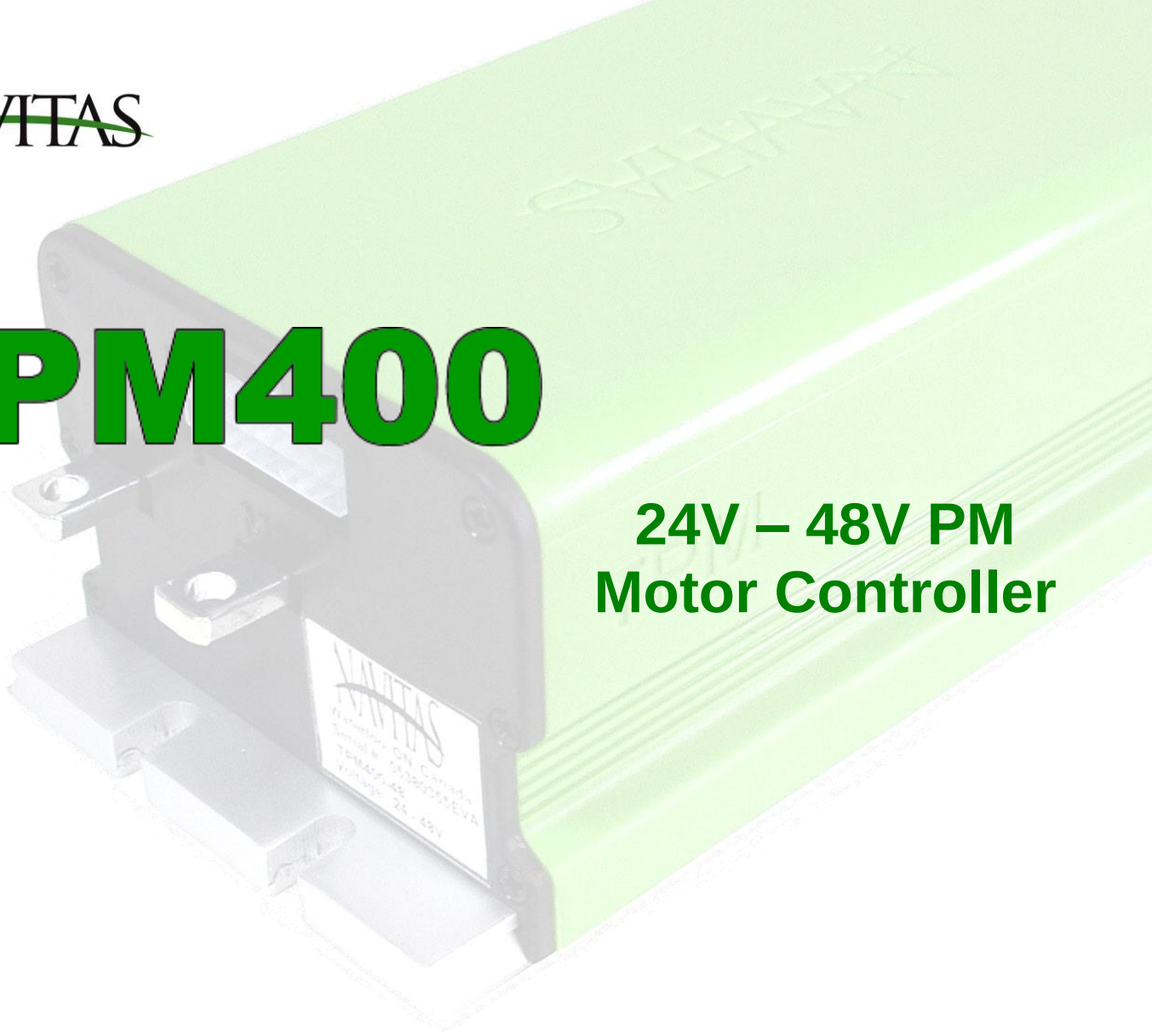
TPM400

24V – 48V PM Motor Controller



Description:
The TPM Controller is a full H bridge (4 quadrant), motor controller designed for use with permanent magnet motor(s) with a drive capacity of up to 400A peak at 24 to 48 VDC. This controller does not require the use of directional contactors. The unit is user configurable through a CAN interface.

