



RUBY-MM-1616A Family

PC/104 / PC/104-Plus I/O Modules with 4, 8 or 16 16-Bit Analog Outputs

User Manual Rev A.4 March 2015



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| A.3 | 5/12/2014 | Initial release |
| A.4 | 3/2/15 | Removed register map details |

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1. IMPORTANT SAFE HANDLING INFORMATION



WARNING!

ESD-Sensitive Electronic Equipment

Observe ESD-safe handling procedures when working with this product.

Always use this product in a properly grounded work area and wear appropriate ESD-preventive clothing and/or accessories.

Always store this product in ESD-protective packaging when not in use.

Safe Handling Precautions

This board contains several I/O and bus connectors with many connections to sensitive electronic components. This creates many opportunities for accidental damage during handling, installation and connection to other equipment. The list here describes common causes of failure found on boards returned to Diamond Systems for repair. This information is provided as a source of advice to help you prevent damaging your Diamond (or any vendor's) embedded computer boards.

ESD damage – This type of damage is usually almost impossible to detect, because there is no visual sign of failure or damage. The symptom is that the board eventually simply stops working, because some component becomes defective. Usually the failure can be identified and the chip can be replaced. To prevent ESD damage, always follow proper ESD-prevention practices when handling computer boards.

Damage during handling or storage – On some boards we have noticed physical damage from mishandling. A common observation is that a screwdriver slipped while installing the board, causing a gouge in the PCB surface and cutting signal traces or damaging components.

Another common observation is damaged board corners, indicating the board was dropped. This may or may not cause damage to the circuitry, depending on what is near the corner. Most of our boards are designed with at least 25 mils clearance between the board edge and any component pad, and ground / power planes are at least 20 mils from the edge to avoid possible shorting from this type of damage. However these design rules are not sufficient to prevent damage in all situations.

A third cause of failure is when a metal screwdriver tip slips, or a screw drops onto the board while it is powered on, causing a short between a power pin and a signal pin on a component. This can cause overvoltage / power supply problems described below. To avoid this type of failure, only perform assembly operations when the system is powered off.

Sometimes boards are stored in racks with slots that grip the edge of the board. This is a common practice for board manufacturers. However our boards are generally very dense, and if the board has components very close to the board edge, they can be damaged or even knocked off the board when the board tilts back in the rack. Diamond recommends that all our boards be stored only in individual ESD-safe packaging. If multiple boards are stored together, they should be contained in bins with dividers between boards. Do not pile boards on top of each other or cram too many boards into a small location. This can cause damage to connector pins or fragile components.

Power supply wired backwards – Our boards are not designed to withstand a reverse power supply connection. This will destroy each IC that is connected to the power supply (i.e. almost all ICs). This type of damage is not covered under Diamond Systems' warranty. The board will most likely will be unrepairable and must be replaced. A chip destroyed by reverse power or by excessive power will often have a visible hole on the top or show some deformation on the top surface due to vaporization inside the package. **Check twice before applying power!**

Overvoltage on bus connector – The PC/104-Plus PCI connector on this product is compatible with 3.3V buses only. If the board is installed on a CPU module with 5V signaling on the PC/104-Plus connector, the FPGA on board that provides the PCI interface may be damaged. The PC/104 ISA bus connector is 5V tolerant and will work without problem in any valid PC/104 system.

Overvoltage on analog output – If an analog output is accidentally connected to another output signal or a power supply voltage, the output can be damaged. On most of our boards, a short circuit to ground on an analog output will not cause trouble.

Overvoltage on digital I/O line – If a digital I/O signal is connected to a voltage above the maximum specified voltage, the digital circuitry can be damaged. On most of our boards the acceptable range of voltages connected to digital I/O signals is 0-5V, and they can withstand about 0.5V beyond that (-0.5 to 5.5V) before being damaged. However logic signals at 12V and even 24V are common, and if one of these is connected to a 5V logic chip, the chip will be damaged, and the damage could even extend past that chip to others in the circuit.

Bent connector pins –This type of problem is often minor and mostly cosmetic, and is easily fixed by bending the pins back to their proper shape one at a time with needle-nose pliers. The most common cause of bent connector pins is when a PC/104 board is pulled off the stack by rocking it back and forth left to right, from one end of the connector to the other. As the board is rocked back and forth it pulls out suddenly, and the pins at the end get bent significantly. The same situation can occur when pulling a ribbon cable off of a pin header. However, if the pins are bent too severely or too often, bending them back can cause them to weaken unacceptably or even break, and the connector must be replaced.

2. MODELS AND FEATURES

2.1 Description

The Ruby-MM-1616 is a family of PC/104 I/O modules featuring 4, 8 or 16 16-bit analog voltage and current outputs, and 48 digital I/O lines. The module uses the Analog Devices AD5755 16-channel 16-bit DAC chip for the D/A outputs and an FPGA with level-shifting transceivers for the DIO lines. A 50-pin connector provides access to the 16 analog outputs, and another 50-pin connector provides access to the 48 DIO lines. The board operates over the industrial temperature range of -40°C to +85°C and is supported by Diamond Systems' Universal Driver software. Models are available with either PC/104 or PC/104-*Plus* I/O expansion buses.

Ruby-MM-1616 utilizes individual digital calibration for each analog output channel. The calibration is performed at the factory prior to shipment. All analog components are high accuracy and low drift, enabling the board to avoid the need for recalibration for many applications during its useful lifetime.

2.2 Features

Board Features

- ◆ 4, 8 or 16 analog outputs with 16-bit D/A resolution
- ◆ Programmable voltage output ranges: 0-5V, 0-10V, ±5V, ±10V, 0-20mA, 4-20mA, 0-24mA
- ◆ Independent output range for each channel
- ◆ Waveform generator on up to 16 channels
- ◆ Simultaneous update of any combination of channels
- ◆ Multi-channel simultaneous waveform output capability with up to 100KHz waveform update rate
- ◆ Output current limit +/-5mA per channel in voltage mode
- ◆ Autocalibration of D/A circuits using the internal offset and gain registers for each channel
- ◆ 40 byte-wide and 8 bit-wide digital I/O lines with programmable direction
- ◆ 2 32-bit programmable counter / timers
- ◆ 4 24-bit pulse width modulators
- ◆ PC/104 ISA 16-bit bus interface or PC/104-*Plus* (ISA + PCI) 3.3V 32-bit bus interface

Software Support

Diamond's Universal Driver software with functions including:

- ◆ D/A output
- ◆ D/A waveform generator
- ◆ Calibration
- ◆ Digital I/O – bit and byte-wide
- ◆ Digital I/O – PWM

