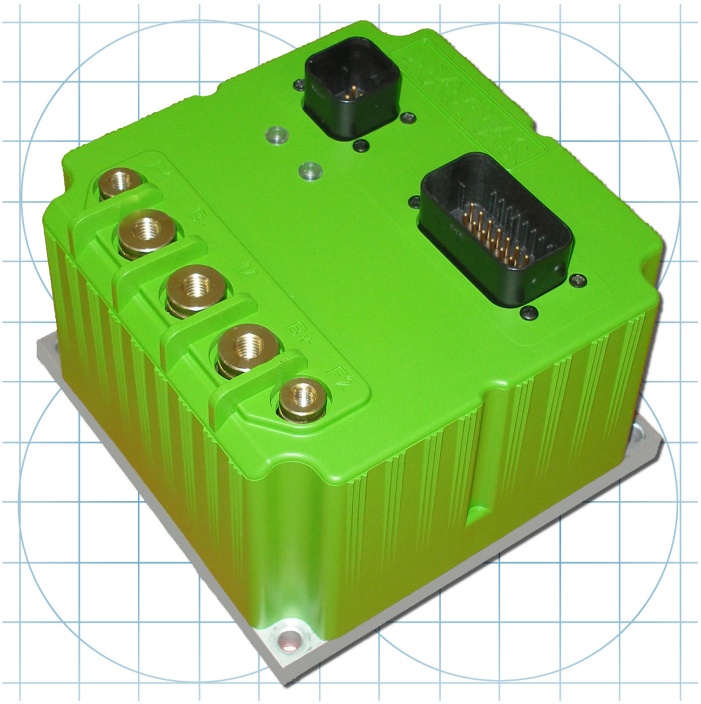
# TSX

## Separately Excited Motor Controller
## User Guide



Navitas Technologies Ltd.
C-855 Trillium Drive,
Kitchener, Ontario N2R 1J9 Canada
Phone: 1-519-725-7871
Fax: 1-519-725-1645
www.navitastechnologies.com
info@navitastechnologies.com

Navitas Technologies (NVT) is in the business of designing, manufacturing and marketing digital drive and hydraulic control systems for electric vehicles. NVT control systems are used in battery powered industrial and commercial vehicles ranging from 96 volt locomotives to 12 volt walkies. NVT's product advantages lie in its efficiency, flexible programmability and reliability. NVT also offers application assistance to help design the best overall solution for your vehicle. NVT is a subsidiary of Tersus Energy Plc. For more information on Tersus please visit www.tersusenergy.com.

# Safety

**Operating and working on electric vehicles can be hazardous and is recommended only for individuals who have the appropriate training and safety equipment. The vehicle manufacture's manual should be consulted before any work is attempted. Always wear safety glasses and use properly insulated tools to avoid shorts when working on electric vehicles.**

Common hazards include electric shock, vehicle run-away, and risk of fire or explosion from hydrogen gas.

Electric Shock – Battery packs in electric vehicles can generate high-power arcs if they are short circuited. Always disconnect the battery when working on other parts of the motor control circuit.

Vehicle Run-Away – Under certain conditions an electric vehicle may run out of control. Before work begins on the vehicle, disconnect the motor (if not needed) and/or using a properly rated jack, raise the drive wheels off the ground to prevent vehicle run-away.

Fire/Explosion – Lead acid batteries emit hydrogen gas during charging and discharging and can build-up around the batteries. Please refer to the battery manufacturers safety guidelines.

**Revision History**

| Issue Date | Revision | Author | Changes |
|---|---|---|---|
| | | | First Revision |
| | | | |
| | | | |
| | | | |

# Table of Contents

# OVERVIEW

Thank you for purchasing a Navitas Technologies TSX motor controller. This document is intended quick reference refresher for electric vehicle technicians already experienced in installing and programming Navitas TSX controllers. If you have never installed a Navitas Technologies TSX motor controller before or require additional information, please refer to the full user manual available from your Navitas distributor or at www.navitastechnologies.com.

# CONTROLLER WIRING AND CONNECTIONS

## *Mounting the Controller*

Position and align the controller in such a way as to allow sufficient access to battery and motor cables as well as low current control wiring. The controller can be mounted horizontally, vertically, or at any angle necessary. If possible, keep the 2 diagnostic LEDs on the top of the cover visible. While the controller is designed to meet IP 66 ingress standards, it is always preferential to mount it in a position which prevents it from direct exposure to moisture or direct water spray. DO NOT MOUNT THE CONTROLLER IN ANY POSITION WHERE IT MAY BECOME SUBMERGED IN WATER.

The mounting surface should be smooth, flat, and have any paint or other debris removed. Using the supplied cut out, drill and tap 4 holes (1/4 – 20 recommended) into a suitable area on the vehicle. Preferably, the controller will be mounted on minimum 1/4" thick aluminum or steel. It is advisable to apply a very thin coating of silicone heat sink compound to the surface before mounting the controller.

When attaching the controller, use either hex head bolts or bolts no larger than 1/4" (7/16" head size) to ensure tools can access the head of the bolts for tightening. Tighten the mounting bolts to a minimum of 72 inch pounds of torque. Check to make sure the controller is flat to the mounting surface once tightened down.

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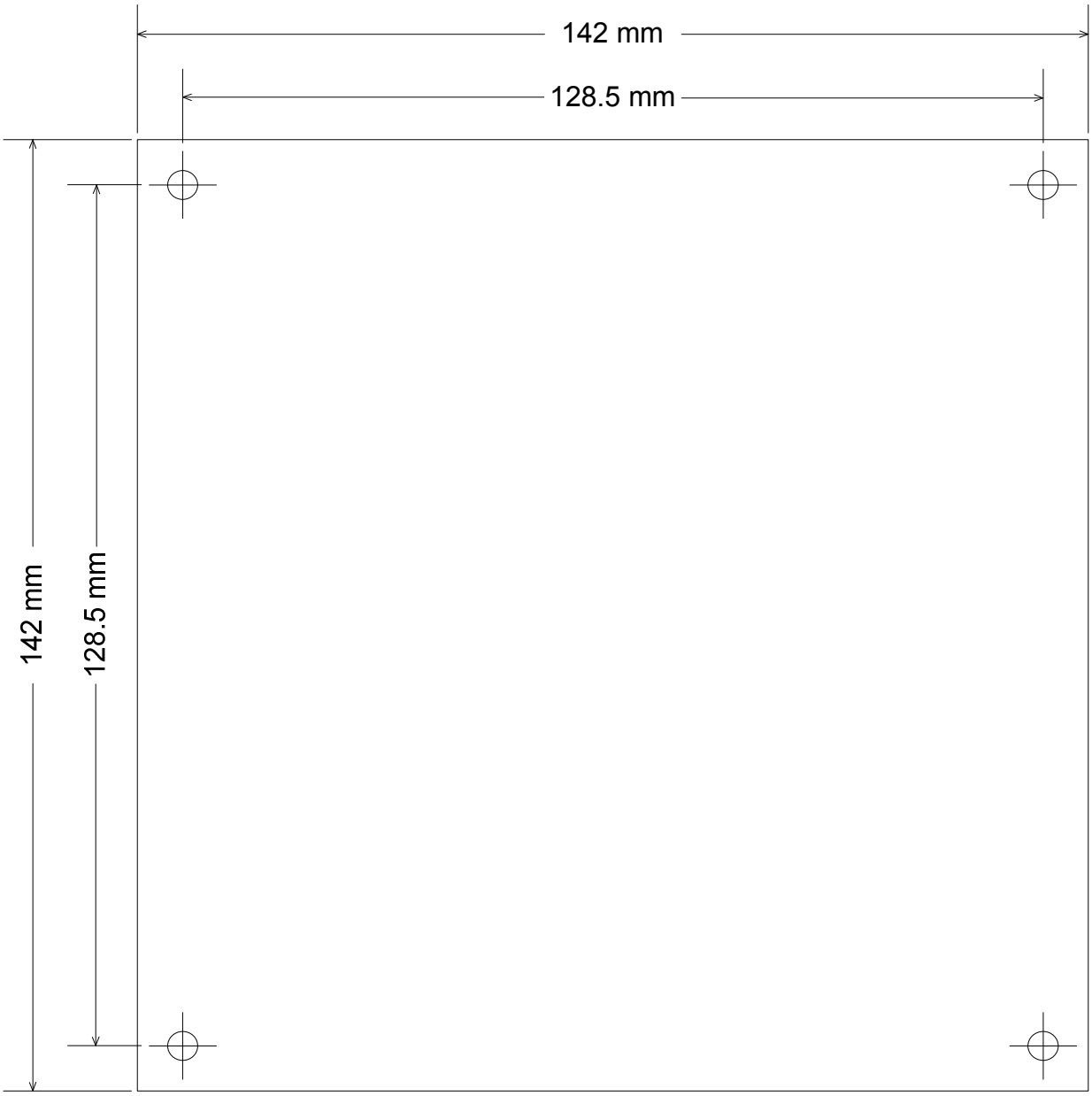


TSX 500-48 CUTOUT
TEMPLATE

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## *Low Current Connections*

The TSX 500-48 comes supplied with a low current control wire harness. The drawing below shows the pin configuration for the Ampseal 23 pin I/O connector:


The pin functions are as shown in the chart below:

| Pin Number | Input/Output | Function | Wire Color |
|---|---|---|---|
| 1 | input | key | red |
| 2 | input | forward enable | white/yellow |
| 3 | input | reverse enable | white/grey |
| 4 | input | brake | white/black |
| 5 | input | SRO | white/red |
| 6 | input | speed limit 3 | white/purple |
| 7 | input | battery negative | black |
| 8 | input | battery positive (pre charge) | orange |
| 9 | input | primary throttle | white |
| 10 | *** | *** | *** |
| 11 | *** | *** | *** |
| 12 | *** | *** | *** |
| 13 | input | speed sensor | white/brown |
| 14 | input | speed limit 2/foot switch | white/orange |
| 15 | input | auxiliary throttle | white/green |
| 16 | input | battery negative (poly fused) | white/blue |
| 17 | output | +12 VDC | yellow |
| 18 | output | line contactor driver | grey |
| 19 | output | lift contactor driver | brown |
| 20 | output | steer contactor driver | blue |
| 21 | output | backup alarm driver | green |
| 22 | output | BDI light driver | purple |
| 23 | input | battery positive | orange |

**Note**: The TSX 500-48 is available in both positive logic and negative logic. For positive logic controllers, forward enable, reverse enable, brake, SRO, and speed limits 1-3 are activated by connecting them to battery +. For negative logic controllers, these are

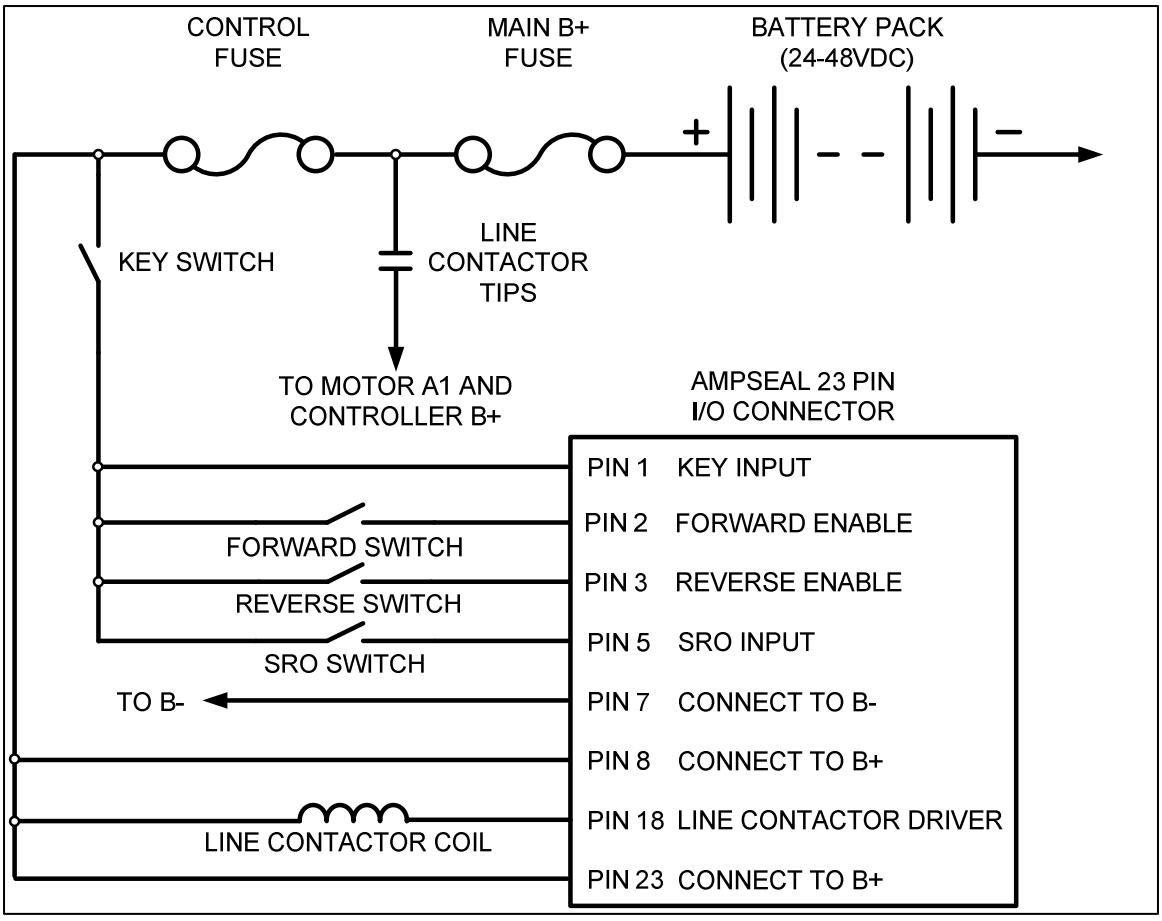
activated by connecting them to battery -. Confirm whether your controller is positive or negative logic before completing low current control wiring connections.

