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MODEL PCI-DA12-8/16

USER MANUAL

FILE: MPCI-DA12-16.D1q

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Chapter 1: Introduction

Features

- 8 or 16 Channels of Analog Output, 12 Bits Resolution.
- 24 Digital I/O Lines Buffered on the Card.
- Digital I/O Buffers Can Be Tri-stated under Program Control.
- Four and Eight Bit Ports Independently Selectable for Input or Output.
- Pull-Ups on Digital I/O Lines.
- Resettable fused +5V Supply Available to the User.
- Three 16-bit 1MHz down-counters, can generate interrupts to clock DACs.

Description

These are full-size cards that can be installed in any PCI slot of PC-AT class computers. They contain either eight or sixteen double-buffered digital-to-analog converters (DACs) that provide independent analog output channels of 12-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 AD7237 double-buffered, dual, DAC chips are used. Data are transferred into outer registers a byte at a time and then transferred into inner registers a word at a time. The analog outputs can be updated either independently, simultaneously by command, or simultaneously by timer.

The DAC outputs are undefined at power-up. Therefore, in order to prevent excessive voltage output to external circuits, the card contains automatic circuits that set D/A outputs to less than 15 percent of span at system power-on. Upon power-up, the card is not 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. Similarly, a software command can be used at any time to set the reference voltage to 15 percent causing all DAC outputs to be equal to 15 percent of each DAC's programmed value.

These cards contain a type 8255-5 Programmable Peripheral Interface (PPI) chip providing 24 bits of parallel digital input/output. They can be programmed as inputs or outputs on three 8-bit ports designated Ports A, B, and C. Port C can be further divided into two 4-bit nibbles.

Each I/O line is buffered by a type 74ABT245B tristate buffer transceiver capable of sourcing 32 mA or sinking 64mA. Pull-ups on the card assure that there are no erroneous outputs at power up. The buffers are configured automatically by hardware logic for input or output according to direction assignment from a control register in the PPI.

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These cards contain a type 82C54 counter/timer which has three 16-bit programmable down counters. Counter/Timer #0 and Counter/Timer #1 are configured for event counting. Counter/Timers #1 and #2 are concatenated and form a 32-bit counter/timer for frequency generation. The dual counter/timer is clocked by a 1 MHZ crystal oscillator and may be gated on/off by a CMOS level signal at the connector. The counters can also be programmed to provide a “clock-tick” interrupt and update of the DAC buffers for more precisely timed outputs.

Specifications

Analog Outputs

- Resolution: 12 bits (0 to 4095 decimal)
- Channels: 16 or 8 Voltage output or Current sink channels
- Current Range: 4 to 20 mA.(with excitation voltage 8-36 VDC)
- Voltage ranges (5mA max): 0V to +2.5V
  0V to +5V
  0V to +10V
  -2.5V to +2.5V
  -5V to +5V
  -10V to +10V

AD7237 D/A Converter, Double Buffered / Simultaneous Update

- Relative Accuracy: + ½ LSB
- Monotonicity: 12 bits over operating temperature range
- Settling Time: 8 usec to one LSB for full-scale step input
- Linearity: + ½ LSB integral non-linearity over rated temperature range
- Gain Stability: 15 ppm/ °C
- Output Drive Capability: 5mA maximum
- Short-Circuit Current: 25 mA maximum
- Output Resistance: Less than 0.1 Ω
- Data Format: 12-bit binary, right justified, and offset binary for bipolar outputs

Digital I/O

Output (0 to 24 Channels)

- Logic High: 2.5 VDC min., source 32 mA
- Logic Low: 0.5 VDC max., sink 64 mA

Input (0 to 24 Channels)

- Logic High: 2.0 to 5.0 VDC, Input Load: +20 µA
- Logic Low: -0.5 to +0.8 VDC, Input Load: -20 µA

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Counter/Timer

- Type: 82C54 programmable interval counters
- Output Drive: 2.2 ma at 0.45 VDC (5 LSTTL loads)
- Input Gate: TTL/CMOS compatible
- Clock: On-board, 1 MHz crystal-controlled oscillator
- Active Count Edge: Negative edge
- Timer Range: 32 bits
- Event Counter Range: 16 bits
- Minimum Clock Pulse Width: 30 ns high, 50 ns low

Environmental

- Operating Temperature Range: 0 °C. to +60 °C
- Storage Temperature Range: -20 °C. to +85 °C
- Humidity: 5% to 95% non-condensing
- External DAC Reference (input): +4.5V to +5.5V
- 5V Source (output): 0 to 500 mA, fused (resetting)
- Size: 12.2" long (310 mm)
- Power Required: +12 VDC at 310 mA maximum (16 channels)
  -12 VDC at 150 mA maximum
  +5 VDC at 662 mA typical with all digital outputs at high impedance

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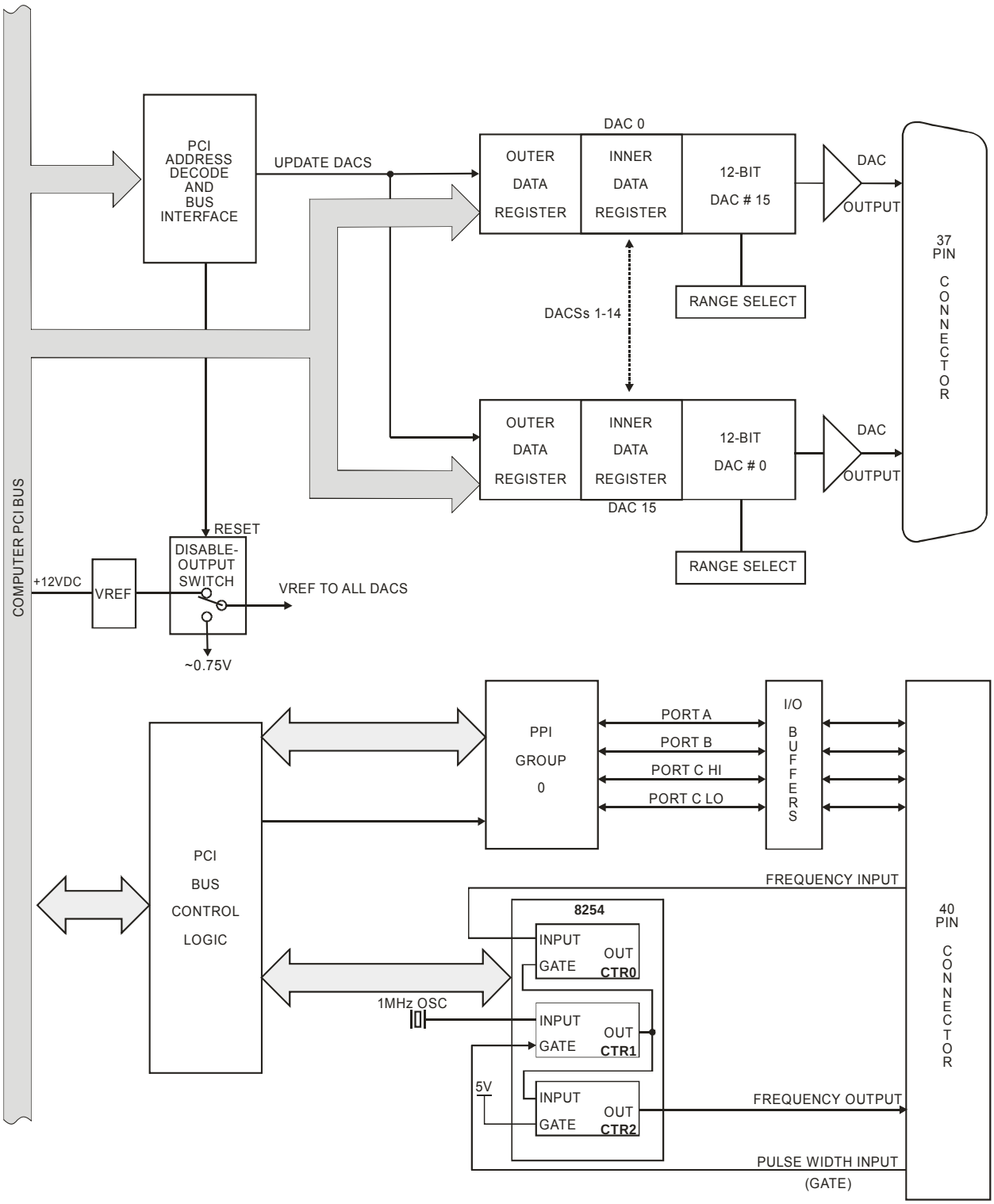


Figure 1-1: Block Diagram

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Chapter 2: Installation

A printed Quick-Start Guide (QSG) is packed with the card for your convenience. If you've already performed the steps from the QSG, you may find this chapter to be redundant and may skip forward to begin developing your application.

The software provided with this card is on CD and must be installed onto your hard disk prior to use. To do this, perform the following steps as appropriate for your operating system.

Configure Card Options via Jumper Selection
Before installing the card into your computer, carefully read Chapter 3: Option Selection of this manual, then configure the card according to your requirements. Our Windows based setup program can be used in conjunction with Chapter 3 to assist in configuring jumpers on the card, as well as provide additional descriptions for usage of the various card options.

CD Software Installation

The following instructions assume the CD-ROM drive is drive "D". Please substitute the appropriate drive letter for your system as necessary.

DOS
1. Place the CD into your CD-ROM drive.
2. Type D : Enter to change the active drive to the CD-ROM drive.
3. Type I N S T A L L Enter to run the install program.
4. Follow the on-screen prompts to install the software for this board.

WINDOWS
1. Place the CD into your CD-ROM drive.
2. The system should automatically run the install program. If the install program does not run promptly, click START | RUN and type D : I N S T A L L, click OK or press Enter.
3. Follow the on-screen prompts to install the software for this board.

LINUX
1. Please refer to linux.htm on the CD-ROM 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.

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Hardware Installation

1. Make sure to set switches and jumpers from either the Option Selection section of this manual or from the suggestions of SETUP.EXE.
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 an available 5V or 3.3V PCI expansion slot (you may need to remove a backplate first).
6. Inspect for proper fit of the card and tighten screws. 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 onto the card's bracket mounted 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 PCIfind.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 (from the CD) to test and validate your installation.

The base address assigned by BIOS or the operating system can change each time new hardware is installed into or removed from the computer. Please recheck PCIFind or Device Manager if the hardware configuration is changed. Software you write can automatically determine the base address of the card using a variety of methods depending on the operating system. In DOS, the PCI\SOURCE directory shows the BIOS calls used to determine the address and IRQ assigned to installed PCI devices. In Windows, the Windows sample programs demonstrate querying the registry entries (created by PCIFind and NTIOPCI.SYS during boot-up) to determine this same information.

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Chapter 3: Option Selection

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

Output Ranges

There is a three-position slide switch associated with each DAC channel to make voltage range selection: switches S1 (Channel 0) through S16 (Channel 15). A silk-screen diagram on the card defines switch positions to use for each range. In addition to the switch, one jumper per channel is used to select Voltage vs Current Output. The following table presents the same information:

Voltage Range	**S1**	**S2**	**S3**	**JP1-16**
0 to +2.5V	OFF	OFF	On	Set in Position V
0 to +5V	OFF	OFF	OFF	
0 to +10V	OFF	ON	OFF	
-2.5V to +2.5V	ON	OFF	ON	
-5V to +5V	ON	OFF	OFF	
-10V to +10V	ON	ON	OFF	
Current Range	S1	S2	S3	JP1-16
4 mA to 20 mA	OFF	OFF	OFF	Position I

Analog Output Update

Analog outputs are updated under program control in any of three ways:

a. Automatic Update: Each channel is updated individually when new data are written to the related high-byte base address. Individual update mode may be set by a special read operation as defined in the programming section of this manual.

b. Simultaneous Update: The outputs of all D/As may be updated simultaneously. This is done 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.

c. Timer Update: The counter/timer can initiate updates. First, disable interrupts and updates (read base+4 and read base+6) and enable Simultaneous Updates (read base+0). Then write the initial values into the DACs. Program the counter/timer for the tick frequency (mode 2 or mode 4), initialize your ISR, enable updates (read base+5), and enable interrupts (read base+3). This counter-generated update pulse is available at the 40-pin header connector (OUT2) to synchronize external devices.

Refer to Chapter 5, Programming of this manual for more detail on this process.

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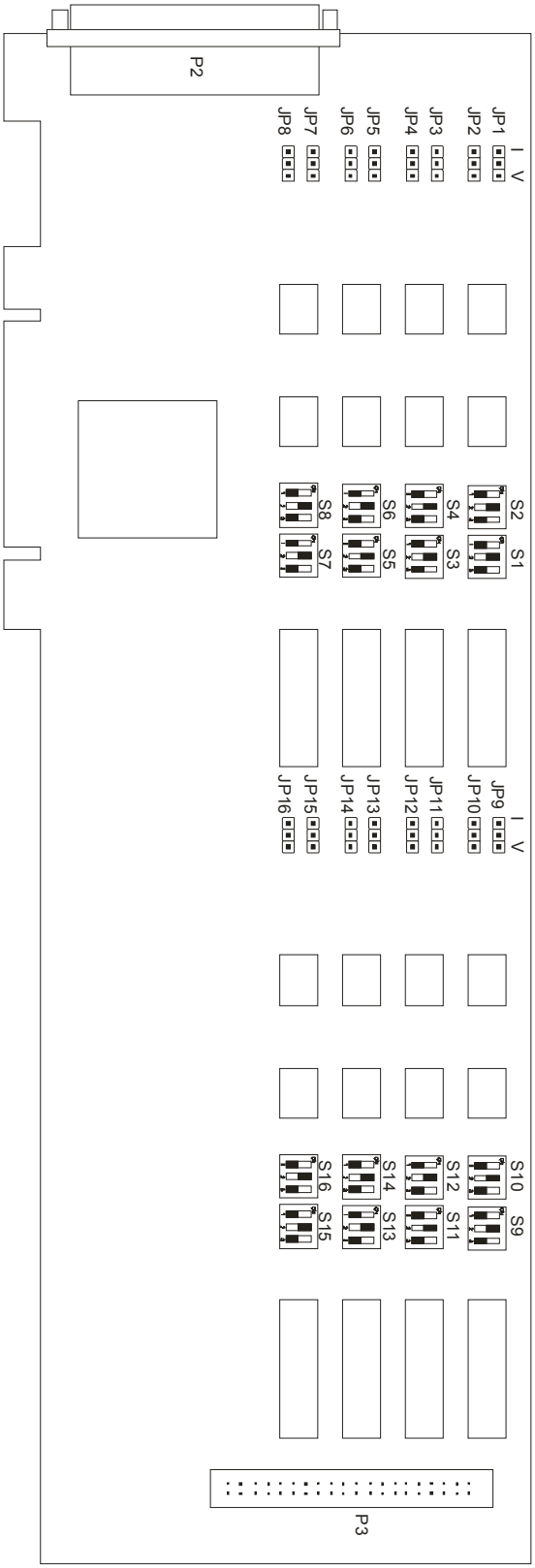


Figure 3-1: Option Selection Map

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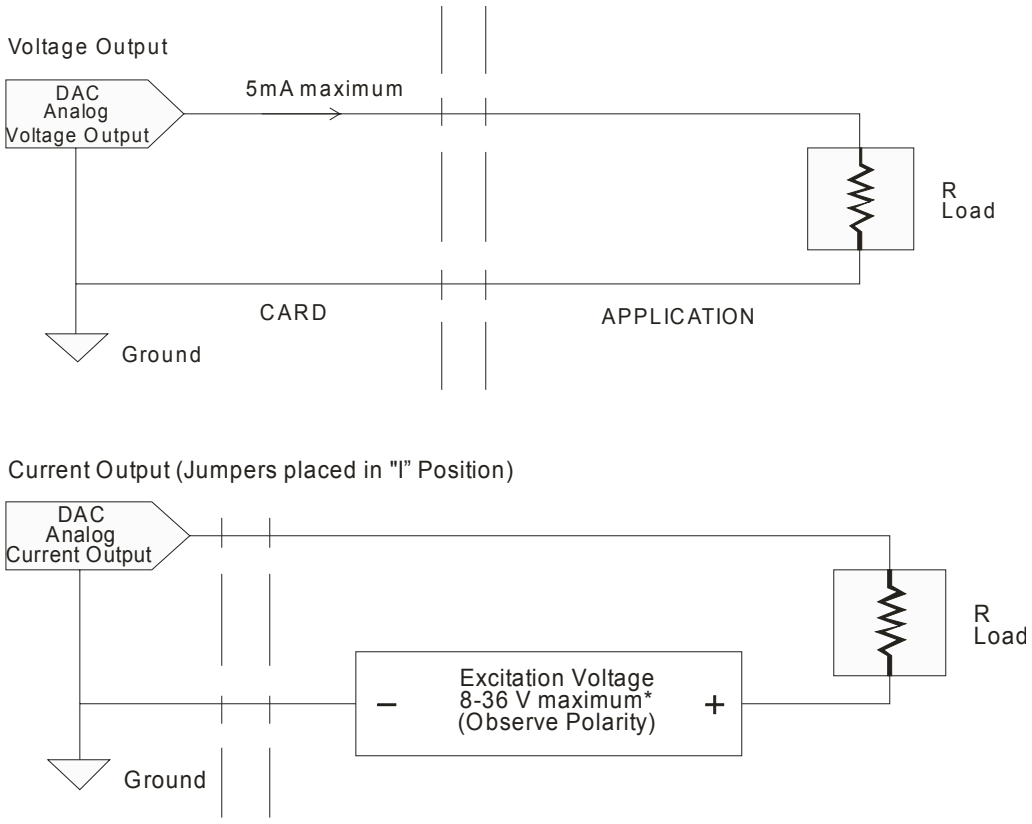


Figure 3-2: Field Wiring Diagram

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

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Chapter 4: Address Selection

These cards use two I/O address spaces, one of 64 bytes and one of 256 bytes. The DACs occupy the first 32 bytes of the first area. The digital I/O circuit uses the next 4 register locations. The timer/counter chip uses 4 locations after that. The other 24 addresses are reserved. The 2nd I/O address space of 256 bytes is used for software calibration data. These two I/O address spaces are defined in the Port Address Selection Table in the Programming section of this manual.

PCI architecture is Plug-and-Play. This means that the BIOS or Operating System determines the resources assigned to PCI 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 PCIFind.EXE utility program provided. This utility will display a list of all of the cards detected on the PCI 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 PCIFind 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.

PCIFind uses the Vendor ID and Device ID to search for your card, then reads the base address and IRQ.

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".) V stands for Voltage Only.

The Device ID for the 8 channel card is 6CA8h.
The Device ID for the 16 channel card is 6CB0h.
The Device ID for the 8 channel V card is 6CA9h.
The Device ID for the 16 channel V card is 6CB1h.

The control / DAC / I/O / Counter/Timer base address is BaseAddresses[2] in the PCI_COMMON_CONFIG structure, while the calibration base address is BaseAddresses[3].

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Chapter 5: Programming

The cards' DACs, Timers, and Digital I/O use 40 consecutive I/O addresses. Programming these cards is very straightforward as there are only three operating modes, three range-selection switches per channel, and one unique addition. The basic operation of a Digital-to-Analog card is to write a 12-bit value to a Digital to Analog Converter (DAC) pre-load (outer) register where it is buffered and loaded by an update command to a DAC (inner) 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. In C:

```
outport(BASE+(CH*2), (Volts*4096/10)-2048);
```

would output "Volts" volts to channel "ch", assuming a bipolar 5V range. For other bipolar ranges, substitute the appropriate voltage span in place of "10" in the equation. For unipolar ranges, also remove the "-2048".

Upon power-up, or hardware reset, the DAC registers are restricted to a safe value and the card is set in Simultaneous Update mode. Since the pre-load register is not cleared upon power-up, but left at an undefined value, a known value must be written to the preload registers before using a "Clear Restrict-Output-Voltage" command.

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.

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. 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.

Timer Update Mode is similar to Simultaneous Update Mode, except that updates are issued by the counter/timer (programmed in mode 2 or mode 4 per Chapter 6, Programming 8254). A read from Base Address+5 will change the card from Simultaneous Update Mode to Timer Update Mode, and a read from Base Address+6 will change it back. The counter-generated update pulse is also available at the 40-pin header connector(OUT2) to synchronize external devices, and can generate interrupts for synchronized loading if enabled by a read from Base Address+3. (Interrupts are disabled by a read from Base Address+4.)

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Restrict-Output-Voltage limits the output of all DAC channels. This is done by reading Base Address +E. The previous outputs will be restored when a "Clear Restrict-Output-Voltage" command is issued by a read of Base Address+F.

Address	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 + C	DAC 6 Low Byte	Clear IRQ
Base + D	DAC 6 High Byte	
Base + E	DAC 7 Low Byte	Restrict-Output-Voltage (Limits outputs to 15% of full scale range).
Base + F	DAC 7 High Byte	Clear Restrict-Output-Voltage (Allows full operating output voltage).
Base + 10	DAC 8 Low Byte	
Base + 11	DAC 8 High Byte	
Base + 12	DAC 9 Low Byte	
Base + 13	DAC 9 High Byte	
Base + 14	DAC 10 Low Byte	
Base + 15	DAC 10 High Byte	
Base + 16	DAC 11 Low Byte	
Base + 17	DAC 11 High Byte	
Base + 18	DAC 12 Low Byte	
Base + 19	DAC 12 High Byte	
Base + 1A	DAC 13 Low Byte	
Base + 1B	DAC 13 High Byte	
Base + 1C	DAC 14 Low Byte	
Base + 1D	DAC 14 High Byte	
Base + 1E	DAC 15 Low Byte	
Base + 1F	DAC 15 High Byte	

* Although it is possible to write the low and high bytes separately as shown above, it is much easier to write both bytes with a single OUT DX, AX instruction. In that case, only even addresses are written.

Table 5-1: Register Map

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Address	Write	Read
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 + 22	Digital I/O Port C, Output	Digital I/O Port C, Input
Base + 23	Digital I/O Control Byte	
Base + 24	Counter/Timer 0	Counter/Timer 0
Base + 25	Counter/Timer 1	Counter/Timer 1
Base + 26	Counter/Timer 2	Counter/Timer 2
Base + 27	Counter/Timer Control Register	Counter/Timer Control Register

Table 5-2: I/O Address Map for the Digital I/O and Counter/Timers

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

Table 5-3: DAC Data Format

For Unipolar ranges: For Unipolar ranges, data are in true binary form.

```
XXXX  0000  0000  0000   =  Zero
XXXX  1000  0000  0000   =  ½ Scale
XXXX  1111  1111  1111   =  Full Scale
          |                   |
MSB or B11   ←                 →   B0 or LSB
```

For Bipolar ranges: For Bipolar ranges, data are in offset binary form.

```
XXXX  0000  0000  0000   =  -Full Scale
XXXX  1000  0000  0000   =  Zero
XXXX  1111  1111  1111   =  +Full Scale
          |                   |
MSB or B11   ←                 →   B0 or LSB
```


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Programming the Digital I/O Circuit

The digital I/O circuit is comprised of an Intel 8255, a direction control latch, and four bi-directional buffers with 10K pull-ups. Please refer to the 8255-5 specification in Appendix A for a detailed description of the PPI.

Address	Assignment	Operation
Base Address +20	Port A	Read/Write
Base Address +21	Port B	Read/Write
Base Address +22	Port C	Read/Write
Base Address +23	Control	Read/Write

Table 5-4: I/O Address Table for Digital

The circuit is designed to use the PPI in mode 0 wherein:

a. There are two 8-bit ports (A and B) and two 4-bit ports (C Hi and C Lo).
b. Any port can be configured as an input or an output.
c. Outputs are latched.
d. Inputs are not latched.

The 8-bit control register is used to set the mode and direction of the ports.

Bit	Assignment	Function
D0	Port C Lo (C0-C3)	1 = Input, 0 = Output
D1	Port B	1 = Input, 0 = Output
D2	Mode Selection	1 = Mode 1, 0 = Mode 0
D3	Port C Hi (C4-C7)	1 = Input, 0 = Output
D4	Port A	1 = Input, 0 = Output
D5,D6	Mode Selection	01 = Mode 1, 00 = Mode 0 1X = Mode 2
D7	Mode Set Flag&Tristate	1 = Active & Tristate

Table 5-5: Control Register Bit Assignments

Note
PPI Mode 1 cannot be used with this circuit without modification. Thus, bits D2, D5, and D6 should always be set to "0". If your card has been modified to operate in Mode 1, then there is an Addendum sheet in the front of this manual describing that modification. This circuit cannot be modified to operate in PPI Mode.

The circuit is initialized by the computer Reset command (all ports set for input and all buffers enabled). Both the 8255 control register and the buffer direction latch are accessed at the same address.

The 8255 control register will latch a new configuration byte when it's written to with bit D7 high. If, for example, hex 80 is sent to Base Address+23, the group 0 PPI will be configured in mode 0 with ports A, B, and C as outputs.

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At the same time, data bit D7 is also latched in the buffer controller. A high state puts the buffers in the tristate mode; i.e., disabled. Now, if any of the ports are to be set as outputs, you may set the values of the respective port with the outputs still in tristate condition. Lastly, to enable the ports a control byte with bit D7 low must be sent to Base Address+23.

Note
All data bits except D7 must be the same for the two control bytes. Those buffers will now remain enabled until another control byte with data bit D7 high is sent to Base Address+23.

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Chapter 6: 8254 Counter/Timer

These cards contain a type 8254 programmable counter/timer that allows you to implement such functions as a Real Time Clock, Event Counter, Digital One-Shot, Programmable Rate Generator, Binary Rate Multiplier, Complex Wave Generator and/or a Motor Controller. The 8254 consists of three, 16-bit, presettable, down counters. Each counter can be programmed to any count between 1 or 2 and 65,535 in binary format depending on the mode chosen.

Operational Modes

The 8254 modes of operation are described in the following paragraphs to familiarize you with the versatility and power of this device. For those interested in more detailed information, a full description of the 8254 programmable interval timer can be found in the Intel (or equivalent manufacturers') data sheets. The following conventions apply for use in describing operation of the 8254 :

Clock:	A positive pulse into the counter's clock input
Trigger:	A rising edge input to the counter's gate input
Counter Loading:	Programming a binary count into the counter

Mode 0: Pulse on Terminal Count
After the counter is loaded, the output is set low and will remain low until the counter decrements to zero. The output then goes high and remains high until a new count is loaded into the counter. A trigger enables the counter to start decrementing.

Mode 1: Retriggerable One-Shot
The output goes low on the clock pulse following a trigger to begin the one-shot pulse and goes high when the counter reaches zero. Additional triggers result in reloading the count and starting the cycle over. If a trigger occurs before the counter decrements to zero, a new count is loaded. This forms a retriggerable one-shot. In mode 1, a low output pulse is provided with a period equal to the counter count-down time.

Mode 2: Rate Generator
This mode provides a divide-by-N capability where N is the count loaded into the counter. When triggered, the counter output goes low for one clock period after N counts, reloads the initial count, and the cycle starts over. This mode is periodic, the same sequence is repeated indefinitely until the gate input is brought low. This mode also works well as an alternative to mode 0 for event counting.

Mode 3: Square Wave Generator
This mode operates like mode 2. The output is high for half of the count and low for the other half. If the count is even, then the output is a symmetrical square wave. If the count is odd, then the output is high for (N+1)/2 counts and low for (N-1)/2 counts. Periodic triggering or frequency synthesis are two possible applications for this mode. Note that in this mode, to achieve the square wave, the counter decrements by two for the total loaded count, then reloads and decrements by two for the second part of the wave form.

Mode 4: Software Triggered Strobe
This mode sets the output high and, when the count is loaded, the counter begins to count down. When the counter reaches zero, the output will go low for one input period. The counter must be reloaded to repeat the cycle. A low gate input will inhibit the counter.

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Mode 5: Hardware Triggered Strobe
In this mode, the counter will start counting after the rising edge of the trigger input and will go low for one clock period when the terminal count is reached. The counter is retriggerable. The output will not go low until the full count after the rising edge of the trigger.

Programming the 8254

On these cards, the 8254 counters occupy the following addresses (hex):

Base Address + 24: Read/Write Counter #0
Base Address + 25: Read/Write Counter #1
Base Address + 26: Read/Write Counter #2
Base Address + 27: Write to Counter Control register

The counters are programmed by writing a control byte into a counter control register at Base Address + 27. The control byte specifies the counter to be programmed, the counter mode, the type of read/write operation, and the modulus. The control byte format is as follows:

B7	B6	B5	B4	B3	B2	B1	B0
SC1	SC0	RW1	RW0	M2	M1	M0	BCD

SC0-SC1: These bits select the counter that the control byte is destined for.

SC1	SC0	Function
0	0	Program Counter #0
0	1	Program Counter #1
1	0	Program Counter #2
1	1	Read/Write Cmd.*

* See section on Reading and Loading the Counters.

RW0-RW1: These bits select the read/write mode of the selected counter.

RW1	RW0	Counter Read/Write Function
0	0	Counter Latch Command
0	1	Read/Write LS Byte
1	0	Read/Write MS Byte
1	1	Read/Write LS Byte, then MS Byte

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M0-M2: These bits set the operational mode of the selected counter.

Mode	M2	M1	M0
0	0	0	0
1	0	0	1
2	X	1	0
3	X	1	1
4	1	0	0
5	1	0	1

BCD: Set the selected counter to count in binary (BCD = 0) or BCD (BCD = 1).

Reading and Loading the Counters

If you attempt to read the counters on the fly when there is a high input frequency, you will most likely get erroneous data. This is partly caused by carries rippling through the counter during the read operation. Also, the low and high bytes are read sequentially rather than simultaneously and, thus, it is possible that carries will be propagated from the low to the high byte during the read cycle.

To circumvent these problems, you can perform a counter-latch operation in advance of the read cycle. To do this, load the RW1 and RW2 bits with zeroes. This instantly latches the count of the selected counter (selected via the SC1 and SC0 bits) in a 16-bit hold register. (An alternative method of latching counter(s) that has an additional advantage of operating simultaneously on several counters is through a readback command to be discussed later.) A subsequent read operation on the selected counter returns the held value. Latching is the best way to read a counter on the fly without disturbing the counting process. You can only rely on directly read counter data if the counting process is suspended by bringing the gate low.

For each counter you must specify in advance the type of read or write operation that you intend to perform. You have a choice of loading/reading (a) the high byte of the count, or (b) the low byte of the count, or (c) the low byte followed by the high byte. This last is most generally used and is selected for each counter by setting the RW1 and RW0 bits to ones. Subsequent read/load operations must be performed in pairs in this sequence or the sequencing flip-flop in the 8254 chip will get out of step.

The readback command byte format is:

B7	B6	B5	B4	B3	B2	B1	B0
1	1	CNT	STA	C2	C1	C0	0

CNT: When 0, latches the counters selected by bits C0-C2.
STA: When 0, returns the status byte of counters selected by C0-C2.
C0, C1, C2: When high, select a particular counter for readback. C0 selects Counter 0, C1 selects Counter 1, and C2 selects Counter 2.

You can perform two types of operations with the readback command. When CNT=0, the counters selected by C2 through C0 are latched simultaneously. When STA=0, the counter status byte is read when the counter I/O location is accessed. The counter status byte provides information about the current output state of the selected counter and its configuration. The status byte returned if STA=0 is:

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B7	B6	B5	B4	B3	B2	B1	B0
OUT	NC	RW1	RW2	M2	M1	M0	BCD

OUT: Current state of counter output pin.
NC: Null count. This indicates when the last count loaded into the counter register has been loaded into the actual counter. The exact time of load depends on the configuration selected. Until the count is loaded into the counter, it cannot be read.
RW1, RW0: Read/Write command.
M2, M1, M0: Counter mode.
BCD: BCD = 0 is binary mode, otherwise counter is in BCD mode.

If both STA and CNT bits in the readback command byte are set low and the RW1 and RW0 bits have both been previously set high in the counter control register (thus selecting two-byte reads), then reading a selected counter address location will yield:

1st Read: Status byte
2nd Read: Low byte of latched data
3rd Read: High byte of latched data

After any latching operation on a counter, the contents of its hold register must be read before any subsequent latches of that counter will have any effect. If a status latch command is issued before the hold register is read, then the first read will read the status, not the latched value.

8254 Driver

A simple driver is provided to perform basic counter/timer operations on the cards. Source code for the driver and a sample program showing how to use the functions is in the DOS\CSAMPLES directory. The following functions are provided:

Frequency Measure

The Frequency Measure function of the 8254 Counter Driver has the ability to measure an unknown frequency from 1KHz to 2MHz. This function requires as input the Base Address of the card. The unknown frequency is applied to the CLOCK IN pin of the card. The function will return the frequency as a long integer in Hz.

```
long frequency_measure(unsigned BaseAddress);
```


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Event Counter
The Event Counter function has the ability to trace the number of events that have occurred. This function accepts as input the Base Address of the card, as well as an additional parameter. The additional parameter identifies which features should be implemented on this call to the function. Each feature can be identified by its unique integer value. Multiple features can be run in a single call to the function by OR ing the respective integer values together. Features will be executed in increasing integer order. The CLOCK IN pin of the card is the point of application for the incoming events. (Note: This function is limited by the input speed of the 8254 counter, and slow signals are preferred. Further only 65,535 events are possible without a RESET.) The function returns the number of events (based on priority) or 0 for those features that do not specify a return value.

Features:	Initialize	= 1;	initialize the counter.
	Start	= 2;	begin counting.
	Sincestart	= 4;	return the number of events since the start.
	Sincelast	= 8;	return the number of events since last check.
	Stop	= 16;	stop counting events.
	Reset	= 32;	reset number of events to 0.

```
unsigned event_counter(unsigned BaseAddress, int feature);
```

Generate Frequency
The Generate Frequency function will generate a square wave (0 to +5V) with the desired frequency. The Base Address of the card as well as the frequency are required as input to the function. The counter can generate a frequency with a range of 1Hz to 250KHz. The square wave can be read on the CLOCK OUT pin of the card.

```
void generatefrequency(unsigned BaseAddress, unsigned long frequency);
```

Pulse Width
The Pulse Width function will measure the width of an applied event from its rise to its fall (effectively one half the period). The Base Address of the card is required as input to the function. The signal should be applied to the CLOCK IN pin of the card. Software latency will be affected by the operating system and will set a limit on the precision of the measurement.

```
unsigned pulse_width(unsigned BaseAddress);
```


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Chapter 7: 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: C++Builder, Delphi, VisualBASIC, and Visual C++.

To output an analog value with 12-bit resolution, a corresponding decimal number N between 0 and 4095 is calculated (2^{12} = 4096).

N/4096 = V(out)/V(full scale)

Next the data are written to the selected analog output channel. (See the preceding I/O Address Map.) In this example, we will assume analog output on channel zero (AO 0).

outport (BASE + 0, N)

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

Examples of this routine are found on the sample disk along with examples in other languages.

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Chapter 8: 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.

This card is calibrated by software using the following formula:

$$Y= (4096 -a - b)/4096) * X + b$$

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 data collected during calibration is stored in an EEPROM located at the second of the I/O base addresses assigned to the device (BaseAddresses[3] in the PCI_COMMON_CONFIG structure). The EEPROM contains two values per channel per range. The ZERO (or OFFSET) and the SPAN calibration constants are stored (a and b from the equation above) for each channel at each possible range (0-6). These constants are used during normal operation to calibrate the output data in real-time. Refer to the samples provided on disk for an example of using this data.

In addition to 'a' and 'b' as shown above, the EEPROM contains a table of ranges assigned to each channel. Starting at Base+F0, 16 base addresses contain one byte each, from 0-6, indicating the voltage output range assigned to that channel. It is important to use the calibration program at least once if the default range (+/- 10V) is changed on any channel, to allow this table of data to be reconfigured. If this data is incorrect, calibration is not guaranteed.

Word Address	Range	Offset ('b' in formula)	Span ('a' in formula)
Base + 00h to Base + 1Eh	0 to +5 V.	DAC 0 to DAC 15	DAC 0 to DAC 15
Base + 20h to Base + 3Eh	0 to +2.5 V.	DAC 0 to DAC 15	DAC 0 to DAC 15
Base + 40h to Base + 5Eh	0 to +10 V.	DAC 0 to DAC 15	DAC 0 to DAC 15
Base + 60h to Base + 7Eh	-5 V to +5 V.	DAC 0 to DAC 15	DAC 0 to DAC 15
Base + 80h to Base + 9Eh	-2.5 V to 2.5 V.	DAC 0 to DAC 15	DAC 0 to DAC 15
Base + A0h to Base + BEh	-10 V to 10 V.	DAC 0 to DAC 15	DAC 0 to DAC 15
Base + C0h to Base + DEh	4 to 20 mA.	DAC 0 to DAC 15	DAC 0 to DAC 15

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The next table shows the location of the range data for each channel. The value stored is a number from 0 to 6, representing the 7 ranges (as shown in the table below). If you set any channel's range switch, be sure to place the correct value in this table. Using the calibration program provided is generally the easiest method of ensuring the table remains accurate.

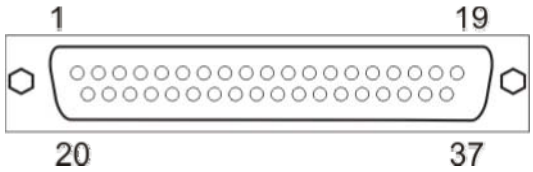
Word Address	Channel
Base + F0h	Channel 0
Base + F1h	Channel 1
Base + F2h	Channel 2
Base + F3h	Channel 3
Base + F4h	Channel 4
Base + F5h	Channel 5
Base + F6h	Channel 6
Base + F7h	Channel 7
Base + F8h	Channel 8
Base + F9h	Channel 9
Base + FAh	Channel 10
Base + FBh	Channel 11
Base + FCh	Channel 12
Base + FDh	Channel 13
Base + FEh	Channel 14
Base + FFh	Channel 15

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

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Chapter 9: Connector Pin Assignments

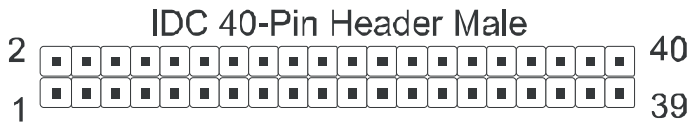
The analog outputs are accessible via a male 37-pin D type connector.



Pin	Name	Function	Pin	Name	Function
1	D/A 0 Out	Analog DAC 0 Output	18	Analog GND	Analog Ground
2	D/A 1 Out	Analog DAC 1 Output	19	Return GND	Return Analog Ground
3	D/A 2 Out	Analog DAC 2 Output	20	Return GND	Return Analog Ground
4	D/A 3 Out	Analog DAC 3 Output	21	Return GND	Return Analog Ground
5	D/A 4 Out	Analog DAC 4 Output	22	Return GND	Return Analog Ground
6	D/A 5 Out	Analog DAC 5 Output	23	Return GND	Return Analog Ground
7	D/A 6 Out	Analog DAC 6 Output	24	Return GND	Return Analog Ground
8	D/A 7 Out	Analog DAC 7 Output	26	Return GND	Return Analog Ground
9	D/A 8 Out	Analog DAC 8 Output	27	Return GND	Return Analog Ground
10	D/A 9 Out	Analog DAC 9 Output	28	Return GND	Return Analog Ground
11	D/A 10 Out	Analog DAC 10 Output	29	Return GND	Return Analog Ground
12	D/A 11 Out	Analog DAC 11 Output	30	Return GND	Return Analog Ground
13	D/A 12 Out	Analog DAC 12 Output	31	Return GND	Return Analog Ground
14	D/A 13 Out	Analog DAC 13 Output	32	Return GND	Return Analog Ground
15	D/A 14 Out	Analog DAC 14 Output	33	Return GND	Return Analog Ground
16	D/A 15 Out	Analog DAC 15 Output	34	Return GND	Return Analog Ground
17	XREF IN	External Ref In	35	Return GND	Return Analog Ground
			36	+5 Vout	Fused +5 VDC from PC
			37	Power GND	Power Ground

Table 9-1: DAC Pin Assignments, DB37M

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The digital I/O and counter outputs are accessible on the board via a 40-pin IDC header. A ribbon cable assembly with a 40-pin header and a DB37 female connector is shipped with the card.

Pin	Function	Pin	Function
1	Digital I/O Port A - Bit 0	21	Digital I/O Port C - Bit 0
2	Digital I/O Port A - Bit 1	22	Digital I/O Port C - Bit 1
3	Digital I/O Port A - Bit 2	23	Digital I/O Port C - Bit 2
4	Digital I/O Port A - Bit 3	24	Digital I/O Port C - Bit 3
5	Digital I/O Port A - Bit 4	25	Return Ground
6	Digital I/O Port A - Bit 5	26	Return Ground
7	Digital I/O Port A - Bit 6	27	Digital I/O Port C - Bit 4
8	Digital I/O Port A - Bit 7	28	Digital I/O Port C - Bit 5
9	Return Ground	29	Digital I/O Port C - Bit 6
10	Return Ground	30	Digital I/O Port C - Bit 7
11	Digital I/O Port B - Bit 0	31	Return Ground
12	Digital I/O Port B - Bit 1	32	Return Ground
13	Digital I/O Port B - Bit 2	33	Clock In
14	Digital I/O Port B - Bit 3	34	Gate
15	Digital I/O Port B - Bit 4	35	Clock Out
16	Digital I/O Port B - Bit 5	36	Return Ground
17	Digital I/O Port B - Bit 6	37	Return Ground
18	Digital I/O Port B - Bit 7	38	Return Ground
19	Return Ground	39	Return Ground
20	Return Ground	40	Return Ground

Table 9-2: Digital I/O & Counter/Timer Pin Assignments, 40-Pin Header

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Pin	Function	Pin	Function
1	Digital I/O Port A - Bit 0		
2	Digital I/O Port A - Bit 2	20	Digital I/O Port A - Bit 1
3	Digital I/O Port A - Bit 4	21	Digital I/O Port A - Bit 3
4	Digital I/O Port A - Bit 6	22	Digital I/O Port A - Bit 5
5	Return Ground	23	Digital I/O Port A - Bit 7
6	Digital I/O Port B - Bit 0	24	Return Ground
7	Digital I/O Port B - Bit 2	25	Digital I/O Port B - Bit 1
8	Digital I/O Port B - Bit 4	26	Digital I/O Port B - Bit 3
9	Digital I/O Port B - Bit 6	27	Digital I/O Port B - Bit 5
10	Return Ground	28	Digital I/O Port B - Bit 7
11	Digital I/O Port C - Bit 0	29	Return Ground
12	Digital I/O Port C - Bit 2	30	Digital I/O Port C - Bit 1
13	Return Ground	31	Digital I/O Port C - Bit 3
14	Digital I/O Port C - Bit 4	32	Return Ground
15	Digital I/O Port C - Bit 6	33	Digital I/O Port C - Bit 5
16	Return Ground	34	Digital I/O Port C - Bit 7
17	Clock In	35	Return Ground
18	Clock Out	36	Gate
19	Return Ground	37	Return Ground

Table 9-3: Digital I/O & Counter/Timer Pin Assignments, DB37F

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Customer Comments

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