Mechanical, Electrical, and Environmental

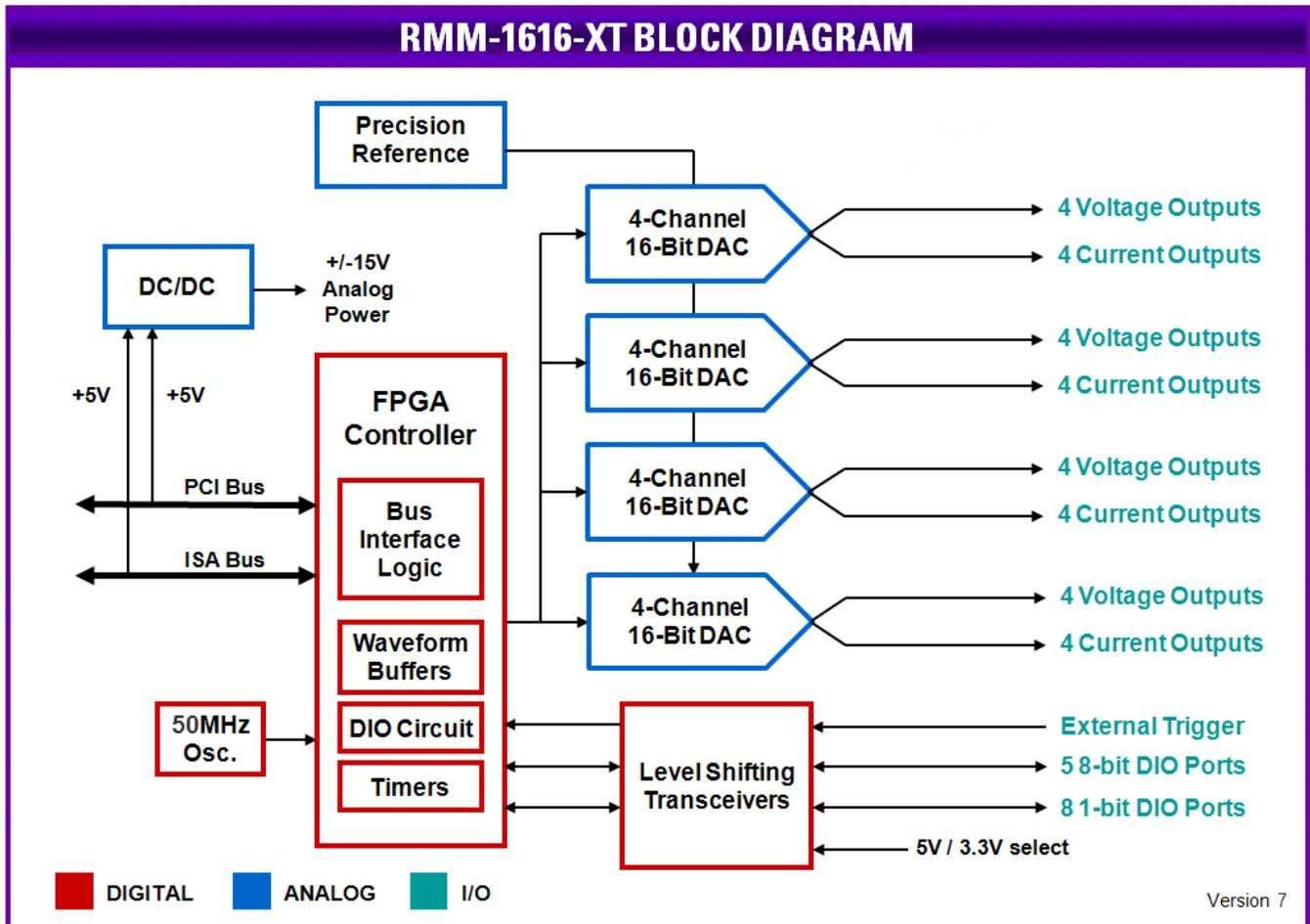
- ◆ PC/104 compliant form factor
- ◆ Dimensions: 3.550 x 3.775" (90 x 96mm)
- ◆ +5VDC input voltage
- ◆ -40°C to +85°C operating temperature
- ◆ RoHS compliant

2.3 Available Models

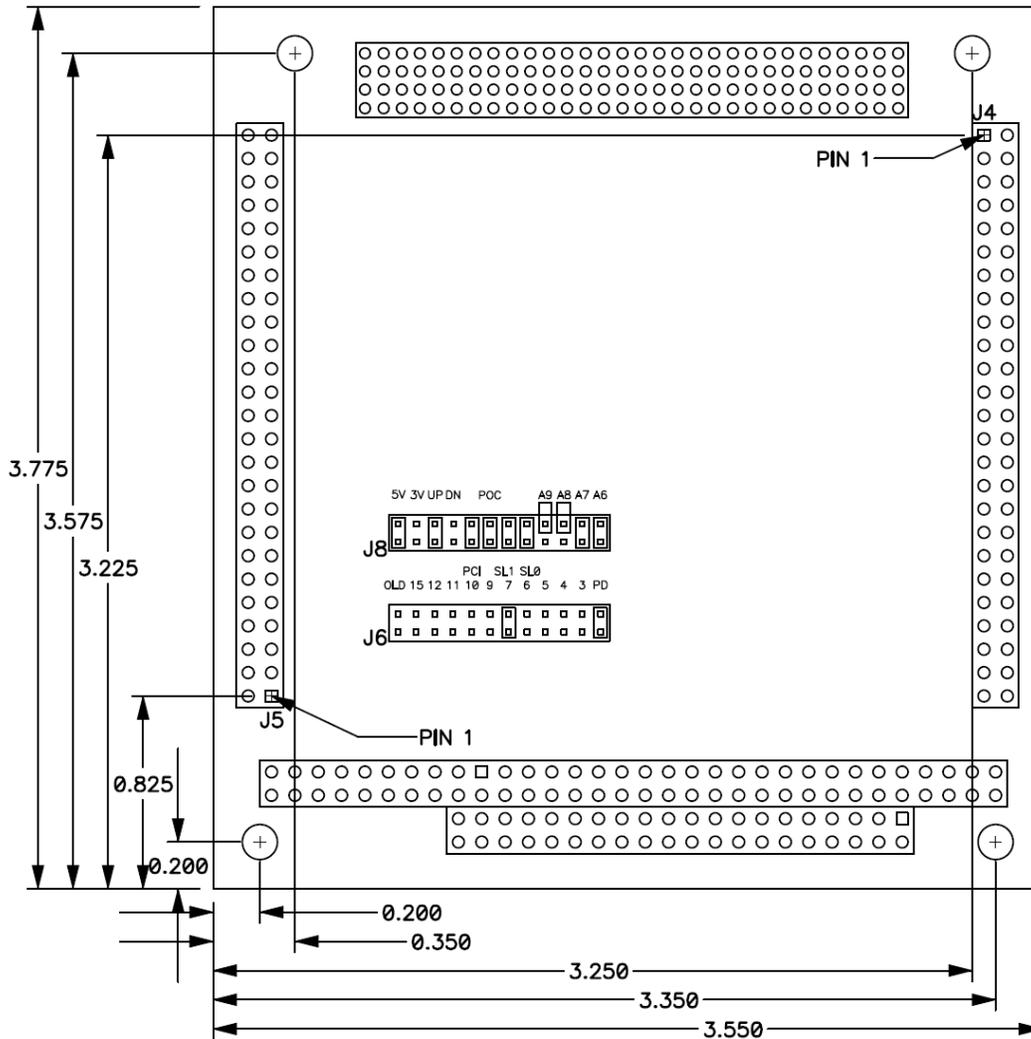
The following models are available, offering a selection of analog outputs for each bus configuration.

