |                    |
MSB or B15  ←                    →      B0 or LSB
```

For Bipolar ranges, data are in offset binary form. (Same as above)

Programming the Digital I/O Circuit

The digital I/O circuit is comprised of a direction control latch, and two bi-directional buffers with 10K pull-ups.

The cards are designed to operate as follows:

a. There are two 8-bit ports (A and B)
b. Either 8-bit port can be configured as an input or an output
c. Outputs are latched
d. Inputs are not latched
e. The card is initialized in the input mode

A write-only, 8-bit register is used to set the mode and direction of the ports. At Power-Up or Reset, all I/O lines are set as inputs. Each GROUP should be configured during initialization by writing to the control registers even if the ports are going to be used as inputs. The DIO Direction-control register is located at base address +23. Bit assignments in each of these control registers are as follows:

Bit	Assignment	Function
D0	Reserved, always use set to zero	Reserved, always use set to zero
D1	Port B	1 = Input, 0 = Output
D2	Reserved, always use set to zero	Reserved, always use set to zero
D3		
D4	Port A	1 = Input, 0 = Output
D5,D6	Reserved, always use set to zero	Reserved, always use set to zero
D7	Mode Set (see note 1)	Scratchpad

Table 5-3: Control Register Bit Assignments

Note 1: This bit is a read/write scratchpad

Chapter 6 Software

These cards are straightforward to program. The following example is in C, but sample code is also provided on the CD in Pascal and four Windows languages: Delphi, VisualBASIC, and Visual C++.

To output an analog value with 16-bit resolution, a corresponding decimal number N between 0 and 65535 is calculated (2^{16} = 65536).

```
double spanVolts = 10.0;  // for ±5V; use "20.0" for ±10
double offsetVolts = spanVolts / 2; //use "0.0" for unipolar
double targetVolts = 1.3; // change to any desired output voltage
counts = (targetVolts + offsetVolts) / spanVolts * 65536.0;
```

Next the data are written to the selected analog output channel. (See the preceding I/O Address Map.)

```
    RelOutPort(DeviceIndex, DAC * 2, counts);
```

For simplicity, it was assumed that the simultaneous-update capability was not used.

Examples of this routine are installed with the software package along with examples in other languages.

See Chapter 7: Calibration for the equivalent command for outputting calibrated data.

Chapter 7: Calibration

Periodic calibration of these cards is recommended if they are used in extreme environmental conditions. The card uses very stable components but high-low temperature cycles might result in slight analog output errors.

The following equation is used with 16-bit cards:

```
Calibrated = ((4096 – LowAdjust - HighAdjust) / 4096) * Counts + 16 * LowAdjust
```

The 12-bit card is calibrated by software using the following formula:

```
Calibrated = ((4096 – LowAdjust - HighAdjust) / 4096) * Counts + LowAdjust
```

To calibrate the card, run the calibration program and follow the screen prompts. No attempt at calibration should be made in noisy locations or with a noisy calibration setup.

The calibration program stores various data to the card to facilitate calibrating the data output in a run-time environment. The calibration constants calculated during calibration are stored in an EEPROM located at BAR[3], which can be determined using the QueryBARBase(iCard, 3, pCalBase) function. The EEPROM contains two values per channel per range. The LowAdjust and HighAdjust calibration constants are stored for each channel at each range code (0-6). These constants can be used during normal operation to calibrate the output data in real-time. Refer to the installed samples for an example of using this data.

EEPROM Offset (hex)	**Range**	**DAC**	**Calibration Constant**
+00	0-5V	DAC 0	LowAdjust
+01	0-5V	DAC 0	HighAdjust
+02..3	0-5V	DAC 1	LowAdjust, HighAdjust
+4..0B	0-5V	DAC 2..5	LowAdjust, HighAdjust
+20..2B	0-2.5V	DAC 0..5	LowAdjust, HighAdjust
+40..4B	0-10V	DAC 0..5	LowAdjust, HighAdjust
+60..6B	±5V	DAC 0..5	LowAdjust, HighAdjust
+80..8B	±2.5V	DAC 0..5	LowAdjust, HighAdjust
+A0..AB	±10V	DAC 0..5	LowAdjust, HighAdjust
+C0..CB	4-20mA	DAC 0..5	LowAdjust, HighAdjust

Table 7-1: Calibration constant locations in EEPROM at BAR[3] “CalBase”

The LowAdjust and HighAdjust constants can be read from the EEPROM using the following code:

```
LowAdjust  = inportb((CalBase + (DAC * 2) + (RangeCode * 32)));
HighAdjust = inportb((CalBase + (DAC * 2) + (RangeCode * 32)) + 1);
```

The current Range Code configured at the per-channel range switches can be read from the BAR[3] “CalBase” registers, starting at +F0.

The value stored is a number from 0 to 6, representing the 7 ranges (as shown in the table below). These are read from the range selection switches in real time.

Byte Address	Channel
Base + F0h	Channel 0
Base + F1h	Channel 1
Base + F2h	Channel 2
Base + F3h	Channel 3
Base + F4h	Channel 4
Base + F5h	Channel 5

Value	Range
0	0 - 5V
1	0 - 2.5V
2	0 - 10V
3	-5 - +5V
4	-2.5 - +2.5V
5	-10 - +10V
6	4 to 20mA

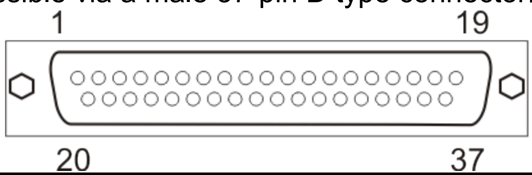
Table 7-2: Range Data Per Channel Locations

The currently configured Range Code for each DAC can be read using the following code:

```
RangeCode = inportb(CalBase + 0xF0 + DAC);
```

Chapter 8: Connector Pin Assignments

All signals are accessible via a male 37-pin D type connector.



Pin	Function	Pin	Function
1	Analog DAC 5 Output	20	Analog Ground
2	Analog DAC 4 Output	21	Analog Ground
3	Digital I/O Port B - Bit 7	22	Ground
4	Digital I/O Port B - Bit 6	23	Ground
5	Digital I/O Port B - Bit 5	24	Ground
6	Digital I/O Port B - Bit 4	25	External Interrupt / DAC Update
7	Digital I/O Port B - Bit 3	26	+VCCIO, fused
8	Digital I/O Port B - Bit 2	27	+12V, fused
9	Digital I/O Port B - Bit 1	28	No connection
10	Digital I/O Port B - Bit 0	29	No connection
11	Ground	30	Digital I/O Port A - Bit 7
12	Analog DAC 3 Output	31	Digital I/O Port A - Bit 6
13	Analog Ground	32	Digital I/O Port A - Bit 5
14	Analog DAC 2 Output	33	Digital I/O Port A - Bit 4
15	Analog Ground	34	Digital I/O Port A - Bit 3
16	Analog DAC 1 Output	35	Digital I/O Port A - Bit 2
17	Analog Ground	36	Digital I/O Port A - Bit 1
18	Analog DAC 0 Output	37	Digital I/O Port A - Bit 0
19	Analog Ground		

Table 8-1: P2 DAC Pin Assignments DB37M

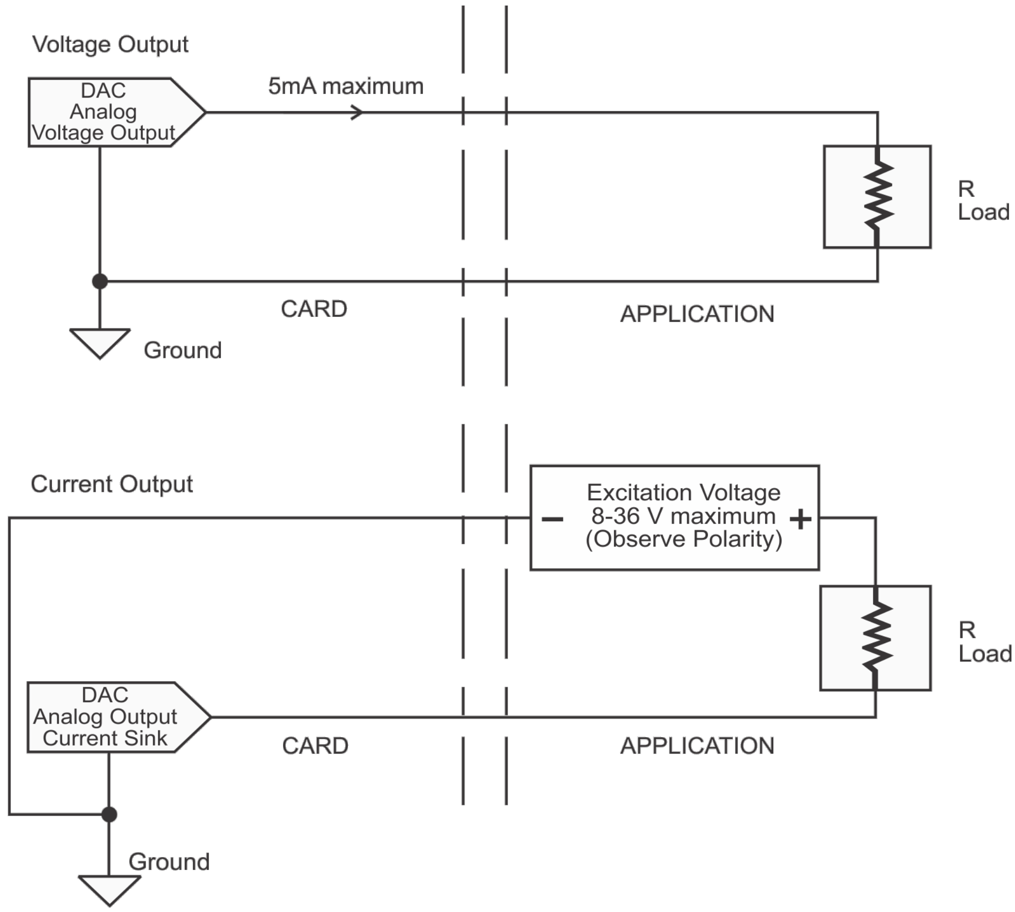


Figure 8-1: Field Wiring Diagrams

Caution!
Do not connect current loops in a DAC that is set to voltage mode. The loop supply can destroy the DAC.

Chapter 9 Specifications

Analog Outputs

- Channels: 6, 4 or 2
- Resolution: 16 bits, 12 bits
- Unipolar Ranges: 0-2.5V, 0-5V, 0-10V
- Bipolar Ranges: ±2.5V, ±5.0V, ±10.0V
- Current Range: 4 to 20 mA (external excitation of 8-36VDC)
- Output Drive: 5 mA maximum
- Output Resistance: Less than 0.1 ohm
- Relative Accuracy: ± 1 LSB max, ± ½ LSB typical
- Diff. Linearity: ± ½ LSB integral non-linearity
- Monotonicity: 16 bits over operating temp
- Settle time: 5 µsec ¼ to ¾ and ¾ to ¼ scale, to ±2 LSB

Digital I/O

- Lines 16: Ports A and B
- Logic Level: VCCIO jumper selectable
- Pull-up/down 10k ohm (pulled up by default)

Logic Levels	VCCIO = 5V	
Low Inputs	≤ 1.5V	≤ 2uA
High Inputs	≥ 3.5V	≤ 2uA
Low Outputs	≤ 0.55V	32mA
High Outputs	≥ 3.8V	32mA
Logic Levels	**VCCIO = 3.3V**	
Low Inputs	≤ 0.8V	≤ 2uA
High Inputs	≥ 2.0V	≤ 2uA
Low Outputs	≤ 0.55V	24mA
High Outputs	≥ 2.4V	24mA

Environmental

- Operating Temp: 0 to +70°C
- Storage Temp: -55 to +150°C
- Humidity: 5% to 95% w/o condensation
- Length: 6.6" (168 mm) long

Customer Comments

If you experience any problems with this manual or just want to give us some feedback, please email us at: ***manuals@accesio.com.*** Please detail any errors you find and include your mailing address so that we can send you any manual updates.

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