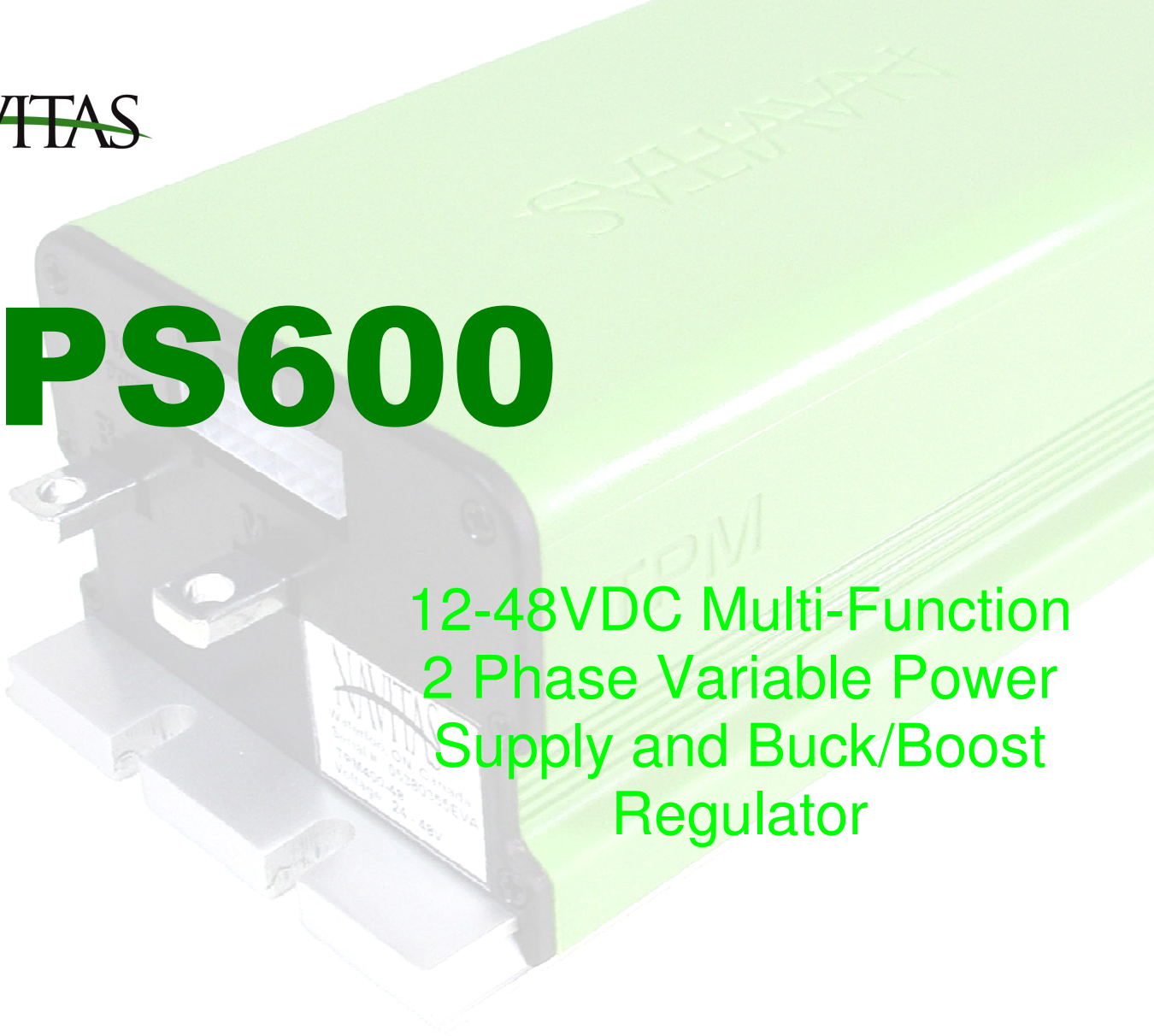
NPS600

12-48VDC Multi-Function 2 Phase Variable Power Supply and Buck/Boost Regulator



Description:
The NPS600 is a dual phase, half H bridge (2 quadrant) device that can serve as a power supply, Buck/Boost voltage regulator, or motor controller designed for use with permanent magnet motor(s). It has a drive capacity of up to 600A peak (300 Amps per phase) at 12 to 48 VDC. The unit is user configurable through a CAN interface.

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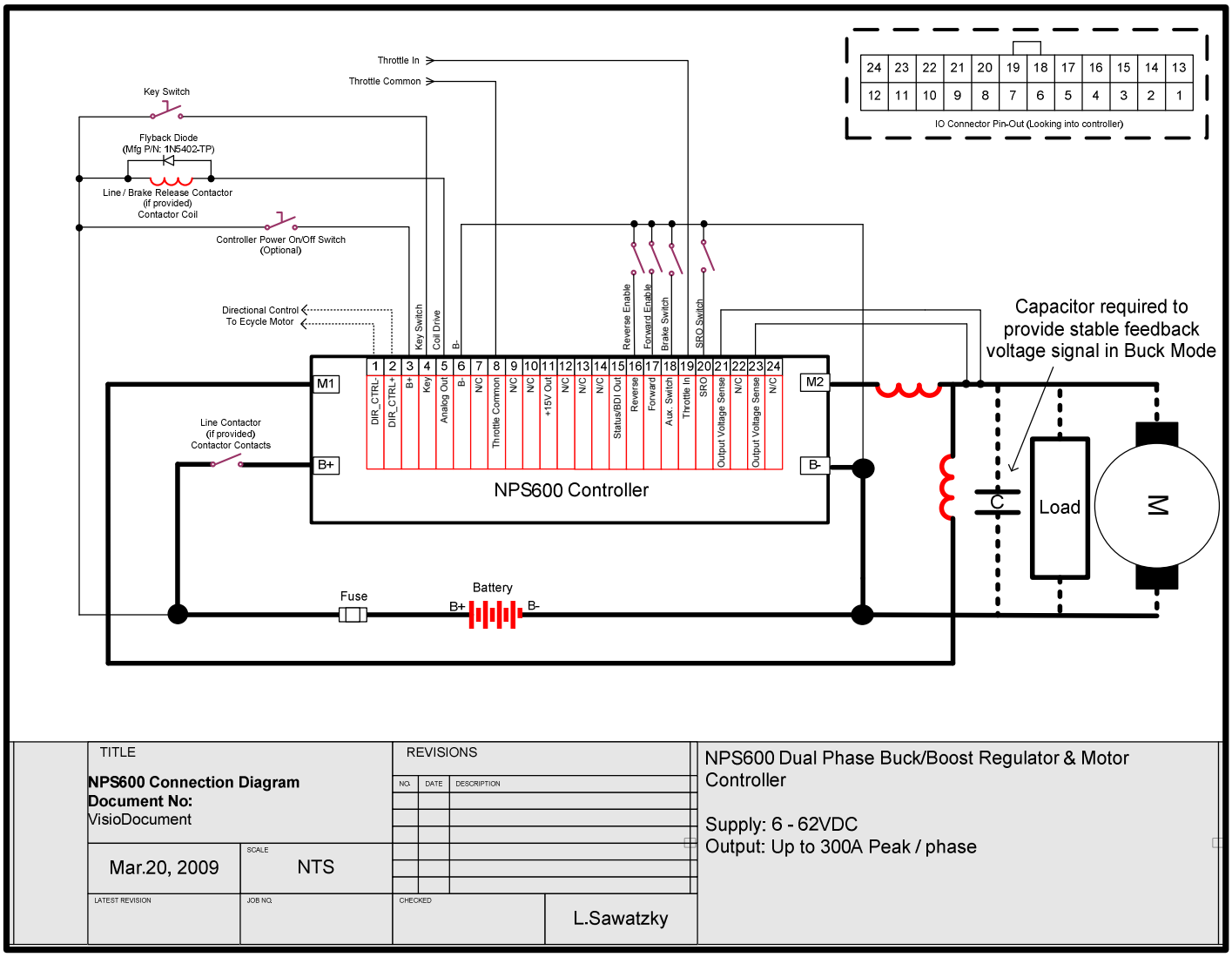
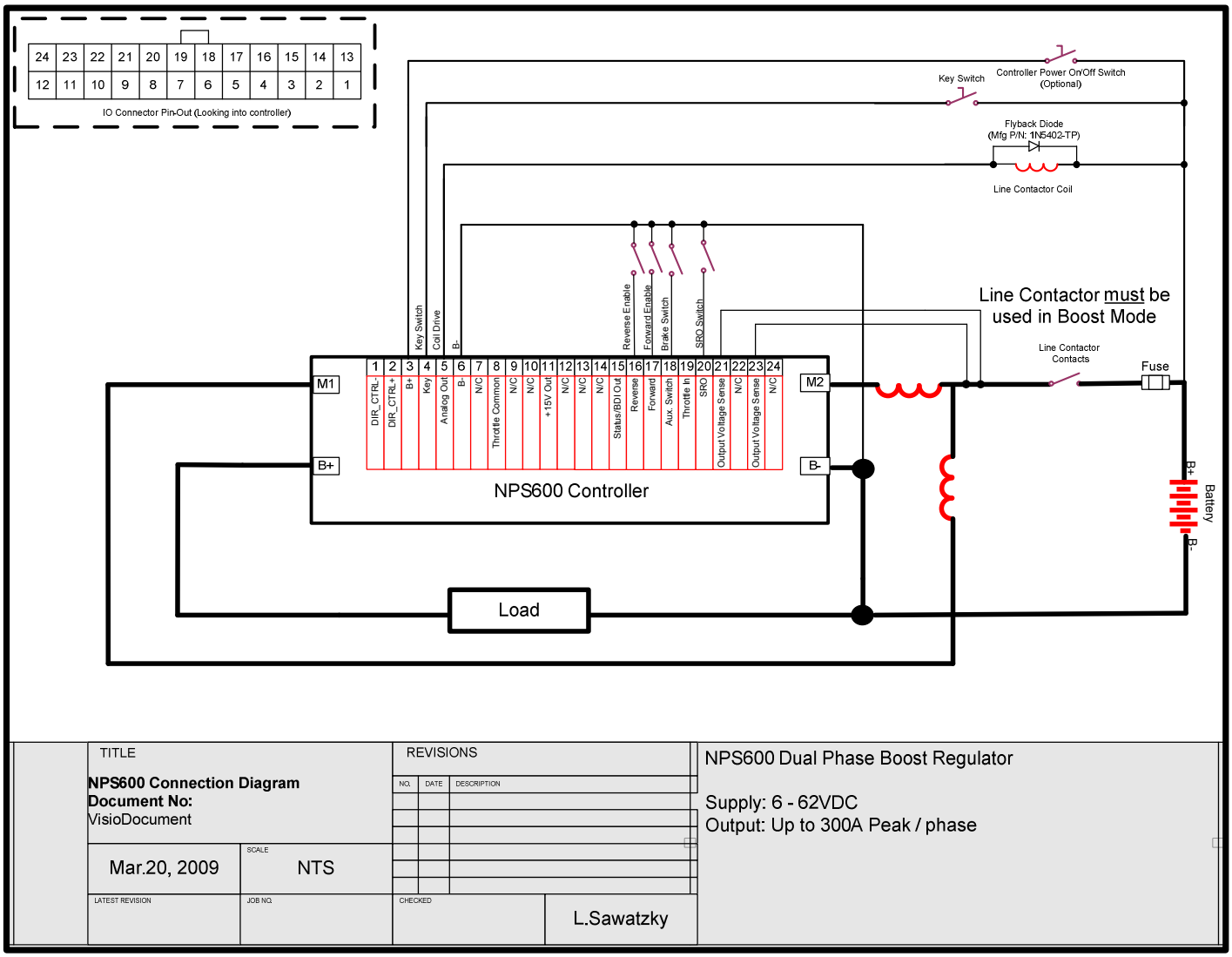


Standard Model Wiring Diagram – Boost Mode

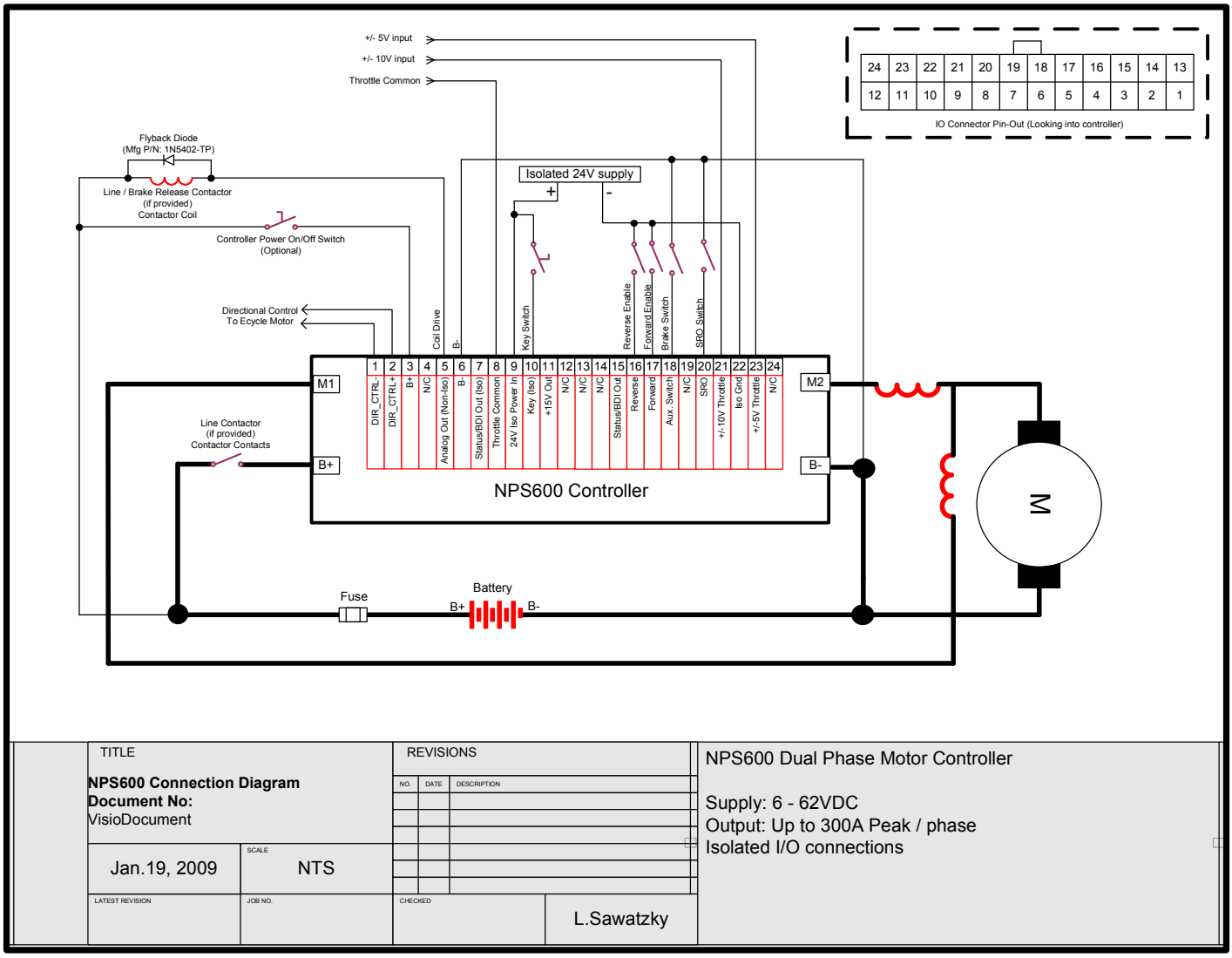


Caution!!!

Configured for Boost Mode, the NPS600 **will be destroyed** if the output is shorted when it is connected to a battery with high current capability. This is true even if the NPS600 is turned off!!!

The current settings in Boost Mode are for INPUT current, not output current. (Current settings are for output current in Buck Mode or Motor Control modes.) Second, in Boost Mode, the output voltage MUST ALWAYS be > or = to the input voltage. Current limiting will not work if the output voltage drops below the input voltage. This is a basic characteristic of Boost regulators in general and is not unique to the NPS600.

Isolated Model Wiring Diagram



TITLE **NPS600 Connection Diagram** **Document No:** VisioDocument	REVISIONS NO. / DATE / DESCRIPTION	NPS600 Dual Phase Motor Controller Supply: 6 - 62VDC Output: Up to 300A Peak / phase Isolated I/O connections
Jan.19, 2009 / SCALE: NTS		
LATEST REVISION / JOB NO.	CHECKED: L.Sawatzky	

Overview

Environmental Specifications

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

Maximum Operating Limits

Maximum Operating Limits	
Continuous Drive Current [1]	60 Amps / phase
Peak Drive Current	300 Amps / phase
Regen Current (coasting)	300 Amps / phase
Regen Current (braking)	300 Amps / phase
Battery Over-Voltage Limit	62 Volts
Battery Under-Voltage Limit	6 Volts

Standard Model I/O

Standard Model Input and Output	
Two Analog Inputs	**Voltage Regulator Mode:** Analog Input 2 is configured as Output Voltage Sense. Analog Input 1 is ignored. **Motor Control Mode:** Analog Input 1 can be configured as an Active throttle (Voltage command) or as a Passive throttle (Resistive command). Active Throttle: 0-5V, 5V-0, or bi-directional. Passive Throttle: 0-5K, 5K-0, or bi-directional Analog Input 2 is ignored.
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	3 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 no extra heat sinking of unit base plate. Higher currents achievable with extra heat sinking.

Isolated Model I/O

Isolated Model Input and Output	
Two Isolated Analog Inputs	**Voltage Regulator mode:** Not Applicable. **Motor Control Mode:** Active Throttle and bi-directional only. Analog Input 1: +/- 10V or +/- 5V (reduced resolution) Analog Input 2: +/- 5V Note: Only one Analog Input can be configured for use (you cannot use both +/-5V and +/-10V concurrently).
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	3 Amp sink, Open collector, PWM Driven Low Side Switching to B-
Communications Port	DB-9, Female, CAN Network
Duty Cycle Range	0 – 100%

Throttle Response

Throttle Response			
	Standard Model	Isolated Model	
Parameter	Throttle 1	Throttle 1	Throttle 2
Response Time Minimum	4 ms	4 ms	4 ms
Throttle Input Minimum	0.0 Volts	-10.0 Volts	-5.0 Volts
Throttle Input Maximum	4.99 Volts	10.0 Volts	5.0 Volts

Red LED Status Indicator Codes

Condition	Flash Code	Description	Type
Temperature Limiting	1-1	Current Cutback due to elevated base temperature	Status
Peak Current	1-2	Unit is supplying peak current (current limiting)	Status
Low Battery	1-3	Battery voltage at or below minimum, shut down	Status / Error
High Battery	1-4	Battery voltage at or above maximum, shut down	Status / Error
Over Temperature	1-5	Power base temperature exceeding maximum, unit will shut down	Error
Under Temperature	1-6	Power base temperature below minimum, unit will shut down	Error
Analog Over-Current	2-1	Excessive current (>3.3 A) is being drawn from the analog output	Error
Unknown	2-6	Unknown error has occurred	Error
Hardware Shutdown	3-3	Absolute maximum voltage or current exceeded	Error
Analog Input 1 Fault	3-4	Analog Input 1 has exceeded limits	Error
Analog Input 2 Fault	3-5	Analog Input 2 has exceeded limits	Error
Base Discharged	4-1	Power Base voltage has dropped more than 1/2V below pre-charge setting (discharged base caps)	Error
Direction Switch Error	4-2	In unidirectional throttle mode, both direction switches are active	Error
Calibration Error – PH2	4-3	Phase 2 current sensor has failed calibration on startup	Error
Calibration Error – PH1	4-4	Phase 1 current sensor has failed calibration on startup	Error
Temperature Error	4-5	Temperature sensor out of range on startup	Error
Invalid Throttle	5-1	Invalid Throttle (Analog Input) type set	Error
Analog Input Min/Max Error	5-2	Analog input Min exceeds Max limit	Error

Condition	Flash Code	Description	Type
Analog Input Max/Min Error	5-3	Analog input Max exceeds Min limit	Error
Analog Input Range Error	5-4	Analog Input range too small	Error
Watch Dog Reset	5-5	Watch Dog Timer has reset CPU	Status
Phase Mismatch	5-6	Phase 1 and Phase 2 current values too far apart	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 1-3 occurs, followed by condition 4-2, then code 4-2 will flash. If condition 4-2 is then cleared, the LED will flash code 1-3 again (if that condition is still present). Both errors will be logged by the NPS600 and be readable through the CAN network using PCProbitII configuration software. Note that Logged errors can only be cleared by using the PCProbitII software.

Interpreting Red LED Status Indicator Flash Codes

The flash codes are presented as “code digit 1 flashes”, short pause, “code digit 2 flashes”, long pause, repeat.

For example, for code 4-2 (Both Direction Switches) we would see the Red LED flash four times, a short pause, 2 flashes, and a longer pause. After the long pause, the sequence repeats with 4 flashes, short pause, 2 flashes, long pause etc.

In normal running mode, the Green LED is on. The green LED flashes if key is off, and remains on (no flashing) when key is on.

Note that at startup (i.e. when power first applied to pre-charge input pin) the NPS600 unit waits in a special ‘waiting for boot loader initialization’ mode for approximately one second – both Red and Green LEDs will be solid on (not flashing) during this wait period.

Functional Description

The following sections describe in more detail the operation of the NPS600 unit. Throughout the text, wherever a name appears in **bold letters**, this indicates a parameter that is user configurable through the CAN network interface using PCProbitII software.

Analog Output

The Analog Output (**Aux 1 Contactor** in PCProbitII Contactor screen) is an open collector, PWM driven, low side switcher. It is capable of sinking up to 3 Amps intermittently and 2 Amps continuously. For configurations that support **Pull-In Voltage** or **Hold Voltage**, it is assumed that the output is pulled up to B+ through an external load. Both the Pull-In Voltage and Hold-Voltage can be set from 12V up to the **System Voltage** (i.e.: B+). To ensure that the maximum sink current of 3 Amps is not exceeded, the load (e.g. contactor coil) must have a resistance of at least 20 ohms.

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 3 Amps 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 NPS600 side of the coil.

There are three 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** and the Key input is active. Line Contactor must be used in Boost Regulator Mode.
BDI Indicator	Output will reflect the present status of the controller, indicating either Normal Operation or BDI 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 condition and Inactive during Normal operation.
Status Indicator	Output will reflect the present status of the controller, indicating either Normal operation, or Error Condition (as listed in "LED Status Indicator Codes" above). 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 an Error condition and Inactive during Normal operation.

Note: Once the Analog Output has been configured, it may be enabled or disabled (independent of its function configuration) by setting its **State.**

Analog Inputs

The NPS600 comes equipped with analog inputs that are defined based on the hardware options. In the Buck Voltage Regulator or Boost Voltage Regulator options, Analog Input 2 is defined as Output Voltage Sense.

In the NPS600 Motor Control configuration, Analog Input 1 is defined as a throttle. When using isolated inputs (available as special order), the throttle can only be configured as Active (Voltage Command). For standard inputs, the throttle may be configured either as Active or as Passive resistive.

	Topology		
Inputs	Motor Controller	Buck Voltage Regulator	Boost Voltage Regulator
Standard	Yes	Yes	Yes
Isolated	Yes (special order)	No	No

The following describes these inputs depending on whether the NPS600 is configured as a Voltage Regulator or Motor Controller (for motor controller, in standard input model or an isolated input model).

Voltage Regulator Option Analog Input

In either Buck or Boost Voltage Regulator modes, Analog Input 2 is defined as Output Voltage Sense (on pins 21 and 23 – using two pins for redundancy). In Buck mode, the input voltage range is **System Voltage** to 12VDC. In Boost mode the input voltage range is 12VDC to System Voltage.

Signal	Pin Number	Connect To
Output Voltage Sense	21, 23	Load side of output inductors

Motor Controller Option Standard Analog Input

When the NPS600 is configured as a Motor Controller, Analog Input 1 (on pin 19) is defined as a throttle, which can be configured as an Active throttle or Passive Resistive throttle with the **Mode** function in the PCProbitII configuration program.

Motor Controller Mode Passive Resistive throttles can be configured as **Type** bi-directional, 0-5K, or 5K-0.

Motor Controller Mode Active throttles can be configured as **Type** bi-directional, 0-5VDC, or 5VDC-0.

Signal	Pin Number	Connect To
Throttle_In	19	Throttle Wiper
Throttle Common	8	Throttle Ground

Motor Controller Option Isolated Analog Input

Isolated Analog Inputs are available as +/-10V or +/-5V inputs. For the isolated model, only active throttle inputs are available.

+/-10V Throttle

For the +/-10V Isolated input, pin 19 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. Note that in isolated mode, the NPS600 Throt1_In signal is factory calibrated to work at +/-10V. User will have to recalibrate throttle input to use a narrower range.

Signal	Pin Number	Connect To
+/-10V Throttle	19	Throttle signal
Throttle Common (Isolated)	22	Throttle Ground

+/-5V Throttle

For the +/-5V Isolated Input pin 21 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. Note that in isolated mode, the NPS600 Throt2_in signal is factory calibrated to work at +/-5V. User will have to recalibrate throttle input to use a narrower range

Signal	Pin Number	Connect To
+/-5V Throttle	21	Throttle signal
Throttle Common (Isolated)	22	Throttle Ground

Digital Output

Standard Model

The Status-BDI signal (on pin 15) is a high impedance logic level output representing either the Normal Operation or the Error/BDI state of the controller. This output can be configured as active low or active high using PCProbitII 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

The Iso_Status_Out signal (on pin 7) is 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.

The Isolated Model of the NPS600 can only operate as a Motor Controller.

This output can be configured as active low or active high using PCProbitII 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 NPS600 unit is configured with 5 switched input signals.

Signal	Description
Key	Global NPS600 enable input. Activating this input takes the unit out of stand-by and places it in run mode.
Forward Enable (Output Enable)	Enables / disables forward direction motor control (using eCycle electronic commutator and BLDC motor). (Enables voltage regulated output in Buck/Boost Modes)
Reverse Enable (Output Enable)	Enables / disables reverse direction motor control (using eCycle electronic commutator and BLDC motor). (Enables voltage regulated output in Buck/Boost Modes)
SRO	**S**tatic **R**eturn to **O**ff 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.
Aux Switch (Brake or Speed Limit)	Selects between **Braking Regen Current Limit** and **Coasting Regen Current Limit**. When enabled, Braking Regen Current Limit is selected. Reduces output voltage to preset cutback percentage when set as Speed Limit.

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 NPS600 due to switch bounce at transition times, the switch inputs must be stable for 8 consecutive I/O reads before the input signal is accepted as a state change. Switch positions are read at an interval of once every millisecond, therefore it takes a minimum of 8 ms for a switch transition to be valid (but can take longer depending on switch bounce time).

SRO Debounce

The SRO input is further debounced to prevent false SRO shutdowns from occurring (for example, in Motor Control mode, 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 Filtering time, as mentioned above, plus an additional user settable **SRO Forgive Time** of 0 to 10000ms.

The default SRO debounce time is set to 500ms.

Safe Sequencing Rules

Motor Control Option

Safe sequencing refers to the sequence of events which must be followed before the NPS600 will transfer current to the motor. It is meant to prevent unsafe starting of the motor during different start up or error conditions. The following will explain safe sequencing for various controller configurations.

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. Direction switch activated. Forward, Reverse, or both can be active. Forward must be active if throttle > throt_mid[2]. Reverse must be active if throttle < throt_mid
5. Throttle set to neutral position
6. Throttle voltage applied
7. Voltage will now be applied to motor based on throttle command

Notes:

- The SRO input can be active any time before step 5.
- 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.

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

[2] Throt_mid is set within the PCProbitII configuration software.

7. Throttle voltage applied
8. Voltage will now be applied to motor based on throttle command

Notes:

- The SRO input can already be active any time before step 5
- If the controller motor output is stopped due to either a diagnostic error or an SRO shutdown, the sequence of events, beginning at step 5, 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.

Buck or Boost Voltage Regulator Mode

Events must occur in the following order for voltage to be output from the NPS600:

1. SRO input activated (input switched to B-)
2. Power to controller
3. Key input switched ON
4. Either Forward or Reverse direction switch activated

Steps 1 and 2 are interchangeable.

Error Detection and Display

The NPS600 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 PCProbitII. Errors will remain in memory until cleared by the user through PCProbitII. 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 NPS600. 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 (5-1)	The **Throttle Type** parameter in the registry is set to an invalid number	Set **Throttle Type** to one of three valid types	Disable
Min Greater Than Max (5-2)	For either a bi-directional or 0K to 5K throttle type, the **Throttle Min** setting is greater than the **Throttle Max** setting	Set **Throttle Min** to be less than **Throttle Max**	Disable
Max Greater Than Min (5-3)	For a 5K to 0K throttle type, **Throttle Max** is set greater than **Throttle Min**	Set **Throttle Min** to be greater than **Throttle Max**	Disable
Throttle Range Too Small (5-4)	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.	Change **Throttle Min** and **Throttle Max** settings such that the difference between them is at least 2 volts	Disable
PH1 Current Sensor Calibration (4-4)	The zero point of the internal current sensor for Phase 1 has exceeded valid range	1. Keep permanent magnets away from M1 bar. 2. Try cycling Key to controller. 3. Contact customer service or dealer.	Disable

PH2 Current Sensor Calibration (4-3)	The zero point of the internal current sensor for Phase 2 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 (3-3)	Battery Voltage exceeding 62V when Key applied to controller	Don't overcharge battery pack. Maximum NPS600 battery voltage is 62V	Disable
Watch Dog Reset	Last reset of microprocessor was due to a Watch Dog Reset	Do nothing. Will not affect operation of controller	Diagnostic

Run Time Errors

Error	Cause	Resolution	Severity
Brake Over Current (2-1)	Analog Output sink current has exceeded approx. 3.3Amps	Increase resistance on Analog Output pin to limit current	Diagnostic
H/W Shutdown (3-3)	Battery voltage has exceeded 62V or phase 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 Throt 1 (3-4) Throt 2 (3-5)	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 (4-2)	Forward Enable and Reverse Enable inputs are both ON while Throttle Type is set to either 0K to 5K or 5K to 0K	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 (1-5)	The temperature of the Power Base has exceeded safe operating temperature of 90^{o}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 (1-4)	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 (1-3)	Battery voltage has dropped below the 6V minimum	Re-charge the battery	Diagnostic

Base Discharged (4-1)	Voltage across the B+ and B- bars of the controller have dropped more than 1/2 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

CAN Accessed Configuration Parameters (User Settable)

The NPS600 has over 160 Configuration parameters categorized as:

- System parameters (read only);
- Status parameters (read only);
- User Configurable parameters (read/write).

They are documented in the PCProbitII User Guide, and listed alphabetically in Appendix **A** of that guide.

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 PCProbitII USB Dongle is required to allow a PC to connect to the CAN bus (the dongle requires device drivers to be installed in Windows).

Figure 2 shows the connection between the NPS600 and the dongle.

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 to dongle)

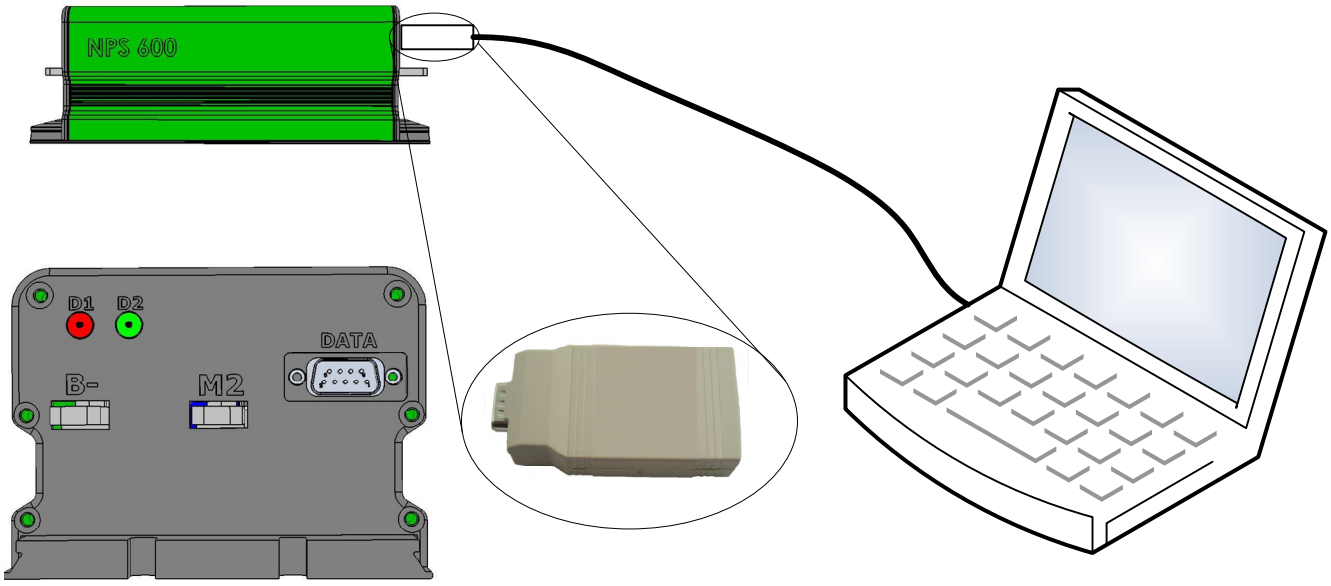


Figure 2. CAN communications connection diagram.

I/O Signals

Standard Model

The following table lists all of the signal I/O to the controller, through its 24 pin I/O port, for the standard model in NPS600.

Pin No.	Signal	Description	Connect To
1	DIR_CRTL-	Direction Output to Electronic Commutator (Negative)	Electronic Commutator Direction Negative Input
2	DIR_CRTL+	Direction Output to Electronic Commutator (Positive)	Electronic Commutator Direction Positive Input
3	B+	Battery Positive (Fused) Power input to digital electronics and base capacitor pre-charge circuit.	B+
4	Key	Controller Enable	B+ (switch to)
5	Analog Out	Open collector, low side switch for driving contactors	Ground side of Contactor Coil. (Other side connected to B+)
6	B-	Battery common	B-
7	N/C	No Connection	
8	Throttle Common	Ground return for throttle input	Throttle Ground
9	N/C	No Connection	
10	N/C	No Connection	
11	+15V Out	15V output to power Hall pot throttle	Hall Pot Power Input
12	N/C	No Connection	
13	N/C	No Connection	
14	N/C	No Connection	
15	Status/BDI Out	Digital High Z output status indicator	Status Monitor
16	Reverse	Reverse Enable	B-
17	Forward	Forward Enable	B-
18	Aux Switch	Aux Switch Enable	B-
19	Throttle In	Primary Throttle signal input	Throttle Source
20	SRO	Static Return to Off Enable	B-
21	Output Voltage Sense	Analog Input to measure NPS600 Output Voltage	Load side of output inductors
22	N/C	No Connection	
23	Output Voltage Sense	Analog Input to measure NPS600 Output Voltage	Load side of output inductors
24	N/C	No Connection	

Isolated Model

The following table lists all of the signal I/O to the controller, through its 24 pin I/O port, for the isolated model.

Pin No.	Signal	Description	Connect To
1	DIR_CRTL-	Direction Output to Electronic Commutator (Negative)	Electronic Commutator Direction Negative Input
2	DIR_CRTL+	Direction Output to Electronic Commutator (Positive)	Electronic Commutator Direction Positive Input
3	B+	Battery Positive (Fused) Power input to digital electronics and base capacitor pre-charge circuit.	B+
4	N/C	No Connection	
5	Analog Out (Non-Iso)	Open collector, low side switch for driving contactors	Ground side of Contactor Coil. (Other side connected to B+)
6	B-	Battery common	B-
7	Status/BDI Out (Iso)	Status Indicator Output (Isolated)	Status Monitor (Isolated)
8	Throttle_Common	Ground return for throttle input	Throttle Ground
9	+24V ISO Power In	Isolated 24V power supply input	Isolated 24V power supply
10	Key (Iso)	Isolated Controller Enable	+24V ISO Power through Key Switch
11	+15V Out	15V output to power Hall pot throttle	Hall Pot Power Input
12	N/C	No Connection	
13	N/C	No Connection	
14	N/C	No Connection	
15	Status/BDI Out	Digital High Z output status indicator	Status Monitor
16	Reverse	Reverse Enable	B-
17	Forward	Forward Enable	B-
18	Aux. Switch	Aux. Switch Enable	B-
19	N/C	No Connection	
20	SRO	Static Return to Off Enable	B-
21	+/- 10V Throttle	Analog Input ISO +/- 10V	+/- 10V isolated Throttle
22	ISO Ground	Ground connection to 24V isolated power supply	Ground of 24V isolated power supply
23	+/- 5V Throttle	Analog Input ISO +/- 5V	+/- 5V isolated throttle source
24	N/C	No Connection	

Signals to the controller are through a 24 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: 39-01-2240

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

Appendix "A"

Selecting Inductors:

For Buck or Motor Controller Mode:

$$L = \frac{V_{out} * (V_{in} - V_{out})}{I_r * F * V_{in}}$$

For Boost Mode:

$$L = \frac{V_{in} * (V_{out} - V_{in})}{I_r * F * V_{out}}$$

Where:

$L = Inductance$
$V_{in} = Input\ Voltage$
$V_{out} = Output\ Voltage$
$I_r = Ripple\ Current$
$F = PWM\ Frequency$

The inductor must be able to withstand maximum phase current levels.

Notes: