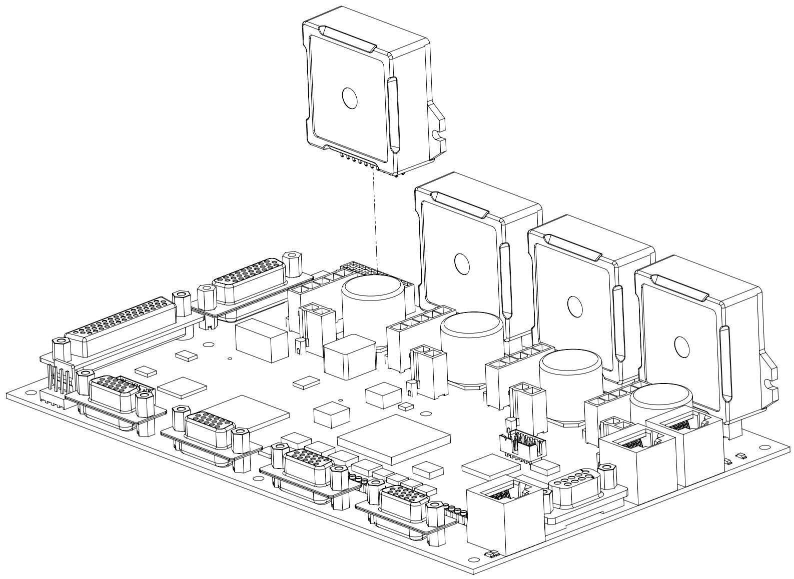

Prodigy®/CME Machine-Controller

User Guide

Revision 1.2 / January 2025

Performance Motion Devices, Inc.

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Related Documents

Prodigy/CME Machine-Controller Developer Kit User Manual

How to install, configure, and operate Prodigy/CME Machine-Controller Developer Kits. Includes quick setup guide, guide to using the Pro-Motion exerciser program, and guide to software development with PMD products.

Magellan Motion Control IC User Guide

Complete description of the Magellan Motion Control IC features and functions with detailed theory of operations.

Atlas Digital Amplifier User Manual

Description of the Atlas Digital Amplifier electrical and mechanical specifications along with a summary of its operational features.

Atlas Digital Amplifier Complete Technical Reference

Complete technical and mechanical description of the Atlas Digital Amplifier with detailed theory of operations.

C-Motion® Engine Development Tools Manual

Complete guide to developing software for PMD controller products. Includes examples on how to use the C-Motion Magellan, C-Motion PRP, and C-Motion PRP II C-language libraries, and details the recommended code development sequence for microcontroller-based, PC-based , and C-Motion Engine-based systems.

C-Motion Magellan Programming Reference

Description of Magellan Motion Control IC commands and C-language library calls with coding syntax, listed alphabetically for quick reference.

C-Motion PRP Programming Reference

Description of C-Motion PRP commands and C-language library calls with coding syntax, listed alphabetically for quick reference.

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1. Installation

1

In This Chapter

- Prodigy/CME Machine-Controller Overview
- Machine-Controller Developer Kits
- Guide to this Manual
- Software Installation
- Feature List
- Typical Applications
- Prodigy/CME Machine Controller Boards in the Production Application

1.1 Prodigy/CME Machine-Controller Overview

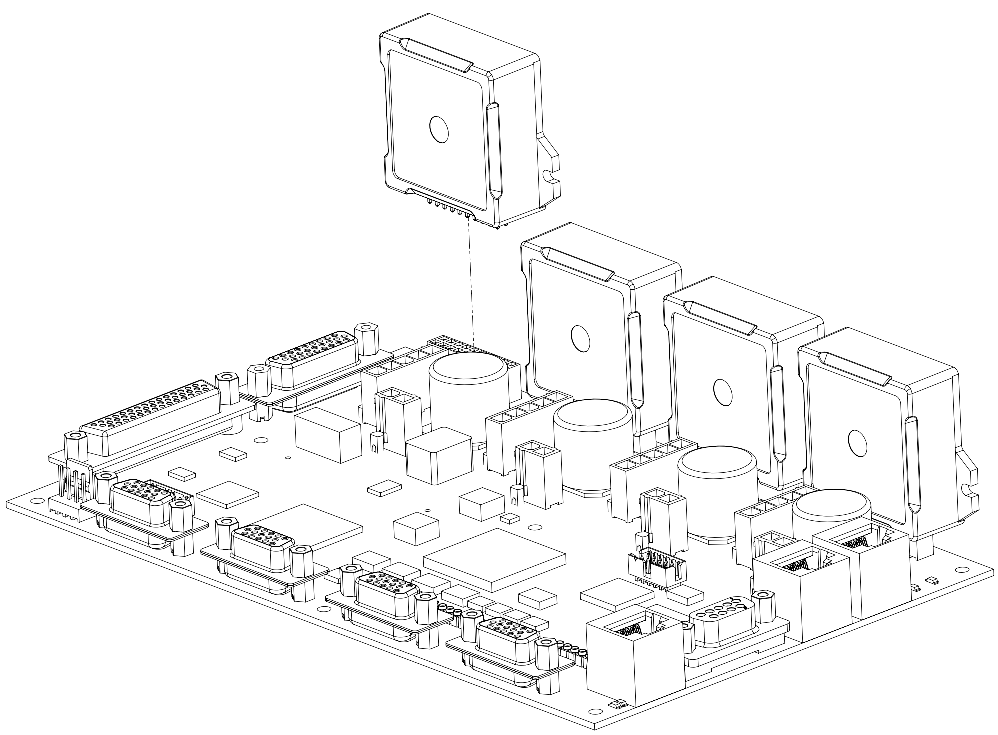


Figure 1-1: Prodigy/CME Machine-Controller Board with Atlas Amplifiers

This manual provides a complete user guide for the Prodigy/CME Machine-Controller. For documentation on other members of the Prodigy family please consult the appropriate documentation.

The Prodigy/CME Machine-Controller boards provide high-performance control of DC Brush, Brushless DC, and step motors. All Prodigy boards are based on PMD's Magellan® Motion Control ICs, which perform high speed motion control functions such as profile generation, servo loop closure, and many other real-time functions.

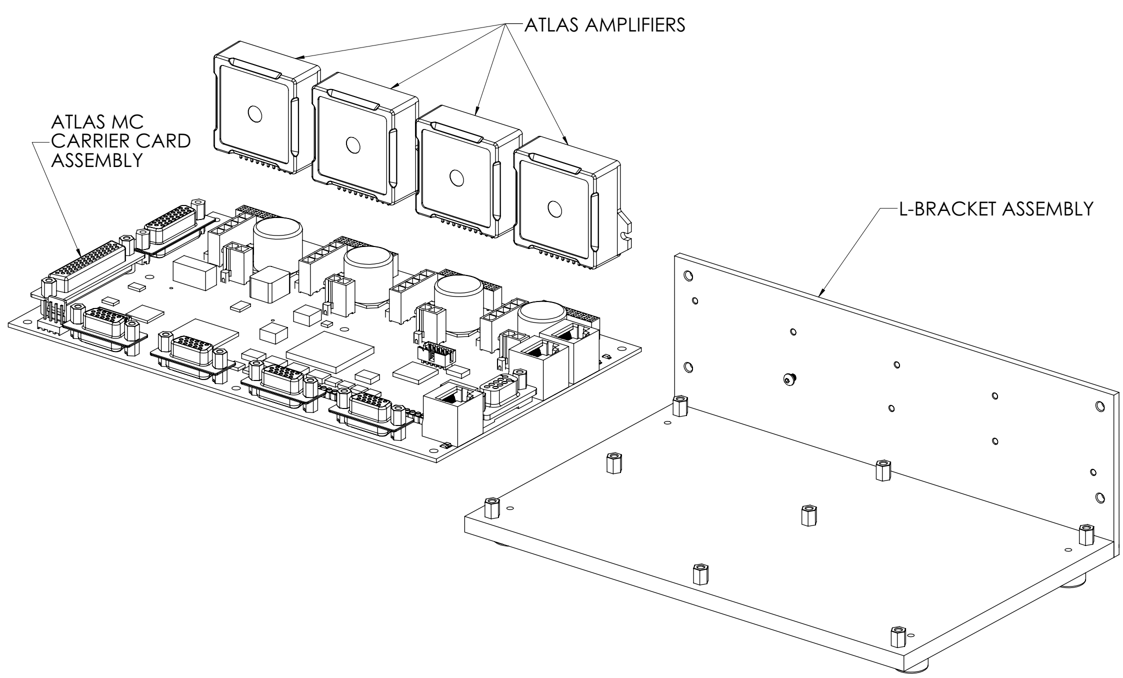
The Prodigy/CME machine-controller boards include a C-Motion® Engine (CME), which allows the user to download application code and execute it directly on the board. In addition, machine controller boards provide the option of onboard amplification via installation of PMD's Atlas Amplifiers.

Prodigy/CME Machine-Controllers come in various configurations of axis number from 1 to 4 as shown in the following table:

Prodigy/CME Machine-Controller P/N	Installed Magellan P/N	Number of Axes	Motor Type
PR33SM00001	MC58120	1	Brushless DC, DC Brush, Step Motor
PR33SM00002	MC58220	2	Brushless DC, DC Brush, Step Motor
PR33SM00003	MC58320	3	Brushless DC, DC Brush, Step Motor
PR33SM00004	MC58420	4	Brushless DC, DC Brush, Step Motor

1.2 Machine-Controller Developer Kits

Figure 1-2: Developer Kit Elements



PMD offers developer kits for Prodigy/CME Machine-Controllers. A typical machine controller developer kit consists of:

- 2, 3, or 4 axis Prodigy/CME Machine-Controller board
- L-bracket mounting hardware consisting of a base plate with PCB mounting posts attached to a vertical plate for Atlas mounting (optional if no Atlas units installed)

- 2, 3, or 4 Atlas Digital Amplifier units
- Miscellaneous cables & accessories to facilitate connection to the application motor hardware and other system components

1.2.1 Developer Kit Part Numbers

There are several available Prodigy/CME Machine-Controller developer kits. Depending on the developer kit ordered some assembly of the developer kit may be required by the user, or the developer kit may come completely assembled and ready to use out of the box.

The following table provides detailed information on each available machine controller developer kit P/N:

Developer Kit P/N	Items Included	Comments
PRK33MK00004	L-Bracket Cables & accessories Software SDK & manuals	Some assembly required. This developer kit type is typically ordered when the machine controller board and Atlas units are purchased separately.
PRK33ML44002	Machine Controller board (2 axis) 2 high power multi motor Atlas units L-Bracket Cables & Accessories Software SDK & manuals	Comes fully assembled. This is a complete 2-axis setup with Atlas units and machine controller board included.
PRK33ML44403	Machine Controller board (3 axis) 3 high power multi motor Atlas units L-Bracket Cables & Accessories Software SDK & manuals	Comes fully assembled. This is a complete 3-axis setup with Atlas units and machine controller board included.
PRK33ML44444	Machine Controller board (4 axis) 4 high power multi motor Atlas units L-Bracket Cables Accessories Software SDK & manuals	Comes fully assembled. This is a complete 4-axis setup with Atlas units and machine controller board included.

For more information on machine controller developer kits refer to the *Prodigy/CME Machine-Controller Developer Kit User Manual*.

For more information on Atlas amplifiers refer to the *Atlas Digital Amplifier User Manual*.

> The PRK33MK00004 Developer Kit consists of the mounting and connection hardware only. To create a complete functioning setup using this DK part the machine controller board and Atlas units must be ordered separately.

1.3 Guide to this Manual

This manual documents the function of the Prodigy/CME Machine-Controller board including complete details on its mechanical, electrical, and operational specifications.

The companion manual is the *Prodigy/CME Machine-Controller Developer Kit User Manual* which provides information on how to quickly connect motion hardware to the machine controller board and how to operate the machine controller board with Pro-Motion - PMD's motion exerciser and application development program. Note that if you have not purchased a machine controller developer kit you can still download the developer kit user manual and Pro-Motion for free from the PMD website. This is highly recommended for simplifying machine controller board startup, motion application performance optimization, and application software development.

Here is a summary of the content in the remaining sections of this manual:

Chapter 1, *Installation*, shows how to download and install software and shows typical applications used with the machine controller board.

Chapter 2, *Specifications & General Information*, provides electrical and mechanical specifications for the machine controller board along with a complete description of all pinouts and connectors.

Chapter 3, *Operation*, provides a complete reference for operation of the board including how to access board functions via user application code C-Motion calls.

1.4 Software Installation

The software distribution for the Prodigy/CME Machine-Controller board is downloaded from the PMD website at the URL: https://www.pmdcorp.com/resources/software. Although most users purchase a developer kit when first using the machine controller board, as mentioned this is not necessary to download software.

To install the software:

1. Go to the Software Downloads section of PMD's website located at https://www.pmdcorp.com/resources/software and select download for "Developer Kit Software".
2. After selecting download you will be prompted to provide information about yourself and your motion application.
3. After selecting submit the next screen will provide a link to the software download. The software download is a zip file containing various installation programs. Select this link and downloading will begin.
4. Once the download is complete extract the zip file. There is a *ReadMe.txt* file that may contain additional useful information. When ready execute the **Pro-Motion** install. Pro-Motion is a Windows application that will be used to communicate with and exercise the board.
5. You can also extract the following SDK (Software Development Kit) used with the Prodigy/CME Machine-Controller:

- **C-Motion PRP SDK** – An SDK for creating PC-based applications using .NET (C#, VB) programming languages and for PC-based or downloadable applications in C-language when using PMD products which have a /CME designation.

1.5 Feature List

The Prodigy/CME Machine-Controller motion board provides a wealth of motion control capabilities and features. Here is a summary

- Available in 1, 2, 3, and 4-axis configurations
- Supports DC Brush, Brushless DC, and step motors
- Supports onboard Atlas® motor amplifiers
- Uses PMD's advanced Magellan® Motion Control IC

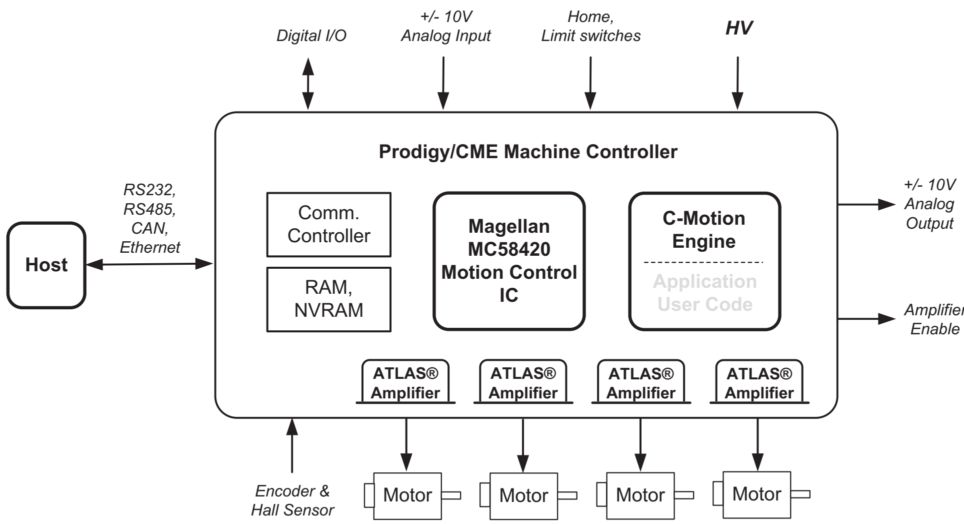
- S-curve, trapezoidal, electronic gearing, and velocity-contouring profiles
- Velocity, position, and acceleration changes on-the-fly
- 100BASE-T Ethernet (UDP & TCP protocols with Dynamic Host Configuration Protocol)
- RS232 & RS485 and CANbus 2.0 communications
- Incremental quadrature and absolute SSI encoder support
- User application code can be downloaded and executed on board
- High speed loop rate: 50 µsec/axis
- Incremental encoder quadrature input (up to 25 Mcounts/sec)
- Up to 256 microsteps per full step resolution
- Two directional limit switches, index input, and home indicator per axis
- Axis settled indicator, tracking window and automatic motion error detection
- Extensive fault detection including over and undervoltage, motor short, and overtemp
- Single voltage supply drives motors and board logic
- Field oriented control
- Advanced PID position servo loop with feedforward and dual biquad filters
- High-speed hardware performance trace
- 8 channels of high precision 16-bit analog input and output
- 12+ channels of general purpose digital I/O
- Support for external amplifiers via +/- 10V analog output

1.6 Typical Applications

The following sections provide information on typical applications utilizing Prodigy/CME Machine-Controller boards.

1.6.1 Multi-axis Motion Controller for DC Brush, Brushless DC, and Step Motors With Onboard Atlas® Digital Amplifier Modules

Figure 1-3: Prodigy/CME Machine-Controller Commanded by External Host



In this application the Prodigy/CME Machine-Controller is commanded directly by a host via an RS232, RS485, CANbus, or Ethernet network connection. The Prodigy/CME Machine-Controller provides high performance profile generation and servo or step motor position control of up to four DC Brush, Brushless DC, or step motors. Onboard amplifiers allow an all-in-one controller function with power levels from 75W to 500W per motor.

Quadrature or SSI position encoders provide motor feedback, and if Brushless DC motors are used Hall sensors provide commutation feedback. With step motors encoder feedback is optional. Additional supported signals include a home switch, directional limit switches, general purpose AxisIn and AxisOut signals, and more.

To power the board an external power supply provides the motor voltage (HV) which powers a DC-to-DC converter used to generate 3.3V DC for board logic. The Atlas amplifiers input this same HV voltage to power their internal logic and to drive the motor windings.

In this diagram four axes are shown but 1, 2, and 3-axis versions of the Prodigy/CME Machine-Controller board are available as well.

1.6.2 Multi-axis Motion Controller for DC Brush, Brushless DC, and Step Motors With Standalone Operation

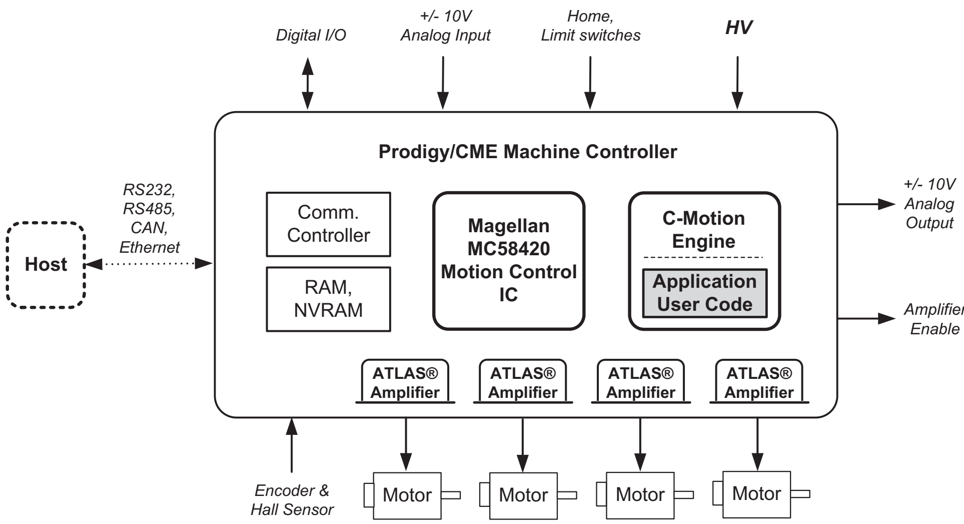


Figure 1-4: Prodigy/CME Machine-Controller Commanded by Onboard User Application Code

In this application the Prodigy/CME Machine-Controller is commanded by user application code downloaded into the board's C-Motion Engine module. As in the previous application the Prodigy/CME Machine-Controller provides high performance profile generation and servo or step motor position control of up to four DC Brush, Brushless DC, or step motors. Onboard amplifiers allow a complete all-in-one controller function with power levels from 75W to 500W per motor.

Although in this mode the Prodigy/CME Machine-Controller board can run entirely standalone, the downloaded user application code can also send and receive messages from the RS232, RS485, CAN and Ethernet connections. This is useful to allow the machine controller board to process application-specific protocols commanded by a host network.

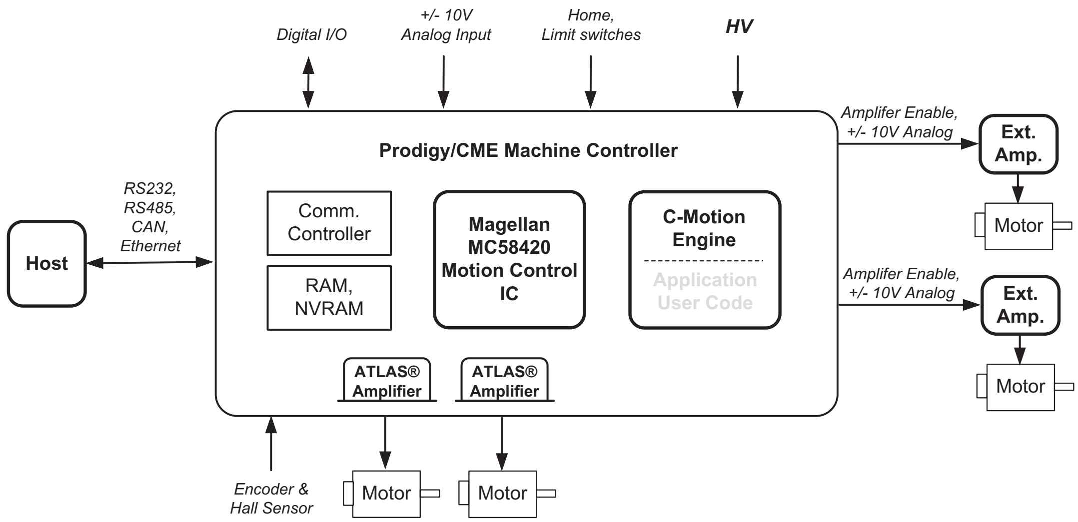
Quadrature or SSI position encoders provide motor feedback, and if Brushless DC motors are used Hall sensors provide commutation feedback. With step motors encoder feedback is optional. Additional supported signals include a home switch, directional limit switches, general purpose AxisIn and AxisOut signals, and more.

To power the board an external power supply provides the motor voltage (HV) which powers a DC-to-DC converter used to generate 3.3V DC for board logic. The Atlas amplifiers input this same HV voltage to power their internal logic and to drive the motor windings.

In this diagram four axes are shown but 1, 2, and 3-axis versions of the Prodigy/CME Machine-Controller board are available as well.

1.6.3 Multi-axis Motion Controller for DC Brush, Brushless DC, and Step Motors With External Amplifiers

Figure 1-5: Prodigy/CME Machine-Controller Using One or More External Amplifiers



In this application the Prodigy/CME Machine-Controller is operated similarly to the previous applications but one or more of the servo motor axes uses an external amplifier commanded via a +/- 10V analog output signal. External amplifiers may be useful when driving DC Brush or Brushless DC motors that exceed the voltage or current specification of Atlas amplifiers, or when driving motors that require special control methods such as AC Induction or Piezo motors. Note that step motors can not be driven via external amplifiers.

As in the previous applications quadrature or SSI position encoders provide motor feedback, and if Brushless DC motors are used Hall sensors provide commutation feedback. With step motors encoder feedback is optional. Additional supported signals include a home switch, directional limit switches, general purpose AxisIn and AxisOut signals, and more.

In this diagram two onboard Atlas and two external amplifiers are shown, but any combination of onboard Atlas and external amplifiers can be controlled, up to four axes in total.

1.6.4 Multi-axis Motion Controller for DC Brush, Brushless DC, and Step Motors Connecting to Additional Motion Controllers

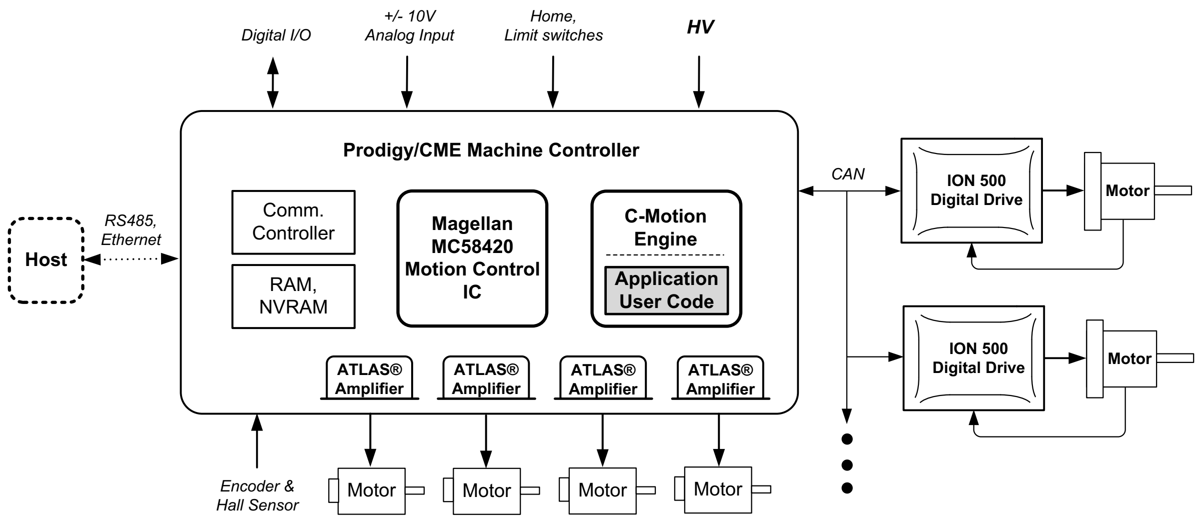


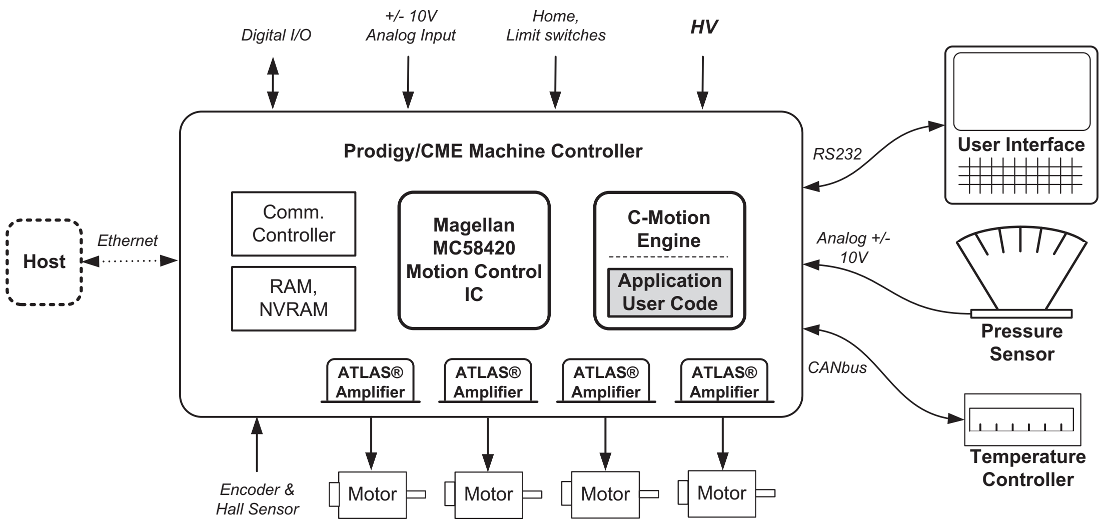
Figure 1-6: Prodigy/CME Machine-Controller Connecting to Off-Board Motion Controllers

In this application the Prodigy/CME Machine-Controller is operated similarly to the previous applications, but in addition to directly controlling up to four motors also commands external PMD controllers via its CAN network functioning as an attached device network. Examples of attached devices that can be controlled via the machine controller's CAN network include ION 500 and ION 3000 drives, DK55420, DK58420, and DK58113 boards, and user-designed boards with Magellan Motion Control ICs.

When using an attached device network the machine controller can run the applications code on its C-Motion Engine, or access the attached devices from a host connection using the PRP (PMD Resource Access Protocol) to communicate through the machine controller to the attached devices.

1.6.5 Standalone Multi-axis Motion Controller for DC Brush, Brushless DC, and Step Motors Interfacing With User Interface and Other Peripherals

Figure 1-7: Standalone Prodigy/CME Machine-Controller Operating a User Interface And Connecting to Peripherals



In this application the Prodigy/CME Machine-Controller operates in a fully standalone mode and connects to a user interface device, a sensor, a sub-system controller such as a temperature controller. Connection to a user interface module and sub-system controller is typically CAN or Serial. Analog input sensors can be interfaced directly to the machine controller board's analog inputs.

In this configuration the machine controller runs user application code on its C-Motion Engine that coordinates movement of the motors being driven, the user interface function, reading and interpreting data from the attached sensor, and commanding the sub-system controller. Many types of peripherals can be controlled and the specific types of peripherals shown here are meant to serve as just one example of this.

1.6.6 Multi-axis Synchronized Contouring of DC Brush, Brushless DC, and Step Motors

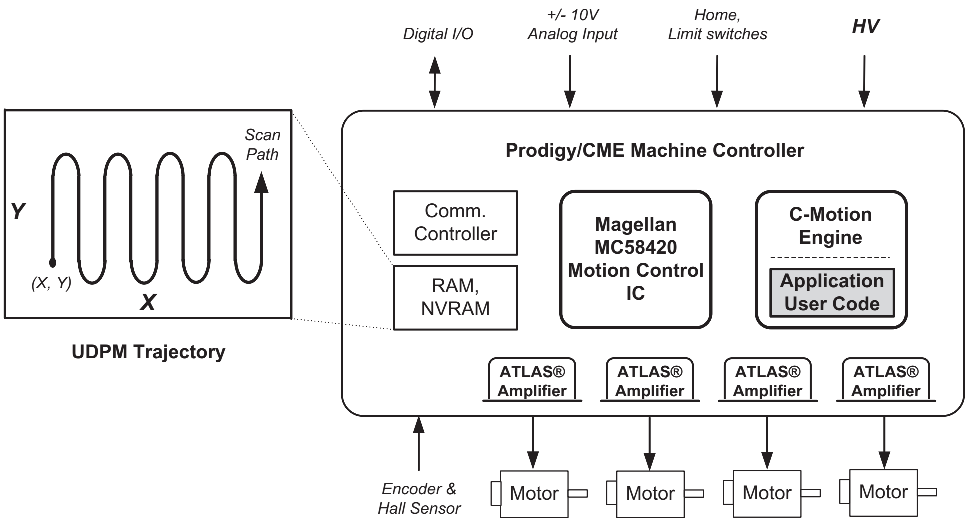


Figure 1-8: Multi-Axis Synchronized Contouring Application

In this application the Prodigy/CME Machine-Controller uses its User Defined Profile Mode to perform precisely synchronized multi-axis contouring such as is used with CNC machine tools, 3-D printers, label cutting machines, laser engravers, SCARA robots, and other devices.

User Defined Profile Mode (UDPM) is available by special order for Prodigy/CME Machine Controllers, MC5x000 Multi-Axis Motion Control ICs, MC58113 Single-Axis Motion Control ICs, and ION/CME N-Series ION Digital Drives. UDPM allows arbitrary trajectory paths for each controlled axis to be loaded into the motion controller's onboard memory and then executed using a master rate generator. This generator which commands all UDPM-controlled axes simultaneously can be either an onboard clock generator, an external encoder (CAM function), or another profiled axis. For more information or to order a PMD product with User Defined Profile Mode contact your local PMD representative.

1.7 Prodigy/CME Machine Controller Boards in the Production Application

Each Prodigy/CME Machine-Controller, before undertaking motion control, must be programmed with control parameters appropriate for the application that it will be used in. These parameters include quantities such as position loop gains, signal sense settings, safety thresholds, and more. In addition, if C-Motion Engine user-code is to be executed on the Prodigy/CME Machine-Controller this executable memory image must be downloaded prior to operation in the production application.

The user has several choices for how control parameters and/or C-Motion user code can be loaded into the Prodigy/CME Machine-Controller board. If a host connection is present the most common approach is for application code on the host (typically a PC but could be a custom-created controller or a PLC) to send the appropriate sequence of commands to the machine controller to initialize the control settings.

If the machine controller board is operating standalone the most common approach is to use a temporary host connection to program the C-Motion Engine user application into NVRAM. This application code, once stored in the C-Motion Engine program space NVRAM, automatically executes after powerup and sets the control parameters and runs the user application. Pro-Motion, PMD's Windows-based exerciser program can be used for this purpose or alternatively the user can write their own PC-based program to perform this transfer.

For more information on downloading a user application to the C-Motion Engine, as well as facilities to check the version of downloaded code see Section 3.7.7, "Downloading and Verifying User Application Code."

Another resource on the Prodigy/CME Machine Controller board sometimes used to facilitate configuring the board for production operation is the general purpose NVRAM block. This NVRAM block allows information to be stored on the board which can be accessed by the host application code or by downloaded application code. This approach allows a single user application to be written that can support multiple board configuration. The application code reads the configuration from the NVRAM and then executes code sequences according to the programmed board configuration. For more information on the machine controller's general purpose NVRAM block see Section 3.6.2, "Non-volatile Memory."

1.7.1 Unit Resource Information & Part Numbers

There are various resources on the Prodigy/CME Machine-Controller board that contain programmable logic or firmware. It may be beneficial to the user to be aware of revision information associated with these logic or firmware resources.

If Atlas units are installed on the machine controller board it may similarly be useful to query each Atlas unit for version information.

For information on how to electronically query machine controller board and Atlas unit revision information refer to Section 3.6.8, "Board Resource Information."

2. Specifications & General Information

In This Chapter

2.1 Configurations, Parameters, and Performance

Number of axes	1, 2, 3, or 4
Supported motor types	DC Brush, Brushless DC, Step motor
Profile modes	S-curve point-to-point - Position, velocity, acceleration/deceleration, jerk Trapezoidal point-to-point - Position, velocity, acceleration, deceleration Velocity-contouring - Velocity, acceleration, deceleration Electronic gearing - gear ratio
Position loop	Scalable PID with velocity and acceleration feedforward, integration limit, offset bias, dual biquad filter, and settable derivative sampling time. Also supports dual encoder feedback.
Current loop (with Atlas Amplifier)	FOC (Field Oriented Control) with space-vector PWM, leg current sensing, scalable PI with integration limit and torque/current limit
General purpose NVRAM	4 KB
Motion Control IC trace RAM	128 KB
Maximum number of simultaneous trace variables	4
Commutation rate	19.53 kHz
Current loop rate (with Atlas Amplifier)	19.53 kHz
PWM frequency (with Atlas Amplifier)	20 kHz, 40 kHz, 80 kHz
Servo cycle time range	51.2 μSeconds per axis (19.53 kHz) to 1.114 seconds

Position range	-2,147,483,648 to +2,147,483,647 counts or steps
Velocity range	-32,768 to +32,767 counts or steps per cycle with a resolution of 1/65,536 counts or steps per cycle
Acceleration and deceleration ranges	0 to +32,767 counts or steps per $cycle^2$ with a resolution of 1/65,536 counts or steps per $cycle^2$
Jerk range	0 to ½ counts or steps per $cycle^3$ with a resolution of 1/4,294,967,296 counts or steps per $cycle^3$
Electronic gear ratio range	-32,768 to +32,767 with a resolution of 1/65,536 (negative and positive direction
Position error tracking	Motion error window allows axis to be stopped upon exceeding programmable window Tracking window allows flag to be set if position error is within a programmable position window Axis settled function allows flag to be set if position error is within programmable position window for a programmable amount of time after trajectory motion is complete
Multi-axis synchronization	<1 μsec difference between master and slave servo cycle
Current measurement resolution (with Atlas Amplifier)	12 bits
Brushless DC commutation sources	Hall sensors, encoder
Microstepping resolution	Up to 256 microsteps per full step
Axis control signals	Enable, AxisIn, AxisOut, Synch, HostInterrupt, PosLim, NegLim, Home, FaultOut
Motor amplifier (with Atlas Amplifier)	Four quadrant MOSFET-based switching amplifier with individual leg current sensing
Current control options (with Atlas Amplifier)	Phase A/B, FOC (Field Oriented Control), third leg floating
Drive safety functions (with Atlas Amplifier)	Over current detect, over temperature detect, over voltage detect, under voltage detect, I^2t current foldback
Host communications options	RS232, RS485, CAN, Ethernet
Serial protocols supported	RS232 (Serial1, Serial2), RS422 (Serial1), RS485 half duplex (Serial1), RS485 full duplex (Serial1)
Serial port baud range	1,200 to 460,800 (Serial1, Serial2)
CAN protocols supported	CANbus 2.0, non-isolated
CAN nominal baud rate	50,000 to 1,000,000
Ethernet port	100 Base-TX
Ethernet protocols supported	TCP, UDP, DHCP
Encoder formats supported	Quadrature AB
Quadrature max rate	25 Mcounts/sec
Position capture signal sources	Index, home
C-Motion engine CPU speed	96 MIPS

User program space NVRAM	256 KB
User stack RAM	8 KB
User scratch RAM	8 KB
General purpose digital IOs	16 total (8 bi-directional digital I/Os, 4 inputs, 4 outputs)
General purpose analog input	8 channel differential +/-10V analog input
Analog input measurement resolution	16 bits
General purpose analog output	8 channel single-ended +/- 10V analog output
Analog output resolutlion	16 bits

2.2 Absolute Maximum Ratings

HV voltage range:	0V to +60V
+5V voltage range:	-0.3V to +5.5V
Storage Temperature:	-20 to +125 C
Operating temperature	0 to +70 degrees C (32° F to +158° F)

2.3 Electrical Ratings

HV power requirement:	+12V to + 56V operating range
Optional +5V requirement:	4.75V to 5.25V operating range
Analog (DAC) output range:	-10.0V to +10.0V, ± 3mA min/axis, short circuit protected
Analog input range:	-10.0V to +10.0V, 80.4 KOhm input impedance
Digital I/O voltage range:	0V to 5V, TTL thresholds, inputs pulled up to 5V through 4.7 kOhm resistors
Digital outputs drive capacity:	DC output source or sink current: ± 50mA

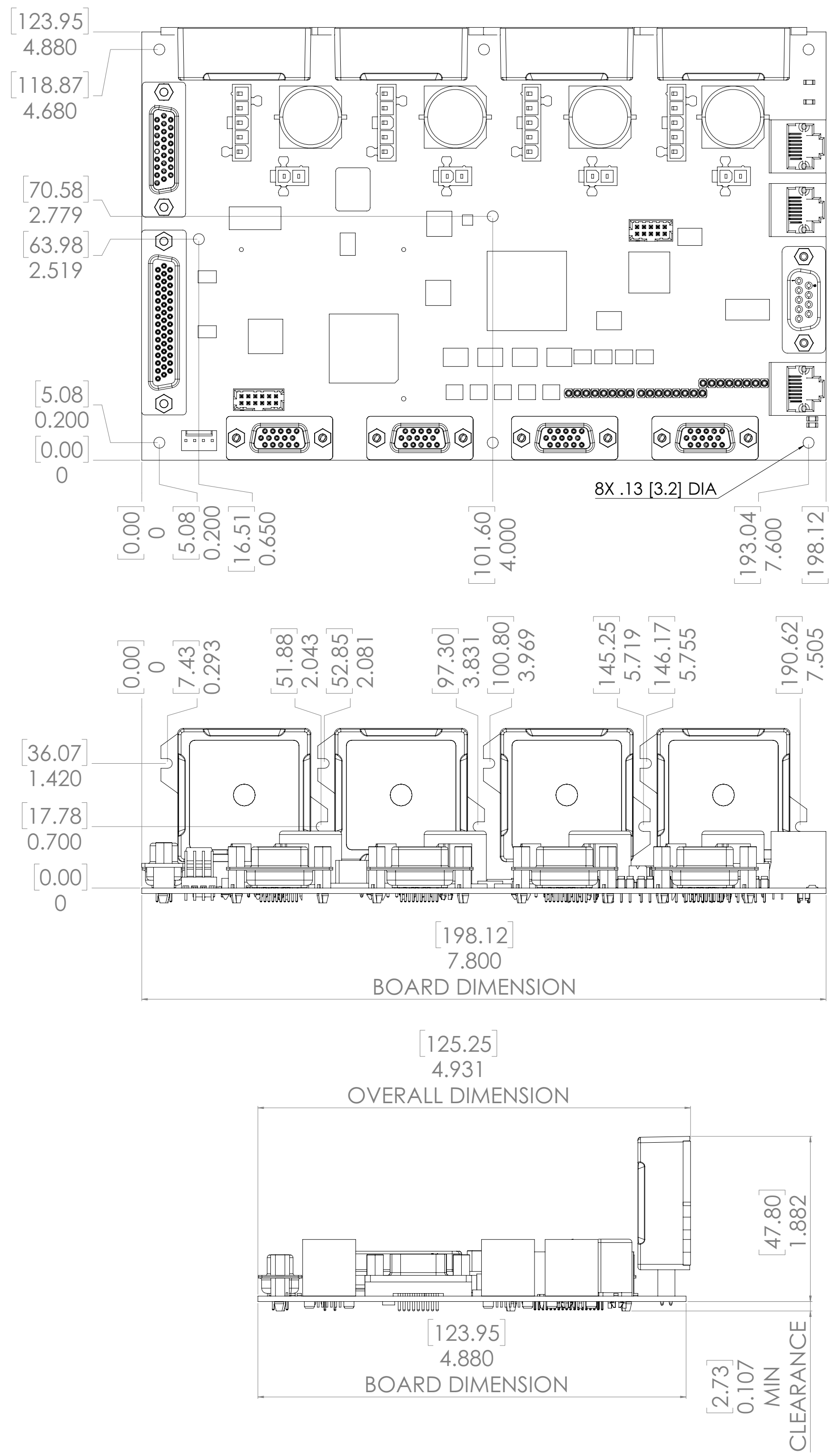
2.4 Certifications & Compliance

Specification	Standard
CE	LVD: EN60204-1 EMC-D: EN6100-6-1, EN61000-6-3, EN55011

2.5 Mechanical Dimensions

The size of the board is 7.80” L x 4.88” W (198.12 mm x 123.95 mm). For purposes of illustration two sets of dimensional drawings are shown, one with compact Atlas units installed in the board, and one with ultra-compact units installed. The vertical dimensions of the installed ultra-compact Atlas units include a converter card. See Appendix A, *Installing Atlas Units into the Board*, for details.

Figure 2-1: Prodigy/CME Machine-Controller Mechanical Dimensions With Compact Atlas Amplifiers Installed



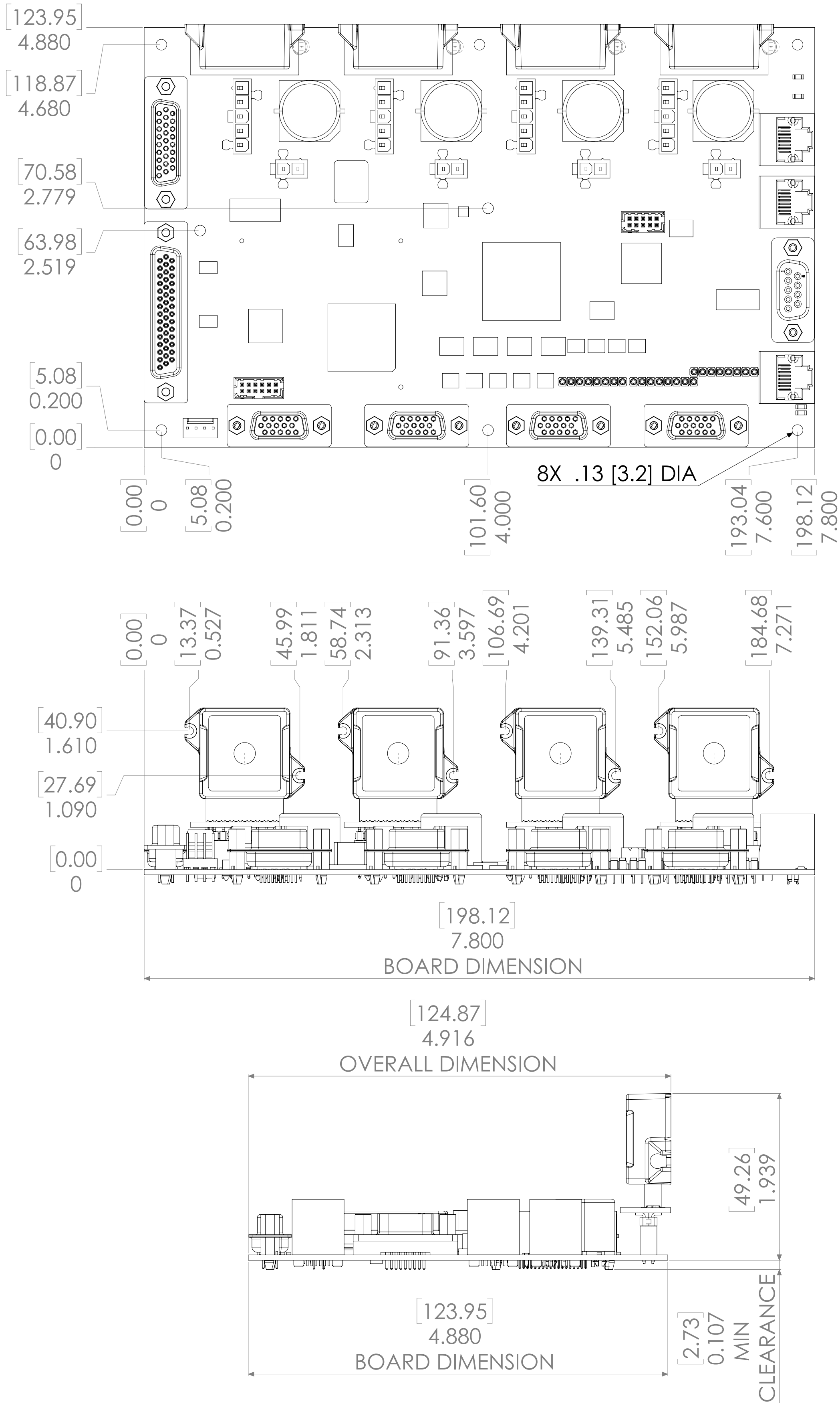


Figure 2-2: Prodigy/CME Machine-Controller Mechanical Dimensions With Ultra-Compact Atlas Amplifiers Installed

2.6 Board Component Placement

Figure 2-3 illustrates the locations of the principal components of the Prodigy/CME Machine-Controller board.

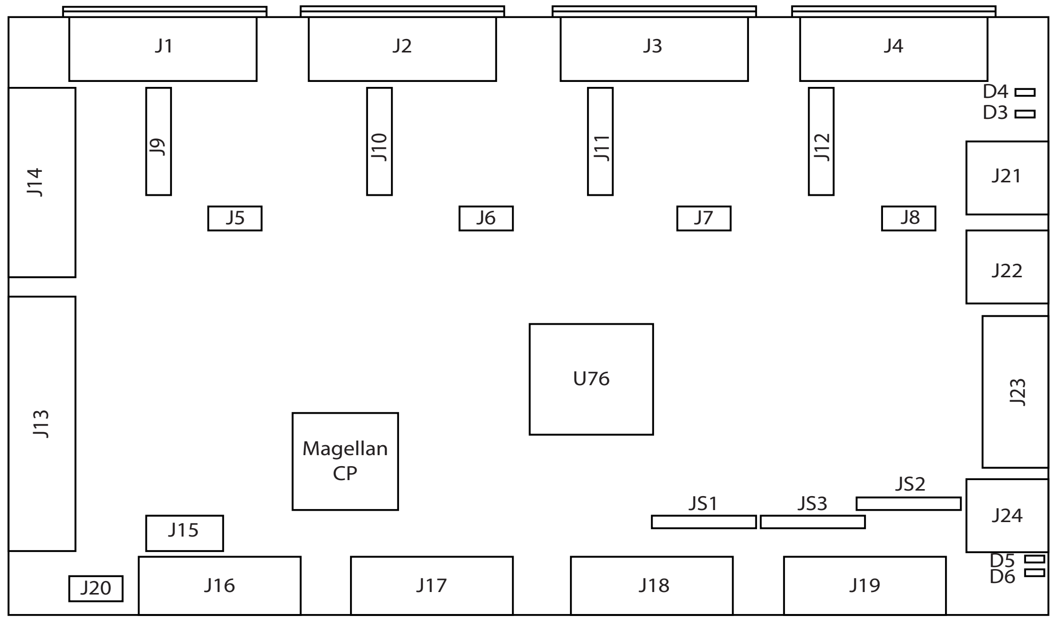


Figure 2-3: Components and Layout, Front of Board

2.7 Connectors

2.7.1 Connector Overview

There are 24 user-accessible connectors on the Prodigy/CME Machine-Controller board. See Figure 2-3 for the specific locations of the connectors on the board. The connectors and their functions are outlined in the following table:

Connector Name	Connector #	Functionality
Axis 1 Atlas	J1	Provides socket for Axis 1 pluggable Atlas unit.
Axis 2 Atlas	J2	Provides socket for Axis 2 pluggable Atlas unit.
Axis 3 Atlas	J3	Provides socket for Axis 3 pluggable Atlas unit.
Axis 4 Atlas	J4	Provides socket for Axis 4 pluggable Atlas unit.
Axis 1 Power	J5	Provides power to the whole board plus Axis 1 Atlas unit. It accepts DC supply in the range of +12 – 56 VDC.
Axis 2 Power	J6	Provides power to the Axis 2 Atlas unit. It accepts DC supply in the range of +12 – 56 VDC.
Axis 3 Power	J7	Provides power to the Axis 3 Atlas unit. It accepts DC supply in the range of +12 – 56 VDC.
Axis 4 Power	J8	Provides power to the Axis 4 Atlas unit. It accepts DC supply in the range of +12 – 56 VDC.
Axis 1 Motor Drive	J9	Provides direct motor control signals for Axis 1.
Axis 2 Motor Drive	J10	Provides direct motor control signals for Axis 2.
Axis 3 Motor Drive	J11	Provides direct motor control signals for Axis 3.
Axis 4 Motor Drive	J12	Provides direct motor control signals for Axis 4.

Connector Name	Connector #	Functionality
General I/O	J13	Provides the following general I/O interfaces to the board: 8 channels of bi-directional digital I/O; 4 channels of digital inputs; 4 channels of digital outputs; 8 channels of differential analog.
Amplifier I/O	J14	Provides amplifier enable outputs for 4 axes. Provides 8 *AnalogOutput* signals for controlling external amplifiers or general purpose ±10V analog output. Provides *AxisIn* and *AxisOut* connections for all four axes.
Expansion	J15	Provides synchronization of multiple Prodigy Machine-Controller boards within a single system.
Axis 1 Feedback	J16	Provides differential or single-ended motor encoder feedback signals such as *Quad A/B*, *Index*, *Hall A/B/C*, *PosLim* and *NegLim* for Axis1.
Axis 2 Feedback	J17	Provides differential or single-ended motor encoder feedback signals such as Quad A/B, Index, Hall A/B/C, PosLim and NegLim for Axis 2.
Axis 3 Feedback	J18	Provides differential or single-ended motor encoder feedback signals such as *Quad A/B*, *Index*, *Hall A/B/C*, *PosLim* and *NegLim* for Axis 3.
Axis 4 Feedback	J19	Provides differential or single-ended motor encoder feedback signals such as *Quad A/B*, *Index*, *Hall A/B/C*, *PosLim* and *NegLim* for Axis 4.
+5V Power	J20	Provides logic power to the board when HV1 is not available.
CAN1, CAN2	J21, J22	RJ45 connector that provide connection to a CAN 2.0B network.
Serial	J23	DB-9 serial port for RS232 or RS485 connections.
Ethernet	J24	RJ45 connector that provide connection to an Ethernet TCP/IP network

2.7.2 Feedback Connectors (J16-J19)

The Feedback Connectors (J16 – J19 in Figure 2-3) provide connections to various motor feedback signals using 15-pin high density DB connectors. If you have ordered the developer kit version of the machine controller you may find it convenient to use the included DB15 expander boards (PMD P/N: MCH-HW-05) to make these connections.

For Brushless DC motors, the Feedback Connector also connects the Hall effect signals typically used to commutate the motor. The Halls are not used with the DC Brush or step motors.

Vcc (+5V) output is provided in each of the Feedback Connectors. These outputs are typically used to power the encoder and Hall circuitry. The drive capacity of each 5V output is 100 mA.

2.7.2.1 Axis 1 Feedback Connector

Pin	Connection	Description
		J16
1	QuadA1+	Axis 1 Quadrature A+ encoder input
2	QuadA1-	Axis 1 Quadrature A- encoder input
3	QuadB1+	Axis 1 Quadrature B+ encoder input
4	QuadB1-	Axis 1 Quadrature B - encoder input
5	GND	Ground
6	Index1+	Axis 1 Index+ input
7	Index1-	Axis 1 Index1- input

Pin	Connection	Description
8	HallA1	Axis 1 Hall A input
9	HallB1	Axis 1 Hall B input
10	HallC1	Axis 1 Hall C input
11	Home1	Axis 1 Home input
12	PosLim1	Axis 1 Positive direction limit switch input
13	NegLim1	Axis 1 Negative direction limit switch input
14	Vcc	+5V
15	GND	Ground

2.7.2.2 Axis 2 Feedback Connector

Pin	Connection	Description
		J17
1	QuadA2+	Axis 2 Quadrature A+ encoder input
2	QuadA2-	Axis 2 Quadrature A- encoder input
3	QuadB2+	Axis 2 Quadrature B+ encoder input
4	QuadB2-	Axis 2 Quadrature B- encoder input
5	GND	Ground
6	Index2+	Axis 2 Index+ input
7	Index2-	Axis 2 Index- input
8	HallA2	Axis 2 Hall A input
9	HallB2	Axis 2 Hall B input
10	HallC2	Axis 2 Hall C input
11	Home2	Axis 2 Home input
12	PosLim2	Axis 2 Positive direction limit switch input
13	NegLim2	Axis 2 Negative direction limit switch input
14	Vcc	+5V
15	GND	Ground

2.7.2.3 Axis 3 Feedback Connector

Pin	Connection	Description
		J18
1	QuadA3+	Axis 3 Quadrature A+ encoder input
2	QuadA3-	Axis 3 Quadrature A- encoder input
3	QuadB3+	Axis 3 Quadrature B+ encoder input
4	QuadB3-	Axis 3 Quadrature B- encoder input
5	GND	Ground
6	Index3+	Axis 3 Index+ input
7	Index3-	Axis 3 Index- input
8	HallA3	Axis 3 Hall A input
9	HallB3	Axis 3 Hall B input
10	HallC3	Axis 3 Hall C input
11	Home3	Axis 3 Home input
12	PosLim3	Axis 3 Positive direction limit switch input
13	NegLim1	Axis 3 Negative direction limit switch input
14	Vcc	+5V
15	GND	Ground

2.7.2.4 Axis 4 Feedback Connector

Pin	Connection	Description
		J19
1	QuadA4+	Axis 4 Quadrature A+ encoder input
2	QuadA4-	Axis 4 Quadrature A- encoder input
3	QuadB4+	Axis 4 Quadrature B+ encoder input
4	QuadB4-	Axis 4 Quadrature B- encoder input
5	GND	Ground
6	Index4+	Axis 4 Index+ input
7	Index4-	Axis 4 Index- input
8	HallA4	Axis 4 Hall A input
9	HallB4	Axis 4 Hall B input
10	HallC4	Axis 4 Hall C input
11	Home4	Axis 4 Home input
12	PosLim4	Axis 4 Positive direction limit switch input
13	NegLim4	Axis 4 Negative direction limit switch input
14	Vcc	+5V
15	GND	Ground

2.7.2.5 Encoder Connections & Resistor Pack Installation

Encoder inputs may be connected differentially, with two wires for *QuadA*, *QuadB*, and *Index* signals, or with just one wire per signal. If differential connections are being used, resistor packs JS1, JS2, and JS3 should remain installed. If single-ended encoders are used, remove all three resistor packs, and connect encoder signals to the positive encoder input only. The negative input may remain unconnected.

The following table shows the relationship between the encoder input mode and resistor packs:

Item	Setting	Description
Resistor packs JSl, JS2, JS3	Installed; this is the default setting of resistor packs JS1 - JS3.	If differential connections are being used, leave the resistor packs installed.
	Removed	If single-ended encoder connections are being used, remove the resistor packs.

Differential encoder connections are detailed in the following table.

Signal	J16 – J19			
	Axis 1	**Axis 2**	**Axis 3**	**Axis 4**
QuadA*n*+	J16-1	J17-1	J18-1	J19-1
QuadA*n*-	J16-2	J17-2	J18-2	J19-2
QuadB*n*+	J16-3	J17-3	J18-3	J19-3
QuadB*n*-	J16-4	J17-4	J18-4	J19-4
Index*n*+	J16-6	J17-6	J18-6	J19-6
Index*n*-	J16-7	J17-7	J18-7	J19-7
Vcc	J16-14	J17-14	J18-14	J19-14
GND	J16-15	J17-15	J18-15	J19-15

Single-ended encoder connections are detailed in the following table.

Signal	J16 – J19 Axis 1	Axis 2	Axis 3	Axis 4
QuadA*n*	J16-1	J17-1	J18-1	J19-1
QuadB*n*	J16-3	J17-3	J18-3	J19-3
Index*n*	J16-6	J17-6	J18-6	J19-6
Vcc	J16-14	J17-14	J18-14	J19-14
GND	J16-15	J17-15	J18-15	J19-15

2.7.2.6 Using Both Single-Ended and Differential Encoder Connections

When both single-ended and differential encoders are used on the same board a special arrangement of the connections is needed. If Axis 1 or Axis 2 has a single-ended encoder, remove the resistor packs installed on JS1 and JS3. JS1, JS2, and JS3 are the connectors that receive the RS1, RS2, and RS3 resistor packs, respectively. If Axis3 or Axis4 has a single-ended encoder, remove the packs installed on JS2 and JS3.

For any axis that has a differential encoder and the corresponding resistor pack has been removed, a 120 ohm resistor needs to be installed as follows:

	Axis 1	Axis 2	Axis 3	Axis 4
Channel A	JS1-1,2	JS1-5,6	JS2-1,2	JS2-5,6
Channel B	JS1-3,4	JS1-7,8	JS2-3,4	JS2-7,8
Index (Z)	JS3-1,2	JS3-3,4	JS3-5,6	JS3-7,8

Every cell in the table above represents an installed 120 ohm resistor at that location. For example JS1-1,2 implies that one terminal of the resistor is connected to JS1-1 and the other terminal is connected to JS1-2.

2.7.3 Atlas Connectors (J1-J4)

The Atlas Connectors (J1 – J4) are sockets that accept vertical Atlas amplifier units.

Installation of Atlas Amplifiers into these sockets is optional. For information on installing both compact and ultra-compact Atlas Amplifiers into the machine controller board, see Appendix A, *Installing Atlas Units into the Board*.

2.7.3.1 Axis 1 Atlas Socket

Pin	Connection	Description
		J1
1	GND	Power return for HV1, Motor A, Motor B, Motor C and Motor D.
2	GND	Power return for HV1, Motor A, Motor B, Motor C and Motor D.
3	HV1	DC power to axis 1 Atlas amplifier, referenced to GND.
4	HV1	DC power to axis 1 Atlas amplifier, referenced to GND.
5	Motor A1	Axis 1 motor output signal A.
6	Motor A1	Axis 1 motor output signal A.
7	Motor B1	Axis 1 motor output signal B.
8	Motor B1	Axis 1 motor output signal B.
9	Motor C1	Axis 1 motor output signal C.
10	Motor C1	Axis 1 motor output signal C.
11	Motor D1	Axis 1 motor output signal D.
12	Motor D1	Axis 1 motor output signal D.
13	~Enable1	An active-low enable signal.
14	FaultOut1	FaultOut1 provides programmable fault indication.
15	NC	Not Connected.

Pin	Connection	Description
16	GND	Ground return for ~Enable, FaultOut, or SPI signals.
17	~SPICS1	Atlas SPI bus slave select1.
18	SPISI	Atlas SPI bus master output, slave input.
19	SPICLK	Atlas SPI bus serial clock.
20	SPISO	Atlas SPI bus master input, slave output.

2.7.3.2 Axis 2 Atlas Socket

Pin	Connection	Description
		J2
1	GND	Power return for HV2, Motor A, Motor B, Motor C and Motor D.
2	GND	Power return for HV2, Motor A, Motor B, Motor C and Motor D.
3	HV2	DC power to Axis 2 Atlas amplifier, referenced to GND.
4	HV2	DC power to Axis 2 Atlas amplifier, referenced to GND.
5	Motor A2	Axis 2 motor output signal A.
6	Motor A2	Axis 2 motor output signal A.
7	Motor B2	Axis 2 motor output signal B.
8	Motor B2	Axis 2 motor output signal B.
9	Motor C2	Axis 2 motor output signal C.
10	Motor C2	Axis 2 motor output signal C.
11	Motor D2	Axis 2 motor output signal D.
12	Motor D2	Axis 2 motor output signal D.
13	~Enable2	An active-low enable signal.
14	FaultOut2	FaultOut2 provides programmable fault indication.
15	NC	Not Connected.
16	GND	Ground return for ~Enable, FaultOut, or SPI signals.
17	~SPICS2	Atlas SPI bus slave select2.
18	SPISI	Atlas SPI bus master output, slave input.
19	SPICLK	Atlas SPI bus serial clock.
20	SPISO	Atlas SPI bus master input, slave output.

2.7.3.3 Axis 3 Atlas Socket

Pin	Connection	Description
		J3
1	GND	Power return for HV3, Motor A, Motor B, Motor C and Motor D.
2	GND	Power return for HV3, Motor A, Motor B, Motor C and Motor D.
3	HV3	DC power to the Axis 3 Atlas amplifier, referenced to GND.
4	HV3	DC power to the Axis 3 Atlas amplifier, referenced to GND.
5	Motor A3	Axis 3 motor output signal A.
6	Motor A3	Axis 3 motor output signal A.
7	Motor B3	Axis 3 motor output signal B.
8	Motor B3	Axis 3 motor output signal B.
9	Motor C3	Axis 3 motor output signal C.
10	Motor C3	Axis 3 motor output signal C.
11	Motor D3	Axis 3 motor output signal D.
12	Motor D3	Axis 3 motor output signal D.
13	~Enable3	An active-low enable signal.
14	FaultOut3	FaultOut3 provides programmable fault indication.
15	NC	Not Connected.
16	GND	Ground return for *~Enable*, *FaultOut*, or *SPI* signals.

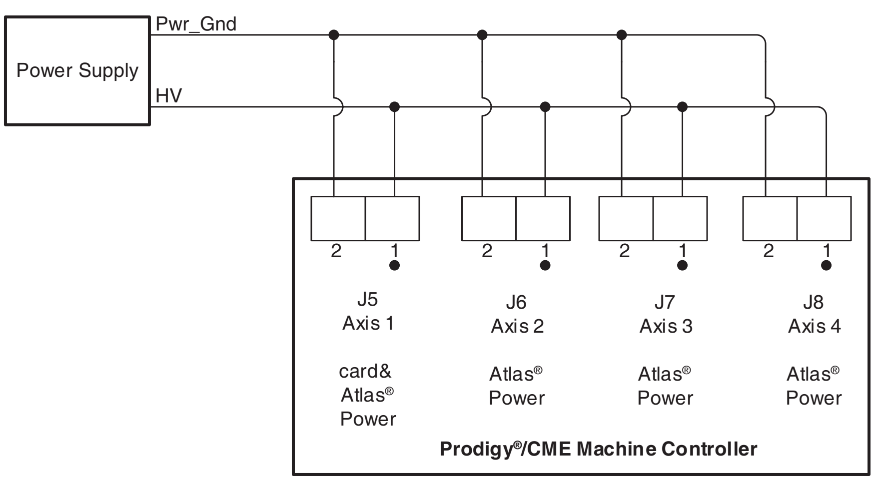
Pin	Connection	Description
17	~SPICS3	Atlas SPI bus slave select3.
18	SPISI	Atlas SPI bus master output, slave input.
19	SPICLK	Atlas SPI bus serial clock.
20	SPISO	Atlas SPI bus master input, slave output.

2.7.3.4 Axis 4 Atlas Socket

Pin	Connection	Description
		J4
1	GND	Power return for HV4, Motor A, Motor B, Motor C and Motor D.
2	GND	Power return for HV4, Motor A, Motor B, Motor C and Motor D.
3	HV4	DC power to Axis 4 Atlas amplifier, referenced to GND.
4	HV4	DC power to Axis 4 Atlas amplifier, referenced to GND.
5	Motor A4	Axis 4 motor output signal A.
6	Motor A4	Axis 4 motor output signal A.
7	Motor B4	Axis 4 motor output signal B.
8	Motor B4	Axis 4 motor output signal B.
9	Motor C4	Axis 4 motor output signal C.
10	Motor C4	Axis 4 motor output signal C.
11	Motor D4	Axis 4 motor output signal D.
12	Motor D4	Axis 4 motor output signal D.
13	~Enable4	An active-low enable signal.
14	FaultOut4	FaultOut4 provides programmable fault indication.
15	NC	Not Connected.
16	GND	Ground return for *~Enable*, *FaultOut*, or *SPI* signals.
17	~SPICS4	Atlas SPI bus slave select4.
18	SPISI	Atlas SPI bus master output, slave input.
19	SPICLK	Atlas SPI bus serial clock.
20	SPISO	Atlas SPI bus master input, slave output.

2.7.4 Power Connectors (J5-J8, J20)

Figure 2-4: Power Connections



The table below summarizes the motor power connections from the power supply to the Prodigy/CME Machine-Controller. Each motor driven by an Atlas amplifier must have separate power provided to it. Although most applications will power each axis at the same voltage from a single common supply, different voltages may be connected if desired. The input voltage range is +12 – 56VDC for high power Atlas units and +12 - 48VDC for low and medium power Atlas units.

When Atlas units are installed power should always be provided to the Axis 1 (J5) Power Connector. In addition to powering an Atlas unit, J5 is the power connection from which the board logic power is derived using onboard DC-DC converters.

If no Atlas units are installed there are two options for powering the board. The first is powering the board through J5 as indicated above. The voltage range in this circumstance is +12 – 56V. The second is powering the board logic directly via J20. See Section 2.7.4.5, “+5V Power Connector,” for details.

The J5-J8 Motor Power Connectors are male two- conductor Molex Mini-Fit Plus 2-style connectors. If you have ordered the developer kit version of the machine controller you may find it convenient to use the provided two-pin power stub cable sets.

2.7.4.1 Axis 1 Power Connector

Pin	Connection	Description
		J5
1	HV1	Provides DC power to the board and Axis 1 Atlas amplifier
2	GND	Ground

2.7.4.2 Axis 2 Power Connector

Pin	Connection	Description
		J6
1	HV2	Provides DC power to the Axis 2 Atlas amplifier
2	GND	Ground

2.7.4.3 Axis 3 Power Connector

Pin	Connection	Description
		J7
1	HV3	Provides DC power to the Axis 3 Atlas amplifier
2	GND	Ground

2.7.4.4 Axis 4 Power Connector

Pin	Connection	Description
		J8
1	HV4	Provides DC power to the Axis 4 Atlas amplifier
2	GND	Ground

2.7.4.5 +5V Power Connector

A direct +5V power connector (J20) is available which powers just the logic on the board. This can only be used when power to HV1 is not present (J5). J20 uses a Molex 3.00 Pitch Micro-Fit Header, 4-signal, single row, vertical connector. This +5V DC supply should have a minimum current capacity of 1.5A.

Providing +5V power at J20 will not power the Atlas amplifiers. There are two main uses of this direct +5V power connector. The first is to allow powering of the board when no Atlas units are installed. The second is to allow board diagnostics to be performed when Atlas units and motors are connected without powering the Atlas units or motors.

Pin	Connection	Description
		J20
1	5V	+5V power
2*	5V	+5V power
3	GND	Ground
4*	GND	Ground

* *These connections are redundant and therefore optional*

2.7.5 Motor Drive Connectors (J9-J12)

The Motor Drive connectors (J9 – J12) provide motor output signals for use with Brushless DC, DC Brush, or step motors. These are Molex 4.20mm Pitch Mini-Fit Plus HCS series, 5-signal, single row, vertical connectors.

2.7.5.1 Axis 1 Motor Connector

Pin	Connection	Description
		J9
1	Motor A1	Axis 1 motor output signal A.
2	Motor B1	Axis 1 motor output signal B.
3	Motor C1	Axis 1 motor output signal C.
4	Motor D1	Axis 1 motor output signal D.
5	Case/Shield	Ground

2.7.5.2 Axis 2 Motor Connector

Pin	Connection	Description
		J10
1	Motor A2	Axis 2 motor output signal A.
2	Motor B2	Axis 2 motor output signal B.
3	Motor C2	Axis 2 motor output signal C.
4	Motor D2	Axis 2 motor output signal D.
5	Case/Shield	Ground

2.7.5.3 Axis 3 Motor Connector

Pin	Connection	Description
		J11
1	Motor A3	Axis 3 motor output signal A.
2	Motor B3	Axis 3 motor output signal B.
3	Motor C3	Axis 3 motor output signal C.
4	Motor D3	Axis 3 motor output signal D.
5	Case/Shield	Ground

2.7.5.4 Axis 4 Motor Connector

Pin	Connection	Description
		J12
1	Motor A4	Axis 4 motor output signal A.
2	Motor B4	Axis 4 motor output signal B.
3	Motor C4	Axis 4 motor output signal C.
4	Motor D4	Axis 4 motor output signal D.
5	Case/Shield	Ground

2.7.5.5 Motor Connections Quick Reference

The following tables provide a quick-reference for Motor Drive connections to different types of motors when the Atlas amplifiers are used.

Brushless DC Motor Connections:

Connection Name	Axis 1	Axis 2	Axis 3	Axis 4
Motor A	J9-1	J10-1	J11-1	J12-1
Motor B	J9-2	J10-2	J11-2	J12-2
Motor C	J9-3	J10-3	J11-3	J12-3
Case/Shield	J9-5	J10-5	J11-5	J12-5

DC Brush Motor Connections:

Connection Name	Axis 1	Axis 2	Axis 3	Axis 4
Motor+	J9-1	J10-1	J11-1	J12-1
Motor-	J9-2	J10-2	J11-2	J12-2
Case/Shield	J9-5	J10-5	J11-5	J12-5

Step Motor Connections:

Connection Name	Axis 1	Axis 2	Axis 3	Axis 4
MotorA+	J9-1	J10-1	J11-1	J12-1
MotorA-	J9-2	J10-2	J11-2	J12-2
MotorB+	J9-3	J10-3	J11-3	J12-3
MotorB-	J9-4	J10-4	J11-4	J12-4
Case/Shield	J1-5	J10-5	J11-5	J12-5

2.7.6 General I/O Connector (J13)

The General I/O connector provides various I/O connections to the board. There are 8 channels of bi-directional digital I/O; 4 channels of digital input; 4 channels of digital output and 8 channels of differential analog inputs. This is a high density DB-44 connector.

Pin	Connection	Description	Pin	Connection	Description
			J13		
1	AnalogIn1+	Analog input 1+	2	AnalogIn1-	Analog input 1-
3	AnalogIn2+	Analog input 2+	4	AnalogIn2-	Analog input 2-
5	AGND	Ground for analog signals	6	AGND	Ground for analog signals
7	Reserved	Reserved signal	8	Reserved	Reserved signal
9	DigitalIO1	Digital input/output 1	10	DigitalIO2	Digital input/output 2

Pin	Connection	Description	Pin	Connection	Description
11	DigitalIO3	Digital input/output 3	12	GND	Ground
13	DigitalOut1	Digital output 1	14	DigitalOut2	Digital output 2
15	DigitalOut3	Digital output 3	16	AnalogIn3+	Analog input 3+
17	AnalogIn4+	Analog input 4+	18	AnalogIn5+	Analog input 5+
19	AnalogIn6+	Analog input 6+	20	AnalogIn7+	Analog input 7+
21	AnalogIn8+	Analog input 8+	22	AGND	Ground for analog signals
23	Reserved	Reserved signal	24	Reserved	Reserved signal
25	DigitalIO4	Digital input/output 4	26	DigitalIO5	Digital input/output 5
27	DigitalIO6	Digital input/output 6	28	DigitalIn1	Digital input 1
29	DigitalIn2	Digital input 2	30	DigitalOut4	Digital output 4
31	AnalogIn3-	Analog input 3-	32	AnalogIn4-	Analog input 4-
33	AnalogIn5-	Analog input 5-	34	AnalogIn6-	Analog input 6-
35	AnalogIn7-	Analog input 7-	36	AnalogIn8-	Analog input 8-
37	AGND	Ground for analog signals	38	GND	Ground
39	GND	Ground	40	DigitalIO7	Digital input/output 7
41	DigitalIO8	Digital input/output 8	42	GND	Ground
43	DigitalIn3	Digital input 3	44	DigitalIn4	Digital input 4

2.7.7 Amplifier I/O Connector (J14)

The Amplifier I/O connector provides various amplifier-related signals including amplifier enable outputs, 8 *AnalogOutput* signals, *AxisIn*, and *AxisOut* signals. This is a high density DB-26 connector.

Pin	Connection	Description	Pin	Connection	Description
			J14		
1	AmpEnable1	Axis 1 amplifier enable signal	2	AmpEnable2	Axis 2 amplifier enable signal
3	GND	Ground	4	AxisIn1	Axis 1 AxisIn input
5	AxisIn2	Axis 2 AxisIn input	6	AGND	Ground for analog signals
7	AnalogOut1	Analog output 1	8	AnalogOut2	Analog output 2
9	AnalogOut3	Analog output 3	10	AmpEnable3	Axis 3 amplifier enable signal
11	AmpEnable4	Axis 4 amplifier enable signal	12	GND	Ground
13	AxisIn3	Axis 3 AxisIn input	14	AxisIn4	Axis 4 AxisIn input
15	AnalogOut4	Analog output 4	16	AnalogOut5	Analog output 5
17	AnalogOut6	Analog output 6	18	AGND	Ground for analog signals
19	AxisOut1	Axis 1 AxisOut output	20	AxisOut2	Axis 2 AxisOut output
21	AxisOut3	Axis 3 AxisOut output	22	AxisOut4	Axis 4 AxisOut output
23	GND	Ground	24	AGND	Ground for analog signals
25	AnalogOut7	Analog output 7	26	AnalogOut8	Analog output 8

2.7.7.1 External Amplifiers

The following tables show Amplifier I/O Connector connections to servo motors such as DC Brush and Brushless DC motors that will be driven by an external amplifier. The output is a single-ended +/-10V analog output intended to connect to a motor amplifier that accepts that command format.

Connection Name	Axis 1	Axis 2	Axis 3	Axis 4
AnalogOut1-4	J15-7	J14-8	J14-9	J14-15

2.7.8 Expansion Connector (J15)

This connector supports multi-board synchronization and an external RESET signal. Depending on whether the board is a master or slave, the *SyncOut* only or both *SyncIn* and *SyncOut* signals are used. This is a Molex 2.00 mini-pitch header, vertical, shrouded connector.

Pin	Connection	Description	Pin	Connection	Description
			J15		
1	Reserved	Reserved signal	2	Reserved	Reserved signal
3	Reserved	Reserved signal	4	SyncIn	Multiple boards SyncIn signal
5	GND	Ground	6	+5V	Maximum 100mA +5V output
7	Reserved	Reserved signal	8	Reserved	Reserved signal
9	Reserved	Reserved signal	10	SyncOut	Multiple boards SyncOut signal
11	GND	Ground	12	Reset	Active Low hardware reset

2.7.9 Serial Connector (J23)

The Serial Connector (J23) provides connections to two serial ports in RS232 mode, or a single serial port in RS485 mode. Electrically these connectors provide access to the same signals; however they have different physical connectors and wiring. The following sections provide information for the serial connector, and provide pinouts when operated in RS232 mode, RS485 full-duplex mode, and RS485 half-duplex mode.

Pin	Connection	RS232	RS485 Full Duplex	RS485 Half Duplex
			J23	
1	RS485Select	Open (default) selects RS232 mode for both Serial1 and Serial2	Tie to ground selects RS485 mode	Tie to ground selects RS485 mode
2	Srl1Xmt	Serial 1 transmit output	no connect	no connect
3	Srl1Rcv	Serial 1 receive input	no connect	no connect
4	No connect	no connect	no connect	no connect
5	GND	Ground	Ground	Ground
6	RS485Rcv+	no connect	Positive (non-inverting) receive input	no connect
7	Srl2Rcv/RS485Rcv–	Serial 2 receive input	Negative (inverting) receive input	no connect
8	Srl2Xmt/RS485Xmt+	Serial 2 transmit output	Positive (non-inverting) transmit output	Positive transmit/receive
9	RS485Xmt–	no connect	Negative (inverting) transmit output	Negative transmit/receive

Note that pins 2 and 9 are connected to each other on the board as are pins 3 and 6.

2.7.10 CAN Connectors (J21, J22)

The Prodigy/CME Machine-Controller's controller area network (CAN) transceivers are designed for use in applications employing the CAN serial communication physical layer in accordance with the ISO 11898 standard. The transceiver provides differential transmit and differential receive capability to/from a CAN controller at speeds up to 1 Mbps.

There are two different CAN connectors, J21, and J22, providing electrically identical signals. These two connectors are designed to make it easy to connect the Prodigy/CME Machine-Controller board in a daisy-chain configuration. Termination at each end of the cable run is generally recommended unless cable lengths are very short and speed is slow. ISO-11898 requires 120 Ohm termination at each end of the bus. Note that it is up to the customer to verify their network topology and operating parameters. The CANbus connector is a female RJ45 type connector.

See Section 4.2, "CAN Communications," for more information on the setting up and operating the CANbus port with Pro-Motion.

The pinouts for both the J21 and J22 CAN connector are as follows:

Pin Number	Signal	Description
		J21, J22
1	CAN+	Positive CAN signal connection
2	CAN-	Negative CAN signal connection
3	GND	Ground
4	No Connect	Pass-through signal
5	No Connect	Pass-through signal
6	No Connect	Pass-through signal
7	GND	Ground
8	No Connect	Pass-through signal

2.7.11 Ethernet Connector (J24)

The Prodigy/CME Machine-Controller's Ethernet transceivers are designed for use with 10/100 base-TX Ethernet and support both TCP and UDP protocols. See Section 4.3, "Ethernet Communications," for more information setting up and operating the Ethernet port with Pro-Motion.

The Ethernet connector is an 8-pin female RJ45, and has two status LEDs, green and amber, which provide information on the status of the Ethernet link. A solid green LED indicates that a link exists. There is a transceiver connected on the 'other side' of the connection, and a blinking green LED means that data is being transmitted. The Amber LED indicates that a 100 Mbps (mega bits per second) network is in use. Without Amber LED indicates that the network is at 10 Mbps.

The pinouts for the J24 Ethernet connector are as follows:

Pin Number	Signal	Description
		J24
1	EthernetTx+	Ethernet differential transmit positive
2	EthernetTx-	Ethernet differential transmit negative
3	EthernetRx+	Ethernet differential receive positive
4	No connect	No connect
5	No connect	No connect
6	EthernetRx-	Ethernet differential receive negative
7	No connect	No connect
8	No connect	No connect

2.8 Connector & Cable Reference

2.8.1 Connectors

The following table is supplied as a reference only.

Label	Description	Connector Part Number	Connector Mate
J1-J4	Atlas Connector	Samtec SSQ-110-01-F-D	Pluggable Atlas Unit
J5-J8	Power Connector	Molex 46015-0203	Molex 39-01-2025
J23	Serial Connector	TE Connectivity -5747150-4	DB-9 Male

Label	Description	Connector Part Number	Connector Mate
J9-J12	Motor Drive Connector	Molex 39-30-2050	Molex 39-01-4051
J22, J28	CAN Connector	(H) Amphenol FRJAE-408 (V) EDAC A00-108-620-450	Male RJ45
J24	Ethernet Connector	(H) Amphenol FRJAE-408 (V) EDAC A00-108-620-450	Male RJ45
J15	Expansion Connector	Molex 87831-1220	Molex 79107-7005
J16-19	Feedback Connector	FCI 10090929-S154VLF	High density DB-15 Male
J13	General I/O Connector	FCI 10090929-S444VLF	High density DB-44 Male
J14	Amplifier I/O Connector	FCI 10090929-S264VLF	High density DB-26 Male

2.8.2 Cables & Accessories

The following table provides a summary of the cables and accessories that are available for the Prodigy/CME Machine-Controller. All of these items are included with Prodigy/CME Machine-Controller developer kits. Alternatively, specific items in this list can be ordered separately from your local PMD representative.

Component Part Number	Description
Cable-5001-01	2-signal HV Power supply cable. This stub cable provides power to the Atlas unit for each axis. This cable may plug into the Prodigy/CME Machine-Controller board's J5 – J8 connectors.
Cable-5002-01	5-signal Motor Drive cable. This stub cable connects to the Motor Drive Connectors.
Cable-RJ45-02	Ethernet connector. This cable connects to the board's Ethernet connector.
Cable-4355-01	Bifurcated serial cable that connects to J23 Serial port and provides two RS232 serial port connections.
Cable-USB-DB9	USB to DB9 serial cable
TRM-RJ45-02	120 ohm CANbus terminator
MC-HW-03	DB44 terminal screw expander board.
MC-HW-04	DB26 terminal screw expander board.
MC-HW-05	DB15 terminal screw expander board.

For detailed signal connections for selected cables from the above table refer to the *Prodigy/CME Machine-Controller Developer Kit User Manual*.

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3. Operation

In This Chapter

- Board Function Summary
- Magellan Functions
- I/O Functions
- Communications Functions
- Atlas Amplifier Functions
- General Board Functions
- C-Motion Engine Functions

Prodigy/CME Machine-Controllers are high-performance fully programmable board-based motion controllers for DC Brush, Brushless DC, and step motors. They are based on Magellan Motion Control ICs, which perform motion command interpretation and numerous other real-time functions. They can directly host Atlas digital amplifiers for each axis, eliminating the need for off-board amplifiers. To assemble a complete motion control system the only additional components needed are motors, cables, and a power supply.

The following diagram provides a functional block diagram of the Prodigy/CME Machine-Controller board:

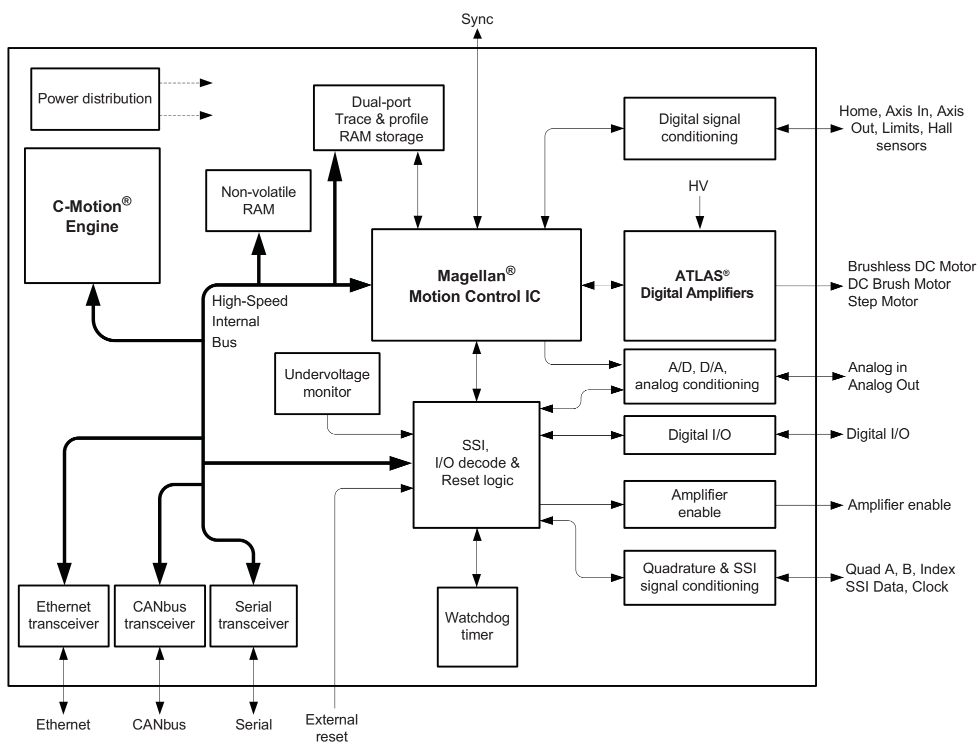


Figure 3-1: Prodigy/CME Machine-Controller Board Internal Block Diagram

3.1 Board Function Summary

Prodigy/CME Machine-Controller board functions can be broken down into six overall categories:

Magellan functions - These are functions which reside in the Magellan Motion Control IC. Included are profile generation, DC Brush and Brushless DC servo loop closure, breakpoint processing, and much more. These functions are accessed through the Magellan Motion Control IC's command set, which allows for sophisticated control of the motion axes and associated hardware.

I/O functions - These are digital and analog input and output functions. There are 16 general purpose digital channels, consisting of four dedicated inputs, four dedicated outputs, and eight bi-directional. There are eight general purpose +/- 10V analog input channels and eight general purpose +/- 10V output channels.

Communications functions - The Prodigy/CME Machine-Controller board provides sophisticated communication facilities consisting of two serial ports, a CANbus port, and an Ethernet port.

Atlas Amplifier functions - The onboard Atlas amplifiers accept motor output commands from the Magellan Motion Control IC and provide high performance current control and amplification for attached step, DC Brush, or Brushless DC motors. There are numerous programmable parameters including current gains, safety parameters, and more.

General Board functions - These are general purpose board functions such as a dual-ported RAM, a non-volatile RAM, a board reset function, a board watch-dog timer, and several others.

C-Motion Engine functions - The C-Motion Engine is a self-contained, high performance code execution unit that allows C-Motion code to be downloaded and executed on the Prodigy/CME Machine-Controller board. It can communicate with various resources on the board including the Magellan Motion Control IC, the board's serial, CANbus, and Ethernet ports, and other onboard resources such as the dual-ported RAM.

3.1.1 Board Access Basics

Access to the Prodigy/CME Machine-Controller board from the serial, CANbus, or Ethernet ports is provided by a protocol called the *PMD Resource access Protocol* (PRP). This easy-to-use yet powerful system utilizes actions, resources, and addresses to access the Prodigy/CME Machine-Controller board's functions. Various board functions are organized into resources, and resources process actions sent to them. Actions can send information, request information, or command specific events to occur. Addresses allow access to a specific resource on the board, or connected to the board, via the serial, CANbus, or Ethernet connections.

A basic communication to the Prodigy/CME Machine-Controller board consists of a 16-bit PRP header, and an optional message body. The message body contains data associated with the specified PRP action, but some actions do not require a message body. After a PRP communication is sent to the board, a return communication is sent by the Prodigy/CME Machine-Controller board which consists of a PRP header and an optional return message body. The return message body may contain information associated with the requested PRP action, or it may contain error information if there was a problem processing the requested action.

There are five different resource types supported by the Prodigy/CME Machine-Controller board. The ***Device*** resource indicates functionality that is addressed to the entire board, the ***MotionProcessor*** resource indicates a Magellan Motion Control IC, the ***CMotionEngine*** resource indicates the C-Motion Engine, the ***Memory*** resource indicates the dual- ported RAM and the non-volatile RAM (Random Access Memory), and the ***Peripheral*** resource indicates a communications connection, the digital and analog I/O functions, or other onboard registers.

There are ten different PRP actions including Command, which is used to send commands to resources such as the Magellan Motion Control IC, Send and Receive, which are used to communicate using the serial, CANbus, and Ethernet ports, Read and Write, which are used to access memory-type devices such as the onboard dual-ported RAM and the non-volatile RAM, and Set and Get, which are used to load or read parameters.

For complete information on the format and function of PMD Resource Access Protocol refer to the *C-Motion PRP Programming Reference*

> Although it may be useful to be familiar with the machine controller's command processing architecture, most users will not need to know all of these details. Most users will prototype motion sequences using PMD's Pro-Motion Windows-based program, and will use PMD's high-level C-Motion library to develop user application code. C-Motion provides C-language calls which hide low level details so that the user may conveniently access the board functions of interest to them.

In the subsequent sections of this chapter the C-Motion library functions used to access the available board functions will be provided along with the descriptions of the board functions themselves.

3.1.2 Peripheral I/O Space

Some of the machine controller's bit and word-oriented resources are accessed through what is known as the Peripheral I/O address space, also called PIO for short. This includes analog input and output, digital input and output, and various bit-oriented control registers.

The following table shows the machine controller's Peripheral I/O address map:

Address	Function	Read/Write	Comments
0x100, 0x120, 0x140, 0x160	SSI configuration register	Read & Write	0x100 is a bit-encoded register that controls the axis 1 SSI format, SSI enable/disable status, and SSI clock direction. 0x120 controls for axis 2, etc… up to 0x160 which controls these parameters for axis 4.
0x102, 0x122, 0x142, 0x162	SSI resolution register	Read & Write	0x102 is a 16-bit register that holds the SSI Absolute encoder word resolution for Axis 1. 0x122 holds the resolution for axis 2, etc… up to 0x162 which holds the resolution for axis 4.
0x104, 0x124, 0x144, 0x164	SSI frequency register	Read & Write	0x104 is a 16-bit register that holds the SSI clock frequency for Axis 1. 0x122 holds the frequency for axis 2, etc… up to 0x162 which holds the frequency for axis 4.
0x200	General purpose digital input values	Read	The 12 available input bits are stored in this register.
0x210	General purpose digital output write mask	Read & Write	The 12-bit output mask is stored in this register.
0x212	General purpose digital output write value	Read & Write	The 12 output bits are stored in this register.
0x218	Amplifier enable signal write value	Read & Write	The 4 Amplifier enable signal output bits are stored in this register.
0x21A	Amplifier enable signal write mask	Read & Write	The 4 Amplifier enable mask bits are stored in this register.
0x220	Bi-directional I/O direction mask	Read & Write	The 8 bi-directional I/O bits are stored in this register.
0x222	Bi-directional I/O direction value	Read & Write	The 8 bi-directional digital I/O bit directions are set with this register.

Address	Function	Read/Write	Comments
0x300 - 0x30E	General purpose analog output channel values for channels 1 through 8.	Read & Write	0x300 holds the channel 1 16-bit word, 0x302 holds the channel 2 16-bit word, etc… up to 0x30E which holds the channel 8 16-bit output word
0x310 - 0x31E	Analog output source selection	Read & Write	0x310 holds the analog output source (either Magellan or PRP) for channel 1, 0x312 for channel 2, etc… up to 0x31E which holds the channel 8 output source.
0x320	Analog output enable	Read & Write	When set to 1, the low bit of this register enables analog channel output. When set to 0, the analog output voltages are shunted to 0.0 volts.
0x340 - 0x34E	Analog input channel values for channels 1 through 8.	Read	0x340 holds the channel 1 16-bit input word, 0x342 holds the channel 2 16-bit input word, etc… up to 0x34E which holds the channel 8 input word.

Various C-Motion commands such as **PeriphOpen**, **PeriphRead**, and **PeriphWrite** are used to access the contents of the registers located in the Peripheral I/O address space. The specific C-motion commands required are discussed along with each of the board functions introduced in the sections below.

3.2 Magellan Functions

The Magellan Motion Control IC in Figure 3-1 forms the core of the Prodigy/CME Machine-Controller boards. Here is an overview of the functions provided by the Magellan Motion Control IC:

- Profile generation
- Quadrature encoder processing and index capture
- DC Brush and Brushless DC servo loop closure
- Breakpoint processing
- *AxisIn* and *AxisOut* signal processing
- Trace
- Motion error detection, tracking windows, and axis-settled indicator
- Limit switch processing
- Atlas amplifier interfacing
- Analog amplifier output signal generation

The Magellan Motion Control IC interfaces with motion hardware components such as feedback encoders and the onboard Atlas amplifiers directly through its own pin connections or through various signal conditioning circuitry. The following sections will provide information on all of these functions.

Magellan instructions are encoded in packets, which are sent to and from the Magellan Motion Control IC. The Magellan processes these packets, performs requested functions, and returns requested data. Generally speaking each command packet has its own C-Motion command associated with it.

Within the Prodigy/CME Machine-Controller board the Magellan uses its high-speed parallel-word communications mode to connect to the board's internal communications bus, which allows the Magellan to be controlled via the C-Motion Engine, or via an external host controller connected to the Prodigy/CME Machine-Controller board by serial, CANbus, or Ethernet port.

3.2.1 Example Magellan Command Mnemonics

The Magellan instruction set is very flexible and powerful. The following example, which sets up and executes a simple trapezoidal profile, uses command mnemonics rather than C-Motion calls to illustrate just a small part of the overall command set.

```
SetProfileMode Axis1, trapezoidal      // set profile mode to trapezoidal for axis 1
SetPosition Axis1, 12345               // load a destination position for axis 1
SetVelocity Axis1, 223344              // load a velocity for axis 1
SetAcceleration Axis1, 1000            // load an acceleration for axis 1
SetDeceleration Axis1, 2000            // load a deceleration for axis 1
Update Axis1                           // Double buffered registers are copied into
                                       // the active registers, thereby initiating the move
```

3.2.2 Example C-Motion Commands

Here is the same sequence as it would look in actual C-Motion calls:

```
PMDSetProfileMode(&hAxis1, PMDProfileTrapezoidal);
PMDSetPosition(&hAxis1, 12345);
PMDSetVelocity(&hAxis1, 223344);
PMDSetAcceleration(&hAxis1, 1000);
PMDSetDeceleration(&hAxis1, 2000);
PMDUpdate(&hAxis1);
```

In this example hAxis1 is a handle to a structure known as a PMDAxisHandle. There are other commands that address different board resources. For example C-Motion functions that address the ***Device*** resource are prefaced with PMDDevice, and C-Motion functions that address the ***Peripheral*** resource are prefaced with PMDPeriph. Each of these command types take a handle to a variable with that structure. For example commands prefaced with PMDDevice take a handle to a structure known as a PMDDeviceHandle, and commands prefaced with PMDPeriph take a handle to a structure known as a PMDPeripheralHandle.

There are many examples of C-Motion structures, and in general they are used to make accessing the Prodigy/CME Machine-Controller boards simpler and more flexible. In particular, by developing code with C-Motion, it is very easy to change the physical location of a PMD axis or other resource type such as a ***Peripheral*** without any changes to the developed C-Motion code sequences.

The manual that provides a broad overview of writing software for PMD controllers is the *C-Motion Engine Development Tools Manual*.

To learn how the Magellan Motion Control IC operates use the *Magellan Motion Control IC User Guide*. The *C-Motion Magellan Programming Reference* and the *C-Motion PRP Programming Reference* provide detailed reference information for Magellan and PRP format protocols respectively.

> To simplify the presentation of command names, most portions of this manual will provide C-Motion commands without the "PMD" preface. The actual commands however should include the PMD preface. For example the C-Motion command given in the manual as PeripheralRead is actually called PMDPeripheralRead.

3.2.3 Quadrature Encoder Input

Each axis provides differential or single-ended input of A & B quadrature inputs along with an **Index** signal. These signals provide position feedback to the motion controller which is used to track motor position. For DC Brush and Brushless DC motors, they are required for proper operation. For step motors, they are optional.

The encoder-processing circuitry provides a multi-stage digital filter of the **QuadA**, **QuadB**, and **Index** signals for each axis. This provides additional protection against erroneous noise spikes, thus improving reliability and motion integrity. The **Index** signal input is generally used to trigger a hardware capture of the quadrature encoder position. For a capture to be recognized **QuadA**, **QuadB**, and **Index** must all be in a low state. If desired however the high/low interpretation of all of these signals can be software programmed. For more on quadrature signal processing and hardware position capture refer to the *Magellan Motion Control IC User Guide*.

3.2.3.1 C-Motion Commands

There are numerous Magellan C-Motion commands that relate to the encoder feedback and index position, including commands that retrieve, capture, compare, set, or otherwise utilize the current encoder position. Refer to the *Magellan Motion Control IC User Guide* for more information.

3.2.3.2 Connections & Associated Signals

These signals are named **QuadA1+** through **QuadB4-** (16 signals), and **Index1+** through **Index4-** (8 signals), and are all located on the Axis Feedback connectors, as are the grounds that should be used with these signals.

A +5V output on each Axis Feedback connector is provided as a convenience for the encoder to power its internal circuitry. As was the case for the quadrature input signals, one or more of the digital grounds must also be connected to access the +5V. The drive capacity of each 5V output is 100mA.

The quadrature and index signals can be connected in one of two ways. Single-ended means that only one wire per signal is used, while differential means two wires encode each signal (labeled + and -). Differential transmission is generally recommended for the highest level of reliability, because it provides greater noise immunity than a single-ended connection scheme.

If single-ended connections are used, only the + wire is connected, and the - wire should be left floating. For example, in connecting to the A quadrature input, **QuadA1+** connects to the encoder's quadrature A signal, and **QuadA1-** remains floating. If differential connections are used, both the + and - signals are used. Differential or single-ended termination must be selected through resistor pack installation. See the table in Section 2.7.2.5, "Encoder Connections & Resistor Pack Installation," for details.

When using the system with differential connections, the polarity of the differential signal can be reversed by swapping the + and - connections. This may be useful for altering the motor and/or encoder direction, however, this same function can also be accomplished through commands to the Prodigy/CME Machine-Controller board. See the *Magellan Motion Control IC User Guide* for more information.

See Section 2.7, "Connectors," for a complete description of the pinout connections to and from the board.

3.2.3.3 Electrical Interfacing

All of the QuadA, QuadB and Index inputs utilize the following onboard circuitry to process these signals:

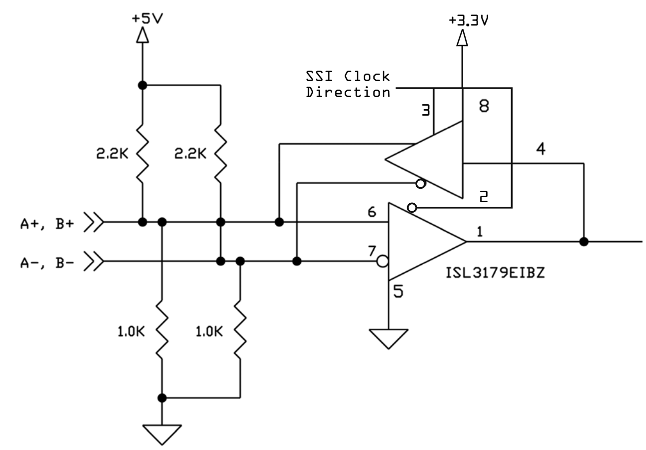
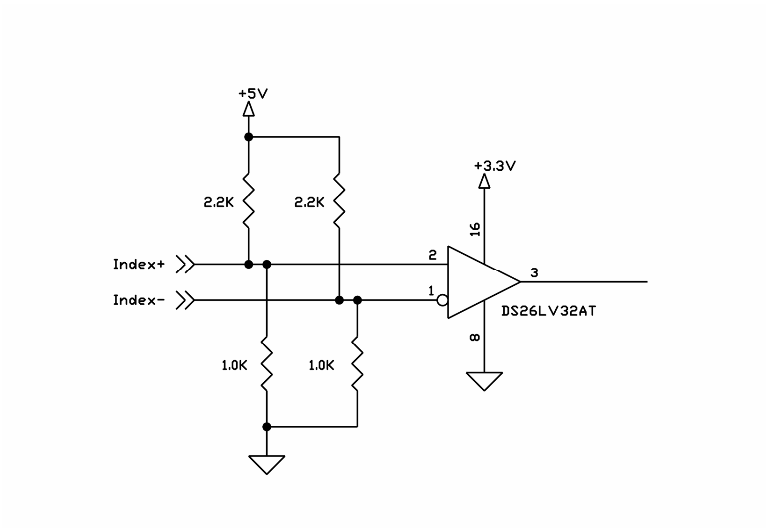


Figure 3-2: Encoder Signal Schematic QuadA/B and Index

Note that the SSI Clock Direction signal is low by default to support Quad A/B input.



3.2.4 SSI (Synchronous Serial Interface) Encoder Input

In addition to incremental quadrature feedback, the machine controller board supports Absolute SSI format encoder feedback for one or more connected axes. The Absolute SSI protocol is used to access high resolution absolute encoders that support this format.

Figure 3-3 shows a typical connection scheme. The machine controller serves as the SSI master and generates the clock signals. The encoder provides its current position at constant, regular intervals based on the SSI communication settings.

Onboard logic processes the SSI protocol, converting the axis position to a format that allows it to be input to the Magellan Motion Control IC, where it is used for servo processing and other encoder-related functions.

There are three SSI interface settings that can be set by the user. They are clock frequency, encoder resolution, and word format. The following table shows the range of settings for these parameters supported by the machine controller board:

Parameter	Range	Default Value	Comments
SSI clock frequency	500 kHz - 4.0 MHz	500 kHz	The user should set the clock frequency at the highest rate supported by the SSI encoder and cable length they will be using. Check the encoder specification for details. The setting value is calculated using the formula value = 40 MHz / F -1, where F is the desired frequency in MHz. For example for a frequency of .5 MHz (500 KHz), a value of 40/ .5 -1= 79 is specified.
SSI encoder resolution	8 bits - 31 bits	25 bits	This should be set to match the encoder word length, in bits, generated by the SSI encoder being used.
SSI encoder word format	binary or Gray	binary	This should be set to match the encoder format generated by the SSI encoder being used.
SSI enable	enabled or disabled	disabled	To enable SSI operation this field must be set to enable.
SSI clock direction	input or output	input (low)	For normal SSI interfacing the clock will be set for output. For setups where one SSI encoder will be input to multiple boards, the non-clock generating boards should be set to input.

The SSI clock frequency and SSI encoder resolution parameters are controlled via dedicated PIO registers for each axis. See Section 3.1.2, "Peripheral I/O Space," for the complete PIO register address map. The SSI encoder word format, SSI enable, and SSI clock direction parameters are encoded in a single PIO register called SSI configuration. There is one SSI configuration register per axis.

The follow table shows the bit mapping of the SSI configuration register:

Bit no.	Field name	Description
0	SSI Clock direction	A 1 in this field sets the clock signal generation for output. A 0 in this fields sets the clock signals to be input from an external source.
1	SSI Enable	A 1 in this field enables SSI operation. A 0 disables SSI operation.
2-5	SSI Encoder word format	A 0 value in this four-bit field sets the encoder format to binary. A 1 value in this four-bit fields sets the encoder format to gray code.
6-15	reserved	Reserved, may contain zeroes or ones.

Each axis allows independent control of all of these parameters, and all controllable parameters are located in the Peripheral I/O space. The table in Section 3.1.2, "Peripheral I/O Space," provides the addresses and format of each control register.

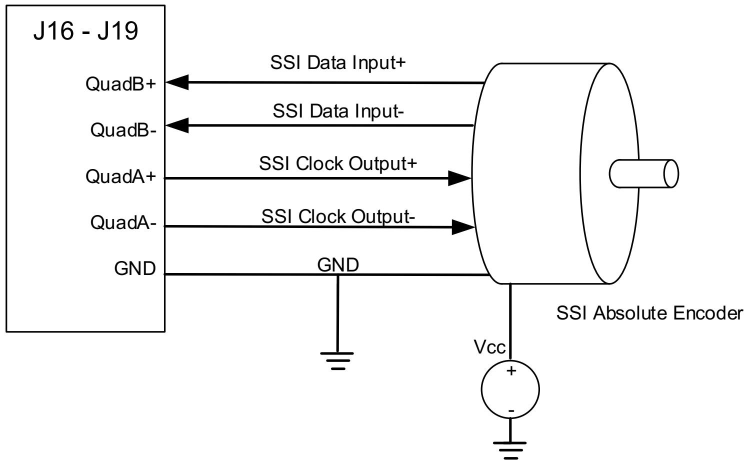


Figure 3-3: SSI with Controller as Clock Master

3.2.4.1 Connecting To Multiple Boards

There may be situations where it is desirable for a single SSI encoder to drive encoder inputs on multiple machine controller boards. The most common reason for this is that an SSI encoder will serve as the electronic gear 'master' input for multiple boards.

This configuration is shown in Figure 3-4.

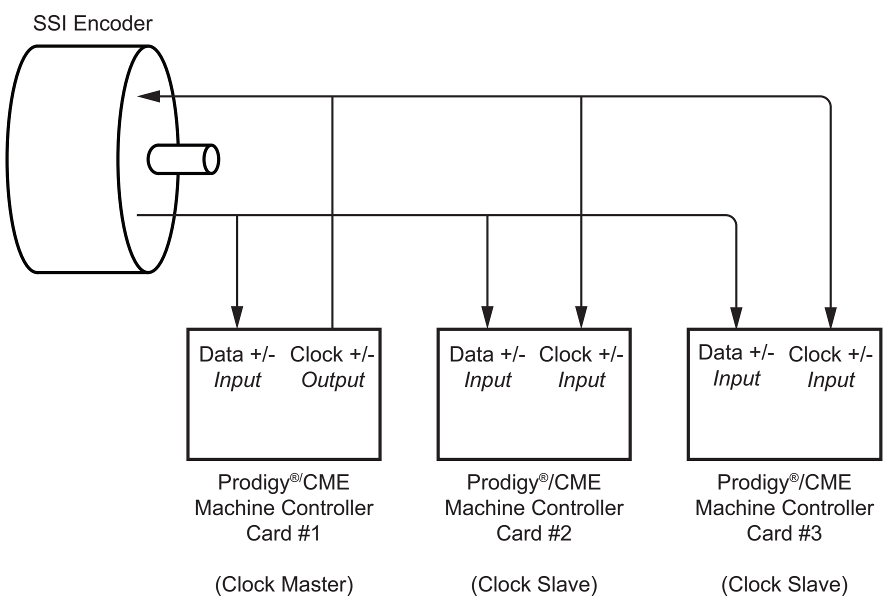


Figure 3-4: Connecting Multiple Boards

To support this configuration the machine controller allows the clock signals for a given SSI axis to be input, rather than output, by the SSI control logic. This is controlled via the SSI clock direction field located in the SSI configuration register.

3.2.4.2 SSI Operation

To enable SSI encoder operation for a particular axis the various control parameters such as word size and clock frequency should be programmed according to the SSI encoder specifications. Then the SSI Enable, SSI clock direction, and SSI encoder word format fields should be set via a single write to the SSI configuration register.

Following this, the Magellan Motion Control IC should be set for 32-bit parallel mode to enable proper data transfer from the board's SSI decode logic.

3.2.4.3 C-Motion Commands

There are several commands needed to set up a particular axis to process SSI encoder information. The Magellan IC encoder input source must be changed from the default value of incremental quadrature to parallel 32-bit word. To change the encoder input source the C-Motion command **SetEncoderSource** with parallel 32-bit word format selected is used. To read back the current value the command **GetEncoderSource** is used.

In addition, if the motor encoder is mounted on a motor that can spin multiple times, a modulus should be specified so that the Magellan IC can correctly track the encoder location as it wraps from maximum to smallest value or vice versa. This is accomplished using the C-Motion **SetEncoderModulus** command. To read the current value back the command **GetEncoderModulus** is used.

Refer to the *Magellan Motion Control IC User Guide* for more information on both of these commands.

To set or retrieve the value of the machine controller's PIO setup registers the user must first open a Peripheral of type PIO. This is accomplished using the C-Motion command **PeriphOpenPIO**.

Using the returned ***Peripheral*** handle, the user can write to the desired SSI registers using the C-Motion command **PeriphWrite**. To read back the current value of a PIO register the command **PeriphRead** is used.

For detailed PIO address register information see Section 3.1.2, "Peripheral I/O Space."

3.2.4.4 Connections & Associated Signals

The signals that support SSI are shared with the quadrature signals. Therefore when an SSI encoder is connected it is not possible to have incremental quadrature connections also input to the board. All of the SSI signals are located on the Axis Feedback Axis connectors.

The following tables shows how to connect SSI encoders:

SSI Absolute Signal Name	Prodigy/CME Machine-Controller Signal Name
Data+	QuadB+
Data-	QuadB-
Clock+	QuadA+
Clock-	QuadA-

In addition to these signals a digital ground should be connected. A +5V output on each Axis Feedback connector is also available, and can be used to power the SSI encoder circuitry.

See Section 2.7, "Connectors," for a complete description of the pinout connections to and from the board.

3.2.4.5 Electrical Interfacing

Refer to Figure 3-2 for the QuadA, QuadB and Index input onboard circuitry.

3.2.5 Home, Limits, Hall Sensors

These signals are conditioned by the board and input directly to the Magellan Motion Control IC. The *Magellan Motion Control IC User Guide* explains the functions provided in connection with these various signals. Most of the signals are optional, and are connected depending on the nature of the application. Hall sensors are used only when connecting to Brushless DC motors.

3.2.5.1 C-Motion Commands

There are numerous Magellan C-Motion commands related to processing home or limit switches as well as Hall sensor input signals. Refer to the *Magellan Motion Control IC User Guide* for complete information.

3.2.5.2 Connections & Associated Signals

These signals are named ***Home1-4***, ***PosLim1-4*** (positive direction limit input), ***NegLim1-4*** (negative direction limit input), and ***Hall1A-4C*** (12 signals in all). They are all located on the Axis Feedback connectors, as are the ground signals that should be used in conjunction with these inputs.

These signals are single-ended digital inputs to the board. One or more of the digital grounds must be connected. The input signals are pulled up through 4.7k Ohm resistors to 5V.

See Section 2.7, “Connectors,” for a complete description of the pin out connections to and from the board.

3.2.5.3 Electrical Interfacing

All of the home, limits, and Hall sensor inputs utilize the following onboard circuitry to process these signals:

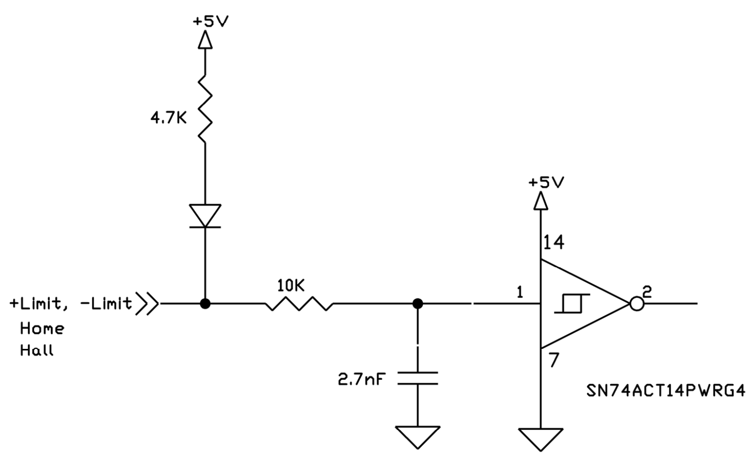


Figure 3-5: Home, Limits, and Hall Sensor Signal Schematic

3.2.6 AxisIn, AxisOut Signals

These signals are input to, or output by, the Magellan Motion Control IC and facilitate coordination of Magellan motion sequences with external hardware. These signals are optional, and are connected depending on the nature of the application.

See the *Magellan Motion Control IC User Guide* for more information on how these signal functions are programmed.

3.2.6.1 C-Motion Commands

There are a number of Magellan C-Motion commands related to processing or generating the ***AxisIn*** and ***AxisOut*** signals. Refer to the *Magellan Motion Control IC User Guide* for complete information.

3.2.6.2 Connections & Associated Signals

These signals are named *AxisIn1-4*, and *AxisOut1-4*, and are located on the Amplifier IO connector. These signals are single-ended digital inputs to the board.

To function properly, one or more of the digital grounds must be connected.

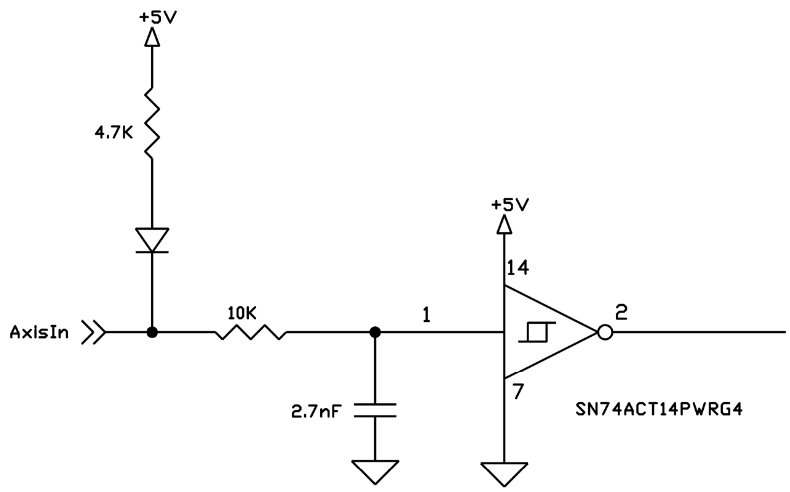
The input signals are pulled up through 4.7k Ohm resistors to 5V. The default power-up value for all *AxisOut* signals is high.

See Section 2.7, “Connectors,” for a complete description of the pinout connections to and from the board.

3.2.6.3 Electrical Interfacing

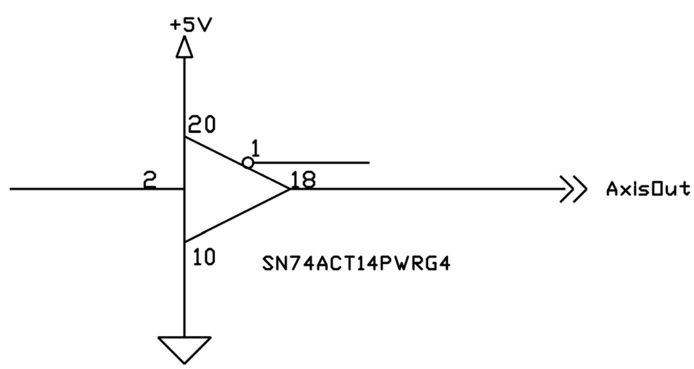
AxisIn signal processing is identical to home, limits, and Hall sensor input and is shown in Figure 3-6.

Figure 3-6: AxisIn Signal Schematic



The *AxisOut* signal is generated using the following circuitry: Note that the *AxisOut* signal can source +/-24mA.

Figure 3-7: AxisOut Signal Schematic



3.2.7 Atlas Interfacing

The Magellan Motion Control IC communicates to installed Atlas amplifiers via an SPI (Serial Peripheral Interface) bus. The format and protocol of this bus is detailed in the *Atlas Digital Amplifier Complete Technical Reference*, however all Magellan/Atlas communications are handled automatically without need for user action.

Many Atlas control parameters are user-settable, and these parameters are accessed through the Magellan Motion Control IC. The Magellan IC provides a single, seamless, interface to the user by determining whether commands sent to it should be routed to the Atlas amplifier or processed by the Magellan IC. See Section 3.5, "Atlas Amplifier Functions," for more information on overall Atlas function. See the *Magellan Motion Control IC User Guide* for information on the Magellan/Atlas control architecture.

3.2.7.1 C-Motion Commands

There are numerous Magellan C-Motion commands that relate to Atlas amplifier operation. Refer to the *Magellan Motion Control IC User Guide* for complete information.

3.2.7.2 Connections & Associated Signals

There are no connections or signals associated with this function. All of the signals interconnecting the Magellan Motion Control IC and Atlas digital amplifiers are internal to the board. For information on connections associated with the Atlas amplifiers, see Section 3.5, "Atlas Amplifier Functions."

3.2.8 Analog Motor Command Output

The Magellan Motion Control IC can output a desired voltage or torque command on analog output signals. There are eight channels in total, with each channel consisting of 16-bit +/- 10V signals (16 signals in all). When driven by the Magellan Motion Control IC these analog outputs carry the desired voltage or torque for a given axis, and are designed to interface to an off-board motor amplifier.

Analog motor outputs are useful when onboard Atlases are not being used as the amplifier for a particular axis. This may be the case when the motor requires a higher voltage or current power range than the Atlas units provide, or when the amplifier must have particular motor-specific characteristics not provided by the Atlas amplifiers.

The analog motor command outputs are used to interface to a DC Brush motor amplifier or to a Brushless DC motor which is commutated externally, one analog output channel is used per axis.

The following table shows how the analog outputs should be connected:.

Motor Type	Axis #	Channel
DC Brush (or externally commutated Brushless DC motors)	1	AnalogOut1
	2	AnalogOut2
	3	AnalogOut3
	4	AnalogOut4

3.2.8.1 AnalogOut Enable

To help insure that machine controller and external amplifier power startups do not induce unexpected motion, the machine controller board provides a mechanism to separately enable or disable the analog output channels. The default on power up is disabled, resulting in a zero voltage output at the analog output signals.

> The analog output channels must be enabled by the user before they can output non-zero voltage values.

Note that the machine controller's analog output circuitry can be controlled by two separate sources. One source is the Magellan Motion Control IC as described above. The other source is via the PRP interface. The default is control by the Magellan Motion Control IC. For information on controlling the analog outputs as general purpose outputs through the PRP interface see Section 3.3.5, "General Purpose Analog Output."

3.2.8.2 C-Motion Commands

Upon powerup the machine controller board will automatically set any axes that do not have an installed Atlas amplifier to analog output mode. Therefore, in most cases it is not necessary to explicitly set a particular axis to analog motor output mode.

If desired, the motor output mode for an axis can be programmed directly. To set an axis for analog output mode the C-Motion command **SetOutputMode** is used. The value set can be read back using **GetOutputMode**. See the *Magellan Motion Control IC User Guide* for more information.

> If the Magellan Motion Control IC is instructed to send motor commands via analog output, any connected Atlas amplifier will immediately cease to communicate with the Magellan. Care should therefore be taken when commanding analog output mode for axes that have an installed Atlas amplifier.

3.2.8.3 Connections & Associated Signals

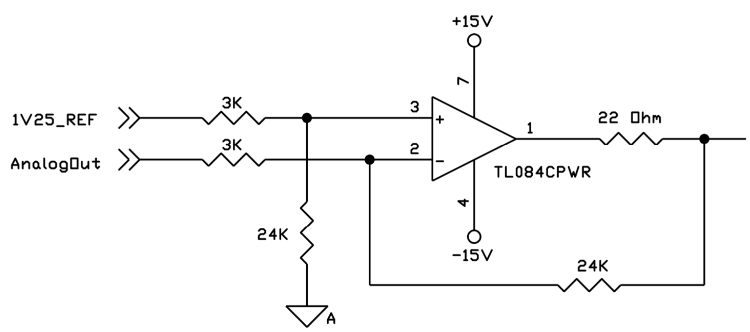
These signals are named AnalogOut1-8+ and are located on the Amplifier IO connector. They are single-ended analog outputs which vary between -10V and +10V.

For the analog outputs to function correctly, AGND (analog ground) must be connected. There are three analog grounds available, all located on the Amplifier IO connector.

3.2.8.4 Electrical Interfacing

The analog output signals are generated using the following circuitry:

Figure 3-8: Analog Output Signal Schematic



3.2.9 Magellan Watchdog Timer

The machine controller board provides a watchdog function for Magellan I/O transactions. When enabled, the watchdog automatically triggers a Magellan reset if communication to the Magellan should be lost. The most common use of this feature is to allow motion functions to be safely shut down if onboard user application code running on the C-Motion Engine unexpectedly stops sending commands to the Magellan, or if an external controller such as a PC unexpectedly stops sending commands to the Magellan.

See Section 3.2.10, “Magellan Reset,” for a description of the actions and signal changes that occur after a board reset.

The Magellan watchdog functions by requiring a specific value (0x5562) be sent to a specific Magellan I/O address (4) at intervals not exceeding 104 mSec. As long as the watchdog value is written within the 104-mSec interval, no reset will occur and Magellan operations will proceed normally. Once enabled, the watchdog mechanism cannot be stopped until a reset or power cycle occurs.

After powerup or Magellan reset, if no command is sent to the watchdog address, then the watchdog will remain disabled. The watchdog is disabled by default at power-up. When the watchdog timer times out, it also disables itself.

3.2.9.1 C-Motion Commands

The C-Motion command WriteIO is used to specify a Magellan I/O write operation. Proper operation of the watchdog function (such that a timeout is not triggered) requires that a value of 0x5562 be written to the Magellan's I/O address 4 no less often than once every 104 mSec.

3.2.9.2 Connections & Associated Signals

Although as noted above a watchdog timeout may affect various board signals, there are no specific signals associated with this function.

3.2.10 Magellan Reset

Although a reset occurs automatically during power-up, it is sometimes desirable to reset the Magellan Motion Control IC explicitly through a user-initiated action. Note that this type of reset is different than a full board reset. See Section 3.6.5, “Board Reset,” for a description of the board reset function.

After a Magellan reset occurs some of the Prodigy/CME Machine-Controller board’s output signals will be driven to known states. These are summarized in the following table:

Signal Name	State
AxisOut 1-4	High
AnalogOut 1-8	Depends on analog output source
AmpEnable 1-4	No change

3.2.10.1 C-Motion Commands

The C-Motion command MPDeviceReset causes a reset of the Magellan Motion Control IC.

3.2.10.2 Connections & Associated Signals

Although as noted in the table above some board signals may be affected by this command, there are no signal connections specifically associated with this feature.

3.3 I/O Functions

3.3.1 General-Purpose Digital I/O

In addition to signals that directly interface to the Magellan motor processor such as *AxisIn*, *AxisOut*, *Home*, *QuadA*, *QuadB*, *Index*, the machine controller board supports general-purpose digital input and output signals through its General IO connector. There are four digital outputs, four digital inputs, and eight bi-directional I/Os.

These resources along with a few others such as analog input and output are part of the machine controller's 'Peripheral I/O' space, or PIO for short. See Section 3.1.2, "Peripheral I/O Space," for more information on the machine controller's PIO address map.

The general purpose digital inputs are TTL-compatible with typical input range of 0–5.5V. The absolute maximum input range is -0.5–7V.

The general purpose digital outputs are 5V TTL-compatible with an output sink current of 24mA, and an output source current of 5mA..

3.3.2 Digital Inputs

There are 12 general purpose digital inputs (4 dedicated inputs, 8 bi-directional). The status of these signals are contained in the lower 12 bits of a C-Motion returned 16-bit word. The following table correlates the signals input with the bits of this returned word. Note that when the input is low, the bit value will be 0, and when the input is high (5V), the bit value will be 1.

Signal Name	General IO Connector Pin No.	Bit No.
DigitalIn1	28	0
DigitalIn2	29	1
DigitalIn3	43	2
DigitalIn4	44	3
DigitalIO1	9	8
DigitalIO2	10	9
DigitalIO3	11	10
DigitalIO4	25	11
DigitalIO5	26	12
DigitalIO6	27	13
DigitalIO7	40	14
DigitalIO8	41	15

3.3.3 Digital Outputs

There are 12 general purpose digital outputs (4 dedicated output, 8 bi-directional). These digital output signals are controlled via a write register that holds the desired output signal levels along with a separate register that holds a write mask. Each bit position in the write mask with a value of one will result in the value in the corresponding bit of the write register becoming the commanded digital output value for that signal. Each bit position in the mask with a value of zero will result in the corresponding bit of the write value being ignored.

A separate register can be read to determine the actual output signal commands. This register can not be directly written to. To change the actual output signal the write value and write mask registers described above must be used.

For the 8 bi-directional I/O bits, selecting the direction of these bits is accomplished using a mask/value method similar to the digital output writes described above. The desired direction (input or output) for each bit is written using the I/O direction value register, and the bits that are to be written to in the I/O direction value register are specified via a separate I/O direction mask. Only the mask bits that are 1 will result in the corresponding I/O direction bits being updated by the write command. Note however from the table below that 1 direction value and mask bit controls two output bits. For example setting the direction at bit 8 in the direction register and mask determines the direction of both DigitalIO1 and DigitalIO2.

The following table correlates the signals with the bits of the write value register, the write mask, the I/O direction register and the I/O direction mask.

Signal Name	General IO Connector Pin No.	Bit No. of Write Register and Mask	Bit No. of I/O Direction Register and Mask
DigitalOut1	13	0	N/A
DigitalOut2	14	1	N/A
DigitalOut3	15	2	N/A
DigitalOut4	30	3	N/A
DigitalIO1	9	8	8
DigitalIO2	10	9	8
DigitalIO3	11	10	9
DigitalIO4	25	11	9
DigitalIO5	26	12	10
DigitalIO6	27	13	10
DigitalIO7	40	14	11
DigitalIO8	41	15	11

For the bi-directional signals DigitalIO1-8, each 0 bit value written to the I/O direction register selects the corresponding signal as an input, and a 1 selects it as an output.

For output signals DigitalOut1-4, each 0 bit value written results in a high (5V) output in the corresponding signal and a 1 results in a low (0V) output.

For the bi-directional signals DigitalIO1-8, for each signal selected as an output, each 0 bit value written to the value write register results in a low (0V) output and a 1 results in a high (5V) output. Note that this is the opposite sense of the DigitalOut1-4 signals. Bi-directional signals defined as inputs are not affected by a write to the value write register.

For information on digital I/O value and mask register addressing see Section 3.1.2, "Peripheral I/O Space."

3.3.3.1 C-Motion Commands

To set or retrieve the value of the machine controller's general purpose digital I/O the user must first open a Peripheral of type PIO. This is accomplished using the C-Motion command **PeriphOpenPIO**.

Using the returned ***Peripheral*** handle, the user can write the 16-bit word value and mask using the C-Motion command **PeriphWrite**. Note that a single two-word write must be used with the write mask in the low 16-bit word and the write value in the high 16-bit word.

To read back a previously written write value or mask, or to read back the current actual output signals commands, or to read back the current input signal states, the command **PeriphRead** is used.

> PIO space writes to the general purpose digital I/O write value and mask register should always be made via a single call to PeriphWrite.

3.3.3.2 Connections & Associated Signals

The general-purpose digital I/O signals are all located on the General IO connector, J13. One or more of the digital grounds must be connected. Digital inputs are pulled up through 4.7k Ohm resistors to 5V. The power-up default value for all general-purpose digital outputs is low.

See Section 2.7, "Connectors," for a complete description of the pinout connections to and from the board.

3.3.3.3 Electrical Interfacing

The digital inputs are open-collector logic. When an output pin is set to 1 (high), the output transistor is off and the pin can be used as an input. When an output pin is set to 0 (low), the output transistor is on which pulls the signal to ground and the pin cannot be used as an input.

The digital signals are processed using the following circuitry:

Figure 3-9: DigitalIn(1-4) Interface Schematic

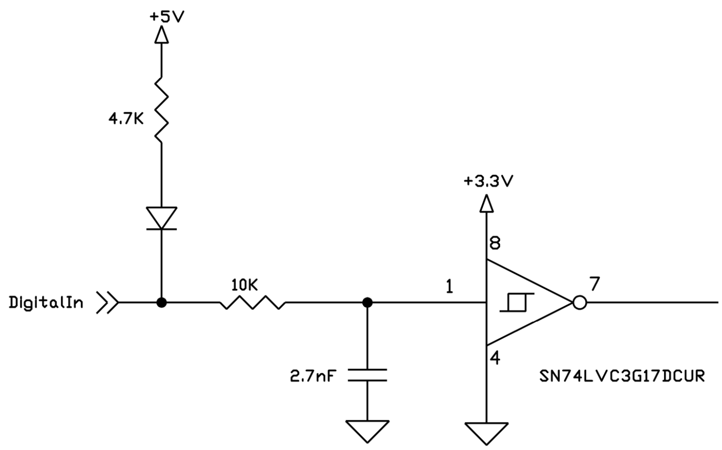
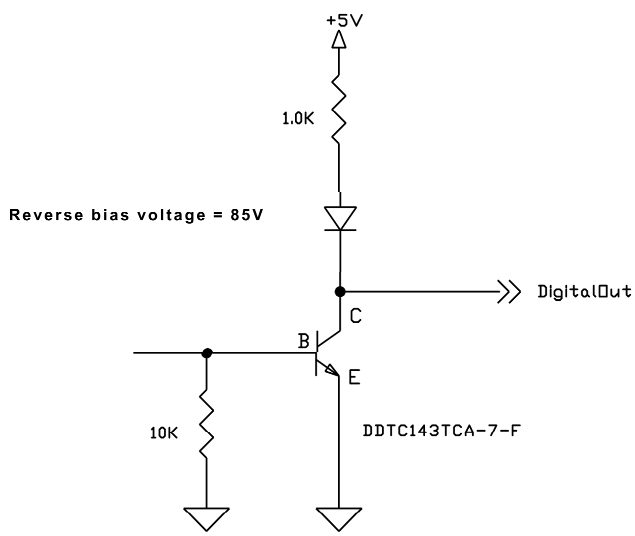


Figure 3-10: DigitalOut(1-4) Interface Schematic



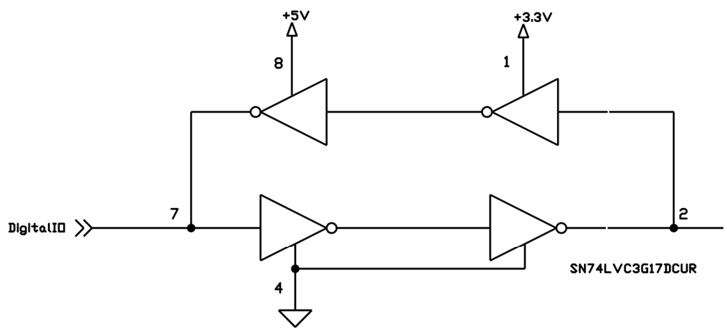


Figure 3-11: DigitalIO(1-8) Interface Schematic

3.3.4 General Purpose Analog Input

The machine controller board supports eight general purpose analog inputs, each consisting of+/- 10V differential analog inputs. The A/D sampling resolution is 16 bits, and the range of the returned value is -32,767 to +32,767 where -32,767 = -10V, and +32,767 = +10V.

The Prodigy/CME Machine-Controller receives both single-ended and differential analog inputs as shown in the following table and Figure 3-12. When used in single ended configuration, AnalogIn- should be connected to ground of the transmitter. When used in differential configuration, AnalogIn+ and AnalogIn- are connected to the differential output of the transmitter. In addition, it is recommended to connect the ground of the transmitter to AGND of the board.

Analog Input Characteristics	Value/Range
Input signal voltage range	-10V to +10V
Resolution	16 bits
Maximum recommended input signal frequency	2 Khz
Throughput	40 kilo samples per second
Integral non linearity error, typical	+/- 1 LSB
Integral non linearity, maximum	+/- 3LSB
Overvoltage protection	-30V to +30V
Common-mode range	-12V to +15V
Typical differential impedance	28 Kohms
Common-mode rejection ratio, minimum:	86 db

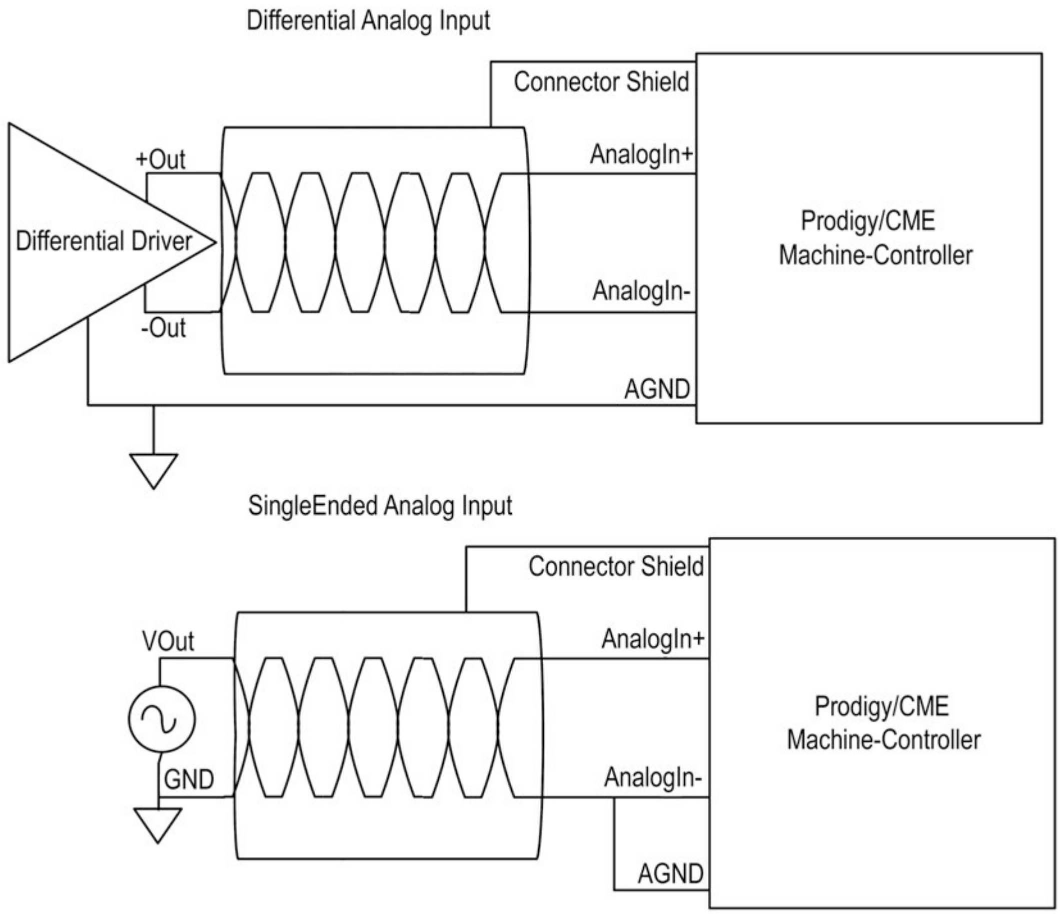
To determine the numerical value that will be read by the Prodigy/CME Machine-Controller board given a specific voltage at the input pins, the following formula is used:

ReadValue = AnalogVoltage*32,767/10.0V

Conversely, given a read value, the voltage at the connection is calculated as:

AnalogVoltage = ReadValue*10.0V/ 32,767

Figure 3-12: Analog Inputs Simplified Diagrams



3.3.4.1 C-Motion Commands

To read the machine controller's analog input channels the user must first open a Peripheral of type PIO. This is accomplished using the C-Motion command PeriphOpenPIO.

Using the returned *Peripheral* handle, the user can read one or more 16-bit word values representing the current analog voltage using the PeriphRead command.

3.3.4.2 Connections & Associated Signals

The general-purpose analog inputs are differential analog inputs located on the General IO connector, J13. To function properly one or more of the analog grounds must be connected.

See Section 2.7, “Connectors,” for a complete description of the pinout connections to and from the board.

3.3.4.3 Electrical Interfacing

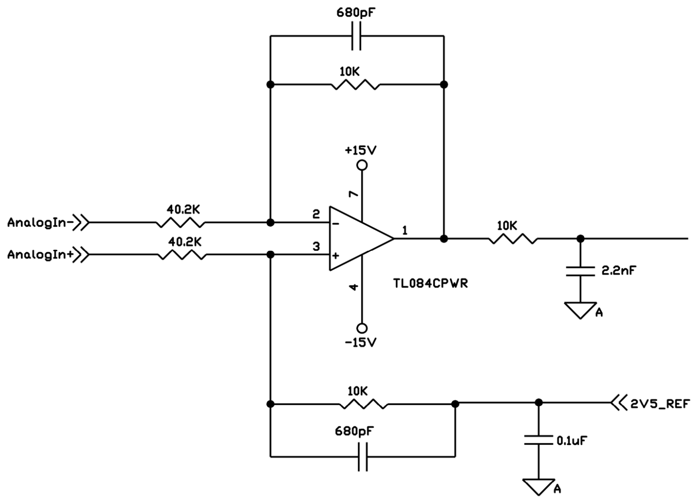


Figure 3-13: Analog Input Interface

3.3.5 General Purpose Analog Output

There are 8 general purpose analog outputs, each consisting of a 16-bit +/- 10V differential analog output. The range of the commanded analog output word is 0-65,535 where 0 = -10V, and 65,535 = +10V.

The analog outputs can be controlled by two separate sources. One source is the Magellan Motion Control IC which uses them to output desired motor torque commands. The other source is user control via the PRP interface. Each of the 8 channels can be individually directed to be controlled by the Magellan or by the user. The default analog output source of all analog output channels is the Magellan Motion Control IC.

The AnalogOut source is controlled via axis-specific registers in the PIO space. See Section 3.1.2, "Peripheral I/O Space," for the detailed location and format of these registers.

Analog Output Characteristics	Value/Range
Output signal voltage range	-10V to +10V
Resolution	16 bits
Integral non linearity error, typical	+/- 2 LSB
Integral non linearity, maximum	+/- 1 LSB
DC output impedance, typical	0.5 ohm
Short circuit current	30mA

To determine the voltage that will be output by the Prodigy/CME Machine-Controller board given a specific commanded output value the following formula is used:

AnalogVoltage = WriteValue*10.0V/65,535

Conversely, given a desired voltage the value that should written to generate this voltage is calculated as:

WriteValue = AnalogVoltage*65,535/10.0V

3.3.5.1 AnalogOut Enable

The Prodigy/CME Machine-Controller boards allow the *AnalogOut* signals, described in Section 3.2.8, "Analog Motor Command Output," to be shunted to 0 volts for safety purposes (disabled), or to be actively controlled (enabled). The

AnalogOut enable/disable mechanism is 'global,' meaning it affects all AnalogOut channels. It is not possible to selectively enable/disable analog output by axis or channel.

The power up default value for the AnalogOut enable function is disabled. In addition, the AnalogOut enable function is disabled upon a board reset, or via the external **Reset** signal. See Section 3.6.5, "Board Reset," for more information.

> The analog output channels must be enabled by the user before they can output non-zero voltage values. See Section 3.2.8.1, "AnalogOut Enable," for information on how to control the *AnalogOut* signal enable/disable.

3.3.5.2 C-Motion Commands

To set the machine controller's analog output channels the user must first open a Peripheral of type PIO. This is accomplished using the C-Motion command PeriphOpenPIO.

Using the returned *Peripheral* handle, the user can write one or more 16-bit word values representing the desired analog voltage command, the AnalogOut source, or AnalogOut enable/disable status using the PeriphWrite command. The written values can be read back using PeriphRead.

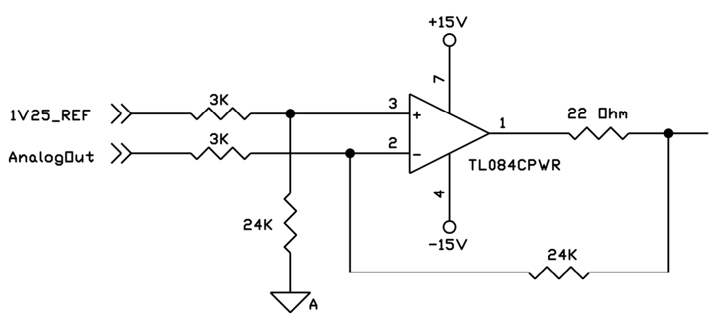
3.3.5.3 Connections & Associated Signals

The general-purpose analog outputs are direct differential analog outputs located on the Amplifier IO connector, J14. One or more of the analog grounds must be connected.

See Section 2.7, "Connectors," for a complete description of the pinout connections to and from the board.

3.3.5.4 Electrical Interfacing

Figure 3-14: Analog Output Interface



3.4 Communications Functions

The Prodigy/CME Machine-Controller board provides three overall communication interfaces, Serial, CANbus, and Ethernet.

Basic access to either the Serial, CANbus, or Ethernet port is accomplished by sending a C-Motion command with the detailed connection parameters that will be used. A ***Peripheral*** is used to access the connection once it is established.

For example to create an Ethernet TCP connection, the IP Address and port number is provided. If the connection is successfully established, a ***peripheralID*** is generated and thereafter used as the reference for any future communications through that connection.

In the subsequent sections the operational characteristics of the Serial (Serial1 & Serial2), CANbus, and Ethernet network ports will be detailed.

3.4.1 Serial1 & Serial2

Machine-Controller boards provide synchronous serial communications in either RS232 or RS485 mode. Access to the serial port controller is managed using peripheral connections.

In RS232 mode two serial ports are supported, referred to as Serial1, and Serial2. While some applications will not need to use two serial ports, the second port may be useful during C-Motion application code debugging, or to communicate with various serial devices connected to the machine. In RS485 mode, a single serial port is supported, referred to as Serial1. Also in RS485 mode, the serial port may be operated in either half duplex or full duplex mode.

Pin #1 of the J23 Serial Connector selects whether RS232 or RS485 communications mode is used. If left open (the default condition), the board operates the serial port in RS232 mode. If closed (tied to ground) the serial port is operated in RS485 mode. Note that a change in the status of this pin will not properly take effect until after a power on or reset of the board.

Both Serial Port 1 and Serial Port 2 can be operated at various communication settings as shown in the following table. All settable serial port parameters can be programmed separately for Serial 1 and Serial 2. For RS232 communications each serial controller only allows one peripheral to be established at a time. For example, if a peripheral is opened to establish RS232 communications via Serial 1, another peripheral may be opened to establish RS232 communication via Serial 2. However if a third peripheral is then opened to establish a new connection with Serial 1, the original Serial 1 peripheral will automatically be closed.

Settings & default values for Serial1 and Serial2:

Parameter	Range	Serial1 Default	Serial2 Default
Baud rate	1,200 to 460,800	57,600	115,200
Parity	none, even, odd	none	none
# Data bits	5, 6, 7, 8	8	8
# stop bits	1, 2	1	1

After a reset or at power-up the board retrieves default information for the serial ports from the onboard non-volatile RAM. To simplify startup these default values can be changed by the user. See Section 3.6.6, "Setting Board Defaults," for information.

3.4.1.1 C-Motion Commands

To create a serial port peripheral connection the above parameters are specified in the C-Motion command **PeriphOpenCom**. Messages to and from the Serial port are transmitted via the **PeriphSend** and **PeriphReceive** commands. Whenever a new serial port peripheral is opened its previous function is canceled. By default Serial1 listens for PRP communications and Serial2 is the console port.

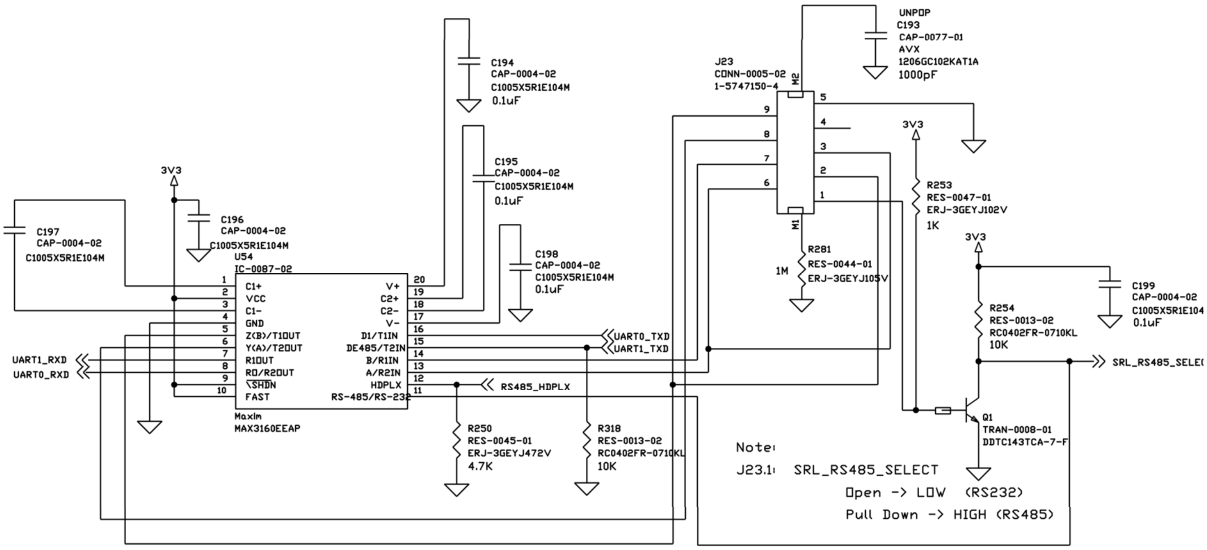
For detailed information on PRP action formats and function, refer to the *PMD Resource Access Protocol Programming Reference*.

3.4.1.2 Connections & Associated Signals

J23 comprises a special 9-pin connector used to connect one or both serial ports. See Section 4.2.8, "Serial Connector," for a detailed signal description of the Serial connector.

3.4.1.3 Electrical Interfacing

Figure 3-15: Serial Interface Schematic



3.4.2 CANbus Communications

The Prodigy/CME Machine-Controller board provides a general purpose CANbus port compatible with the CAN2.0B standard which may be operated at various communication rates from 10,000 to 1,000,000 bps (bits per second). In addition, each CANbus device is assigned two CAN identifiers (also called addresses); one for transmission of messages, and one for reception of messages.

The following table summarizes this information along with the factory defaults for these values:

Parameter	Range	Default
Baud rate	10,000 to 1,000,000 bps	1,000,000
Host send address	0 - 0x800	0x580
Host receive address	0 - 0x800	0x600

After a reset or at power-up the board retrieves default information for the CANbus port from the board's non-volatile RAM. See Section 3.6.6, "Setting Board Defaults," for more information on changing these default values.

3.4.2.1 C-Motion Commands

To create a CANbus peripheral connection, the above parameters are specified in the C-Motion command PeriphOpenCAN. Messages to and from the CANbus port are transmitted via the PeriphSend and PeriphReceive commands.

3.4.2.2 Connections & Associated Signals

J21 and J22 provide standard RJ-45 connectors to connect to a CANbus network. See Section 4.2.9, "CAN Connectors," for a detailed signal description of the CAN connectors.

3.4.2.3 Electrical Interfacing

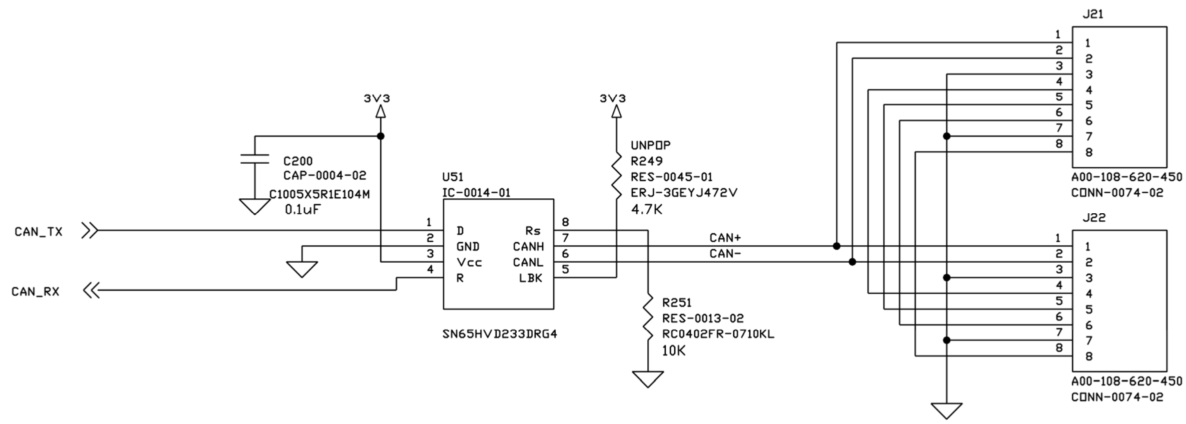


Figure 3-16: CANbus Interface Schematic

3.4.3 Ethernet Communications

The Prodigy/CME Machine-Controller boards support two different Ethernet protocols, TCP (Transmission Control Protocol) and UDP (User Datagram Protocol). TCP is typically used for primary Ethernet communications to the board, while UDP is typically used for non-critical applications such as data logging, or for the Pro-Motion console window. See Section 3.7.6, "Debug Console Window," for more information on the C-Motion Engine console window.

When used to receive PRP messages the physical node on the Ethernet network controller is assigned a 32-bit IP (Internet Protocol) address, along with a 32-bit netmask and a 32-bit gateway value. The Netmask is used to indicate which IP addresses are local, and the gateway value is used to route non-local addresses. To correctly receive communications from the host controller, a 16-bit identifier known as a port must also be specified. Note that when used as the connection between the host controller and the Prodigy/CME Machine-Controller board, TCP rather than UDP communications are used. To determine what the unused IP addresses are for your Ethernet network, and what values for netmask and gateway to use, you should contact your network administrator.

> By convention, the 32 bit values for IP Address, Netmask, and Gateway are shown in Dotted Quad Notation. In this notation each of the four numbers are separated by dots, and denote a decimal value for each byte of the four byte word.

The table below shows the range and default settings for the Ethernet controller of the Prodigy/CME Machine-Controller board:

Parameter	Range	Default
IPaddress	0.0.0.0 –255.255.255.255	192.168.2.2
Netmask	0.0.0.0 –255.255.255.255	255.255.255.0
Gateway	0.0.0.0 –255.255.255.255	0.0.0.0
PRPListenTCPPort	0 - 65,535	40100

Each physical hardware device on an Ethernet network is assigned one IP address, however, a given IP address can have multiple ports. This is useful because it allows user application code running on the C-Motion Engine to open up peripheral connections using port numbers other than the PRP communications port (which has a default value of 40100), thereby allowing PRP messages and application-specific data in any format to co-exist on the same Ethernet IP node.

After a reset or at power-up, the board retrieves default information for the Prodigy/CME Machine-Controller Ethernet port from the board's non-volatile RAM. To change these default values see Section 3.6.6, "Setting Board Defaults."

3.4.3.1 TCP Connection Keep-Alive

All prodigy/CME board TCP connections, including the PRP communications port, use a 'keep-alive' mechanism to detect whether a connection is still valid.

The keep-alive mechanism is a standard part of the TCP protocol specification, and is useful for preventing the prodigy/CME board from leaving connections open if the host has not properly closed a connection. This may occur, for example, if the host has been physically disconnected, or otherwise stops functioning.

The default keep-alive parameters for the Prodigy/CME boards are:

Parameter	Range	Default
idle time	0-65,535 seconds	60 seconds
interval time	not settable	30 seconds
retry count	not settable	2

The *idle time* is the amount of time after the last message on the port that must occur for a 'keep-alive' message to be sent. When sent, the keep-alive message requests the host connection to acknowledge that it is still functioning properly. If it provides this acknowledgment, the *idle time* counter is reset to 0. If it does not, a second 'keep-alive' message will be set after the *interval time*, and this will be repeated a total of *retry count* number of times. If the host ultimately does not correctly respond, the Prodigy/CME connection will automatically be closed.

Note that all of these functions are handled automatically by the Prodigy/CME board's TCP processing system, and should in turn also automatically be handled by the host's TCP system. No user action is required to initiate or monitor these automatic TCP 'keep-alive' messages.

See Section 3.6.6, "Setting Board Defaults," for information on how to change machine controller default values including the keep-alive parameters described above.

3.4.3.2 C-Motion Commands

To create an Ethernet/TCP or Ethernet/UDP peripheral conversation the IP address and port are specified in the C-Motion commands **PeriphOpenTCP** or **PeriphOpenUDP**, respectively. To transfer messages via this peripheral connection the **PeriphSend** and **PeriphReceive** commands are used

For detailed information on PRP action formats and function, refer to the *PMD Resource Access Protocol Programming Reference*.

3.4.3.3 Connections & Associated Signals

The Ethernet connector is a standard RJ-45 connector and is located at J24.

3.5 Atlas Amplifier Functions

3.5.1 Atlas Digital Amplifier Overview

Atlas Digital Amplifiers are single-axis amplifiers that provide high performance torque control of Brushless DC, step motor, and DC Brush motors. They accept digital torque commands from an external source and are used directly for motor torque control applications, or in conjunction with higher level controllers for velocity or positioning applications. Their compact size and high power output make them an ideal solution for single-board machine controllers that require high performance in a small envelope.

Atlas amplifiers that mount in the Prodigy/CME Machine-Controller are always of the vertical mounting type. There are three different power levels available; 75 watts, 250 watts, and 500+ watts. The 75W and 250W versions come in an ultra-compact package size and the 500W+ units come in a compact package size. For detailed mechanical information on these Atlas packages refer to Section 2.5, "Mechanical Dimensions." For information on installing Atlas amplifiers into the machine controller board refer to Appendix A, *Installing Atlas Units into the Board*.

Atlas digital amplifiers provide many advanced control features including user-programmable gain parameters, performance trace, field oriented control, and I^2t current management. Atlas amplifiers are powered from a single supply voltage, and provide automatic protection from overcurrent, undervoltage, overvoltage, overtemperature, and short circuit faults.

The Atlas family has been designed to work seamlessly with PMD's Magellan family of motion control ICs. Communication to/from Atlas amplifiers is via SPI (Serial Peripheral Interface) using a simple, packet-oriented protocol.

For complete documentation on all aspects of the Atlas Digital Amplifier, refer to *Atlas Digital Amplifier Complete Technical Reference*.

3.5.2 Atlas Drive Ratings

Low Power Units

Specifications	DC Brush Motor	Brushless DC Motor	Step Motor
Nominal supply voltage (HV)	12-48 VDC	12-48 VDC	12-48 VDC
Continuous current	1.5 ADC	1.5 Arms	1.5 Arms
Peak current (per phase)	3.8 A	3.8 A	3.8 A
Maximum continuous power	72 W	88 W	102 W

Medium Power Units

Specifications	DC Brush Motor	Brushless DC Motor	Step Motor
Nominal supply voltage (HV)	12-48 VDC	12-48 VDC	12-48 VDC
Continuous current	7.0 ADC	5 Arms	4.5 Arms
Peak current (per phase)	12.5 A	12.5 A	12.5 A
Maximum continuous power	336 W	294 W	305 W

High Power Units

Specifications	DC Brush Motor	Brushless DC Motor	Step Motor
Nominal supply voltage (HV)	12-56 VDC	12-56 VDC	12-56 VDC
Continuous current	14.0 ADC	10.0 Arms	9.0 Arms
Peak current (per phase)	25.0 A	25.0 A	25.0 A
Maximum continuous power	670 W	590 W	610 W

3.5.3 Safety Processing Functions

Atlas provides a number of amplifier control features that automatically detect and manage safety-related conditions. In addition, Atlas can signal when various conditions, safety-related or otherwise, occur.

The subsequent sections describe these features.

3.5.3.1 Overcurrent Fault

Atlas supports automatic detection of excessive current output. This fault occurs when the motor, the wiring leading from Atlas, or Atlas unit's power stage becomes short circuited or the requested current is too large to be processed by Atlas.

An overcurrent fault will cause the current loop and power stage modules to be disabled, thereby halting further motor output. To recover from this condition the user should determine the nature of the fault. It is generally desirable to power down Atlas to check connections or otherwise correct the Atlas-attached hardware so that the problem does not occur again.

If the overcurrent condition has been resolved, when restart is attempted Atlas will resume normal operations. If the overcurrent condition has not been resolved, the overcurrent condition will immediately occur again.

> Over current faults are serious conditions and warrant the utmost caution before re-enabling amplifier operation. It is the responsibility of the user to determine the cause and corrective action of any electrical fault.

3.5.3.2 Overtemperature Fault

Atlas provides the capability to continually monitor and detect excessive internal temperature conditions. Such a condition may occur if excessive current is requested, if heat sinking of the Atlas unit is inadequate, or if some other problem results in elevated drive temperatures.

To detect this condition a programmable temperature threshold is continuously compared to an internal temperature sensor. If the value read from the internal sensor exceeds the programmed threshold, an overtemperature fault occurs. In addition, a settable overtemperature hysteresis allows the user to ensure that the Atlas temperature drops by a specified number of degrees before allowing drive restart.

The maximum allowed setting for the temperature threshold is 75.0° C, which is also the default value. The maximum allowed value of the hysteresis parameter is 50° C, and the default value is 5° C.

An overtemperature fault will cause the current loop and power stage modules to be disabled, thereby halting further motor output. To recover from this condition the user should determine the nature of the fault. It is generally desirable to power down Atlas to correct the condition.

If the overtemperature condition has been resolved, when restart is attempted Atlas will resume normal operations. If the overtemperature condition has not been resolved, the condition will immediately occur again.

> Overtemperature faults indicate that the internal safe limit of the drive temperature range has been exceeded. This potentially serious condition can result from incorrect motor connections, excessive power demands placed on the Atlas amplifier, or inadequate heat sinking. It is the responsibility of the user to operate Atlas within safe limits.

3.5.3.3 Overvoltage Fault

Atlas provides the capability to continually monitor and detect excessive voltages on the incoming voltage supply. Such a condition may occur if there is a fault in the system power supply, if a large back EMF (electromotive force) is generated during motor deceleration, or if some other problem results in an elevated bus voltage.

To detect this condition a programmable bus voltage threshold is continuously compared to the bus voltage sensor. If the value read from the internal sensor exceeds the programmed threshold, an overvoltage fault occurs.

The maximum allowed setting for the overvoltage threshold is 60.0 volts, which is also the default value. The minimum allowed threshold is 10.0 volts.

An overvoltage fault will cause the current loop and power stage modules to be disabled, thereby halting further motor output. To recover from this condition the user should determine the nature of the fault. In most cases it is desirable to power down Atlas to correct the condition.

If the overvoltage condition has been resolved, when restart is attempted Atlas will resume normal operations. If the overvoltage condition has not been resolved, the condition will immediately occur again.

> Overvoltage faults indicate that a serious safety condition has occurred. It is the responsibility of the user to operate Atlas within safe limits.

3.5.3.4 Undervoltage Fault

Atlas also provides the capability to sense undervoltage conditions. This value is compared to the value read from the drive DC bus, and if the value read is less than the programmed threshold, an undervoltage fault occurs. The minimum allowed value for this threshold is 10.0 volts, which is also the default value. The maximum allowed value is 56.0 volts.

All other aspects of this feature are the same as for overvoltage sense. Just as for overvoltage conditions, it is the user's responsibility to determine the seriousness of, and appropriate response to, an undervoltage condition.

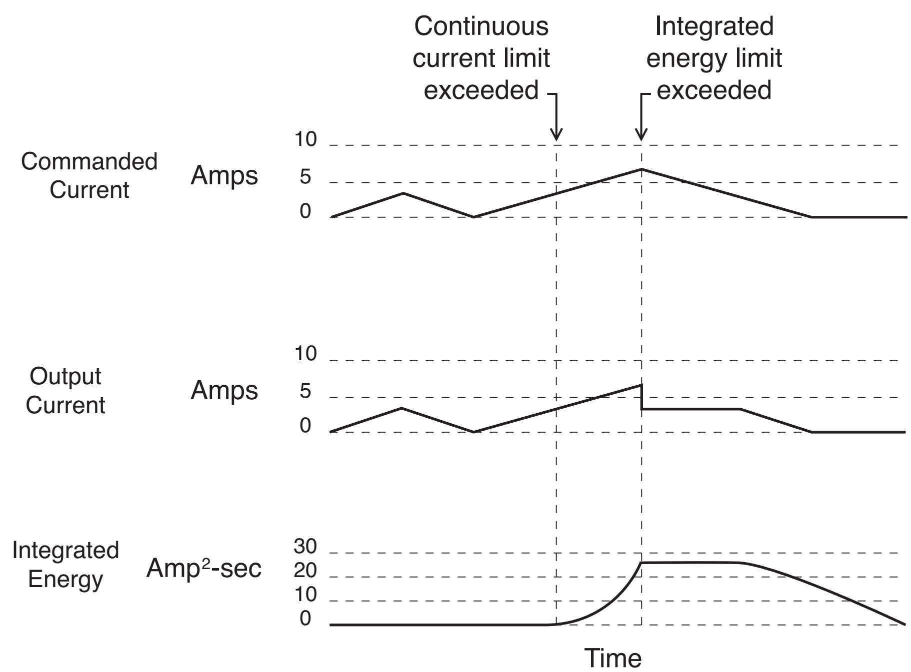
3.5.3.5 Current Foldback

Current foldback, also known as I^2t foldback, is a general purpose tool to protect the drive output stage or the motor from excessive current.

I^2t current foldback works by integrating, over time, the difference of the square of the actual motor current and the square of a user-settable continuous current limit. When the integrated value reaches a user-settable energy limit, Atlas goes into current foldback. When in this condition, and correctly programmed, Atlas will attempt to clamp the maximum current to the continuous current limit value. Note that the Atlas unit's ability to do so depends on a properly functioning current loop. For more information refer to the *Atlas Digital Amplifier Complete Technical Reference*.

Atlas will stay in foldback until the integrator returns to zero. This is shown in Figure 3-17.

Figure 3-17: Current Foldback Processing Example



Each Atlas amplifier motor type has particular default and maximum allowed values for both the continuous current limit and energy limit. These values are designed to protect the Atlas from excessive heat generation. For more information refer to the *Atlas Digital Amplifier User Manual*.

Current foldback, when it occurs, may indicate a serious condition affecting motion stability, smoothness, and performance. It is the responsibility of the user to determine the appropriate response to a current foldback event.

3.6 General Board Functions

There are a number of features and resources on the Prodigy/CME Machine-Controller board that are not directly controlled by the Magellan Motion Control IC, or associated with general I/O or the C-Motion engine. The next several sections describe these general board functions.

3.6.1 Dual-Ported RAM (DPRAM)

The Prodigy/CME Machine-Controller board has an onboard dual-ported memory (DPRAM) which has one port interfaced to the Magellan Motion Control IC and the other port interfaced to the board's high speed internal communications bus, allowing two paths of communication. Figure 3-18 shows this configuration.

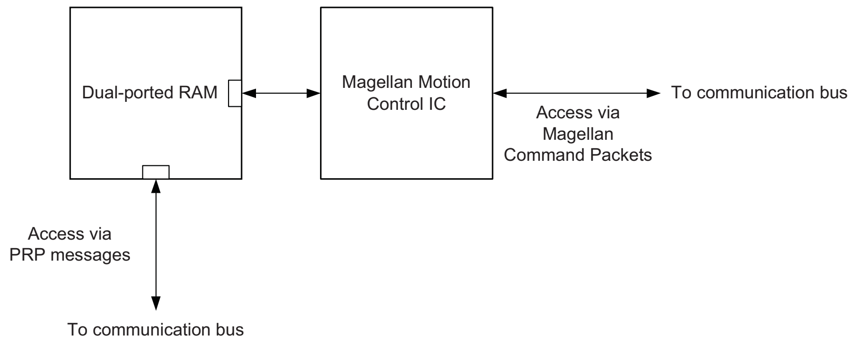


Figure 3-18: Onboard Dual-ported Memory

The dual-ported RAM is most often used to allow various Magellan Motion Control IC parameters and registers to be continuously captured and stored to a memory buffer. The captured data may be downloaded to the C-Motion Engine or to an off-board host using the Prodigy/CME Machine-Controller board's serial, CANbus, or Ethernet communication channels.

Magellan data traces are useful for optimizing DC Brush and Brushless DC servo performance, verifying trajectory behavior, capturing sensor data, or to assist with any type of monitoring where a precise time-based record of the system's behavior is required. For more information on how to set up a trace within the Magellan Motion Control IC, see the "Trace Capture" section of the *Magellan Motion Control IC User Guide*.

Beyond trace, the dual ported memory may also be used for general purpose RAM memory storage, particularly by user code located on the C-Motion Engine.

The machine controller board is available with two available memory configurations. The standard dual port memory configuration is 128Kbyte capacity. The enhanced memory option is 468 Kbyte capacity.

The contents of the dual-ported RAM are volatile. They are not saved during power-down of the board.

3.6.1.1 Accessing The Dual-Ported RAM

To access the contents of the dual ported RAM via the Magellan port the Magellan's built in memory buffer commands are used. The Magellan provides a sophisticated command set that lets you set up, monitor, and read from the trace buffer. See the *Magellan Motion Control IC User Guide* for more information on these commands. In this read configuration, the Magellan Motion Control IC stores data to the DPRAM autonomously, and the host controller reads the data using the Magellan Motion Control IC as well.

An alternate path for reading from, or writing to, the dual ported RAM is via the Prodigy/CME Machine-Controller board's high speed communication bus. In this mode the dual-ported RAM is accessed via the PMD Resource Access Protocol.

3.6.1.2 C-Motion Commands

There are a number of C-Motion commands related to Magellan buffer operations. Refer to the *Magellan Motion Control IC User Guide* for a detailed description of these commands.

To read or write to the dual-ported RAM using the PRP system, a resource address must first be obtained via the MemoryOpen command with memory type DPRAM. To write data to the dual-ported RAM, the C-Motion command MemoryWrite is used. To read the contents of the dual-ported RAM, the C-Motion command MemoryRead is used.

Note that byte-sized memory operations are not supported to the dual-ported RAM.

For complete information on the format and function of these commands, refer to the *C-Motion PRP Programming Reference*.

3.6.1.3 Connections & Associated Signals

There are no signals associated with this function.

3.6.2 Non-volatile Memory

The Prodigy/CME Machine-Controller boards have a general purpose 4,094 byte memory that retains its contents after a board power down or reset. This memory is useful for storing parameters that are set only occasionally and stay with the board, such as machine calibration information.

Accessing the non-volatile memory is accomplished in the same manner as accessing the dual-ported RAM, except that the NVRAM memory type is specified instead of the DPRAM memory type. Addresses are specified from 0 to 1,023. When writing to this memory, a typical write takes 50µSecs, however under certain circumstances it can take much longer, up to several 100mSec. Read speed is the same as for other memory resources, and takes just a few nanoseconds. As for the dual-ported RAM, byte-size memory operations are not supported by the non-volatile memory. The smallest memory unit that can be accessed is 16 bits.

The non-volatile memory can be rewritten a limited number of times. The worst case write limit cycle is 100,000 times for a given memory address, but in typical operation the limit is much higher. As a general guideline, to avoid erase/write cycle limit problems, the non-volatile RAM should not be used for general purpose scratch RAM, and should only be used to store permanent or semi-permanent parameters.

> The typical write time to the non-volatile RAM is 50µSec, however it may take as long as several 100 mSec. If other portions of the user application code, or any other PRP-connected device, depends on these values having been written, it is recommended that you ensure that the write operation has been completed by adding code that explicitly checks the value, or by waiting a fixed period of time after the NVRAM write operation.

3.6.2.1 C-Motion Commands

To read or write to the non-volatile RAM a resource address must first be obtained via the **MemoryOpen** command with memory type NVRAM. To write data to the NVRAM the C-Motion command **MemoryWrite** is used. To read the contents of the NVRAM the C-Motion command **MemoryRead** is used.

For complete information on the format and function of these, and other commands, refer to the *C-Motion PRP Programming Reference.*

3.6.2.2 Connections & Associated Signals

There are no signals associated with this function.

3.6.3 Amplifier Enable

The Prodigy/CME Machine-Controller boards provide four digital output signals directly controllable by the user that are intended to be used as amplifier enable signals, one per axis. If not used for this purpose these signals may be used as general purpose outputs.

The four **AmpEnable** digital output signals are controlled via a write register that holds the desired output signal levels along with a separate register that holds a write mask. This register along with all of the registers used to control the amplifier enable signals is located in the Peripheral I/O space (PIO). See Section 3.1.2, "Peripheral I/O Space," for a complete description of this space. Each bit position in the write mask with a value of 1 will result in the value in the corresponding bit of the write register becoming the commanded digital output value for that signal. Each bit position in the mask with a value of zero will result in the corresponding bit of the write value being ignored.

A separate register can be read to determine the actual output signal commands. This register can not be directly written to. To change the actual output signal commands the write value and write mask registers described above must be used.

For convenience, the following table correlates the signal outputs with the bits of the write register and mask.

Signal Name	Amplifier IO Connector Pin No.	Bit No. of Write Register and Mask Register
AmpEnable1	1	0
AmpEnable2	2	1
AmpEnable3	10	2
AmpEnable4	11	3

The power-up default value for all amplifier enable signals is low (disabled).

3.6.3.1 C-Motion Commands

To set or retrieve the value of the machine controller's **AmpEnable** outputs the user must first open a Peripheral of type PIO. This is accomplished using the C-Motion command **PeriphOpenPIO**.

Using the returned Peripheral handle, the user can write the 16-bit word value and mask using the C-Motion command **PeriphWrite**. Note that a single two-word write must be used with the write mask in the low 16-bit word and the write value in the high 16-bit word.

To read back a previously written write value or mask, or to read back the current actual output signals commands, or to read back the current input signal states the command **PeriphRead** is used.

> PIO space writes to the general purpose digital I/O write value and mask register should always be made via a single call to PeriphWrite.

3.6.3.2 Connections & Associated Signals

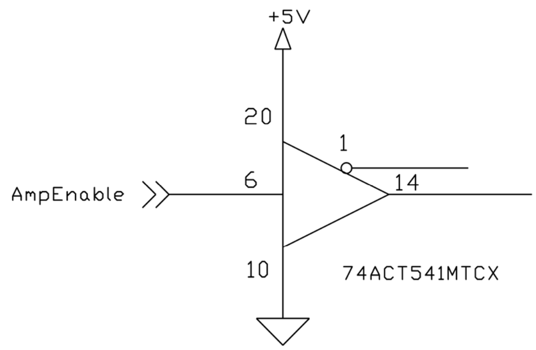
AmpEnable1-4 are direct digital outputs and appear on the board's Amplifier IO connector. To function properly one or more of the digital grounds must be connected.

See Section 2.7, "Connectors," for a complete description of the pinout connections to and from the board.

3.6.3.3 Electrical Interfacing

The **AmpEnable** signals are generated using the following circuitry onboard:

Figure 3-19: AmpEnable Output Interfacing



3.6.4 Reset Monitor

During normal operations, the Prodigy/CME Machine-Controller board is only reset during power-up. There are, however, several other ways that the Prodigy/CME Machine-Controller board can be reset, many of which are not related to a power cycle. See Section 3.6.5, "Board Reset," for a description of how the board can be reset. Whether via a power up or some other event, a reset serves the purpose of initializing values and bringing the Prodigy/CME Machine-Controller board to a known and consistent state.

To determine the cause of a board reset, a C-Motion command can be sent to read the reset source. The following table details the encoding of this word, which can be read via the Reset Cause register of the Peripheral I/O space.

I/O Address	Bit Location	Signals
2	0-9	*Reserved*
	10	User code exception
	11	C-Motion Engine user application code fault. A 1 value in this bit indicates an instruction or address access fault.
	12	Commanded reset. A 1 value in this bit indicates a board-level reset commanded via a C-Motion command.
	13	Undervoltage detection: a 1 value in this bit indicates a reset caused by undervoltage detection.
	14	*Reserved*
	15	Magellan Watchdog timeout: a 1 value in this bit indicates a reset caused by the board watchdog timeout. See Section 3.2.9, "Magellan Watchdog Timer," for a description.

Note that after a board power cycle this register will always contain 0x2000, indicating an undervoltage condition.

The most common use of this feature is as a safety check, contained in user application code residing on the C-Motion Engine. Since user application code most often automatically executes after board powerup, a check of this register by the user application code will allow anomalous occurrences of a board reset to be flagged and investigated.

Another common use is to determine the nature of a Magellan reset. If an unexpected Magellan reset occurs, such as from a Magellan watchdog timeout, the user may use this register to assist with determining the cause.

3.6.4.1 C-Motion Commands

To read the machine controller's reset monitor register the command DeviceGetResetCause is used.

3.6.4.2 Connections & Associated Signals

There are no signals associated with this function.

3.6.5 Board Reset

Although a reset occurs automatically during power-up, it is sometimes desirable to reset the Prodigy/CME Machine -Controller board explicitly through a user-initiated command or action.

After a board reset occurs the Magellan Motion Control IC and the C-Motion Engine modules will be reset, and many of the Prodigy/CME Machine-Controller board's output signals will be driven to known states. These are summarized in the following table:

Signal Name	State
AxisOut1-4	High
AnalogOut1-8	0.0 volts
DigitalOut1-4	Low
AmpEnable1-4	High

Digital I/O(1-4) default to be inputs at board reset.

In addition, upon a board reset all board default parameters are reloaded. See Section 3.6.6, "Setting Board Defaults," for more information on default values.

3.6.5.1 C-Motion Commands

The C-Motion command DeviceReset is used to reset the board.

3.6.5.2 Connections & Associated Signals

Although as noted above there are many board signals affected by a reset, there are no specific signals associated with this function.

3.6.6 Setting Board Defaults

There are a number of user-settable parameters that are saved by the board in non-volatile RAM and that are utilized after a powerup, or after a board reset. The following table shows these parameters, and provides the initial factory default values:

Parameter	Factory Default Value
Ethernet Communications	
IP Address	192.168.2.2
Net Mask	255.255.255.0
Gateway	0.0.0.0
PRP Port	40100
Serial Communications	
Serial 1 settings	57600, no parity, 8 data bits, 1 stop bit
Serial 2 settings	115200, no parity, 8 data bits, 1 stop bit
RS485 duplex	Full
CANbus Communications	
Baud Rate	1,000,000
Send Address	0x580
Receive Address	0x600
Task Control & User Application Code	

Parameter	Factory Default Value
Auto start (y/n)	No
Debug/Console channel	None

If desired, new default values can be stored by the user. Note that the updated defaults will only take effect after a board reset.

The default values are stored in the board's NVRAM area. As such, writing and reading operations to the default value area involves special considerations. See Section 3.6.2, "Non-volatile Memory," for more information on NVRAM memory operations.

3.6.6.1 C-Motion Commands

The C-Motion command **DeviceSetDefault** is used to set new default values. The command **DeviceGetDefault** is used to read these values back.

For detailed information on these C-Motion commands consult the *C-Motion PRP Programming Reference*.

3.6.7 Board Undervoltage Monitor

The Prodigy/CME Machine-Controller boards provides an internal logic undervoltage detection circuit. An undervoltage condition occurs when the board's 3.3V internal voltage drops below 2.7V.

If a board undervoltage condition occurs the board will be automatically reset. See Section 3.6.5, "Board Reset," for more information on the signal and other conditions affected by a board reset. See Section 3.6.4, "Reset Monitor," to determine if a reset was caused by an undervoltage condition.

> An undervoltage fault is a very serious condition. On the occurrence of an undervoltage fault the user should immediately power down the board and determine the cause of the fault before repowering the board.

3.6.7.1 C-Motion Commands

There are no user-settable parameters associated with this feature. See Section 3.6.4, "Reset Monitor," for a description of the reset monitor, and how to determine what type of reset occurred.

3.6.8 Board Resource Information

There are various resources on the machine controller that contain programmable or otherwise changeable logic. It may be beneficial to the user to be aware of revision information associated with these logic or firmware entities.

In general, once the user has developed his motion application they may want to query and record the board resource revision information so that they can be aware of any changes to these revisions in future production units purchased from PMD, or to allow them to order specific revisions.

Along these lines, the Prodigy/CME Machine-Controller board resource information that may be queried is the board logic version, the device firmware version, and the dual-ported RAM size.

3.6.8.1 C-Motion Commands

To query the board logic version the C-motion command **DeviceGetLogicVersion** is used. To query the device firmware version the command **DeviceGetVersion** is used, and to query the DP-RAM size the command **DeviceGetRAMSize** is used.

3.7 C-Motion Engine Functions

The C-Motion Engine on the Prodigy/CME Machine-Controller board allows C-Motion code to be downloaded and executed on the board. The C-Motion Engine is a powerful and flexible engine that can be used to:

- Operate Prodigy motion boards in a standalone mode
- Offload time-critical code from the host to the motion board
- Create a complete machine controller that communicates via serial, CANbus, or Ethernet to a cell controller or other high level controller
- Extend the functionality of the Magellan Motion Control IC with higher level functions such as contouring, macros, or other complex behaviors
- Lower system cost by combining a motherboard function with a dedicated motion board function in a single-board format.

3.7.1 C-Motion Engine Hardware Configuration

The C-Motion Engine is a self-contained module that provides non-volatile RAM space to store downloaded user application code, RAM space for 'scratch' data variable storage, and connections to the communication bus allowing the C-Motion Engine to send and receive messages through the network ports, communicate with the Magellan Motion Control IC, and access other onboard resources such as the dual-ported RAM.

Creating, compiling, downloading, and verifying a specific user C-Motion application on a Prodigy/CME Machine-Controller board is accomplished with the C-Motion Engine development system, described in *C-Motion Engine Development Tools Manual*. The outcome of such a development sequence is a downloadable code image, run on the C-Motion Engine, that contains the user application code and that is executed by the C-Motion Engine on the Prodigy/CME Machine-Controller board. Figure 3-20 provides an overview of the architecture of the C-Motion Engine.

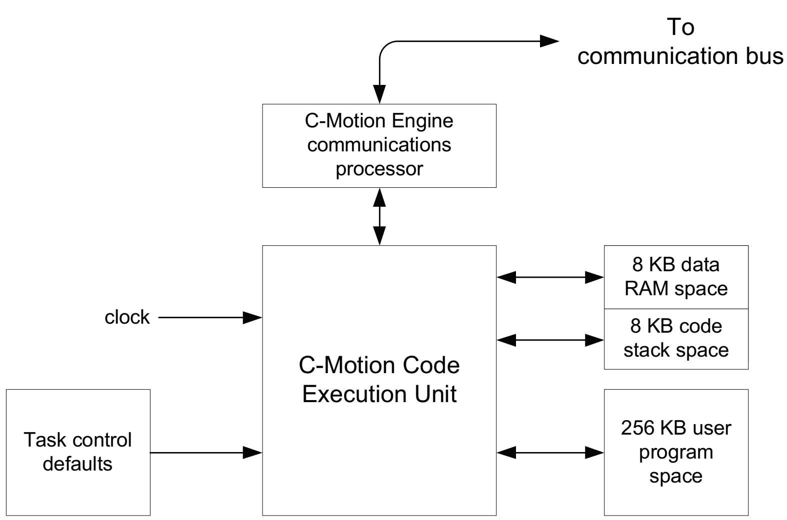


Figure 3-20: Overview of C-Motion Engine Architecture

The following table provides an operational overview of the capabilities and resources provided by the C-Motion Engine:

Resource	Specification
MIPS (millions of instructions per second)	96
User program space (stored in flash)	256KB

Resource	Specification
User data RAM space	8 KB
User code stack space	8 KB

3.7.2 Powerup & Operation

Upon reset or powerup the C-Motion Engine initializes itself and checks to see whether execution of user application code, if downloaded, should automatically begin. If the factory default settings have not been changed, user application code automatically begins executing and continues until the board is powered down or until a specific 'stop executing' command is given. If this default value is changed, then the C-Motion Engine will hold in a wait state, and code execution will not occur automatically.

While there are numerous safety checks and features built into the C-Motion Engine system, application code developed for the C-Motion Engine is C-based, and thus there are limits to code size, RAM usage, and stack usage that should be observed during runtime operation of downloaded C-Motion code. The table above provides these numerical limits.

For user downloaded code that does not correctly observe these limits, or for files that have become corrupted, there are a number of fault conditions that can occur while the C-Motion Engine is executing downloaded user application code. These very serious run-time faults include instruction errors- indicating that an unknown instruction was encountered during execution of the User code, and address faults- indicating that either a program space or RAM space access limit was violated. If either of these conditions occur, the C-Motion Engine will immediately halt user code execution, and reset the Prodigy/CME Machine-Controller board. This C-Motion Engine-initiated reset is identical to the reset that occurs after sending a board reset C-Motion command, except that the cause of the reset is recorded as 'C-Motion Engine user code Fault' rather than 'commanded' reset. See Section 3.6.5, "Board Reset," for more information on the Reset command. See Section 3.6.4, "Reset Monitor," for information on retrieving the reset cause.

Whether or not user application code is running, after reset or powerup, the C-Motion Engine begins processing PRP actions sent to it. These commands are typically sent from a host controller. The supported commands include functions such as checking the downloaded user application code version stored in the C-Motion Engine, and sending and receiving messages to the user code loaded on to the C-Motion Engine.

For additional guidelines on managing run-time usage of the C-Motion Engine see the *C-Motion Engine Development Tools Manual*.

3.7.3 Task Control

The primary purpose of the C-Motion Engine is to execute user application code that has been downloaded to it using the C-Motion Engine development system.

In a production environment, this code will typically automatically start upon powerup, and run continuously while the system is in operation. For debugging however, there are a number of additional controls.

At any point in time it is possible to stop or restart execution of the C-Motion Engine user application code. To access this function the C-Motion command actions **TaskStart** and **TaskStop** are used. To read the current status of the task the command **GetState** is used.

> Extreme caution should be applied when stopping or starting user application code running on the C-Motion Engine, as depending on the specific application code, this may cause unexpected or unsafe motion. It is the responsibility of the user to determine whether stopping or restarting of user application code is safe and appropriate.

Whether or not the user application code automatically executes upon powerup or reset can also be controlled. The two options are operation under manual mode, in which case the User code will not begin execution until an explicit start command is given, and auto-start, where the code automatically begins execution from powerup or reset.

This setting is part of the board default parameters, so to change these parameters the C-Motion command **DeviceSetDefault** is used. See Section 3.6.6, "Setting Board Defaults," for more information on default settings and how to program them.

For a detailed description of the supported Prodigy/CME commands see the *C-Motion PRP Programming Reference*.

3.7.4 Sending Messages to/from User Application Code

A common function of user application code running on the C-Motion Engine is to parse command messages sent to it by a host controller. For example a user might write code for the C-Motion Engine that responds to an "Extend RobotArm" command sent by the host controller, and then send a series of commands to the Magellan Motion Control IC to execute this motion sequence. At the end of the motion sequence the user application code might send an "Arm Extended" message confirming the movement sequence has completed.

One method of achieving this is to use the Prodigy/CME Machine-Controller board's peripheral mechanism to open, and operate, a low-level communications link via the serial, CANbus, or Ethernet link. This method has the advantage of giving relatively direct control over the communication traffic. The disadvantage is that the user has to implement specific send and receive communications in the host controller, and the C-Motion Engine needs to have similar code implemented that can process these messages.

Another method that may be more convenient, particularly during early debugging of the User application code, is to use a capability of the PRP system to connect directly to the user application code on the C-Motion Engine. Messages sent and received by the C-Motion Engine from a host controller are stored in a special buffer, and can be easily read or written to by the user application code. In addition, PMD's Pro-Motion application supports a simple way of entering, sending, and/or receiving such messages. This makes it easy to manually enter commands from Pro-Motion and exercise the user application code which is programmed to parse these messages.

To utilize this approach, a new peripheral is opened using the C-Motion command **PeriphOpenCME**. Thereafter **PeriphSend** or **PeriphReceive** commands are used to send and receive these messages within the C-Motion Engine.

In addition to these communications commands, the C-Motion command **DeviceNoOperation** performs a basic connection check. A return without an error code indicates that the C-Motion Engine is accessible and processing commands.

3.7.5 Connecting To The C-Motion Engine Code During Development

To develop code that is downloaded to the C-Motion Engine a communications link is required between the C-Motion Engine and the PC-based C-Motion Engine development environment. This link contains the information required for code downloads, as well as other information utilized during application debugging.

While serial, CANbus, or Ethernet can all be used as the communications link, typically, this link is chosen to be Ethernet because it is significantly faster than the other two. If the production machine network is also Ethernet, then only one network need be used for both code development, and operation of the machine.

It is also possible to use separate communication channels, so that one type of link is used for code development and download, and another for the 'application' communications. This has the advantage that application and code development traffic are not intermingled. For example, in a production machine control application that involves a PC and two Prodigy/CME Machine-Controller boards communicating via CANbus, Ethernet can be used as the development link, while the application software contained in the C-Motion code will send and receive messages using the CANbus port.

Most combinations of application and download/debug link selection are allowed. However the exception is the serial port. If one serial channel is used as the application link, the other serial port, or the CANbus or Ethernet port, must be used for the download link. This is because unlike CANbus and Ethernet ports, serial ports do not support multiple 'conversations' within a single physical port.

Selecting which Prodigy/CME Machine-Controller channel will be used for download is specified via the C-Motion development system. For more information see the *C-Motion Engine Development Tools Manual.*

3.7.6 Debug Console Window

During development, the user can use procedure calls similar to **printf()** from the downloaded application on the C-Motion Engine to send messages to the PC Development Environment for display in a special console window. These console messages may be useful for checking code progress, displaying internal variables, or for other code development-related purposes.

The default console channel is none, however this can be changed using the **DeviceSet** command with the **Device** resource specified as CANbus or Ethernet/UDP.

3.7.7 Downloading and Verifying User Application Code

The C-Motion Engine development system is used to create, compile, and download user application code. The development system can download the file image for the current code project being worked on, or a specific named file can be downloaded. Downloaded files images end with a *.bin* extension. Only one code image file may be downloaded into the C-Motion Engine at a time. Downloading a new image automatically erases the previous code image.

Code that is downloaded gets stored in the C-Motion Engine's User Program space. This 256 KB memory block is non-volatile, meaning its contents are retained even if power is turned off. Refer to Section 3.7.1, "C-Motion Engine Hardware Configuration," for a memory map of the machine controller's C-Motion Engine.

There are times when it may be useful to read specific characteristics of a code file that has been downloaded into the C-Motion Engine. To accomplish this, the C-Motion command **DeviceGet** is used. Using this command the file name of the downloaded user application code, the checksum of the downloaded file, the date & time of file creation, and the version number of the C-Motion Engine itself (loaded by PMD at the Prodigy/CME factory) can be retrieved.

For complete information on the format and function of these, and other C-Motion calls refer to the *C-Motion PRP Programming Reference.*

3.7.8 C-Motion Engine Heartbeat LED

The Prodigy/CME Machine-Controller board utilizes an LED, labeled D3, locatable using Figure 2-3 to provide visual confirmation of C-Motion Engine activity. Two different states can be distinguished, user application code running, and user application code not running.

User application code running means that a file has been downloaded and is actively being executed by the C-Motion Engine. This is indicated by a steady on/off blinking of the LED, once per second.

If no user application code has been downloaded, or if code execution has been halted by the user or for some other reason, the LED changes to a ‘chirp’ indication, with a blinking pattern consisting of very brief on, followed by one second off.

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A. Installing Atlas Units into the Board

A

In This Appendix

- Atlas Thermal Pad Attachment

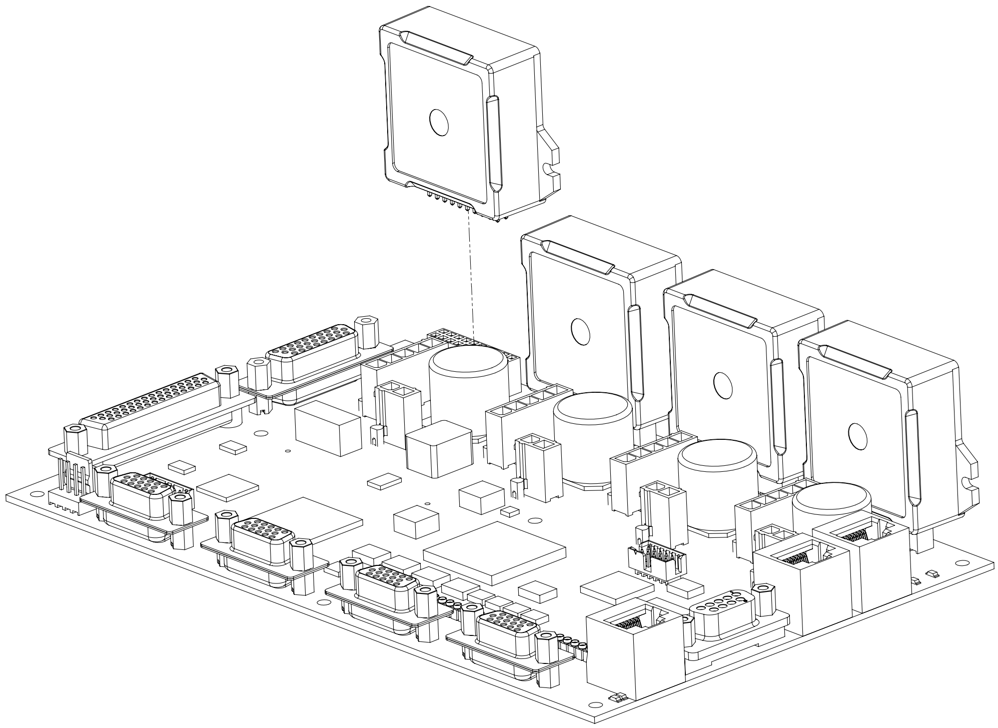


Figure A-1: Atlas Installation into Machine-Controller Board

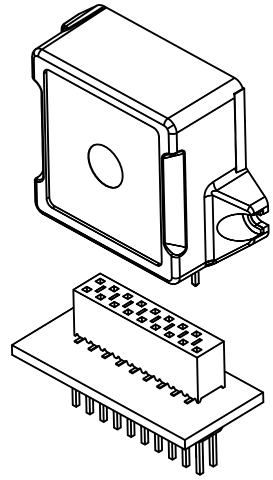
To install Atlas units into the machine controller board sockets confirm that the Atlas is oriented correctly with the metal heat sink surface facing toward the closest board edge. Carefully align the Atlas pins to the socket and press firmly down until the Atlas is fully seated in the socket.

If using Atlas units for specific motor types, the motor type of the Atlas should conform to the motor type that will be utilized for that axis. For example if your system has a DC Brush motor at axis #1, and a step motor connected at axis #2, you should install a DC Brush motor Atlas in the axis #1 socket, and a step motor Atlas in the axis #2 socket.

> Care should be taken when installing the Atlas into its socket. Failure to orient the Atlas correctly, or mis-alignment of pins may result in damage to the Prodigy/CME Machine-Controller board, Atlas units, or both.

Installation of ultra compact units, which are the package sizes for the low and medium power Atlas units, require the installation of a conversion card before installation into the machine controller board. When connecting the Atlas to the converter card care should be taken to insure that they are oriented correctly, and that all pins align correctly without overhang. Once the ultra-compact Atlas has been properly mated to the converter card, the converter/Atlas assembly can then be inserted into the machine controller board.

Figure A-2: Compact to Ultra Compact Atlas Format Converter



Four of these converter cards are included in the PRK33MK00004 developer kit, or they can be ordered directly from your local PMD representative, part number: PL-1039-02.

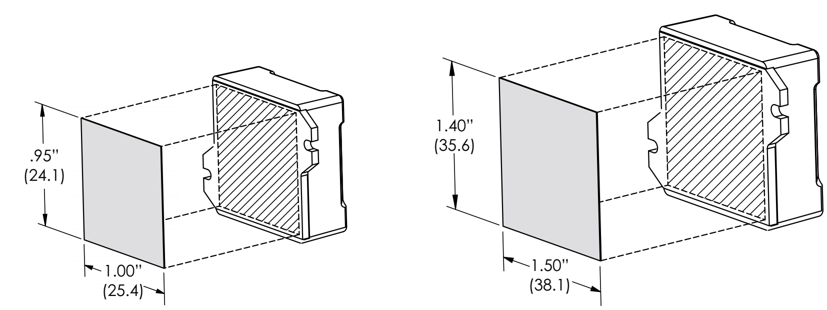
Note that the socket installation location of the compact and ultra compact Atlas units on the machine controller board is interchangeable. There is no restriction on the location of compact Atlas units versus the location of ultra compact Atlas units.

A.1 Atlas Thermal Pad Attachment

Most Prodigy/CME Machine-Controller applications, when using Atlas amplifiers, will attach heatsinks to each Atlas unit. As is the case for the Prodigy/CME Machine-Controller Developer Kit, it is convenient to use a single vertical plate to achieve this heat sinking for all installed Atlas units. It should be noted though that in the production application other approaches may also be used depending on how the machine controller board is mounted. For more information on the machine controller developer kit refer to the *Prodigy/CME Machine-Controller Developer Kit User Manual*.

For Atlas units that have a heat sink it is important to have good thermal contact between the Atlas and the heat sink. For this purpose thermal pads or some other transfer substrate such as thermal epoxy should be applied to each Atlas. The figure below provides recommended dimensions for thermal pads for both the ultra compact and compact Atlas packages. For more information on Atlas unit mounting and heat sinks refer to the *Atlas Digital Amplifier User Manual*.

Figure A-3: Thermal Transfer Material Attachment



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