The TSX 500-48 is also capable of operating on a CAN based network either alone or in a master/slave configuration (multiple controllers). For information regarding CAN network connections, refer to the full TSX 500-48 manual.

Programming of the TSX 500-48 controller is accomplished with the Navitas PC Probit II programming package via the 8 pin Ampseal connector and a Windows based computer. The PC Probit II programming package contains a software CD, serial cable, and CAN to serial dongle which allows a computer to connect to the controller. If programming is required, please contact your local Navitas distributor to purchase a PC Probit II programming package.

The following drawings illustrate commonly used control wiring. Specific wiring may vary depending on which TSX 500-48 features and throttle types are used.

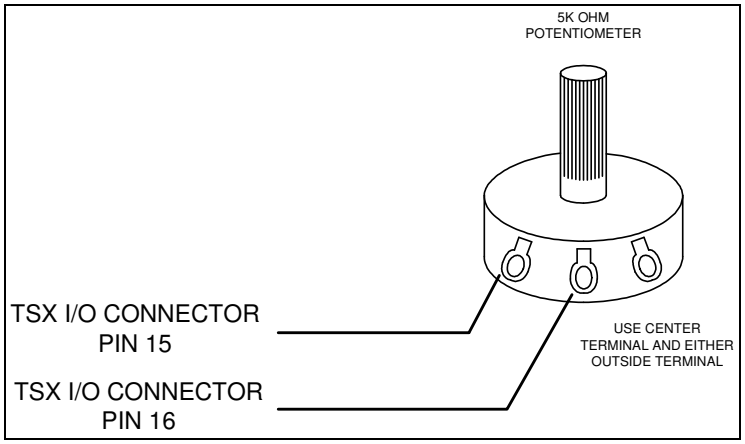
**Basic I/O Wiring (throttle not shown)**



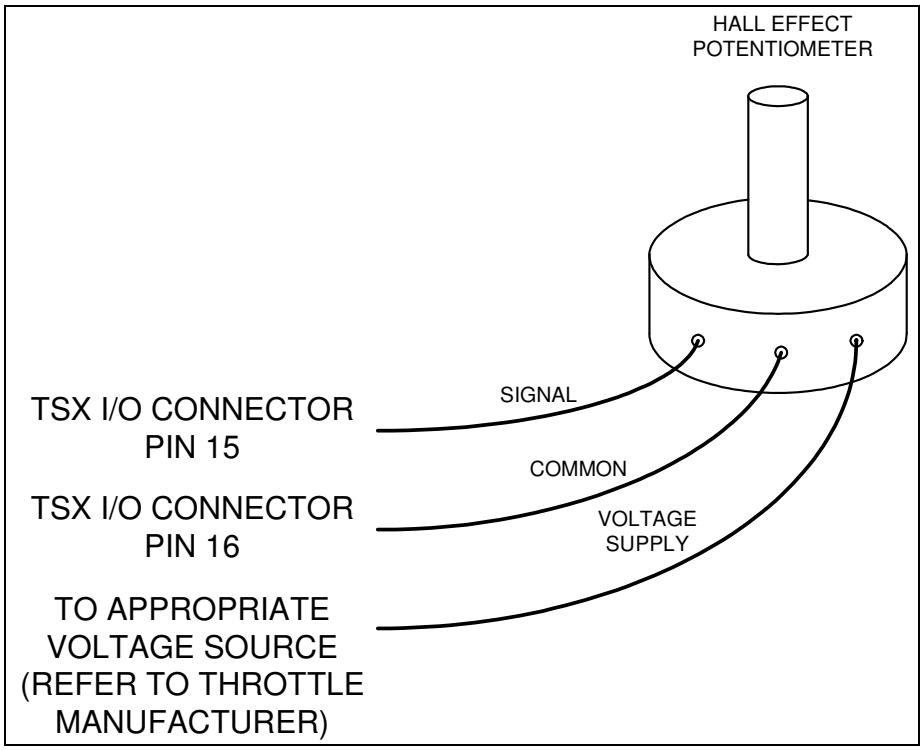
## *Wiring Various Throttle Types*

The TSX 500-48 is designed to be able to utilize a number of different types of throttles. Once the throttle type is determined for the vehicle, chose the correct wiring configuration from the diagrams below.

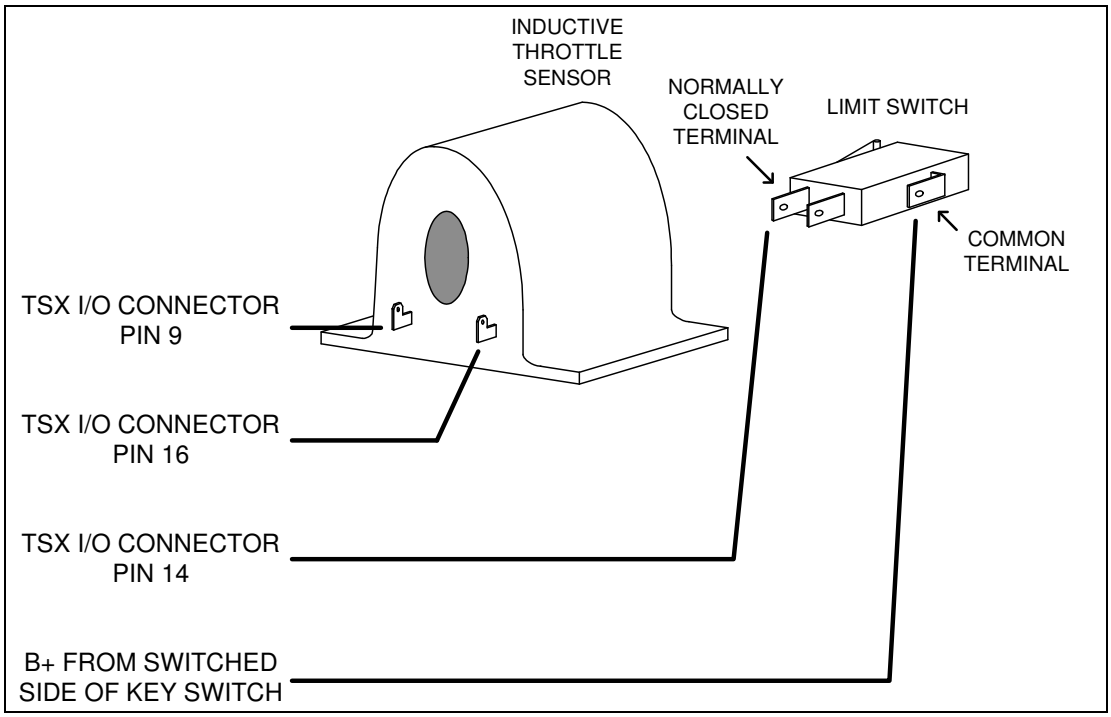
### 0-5k Resistive Throttle




### 0-5v Hall Effect Throttle



**ITS (Inductive) Style Throttle**

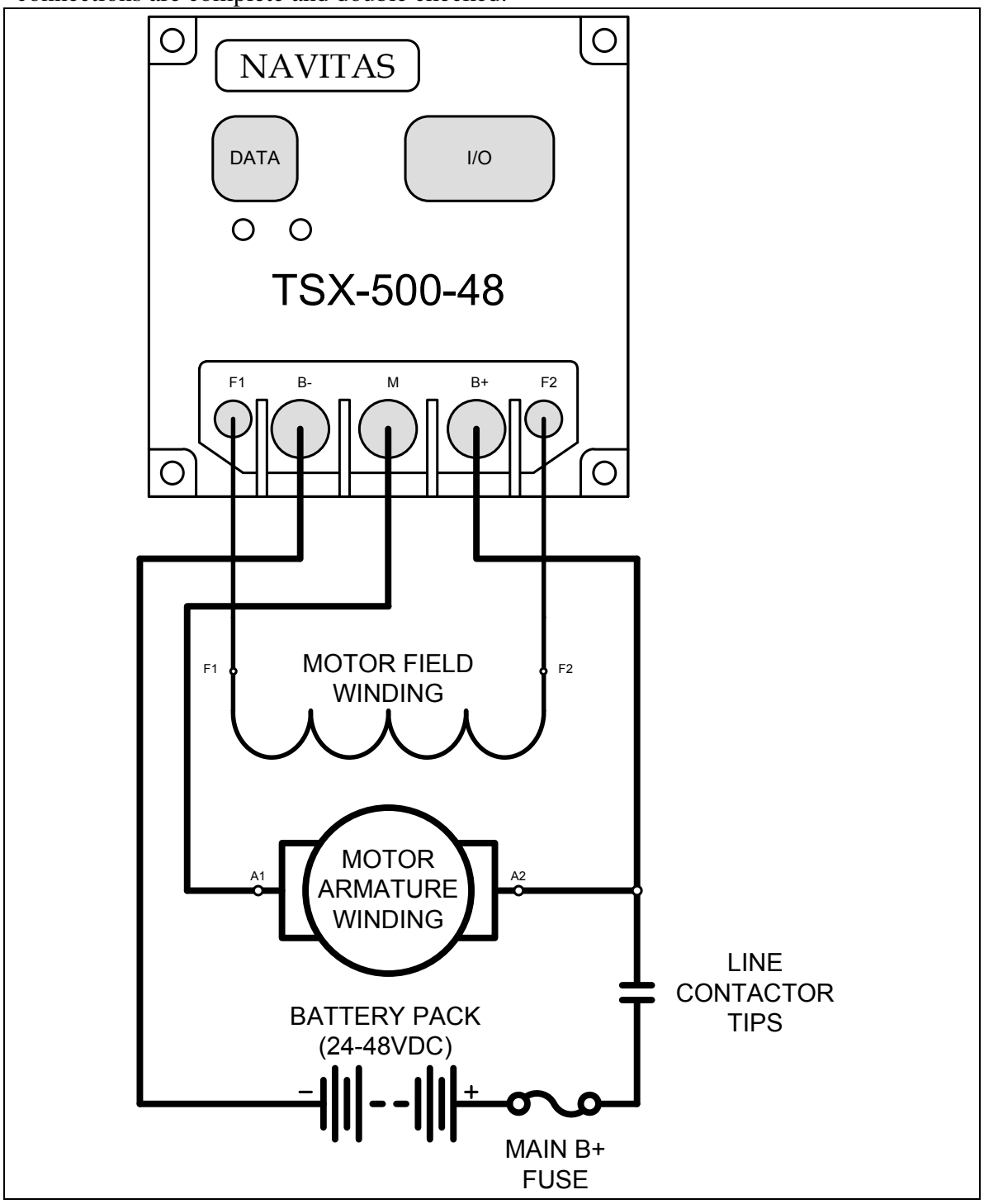


## *Choosing and Using Contactors*

While the TSX 500-48 is capable of using contactor coils ranging anywhere from 12V to battery voltage. For example, a vehicle may have a 48V battery and the coils could be rated for 48V, 36V, 24V, or 12V. The TSX 500-48 has built in "snubber" diodes for all contactor and brake coil driver circuits, therefore diodes are generally not required on the contactor coil. The only time an external diode may be required across a coil is if a switch is connected in series with the coil and the battery + connection.

## *High Current Connections*

NOTE: Before making any high current connections, make sure the battery is disconnected from battery +, battery -, or both. Only reconnect the battery after all connections are complete and double checked.



With the controller mounted to the vehicle, connect the motor's field and armature connections as shown in the drawing above. Be sure to use adequate sized cabling for the expected motor and battery current. Make sure all lugs are attached solidly to the cables and inspect all existing wiring for damage to the insulation such as cuts, nicks or burns. Replace any questionable cabling. When connecting the battery cables, it is extremely important to ensure proper polarity. IF THE BATTERY + AND BATTERY – CABLES ARE CONNECTED IMPROPERLY, THE CONTROLLER WILL BE SEVERLY DAMAGED. THIS TYPE OF DAMAGE IS NOT COVERED BY NAVITAS WARRANTY.

Tighten F1 and F2 cables to 72 inch lbs and B+, M, and B- to 180 inch lbs of torque. The controller is shipped with 2 spare cable fasteners, one 1/4 - 20 x ¾" long for the F1 or F2 connection and one 5/16 – 18 x ¾" long for the B+, M, or B- connection. Ensure that cable lugs bolted to the controller are separated by a minimum of 1/8" to prevent electrical short circuits.

Once the controller wiring is completed and double checked, test the vehicle operation with a fully charged battery and the drive wheels off the ground. If the rotation of the wheels is opposite to what is require and the direction switch is in the correct position, it may be necessary to reverse the connections for F1 and F2 at either the motor or the controller.

# INTRODUCTION TO THE PC-PROBIT II SOFTWARE

In order to complete the installation of the TSX 500-48, the controller must be programmed to suit the vehicle and tuned to the motor characteristics. The user must be aware of the motor's peak and continuous current ratings for both the armature and the field, as well as the motor's voltage rating. Information regarding the speed sensor (if equipped) is necessary should the user intend to implement speed limiting with the controller.

**OPERATING THE MOTOR OUTSIDE OF THE MOTOR MANUFACTURER'S SPECIFICATIONS MAY CAUSE PERMANENT DAMAGE TO THE MOTOR AND/OR CONTROLLER. NAVITAS TECHNOLOGIES IS NOT RESPONSIBLE FOR DAMAGE CAUSED TO A MOTOR DUE TO INCORRECT PROGRAMMING OF THE CONTROLLER BY THE USER.**

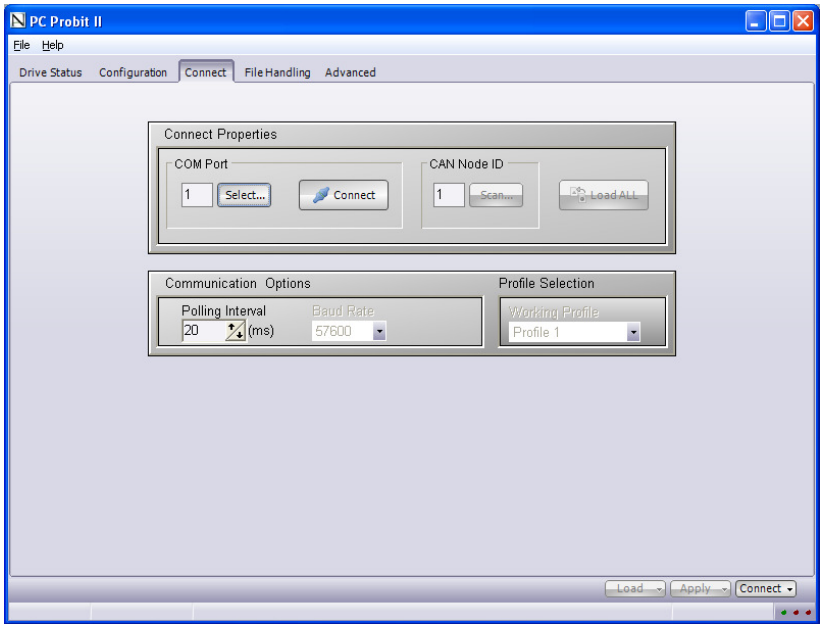
Programming the controller requires the use of Navitas' PC-Probit II user interface software and dongle package and a Windows based computer running Windows XP or new operating system and at least one available com port.

## *Installing Navitas PC Probit II Software and Drivers*

**********software information – CD and internet **********

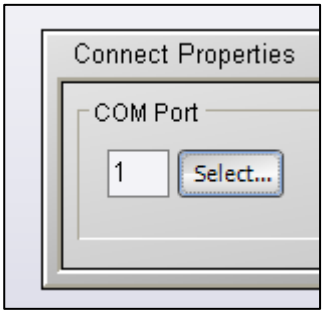
## *Connecting the Computer to the TSX 500*

Connect the 8 pin Ampseal connector with programming harness to the 8 pin data port on the TSX 500-48. The other end of the programming harness (with DB-9 connector) connects to the PC-Probit II dongle. The supplied USB cable will connect the dongle to the computer being used for programming. With battery + voltage applied to pin 8 and battery – connected to pin 7 of the 23 pin I/O connector, open the PC-Probit II software. The software opens on the "CONNECT" tab.

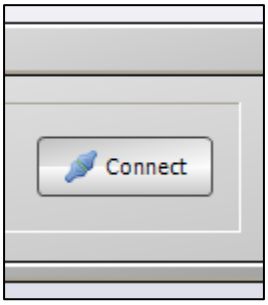



PC Probit II – "CONNECT" tab

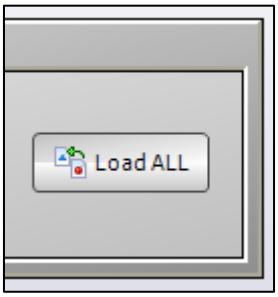
Click on the "SELECT" button to choose the appropriate com port.



Next, click on the “CONNECT” button to allow the software to begin communicating with the controller.

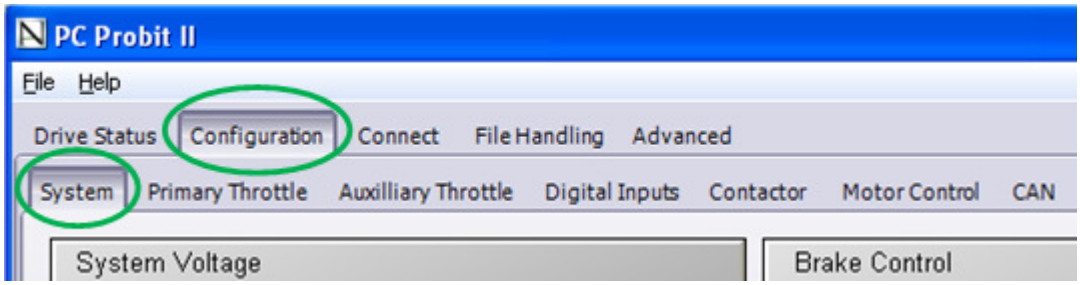



Finally, click on “LOAD ALL” to upload the current parameters from the controller to the computer.

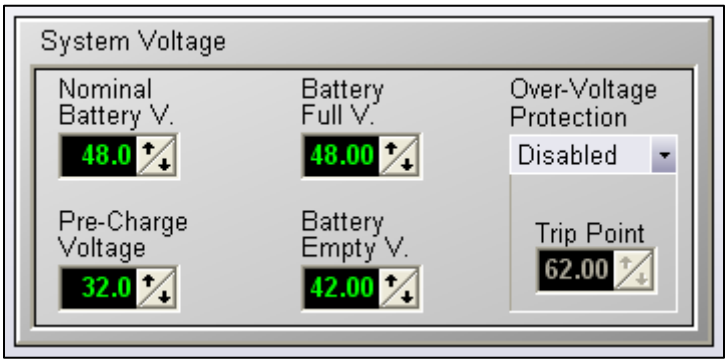


## Configuring Controller Parameters

Once the controller is connected to the computer and the parameters have been uploaded, select the "CONFIGURATION" tab and move to the "SYSTEM" sub-tab.

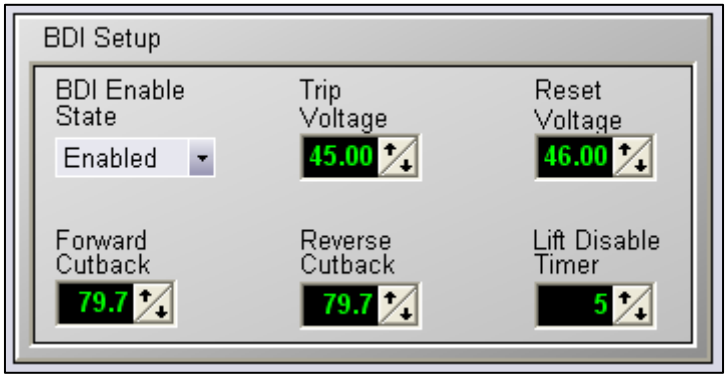



In the "SYSTEM VOLTAGE" box, enter the correct values and settings for the vehicle:



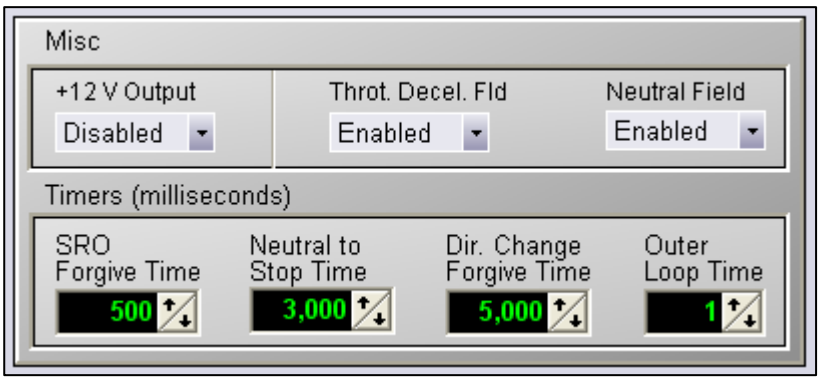

| | |
|---|---|
| **Nominal Battery V** | typical operating voltage of battery |
| **Battery Full V** | battery voltage with full charge (lead acid batteries typically measure 2.14 volts per cell.) |
| **Pre-Charge Voltage** | voltage level that must be present inside the controller before line contactor is allowed to pull in |
| **Battery Empty V** | battery voltage when discharged. (lead acid batteries typically measure 1.75 volts per cell) |
| **Over-Voltage Protection** | Enabled – controller disabled/will not start up if battery voltage rises above "Trip Point" value |
| **Over-Voltage Protection** | Disabled – controller ignores "Trip Point" value |

In the "BDI SETUP" box, enter the values and settings you wish to use:



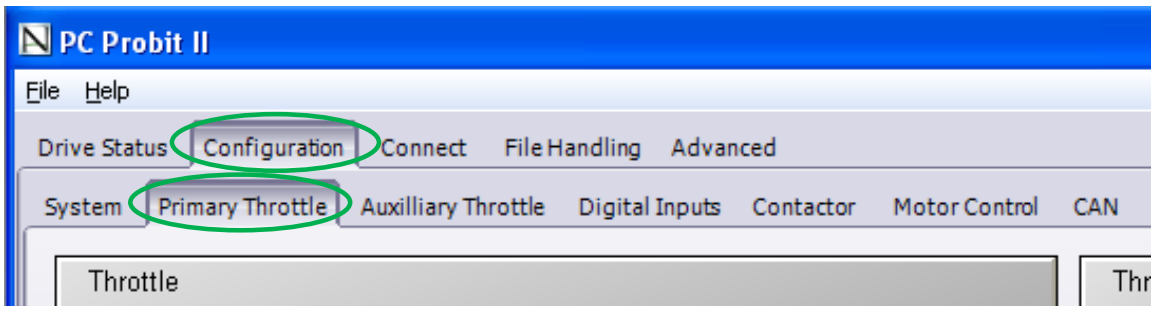

| | |
|---|---|
| **BDI Enable State** | defaults to disabled, select enable to activate BDI features |
| **Trip Voltage** | voltage level at which the controller will go into BDI cutback mode |
| **Reset Voltage** | voltage level at which the controller will automatically exit BDI cutback mode |
| **Forward Cutback** | percentage of full forward speed that vehicle will be limited to during BDI cutback |
| **Reverse Cutback** | percentage of full reverse speed that vehicle will be limited to during BDI cutback |
| **Lift Disable Timer** | the amount of time (seconds) until the lift contactor (if used) no longer functions after BDI is tripped |

Settings for “MISC” box:

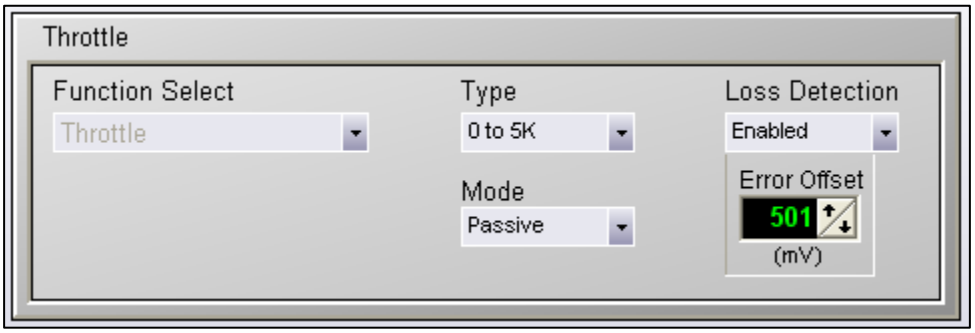



| | |
|---|---|
| **+12V Output** | when enabled, +12VDC is available on pin 17 of the 23 pin I/O connector |
| **Throt. Decel. Fld** | when enabled (recommended) the controller will set field current to the ‘Field Brake Regen’ level during deceleration |
| **Neutral Field** | when enabled the controller will maintain the field current at the level specified by ‘Fwd Field Min’ value |
| **SRO Forgive Time** | specifies in mS amount of time SRO can be open without forcing controller to go to neutral |
| **Neutral to Stop Time** | specifies in mS amount of time controller direction switch can remain in neutral when changing directions before throttle must be returned to neutral as well. |
| **Dir. Change Forgive Time** | timer in mS will retard the controller from changing directions |
| **Outer Loop Time** | system parameter, not recommended to be adjusted without instruction from Navitas Technologies. |

Once all settings are confirmed in the "SYSTEM" sub-tab, move on to the "PRIMARY THOTTLE" sub-tab and fill in parameters:

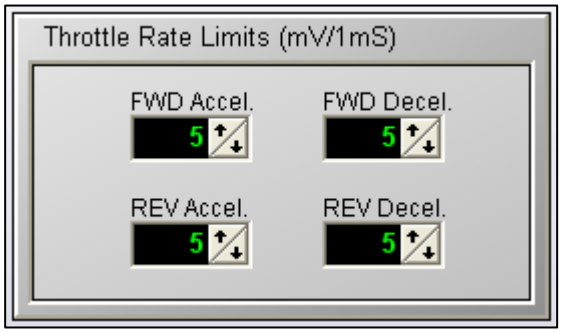



"THROTTLE" box settings:



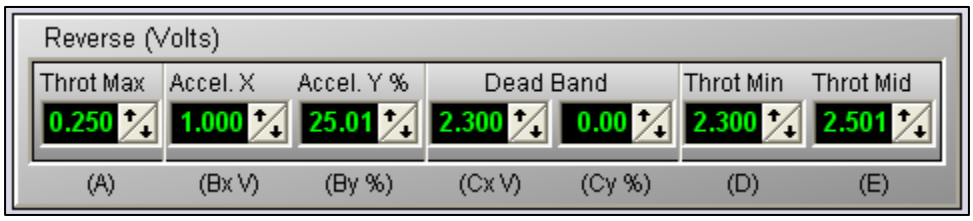

**Function Select** not available on primary throttle
**Type** select 0-5K, 5K-0, or bi directional throttle
**Loss Detection** enabling causes controller to shut down if no throttle is detected or throttle level is too high on the primary input
**Mode** select between passive (resistive) or active (voltage)
**Error Offset** tolerance voltage for throttle loss detection

Settings for "THROTTLE RATE LIMITS" box:




| | |
|---|---|
| **FWD Accel** | adjusts maximum rate of throttle change in mV/mS during forward acceleration |
| **FWD Decel** | adjusts maximum rate of throttle change in mV/mS during forward deceleration |
| **REV Accel** | adjusts maximum rate of throttle change in mV/mS during reverse acceleration |
| **REV Decel** | adjusts maximum rate of throttle change in mV/mS during reverse deceleration |

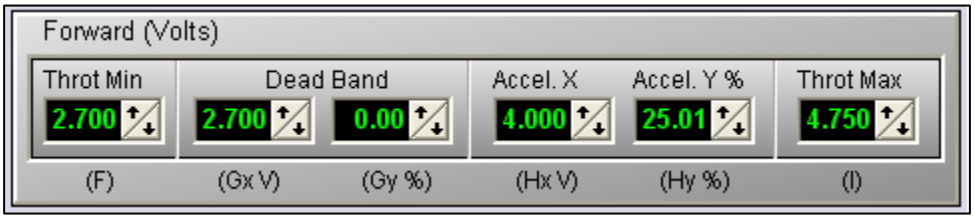
"REVERSE VOLTS" settings:




Note: these settings are only accessible if the throttle type is set to BI DIRECTIONAL. Otherwise, this box will be grayed out and only the forward settings can be changed.

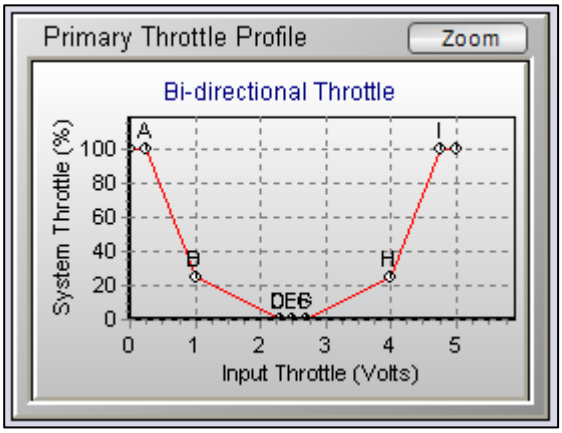
| | |
|---|---|
| **Throt Max** | throttle voltage at full speed reverse (100% system throttle) |
| **Accel. X** | throttle voltage "knee" (Accel Y% system throttle) |
| **Accel. Y%** | percentage of system throttle at Accel X voltage |
| **Dead Band** | throttle voltage at which controller will start driving motor %age is the minimum output voltage of the controller at start. This parameter is usually set to the same voltage as Throt Min and the %age is set to 0% |
| **Throt Min** | throttle voltage where controller will start to drive in the reverse direction |
| **Throt Mid** | center point of throttle when Bi-directional throttle is used |

"FORWARD VOLTS" settings:



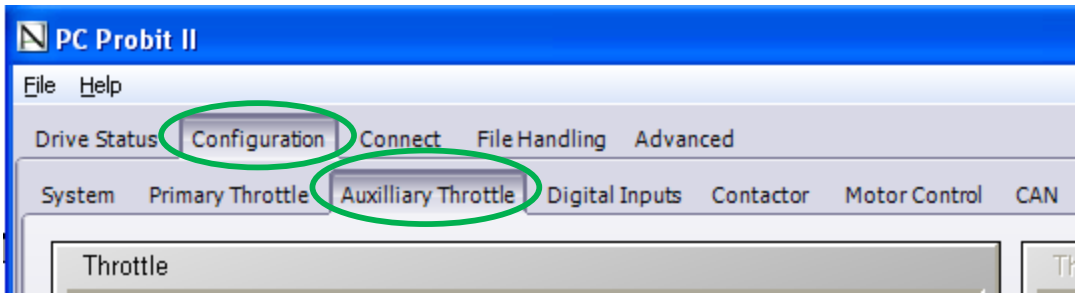

| | |
|---|---|
| **Throt Min** | throttle voltage at which controller will begin to operate |
| **Dead Band** | throttle voltage at which controller will start driving motor %age is the minimum output voltage of the controller at start. This parameter is usually set to the same voltage as Throt Min and the %age is set to 0% |
| **Accel. X** | throttle voltage "knee" (Accel Y% system throttle) |
| **Accel. Y%** | percentage of system throttle at Accel X voltage |
| **Throt Max** | throttle voltage at full speed (or full speed forward if in Bi-directional mode) |

"PRIMARY THROTTLE PROFILE" box:



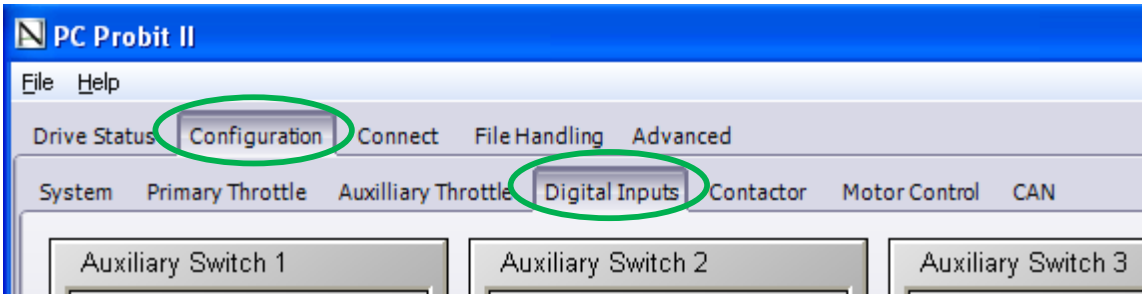

The curve plotted in this graph represents the way the controller will respond to the parameters that have been programmed into the software. As changes are made to the throttle parameters, the shape of the curve will change. For a larger view of the graph, click "Zoom" in the PC Probit II software.

Once all settings are confirmed in the “PRIMARY THROTTLE” sub-tab, move on to the “AUXILIARY THOTTLE” sub-tab and fill in parameters:

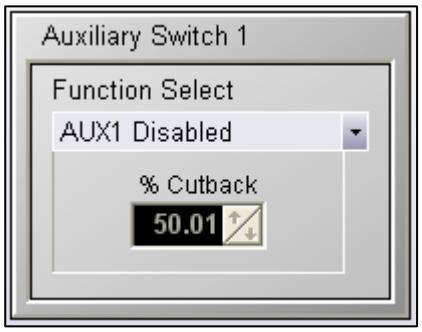



Note: the type of throttle or throttle signal that can be used on both the Primary and Auxiliary throttle inputs will vary with the specific version of controller being used. Please contact the local Navitas distributor to determine what types of throttles can be used on a specific controller. In many cases, only the Primary throttle needs to be set up and the Auxiliary throttle can be left in the “DISABLED” state. Otherwise, follow the same format for configuring the Auxiliary throttle as the steps shown previously for the Primary throttle.

With all throttle settings configured, continue to the “DIGITAL INPUTS” sub-tab:

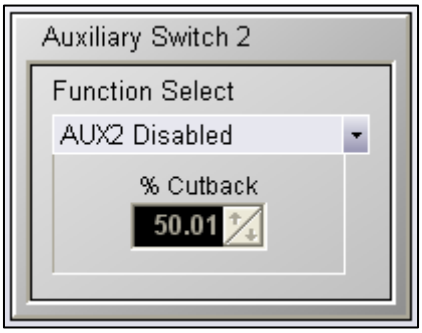



“AUXILIARY SWITCH 1” settings:



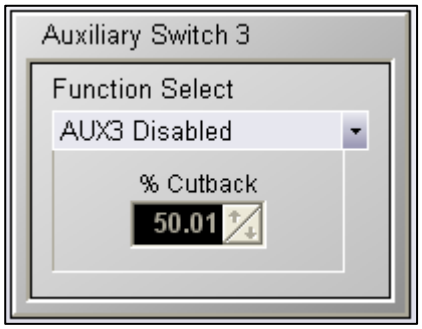

| | |
|---|---|
| **AUX1 Disabled** | when disabled, controller ignores this switch input |
| **Speed Limit 1 Input** | forces controller into reduced speed mode 1 when active |
| **Belly Switch** | temporarily forces controller into reverse direction for a brief period when activated |
| **Foot Switch** | when enabled, the line contactor/battery solenoid is activated by closing the foot switch |
| **% Cutback** | % of full speed utilized when Speed Limit 1 Input is activated |

"AUXILIARY SWITCH 2" settings:



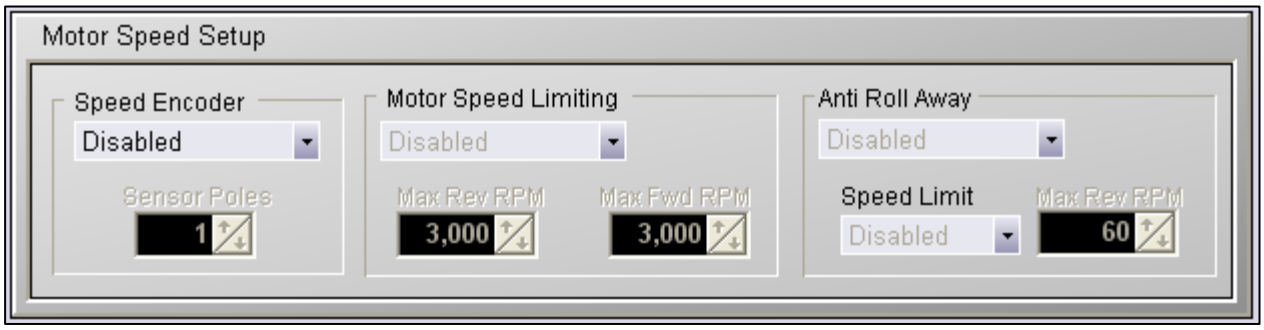

**AUX2 Disabled** when disabled, controller ignores this switch input
**Speed Limit 2 Input** forces controller into reduced speed mode 2 when active
**% Cutback** percentage of full speed utilized when Speed Limit 2 Input is activated

"AUXILIARY SWITCH 3" settings:



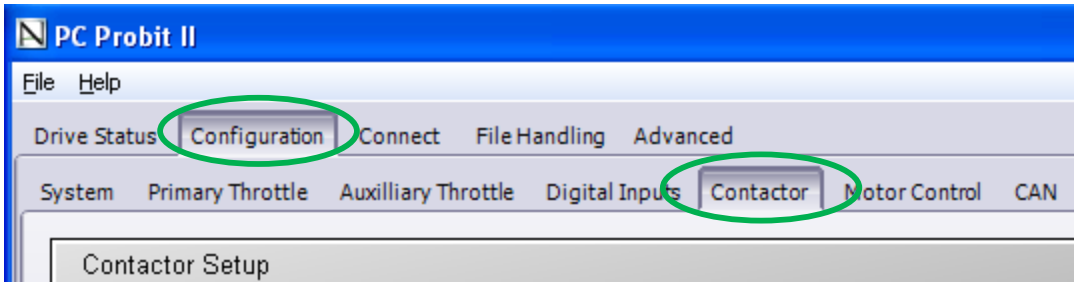

**AUX3 Disabled** when disabled, controller ignores this switch input
**Speed Limit 3 Input** forces controller into reduced speed mode 3 when active
**% Cutback** percentage of full speed utilized when Speed Limit 2 Input is activated

"MOTOR SPEED SETUP" parameters:




| | |
|---|---|
| **Speed Encoder** | when enabled, controller will report current motor speed on Drive Status screen and also allows motor speed limiting and anti roll away |
| **Sensor Poles** | number of pulses per revolution of motor |
| **Motor Speed Limiting** | when enabled, will limit the top speed of motor to preset value |
| **Max Rev RPM** | when Motor Speed Limiting enabled, the maximum RPM of motor in reverse |
| **Max Fwd RPM** | when Motor Speed Limiting enabled, the maximum RPM of motor in forward |
| **Anti Roll Away** | when enabled, controller will prevent vehicle from rolling away if left on a slope. |
| **Speed Limit** | when enabled, limits the maximum speed that vehicle is allowed to roll when left on a slope |
| **Max Rev RPM** | maximum RPM when in Anti Roll Away |

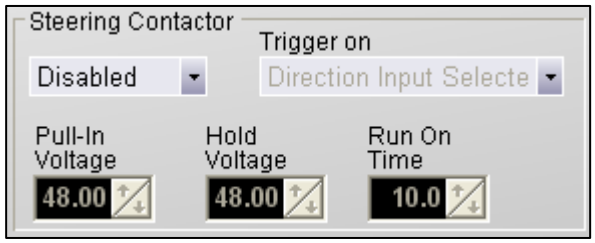
With “DIGITAL INPUTS” configured, move to the “CONTACTOR” sub-tab:




All contactor outputs utilize PWM driver logic. These outputs, when activated, provide a voltage between B+ and the drive circuit that briefly starts out at “Pull In Voltage” and transitions to “Hold Voltage” until the corresponding activating signal is removed.

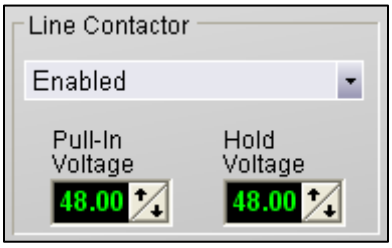
“CONTACTOR SETUP” can be broken down into the following parameters:

“STEERING CONTACTOR”:



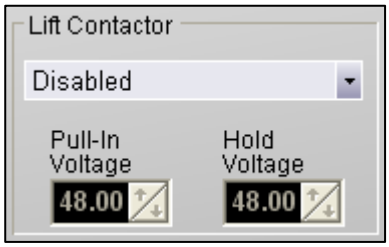

| | |
|---|---|
| **Disabled** | when disabled, steer contactor drive is not used |
| **Enabled** | activates steer contactor drive |
| **Trigger on:** | |
| **- Direction Input Selected** | energizes steer contactor when direction is selected |
| **- SRO Input Active** | energizes steer contactor when SRO input is activated |
| **Pull-In Voltage** | initial voltage applied when steer contactor is energized |
| **Hold Voltage** | continuous voltage applied to steer contactor |
| **Run On Time** | amount of time contactor will be held in after trigger signal is removed |

"LINE CONTACTOR":



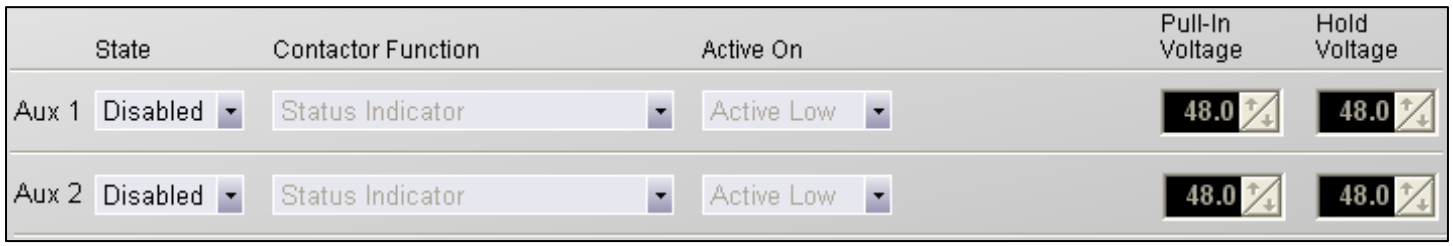

| | |
|---|---|
| **Disabled** | when disabled, line contactor drive is not used |
| **Enabled** | activates line contactor drive |
| **Pull-In Voltage** | initial voltage applied when line contactor is energized |
| **Hold Voltage** | continuous voltage applied to line contactor |

"LIFT CONTACTOR":




| | |
|---|---|
| **Disabled** | when disabled, lift contactor drive is not used |
| **Enabled** | activates lift contactor drive |
| **Pull-In Voltage** | initial voltage applied when lift contactor is energized |
| **Hold Voltage** | continuous voltage applied to line contactor |

"AUXILIARY CONTACTOR":




Aux 1:

**Disabled** when disabled, aux 1 contactor drive is not used

**Enabled** activates aux 1 contactor drive

**Status Indicator** displays presence of controller fault via aux 1 drive circuit

**- Active Low** aux 1 drive circuit drops to "hold voltage" to indicate presence of fault

**- Active High** aux 1 drive circuit changes from "hold voltage" to open circuit to indicate presence of fault

**BDI Indicator** indicates controller is in battery discharge state

**- Active Low** aux 1 drive circuit drops to "hold voltage" to indicate BDI state

**- Active High** aux 1 drive circuit changes from "hold voltage" to open circuit to indicate BDI state

**Brake Release** energizes coil to release electric brakes

**Trip On:**

**- Neutral to Stop Time** de-energizes brake coil after "Neutral to Stop Time" elapses

**- SRO Open for Set Time** de-energizes brake coil after "SRO Forgive Time" elapses

**Error Code Flasher** displays error codes via aux 1 drive circuit by pulsing to "Hold" voltage level

**Back Up Alarm** activates aux 1 drive circuit when reverse is selected

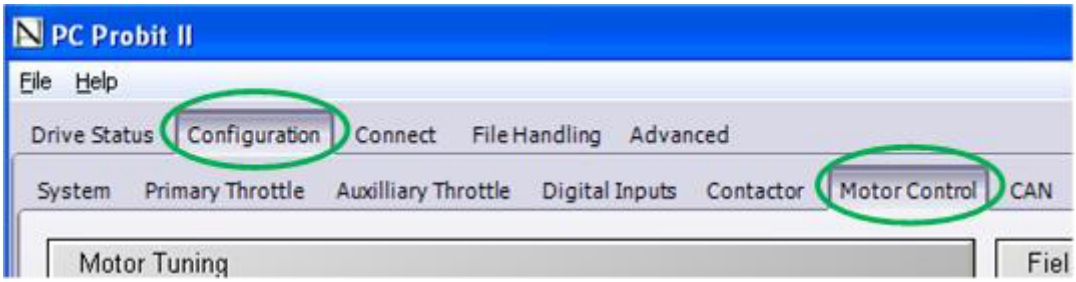
**Hour Meter Enable** activates aux 1 drive circuit when controller is driving motor

**Pull-In Voltage** voltage level applied to aux 1 output when initially activated (approx 500ms)

**Hold Voltage** continuous voltage level applied to aux 1 output until deactivated

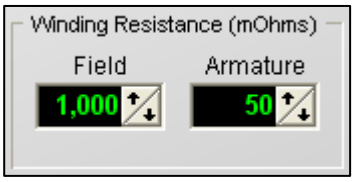
For Aux 2, all settings are the same except for the omission of Brake Release

Now select “MOTOR CONTROL” sub-tab:



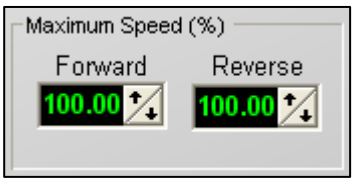

“MOTOR TUNING” is broken down into the following parameters:

“WINDING RESISTANCE (mOMS)”:



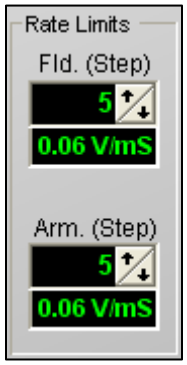

**Field** resistance of field winding
**Armature** resistance of armature winding

“MAXIMUM SPEED %”:




**Forward** % of full speed forward
**Reverse** % of full speed reverse

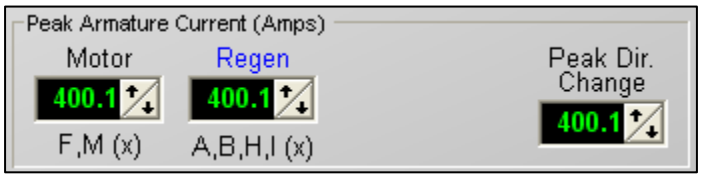
"RATE LIMITS":




**Fld. (Step)** limits how fast field voltage can decay based on armature/field map - recommended to have this parameter set to 1

**Arm. (Step)** recommended that this parameter remains at its default value - do not change without instruction from Navitas Technologies

"PEAK ARMATURE CURRENT (AMPS)":




**Motor** maximum motor current allowed in armature

**Regen** maximum current to be pulled from armature during regen

**Peak Dir. Change** regen current must be less than this value for controller to switch from forward to reverse or vice versa

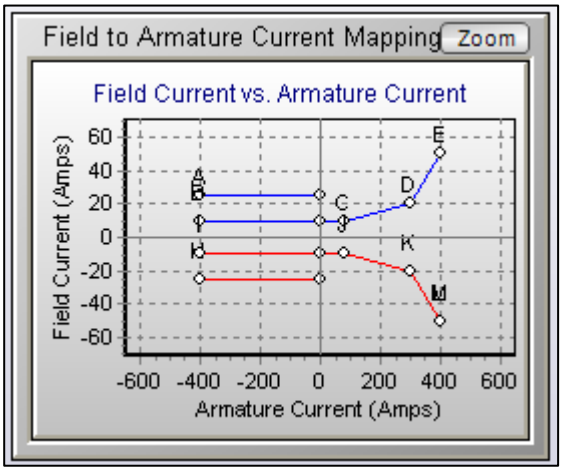
"REVERSE CURRENT (AMPS)":


| | |
|---|---|
| **Arm. Min** | currents through armature of less than Arm. Min will result in field currents of Field Min |
| **Field Min** | minimum field current applied to motor |
| **Arm. Mid** | currents through armature of less than Arm. Mid but greater than Arm. Min will result in field current being interpolated between Field Min and Field Mid |
| **Field Mid** | allows shape of armature/field map to be adjusted for best performance with motor |
| **Arm. Max** | currents through armature of less than Arm. Max and greater than Arm. Mid will result in field current being interpolated between Field Mid and Field Max - armature currents greater than Arm. Max will result in Field Max |
| **Field Max** | maximum field current applied to motor |
| **Field Brake Regen** | when braking, field is set to this current to provide regen braking |
| **Field Coast Regen** | not currently implemented |

"FORWARD CURRENT (AMPS)":

All settings for "FORWARD CURRENT (AMPS)" are based on the same principals as "REVERSE CURRENT (AMPS)" except they apply to the forward direction of the vehicle instead of the reverse direction.

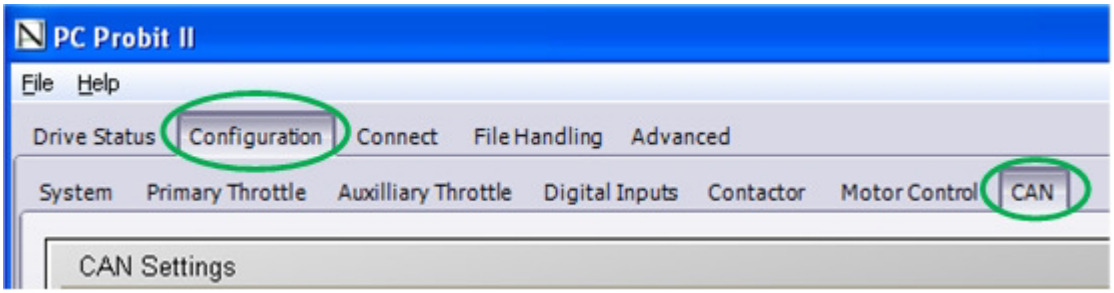
"FIELD TO ARMATURE CURRENT MAPPING":



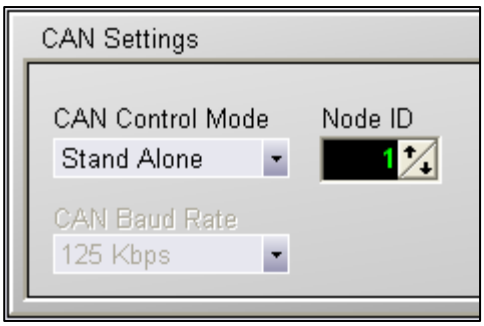

This chart graphically represents the armature and field current settings entered into the "FORWARD CURRENT (AMPS)" and "REVERSE CURRENT (AMPS)" areas. Clicking on "ZOOM" enlarges the graph and provides more detail. Labeled points on the graph correspond to specific values for "FORWARD CURRENT (AMPS)" and "REVERSE CURRENT (AMPS)" shown below each independent value window.

For most single motor applications, no further parameters will need to be added under the "CONFIGURATION" tab. If multiple controllers are connected via the CAN network, continue on with the section on the "CAN" sub-tab. Otherwise, skip ahead to the "APPLYING CHANGES" section.

Parameters in the “CAN” sub-tab:

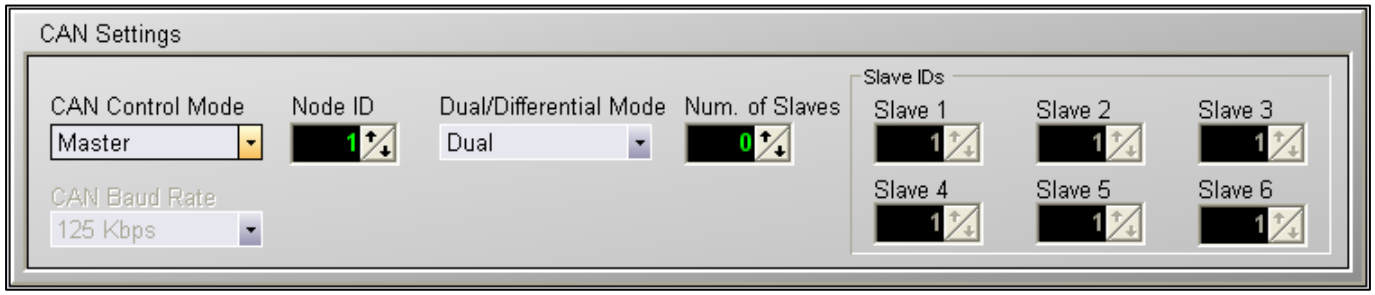



“CAN” in “STAND ALONE” mode:




**Node ID** set to Node 1 by default - address used for communicating with the controller - in Stand Alone mode, it is recommended to leave as Node 1.

"CAN" in "MASTER" mode:




**Node ID** — the address of controller currently being programmed - must be different than address of slave controller(s)

**Dual/Differential Mode**

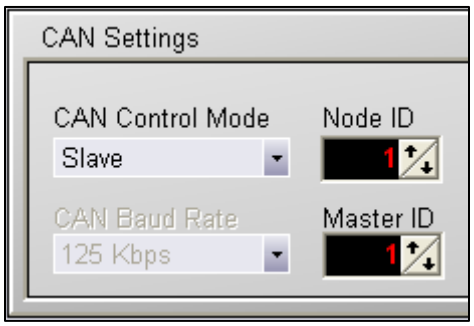
**Dual** — mode where speed of Slave is controlled via Master controller

**Differential** — master and slave controllers react as an electronic differential with inputs from a single throttle and steer position sensor

**Num. of Slaves** — indicates number of Slave controllers connected to network

**Slave IDs (1 through 6)** — each Slave controller must be assigned its own unique Node ID - allows Master to know which Slave to talk to.

"CAN" in "SLAVE" mode:

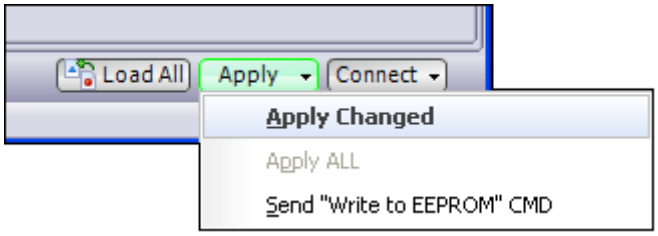



**Slave Node ID** — address of Slave controller on network - must be different than address of Master

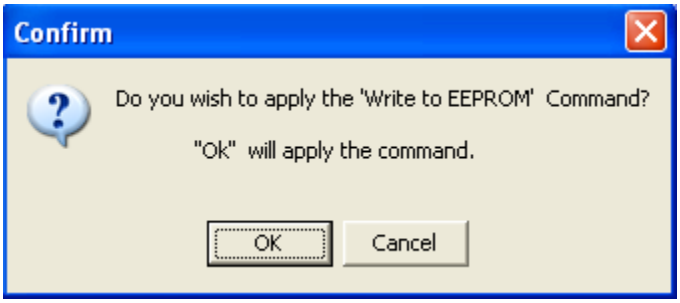
**Master ID** — address of the Master on network

"APPLYING CHANGES"

Once all desired parameters have been set into the PC Probit II software the user must "APPLY CHANGES" or load the parameters or parameter changes into the controller. Clicking on the "APPLY" button on the bottom right of any tab window starts this process:



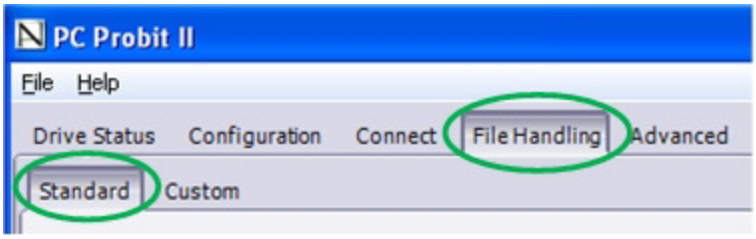

Click "APPLY CHANGED", and the following prompt will appear:



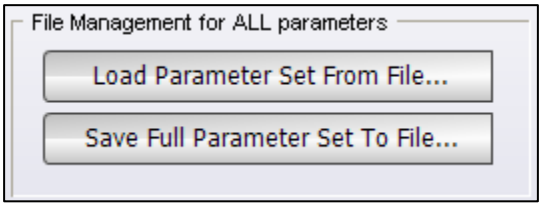

Click "OK" and then cycle the key switch on and off to ensure the changes are correctly loaded into the controller's memory. If any changes have been made to the CAN parameters of the controller, the main power must be cycled to the controller, not just a key on/off

**File Handling**

"FILE HANDLING" tab, "STANDARD" sub-tab:

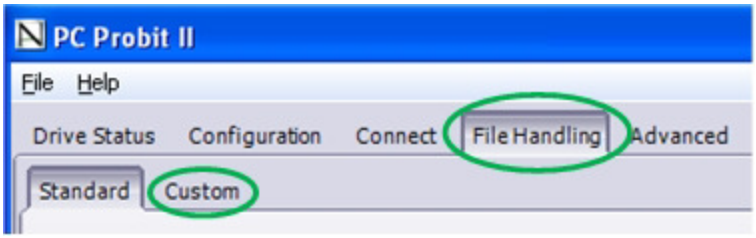



"FILE MANAGEMENT FOR ALL PARAMETERS":

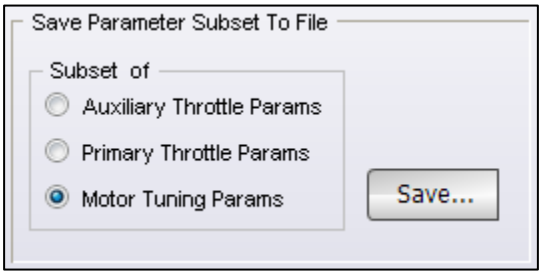



**Load Parameter Set From File**
**Save Full Parameter Set to File**

"FILE HANDLING" tab, "CUSTOM" sub-tab:



"SAVE PARAMETER SUBSET TO FILE" sub-tab:

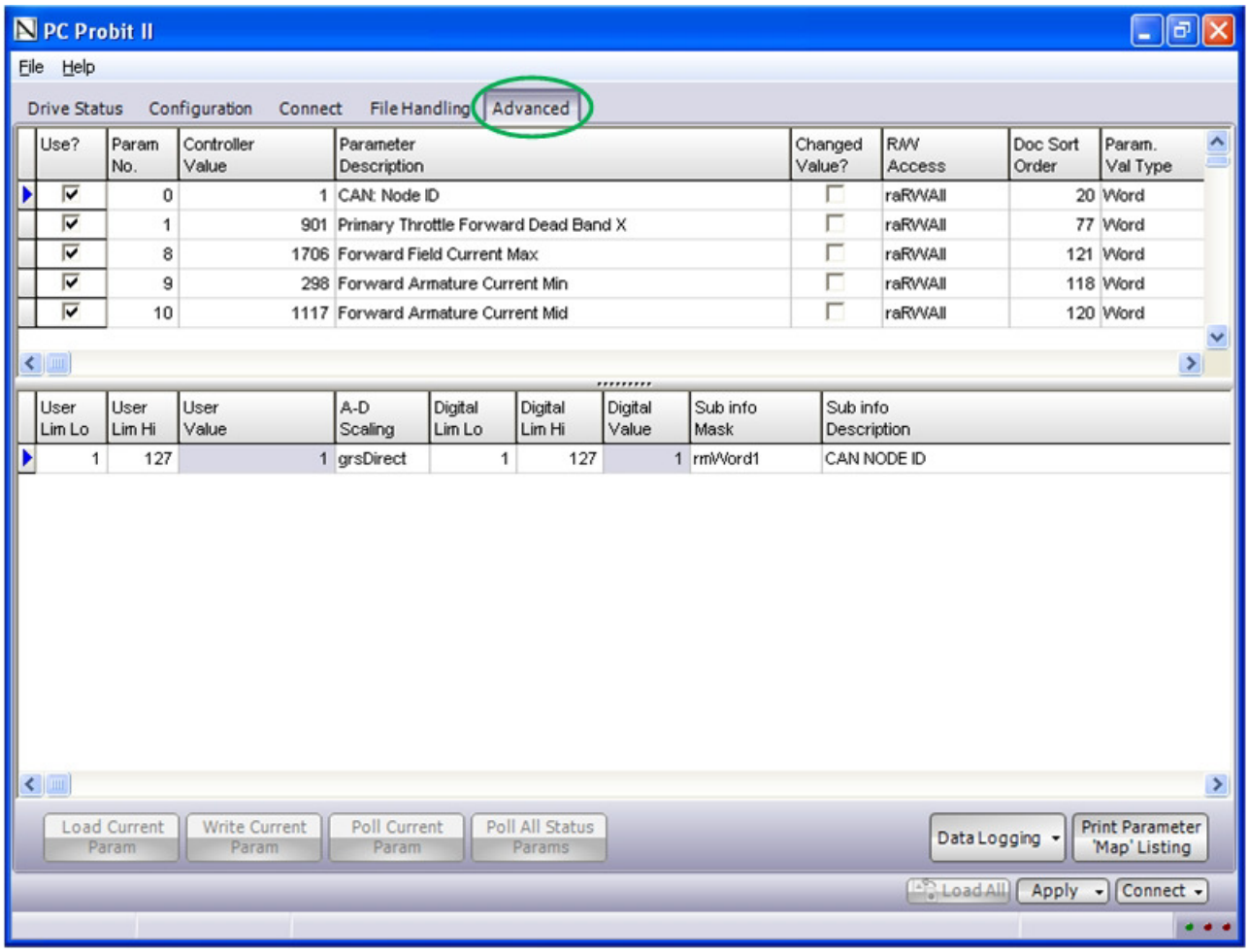



**Auxiliary Throttle Params** loads and saves only Auxiliary Throttle parameters
**Primary Throttle Params** loads and saves only Primary Throttle parameters
**Motor Tuning Params** loads and saves only Motor Tuning parameters

A detailed description of parameter subsets is provided on this screen of the PC Probit II software. Once a parameter sub-set has been chosen, click "SAVE".
Parameter in the "ADVANCED" tab:

### The Advanced Tab

The "ADVANCED" tab opens a page in the PC Probit II software that will allow the user access to all available parameters. The top portion of the page is a continuous list of parameters that may be sorted by any column heading. The columns are as follows:




| | |
|---|---|
| **Use?** | indicates whether or not specific parameter is active in software |
| **Param No.** | numeric ID of registry parameter |
| **Controller Value** | internal digital value of registry parameter |
| **Parameter Description** | function of controller affected by parameter value |
| **Changed Value?** | indicates value of parameter has changed |

The bottom portion of the page contains detailed information regarding a specific parameter. The parameter detailed is indicated in the top section by the blue arrow in the leftmost side of the page. This information is broken down into the following headings:

| | |
|---|---|
| **User Lim Lo** | lowest available limit of "user value" |
| **User Lim Hi** | highest available limit of "user value" |
| **User Value** | user specified value for selected parameter |

From the "CONFIGURATION" tab and "MOTOR CONTROL" sub-tab, the advanced screen can be accessed simply by right-clicking on a specific parameter's value and selecting "JUMP TO ADVANCED". This will redirect the user to the "ADVANCED" page with the chosen "MOTOR CONTROL" parameter selected and detailed view of that parameter's values shown on the bottom half of the page.

The buttons on the bottom left of the "ADVANCED" page are:


| | |
|---|---|
| **Load Current Param** | reads selected parameter value from controller |
| **Write Current Param** | writes selected parameter value into controller |
| **Poll Current Param** | constantly refreshes selected parameter value from controller |
| **Poll All Status Params** | constantly refreshes all parameter values from controller |

## Data Logging and Graphing

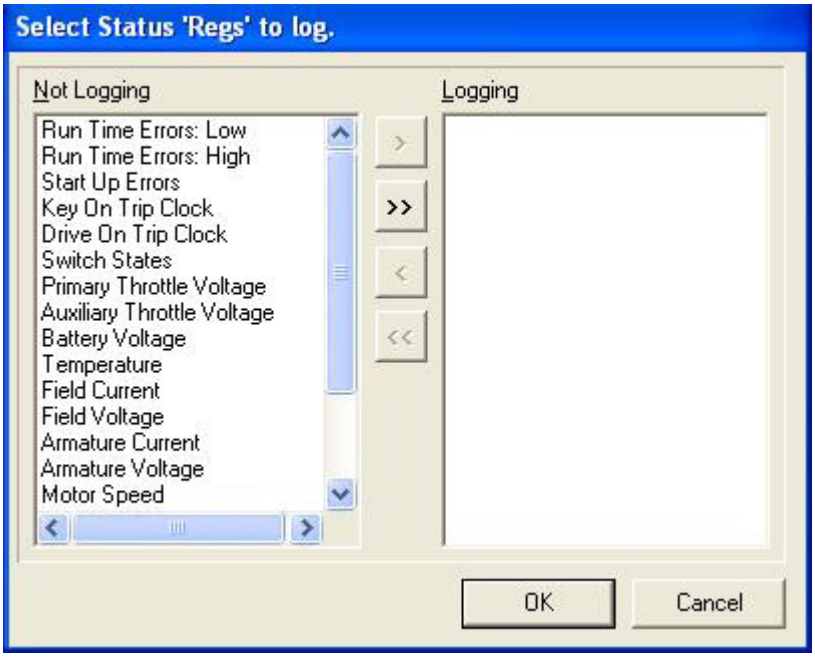
The buttons on the bottom right of the "ADVANCED" page are:


**Data Logging**

| | |
|---|---|
| **Create New Log** | initiates logging software that tracks parameter values over time (see details) |
| **View Saved Log** | displays previous log files |
| **Print Parameter 'Map' Listing** | creates printable 'map' of all parameters |

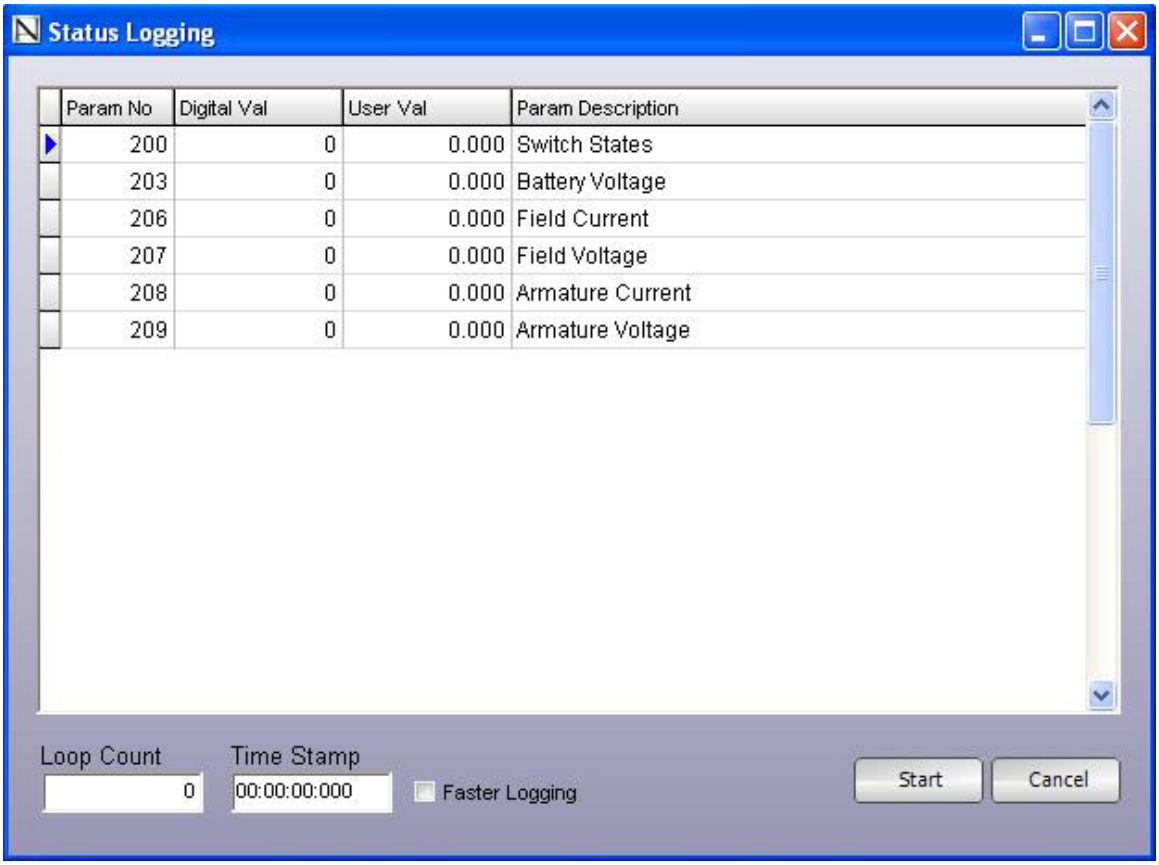
"DATA LOGGING", "CREATE NEW LOG" details:

"SELECT STATUS 'REGS' TO LOG" window:




To create a new data log, review the list of available parameters. Select those parameters which will be logged from the "Not Logging" list and add them to the "Logging" list by clicking the parameter and then clicking the single right arrow. To add multiple consecutive parameters, click on the top parameter of the required set, hold the shift key down, and use the down arrow key to highlight the remaining parameters. If all parameters are to be logged, simply click the double right arrow. To remove parameters, select the parameter(s) on the "Logging" list and click the single or double left arrow as required. Click "OK" when the "Logging" list is complete. This will open the "STATUS LOGGING" window.

"STATUS LOGGING" window:



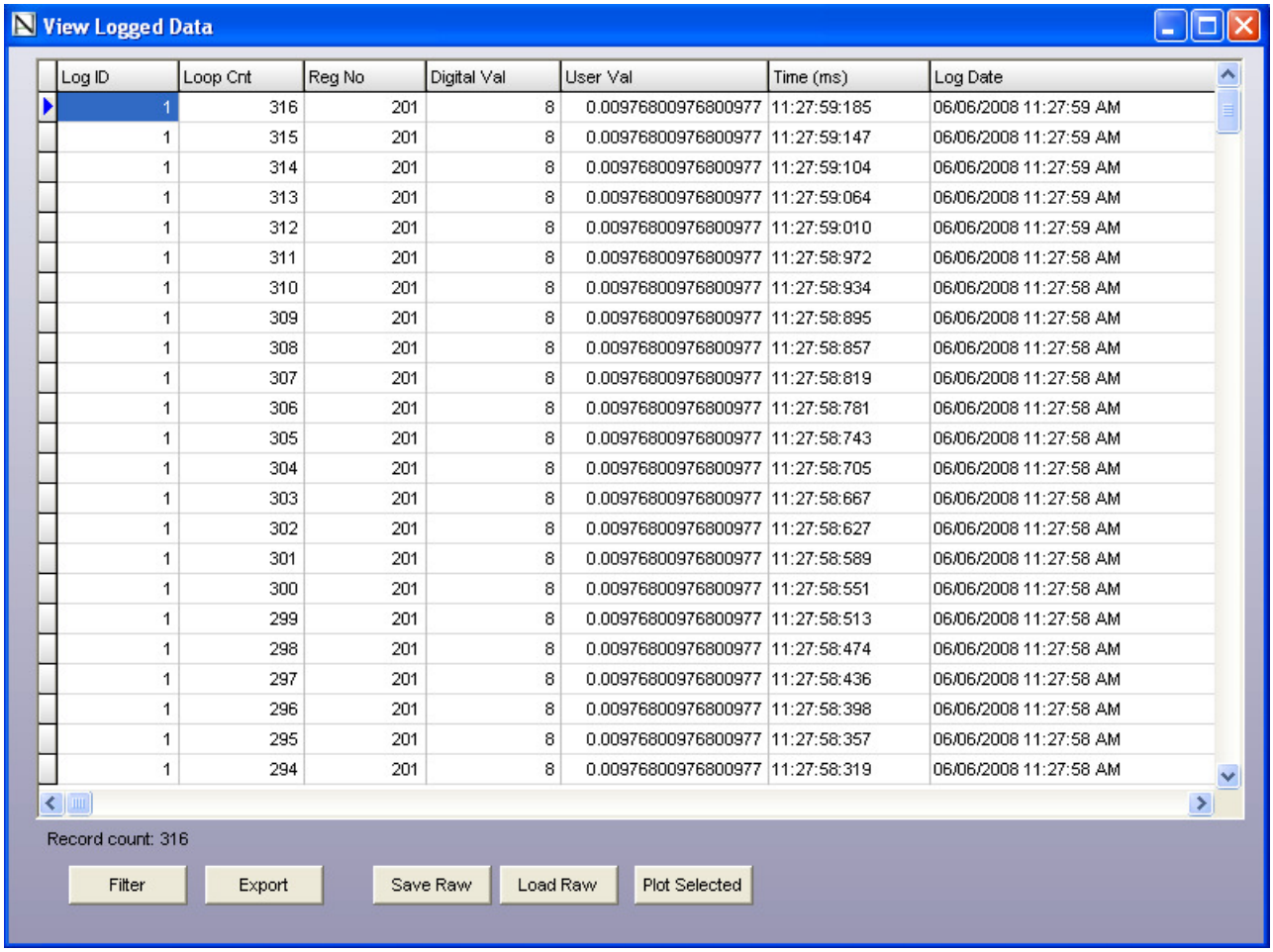

When the "STATUS LOGGING" window opens, it will show all parameters selected in the "SELECT STATUS 'REGS' TO LOG" window.

**Loop Count** indicates number of parameters that have been logged
**Time Stamp** system clock value at time parameter was logged
**Faster Logging** disables visual output of log results
**Start** initiates logging
**Cancel** halts logging

When the "START" button is clicked, an additional timer appears:


To stop the data logging, click the "STOP" button. The logging will stop and the "VIEW LOGGED DATA" window will open.

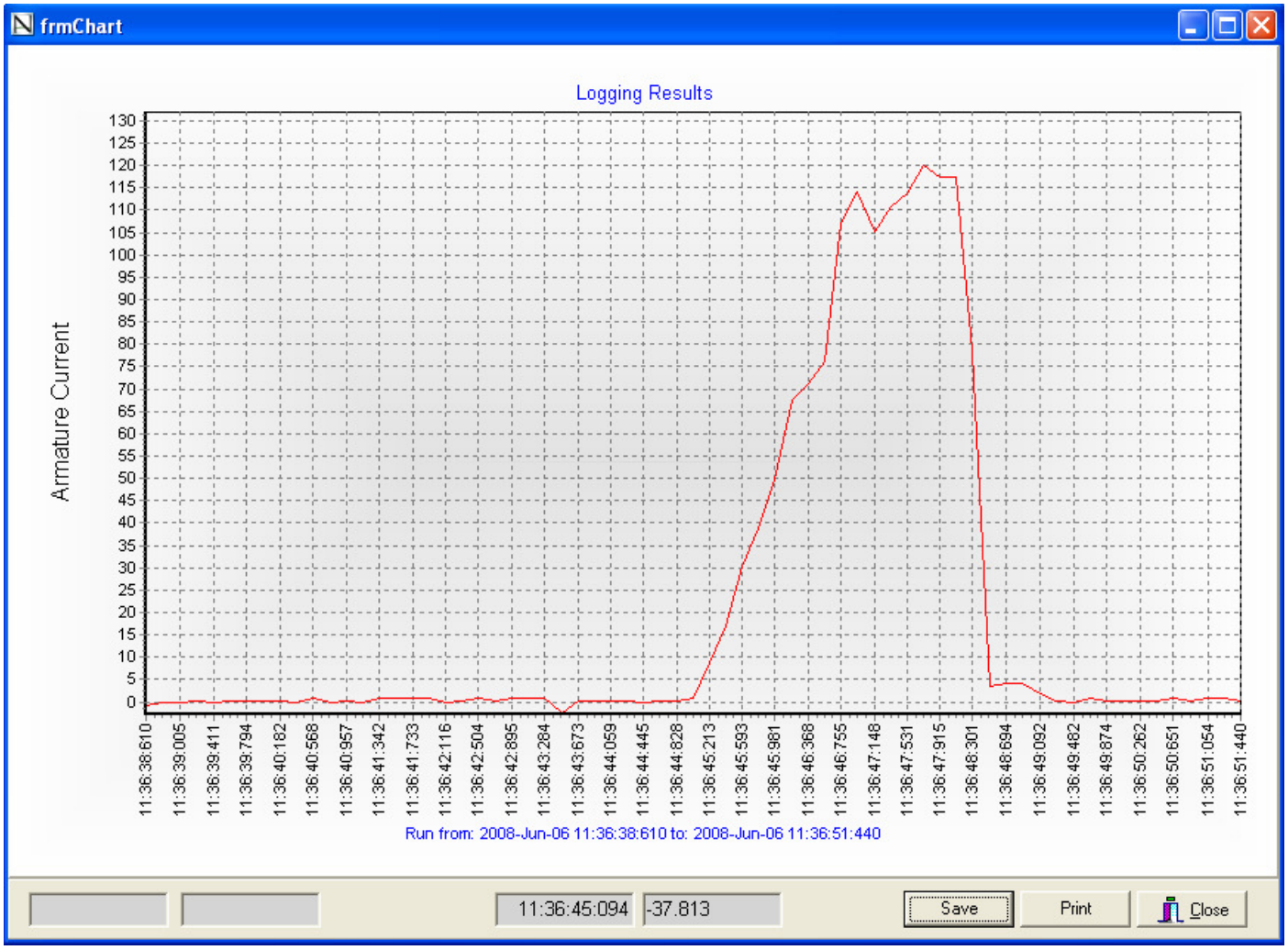
"VIEW LOGGED DATA" window:




The "VIEW LOGGED DATA" window shows the logged data in a numerical format. Any row can be selected to plot into a graph or the data can be saved. Previously saved data can be loaded into this screen as well.

| | |
|---|---|
| **Filter** | allows advanced filtering of logged results |
| **Export** | sends logged data to a variety of different file formats |
| **Save Raw** | saves logged data |
| **Load Raw** | loads previously saved logged data |
| **Plot Selected** | graphs current parameter |

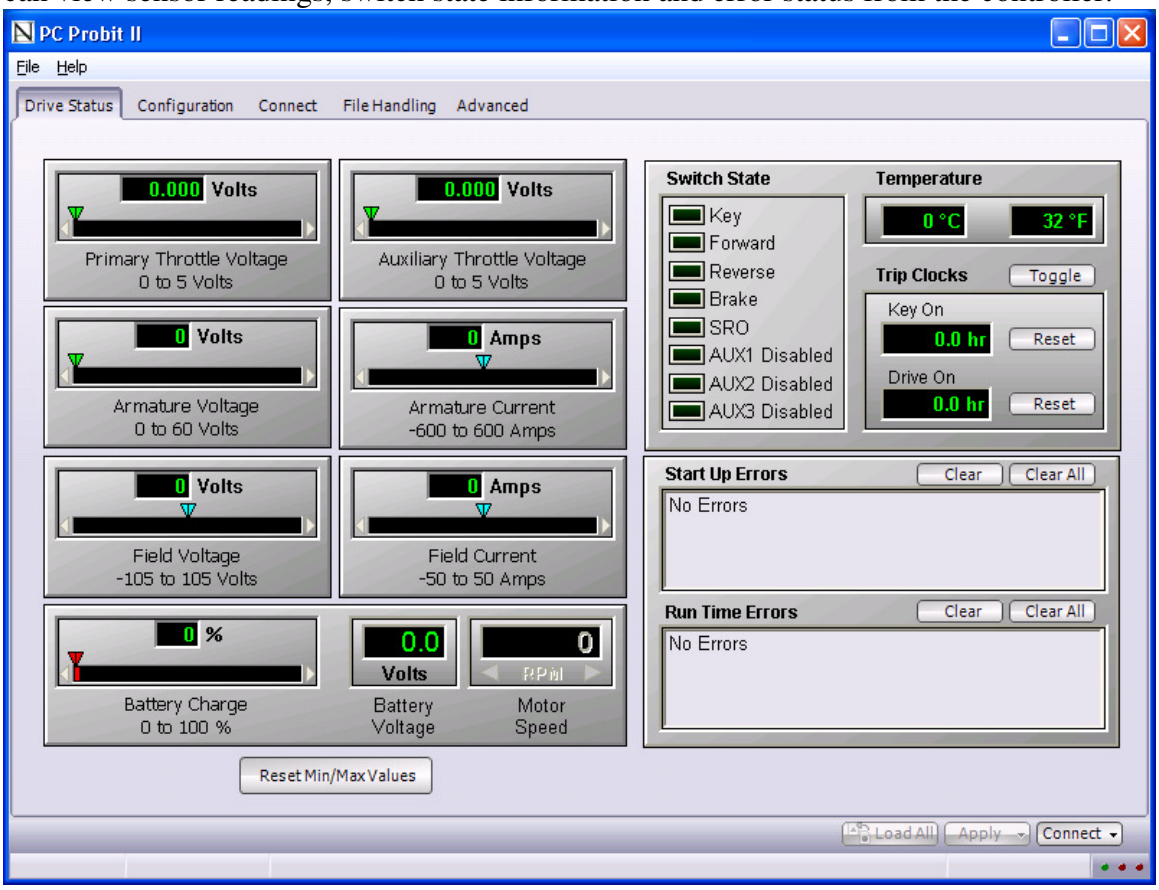
Sample of Logged Data Graph




The above sample graph illustrates the results of plotting logged data relating to the controller's armature current during operation. The X axis represents elapsed time and the Y axis represents the armature current. This graph can be saved or printed from the menu at the bottom right of the window. Graphs such as this can be produced from data logged from any of the parameters available in the "SELECT STATUS 'REGS' TO LOG" window.

## Drive Status

The "Drive Status" tab displays 'live' parameters from the controller. On this screen, you can view sensor readings, switch state information and error status from the controller.




The information shown on this tab is 'live' whenever the controller is connected to the software.
The sensors show both a numeric reading of the current sensor value and also a bar-graph display of the measurement.
Above the bar-graphs, there are a pair of pointers. These pointers indicate the minimum and maximum value that the sensor has read. When the mouse cursor is placed on top of the bar-graph, it will show a numeric display of current sensor value along with the minimum and maximum values that the sensor has read. To reset these pointers, press the Reset Min/Max Values button under the sensor information.

Motor speed will only be displayed if the input has been enabled.
See: #Motor_Speed_Setup

The indicator next to the switch inputs will light up when the switch has been enabled.
Note: When a bi-directional throttle is used, the indicator will light up when the controller has determined that a direction has been selected.

## *Fine Tuning the Throttle Response*

When setting up the throttle, you will want to use as much of the range of the throttle as possible.
Start by looking at the 'Drive Status' tab.
With the throttle at rest, make note of the voltage for the throttle input you are using.
Apply full throttle. Make note of the voltage at full throttle.
Now that you know the sweep of the throttle, we will set the Throttle Min and Throttle Max parameters.
Switch to the Configuration Tab of the PCProbit and select the tab for the throttle you are using (Primary/Auxiliary).
We need to create a small window for both the Throttle Min and Throttle Max positions to ensure that the controller will read the throttle at rest and full throttle properly. To do this we will use 5% of the throttle sweep as a window for Throttle Min and Throttle Max.
Calculate this by taking the value read at full throttle and subtract the value read at rest.
Multiply this by 0.05.
Take the value read when the throttle was at rest and add the number that was just calculated to it. Enter this value into the Throttle Min setting on the PCProbit.
Take the value read at full throttle and subtract the calculated number from it. Enter this value into the Throttle Max setting on the PCProbit.
Note: Apply the opposite for throttles that read from 5V at rest to 0V at full throttle.

If a foot switch is used on the throttle, make Throttle Min measurements from after the switch closes.

Next we will set the Deadband parameter for the controller.
For most throttles, the Deadband voltage will be equal to Throttle Min. The Deadband percentage should be set to 0.

To create a 'Creep' zone in the throttle, adjust the Accel X and Accel Y% values.
To provide the smoothest possible throttle, set the Accel X and Accel Y% values to provide a linear throttle response. This will be seen on the Throttle Profile display as a straight line from Throttle Min to Throttle Max.

For Bi-directional throttles, there are some differences. In this throttle mode, the Throttle Min is used to determine the direction command to the controller. It then uses the Deadband parameter for the start point of the throttle. Leave the Deadband set to 0.
For this type of throttle, it is recommended that the Accel X and Accel Y% values be set to provide a linear throttle from Deadband to Throttle Max.

## *Optimizing Motor Performance*

Tuning the controller for the motor will make a large difference in the performance of the motor. Improperly set, the motor may lack torque, speed or may have drivability issues.

Parameters to control motor performance are found on the 'Motor Control' tab of the PCProbit.

### A couple of basic guidelines:

Torque is produced by a combination of Armature current and Field current.
Maximum torque will be produced when the field is at its highest level.
Speed is produced by maximum armature voltage and minimum field current.
There are numerous ways to configure the controller to work with the motor to achieve the same performance. The goal is to achieve the performance with the best efficiency.

### Setting the Field Max parameter:

If the maximum field strength of the motor is known, set the Field Max (both Forward and Reverse) to this value.
If you know the resistance of the field winding, divide the nominal battery voltage by the known resistance and enter the result into the Field Max settings.
If the maximum field strength is not known, it can be determined with some testing.
The characteristics of the motor will change with the motor temperature. When the motor is cold, it is possible to have higher field strength than when the motor is hot.
To set for the maximum torque possible, set the field max when the motor is cold.
To set for the maximum constant torque, set the field max when the motor is hot.
Caution: Do not do the following procedure if the nominal battery voltage is higher than the rated motor voltage. Damage to the motor could occur.
To determine the maximum field current by measurement, set Field Min, Field Mid and Field Max to 50A. On the PCProbit, select the 'Drive Status' tab. You will be monitoring the Field current sensor data. Activate the field by selecting a direction and if necessary, activating the foot switch, it is not necessary to actually apply throttle. The field current on the 'Drive Status' tab should increment. For peak torque, make note of the current after 20 seconds. For continuous torque, make note of the current after 1 minute. Turn off the key on the controller after making this measurement. Enter the measured current into the Field Max (both Forward and Reverse) parameters.

### Setting the Field Min parameter:

This parameter will determine the maximum speed of the motor. This parameter also affects the partial throttle drivability.

If you know the minimum field strength as specified by the motor manufacturer, enter that into the Field Min parameter.
If you do not have this information, set the Field Min to 5A. Set the Field Mid value to provide a linear slope between the Field Min and Field Max parameters. With the vehicle on the ground apply partial throttle and drive slowly. You should not feel any 'shuddering' or hear any abnormal noises from the motor. If low speed/torque performance is ok at this level then it is possible to lower the field further to increase maximum speed. If there are any issues with partial throttle driving, it may be necessary to increase the Field Min values.

If desired, you can set the Field Min to different values in Forward and Reverse. This will change the driving characteristics for each direction.

### Setting the Field Mid parameter:

In most cases, setting the Field Mid parameter to provide a linear slope from Field Min to Field Max will provide acceptable performance and drivability. Make adjustments from here as necessary.

### Setting the Armature Max parameter:

This parameter determines when the maximum field strength will be applied to the motor. Setting this parameter too low will cause drivability issues. Setting this parameter too high will lower the efficiency of the system.

### Setting the Armature Min parameter:

This parameter determines when the minimum field strength will be applied to the motor. It should be set high enough that when driving on level ground with full weight on the vehicle the field current can drop to the minimum level.

### Setting the Armature Mid parameter:

In most cases, setting the Armature Mid value to the midpoint between Armature Min and Armature Max provides acceptable performance and drivability. Make adjustments from here as necessary.

## Using the Datalogger to help tune the motor:

Caution: Make sure you can perform the following tasks safely and that you have room to do so.

Setup the Datalogger as explained previously.

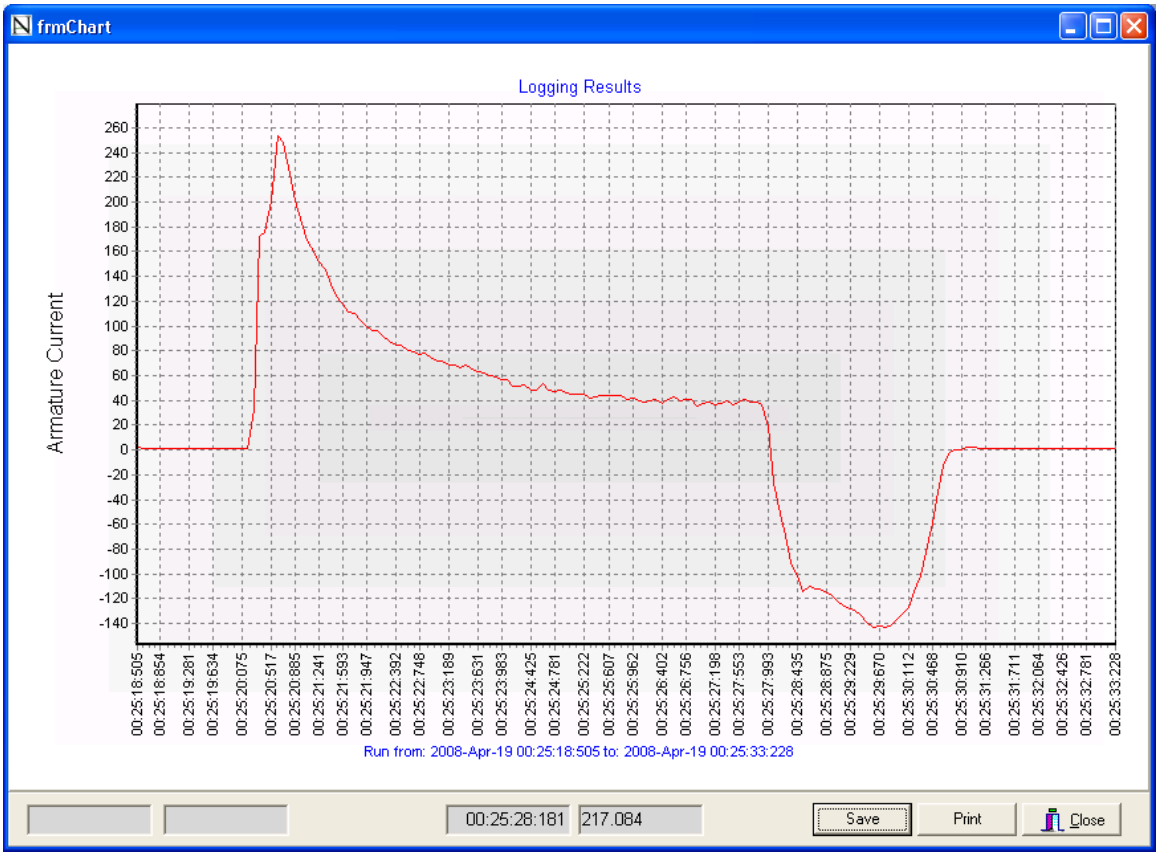
For the parameter selection, select Armature Current and Field Current.

Start the Datalog, then accelerate at full throttle. When it feels that the vehicle is no longer accelerating, release the throttle and come to a stop. Stop the datalogger and select a variable to view. The variables in the datalog are described by their registry number. For a listing of registry variables in the controller, look at the Print Parameter Map function on the Advanced screen of the PCProbit.

For our use here, Registry number 208 is Armature Current and Registry number 206 is Field Current.

On the output of the Datalogger, select one row of the table that has Registry number 208 in it and select 'Plot Selected'

The object is to get a smooth acceleration curve with the armature current. It should look similar to the following.




If there are any spikes in the graph, that indicates an area where the armature or field map variables will need to be adjusted.

## *INSTALLATION NOTES*