| Model Number | Analog Outputs | Digital I/O | Bus Interface | Notes |
|---------------|----------------|-------------|---------------|-----------------------|
| RMM-1616AP-XT | 16 | 48 | PCI + ISA | Standard stocked item |
| RMM-816AP-XT | 8 | 48 | PCI + ISA | Standard stocked item |
| RMM-416AP-XT | 4 | 48 | PCI + ISA | 50 unit minimum order |
| RMM-1616A-XT | 16 | 48 | ISA | Standard stocked item |
| RMM-816A-XT | 8 | 48 | ISA | Standard stocked item |
| RMM-416A-XT | 4 | 48 | ISA | 50 unit minimum order |

3. BLOCK DIAGRAM



4. BOARD DRAWING



| Connector | Description |
|-----------|---------------------------|
| J1 & J2 | PC/104 connectors |
| J3 | PCI connector |
| J4 | Analog connector |
| J5 | Digital connector |
| J6 | IRQ jumper block |
| J8 | Base Address jumper block |

Note: Connectors that are not intended for customer use are not identified or described in this manual.

5.2 PC/104-Plus PCI Bus Connector (J3)

Connector J3 provides the standard PC/104-Plus 32-bit PCI bus interface. This connector is installed on all models with **P** in the model number.

Warning: The PC/104-Plus connector on RMM-1616A-XT is not 5V tolerant. The board must be used in a system with 3.3V signaling on the PC/104-Plus connector.

The PC/104-Plus connector has pins for both +3.3V and +5V power. RMM-1616A-XT uses only the +5V pins for power and does not require +3.3V from the host computer. If the PC/104-Plus connector is not installed, the board will still obtain +5V from the PC/104 ISA connectors J1 and J2.

For information on the signal definitions of this connector, please view the PC/104-Plus specification available on www.pc104.org.

| | | | | | | | |
|-----|----------|-----|----------|-----|--------|-----|----------|
| A1 | GND/KEY5 | B1 | Reserved | C1 | +5V | D1 | AD00 |
| A2 | VI/O | B2 | AD02 | C2 | AD01 | D2 | +5V |
| A3 | AD05 | B3 | GND | C3 | AD04 | D3 | AD03 |
| A4 | C/BE0* | B4 | AD07 | C4 | GND | D4 | AD06 |
| A5 | GND | B5 | AD09 | C5 | AD08 | D5 | GND |
| A6 | AD11 | B6 | VI/O | C6 | AD10 | D6 | M66EN |
| A7 | AD14 | B7 | AD13 | C7 | GND | D7 | AD12 |
| A8 | +3.3V | B8 | C/BE1* | C8 | AD15 | D8 | +3.3V |
| A9 | SERR* | B9 | GND | C9 | SB0* | D9 | PAR |
| A10 | GND | B10 | PERR* | C10 | +3.3V | D10 | Reserved |
| A11 | STOP* | B11 | +3.3V | C11 | LOCK* | D11 | GND |
| A12 | +3.3V | B12 | TRDY* | C12 | GND | D12 | DEVSEL* |
| A13 | FRAME* | B13 | GND | C13 | IRDY* | D13 | +3.3V |
| A14 | GND | B14 | AD16 | C14 | +3.3V | D14 | C/BE2* |
| A15 | AD18 | B15 | +3.3V | C15 | AD17 | D15 | GND |
| A16 | AD21 | B16 | AD20 | C16 | GND | D16 | AD19 |
| A17 | +3.3V | B17 | AD23 | C17 | AD22 | D17 | +3.3V |
| A18 | IDSEL0 | B18 | GND | C18 | IDSEL1 | D18 | IDSEL2 |
| A19 | AD24 | B19 | C/BE3* | C19 | VI/O | D19 | IDSEL3 |
| A20 | GND | B20 | AD26 | C20 | AD25 | D20 | GND |
| A21 | AD29 | B21 | +5V | C21 | AD28 | D21 | AD27 |
| A22 | +5V | B22 | AD30 | C22 | GND | D22 | AD31 |
| A23 | REQ0* | B23 | GND | C23 | REQ1* | D23 | VI/O |
| A24 | GND | B24 | REQ2* | C24 | +5V | D24 | GNT0* |
| A25 | GNT1* | B25 | VI/O | C25 | GNT2* | D25 | GND |
| A26 | +5V | B26 | CLK0 | C26 | GND | D26 | CLK1 |
| A27 | CLK2 | B27 | +5V | C27 | CLK3 | D27 | GND |
| A28 | GND | B28 | INTD* | C28 | +5V | D28 | RST* |
| A29 | +12V | B29 | INTA* | C29 | INTB* | D29 | INTD* |
| A30 | -12V | B30 | REQ3* | C30 | GNT3* | D30 | GND/KEY3 |

5.3 Analog Output (J4)

Connector J4 brings the analog output signals to a pin header.

| | | | |
|----------|----|----|---------|
| VOUT 0 | 1 | 2 | IOUT 0 |
| AGND | 3 | 4 | VOUT 1 |
| IOUT 1 | 5 | 6 | AGND |
| VOUT 2 | 7 | 8 | IOUT 2 |
| AGND | 9 | 10 | VOUT 3 |
| IOUT 3 | 11 | 12 | AGND |
| VOUT 4 | 13 | 14 | IOUT 4 |
| AGND | 15 | 16 | VOUT 5 |
| IOUT 5 | 17 | 18 | AGND |
| VOUT 6 | 19 | 20 | IOUT 6 |
| AGND | 21 | 22 | VOUT 7 |
| IOUT 7 | 23 | 24 | AGND |
| VOUT 8 | 25 | 26 | IOUT 8 |
| AGND | 27 | 28 | VOUT 9 |
| IOUT 9 | 29 | 30 | AGND |
| VOUT 10 | 31 | 32 | IOUT 10 |
| AGND | 33 | 34 | VOUT 11 |
| IOUT 11 | 35 | 36 | AGND |
| VOUT 12 | 37 | 38 | IOUT 12 |
| AGND | 39 | 40 | VOUT 13 |
| IOUT 13 | 41 | 42 | AGND |
| VOUT 14 | 43 | 44 | IOUT 14 |
| AGND | 45 | 46 | VOUT 15 |
| IOUT 15 | 47 | 48 | AGND |
| EXT TRIG | 49 | 50 | DGND |

Connector type: 0.1" pitch 50-pin (2x25) dual row right-angle pin header with gold flashing.

Mating cable: Diamond Systems C-50-18

Connector signal definitions

| | |
|-----------|--|
| Vout 0-15 | Analog voltage outputs; quantity depends on model; All outputs start with Vout 0 and go up from there to Vout 3, Vout 7, or Vout 15 |
| Iout 0-15 | Analog current outputs; quantity depends on model; Outputs are aligned in the same manner as voltage outputs |
| Agnd | Analog ground; one is provided for each channel, however all analog grounds are tied together so the application can use one or more as desired. |
| Ext Trig | External trigger for D/A waveform generator when using external clocking |
| Dgnd | Digital ground, used as return for Ext Trig signal |

5.4 Digital I/O (J5)

Connector J5 brings the 48 digital I/O signals to a pin header. These lines have 3.3V logic levels with 5V input tolerance.

| | | | |
|--------|----|----|--------|
| DIO A0 | 1 | 2 | DIO A1 |
| DIO A2 | 3 | 4 | DIO A3 |
| DIO A4 | 5 | 6 | DIO A5 |
| DIO A6 | 7 | 8 | DIO A7 |
| DIO B0 | 9 | 10 | DIO B1 |
| DIO B2 | 11 | 12 | DIO B3 |
| DIO B4 | 13 | 14 | DIO B5 |
| DIO B6 | 15 | 16 | DIO B7 |
| DIO C0 | 17 | 18 | DIO C1 |
| DIO C2 | 19 | 20 | DIO C4 |
| DIO C4 | 21 | 22 | DIO C6 |
| DIO C6 | 23 | 24 | DIO C7 |
| DIO D0 | 25 | 26 | DIO D1 |
| DIO D2 | 27 | 28 | DIO D3 |
| DIO D4 | 29 | 30 | DIO D5 |
| DIO D6 | 31 | 32 | DIO D7 |
| DIO E0 | 33 | 34 | DIO E1 |
| DIO E2 | 35 | 36 | DIO E3 |
| DIO E4 | 37 | 38 | DIO E5 |
| DIO E6 | 39 | 40 | DIO E7 |
| DIO F0 | 41 | 42 | DIO F1 |
| DIO F2 | 43 | 44 | DIO F4 |
| DIO F4 | 45 | 46 | DIO F6 |
| DIO F6 | 47 | 48 | DIO F7 |
| +5VDC | 49 | 50 | DGND |

Connector type: 0.1" pitch 50-pin (2x25) dual row right-angle pin header with gold flashing.

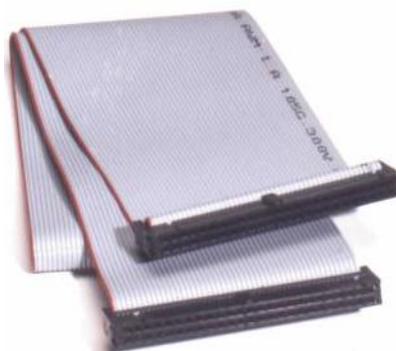
Mating cable: Diamond Systems C-50-18

Connector signal definitions

| | |
|-----------|--|
| DIO A0-A7 | Digital I/O port A or 0; directions of all 8 bits are set in unison |
| DIO B0-B7 | Digital I/O port B or 1; directions of all 8 bits are set in unison |
| DIO C0-C7 | Digital I/O port C or 2; directions of all 8 bits are set in unison |
| DIO D0-D7 | Digital I/O port D or 3; directions of all 8 bits are set in unison |
| DIO E0-E7 | Digital I/O port E or 4; directions of all 8 bits are set in unison |
| DIO F0-F7 | Digital I/O port F or 5; directions of each bit is set independently; these bits also serve as counter and PWM I/O signals |
| +5VDC | +5VDC available for powering external logic; limited to ~100mA |
| Dgnd | Digital ground, used as return for Ext Trig signal |

5.5 Ribbon Cable

The figure below shows Diamond Systems Cable C-50-18, which mates with both I/O connectors J4 and J5 on the RMM-16161 board. This is a 50-conductor ribbon cable, 18 inches length, with 2x25 .1" pitch IDC female connectors at both ends.



6. ARCHITECTURE OVERVIEW

6.1 Bus Interface

The RMM-1616A-XT family uses a new FPGA architecture that includes both PCI and ISA bus interfaces. This allows the full functionality of the board to be offered in both PC/104 (ISA connector only) and PC/104-Plus (ISA and PCI connector) formats. (A PCI-104 version with only the PCI connector is available by special order.) The PC/104-Plus models may use either the PCI or ISA connector with a jumper option. In most cases the user will want to use the default PCI interface.

The board's register map contains a total of 256 addressable 8-bit registers organized as 16 pages of 16 registers each. Registers are grouped into pages according to function: A/D, D/A, digital I/O, etc. This page method allows the board to occupy a small footprint of only 16 bytes in ISA mode. For consistency purposes the identical page system is utilized in PCI mode as well.

In both PCI and ISA modes all I/O is 8 bits wide. Operations that require 16-bit or wider data, such as D/A registers, counter/timer registers, and PWM registers, are managed with multiple 8-bit transactions.

6.2 D/A Circuit

The RMM-1616A-XT family utilizes the Analog Devices AD5755 D/A converter for all analog output functions. The AD5755 provides 4 16-bit DACs with high accuracy, low drift, programmable voltage and current output ranges, and digital calibration. Up to 4 of these devices may be installed on the board depending on the model. A precision, low-drift 5V voltage reference circuit provides the basis for the overall accuracy of the analog outputs.

The AD5755 contains an integrated digital calibration circuit consisting of a multiplier and adder. Each time data is written to a DAC, it undergoes a multiplication / addition operation, and the result is then transferred to the DAC channel. This operation takes about 5 microseconds to complete. Thus each write to a DAC channel results in a 5 us delay before the output begins to update to the new value. The total settling time for one channel consists of the settling time for the DAC plus this calibration time.

6.3 Digital I/O

The FPGA provides 48 digital I/O lines that are brought out to a separate I/O connector. All I/O lines are buffered for protection and have user-configurable pull-up/down resistors as well as user-configurable 3.3V/5V logic levels. These lines are grouped as 5 8-bit ports and 8 1-bit ports. The 8-bit ports utilize 8-bit bi-directional transceivers whose directions are individually controlled via a register. The 1-bit ports utilize 1-bit bi-directional transceivers whose directions are similarly individually controlled via a separate register. These 1-bit ports also serve as handshake signals for the other 5 ports, as well as I/O signals for the counter/timers and PWMs.

Special functions are enabled on Port F to support digital I/O, counter/timer, and PWM operation. These functions are controlled via register bits or commands in these other circuit blocks. The special configuration, when enabled, overrides the current direction and value of the assigned port F bit.

The special functions for digital I/O and counter/timer operation are shown below:

| Port F bit | F7 | F6 | F5 | F4 | F3 | F2 | F1 | F0 |
|------------|-----|-------|---------|---------|---------|---------|----------|----------|
| Function | Ack | Latch | Ctr1Clk | Ctr0Clk | Ctr1Out | Ctr0Out | Ctr1Gate | Ctr0Gate |
| Direction | Out | In | In | In | Out | Out | In | In |

I/O signals F3-0 may also be reassigned as PWM outputs as shown below:

| Port F bit | F7 | F6 | F5 | F4 | F3 | F2 | F1 | F0 |
|------------|----|----|----|----|------|------|------|------|
| Function | | | | | PWM3 | PWM2 | PWM1 | PWM0 |
| Direction | | | | | Out | Out | Out | Out |

When a board reset occurs, all DIO lines are released from any counter or PWM assignment and return to normal operation. They are reset to input mode, and their output registers are reset to 0.

6.4 Counter/Timers and Clock Sources

The FPGA includes 2 32-bit programmable counter/timers that serve a variety of purposes. The most common uses are a divide-by-n counter to create a programmable rate generator and counting external pulses. Each counter has programmable input, gate (count enable), and output functions. The input may be selected from the on-board 50MHz clock, a 1MHz clock derived from the 50MHz clock, or an external signal via one of the 1-bit digital I/O ports. The gate is optional and also derives from one of the 1-bit ports. The output is also optional. If enabled it is driven onto one of the 1-bit ports as well. Both positive and negative output polarities are supported.

6.5 Pulse Width Modulators

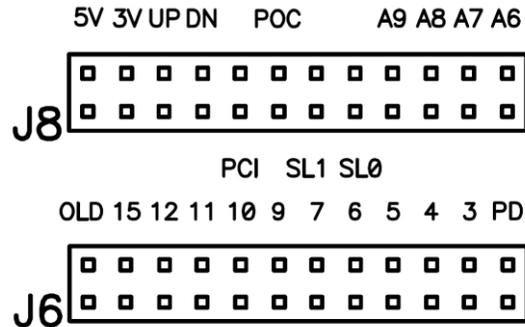
The FPGA includes 4 24-bit pulse-width modulator circuits. Each circuit includes a period register as well as a duty cycle register. Both registers may be updated in real-time without stopping the PWM. Duty cycles from 0-100% inclusive are supported, as well as both positive and negative output polarity. The PWM clock may be selected from the on-board 50MHz clock or a 1MHz clock derived from the 50MHz clock. The PWM outputs may be enabled onto the 1-bit port pins. These are general purpose I/O pins with limited voltage and current capability. The user must determine whether these pins provide the appropriate voltage and current levels for the intended application or whether additional buffering or amplification is required.

6.6 Interrupts

Interrupts enable the board to request service independently of program operation, typically in response to a user-defined time interval or an external event. The board supports interrupts from a variety of sources, including both counter/timers and the digital I/O circuit. The application program is responsible for providing the interrupt service routine to respond to the interrupt request. An unserviced interrupt request may cause the computer to crash. Diamond's Universal Driver software includes built-in interrupt handling routines that can link to user-defined code. This feature lets you define the conditions that will generate an interrupt and then define the behavior of the system when an interrupt occurs.

7. JUMPER CONFIGURATION

This section describes how to configure the RMM-1616 board using jumper blocks J6 and J8. An illustration of the two jumper blocks is shown below. All jumpers which are in use are installed in a vertical orientation across two pins in the jumper blocks. The board may be supplied with several jumpers installed over only one pin, which is a storage position. The jumper is not needed in the default configuration but is supplied for possible future use. Jumpers that are not needed may be removed.



7.1 Base Address (ISA models only)

RMM-1616 occupies a range of 16 bytes in the I/O memory of the PC. The starting address of this 16-byte window is called the base address. On ISA bus models, the base address is configurable with jumper block J8. On PCI models, the base address is configured by the BIOS during system startup.

The jumper locations labeled A9 – A6 are used to select the ISA base address. These lines correspond to ISA bus address lines SA9 – SA4. By definition, the lowest 4 address bits, SA3 – SA0, are all 0 for the base address, since these are used to select a byte within the 16-byte window. The upper address lines, SA15 – SA10, are always decoded as 0 to ensure a unique base address decode.

The table below lists the valid base address settings. When a jumper is installed, the corresponding address line is 0. When a jumper is removed, the corresponding address line is 1. Addresses that are below 100 hex are considered invalid and should not be configured. The default base address is 300 hex / 768 decimal.

| A9 | A8 | A7 | A6 | Base Address (Hex) | Base Address (Decimal) | |
|-----|-----|-----|-----|--------------------|------------------------|---------|
| In | Out | In | In | 100 | 256 | |
| In | Out | In | Out | 140 | 320 | |
| In | Out | Out | In | 180 | 384 | |
| In | Out | Out | Out | 1C0 | 448 | |
| Out | In | In | In | 200 | 512 | |
| Out | In | In | Out | 240 | 576 | |
| Out | In | Out | In | 280 | 640 | |
| Out | In | Out | Out | 2C0 | 704 | |
| Out | Out | In | In | 300 | 768 | default |
| Out | Out | In | Out | 340 | 832 | |
| Out | Out | Out | In | 380 | 896 | |
| Out | Out | Out | Out | 3C0 | 960 | |

7.2 IRQ Selection (ISA models only)

The ISA bus interrupt level is selected with jumper block J6 from levels 3, 4, 5, 6, 7, 9, 10, 11, 12, and 15. Install a jumper in any **ONE** location to select that IRQ number. Only one IRQ may be selected at a time.

The PC/104 bus requires a 1K ohm pull-down resistor on each IRQ line that is in use by a peripheral. If multiple boards in the system are sharing the same IRQ number, only one board should have the pull-down resistor installed. The pull-down resistor is enabled with jumper position PD on jumper block J6. The default is IRQ 7 and pull-down enabled.

In PCI bus systems, the IRQ level is unique to each slot and is selected with the PCI slot selection jumpers.

7.3 PCI Slot Number (PCI models only)

PCI devices in a PC/104 system are configurable to occupy a “slot” on the bus. This emulates the physical slots on a PCI backplane, where each PCI slot has its own unique signals for ID select, clock, and IRQ. Each PCI device must be assigned to a unique slot. The PCI slot number for RMM1616 is selected with jumper positions SL1 and SL0 on jumper block J8. The default is both jumpers installed to set PCI slot ID=00. **Note:** On many PC/104-Plus SBCs, slot 0 may already be occupied by a device on the SBC, such as an Ethernet controller or some other on-board peripheral.

| SL1 | SL0 | Slot |
|-----|-----|------|
| In | In | 0 |
| In | Out | 1 |
| Out | In | 2 |
| Out | Out | 3 |

7.4 Bus Select

On models with both the ISA and PCI connectors installed, the board can be set in auto-bus select mode. In this mode, if the board is installed in a system with only the PC/104 connector, it will use the ISA interface, and if it is installed in a system with the PCI connector (with or without the ISA connector), it will use the PCI interface. To use auto-bus select mode, or to use PCI mode, install a jumper in position PCI on jumper block J8. This is the default configuration. The jumper must be installed to enable PCI bus mode. If this jumper is removed, the board will always communicate over the ISA bus, even if the PCI bus is present. The table below lists all the possible configurations:

| Jumper | PCI present | ISA present | Bus Used |
|--------|-------------|-------------|----------|
| Out | No | Yes | ISA |
| Out | Yes | Yes | ISA |
| In | No | Yes | ISA |
| In | Yes | Yes | PCI |

7.5 Digital I/O Logic Level

The logic levels for the digital I/O can be set to either +5V or +3.3V logic levels. All DIO lines are configured for the same voltage levels; it is not possible to configure some for 5V and some for 3.3V operation. The voltage level is selected on jumper block J8. Install **ONE** jumper in either the 5V or 3V jumper location. The default is +5V.

WARNING: Install only one jumper in either 5V or 3.3V positions. Installing jumpers in both positions will short the two power supplies together and cause damage to the board and/or the entire system.

7.6 Digital I/O Pull-Up/Down

The digital I/O lines are tied to individual pull-up/down resistors which may be jumpered to either the DIO logic level voltage selected above or ground using locations UP or DN on jumper block J8, respectively. All DIO lines are pulled up or down together; it is not possible to configure some for pull-up and some for pull-down. The default is pull-up.

7.7 D/A Converter Power On Control

The D/A converters can be configured to power up in two modes, selected with jumper position POC on jumper block J8:

1. Jumper installed: Current outputs are tristated and voltage outputs are tristated.
2. Jumper not installed: Current outputs are tristated and voltage outputs are tied to analog ground with a 30K ohm resistance.

The default setting is "jumper installed".

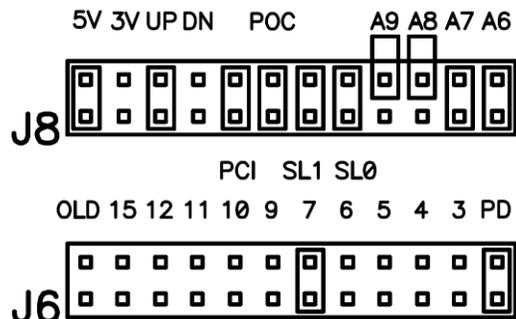
7.8 Old Jumper

Jumper block J6 has one position labeled "Old". This jumper is reserved for future use and is currently not enabled.

7.9 Default Configuration

The default configuration (configuration in which the board is shipped from stock) is shown and illustrated below. Note that both ISA and PCI configurations are provided for all boards, however only the relevant configuration will matter depending on which bus connector is installed / in use.

- ◆ ISA base address: 300 hex / 768 decimal
- ◆ ISA IRQ level: IRQ 7, pull-down resistor enabled
- ◆ PCI slot number: Slot 0
- ◆ Bus select: Auto-bus select / PCI bus if available
- ◆ Digital I/O logic levels: 5V
- ◆ Digital I/O pull-up/down: Pull-up
- ◆ D/A power-on control: Current and voltage outputs tristated



8. ANALOG OUTPUT TECHNOLOGY

8.1 Output Channel Organization

The RMM1616A/AP-XT modules use the Analog Devices AD5755 quad 16-bit D/A converter chips to provide the analog outputs. One to four chips are installed on the board, depending on the model. The channels are organized as follows:

| Board Channel | Chip Number | Channel Number on Chip |
|---------------|-------------|------------------------|
| 0 | 0 | 0 |
| 1 | 0 | 1 |
| 2 | 0 | 2 |
| 3 | 0 | 3 |
| 4 | 1 | 0 |
| 5 | 1 | 1 |
| 6 | 1 | 2 |
| 7 | 1 | 3 |
| 8 | 2 | 0 |
| 9 | 2 | 1 |
| 10 | 2 | 2 |
| 11 | 2 | 3 |
| 12 | 3 | 0 |
| 12 | 3 | 1 |
| 12 | 3 | 2 |
| 12 | 3 | 3 |

8.2 Output Ranges and Resolution

These chips provide both voltage and current outputs in multiple output ranges. Each channel on each chip can be set to a different output range, including voltage and current ranges on the same chip. Each channel has a voltage output pin, a current output pin and a ground return pin. The application wiring must connect to the voltage output pin or the current output pin, as needed.

A D/A converter converts a number, or output code, into an output voltage or current that is proportional to the number. The output range is the range of possible output values, from the smallest (lowest) value up to the highest (largest) value. The difference between the highest and lowest output value is called the span. For a +/-5V output range, the span is 10V, and for a 4-20mA output range, the span is 16mA.

The smallest change in output value, or resolution, is equal to $1/2^n \times$ the span, in which n = the number of bits (in this case 16). For a +/-5V output range, the resolution is $10V / 65535 = 153\mu V$. This smallest change is commonly referred to as 1 LSB or the Least Significant Bit.

RMM-1616AP-XT uses straight binary coding for all output values; the range of output codes is 0-65535. The theoretical top value, 65536, requires 17 bits to be represented in binary form, which is unachievable in a 16-bit value. Therefore the top value of each output range is unavailable, and instead the maximum output value is 1 LSB less than the top value. Because the lowest output code is always 0, which is represented in binary form, the bottom value of each range is always equal to the exact nominal value of the range (within tolerance of the accuracy).

The table below summarizes all this information for all output ranges on RMM-1616AP-XT.

| Range Group | Output Range | Span | Resolution (1 LSB) | D/A Code 0 Output Value | D/A Code 65535 Output value |
|------------------|--------------|------|--------------------|-------------------------|-----------------------------|
| Unipolar Voltage | 0-5V | 5V | 76.3uV | 0.0000V | 4.9999V |
| Unipolar Voltage | 0-10V | 10V | 153uV | 0.0000V | 9.9998V |
| Bipolar Voltage | +/-5V | 10V | 153uV | -5.0000V | 4.9998V |
| Bipolar Voltage | +/-10V | 20V | 305uV | -10.0000V | 9.9997V |
| Current | 0-20mA | 20mA | 0.305uA | 0.0000mA | 19.9997mA |
| Current | 0-24mA | 24mA | 0.366uA | 0.0000mA | 23.9996mA |
| Current | 4-20mA | 16mA | 0.244uA | 4.0000mA | 19.9998mA |

The conversion formula for analog outputs is the same for all ranges and is shown below (minimum output value = output value for a code of 0 shown in the table above):

$$\text{Output V/I} = (\text{D/A code} / 65536) \times \text{Span} + \text{Minimum output value}$$

On power-up or when the board is reset, all voltage and current output pins are set to a tristate mode. All outputs are reset to the 0-5V output range with the output code of 0 programmed into the output registers, so that when outputs are enabled the voltage pins will have 0V on them (and the current pins will remain tristated). The D/A initialization sequence described later in this manual also sets all outputs to 0-5V range with 0V output. This sequence can be modified to use a different output range as desired.

8.3 Output Modes

Each output channel on RMM-1616AP-XT can be updated individually, or any number of channels can be updated simultaneously, including different channels on different chips. Simultaneous update is useful when the application requires precise timing to avoid distortion or errors in the behavior of the controlled device, for example when controlling the movement of an X-Y table or a laser beam. The **Error! Reference source not found.** chapter in this manual describes both single-channel and multi-channel output modes.

8.4 Calibration

Note: The RMM-1616 is factory calibrated. All calibration settings are stored in an on-board EEPROM for instant automatic recall each time the board powers up. All analog outputs power up to 0V for safety. If recalibration or calibration for nonstandard D/A ranges are needed, please contact Diamond Systems for technical support. All analog components contain inherent errors in offset and gain which affect the accuracy of the signals they generate. These errors are very small on RMM-1616AP-XT; however they are still present and could present a problem for some high-precision applications. Calibration is used to correct these errors so that the actual output of the D/A channels is as close as possible to the theoretical output.

The AD5755 D/A converter uses a digital calibration method to correct for offset and gain errors. Each output channel has a 16-bit Offset register, called the C register, and a 16-bit Gain register, called the M register. This enables each channel to be calibrated independently for maximum overall accuracy. Each time an output code is written to a channel, the chip will automatically apply the offset and gain correction to the code, resulting in a corrected digital value. This corrected value is then converted to the output voltage or current according to the output range. The calibration process takes about 5 μ s and is unavoidable. This 5 μ s delay is included in the specified settling time for the analog outputs.

For improved accuracy, the bipolar voltage, unipolar voltage, and current output range groups each have their own calibration settings. Within any group, for example between the 0-5V and 0-10V ranges, the differences in errors are very small, so the same calibration values are used for the entire group. However between range groups the errors are noticeable, so separate calibration values are used for each group.

The calibration values for the unipolar and bipolar voltage range groups are stored in an EEPROM on the board. On power-up or reset, the unipolar voltage range calibration values are read from the EEPROM and loaded into the AD5755 chips. If needed, the calibration values for a different range can be read from the EEPROM and stored. This is explained in the How-to section later in this manual.

Note: There are no calculated calibration values for current output ranges. Instead, default values are used. When using a current output range, the application software can load the default calibration values into the DACs. See the Calibration EEPROM information below for the default values.

The conversion formula from the written output code and the calibrated code is as follows:

$$\text{Corrected code} = \text{Written code} \times (\text{M register} / 65535 (0xFFFF)) + (\text{C register} - 32768 (0x8000))$$

The minimum value is always 0, and the maximum value is always 65535 / 0xFFFF. Any result which exceeds these limits will be automatically set to the limit.

The corrected code is then converted to the output voltage or current according to the formula above.

9. CALIBRATION EEPROM

The board contains an EEPROM that stores the factory calibration settings for the board. For safety, a protected area of the EEPROM stores a backup copy of the factory calibration settings. In case the calibration settings become accidentally corrupted, contact Diamond Systems Technical Support for information on how to restore the calibration settings from the backup copy.

Each channel has its own set of calibration values. Each calibration value is 16 bits, occupying two bytes in the EEPROM. Each output range group has two calibration values, one for offset (called the C value) and one for gain (called the M value). There are two output range groups with calibration values, unipolar voltage (0-5V and 0-10V) and bipolar voltage (+/-5V and +/-10V). Thus there are a total of 8 calibration bytes for each channel, or 128 bytes total for the board:

| | |
|---------------------|---------|
| Unipolar offset (C) | 2 bytes |
| Unipolar gain (M) | 2 bytes |
| Bipolar offset (C) | 2 bytes |
| Bipolar gain (M) | 2 bytes |

Current output ranges do not have calibration values. The calibration values for all current ranges on all channels are fixed as follows:

| | |
|------------------|--------|
| Offset / C value | 0x8000 |
| Gain / M value | 0xFE00 |

The calibration data is stored in the EEPROM as shown below:

| Address | | Definition |
|---------|---------|---|
| Hex | Decimal | |
| 0 | 0 | Channel 0 M (gain) value LSB for unipolar ranges |
| 1 | 1 | Channel 0 M (gain) value MSB for unipolar ranges |
| 2 | 2 | Channel 0 C (offset) value LSB for unipolar ranges |
| 3 | 3 | Channel 0 C (offset) value MSB for unipolar ranges |
| 4 | 4 | Channel 1 M (gain) value LSB for unipolar ranges |
| 5 | 5 | Channel 1 M (gain) value MSB for unipolar ranges |
| 6 | 6 | Channel 1 C (offset) value LSB for unipolar ranges |
| 7 | 7 | Channel 1 C (offset) value MSB for unipolar ranges |
| ... | ... | ... |
| 3C | 60 | Channel 15 M (gain) value LSB for unipolar ranges |
| 3D | 61 | Channel 15 M (gain) value MSB for unipolar ranges |
| 3E | 62 | Channel 15 C (offset) value LSB for unipolar ranges |
| 3F | 63 | Channel 15 C (offset) value MSB for unipolar ranges |

In general you should never have to write new data to the EEPROM, since the analog components on RMM-1616A-XT feature high accuracy and very low drift. However reading from the EEPROM is necessary to recall calibration settings when you change analog output ranges in order to ensure best accuracy. It is advisable to recall the calibration values from the EEPROM whenever the range is changed from one range group to another. When changing ranges within a range group, no calibration recall is necessary.

Unipolar voltage range group: 0-5V, 0-10V

Bipolar voltage range group: +/-5V, +/-10V

Current range group: 0-20mA, 0-24mA, 4-20mA

10. SOFTWARE DRIVER OVERVIEW

10.1 Universal Driver

Diamond Systems' free Universal Driver software provides a powerful and efficient method of accessing all of the features and capabilities of RMM-1616A-XT. While many I/O boards are very simple in operation and can be controlled easily with simple I/O commands, the D/A, counter/timers, PWM, and interrupt features of RMM-1616A-XT are sophisticated and require complex setup and management to utilize their full capabilities. The how-to section of this manual provides an overview of the most common uses of the board which can suffice for many applications if you are using an operating system not supported by Universal Driver. However if you are using an OS supported by Universal Driver it is far more efficient and effective to use Universal Driver. The Universal Driver software and documentation are available online at www.diamondsystems.com/products/dscud. The driver package consists of several downloadable modules: The main driver software package, the board-specific demo programs, and the documentation.

Universal Driver provides a collection of high level software functions in a library compatible with popular C language compilers. The functions include board initialization, D/A operations, D/A waveform generator, digital I/O, counter/timer operations, PWM functions, and interrupts. Universal driver lets you utilize all the features of RMM-1616 quickly and efficiently without having to deal with register-level commands or complex sequences of operations. A collection of demo programs provide illustration of the use of the driver functions and also provide a convenient starting point for your own application development.

10.2 Control Panel

Included with Universal Driver is a Windows Control Panel program (graphical user interface) that runs in Windows XP and 7. The Control Panel provides a quick way to access all the features of the board in a simple and intuitive manner. It is highly recommended as a starting point when using the RMM-1616. It can be used to verify that the board is installed and operating correctly as well as to become familiar with the various capabilities of the board. The Control Panel is included with the main Universal Driver package.

11. SPECIFICATIONS

| Host Interface | |
|--|---|
| Interface bus | PC/104 8-bit ISA bus or PC/104- <i>Plus</i> PCI bus |
| Bus selection | Autodetection with PCI priority; manual ISA override |
| Analog Outputs | |
| Number of outputs | 4, 8 or 16 |
| Resolution | 16 bits |
| Output ranges | 0-5V, 0-10V, $\pm 5V$, $\pm 10V$, 0-20mA, 0-24mA, 4-20mA |
| Settling time | 10 μ s maximum to $\pm 0.003\%$ |
| Linearity error | ± 2 LSB maximum |
| Differential nonlinearity | ± 2 LSB maximum |
| Monotonicity | 15 bits minimum |
| Output current limit (voltage outputs) | 8mA or 16mA, software selectable per channel |
| Open-circuit voltage limit (current outputs) | 23V, 24.5V, 27V or 29.5V, software programmable per channel |
| Reset | All DACs reset to tristate on voltage and current output pins Programmable clear code, independent value per channel |
| Waveform Generator | |
| Number of channels | 1 to 16 |
| Buffer size per channel | 1 to 2048 samples, software programmable 2048 total sample limit |
| Trigger source | Software, counter/timer or external signal, software selectable |
| Digital I/O | |
| Number of lines | 40 byte-wide, 8 bit-wide, programmable direction TTL/CMOS compatible |
| Input voltage | Logic 0: -0.5V min, 0.8V max Logic 1: 2.0V min, 5.5V max |
| Output voltage | Logic 0: 0.0V min, 0.4V max Logic 1: 3.0V min, 4.6V max |
| Output current | ± 2.5 mA maximum per line |
| I/O data transfer modes | Normal or latched, software selectable |
| Counter/Timers | |
| Number of counters | 2 32-bit, software programmable |
| Clock sources | 50MHz, 5MHz or external signal, software selectable |
| Count direction | bidirectional, software programmable; optional automatic reload at 0 for rate generator use |
| Clock source | Internal or external, software selectable |
| Gate | Programmable counter gate for each counter |

| PWMs | |
|------------------------|---|
| Number of PWM channels | 4 24-bit, software programmable period and on-time |
| Duty cycle | 0 – 100%, programmable |
| Output polarity | Positive or negative, programmable |
| Clock sources | 50MHz or 5MHz, software selectable |
| Interrupts | |
| Sources | Counter/timer, digital I/O or D/A fault, software selectable |
| Software support | Universal Driver supports execution of user-supplied code on interrupt |
| Mechanical | |
| Dimensions | 3.550" x 3.775" / 90.2 x 95.9mm; PC/104 compliant |
| Component height | Top side: 0.435" / 11.2mm max Bottom side: 0.1" / 2.5mm max (not including PC/104 connector pins and PC/104-Plus shroud) |
| PC/104 stacking | Compatible with both top and bottom stacking |
| I/O connectors | Dual 50-pin 2x25.1" pitch right angle pin headers; compatible with industry standard 50-pin ribbon cables |
| Weight | 3.0oz (85g) |
| General | |
| Operating temperature | -40°C to +85°C |
| Input power | +5VDC +/-5% |
| MTBF | 100,000 hours (calculated) |
| RoHS | Compliant |