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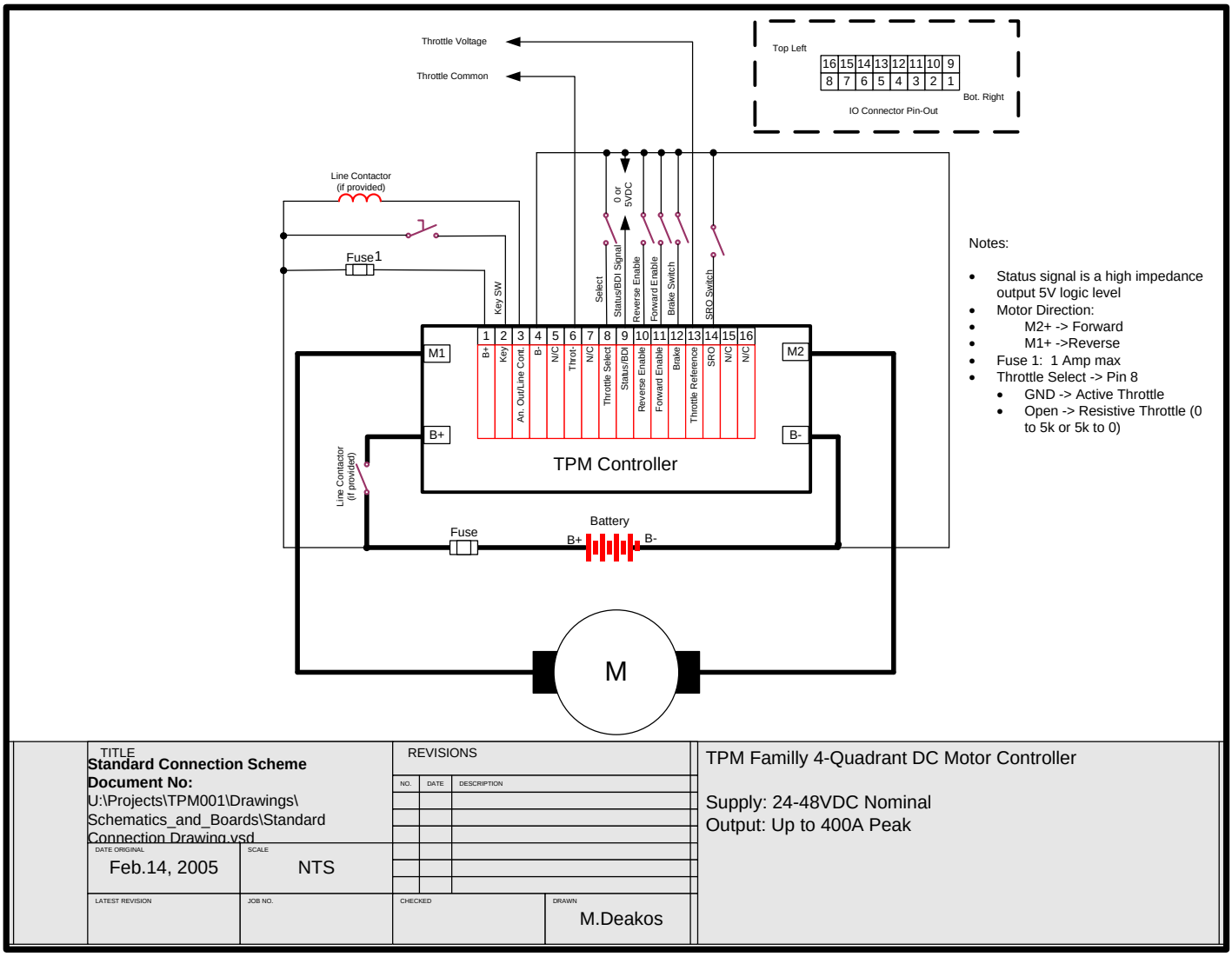
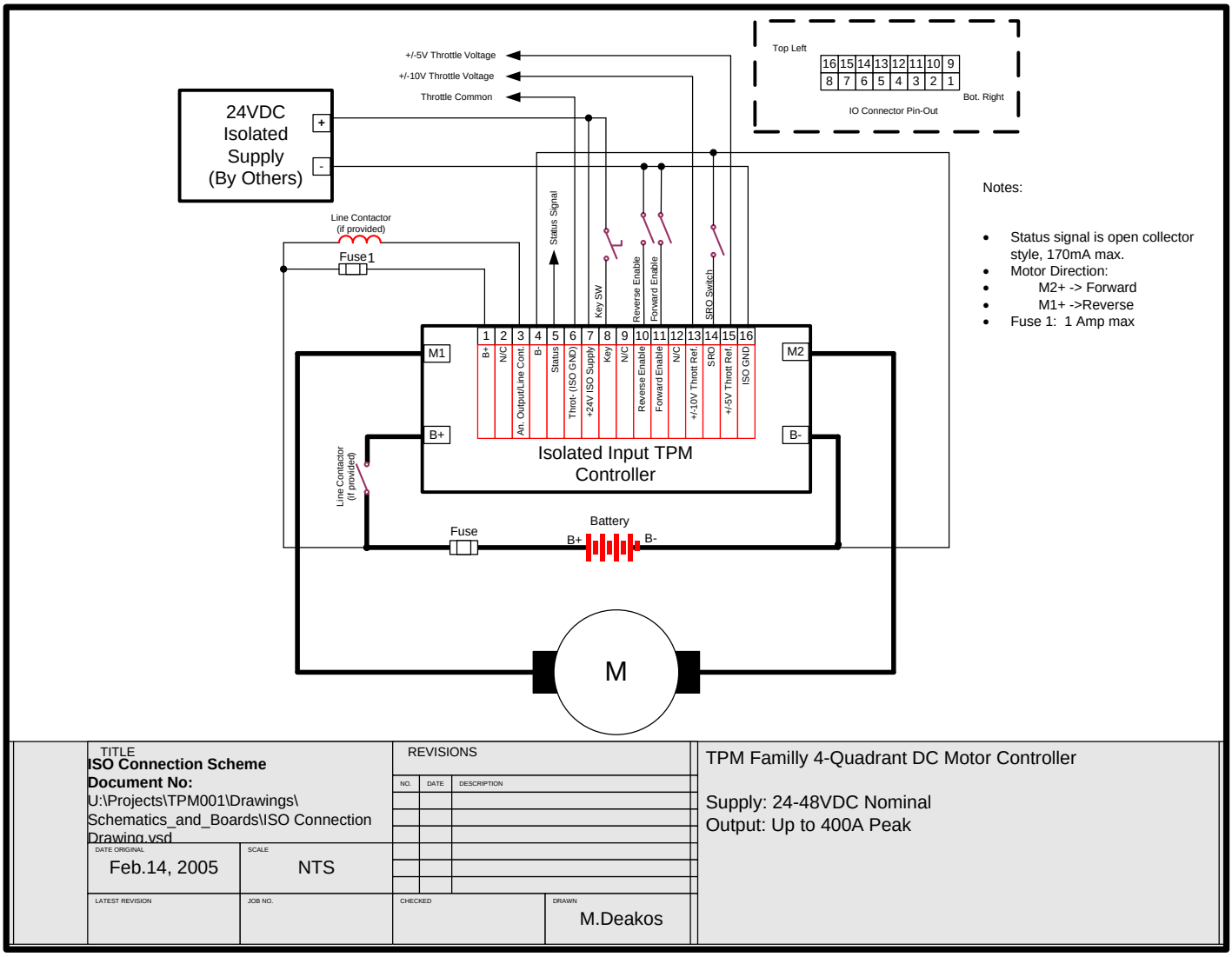
TABLE OF CONTENTS

Wiring Diagrams

Standard Model Wiring Diagram



Isolated Model Wiring Diagram



Overview

Environmental Specifications

Environmental Specifications	
Heat Sink Temperature Max.	90 Degrees Celsius
Relative Humidity Max.	95% RH, non-condensing
Vibration	25 G
Splash Proof	Upon Request

Maximum Operating Limits

Maximum Operating Limits	
Continuous Drive Current [1]	200 Amps
Peak Drive Current[2]	200, 300, 400 Amps
Regen Current (coasting) [2]	200, 300, 400 Amps
Regen Current (braking) [2]	200, 300, 400 Amps
Battery Over-Voltage Limit	62 Volts
Battery Under-Voltage Limit	16 Volts

Standard Model I/O

Standard Model Input and Output	
Two Analog Inputs	• 0 to 5Kohm, 5Kohm to 0, or Bi-directional • Voltage command or Passive throttle input capable
Five Digital Inputs (Activate Connection)	Key (B+), Forward Enable (B-), Reverse Enable (B-), SRO (B-), Brake(B-)
One Digital Output	0/5V, Active High/Low Selectable – Status/BDI Output
One Analog Output	2 Amp Sink, Open Collector, PWM Driven Low Side Switching to B-
Communications Port	DB-9, Female, CAN Network
Duty Cycle Range	0 – 100%

Isolated Model I/O

Isolated Model Input and Output	
Two Isolated Analog Inputs	+/- 10V and +/- 5V Bi-directional throttle
Three Isolated Digital Inputs (Activate Connection)	Key (+24V ISO), Forward Enable (ISO_GRND), Reverse Enable (ISO_GRND)
Two Non-isolated Digital Inputs (Activate Connection)	SRO (B-), Brake (B-)
One Isolated Digital Output	Open Collector, 170mA sink max, Internally switched to ISO_GRND. External pull up to +24V Isolated Supply
One Non-isolated Analog Output	2 Amp sink, Open collector, PWM Driven Low Side Switching to B-
Communications Port	DB-9, Female, CAN Network
Duty Cycle Range	0 – 100%

1. With appropriate heat sinking of controller base plate.
2. Depending on model.

Throttle Response

Throttle Response			
	Standard Model	Isolated Model	
Parameter	Throttle 1	Throttle 1	Throttle 2
Response Time Minimum	12 ms	12 ms	12 ms
Dead Band Minimum	+/-10 mV	+/-56 mV	+/-28 mV
Throttle Input Minimum	0.0 Volts	-10.0 Volts	-5.0 Volts
Throttle Input Maximum	5.0 Volts	10.0 Volts	5.0 Volts

Red LED Status Indicator Codes

Condition	Flash Code	Description	Type
Temperature Limiting	1	Current Cutback due to elevated base temperature	Status
Peak Current	2	Controller is supplying peak current to motor	Status
Low Battery	3	Battery voltage nearing minimum, reduced duty cycle / Battery voltage at or below minimum, shut down	Status / Error
High Battery	4	Battery voltage nearing maximum, limit regen current / Battery voltage at or above maximum, shut down	Status / Error
Over Temperature	5	Power base temperature exceeding maximum, controller will shut down	Error
Analog Over-Current	6	Excessive current (>3.3 A) is being drawn from the analog output	Error
Unused	7	Unused	
Hall Calibration Error	8	Failure in current sensor on startup	Error
Hardware Shutdown	9	Absolute maximum voltage or current exceeded	Error
Throttle Error	10	Throttle voltage has exceeded upper or lower error limits	Error
Unused	11	Unused	
Base Discharged	12	Power Base voltage has dropped more than 2V below pre-charge setting	Error
Direction Switch Error	13	In unidirectional throttle mode, both direction switches are active	Error

Note: The red status indicator LED will flash the code for the most recent condition that has been detected. So for example, if condition 3 occurs, followed by condition 10, code 10 will flash. If condition 10 is then cleared, the LED will flash code 3 again, if that condition is still present. Meanwhile both errors will be logged by the TPM and be readable through the CAN network using the PC Probit configuration software.

Functional Description

The following sections describe in more detail the operation of the TPM controller. Throughout the text, wherever a name appears in **bold letters**, this indicates a parameter that is user configurable through the CAN network interface using the PC Probit software.

Analog Output

The analog output is an open collector, PWM driven, low side switcher. It is capable of sinking up to 3Amps intermittently and 2 Amps continuously. When configuring the **Analog Output Voltage**, it is assumed that the output is pulled up to B+ through an external load. To meet the maximum sink current of 3Amps, the load (contactor coil for example) must have a resistance of at least 20ohms.

Note:
If driving a coil with the analog output, a fly-back diode must be placed across the coil to suppress voltage spikes. The diode should have a Peak Inverse Voltage rating of 100V minimum, and a Forward Current Rating of 3Amps minimum. Connect the cathode (bar end) of the diode to the B+ end of the coil, and the anode end of the diode to the TPM side of the coil.

There are six possible configurations for the Analog Output, as described in the following table:

Configuration	Description
Line Contactor	Unit detects power base voltage and will energize a line contactor coil when the base voltage reaches the **Pre-Charge Voltage**. The **Analog Output Voltage** can be set from 12V up to the **System Voltage** (i.e.: B+).
Brake Release / Field Enable	For use on vehicles equipped with an electric brake release. Brakes are set in **Neutral to Stop Time** seconds after the throttle is in a neutral position, and immediately released when a throttle signal is applied. (Note: When configured as a Brake Release, there will be a 320ms delay from when a throttle command is given to when the voltage to the motor begins to ramp up. This delay allows time for the mechanical brake to disengage before the motor begins to spin.)
Status Output	Output will reflect the present status of the controller, indicating either normal operation, or BDI / Error Condition. When used in this mode, the analog output can be configured as an Active Low (B-), or Active High (floating) signal. The output is Active under a BDI / Error condition and Inactive during Normal operation.
Current Monitor	A PWM output that will change in proportion to the motor current. (Requires external pull-up. See Figure 1 below.) • 10% PWM - Controller supplying negative peak current to motor • 50% PWM - Controller supplying 0Amps to motor • 90% PWM - Controller supplying positive peak current to motor
Voltage Monitor	A PWM output that will change in proportion to the motor voltage. (Requires external pull-up. See Figure 1 below.) • 10% PWM - Controller supplying full battery voltage to motor in reverse direction • 50% PWM - Controller supplying 0 Volts to motor • 90% PWM - Controller supplying full battery voltage to motor in forward direction
Disabled	Output not used

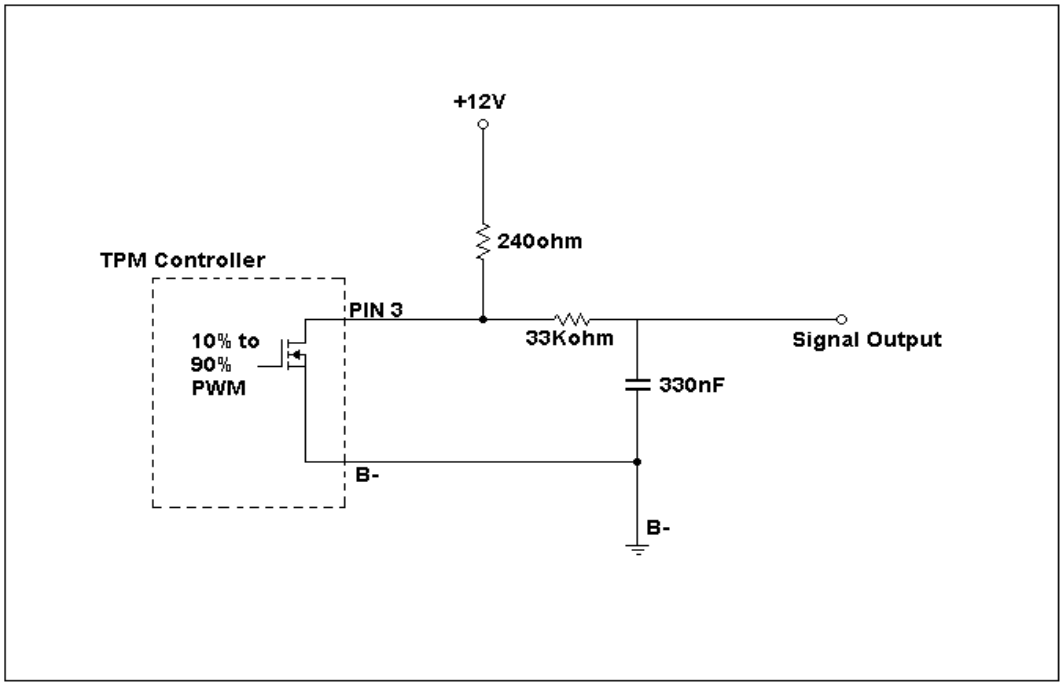


Figure 1: External Circuitry for Voltage / Current Monitor

Analog Inputs

The TPM comes equipped with up to two analog inputs, configurable as the throttle input. The following describes these inputs depending on whether the controller is a standard model or an isolated model.

Standard Model Throttle Inputs

The throttle input can be configured as bi-directional, 0K to 5K or 5K to 0K, using the PC Probit Throttle configuration screen. Also, the unit can be configured for a passive resistive throttle or an active throttle.

Passive Resistive Throttle

When using a resistive throttle, leave pin 8 of the I/O connector floating, and connect a 5Kohm pot from throttle ground (pin 6) to throttle input 1 (pin 13).

Active Throttle

When using an active throttle, such as a hall pot, connect pin 8 of the I/O connector to B-. This will disable internal pull-up resistors normally used to bias a resistive throttle. Connect ground from the active throttle to throttle ground (pin 6), and the output from the active throttle to throttle input 1 (pin 13).

Isolated Model Throttle Inputs

For the isolated model, only bi-directional, active throttle inputs are available.

+/-10V Throttle

Throttle input 1 (pin 13) is scaled to work with a voltage input ranging from -10V to +10V. A throttle range of less than +/-10V can be used, but with a decrease in resolution. Protection circuitry will prevent damage to the unit from throttle voltages exceeding this allowable range.

+/-5V Throttle

Throttle input 2 (pin 15) is scaled to work with a voltage input ranging from -5V to +5V. A throttle range of less than +/-5V can be used, but with a decrease in resolution. Protection circuitry will prevent damage to the unit from throttle voltages exceeding this allowable range.

Digital Output

Standard Model

A high impedance logic level output representing either the Normal or the Error/BDI state of the controller. This output can be configured as active low or active high using the PC Probit software. An active output signifies an Error/BDI condition exists.

Controller State	Active Low Output	Active High Output
Normal Operation	5V	0V
Error / BDI	0V	5V

Isolated Model

An open collector output. Capable of sinking up to 170mA. This output is internally switched to isolated ground. An external pull-up to +24V Isolated Supply is required. The load between this output pin and the +24V supply must be at least 145 ohms to limit the sink current to 170mA.

This output can be configured as active low or active high using the PC Probit software. An active output signifies an Error/BDI condition exists.

Controller State	Active Low Output	Active High Output
Normal Operation	Floating	0V (Iso gnd)
Error / BDI	0V (Iso gnd)	Floating

Switch Inputs

The TPM controller is configured with 5 switched input signals, as described in the following table:

Signal	Description
Key	Global controller enable input. Activating this input takes the controller out of stand-by and places it in run mode.
Forward Enable	Enables / disables forward direction motor control
Reverse Enable	Enables / disables reverse direction motor control
SRO	**S**tatic **R**eturn to **O**ff or Deadman switch input. This is often a safety switch that is closed only when the vehicle operator is standing or sitting in a safe location on the vehicle. When connected to B- through the safety switch, the motor will run. Otherwise output to the motor is disabled. See **SRO Debounce** below for more information.
Brake	Selects between **Braking Regen Current Limit** and **Coasting Regen Current Limit**. When enabled, Braking Regen Current Limit is selected.

With the exception of the Key input, all switch inputs are active low. To enable an input, switch it to the appropriate ground, as outlined in the following table:

Input	Standard	Isolated
Key	Switched to B+	Switched to Isolated +24V Supply
Forward Enable	Switched to B-	Switched to Isolated Ground
Reverse Enable	Switched to B-	Switched to Isolated Ground
SRO	Switched to B-	Switched to B-
Brake	Switched to B-	Switched to B-

Switch Filtering

In order to avoid false signals to the TPM due to switch bounce at transition times, the switch inputs must be stable for 8 consecutive I/O reads in order for the input signal to change state. Switch positions are read at an interval of once every **I/O Scan Time** milliseconds. Therefore it takes (8 x **I/O Scan Time**) ms for a switch transition to be valid. So, for example, if the **I/O Scan Time** is set to 5 ms, it will take 40 ms after the switch has stabilized for a switch transition to be registered.

SRO Debounce

The SRO input is further debounced to prevent false SRO shutdowns from occurring while the vehicle operator is bouncing on the safety switch during normal operation. An SRO shutdown will occur if the SRO input is open (not connected to B-) for more than the switch debounce time, as mentioned above, plus an additional user settable **SRO Debounce** time of 0 to 2000ms. The default debounce time is set to 500ms.

Safe Sequencing Rules

Safe sequencing refers to the sequence of events which must be followed before the controller will transfer current to the motor. It is meant to prevent unsafe starting of the motor during different start up or error conditions. There is a settable over-ride to this feature which allows a higher level control system to take responsibility for the safe operation of the vehicle, and bypass the normal safe sequence of events. A **Safe Sequencing** parameter can be enabled or disabled to control this over-ride feature. The following will explain safe sequencing for various controller configurations.

Safe Sequencing Enabled

Controller Power Up or Key Enable:

When the controller is first powered up and/or the key is enabled, current will not be passed to the motor, regardless of any of the switch positions or throttle settings, until the throttle has been returned to the zero or neutral position. This prevents unexpected vehicle motion if the throttle is pressed while the controller is first powered on and enabled.

Throttle Type: Bi-directional

Events must occur in the following order for voltage to be applied to the motor:

1. Power to controller
2. Key input switched ON
3. SRO input activated (input switched to B-)
4. Throttle set to neutral position
5. Throttle voltage applied
6. Voltage will now be applied to motor based on throttle command

Notes:

- The Forward Enable and Reverse Enable inputs can be activated at any time during the sequence, and not affect the safe start of the motor.
- The SRO input can be active when the Key input is applied. (Steps 2 and 3 can be interchanged.)
- If the controller motor output is stopped due to either a diagnostic error or an SRO shutdown, the throttle must pass through the neutral setting value before current will once again be supplied to the motor. All other switch inputs can remain active during this process.
- If the motor output is stopped due to a fatal error, the key input must be switched OFF, and the sequence begun again starting at step 2, after the source of the error has been corrected.
- If the controller is given a Reset command from the PC Probit, it will be necessary to return the throttle to the neutral position before output to the motor will be possible.

Throttle Type: 0k-to-5K or 5K-to-0K

Events must occur in the following order for voltage to be applied to the motor:

1. Power to controller
2. Key input switched ON
3. SRO input activated (input switched to B-)

4. Both Forward Enable and Reverse Enable switches OFF
5. Throttle set to neutral position
6. Forward or Reverse Enable input switched ON
7. Throttle voltage applied
8. Voltage will now be applied to motor based on throttle command

Notes:

- The SRO input can already be active when the key input is switched ON. (Steps 2 and 3 are interchangeable.)
- If the controller motor output is stopped due to either a diagnostic error or an SRO shutdown, the sequence of events, beginning at step 3, must be repeated before power will once again be supplied to the motor.
- If the motor output is stopped due to a fatal error, the key input must be switched OFF, and the sequence begun again starting at step 2, after the source of the error has been corrected.
- If the controller is given a Reset command from the PC Probit, it will be necessary to return the throttle to the neutral position before output to the motor will be possible.

Safe Sequencing Disabled

Disabling of the safe sequencing is only recommended for AGV users, where a higher level control system is in place to monitor the safe operation of the vehicle.

The following sequence will result in immediate power output to the motor, regardless of the throttle type configuration:

1. Power to controller
2. SRO input activated (input switched to B-)
3. Key input switched ON
4. Voltage will now be applied to motor based on present throttle command and direction switches

Notes:

- The SRO input is a master shutdown to the controller. The SRO input must always be applied before the throttle changes from neutral, regardless of safe sequencing being enabled or disabled.
- After an SRO shutdown event has occurred, the throttle must be returned to neutral to regain output control to the motor.
- If the controller motor output is stopped due to a diagnostic error, output to the motor will resume, based on switch and throttle positions, as soon as the error is no longer present. It will not be necessary to return the throttle to the neutral position.
- If the motor output is stopped due to a fatal error, the key input must be switched OFF and back ON again, after the error has been corrected, for the controller to respond to switch or throttle inputs.
- If the controller is given a Reset command from the PC Probit, it will be necessary to return the throttle to the neutral position before output to the motor will be possible.

Error Detection and Display

The TPM will detect and log errors during start up as well as during run time. These errors are stored in non-volatile memory for later read-back through the PC Probit. Errors will remain in memory until cleared by the user through the PC Probit. The following tables outline the different errors that can be logged.
Error (code**)**: Identifies the error name and error flash code, if applicable
Cause: Typical condition that will result in this error being generated
Resolution: Possible methods to remove the error condition
Severity: Two error levels exist, Diagnostic and Disable.

Diagnostic: Controller will halt operation when error is detected, and will resume normal operation after error is cleared and safe sequencing rules are followed.
Disable: Controller will halt operation when error is detected, and will resume normal operation only after error is cleared and key is cycled.

A subset of errors is indicated by flashing the red indicator LED on the TPM. For those errors included in this subset, the flashed error code will appear in the table in brackets, just after the error name.

Start Up Errors

Error (code)	Cause	Resolution	Severity
Invalid Throttle Type	The **Throttle Type** parameter in the registry is set to an invalid number	1. Set **Throttle Type** to one of three valid types	Disable
Min Greater Than Max	For either a bi-directional or 0K to 5K throttle type, the **Throttle Min** setting is greater than the **Throttle Max** setting	1. Set **Throttle Min** to be less than **Throttle Max**	Disable
Max Greater Than Min	For a 5K to 0K throttle type, **Throttle Max** is set greater than **Throttle Min**	1. Set **Throttle Min** to be greater than **Throttle Max**	Disable
Throttle Range Too Small	The difference between the **Throttle Min** setting and **Throttle Max** setting is too small for a 0k-to-5K or 5K-to-0k throttle type.	1. Change **Throttle Min** and **Throttle Max** settings such that the difference between them is at least 2 volts	Disable
Current Sensor Calibration (8)	The zero point of the internal current sensor has exceeded valid range	1. Keep permanent magnets away from M2 bar. 2. Try cycling Key to controller. 3. Contact customer service or dealer.	Disable
H/W Shut Down (9)	Battery Voltage exceeding 62V when Key applied to controller	1. Don't overcharge battery pack. Maximum TPM battery voltage is 62V	Disable
Watch Dog Reset	Last reset of microprocessor was due to a Watch Dog Reset	1. Do nothing. Will not affect operation of controller	Diagnostic

Run Time Errors

Error	Cause	Resolution	Severity
Brake Over Current (6)	Analog Output sink current has exceeded approx. 3.3Amps	1. Increase resistance on Analog Output pin to limit current	Diagnostic
H/W Shutdown (9)	Battery voltage has exceeded 62V or motor current has exceed 420 Amps	1. Avoid overcharging battery. 2. Check for system failure causing motor bars to short together.	Disable
Throttle Out of Range (10)	Throttle voltage has either gone below (**Throttle Min** – **POT Error**) or above (**Throttle Max** + **POT Error**) and **Throttle Loss Protection** is enabled	1. Set **Throttle Min** and/or **Throttle Max** to allow greater throttle extremes, 2. Increase **POT Error** setting 3. Disable **Throttle Loss Protection**	Diagnostic
Both Dir Switches (13)	Forward Enable and Reverse Enable inputs are both ON while Throttle Type is set to either 0K to 5K or 5K to 0K	1. At any given time, Only 1 direction enable input should be active when Throttle Type is set to either 0K to 5K or 5K to 0K	Diagnostic
Over Temp (5)	The temperature of the Power Base has exceeded safe operating temperature of 90°C	1. Turn off unit and allow time to cool down. 2. Reduce **Peak Current** limit to prevent over-heating 3. Add extra cooling using larger heat sink or forced air	Diagnostic
Battery Over Voltage (4)	Battery voltage has exceeded the **Over Voltage Trip** setting, if enabled	1. Avoid overcharging battery. 2. Increase **Over Voltage Trip** setting if enabled and not already set to 62V maximum	Diagnostic
Battery Under Voltage (3)	Battery voltage has dropped below the 16V minimum	1. Re-charge the battery	Diagnostic
Base Discharged (12)	Voltage across the B+ and B- bars of the controller have dropped more than 2 Volts below the **Pre-Charge Voltage** setting	1. Ensure line contactor (if used) is closing properly. 2. Try decreasing **Pre-Charge Voltage** as the error may be caused by sagging battery voltage under heavy motor loading	Diagnostic

IR Compensation

IR compensation is a feature used to overcome the voltage drop across the resistance of the motor winding, which results in a droop in the motor's speed. IR compensation is positive feedback that causes the control output voltage to rise slightly with increasing output current. This will help to stabilize the motor's speed as the load on the motor increases. The amount of extra voltage applied to the motor is determined by setting the **IR Comp Percentage** and the **Motor Resistance** using the PC Probit. Caution must be taken to not set the IR compensation too high. Due to the positive feedback nature, if the amount of compensation is set too high, the increase in motor voltage will cause an increase in motor current, which will cause a further increase in motor voltage, etc, causing an oscillation in the motor. Therefore it is wise, when using IR compensation, to begin with a low percentage of compensation and slowly increase it until the desired motor response is achieved.

If the motor winding resistance is not known, it can be measured using a precision ohm-meter capable of measuring in the milli-ohm range. Measure the open circuit resistance across the motor terminals several times and average the values together. Between measurements, turn the motor shaft slightly to average out the effect of the motor brushes.

Always Switching

Always switching is a feature that allows for the continuous switching of the motor bars when the throttle is set to zero. While the effective voltage across the motor will still be zero and the motor will not spin, the motor voltage will be switching from full forward to full reverse at a very fast rate. The effect of this is too essentially hold the motor from free wheeling. The motor bars will remain in this hold state as long as either one or both of the forward and reverse enables are active. If both enables go inactive, the rapid switching of the motor bars will cease after the Neutral to Stop Time has expired.

CAN Accessed Configuration Parameters (User Settable)

The following table lists all of the user settable parameters which may be set using the PC Probit configuration software. As well, a brief description is provided for each parameter. For more details on these parameters and how to set them, please contact Navitas Technologies Ltd.

Parameter	Description
BDI Enable	Flag that enables the battery discharge indication and cutback
BDI Trip Point	The voltage, below which, available full speed will be reduced
BDI Recover Point	The voltage, above which, the unit will return to normal full speed
Pre-charge Voltage	The voltage at the power base when the line contactor will close
System Voltage	The battery voltage at which the controller will operate
Over-voltage Trip Point	The battery voltage at which an over-voltage condition exists. Used by software to limit regen current or shut down the controller.
Over-voltage Enable	Enables the over-voltage trip point. Otherwise, a hardware over-voltage protection value of 62 volts is used.
Peak Current	The maximum current the controller will supply to the motor
Rated Current	The rated continuous current the controller will supply to the motor

Parameter	Description
Braking Regen Current	The maximum regenerative current when braking
Coasting Regen Current	The maximum regenerative current when coasting
Maximum Current Allow Time	Time limit for current to exceed rated current limit
Maximum Current Reset Time	Time required for current to be below rated current limit for the Maximum Current Allow Time to reset
Maximum Forward Speed	The maximum percent of battery voltage applied to the motor in forward direction
Maximum Reverse Speed	The maximum percent of battery voltage applied to the motor in reverse direction
Limp Forward Speed	The maximum percent of battery voltage applied to the motor in forward direction when in BDI state
Limp Reverse Speed	The maximum percent of battery voltage applied to the motor in reverse direction when in BDI state
Acceleration Forward	Output ramp up time in milliseconds from 0 to full forward speed
Deceleration Forward	Output ramp down time in milliseconds from full forward speed to 0
Acceleration Reverse	Output ramp up time in milliseconds from 0 to full reverse speed
Deceleration Reverse	Output ramp down time in milliseconds from full reverse speed to 0
Throttle Dead Band - Stopped	Minimum measured change in throttle when at rest
Throttle Dead Band - Running	Minimum measured change in throttle when supplying power
Throttle Mode	Selects unidirectional or bi-directional throttle
Throttle Middle	Sets midpoint of bi-directional throttle
Throttle Minimum	Sets minimum analog throttle input
Throttle Maximum	Sets maximum analog throttle input
Throttle Shape	Sets linear or logarithmic throttle response
Throttle Error Detect Enable	Enables detection of throttle exceeding limits error
Throttle Error Offset	Offset voltage below throttle minimum or above throttle maximum at which a throttle error will be generated
Throttle Input Select	Selects between throttle input 1 and throttle input 2
SRO Debounce Time	Minimum time SRO switch must be open for an SRO shutdown
Analog Output Function	Configures analog output to function as either a line contactor, brake release, status output, current monitor, or voltage monitor
Analog Output Voltage	Voltage used to drive the analog output
CAN Address	Address used to identify the controller on a CAN Network
Safe Sequence Enable	Enables safe sequencing on throttle and switch inputs
IR Comp Percentage	Percentage of IR compensation applied
Motor Resistance	Resistance of motor windings. Used by IR compensation
I/O Active State	Used to set active high or active low analog and status outputs
I/O Scan Time	Time interval between readings of the analog and digital inputs
Neutral to Stop Time	Time delay from throttle set to zero until controller enters neutral

CAN Accessed Read Only Parameters

The following table lists all of the parameters used for diagnostics and monitoring of controller I/O.

Parameter	Description
Throttle	Current throttle value in volts (analog input 1 or 2)
Forward Switch	Position of forward switch
Reverse Switch	Position of reverse switch
Heading	The desired speed output from the controller
SRO Switch	State of SRO switch
Target PWM	Output PWM as a percent
Motor Current	Current being applied to the motor in amps
Motor Voltage	The voltage being applied to the motor in volts
Battery Voltage	The battery voltage in volts
Temperature	The controller base temperature in degrees Celsius
BDI Active	Flag to indicate controller is in BDI mode
Start Up Errors	Register showing errors generated on start-up
Run Time Errors	Register showing errors generated during run time
Brake Switch	State of brake switch
Hall Sensor Zero	Zero calibration point of current sensor
Base Charged	Flag to indicate that the power base voltage has met or exceeded the pre-charge voltage parameter setting
Controller Enable	Flag to indicate if controller is enabled or is in stand-by mode

CAN Accessed Motor Control

The direction and speed of the motor can be controlled over the CAN network. When used in this mode, the direction switch inputs and analog throttle input signals are ignored. The two registry parameters used for this type of control are listed in the following table:

Parameter	Description
Heading Net Select	Enables the use of CAN Network Heading instead of the analog throttle inputs
Heading	The desired speed output from the controller

To put the controller in CAN control mode, the **Heading Net Select** is enabled. Once enabled, the voltage applied to the motor will be dictated by writing to the **Heading** parameter. The **Heading** parameter is written as a percentage of full battery voltage. The following table provides an example of this type of control:

Battery Voltage: 48V

Heading (%)	Motor Voltage Applied (Volts)	Direction
-100	-48	Reverse
-50	-24	Reverse
0	0	Stopped
50	+24	Forward
100	+48	Forward

To put the controller back under the control of the direction switches and analog throttle inputs, the **Heading Net Select** should be disabled.

CAN Interface Port

This port consists of a Female, DB-9 connector. The following table outlines the pin connections used for CAN communications. In order to communicate with the controller, a PC Probit Dongle is required to convert serial data from a PC into proper CAN bus packets. Figure 2 shows the connection between the TPM and the computer.

CAN Data Port Pin #	Description
1	Do Not Connect. Factory Use Only.
2	CAN_L (Data low line)
3	Do Not Connect. Factory Use Only.
4	Do Not Connect. Factory Use Only.
5	Do Not Connect. Factory Use Only.
6	Ground (Power Supply Ground to dongle)
7	CAN_H (Data high line)
8	Do Not Connect. Factory Use Only.
9	+15V (Power supply from controller to dongle)

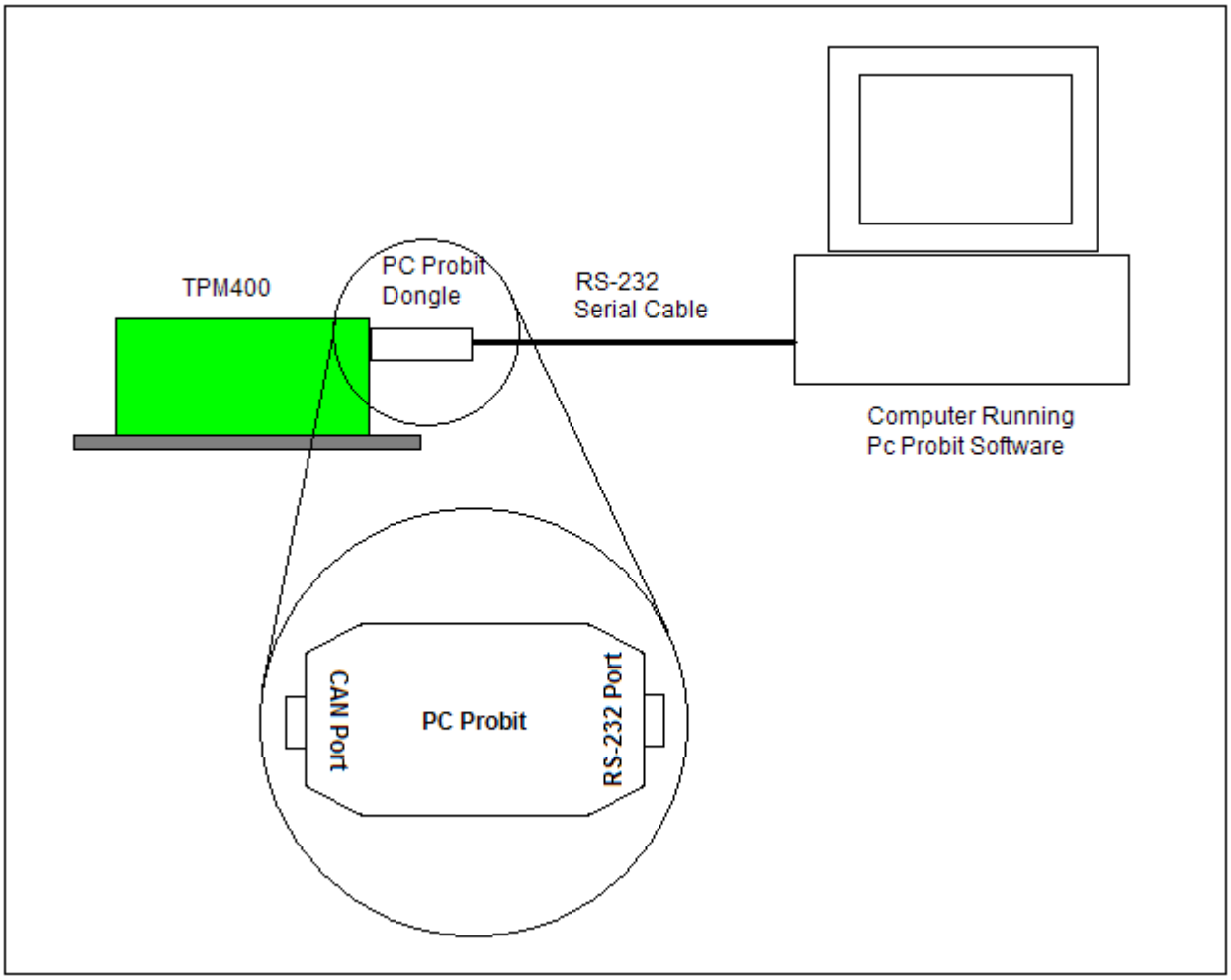


Figure 2. CAN communications connection diagram.

I/O Signals

Standard Model

The following table lists the signal I/O to the controller, through its 16 pin I/O port, for the standard model.

Pin No.	Signal	Description
1	B+	Battery Positive (Fused)
2	Key	Controller Enable. B+ through Key switch
3	AN_OUT	Analog Output (5 modes)
4	B-	Battery Negative
5	N/C	No Connection
6	AN_RET	Analog Input Ground (Throttle referenced to B-)
7	N/C	No Connection
8	THROTTLE SELECT	Selects active or resistive throttle input Connect to B-: Active Throttle Input Floating: Resistive Throttle Input
9	DIG_OUT	Digital Output (Status / BDI)
10	REVERSE_ENABLE	Reverse Enable
11	FORWARD_ENABLE	Forward Enable
12	BRAKE	Brake Switch Input
13	AN1_IN	Analog Input 1 (0 to 5V or 0 to 5Kohm, depending on Throttle Select)
14	SRO	Static Return to Off
15	AN2_IN	Analog Input 2 (0 to 5V or 0 to 5Kohm, depending on Throttle Select)
16	N/C	No Connection

Isolated Model

The following table lists the signal I/O to the controller, through its 16 pin I/O port, for the isolated model.

Pin No.	Signal	Description
1	B+	Battery Positive (Fused)
2	N/C	No Connection
3	AN_OUT	Analog Output (Five modes)
4	B-	Battery Negative
5	DIG_OUT	Digital Output (Status / BDI)
6	AN_RET	Analog Input Ground (ISO_GRND)
7	ISO_24V	Isolated +24V supply
8	KEY_ISO	+24V ISO Through Key Switch
9	N/C	No Connection

Pin No.	Signal	Description
10	REVERSE_ENABLE	Reverse Enable
11	FORWARD_ENABLE	Forward Enable
12	BRAKE	Brake Switch Input
13	AN1_IN	Analog Input 1 (+/-10V)
14	SRO	Static Return to Off
15	AN2_IN	Analog Input 2 (+/-5V)
16	ISO_GRND	Isolated Ground

Signals to the controller are through a 16 pin Molex 4.20mm Pitch Mini-Fit Jr., Dual Row header.

The mating connector and matching pins are the following:

Crimp Pins: Molex – Part Number: 39-00-0038
Connector: Molex – Part Number: 39-01-2160

Physical Dimensions

Dimension	Value (inches)
Base Plate Length	9.000
Base Plate Width	4.250
Base Plate Thickness	0.375
Cover Length	7.330
Overall Height	3.14

Notes: