



# Cycle Analyst 3.0



## Unofficial User Guide

This is a 'best effort' work provided 'as is' without warranty of any kind, express or implied, including but not limited to fitness for a particular purpose. It is intended as a temporary measure until formal documentation is available from Grin Tech. See the post "[Cycle Analyst V3 Unofficial User Guide](#)" for the most recent version of this document. Selected text from the [Grin Tech](#) site is quoted in-line with colored background for reference; please review documentation on that site for authoritative information. Also see the [Endless-Sphere.com](#) thread "[Cycle Analyst V3 preview and first beta release](#)" from which much of this material has been drawn.

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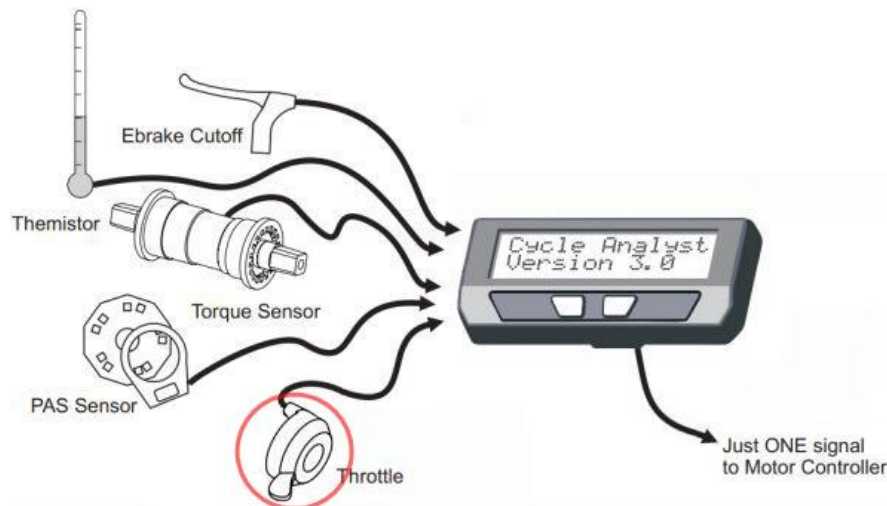
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## 1.0 Overview

### 1.1 Concept

The Cycle Analyst V3 measures and displays information about the battery, acts as a general purpose trip computer, records and calculates vehicle and rider performance statistics, monitors and displays data from optional input devices, and operates or limits the motor controller based on the monitored and calculated data. Combined control for all features is passed to the controller via the throttle signal. The Cycle Analyst can upgrade any motor controller with advanced features like torque-sensing PAS or high temperature power rollback.



The Cycle Analyst also provides enhanced throttle features to improve the driving experience by eliminating throttle dead zones, smoothing power application, and integrating proportional regen with Grin Tech controllers.

### 1.2 Features

The V3 is housed in the same Large Screen console as the V2 but offers many additional features using a more powerful processor and increased memory.

#### 1.2.1 User Configurable Presets

The V3 supports two *Battery Presets* that allow rapid reconfiguration when installing different battery packs. Battery statistics are maintained independently for each preset so unique historical information is maintained for each pack.

Three *Mode Presets* allow selection of different suites of pre-configured parameter settings. These may be used to switch between differing power limitations (e.g. legal, off-road), to enable/disable assist modes, or to customize throttle behavior for different riding situations.

#### 1.2.2 Auto-Cruise Control

The Cycle Analyst provides an auto-cruise control capability that holds the present throttle setting if the throttle remains unchanged for a period of time. Auto-cruise releases on ebrake input or throttle application.

#### 1.2.3 Proportional Regenerative Braking

The Cycle Analyst integrates with Grin Tech controllers (Grinfineon, Phase Runner) to provide proportional regen braking via the throttle. With ebrakes applied, increased throttle increases regenerative braking. This feature is unique to Grin Tech controllers but does not interfere with regenerative braking features provided by controllers from other manufacturers.

## 1.2.4 Limiting

The Cycle Analyst continually monitors three vehicle attributes: battery voltage, current, and speed. Four configurable parameters (Low Voltage Cutoff, Current, Power, and Speed) provide limits beyond which the V3 will reduce the throttle to alleviate the limit violation. These limits are always in play although any may be effectively disabled by configuring it to an unattainably high value.

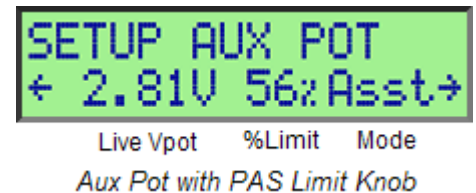
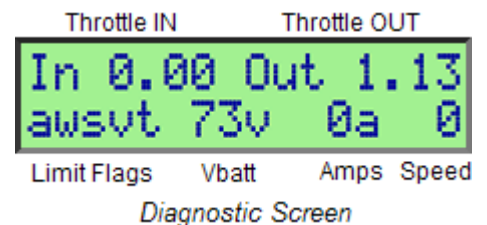
## 1.2.5 Temperature Sensing

The Cycle Analyst temperature sensor input supports either NTC (Negative Temperature Coefficient) thermistors or linear voltage devices like the LM335. In addition to displaying the temperature, the V3 moderates heat generation by throttling back the controller as temperature rises through a configurable limit range.

## 1.2.6 Diagnostic Displays

The Cycle Analyst has several displays that simplify setup and problem resolution. The status screen to the right shows throttle input and output voltages as well as an array of flags that indicate which of the limiting parameters are violated and restricting controller power.

Other Setup screens display real time data values of related input parameters. This allows the signals from throttle, 3-position switch, PAS, and temperature devices to be inspected without external test equipment. For example, the display to the right shows the voltage from a custom external PAS assist level adjustment knob.



## 1.2.7 Throttle Enhancements

The V3 provides three means to enhance throttle operation:

- throttle/controller voltage matching,
  - throttle ramping, and
  - optional feedback-based throttle modes.
1. Throttle dead zones and motor creep occur when the throttle output voltage range is not identical to the throttle input range of the motor controller. The Cycle Analyst provides configuration options to easily match the output and input ranges of these two devices without the use of test equipment.
  2. Configurable throttle ramping provides a means to smooth controller power application. This is of particular value to vehicles with powerful motors or with motors/drivetrains containing gears, clutches, chains, etc. Ramping is universally applied to the generated Throttle Out signal and so affects all operation, not just the operator throttle. This feature can make the bike more controllable and safeguard drivetrain components.
  3. Perhaps the most valuable throttle features are the optional closed-loop feedback modes: *Current*, *Power*, and *Speed Throttle*. In these modes the operator throttle provides a 0-100% target for the Cycle Analyst to achieve. This percentage is configured to apply to one of the configured maximum current, power, or speed limits. Based on this percentage of maximum Watts/Amps/mph set by the operator throttle, the V3 continuously computes the necessary controller throttle voltage to achieve the operator target. With Current Throttle for example, turning the throttle 10% with a configured maximum current limit of 40A runs the motor at 4A regardless of terrain or load. This fly-by-wire feature makes difficult controller throttle adjustment the responsibility of the CA, not the operator.

## 1.2.8 External Controls

The Cycle Analyst affords an optional input that may be used with an external control such as a 3 position switch or potentiometer. This auxiliary input may be configured to either select configuration presets or to adjust current, power, speed, or PAS limits. Off the shelf plug and play controls are available or custom controls may be fabricated. A transient 'Aux Adjust' display of the live adjustment setting automatically appears on the console whenever the auxiliary input is being adjusted.

## 1.2.9 RC Electronic Speed Controller (ESC) Support

The Cycle Analyst can provide either a voltage level or PWM throttle signal to the controller to directly drive either conventional vehicle controllers or RC ESCs (a separate ESC servo tester is not required). The CA can also act as an ESC Battery Eliminator Circuit (BEC).

## 1.2.10 Pedal Assist

The Cycle Analyst supports both PAS cadence sensors and torque-sensing devices such as the Thun or TDCM bottom brackets. Several PAS modes are available:

1. **Auto PAS:** When pedaling is detected, the bike supplies a fixed configurable 'background' assist power level. If the throttle is applied while pedaling, then the PAS signal is ignored and the throttle alone controls power. Assist power is ON or OFF and does not vary with pedaling speed or effort.
2. **Throt PAS:** There is no pedaling assist but you must be pedaling for the throttle to work.
3. **Torq PAS:** Assist power is proportional to both crank rpm and a pedal torque so the more effort you exert the more power you get from the motor. If the throttle is applied while pedaling, then the torque signal is ignored and the throttle alone controls power.

Configuration parameters allow specification of the maximum speed limit for assist and the maximum speed for throttle use without pedaling. Together these parameters and modes can provide compliance with a variety of pedelec legal requirements.

## 1.2.11 High Voltage Monitoring

Vehicles with high voltage traction batteries can pose safety issues if the traction battery voltage is routed directly to the operator instruments. The Cycle Analyst operates over a voltage range of 11–150 volts but provides an optional input to allow monitoring voltages up to 500V while the CA itself is powered from a separate lower voltage source. However, high and low voltage grounds remain shared so the CA is not fully isolated.

## 1.2.12 Serial Communications

The Cycle Analyst V3 continually streams live data (voltage, throttle, distance, speed, etc.) via a serial data port. This data may be collected by a Cycle Anologger other external device. The Anologger records complete trip data (from the CA) and optional GPS data (from the Anologger). The CA serial port can also be used to update the CA firmware or remotely configure Setup parameters.

## 1.2.13 Interactive PC Setup Utility

The Cycle Analyst Setup Utility is an interactive application to communicate with the CA via the serial communications port and USB-TTL download cable. The utility is available for Windows and other platforms and may be downloaded from the [Grin Tech web site](#). The application performs two functions:

1. *Update Firmware:* This feature updates the CA with new program features. Firmware files are installed with the utility and new versions are released from time to time and made available on the V3 web site.
2. *Save/Restore Setup Configuration:* This feature allows complete Cycle Analyst configurations to be read from or written to the CA, modified interactively, and saved/restored from files. All parameters configurable from the CA console can be altered, as well as several hidden features that impose Setup configuration limits or exclude access to specific Setup screens. These hidden features may be used to limit CA console access to critical settings.

All lifetime and trip statistics are saved/restored with the Setup parameters making the the utility a simple means to periodically archive historical vehicle and battery information.

## 2.0 Console Operation and Display Screen Summary

### 2.1 Basic Console Navigation

- Press right/left buttons to navigate to the next/previous Status or Setup Screen
- Press/hold the left button to enter Setup Navigation mode
- Press/hold the left button to exit Setup Navigation mode
- Press/hold the right button to reset trip statistics
- From the 'Max & Min Stats' status screen, press/hold the right button to reset the peak trip statistics

### 2.2 Mode Presets

Mode and battery presets are configured in Setup and may be selected from any main status screen using both buttons in 'hot swap' mode:

1. Select *Mode Presets* by holding the left button then tapping the other button to sequence through presets.
2. Select *Battery Presets* by holding the right button then tapping the other button to sequence through presets.

The CA can be configured to power up either with a specific mode preset or the preset in effect when last powered down. Mode presets may also be selected using an external 'preset switch' (see '5.6 Auxiliary Pot'). When controlled by an external switch, mode presets cannot be altered using the 'Hot Swap' or Setup parameter methods.

Historical battery statistics (see '2.3 Status Screens' below) are accumulated independently for each battery preset. By assigning separate battery presets to different battery packs, unique historical data will be available for each.

### 2.3 Status Screens

The CA powers up to the status screens which may be traversed with short L/R button presses. There are eleven screens which display information grouped by function. Certain values (e.g. speed, Amps) are displayed on more than one screen to give a more comprehensive view of related information without changing screens.

1 - Main Display

```

72.3 V 0.00 mA
L 3 W 23.8 mi
    
```

2 - Electrical Only

```

72.8 V 0 W
0.02 A 16.45 Ah
    
```

3 - Human Power

```

73v 0A 0.00 mA
0 hwt 0.0 R%
    
```

4 - Energy Mileage

```

Watt-hrs Wh/mi
1093.7 24.8
    
```

5 - Human Statistics

```

HWhrs A%HW A%RPM
46.1 19 36.7
    
```

6 - Regenerative Braking

```

%Regen Fwd Ah
0.0% 0.0098
    
```

7 - Max and Mins

```

Amin Amax Umin
0.88 62.8 60.1
    
```

8 - Speed Statistics

```

MaxS AvgS 2 hrs
40.2 15.5 25m33s
    
```

9 - Odometer

```

Trip mi Totl mi
32.78 4289
    
```

10 - Battery Statistics

```

RBatt Cycl TotAh
1.40a 169 2348
    
```

11 - Diagnostic Screen

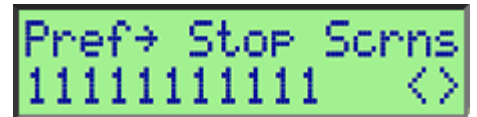
```

In 0.82 Out 1.09
Awsvt 73v 0a 0
    
```

Status Screen Summary

To streamline access to information of interest, the Setup Preferences section provides two flagword parameters to select those status screens to be displayed or hidden when at rest and when underway.

Both configurations operate similarly: the strings of 1's and 0's are configured to display or hide status screens in the order navigated by pressing the right console button. In the sample screens to the right, all screens are visible at rest while only screens 1, 4, and 8 are displayed when underway - three button presses will traverse them all and return to the initial screen.



At Rest

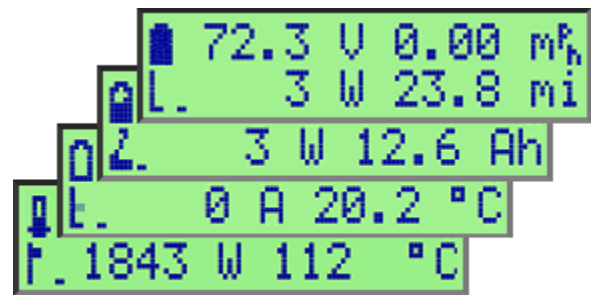


1 2 3 4 5 6 7 8 9 10 11 Moving

Visible Screen Configuration

Most status screens are self-explanatory, but some deserve a bit of clarification:

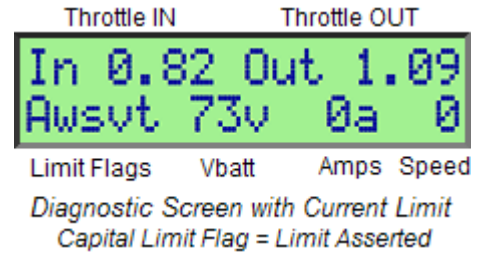
1. The Main Status screen displays the following status information in addition to the numeric values:
  - a. the Battery Gas Gauge graphic indicates battery state of charge (SOC) from Full to Empty,
  - b. when temperature limiting is in effect the Battery Gas Gauge alternates with a Thermometer alert with 'mercury' showing relative temperature in the range **Temp->ThreshTemp** to **Temp->Max Temp**,
  - c. the Operator Throttle Bar:
    - shows 0-100% of the configured Throttle IN range (far left on 2<sup>nd</sup> line),
    - shows a second (blinking) slider at the selected 'cruise throttle' position when auto-cruise is engaged - the normal throttle slider is unchanged and moves normally,
    - is replaced by an animated ebrake lever glyph when ebrakes are applied,
    - flashes if the input voltage exceeds the configured value of **ThrI->FaultVolt**, indicating a throttle fault voltage – typically caused by powering up the CA with a a non-ZERO throttle or a broken throttle Gnd connection, and
    - flashes/alternates with the ebrake lever glyph if ebrakes are released with throttle > 35% when significant regen is being generated (this is a transient alert meant for safety when using proportional regen).
  - d. the bar graph adjacent to throttle graph shows one of:
    - in *Auto PAS* mode, pedal RPM (0-120rpm)
    - in *Torq PAS* mode, the number of Human Watts produced by pedaling (0-400W)
    - otherwise, the bar graph is inactive.
  - e. display elements flash to indicate significant status conditions:
    - exceeding a limit causes the units to flash: 'kph/mph' flashes if over the configured speed limit, 'V' flashes if below LVC,
    - the speed digits flash if the present speed is less than the configured *Start Speed*,
  - f. the leftmost numeric value of the 2<sup>nd</sup> line may be configured to display either Watts or Amps, and
  - g. the rightmost numeric value on the 2<sup>nd</sup> line alternates display of distance, Amp hours, and if the sensor is enabled, temperature in degrees C.
2. In PAS screens (#3 and #5 above) 'HW' refers to generated 'Human Watts' measured by the CA.
3. 'Rbatt' on the Battery screen (#10 above) refers to the calculated battery resistance. This will normally vary with age and temperature.



Main Status Screen Variations



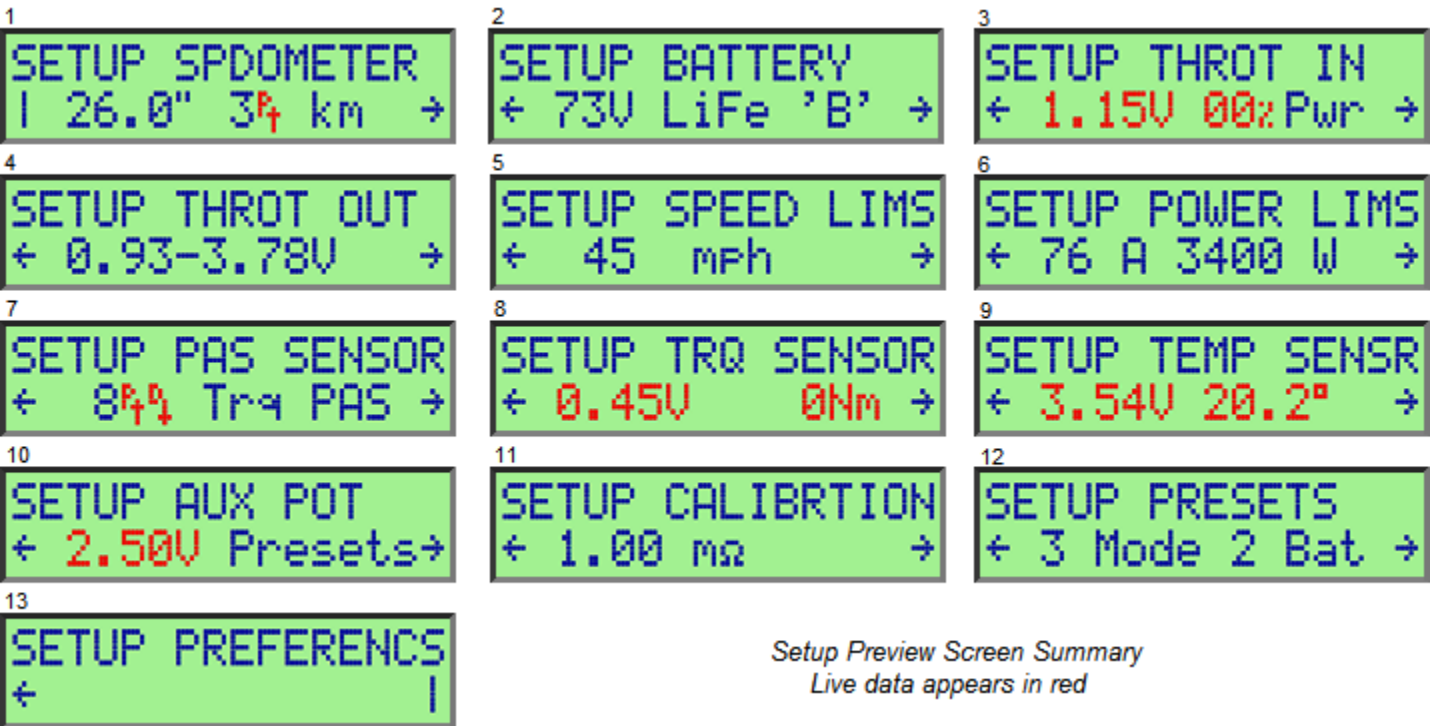
- 4. The Diagnostic Screen contains a character string of *Limit Flags*. A capital letter indicates that the limit is asserted and may be moderating power to some degree. More than one limit flag may be in play at once. When the throttle is configured for one of the closed-loop throttle modes, the associated limit flag will appear asserted almost continuously, even at standstill, since in these modes the throttle operates by limiting Throttle OUT to some fraction of a particular limit parameter (e.g. **MaxCurrent** = 100A).
- 5. The 'In' label of the Diagnostic Screen blinks if Auto-Cruise is engaged and the throttle input voltage is 'set'.



## 2.4 Setup Screens

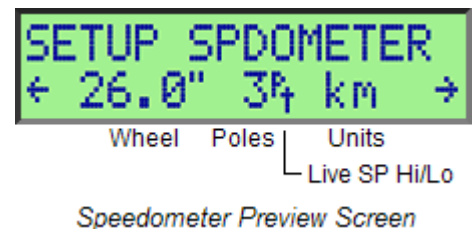
### 2.4.1 Setup Section Preview Screens

The setup screens are divided into sections, each prefaced with a section preview screen. The preview screens typically show an abbreviated summary of important parameters within the section.



Some preview screens display *live data* which can be identified by rapid blinking of the displayed value. These screens are generally self-explanatory, but the animated arrow glyphs warrant special mention.

The Speedometer and PAS preview screens use up/down arrows to indicate the live hi/lo values of digital inputs. The screen to the right shows a speedometer with 3 poles (spoke magnets). The small arrow adjacent to the tiny raised "P" indicates the present hi/lo state of the **SP** input (wheel pickup). Proper pickup operation can be easily verified by observing the arrow while rotating the wheel. The PAS Preview Screen has similar arrows indicating the hi/lo states of the **RPM** and **Dir** inputs.



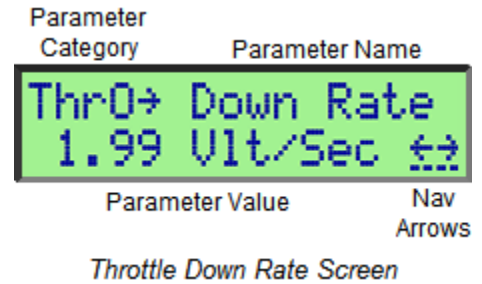
### 2.4.2 Navigating / Editing Setup Parameter Screens

Press-hold the right button on any section preview screen to enter the section and navigate related parameters. Each parameter is configured on an individual screen. Short left or right button presses traverse all parameter screens of the category. Navigation arrows appear on the second line with a vertical bar replacing an arrow to show the first or last parameters of the category. Traversing beyond the first or last parameter exits the section and returns to the section preview screen.

Setup parameters are either *global* and affect all presets (e.g. **Spd->Circumf**) or *per-preset* and are set independently in each preset (e.g. **PLim->MaxPower**). Multiple dashes beneath the nav arrows indicate that the parameter is per-preset (can have *multiple* values).

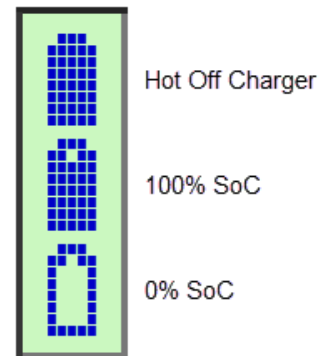
Select a parameter for editing with a long right button press. Short L/R presses move the the next/prev item of fixed selection choices or increment/decrement the digit under the cursor. Long L/R presses save the digit value and move the cursor to the left or right. Moving the cursor beyond the first or last digit exits edit mode and re-displays the navigation parameter screen.

Setup parameters are described in detail on the [Grin Tech V3 web page](#).



### 2.5 State of Charge Display

The SoC graphic has a 'Hot Off Charger' pixel at the center top that is set when the battery voltage is greater than 100% of the normal open circuit voltage according to the discharge curve for that chemistry. This elevated voltage is common, depends on the cell manufacturer and charger, and represents only a small amount of extra usable capacity. Self discharge will typically reduce battery voltage to normal levels after a period of minutes to days, preventing the HOC pixel from being set. The remaining pixels show the actual usable 0-100% charge state and are extinguished one by one as the battery discharges.

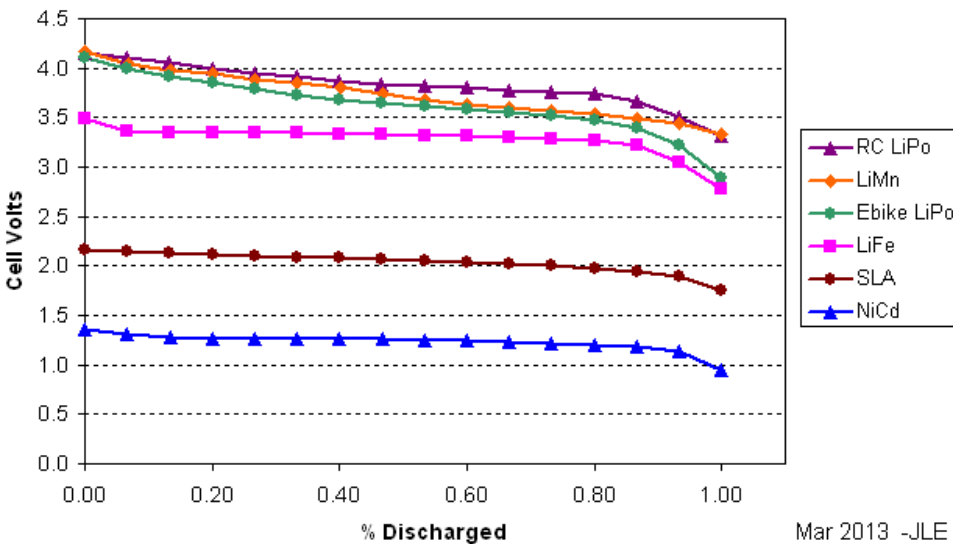


State of Charge Indications

There are two established means for estimating battery state of charge:

- conversion of the unload or 'open circuit' voltage to charge percentage using a state of charge curve and
- comparison of known battery capacity to the running total of expended Amp-hours.

Battery SOC Curves in CA3 Prelim



The accuracy of these two techniques differ according to situation and chemistry, so the Cycle Analyst combines them to obtain the best possible accuracy in all operating modes. As part of this strategy, the CA calculates battery resistance (see **Rbatt** on status screen 10, '2.3 Status Screens') which is used to minimize gas gauge fluctuations under varying load conditions.

The plots to the left show the V3 state of charge curves for supported chemistries.

To use an unsupported chemistry, first locate a sample low rate discharge curve (e.g. 0.2C) for the new battery type (the low rate better approximates the open circuit voltage). Then examine the V3 SOC plots and select the chemistry with a curve that most closely matches the 'new chemistry' curve – giving particular weight to the 10% and 90% charge voltages. Since the SOC indicator is likely to be most closely scrutinized close to full discharge, a more accurate voltage match at the 10% charge point is recommended.

**Note:** Unlike other chemistries, LiFePo4 has a very flat discharge curve making it particularly difficult to ascertain SoC by voltage. The CA handles LiFePo4 uniquely, disregarding voltage as a SoC metric except at the knees of the curve. This allows it to accurately detect 'full' and 'empty' conditions by voltage while tracking Ah at all other times. This generally gives a reliable charge indication but anomalous LiFePo4 displays are possible if the voltage makes transient low excursions due to sag (more pronounced in cold weather), slow controller capacitor discharge when powering down, etc. In these situations the lower SoC indication due to low voltage can 'stick' as the CA ignores subsequent rise to higher voltages in the middle voltage zone. A fresh charge brings the voltage above the top knee and restores proper indications.

## 2.6 Display Averaging

Voltage, amperage, and temperature measurements are prone to jitter so the Cycle Analyst smooths display of these values according to the **Pref->Averaging** Setup parameter. The configured value determines the period of time over which consecutive data values are averaged; a new sample is obtained every 18msec and the average is cleared and begun anew when an average is computed and displayed. Averaging affects only the display – all other internal calculations use instantaneous measurement values.

**Note:** During installation and tuning it can be useful to temporarily reduce the averaging period to force more responsive display updates. This avoids misinterpreting ramping or throttle response due to display averaging delays.

## 3.0 Before You Start: Concepts and Considerations

### 3.1 About Cycle Analyst Models: CA3-DP vs CA3-DPS

The Cycle Analyst V3 has two base models:

- 'CA3-DP' using speedometer signals from the controller (DD motors) and
- 'CA3-DPS' with wheel pickup wired to the console (DD or gear motors).

These models differ only in the wiring of the CA-DP cable and optional wheel sensor but are otherwise identical in all aspects of electronics and firmware. Either model may be operated with direct connection to a controller or with an external shunt. See ['Appendix B. Add/Remove Wheel Speed Pickup Sensor'](#) for instructions to convert one model to the other.

### 3.2 Operating Modes: Normal vs Legacy

The V3 can be operated in either of two modes: 'normal' mode or 'legacy V2' mode. In normal mode, the operator throttle (if present) connects to the CA and the CA provides the throttle signal to the controller. In legacy mode, the operator throttle remains connected to the controller and the CA overrides the operator throttle only as needed to limit power in the same fashion as the earlier V2 models. The following table shows features available in each mode:

Normal Mode	Legacy Mode	Feature
✓		Throttle ZERO and WOT dead zone adjustments
✓		PassThru / Current / Power / Speed Throttle Modes
✓		Throttle Ramping
✓		Auto Cruise
✓		PAS (Wheel or Torque Sensor)
✓		AuxPot - PAS Level Adjust
✓		AuxPot - Current / Power / Speed Limiting (throttle effect scaled 0-100% by rotation)
✓	✓	AuxPot - Current / Power / Speed Limiting (throttle max at less than 100% rotation)
✓	✓	AuxPot - Preset Mode Selection
✓	✓	Current / Power / Speed / LVC Limiting
✓	✓	Temp Monitor with Throttle Rollback to limit Temperature
✓	✓	Ebrake Signal Pass Through as Uniquely Detectable Throttle Out Voltage
✓	✓	Proportional Regen Integration with Grin Controllers

Although special circumstances may make legacy V2 mode desirable, most installations use normal mode to make the full feature suite available.

### 3.3 Monitor-Only Mode

The Cycle Analyst has no specific monitor-only mode where all limiting and throttle control are disabled. However, either of these approaches will accomplish that end:

1. Follow the most convenient installation instructions for either normal or legacy V2 operation but sever or do not connect the CA-DP connector throttle signal (pin 6 - green).
2. OR - Follow the installation instructions for legacy V2 operation and make these settings:

**ThrI->CntrlMode** = Off (WOT), **ThrO->MinOut** = 4.90V, **ThrO->MaxOut** = 4.99V

In legacy mode the CA limits by reducing the controller input voltage below that of the operator throttle. The settings above cause the CA to attempt limiting in a range that is too high to affect normal throttle operation (1V to 4V). Although the CA may attempt to limit, the efforts are completely ineffective.

### 3.4 Important Conflicts with Controller Features

Cycle Analyst features such as Current Throttle, auto-cruise, PAS, etc can interact with certain controller features. If interacting features are not controlled by same device, conflicts may arise that can lead to unexpected or unsafe behavior. The preferred solution is to centralize all advanced features in a single device.

A recommended strategy is to restrict the controller to simple throttle-based motor control and to rely only on the CA to implement advanced features. This is not to say that certain controller features cannot be made to operate with a Cycle Analyst, but deeper knowledge of both controller and CA behavior is required (i.e. advanced users only).

Here are some considerations for utilizing specific controller features (all are discouraged except ebrakes/regen):

- **Ebrakes** – When applied, controller ebrakes temporarily suspend motor power and also release auto-cruise, suppress PAS, or activate regen. Unless specifically required by a controller feature, ebrake wiring need not be connected to the controller.

Ebrakes must be connected to the CA if using CA PAS or CA auto-cruise so those features are properly disabled when braking.

- **Cruise Control** – Controller cruise control applies motor power by means other than the operator throttle connection used by the CA for control. In certain situations, attempts by the CA to limit power can thus prove ineffective and can lead to apparent deactivation of the operator throttle and a possible runaway bike. This feature should not be used for safety reasons. (See '[5.5 Auto-Cruise Control](#)' and '[5.4 Ebrakes](#)')
- **PAS** – Controller PAS applies motor power by means other than the operator throttle connection and so may create control conflicts as the CA attempts to limit power by manipulating the throttle. Problems are generally less acute than with auto-cruise, but CA-based PAS is preferred. If controller PAS is used, ebrakes must (at least) be wired to the controller (see '[Install Using a CA Adapter Module](#)' and '[5.4 Ebrakes](#)').
- **3-Speed Switch** – This controller feature scales the operator throttle so that the maximum motor PWM (and hence effective motor voltage) is limited. This works properly for CA PasThru Throttle but can result in a pronounced upper throttle 'dead zone' for CA Current and Power Throttle modes. Using the equivalent CA AuxPot feature will scale the reduced power range across 0-100% throttle rotation (see '[5.6 Auxiliary Pot](#)'). Use of this controller feature is not recommended.
- **Regen Braking** – There are many controller regen implementations – here are three:
  - a. *Proportional Regen on Grin Tech Controllers* uses a unique system that integrates with the CA to provide throttle regen control. Ebrakes should be wired only to the CA and not to the controller. (see '[5.3 Grin Tech Proportional Regenerative Braking](#)' and '[5.4 Ebrakes](#)')
  - b. For other controllers:
    1. *Brake activated regen* requires that ebrakes are wired to the controller. Ebrakes must also be wired to the CA or V3 features that control the throttle may cause a power surge when ebrakes are released (see '[5.4 Ebrakes](#)').
    2. *Throttle-based Regen (Infineon Slip Current Charge Mode)* applies regen braking when the throttle is backed off and is only suitable for use with CA PassThru Throttle. This feature conflicts with any CA feature where the CA controls the throttle programmatically (e.g. Current/Power/Speed Throttle, PAS, autocruise). Use of this feature is not recommended.

### 3.5 Upgrading from a V2 to a V3

When upgrading to a V3 from an existing V2, it may be desirable to retain existing custom wiring instead of installing the new V3 cabling. The supplied V3 CA-DP and wheel pickup cables may be unsoldered from the V3 printed circuit board (PCB) and replaced directly with installed V2 wiring.

Older V2 CA-DP cable and speedometer pickups have the same cable color coding and can directly replace those of the V3. The older V2 external shunt is an acceptable external shunt for V3 operation and the four wires of the V2 shunt have the same color coding as the new V3 CA-DP cable/molded shunt combination. The new V2/V3 molded shunt module has an added breakout cable to make throttle wiring a bit easier, but this can be achieved by other means.

**IMPORTANT:** Although the V3 CA-DP connector is identical in form to that of the CA V2, there is a significant difference in operation of the throttle connection on pin 6. V2 and V3 models are not generally out-of-box plug compatible and the full installation and setup procedure for the new V3 must be followed.

## 4.0 Basic Installation (Install/Connect CA and Tune Throttle)

This section of presents step by step instructions to install the hardware and configure basic monitoring and throttle operation. Relevant material is presented as needed so completing all steps will not only yield a properly operating Cycle Analyst but will provide sufficient knowledge to tackle installation and configuration of more advanced features.

Please ensure the vehicle operates properly on the road without the Cycle Analyst connected and ONLY THEN carefully follow the following steps in the order presented and without modification.

### 4.1 Third Party Vendor Kit Installation and Configuration

If the Cycle Analyst has been supplied or customized by a vendor (e.g. EM3EV) then follow the vendor instructions for installation. Package or kit installations typically use:

- 'normal' mode V3 operation,
- a controller with a contemporary 'Large Screen Compatible' CA-DP interface to provide a simple plug and play installation, and
- the same 'standard' cable connections as described below, although some minor wiring changes may exist (e.g. use CA-DP yellow **Spd** wire to carry a signal from a temperature sensor).

The vendor may have pre-configured the CA for out-of-box operation with the provided kit components. Consult the vendor to determine what configuration is already in place. Complete parameter configuration as described here may be required, but at the least, verifying throttle tuning by the following procedure is advised.

**IMPORTANT:** Vendor Setup parameter settings are not the normal CA 'defaults' and may not be available from any source, including the vendor. Before making changes, use the Setup Utility (see '[Appendix H. Updating CA Firmware and Saving/Restoring Settings](#)') to read all settings from the CA and save them as a file. These unmodified baseline settings will allow the CA to be restored to 'vendor original' condition if necessary.

### 4.2 Install Hardware

Except for the external wheel pickup, the CA3-DP and CA3-DPS models have identical console units with identical CA-DP cable, processor, and programming. This section applies apply to both models.

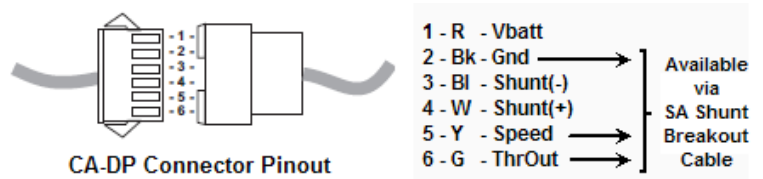
1. If upgrading from a CA V2, record the V2 **Rshunt** value prior to removing the old CA.
2. Familiarize yourself with V3 connections by briefly reviewing '[Appendix I. CA V3 Connector and PCB Images](#)'.

**Note:** The Cycle Analyst uses familiar JST-SM style connectors with tin-plated connection pins and locking plastic shrouds. These connectors generally operate reliably with no special attention. However, users in unusually wet or humid climates may find it useful after the CA is installed and tested to open the connections, wipe the contact pins with Permatex dielectric grease (available in auto supply stores) and then re-seat the connectors. This optional dielectric grease can be refreshed as part of annual maintenance.

#### 4.2.1 Connect Cycle Analyst to Controller

Basic Cycle Analyst operation requires power, shunt, speed input, and throttle output connections which are provided by the 6 wire CA-DP cable and connector.

This connector can directly connect to a suitably equipped controller or to an external shunt and other controller wiring. The former can give a plug and play solution suitable for most installations while the second requires a bit more technical skill and is used where the controller lacks an appropriate connector, where higher current monitoring is required, or where multiple controllers are operated from a single Cycle Analyst.



The following subsections ( 4.2.1.1 - 4.2.1.6 ) explain common installation scenarios.

Choose only the single following subsection appropriate for your situation to install your CA then move on to section [4.2.2](#) .

### 4.2.1.1 Direct Connect: Controllers with CA Interface Connectors

Controllers available from certain vendors (e.g. Grin Tech, EM3EV, Lyen) provide all required connections for power, shunt, etc. via a single mating CA-DP connector. However, there are two distinct interface types that have electrically different throttle support – even though the connectors are identical:

- a newer 'Large Screen Compatible' interface (controllers produced after mid-2013) or
- an older 'V2 Compatible' interface (all controllers prior to mid-2013).

**IMPORTANT:** It is critical to correctly identify the controller interface type. Either interface style may be used with the V3 in either normal or legacy mode, but electrical differences require very different connection techniques.

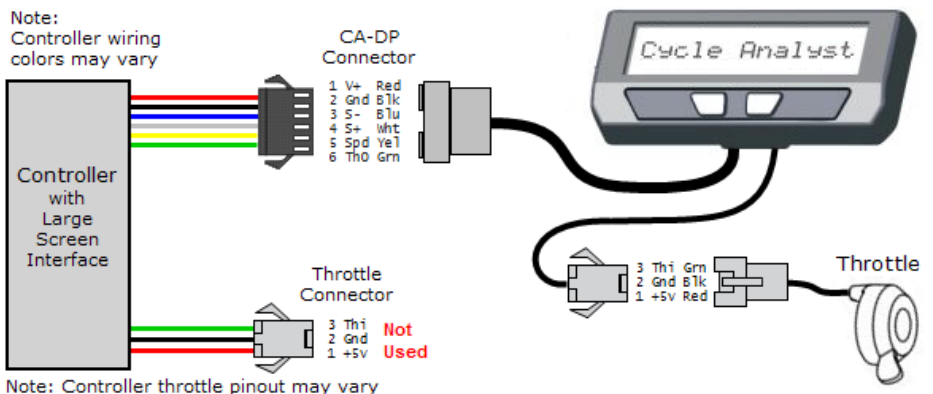
1. If the CA interface type is unknown (the controller is not clearly labeled 'Large Screen Compatible') then perform the following test to ascertain the type:
  - a. place the bike on a stand or invert it onto handlebar/seat so that the motor can run safely, then
  - b. plug the CA into the controller CA-DP interface and a throttle into the controller.
  - c. If the CA is not new and known to have factory default settings, follow the instructions in section '[Appendix H. Updating CA Firmware and Saving/Restoring Settings](#)' to restore factory defaults.
  - d. Power up the controller and CA,
  - e. enter Setup, use all default CA settings, and configure ONLY:
    - ThrI->CntrlMode = Off(WOT),** and
    - ThrO->MaxOut = 2V.**
  - f. Be prepared to quickly power down the controller if the motor starts then exit CA setup.
  - g. Power down the controller.
  - h. If the motor powered up spontaneously leaving Setup (without manually applying throttle), then the controller interface is Large Screen Compatible, otherwise it is V2 Compatible.
  - i. Power up the controller and restore
    - ThrI->CntrlMode = Passthru** and
    - ThrO->MaxOut = 3.65v**
2. There are four combinations of two interface types and two operating modes as listed below. Connect the CA to the controller using whichever combination is appropriate:
  - A. Normal Mode Operation with 'Large Screen Compatible' Interface (V3 with New Controller)
  - B. Normal Mode Operation with 'V2 Compatible' Interface (V3 Retrofit to Older Controller)
  - C. V2 Legacy Mode Operation with 'Large Screen Compatible' Interface
  - D. V2 Legacy Mode Operation with 'V2 Compatible' Interface

#### A. Normal Mode Operation with 'Large Screen Compatible' Interface (V3 with New Controller)

This is a simple plug and play installation: plug the CA-DP cable into the mating controller CA connector.

**Note:** A CA Adapter Module may be stacked on the CA-DP connector to provide throttle and ebrake signals to the controller (e.g. for regen braking). See '[5.4 Ebrakes](#)'.

Step Complete. Go to section '[4.2.2 Mount Console and Wheel Pickup](#)'.

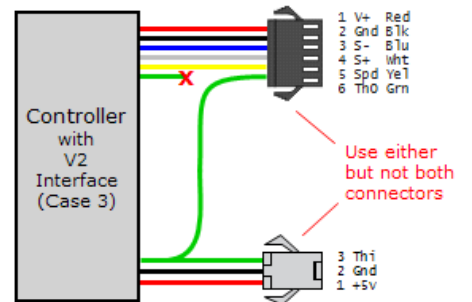
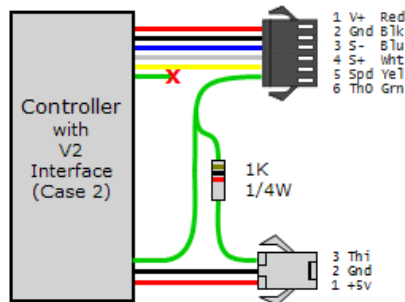
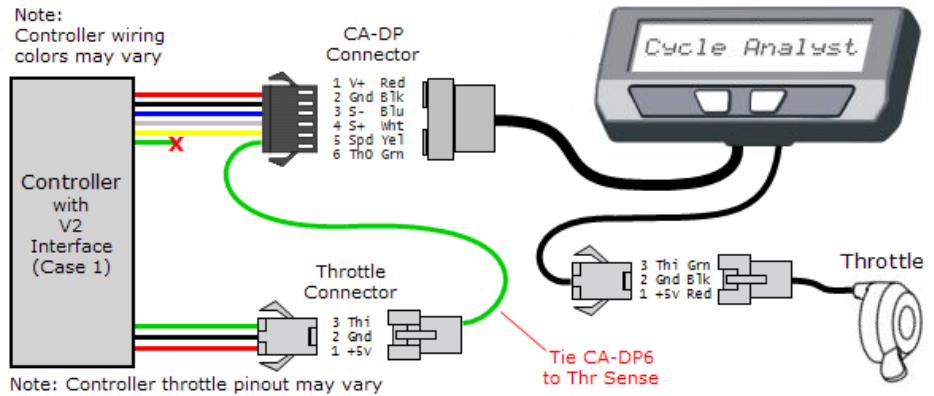


**B. Normal Mode Operation with 'V2 Compatible' Interface (V3 Retrofit to Older Controller)**

The CA-DP cable is plugged into the mating controller connector, but the CA-DP connector pin 6 throttle signal must be severed and re-routed to the controller throttle input connector. There are many means to accomplish this - five examples are shown below. Select and implement one option (Cases 1, 2, or 5 are recommended):

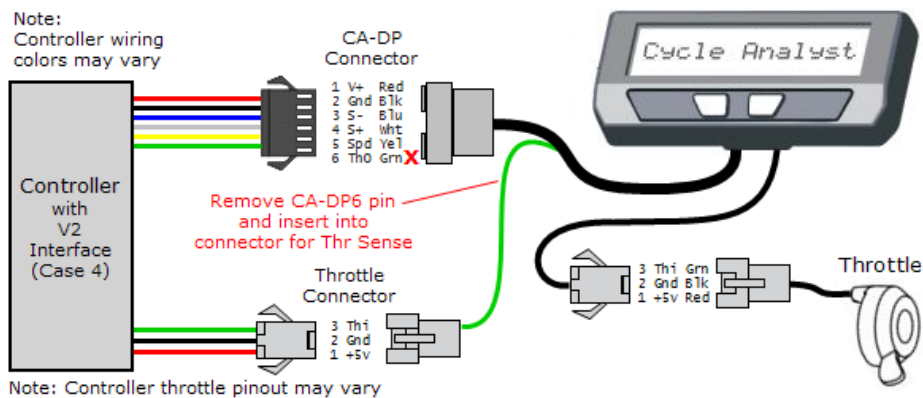
1. Modify the controller wiring to bypass the V2 style interface and provide a 'V3 Compatible' interface instead. The illustration below shows three means to achieve this.

- a. **Case 1:** Pin 6 of the controller CA connector is re-routed to the 'Sense' pin of a mating throttle connector and plugged into the controller. The controller can be restored to normal operation by instead plugging in an operator throttle.
- b. **Case 2:** Pin 6 of the controller CA connector is routed directly to the controller throttle 'Sense' input wire and a 1K resistor is added as shown. This converts the controller to the newer 'Large Screen Compatible' interface so it will work with either V2 or V3 Cycle Analysts.
- c. **Case 3:** This is a simplified version of Case 1 without the connector. The throttle and CA interface connectors must not be plugged in at the same time – use one or the other – not both.



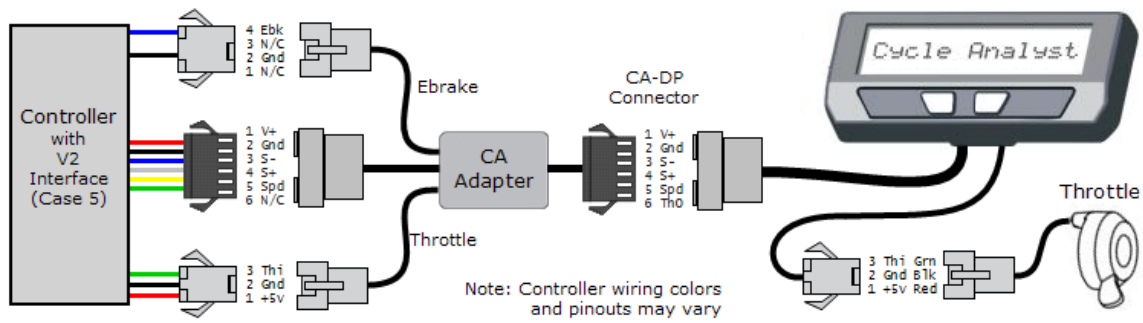
For Case 2: Sleeve the resistor together with the adjacent wire for strength

2. Or Modify the CA-DP cable by removing the heatshrink from the CA-DP connector, sliding out pin 6, then seating pin 6 into a mating connector for the controller throttle input (**Case 4**).





- 3. Or Install Using a CA Adapter Module from Grin Tech (**Case 5**). This module breaks out the throttle connection and contains logic to recover the ebrake signal from the throttle signal. This can be handy to avoid an extra wire run where ebrakes applied to the Cycle Analyst must also be applied to the controller.

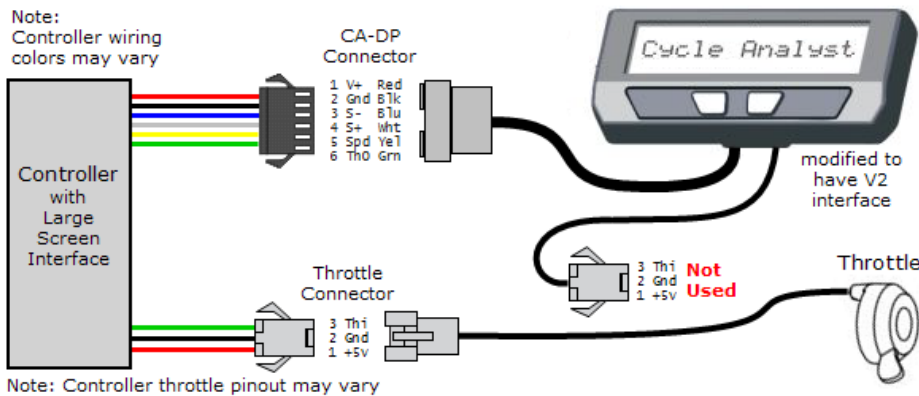
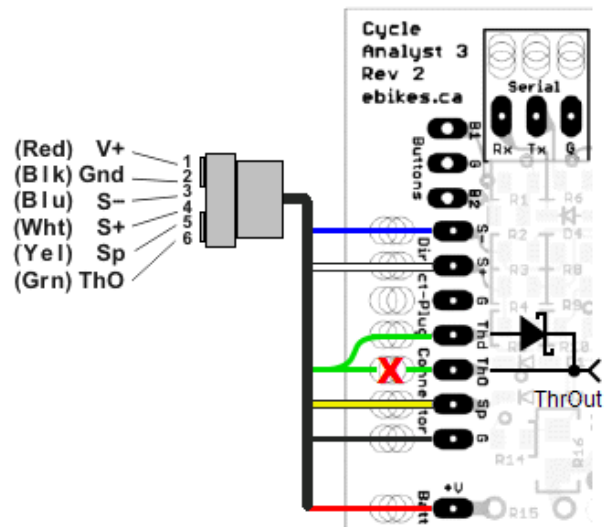


Step Complete. Go to section '4.2.2 Mount Console and Wheel Pickup'.

### C. V2 Legacy Mode Operation with 'Large Screen Compatible' Interface

The Cycle Analyst V3 CA-DP cable interface is first modified so that it is the electrical equivalent of a V2 interface.

- Open the case (see '6.3 Opening the Cycle Analyst Case').
- Expose the **Thd** and **Tho** PCB pads by gently bending the square brown polyfuse upright.
- Unsolder the CA-DP cable green throttle wire from the **Tho** pad and solder it to the **Thd** pad.
- Reposition the brown polyfuse and close the console case.

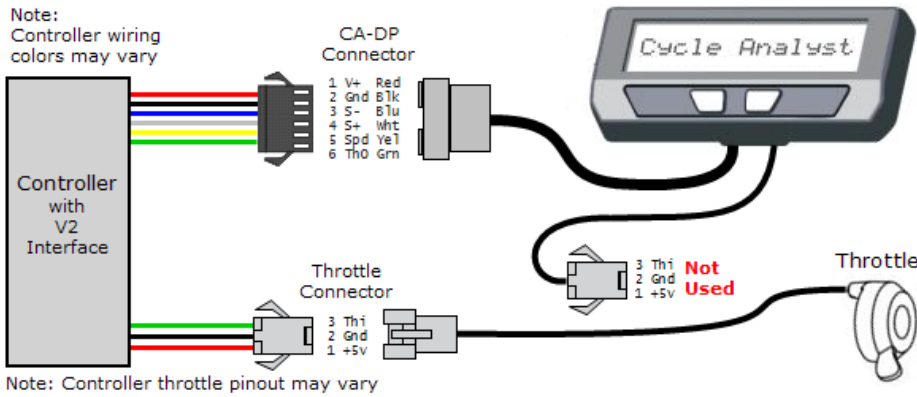


Next, since a 'Large Screen Compatible' controller will operate either a V2 or V3 in their respective 'normal' modes, the V3 with modified V2 style interface can now be directly plugged into the controller CA connector and it will behave in legacy V2 mode.

Step Complete. Go to section '4.2.2 Mount Console and Wheel Pickup'.

### D. V2 Legacy Mode Operation with 'V2 Compatible' Interface

This is a simple plug and play installation – plug the CA-DP cable into the mating controller cable as shown above. No Cycle Analyst or controller modifications are required.



In this case, the unmodified V3 behaves in legacy V2 mode because that is the only mode the controller interface can support.

Step Complete. Go to section '4.2.2 Mount Console and Wheel Pickup'.

#### 4.2.1.2 Direct Connect: Upgrading Controllers without CA Interface Connectors

A CA-DP interface connector may be added to any controller to allow plug and play CA connection as described in the previous section. See 'Appendix D. Adding a CA-DP Connector to a Generic Controller'.

#### 4.2.1.3 Installation with High Current External Shunt (Normal Mode)

The High Current model attaches to a 3rd party shunt resistor and the positive battery lead.

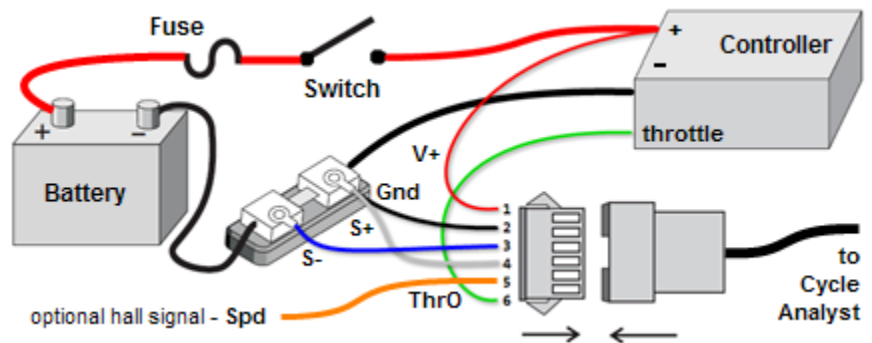
**IMPORTANT:** The shunt must be connected to the ground side of the battery; connection of the shunt to the positive side of the battery can damage the circuitry.

Wire a male JST-6 connector to the right. The shunt and Cycle Analyst **S+** connections must be arranged as shown relative to **Vbatt-** to give the proper forward/regen current sensing.

The **CA Gnd** (pin 2) must be connected to **Controller Gnd** to improve the quality of ground-relative signals (e.g. throttle or motor temperature sensors that share **Controller Gnd** wiring with hall sensors).

The **Spd** wire on CA-DP pin 5 can optionally be tied to any motor hall wire (between hall connector and controller) as an alternative to using a wheel pickup.

Connect the new connector to the Cycle Analyst.



**Note:** A CA Adapter Module may be stacked with the custom connector to provide throttle and ebrake signals to the controller (e.g. for regen braking). See '5.4 Ebrakes'.

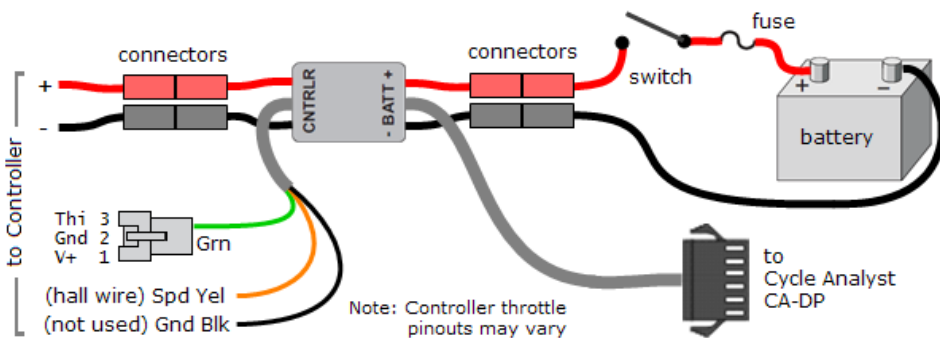
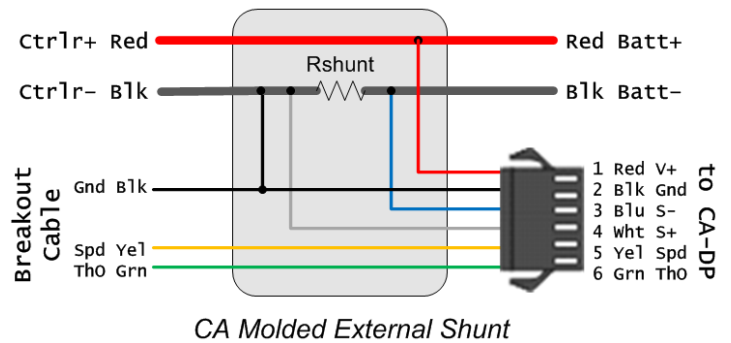
**Note:** There is no electrical significance to the common connection of **CA-Gnd** and **S+**; it is incidental to fulfilling the ground and shunt polarity requirements above. For external shunts **CA-Gnd** and **Controller Gnd** are typically tied to **S+/Rshunt+**; this is the case with the CA-SA molded external shunt. However, **CA-Gnd** and **Controller Gnd** are typically tied to **S-/Rshunt-** in controllers with an internal shunt.

Step Complete. Go to section '4.2.2 Mount Console and Wheel Pickup'.

### 4.2.1.4 Installation with Cycle Analyst Molded External Shunt Module (Normal Mode)

The Grin Tech CA Molded External Shunt uses a 1.0mOhm shunt resistor and brings out necessary CA shunt and power connections to a 6 pin CA-DP compatible connector. The unused CA-DP **Spd** and **ThO** signals are brought out to a Breakout Cable for custom handling. The rated capacity is 50A but sanding the face flat and clamping the shunt to an aluminum plate or other heatsink will allow higher current.

The module 'Controller' and 'Battery' wires are unterminated and can be permanently wired in place or fitted with connectors.



Connect the shunt as shown to the left.

The green **Tho** wire from the breakout cable provides the controller throttle Sense signal. Attach an appropriate mating connector.

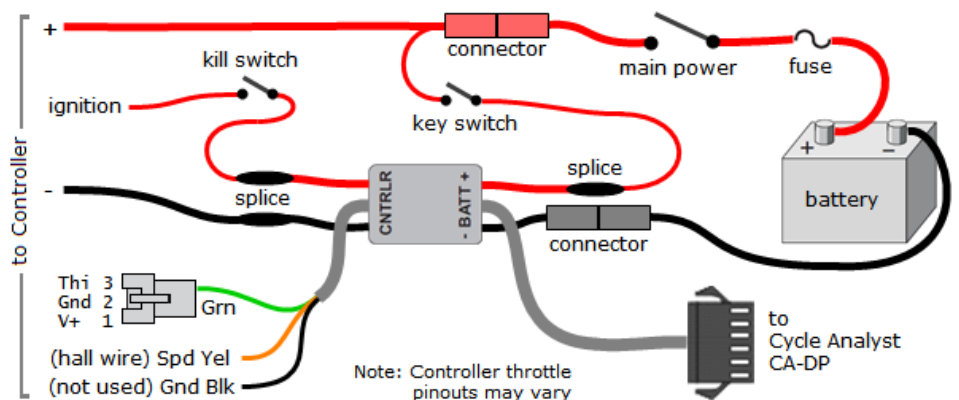
The yellow **Spd** wire from the breakout cable can optionally be tied to any motor hall wire (between hall connector and controller) as an alternative to using a wheel pickup.

As shown in the top illustration, the shunt resistor is in the negative power path and carries primary controller power. However, the heavy red positive leads are only a packaging consideration and a convenient means to pick up **Vbatt+** for CA power and monitoring; *they need not carry primary controller power.*

For instance, if a key switch is desired, then **Vbatt+** can bypass the shunt module and run directly to the controller. The controller 'ignition' lead carries **Vbatt+** back to the controller to power the +5V regulator and logic by way of the key and kill switches. Normally, when a controller has a CA interface connector, the ignition **Vbatt+** runs to pin 1. In this case with no controller CA interface connector, **Vbatt+** is picked off the key switch and is run to either of the shunt module heavy gauge red power leads to supply pin 1 of the shunt module CA connector. The other heavy red module lead need not be connected or can be used as a pass-through as shown below.

**Note:** A CA Adapter Module may be stacked with the molded External Shunt Module to provide throttle and ebrake signals to the controller (e.g. for regen braking). In that case, the Adapter Module throttle connector must be used in lieu of the green breakout cable wire (see '5.4 Ebrakes').

Step Complete. Go to section '4.2.2 Mount Console and Wheel Pickup'.



### 4.2.1.5 Installation with RC Electronic Speed Controller (Normal Mode)

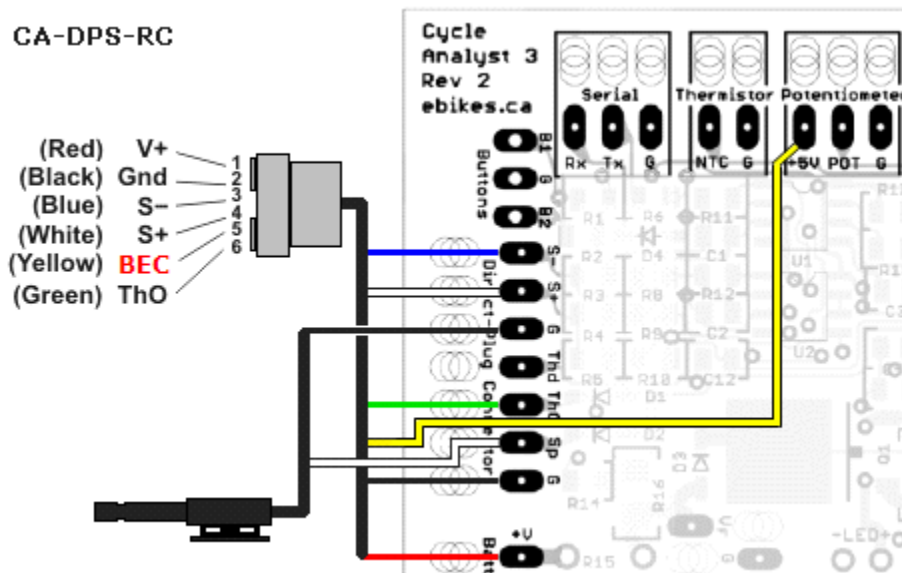
Depending on whether the Electronic Speed Controller (ESC) uses 50A or less, wire the unit according to either:

- '4.2.1.3 Installation with High Current External Shunt (Normal Mode)' or
- '4.2.1.4 Installation with Cycle Analyst Molded External Shunt Module (Normal Mode)'.

In either case, also wire CA-DP(6) (**Thro**) to the ESC Servo Pulse Input. This signal is available as the green wire on the CA-SA Molded External Shunt breakout cable.

If the ESC has no on-board BEC (Battery Eliminator Circuit), the CA may be able to supply the required 5V if the current requirements of other accessories is not too great. See section '5.10 Powering Accessories with the CA' to evaluate available current capacity. If adequate, then the yellow CA-DP(5) connection for **SP** input can be re-purposed to utilize the CA 5V supply as a BEC.

1. On the controller end, tie CA-DP(5) to the ESC BEC input. This connection is available on the CA-SA molded shunt breakout cable as the yellow wire.
2. On the CA end, tie the yellow CA-DP wire to either the *Throttle* or *AUX Pot 5V* PCB pads. If working with a CA-DP instead of CA-DPS, it will be necessary to first unsolder the yellow wire from the CA PCB **SP** pad under the brown square polyfuse.



CA-DPS Wiring to Supply +5V to RC ESC without BEC

Step Complete. Go to section '4.2.2 Mount Console and Wheel Pickup'.

### 4.2.1.6 Installation with Multiple Controllers (2WD)

A single Cycle Analyst CA-DPS can be used in multiple controller installations by supplying power to both controllers using a single external shunt. Follow the Cycle Analyst installation instructions for the appropriate type of external shunt and simply parallel the controller power, 'ignition' wires, and throttle connectors (use only the throttle Sense connections). If both wheel-motor-controllers are identical then it can reasonably be assumed that each drive will use half the monitored/controlled current so maximum CA current/power can be configured accordingly. Operation of the single throttle allows the CA to give coordinated power to both drives using any of the available CA throttle modes (e.g. PassThru, Current, etc). Auto-cruise and PAS will operate both motors in unison.

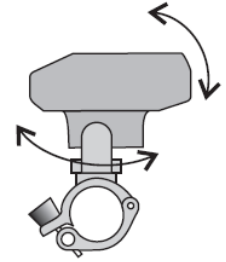
Switching between one and two motor operation requires special attention to accommodate different current/power limits and can be accomplished with the **AuxPot** input. Installations with differing drives (wheel size, controller, or motors) are more problematic and are beyond the scope of this manual.

Step Complete. Go to section '4.2.2 Mount Console and Wheel Pickup'.

### 4.2.2 Mount Console and Wheel Pickup

1. Mount the Cycle Analyst Console

The Cycle Analyst display console comes with a mounting bracket for installation on the handlebar. This bracket can rotate in two axes to adjust the display position and fits 22 to 36mm bars. Use the provided rubber shims around the tube if the clamp diameter is too large and fails to hold securely.

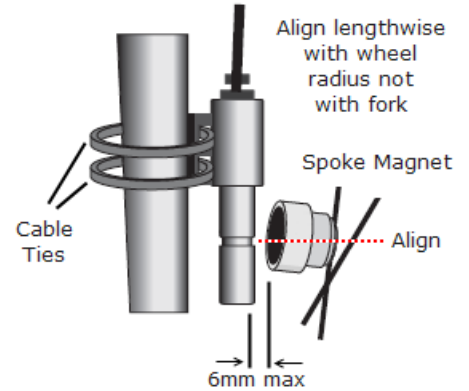


**Note:** The standard clamping thumbscrew may be replaced with the optional security screw available separately from Grin Tech.

2. Mount the Optional Wheel Pickup

Attach the pickup sensor to the fork using the two provided cable ties and attach the magnet to a spoke using the screw in the magnet body. Moving down the fork towards the hub will bring these two components closer together. The magnet and pickup sensor MUST be aligned as follows:

1. Position the pickup sensor so that it is aligned perpendicular to the travel direction of the magnet (i.e. aligned with the radius of the wheel). Because of fork design this may not be exactly in line with the fork.
2. Position the magnet so that it is aligned with the groove around the body of the pickup.
3. Position the magnet and pickup sensor no more than 6mm apart - the closer the better.



The sensor may be used with wheels lacking spokes (scooters, etc) by custom mounting to accommodate the required alignment/clearance and gluing one or more rare earth Neodymium magnets to the wheel.

**Note:** Multiple spoke magnets may be installed to improve low speed responsiveness when using closed-loop 'speed throttle' (see '5.2 Closed-Loop Throttle Modes'). They need not be placed exactly evenly.

**Note:** Spurious power cutouts due to speed limiting or very large recorded maximum speed (see **MaxS** status display) can arise from contact bounce in the sensor. Simple repositioning may remedy this problem, but failed sensors with this issue require replacement – contact Grin Tech. A temporary remedy until replacement is available is to defeat speed sensing by relocating the pickup so it cannot be triggered by the magnet(s).

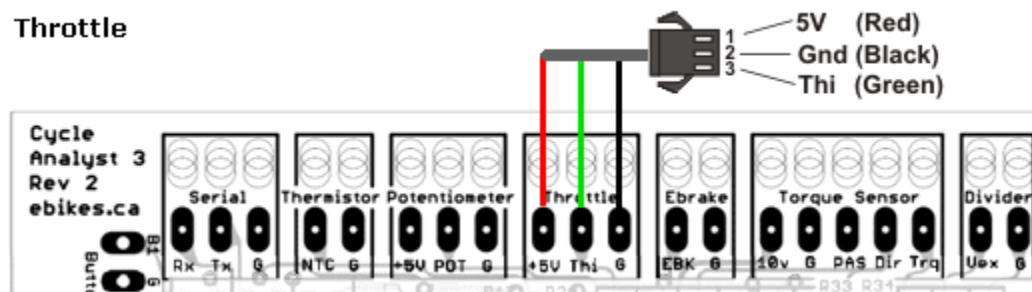
### 4.2.3 Connect Throttle

Any device that can provide a voltage in the range 0-5V can serve as a Cycle Analyst throttle. Hall throttles typically provide outputs of 1V – 4V while resistive throttles (e.g. Magura) typically provide outputs of 0V – 5V; either type is acceptable.

Follow either of the two following steps according to throttle type:

1. **Hall Throttles**

The section '4.2.1 Connect Cycle Analyst to Controller' showed the proper point to connect the throttle for each of the installation situations. If this has not yet been done, connect the throttle.



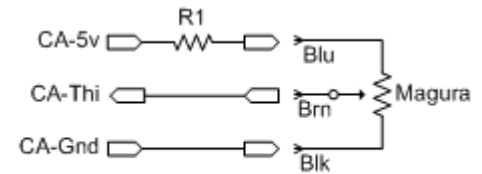
## 2. Resistive Throttles

Loss of the throttle **Gnd** connection generally causes throttle output to swing to the rail voltage (+5V) resulting in a Wide Open Throttle (WOT) runaway. The Cycle Analyst can prevent such runaways by detecting an 'input fault voltage' when the throttle voltage exceeds a specified limit somewhat above the normal throttle maximum output.

Resistive throttles present a problem in that the maximum output is the +5V rail voltage making it impossible to discriminate a fault condition.

A simple workaround is to introduce a resistor as shown to slightly reduce the actual max throttle voltage. Loss of the **Gnd** connection will still raise the **Thi** input to approximately 5V. Setup parameters are adjusted for the slightly reduced working range so normal throttle operation is unaffected.

Select a resistor to yield a 0.5V – 1.0V drop. For instance, with a nominal Magura resistance of 5K, a 470 ohm to 1K resistor is suitable.



*Magura Throttle Mod for Thi->FaultVolt*

The standard Cycle Analyst connector cable 'tree' shares a +5V connection for both Throttle and AuxPot connectors. This makes addition of the resistor inside the CA case problematic if an AuxPot switch draws varying amounts of current depending on setting – these current changes will upset throttle settings. The resistor is best added to the throttle proper, in-line in the throttle cable, or within the CA case with a revised CA throttle cable/connector that does not share wiring the AuxPot connector. In the latter case the resistor can be soldered directly in-line with the (+5V) lead of the throttle cable within the case and then entirely sleeved with heat shrink.

The section '[4.2.1 Connect Cycle Analyst to Controller](#)' showed the proper point to connect the throttle for each of the installation situations. Connect the throttle as indicated.

**IMPORTANT:** If upgrading a previous V3 'legacy' installation to 'normal', set **ThrI->CntrlMode = PassThru** before applying power, otherwise the existing setting of **off (WOT)** will apply WOT when the bike is powered ON.

**Note:** If in later steps the controller does not respond even though the V3 applies a proper throttle voltage (as measured at the controller throttle input pin), then the controller may employ a 'missing throttle' safety circuit. Such circuits block operation if the throttle is unplugged as determined by the absence of current at the throttle connector power pins. If this symptom presents, simulate the presence of a throttle by adding a 1K resistor across the controller throttle +5V/Gnd leads. This can be conveniently done on the pins of a mating throttle connector. This resistor is harmless although unnecessary for controllers lacking a safety circuit.

### 4.3 Determine and Save Device-Specific Settings

1. Enter Setup and record the value of **Cal->VScale** which calibrates voltage measurements. Do not lose this setting value.

**IMPORTANT:** This is a specific calibration for your particular CA and is set by Grin Tech during production.

2. Determine and save the value to be used for **Cal->RShunt** which calibrates current measurements. This is one of:
  - 1 mOhm if using a new CA molded external shunt,
  - the shunt value of your specific controller,
  - the shunt value of your old V2 wired-in external shunt (value was saved above),
  - the shunt value of an external shunt specified in terms of Amps and Volts, (see '[6.13 Determining External Shunt Resistance](#)'), or
  - the (unknown) value of a controller or external shunt (see '[Appendix A. Calibrating the Cycle Analyst RShunt Value](#)' for a default value).
 After the CA is operational, use one of the procedures there to determine the proper value.

## 4.4 Update CA with Most Recent Firmware and Clear CA to Default Settings

The CA splash screen displays the version of the installed firmware. If the most recent version is not already installed then download both the most recent firmware and Software Setup Utility from the [Grin Tech V3 web page](#).

Follow the steps in section '[Appendix H. Updating CA Firmware and Saving/Restoring Settings](#)' to preserve any pre-existing vendor settings, update to the most recent firmware, and most importantly – restore all CA Setup parameters to a default factory-fresh condition.

During the flash procedure the Cycle Analyst will enter bootloader mode and will display the screen to the right. The unit will reboot and display the splash screen when re-flash completes successfully.



*Bootloader Serial Connection Screen*

## 4.5 Calibrate Current and Voltage Measurements (Make Device-Specific Settings)

### 4.5.1 Configure Current Range and Shunt

**IMPORTANT:** The V3 can operate in either of two modes to support vehicles drawing a maximum of either 99.9 Amps (**Cal->Range=Lo**) or 999 Amps (**Cal->Range=Hi**).

**Cal->Range** differs from other Setup parameters and should not be changed once the unit is configured. Altering **Cal->Range** can have unforeseen effects on previously configured settings and associated Setup entry screens. If configuration entry difficulties arise due to such alterations, re-flashing to defaults may be necessary.

- a. If (Controller Maximum Amps) < 100A **AND** (CA Shunt Resistance) >= 0.763 mOhm
  1. Set **Cal->Range = Lo (W)**
  2. Set **Cal->VScale** and **Cal->RShunt** as determined above in section '[4.3](#)'
  3. Leave **PLim->AGain** and **PLim->WGain** at the default values.
  
- b. If (Controller Maximum Amps) >= 100A **OR** (CA Shunt Resistance) < 0.763 mOhm
  1. Set **Cal->Range=Hi (kW)**
  2. Set **Cal->VScale** and **Cal->RShunt** as determined above in section '[4.3](#)'
  3. Scale up the default values of **PLim->AGain** and **PLim->WGain** by 10x or set to 999 if the scaled value is 1000 or greater and cannot be entered into the Setup screen

**IMPORTANT:** Unlike all other values in the 'Calibration' section, **Cal->Range** is not preserved when flashing or loading a setup file to restore defaults. If you are using the Hi setting, always verify/reset **Cal->Range = Hi** immediately after flashing and prior to altering any other configuration items. This will ensure that other preserved calibration values are properly interpreted and that entry fields are correctly displayed.

### 4.5.2 Verify Zero Current Calibration

Enter Setup and navigate to the **Calibration** section, select **Cal->ZeroAmps**, and press-hold the right button. This re-calibrates the present current as 0.0 Amps. With ZERO throttle the CA should show a power reading in the neighborhood of 0-5W due to controller idle current. Should idle current readings subsequently change, revisit this step to reset the zero-current offset.

If you have an external shunt or other custom wiring such that the CA obtains power independently of the controller, then zero calibration is best done with the controller main power or 'ignition wire' disconnected. This gives a 'true' zero current reading so that the CA will log a small battery drain due to the idle current when the controller is ON but at zero throttle.

## 4.6 Configure Setup Parameters

### 4.6.1 Set Up Baseline Configuration

Only a few non-default parameters are required for basic operation. Enter Setup and configure only the following items - leave all others at defaults.

Other necessary settings are addressed later - do not enable or configure more advanced features until all setup steps in this entire section ('[4.0 Basic Installation \(Install/Connect CA and Tune Throttle\)](#)') are successfully completed.

```
(unless otherwise noted, the following values are only illustrative and should be
adjusted for your bike)

[...] = numeric entry field
{ ... | ... } = menu chooser

1.SETUP SPDOMETER
  1. Spd -> Units   = { mi | km }
  2. Spd -> Circumf = [2150] mm      (see 6.12 Determining Tire Circumference)
  3. Spd -> #Poles  = [1]           (see 6.14 Determining Pole Count)

2.SETUP PRESETS
  1. PrSt -> Preset Cnt = { Only1 } - (leave at one preset for simplicity)
  2. PrSt -> Batteries? = { Batt A Only } - (leave at one pack for simplicity)

3. SETUP BATTERY
  1.Batt -> A = { [A] }
  2.Batt -> Chemistry = { LiFe | SLA | NiMH | LiMn | LiPo }
  3.Batt -> String#   = [20] Cells
  4.Batt -> Capacity  = [20] Ah
  5.Batt -> Vlt cutoff = [50.0] volts

4.SETUP THROT OUT
  1.Thro -> Output Mode = { voltage | R/C Pulse }

5.SETUP POWER LIMS
  1.PLim -> Max Current = [99.0] Amps - (set to controller max rating)
```

To avoid unwanted interactions with other CA functionality, leave all other CA options in the default Disabled state.

```
1. PAS->PASMode      = Off
2. Trq->SensrType    = Disbld
3. Temp->Sensor      = Disabled
4. Aux->AuxFunct     = Off
```

### 4.6.2 Set Throttle Input/Output Voltages

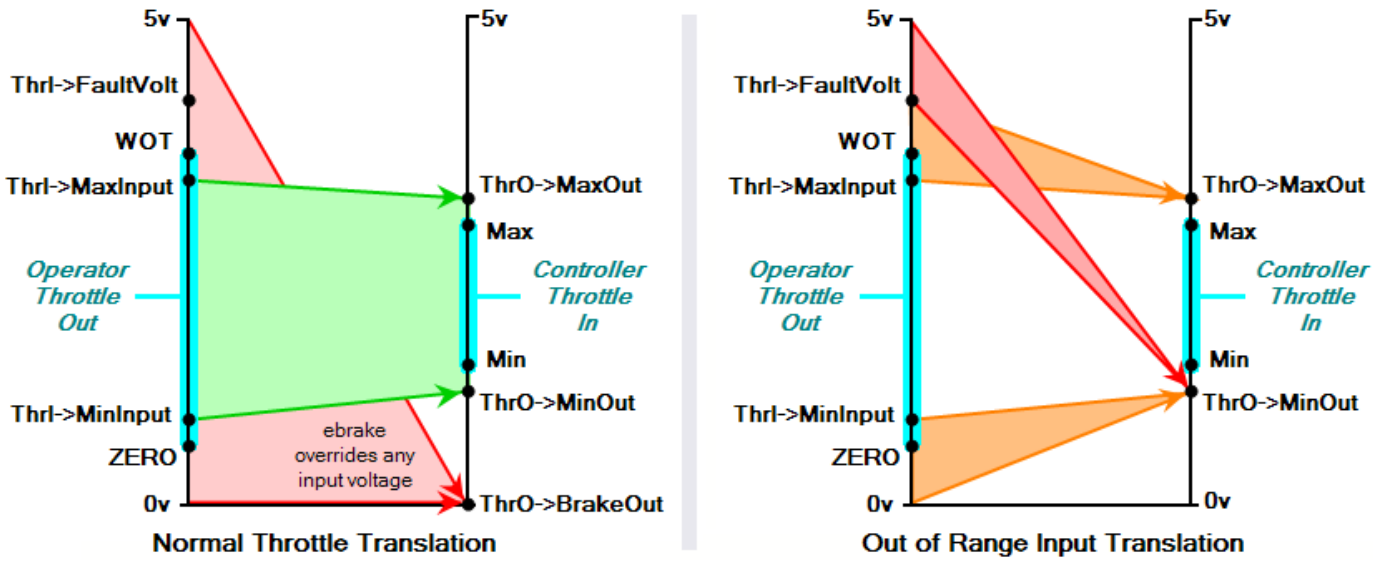
The goal of these voltage level adjustments is to match the output of the operator throttle with the controller throttle input. This tuning

- minimizes throttle dead zones,
- ensures that wide open throttle (WOT) achieves maximum controller output, and
- ensures that the controller is completely shut down at zero throttle.

These are one-time adjustments and once made should never require alteration. Throttle voltage adjustments are not designed to adjust controller power, although misadjustment can reduce power.

The following figures show the relationships of properly configured throttle settings:





Voltage Range Mapping - Operator Throttle Output (ThrI) to Controller Input (ThrO)

The left figure above shows how the CA parameters are set near but not exactly equal to the related throttle and controller values to ensure effectiveness in case of small mechanical and electrical variations with time and temperature. For instance, **ThrI->MaxInput** and **ThrO->MaxOut** are adjusted so the CA detects max operator throttle slightly before true WOT and accordingly delivers a bit more than the required maximum controller input. Applying ebrakes always remaps any input voltage to **ThrO->BrakeOut** (normally 0.0V).

The right figure above illustrates the mapping of out-of-range inputs which can be caused by broken throttle connections. As in the left figure, ebrake application supersedes these mappings but is not shown for clarity.

- Breaks in the throttle Sense or +5V connections send **Throttle IN** to 0.0V which the CA maps to **ThrO->MinOut**.
- Breaks in the throttle Gnd connection drive **Throttle IN** to +5V, a dangerous failure. The CA prevents WOT runaway by mapping voltages of **ThrI->FaultVolt** and above to **ThrO->MinOut**.

The following steps should ensure a near optimal configuration without guesswork - there are just a few steps and no foreknowledge of the throttle or controller voltages is required. Please postpone alterations to these recommended settings until the entire throttle adjustment procedure is complete and fully operational.

**IMPORTANT:** The following adjustments should be undertaken with the bike on a stand so the motor can be run to speed safely. Use care in making these adjustments since high motor speeds may accidentally occur during the adjustment process.

**1. EITHER – for 'Normal' Operation (CA Provides Throttle)**

- a. Set **ThrI->CntrlMode = Pass-thru**
- b. Tune **ThrI->MinInput** and **ThrI->MaxInput** to match the actual throttle voltage range:
  1. Adjust the throttle to each extreme and use the live Throttle In voltage display on the **Setup Throt In** screen to determine the voltages at ZERO and WOT throttle.
  2. Transfer these readings to **ThrI->MinInput** and **ThrI->MaxInput** but increase/decrease the Min/Max settings respectively by 0.15V over the actual readings to ensure full throttle range e.g. if read (min,max) = (1.1, 3.9) then set to (1.25, 3.75).

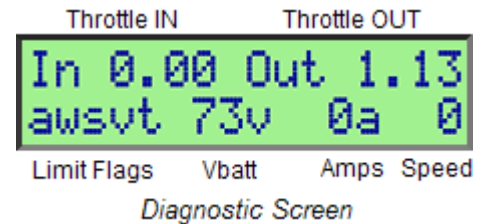


Live Thr In Voltage Live Thr % Mode Throttle-In Preview Screen

- c. Set **Thrl->FaultVolt** auto-shutdown feature for damaged throttle connection:  
Set **Thrl->FaultVolt** about half way between 4.99V and the actual measured max **Throttle IN** e.g. for the example above  $(4.99+3.93)/2 \approx 4.5V$ .
- d. Verify the **MinInput**, **MaxInput**, **FaultVolt** settings by examining the 'Live Throttle %' field on the Throttle-In Preview Screen shown above while rotating the throttle slowly ZERO to WOT. The percentage should change from exactly 0% to 99% with a small 'dead zone' at the start and end. If the WOT reading falls to 0% then **FaultVolt** is likely set incorrectly.  
Revisit the adjustments in steps (c) and (d) if the percentages are not as specified.
- e. Adjust **Thro->MinOut** and **Thro->MaxOut** to match the controller min/max throttle input voltage range:

**Note:** The basic setup procedure outlined in this step is applicable to RC ESC installations although the units are in msec instead of volts and the initial min/max range may be ESC-specific.

1. Start by setting **Thro->MinOut** and **Thro->MaxOut** to 0.00V and 4.99V respectively.
2. Use the Diagnostic Screen (left button once from Main Display) that shows **Throttle OUT**. While increasing the throttle, note the **OUT** voltages at which the wheel begins to turn (min) and stops turning faster (max).
3. Verify the max setting does not cause the controller to shut down from an input voltage fault. Slowly ramp the throttle up until the controller shuts down from throttle over-voltage fault; note the **OUT** voltage when this occurs and in the next steps ensure that **Thro->MaxOut** is at least 0.25V less than this value.  
Disregard this test if the controller does not shut down (it may lack this feature).
4. Transfer the min/max readings to **Thro->MinOut** and **Thro->MaxOut** but decrease/increase the settings respectively by 0.10V over the actual readings to ensure the controller is shut off at zero throttle and actually reaches WOT e.g. if read (min,max) = (1.4, 3.9) then set to (1.3, 4.0).
5. *If necessary*, fine tune the **Thro** settings so there is minimal 'dead zone' at zero throttle and WOT.  
Verify 'dead zones' by watching the Watts display on Main Screen while moving the throttle near/at zero and WOT – the reading will not change in dead zones.



## 2. OR – for 'Legacy' Operation (CA Limits Operator Throttle)

- a. Set **ThrI->CntrlMode=Off (WOT)**
- b. In legacy mode, **ThrI->MinInput** and **ThrI->MaxInput** have no effect; these parameters may be left at the default settings.
- c. In legacy mode, **Thro->MinOut** and **Thro->MaxOut** are equivalent to the CA v2.x parameters **ITermMin** and **ITermMax** respectively. To paraphrase sections 8.11 and 8.12 of the CA v2.3 Manual:

"**Thro->MaxOut** puts an upper limit on how high the throttle over-ride will drift upwards when none of the limit values are being exceeded. Ideally this value is set to the voltage that is considered full throttle by the controller. For hall effect throttles, full power occurs at about 4V, and limiting the ITerm to this value will speed up the response time of the limiting features. Allowable values are from 0 to 4.99V."

"**Thro->MinOut** imposes a lower bound on how low the throttle over-ride can drift downwards when one of the limiting values is being exceeded. By preventing the over-ride signal from going all the way to 0V, you can decrease the recovery time for the signal to go back upwards. Allowable values are from 0 to 4.99V and must be less than **Thro->MaxOut**."

Ideally, these values are the controller throttle input voltages at which the motor just begins to turn (actually a bit less) and stops turning faster at no-load (actually just a bit more).

Unlike 'normal' mode, legacy mode has no means to measure and determine these settings using the CA alone. Unless you have specific knowledge of the controller throttle input voltage range, leave these settings at the defaults for the first try. Adjustment for more optimal limiting operation can be undertaken using a DMM to directly measure the throttle voltage while otherwise following the normal mode **ThrO** adjustment procedure. This more rigorous adjustment speeds limiting response and can help suppress surging that cannot be eliminated with gain adjustments.

- d. Use the Diagnostic Screen to verify that the **Throttle OUT** voltage is equal to the configured **ThrO->MaxOut**. When underway, this value will fall towards **ThrO->MinOut** as any limiting parameter comes into play.

## 4.7 Test Throttle and Limit Settings (Interpreting Limit Flags)

Your CA is now ready for a test ride where one or more of the limit parameters may affect the throttle output voltage.

### 1. Verify Throttle Adjustments

- Verify that at zero throttle there is no motor creep and the dead zone is not excessively large. Otherwise, revisit the **ThrI->MinInput** and **ThrO->MinOut** adjustments above.
- Verify that at WOT the bike delivers maximum power and the dead zone is not excessively large. Otherwise, revisit the **ThrI->MaxInput** and **ThrO->MaxOut** adjustments above.

**Note:** The recommended 0.15V throttle adjustment offsets may be reduced to minimize throttle dead zones, but motor creep, maximum power reduction, or auto-cruise/PAS problems may arise. Reducing the offsets is not recommended, but if undertaken, should be accompanied with a policy of regular throttle setting verification.

Persistent auto-cruise or PAS dropouts may be remedied by increasing the **ThrI->MinInput** offset to 0.20V.

A flashing throttle bar graphic on CA power-up indicates detection of a non-ZERO throttle. A common cause is an improperly low setting of **ThrI->MinInput** resulting in no low end throttle dead zone.

### 2. Verify Limit Configuration

If the throttle is correctly adjusted and the bike still fails to achieve full power, then some Limiting Parameter is likely in play. Use the 'Limit Flags' display on the Diagnostic Screen to identify any limits in effect (see table below). Upper case flag characters indicate that the associated parameter is actively limiting throttle output and so may require adjustment. Gain Parameters are discussed in the next section.

Flag	Limit	Units	Limiting Parameter	Gain Parameter
A	Current	Amps	PLim->MaxCurrent	PLim->AGain
W	Power	Watts	PLim->MaxPower	PLim->WGain
S	Speed	kpm/mph	SLim->MaxSpeed	SLim->IntSGain SLim->PSGain SLim->DSGain*
V	Voltage (LVC)	V	Batt -> VltCutoff	n/a
T	Temperature	degC	Temp->MaxTemp	n/a

\* Parameter affects operation but cannot directly cause Limit Flag display

*Limit Flags ... lower case = output not limited, upper case = output limited*

Note that the speed limit flag is only asserted if the limit is actually exceeded. There are other aspects of the speed control logic that can lead to limiting or speed oscillations (next section) but that are difficult to determine as causing a problem. As a result, there can be a speed-related issue with no 'S' Limit Flag.

#### Legacy mode only:

Limiting is in effect whenever **Throttle OUT** (plus a diode drop) is a lower voltage than that of the operator throttle. If the bike does not achieve full power, the value of **ThrO->MaxOut** may be set too low causing limiting to accidentally be in effect in spite of Limit Flag indications.

- Temporarily adjust **ThrO->MaxOut = 4.99**.

If this remedies the problem, then set **ThrO->MaxOut** by using a DMM to measure the throttle voltage at the connector to determine the minimum voltage necessary to achieve maximum unloaded motor speed at WOT.

- Alternatively, reset **ThrO->MaxOut** to the default then iteratively increase the value by 0.1V and test until no further WOT speed improvement occurs.

## 4.8 Adjust Throttle Ramping

Throttle ramping is not available in legacy mode.

**Note:** Ramping adjustments in this section and gain adjustments in the next section may interact so some iteration may be required. Adjustment may be unnecessary for low to moderate powered builds, but review of these sections will assist in recognizing and addressing less than optimal performance.

Throttle ramping affects Throttle OUT universally and so plays a role in operator throttle, closed-loop throttle, PAS, auto-cruise, etc. The ramping logic clamps the rate of Throttle OUT change and participates only when the rate of change exceeds configured limits – at lower rates it has no effect.

Ramping can affect the stability of controller current and speed limiting logic for certain vehicles. It may be best to at least roughly configure ramping before gain adjustments are undertaken. This policy allows conservative ramping adjustments to be made later with little likelihood of stability impact. This is not strictly necessary, but may prove a useful policy. In any case, CA ramping should not be set to a rate less than that of any built-in controller ramping.

Adjust **ThrO->DownRate**, **ThrO->UpRate**, **ThrO->FastRate**, and **ThrO->FastThrsh** as appropriate to achieve the desired throttle response. All ramp settings are in V/sec so smaller values yield longer ramp times. Typical values given here are just that and values outside these ranges are quite possible.

- **DownRate** sets the maximum rate at which throttle voltage can be reduced. Slower **DownRate** can be beneficial for PAS or certain drive systems, otherwise a rapid rate may be desirable to give brisk throttle response. Ebrake application immediately suppresses **DownRate** (see '5.4 Ebrakes') so **DownRate** tuning need not consider braking. Values of 4-8V/s are typical, 99V/s is as fast as possible.
- **UpRate** sets the maximum rate at which throttle voltage can be increased. This can be used to slow power application giving smoother getaways without harsh acceleration. Gear motors, mid-drives, and powerful DD motors may benefit from smaller values to moderate power on dead starts. Values of 0.5-2.0V/s are typical.
- **FastRate** is similar to **UpRate** and is typically set to a faster rate. Values of 4-8V/s are typical.
- **FastThrsh** sets current at which the CA switches from **FastRate** to **UpRate**.
  - If **FastThrsh** = 0.00A, **FastRate** is ignored and **UpRate** is always employed, otherwise:
  - When current is less than **FastThrsh**, the CA uses **FastRate** to quickly advance Throttle OUT to the point where the motor is bearing load. When already underway, this shortens the ramping delay that would otherwise occur if using the slower **UpRate** ramping.
  - When current is equal to or greater than **FastThrsh**, the motor is bearing load and the CA switches to **UpRate** to apply slower ramping.

**FastThrsh** should be set higher than the current necessary to accelerate the unloaded wheel to maximum rpm. This is always greater than the maximum unloaded current. Setting the current too low will cause the CA to prematurely switch to **UpRate**. Typical DD values are 0.5-1.0A, gear motor values are typically 2-4A.

**UpRate** and **DownRate** are per-preset settings; **FastRate** and **FastThrsh** are global and affect all presets.

The approximate ramp time for a full throttle excursion (ZERO to WOT or WOT to ZERO) is determined by:

$$\text{ramp time} = (\text{ThrO->MaxOut} - \text{ThrO->MinOut}) / (\text{ThrO->xxxRate})$$

Examples:

- The fastest ramp time can be achieved by using the largest allowable **xxxRate** setting (99.99V/sec). This typically yields a delay of  $(3.9V - 0.8V) / (99.99V/sec) = 0.031$  sec (essentially undetectable).
- To get a 2.5 second up-ramp time for a gear motor, **UpRate** might be  $(3.9V - 0.8V)/2.5sec = 1.25V/sec$

## 4.9 Adjust Gain: Minimize Surging or Speed Oscillations

Control overshoot and power oscillations may occur whenever the Cycle Analyst provides current, power, or speed limiting. Closed-loop throttle modes are just special cases of classic 'maximum value limiting' where maximum limit is instead scaled 0-100% by the throttle (e.g. Current Throttle and **MaxCurrent**).

The Cycle Analyst utilizes PID controllers for current, power, and speed limiting (see '[Appendix E. PID Controllers and Gain Parameters](#)'). Gain settings determine the amplitude of feedback or correction and so affect the responsiveness and stability of the controllers. By adjusting the gain settings, the Cycle Analyst can be tuned to operate across a wide range of vehicle powers and weights. Although the default settings are suitable for many low to moderate powered builds, some vehicles require additional adjustment (e.g. those with high power to weight ratios).

Throttle correction is controlled by the gain setting of whichever Limiting Parameter is in play (see '[Limit Flags](#)'). For example, if **PLim->MaxAmps** forces limiting, then **PLim->AGain** will control throttle correction. If power oscillation is present, inspect the 'Limit Flag' display on the Diagnostic Screen while surging is underway. Limit Flag(s) that change state in synchronization with the surging indicate the gain settings of interest.

Speed, current, and power gain settings are global parameters and are common across all presets.

**Legacy mode only:** Slow throttle correction can also occur if **Thro->MinOut** or **Thro->MaxOut** are set far from the optimal values described earlier. These correction delays arise as the CA limiting voltage takes time to change across the 'dead zone' between the actual and optimal settings. This issue can be identified by examining the Throttle OUT voltage on the Diagnostic Screen and watching if there is substantial OUT change with no apparent effect on bike power - followed by the delayed/desired correction. If necessary, adjust these parameters as described earlier.

#### 4.9.1 Current and Power Gain (AGain, WGain)

**AGain** and **WGain** participate whenever current or power limiting are in play and in particular during operation of PAS and Current or Power Throttle. Reducing the related gain setting minimizes overshoot and dampens oscillation, while excessive reduction leads to sluggish response.

Here are specific recommendations for each gain setting:

##### **Grin Tech V3 web page:**

**AGain:** Feedback gain for the current control loop. Generally it should be increased until you start to feel the current limit being rough or oscillating, and then scaled back about 30%.

**WGain:** Same story as A Gain above, only now applied to the power limiting feedback loop.

It may also be worth a small gain adjustment if the bike appears to ride smoothly but the Amp/Watt displays fluctuate widely around the limit setting - over/under fluctuations should be modest and easily tracked by eye.

#### 4.9.2 Speed Gain (PSGain, IntSGain, DSGain)

These gains participate whenever speed limiting is in play and in particular during operation of Speed Throttle.

##### **Grin Tech V3 web page:**

**PSGain:** Proportional feedback term for speed control loop. Displayed in terms of Volts / (mph or kph). So if it is set to 0.5V/kph, then for each km/hr you go above the speed limit, the throttle output will immediately drop by 0.5V.

**IntSGain:** Integral feedback gain for speed PID control loop. Lower values give smoother control and less likelihood of hunting, but can increase the time it takes for the speed limit to stabilize.

**DSGain:** Differential feedback term for speed control loop. This is used to dampen oscillations from speed limiting as it allows the CA to anticipate that you are accelerating towards the speed limit and scale back power before you reach it. Values in the 100-300 range seem to work well.

Because the speed PID controller tries to anticipate speed overshoot before it occurs, some vehicles may experience cutouts during hard acceleration. The problem arises as the vehicle rapidly accelerates and the CA preemptively reduces the throttle to avoid overshoot - even though the limit has not yet been reached. Such cutouts indicate that the **DSGain** setting is too high (too much 'future sense'). The CA cannot actually discern that meaningful limiting is in effect and so the associated 'S' limit flag gives no indication.

If speed-related surging or power cutouts occur, apply one of these two remedies:

1. If Speed Throttle or enforcement of **SLim->MaxSpeed** are desired, please follow the tuning procedure for the speed controller outlined in '[Appendix F. Speed Gain Adjustment Procedure](#)'.
2. If Speed Throttle and maximum speed limit enforcement are not required, disable the speed control logic: set **SLim->MaxSpeed** to the maximum value, **IntSGain** = 100, **PSGain** = 0, **DSGain** = 0.

## 5.0 Advanced Features

Features in this section may be enabled once basic setup is complete. Some of the features may interact in unexpected ways and configuring/tuning them one by one is recommended. The Software Setup Utility may be used to preserve intermediate configurations as 'restore points' until the entire desired feature suite is fully operational.

### 5.1 Battery Low Voltage Cutoff (LoVGain)

1. **Overview:** The Cycle Analyst provides low voltage cutoff (LVC) that reduces power (throttle) until the LVC condition is alleviated or until power is removed completely. All batteries exhibit some internal resistance that causes voltage sag under load as the current impressed across the resistance develops a 'sag' voltage. Reducing the throttle reduces the current drawn by the motor thus reducing the sag and causing the battery terminal voltage to rise – possibly eliminating the LVC condition. The V3 attempts to 'feather' the throttle to reduce voltage sag and so remove the LVC condition. The CA rolls the throttle completely to ZERO in severe LVC situations that reflect a true low state of charge, not simple sag.

LVC is implemented with an integration controller similar to the controllers for current and power limiting (see *'Appendix E. PID Controllers and Gain Parameters'*). When the LVC limit is exceeded, the CA begins correcting (reducing) the throttle in an attempt to remove the LVC condition. The gain setting determines the magnitude of the corrections and so, indirectly, the rate at which the condition is alleviated.

2. **Adjustment:** LVC is individually configured for each of the available battery presets. Switching presets thus applies the LVC configuration appropriate for the associated battery. For each battery preset:
  - **Batt->VltCutoff** is the limiting voltage and should be set high enough to take effect before the battery BMS or controller LVC come into play. In some cases, reprogramming the controller LVC lower to an absolute safety minimum can allow the CA a wider range of adjustment to more properly manage LVC.
  - **Batt->LoVGain** is a dimensionless gain setting. Large values cause larger corrections and more rapid action, smaller values have the opposite effect, slowing the power roll-off. Specifically, lower values will allow brief excursion of the battery voltage below the LVC on acceleration with no immediate power reduction so cutouts are avoided while reaching cruising speed and lower current draw/voltage sag.

### 5.2 Closed-Loop Throttle Modes

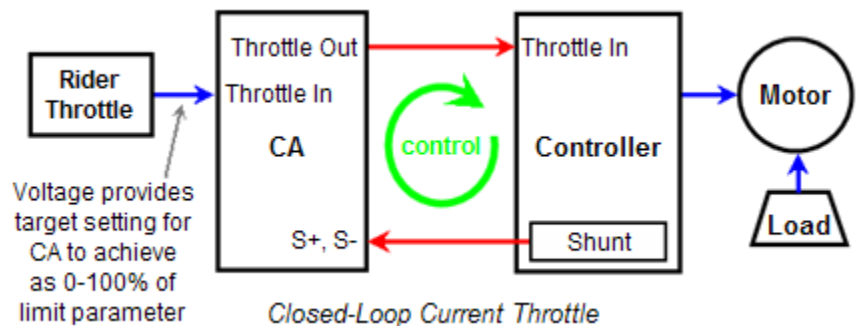
1. **Overview:** In 'normal' mode, the CA offers three additional closed-loop throttle modes that can give substantially improved throttle control:
  - Current Throttle
  - Power Throttle
  - Speed Throttle



Selecting 'Current Throttle' Mode

These are 'fly by wire' modes where the operator throttle sets 0-100% of the associated limit parameter as a target for the CA to achieve. The CA alone supplies the controller throttle and receives feedback from the shunt or speed sensor to determine any error in achieving that target. It then adjusts the controller throttle in a closed loop to cause the output to track the desired rider throttle input. The CA will maintain the target limit regardless of changes in load (see *'Appendix E. PID Controllers and Gain Parameters'*). This makes control of twitchy controller-motor setups exclusively the responsibility of the Cycle Analyst, while the rider sees a smooth throttle response.

For example, for Current Throttle, if **PLim->MaxCurrent** is set to 50A, then WOT is 50A. Assuming the rider throttle is more or less linear, adjusting the throttle to 10% rotation yields a predictable controller output of 10% of 50A or 5A.



The table below shows the available throttle modes - all but Pass-thru are closed loop. The columns show the feedback source and the relevant parameters for each mode of operation. To get the smoothest and most consistent operation it may be best to set the 'other' limits as loosely as possible so only the single throttle limiting parameter is generally in play. For instance, if using Current Throttle the controlling parameter is **MaxCurrent**. There is nothing to be gained by setting **MaxPower** to provide essentially the same limit - it can be left at the maximum so the **WGain** parameter will never be invoked and will not require tuning.

Throttle Mode	Loop Type	Feedback Source	Limiting Parameter	Gain Parameter	Thrl->CtrlMode=	scale throttle if Aux->ScaleLim=
PassThru	open	n/a	n/a	n/a	PassThru	n/a
Current	closed	Shunt Current	PLim->MaxCurrent	PLim->AGain	Current (A)	Amps Lim
Power	closed	Shunt Current + Vbatt	PLim->MaxPower	PLim->WGain	Power (W)	Power Lim
Speed	closed	Wheel Pickup or Hall Pulses via DP connector	SLim->MaxSpeed	SLim->IntSGain SLim->PSGain SLim->DSGain	Speed	Speed Lim

Throttle Mode Summary

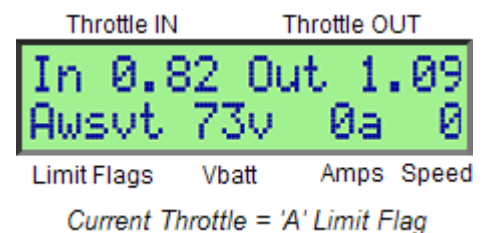
Note that the CA Speed Throttle is completely different than the Infineon controller throttle logic which is often referred to as a 'speed throttle'. The CA Speed Throttle is a true closed loop control system that measures the bike speed and corrects for variations. In contrast, the Infineon throttle uses open loop control to vary phase PWM duty cycle according to the input throttle voltage without regard for directly measured bike or motor speed; the 'speed' derives only from phase voltage and Kv and varies with load.

Current and Power Throttle modes have a familiar feel and are the easiest to set up and control.

2. **Adjustment:** If surging or power oscillations are present after selecting a closed-loop mode, revisit '4.9 Adjust Gain: Minimize Surging or Speed Oscillations'. Existing ramping settings are typically unaffected.  
**Note:** It may be useful to use a new preset when tuning a new closed-loop throttle mode so that operation in PassThru mode remains readily available until the new mode operates satisfactorily.

3. **Hall Throttle Linearity:** The closed-loop control strategy cannot compensate for throttle non-linearities. Many hall-effect throttles are intrinsically non-linear and so will compromise the effectiveness of these throttle modes. Better quality hall throttles with a linear strip magnet or resistive throttles like a Magura will yield the best results.

4. **Limit Flag Behavior:** It is normal when using any closed-loop throttle mode for the corresponding Limit Flag on the Diagnostic Screen to show almost continuous limiting - even at standstill. Similarly, in the case of Speed Throttle, the main screen 'kph/mpH' units will flash almost continuously. This occurs because these modes are implemented using the normal limiting logic except that internally the logic input is assumed to be WOT and the operator throttle instead scales 0-100% of the Limit Parameter. As a result, the CA is always trying to go WOT but is almost always being restrained by the adjustable throttle limiting. This asserts the Limit Flag.



5. **Spoke Magnets and Speed Throttle:** Using Speed Throttle at very low speeds can be problematic if using a wheel pickup in the standard configuration. With only a single spoke magnet, the Cycle Analyst gets a speed update only once per revolution or about once every two meters. Off the line or at very low speeds, this is inadequate for smooth speed control. There are two means to remedy this:
  - a. Set **SLim->StrtSpeed** to 5 or 6mph so that the Cycle Analyst will not attempt Speed Throttle control until the **Sp** pulses are arriving with adequate frequency.
  - b. Add more spoke magnets. These need not be placed exactly evenly. Each magnet generates a speed update, reducing the ground speed necessary to achieve adequate pulse frequency. As few as three or four magnets will give satisfactory results. Additional magnets may be ordered from Grin Tech.



### 5.3 Grin Tech Proportional Regenerative Braking

**Overview:** The Cycle Analyst integrates closely with Grin Technologies *Phase Runner* and *Grinfineon* controllers to provide proportional throttle-controlled regen when ebrakes are applied. This feature operates entirely through the standard throttle connection using a specially assigned voltage range and requires that there is no controller ebrake connection. Throttle and regen operation of other controllers is unaffected since all but the Grin controllers ignore voltages in this range.

Grin Tech controllers can provide proportional regen using either of two schemes:

1. An normal ebrake signal is sent to the controller and regen is controlled by a throttle signal in the usual throttle range (approximate 1V-4V) which delivers increasing regen with increasing throttle voltage. This is a convenient no-CA scheme for simple direct throttle connection to the controller.
2. No ebrake signal is sent to the controller and regen is controlled by throttle voltages in the 0.0V-0.8V range which deliver maximum and minimum regen respectively. This is the scheme used by the Cycle Analyst.

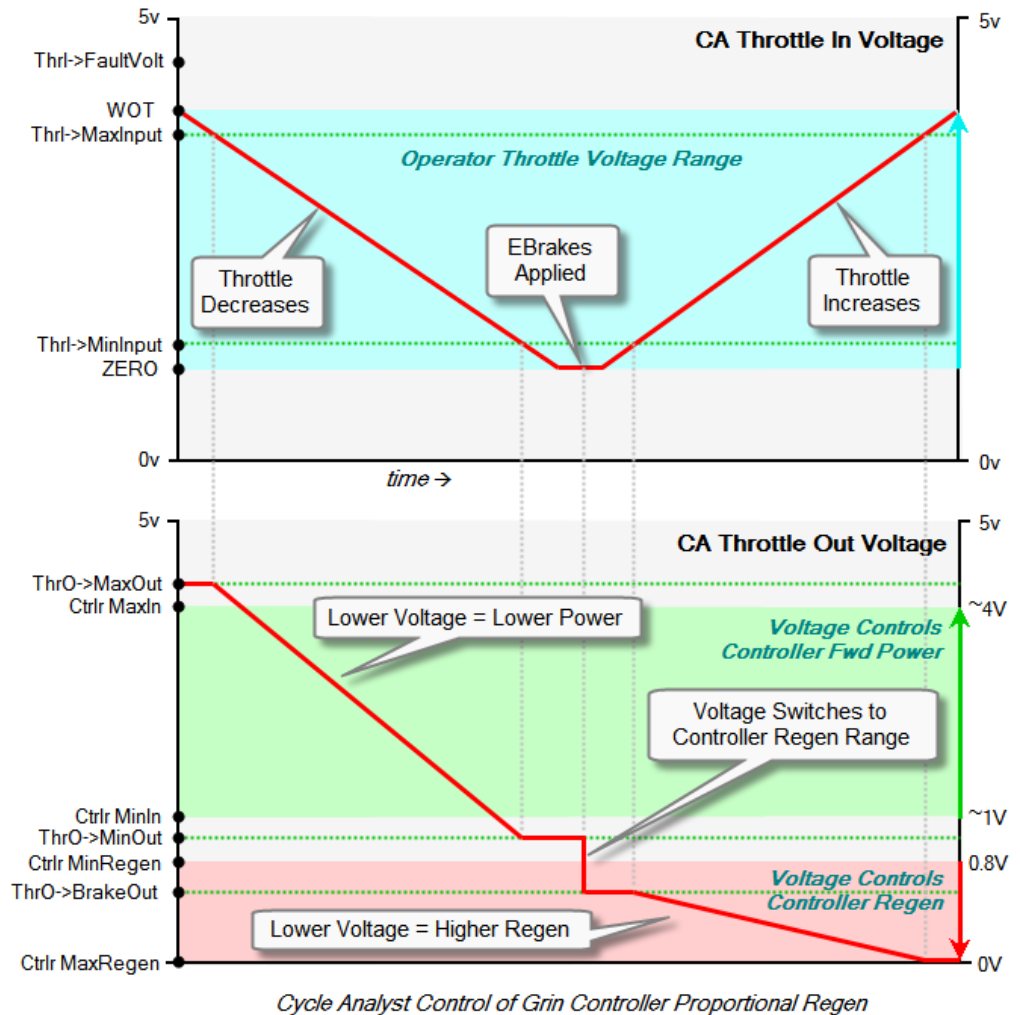
Using scheme 2, when ebrakes are applied, the CA supplies a Throttle OUT throttle voltage from **ThrO->BrakeOut** to 0.0V scaled by 0-100% of the Throttle IN voltage. With the default **BrakeOut** value of 0V, this applies 100% unscaled regen. However, raising the value of **BrakeOut** to a maximum of 0.8V reduces the regen at ZERO throttle and allows it to be increased proportionally up to maximum regen at 0V by increasing the throttle.

The illustration shows a short example timeline of reducing the throttle, applying ebrakes, then increasing the throttle with the ebrakes still applied. The top graph plots the CA Throttle IN voltage and the lower plots the corresponding Throttle OUT to the Grin controller. These are the IN and OUT voltages displayed on the Diagnostic Screen.

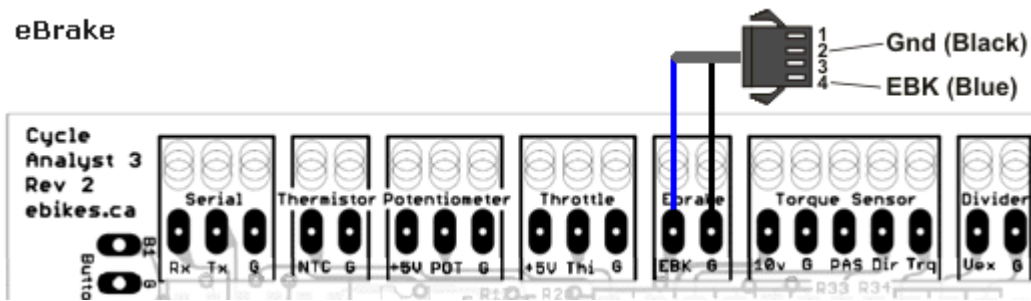
Other controllers only consider Throttle OUT voltages in the green region and so ignore the special signaling on the red region.

**Setup:** Adjust **ThrO->BrakeOut** for the desired level of regen at ZERO throttle. Ebrakes should be wired only to the CA and not to the controller (see the next section '5.4 Ebrakes').

**Ebrake Faults:** If ebrakes are released with the throttle greater than 35% and if regen presently exceeds 2A, then an Ebrake Fault will occur to avoid a sudden power surge. Ebrake Faults are indicated by alternately flashing the ebrake lever and Throttle Fault graphics on the main screen. After one second power is automatically reapplied with normal ramping to soften power application. Under light power the fault criteria ignore ebrake use or sloppy throttle closure while the brief power interruption warns the rider to correct the throttle when more power is in play.



## 5.4 Ebrakes



- Grin Tech:**  
 "This input has an on-board pull-up to 5V to be used with an ebrake cutoff switch. When the signal is shorted to ground, the CA thinks that your brake levers are depressed..."
- Operation:** The Cycle Analyst **EBK** input is asserted when low. This causes **ThO** to be driven to **Thro->BrakeOut** which is nominally 0.00V; no other operation reduces **ThO** lower than **Thro->MinOut** making it possible to examine the **ThO** level to discriminate between throttle ZERO and ebrake application (see ' 5.3 Grin Tech Proportional Regenerative Braking').

PWM output is affected similarly when **Thro->OutptMode=R/CPulse**. Some ESCs fault when the pulse width goes to zero so in those cases **Thro->BrakeOut** can be set to a low non-zero value that is compatible with the particular ESC.

  - Ebrake application suppresses **Thro->DownRate** so Throttle OUT changes are affected immediately.  
**IMPORTANT:** Setting **Thro->BrakeOut** higher than **Thro->MinOut** causes **EBK** assertion to apply non-ZERO throttle. Use care in configuring this value.
  - Ebrake application causes auto-cruise to disengage (See ' 5.5 Auto-Cruise Control').  
**IMPORTANT:** Do not use the auto-cruise feature unless ebrakes are installed and wired to the Cycle Analyst **EBK** input. Connecting ebrakes instead to the controller is not a substitute and can cause a dangerous runaway situation when the ebrakes are released since the CA auto-cruise will remain engaged and applying power.
  - Ebrake application causes PAS assist to cease immediately (See ' 5.7 Pedal Assist').  
**IMPORTANT:** Depending on the installation and CA configuration, some PAS power overrun may occur when pedaling ceases. Unsafe stopping situations may arise if ebrakes are not wired to the Cycle Analyst **EBK** input. Although such situations are seldom an issue for low powered PAS installations, use of ebrakes with CA PAS is recommended.
- Live Data:** When **EBK** is asserted, an animated eBrake graphic replaces the Throttle Gauge on the main display (see '[Main Status screen](#)'). The effect on Throttle OUT can be seen on the Diagnostic Screen.
- Electrical Characteristics:** The **EBK** pad ties to a microprocessor port through a 1K resistor. The pull-up current is approximately 150uA with an effective (min,typical,max) pull-up resistance of (15K,30K,200K). The threshold voltages at the **EBK** pad are approximately 1.5V to activate and 2.1V to release. Either a mechanical switch or hall effect device is a suitable sensor.
- Device Connection:** The Cycle Analyst **Ebk** input is wire-compatible with common Normally Open ebrakes implemented with mechanical switches, magnetic reed switches, or by electronic means (e.g. hall sensors, as with HWBS – hidden wire brake sensors).

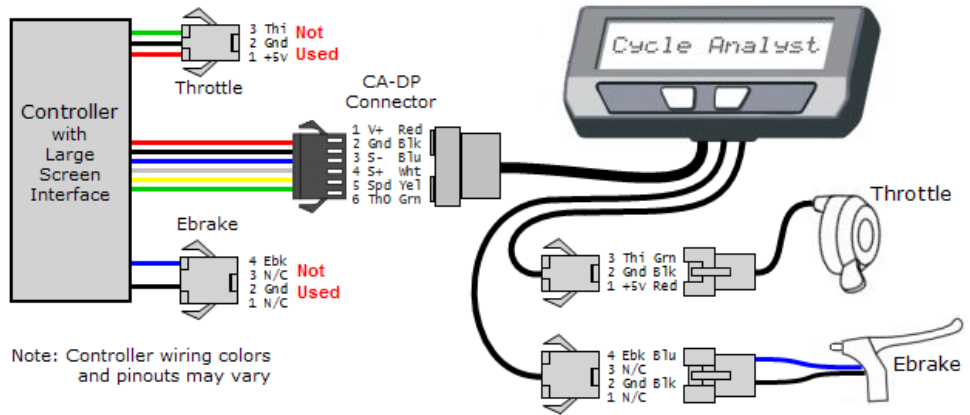
If ebrake application is to provide Grin Tech Proportional Regen or simple throttle cutout, then ebrakes should be connected to the CA (only) using the connector shown above. This works in either new or legacy modes.

If any controller feature is employed that relies on direct ebrake input (e.g. conventional regen), then the ebrake connection must be run to the controller in addition to the Cycle Analyst.

The figures on the following page illustrate three common connection scenarios:

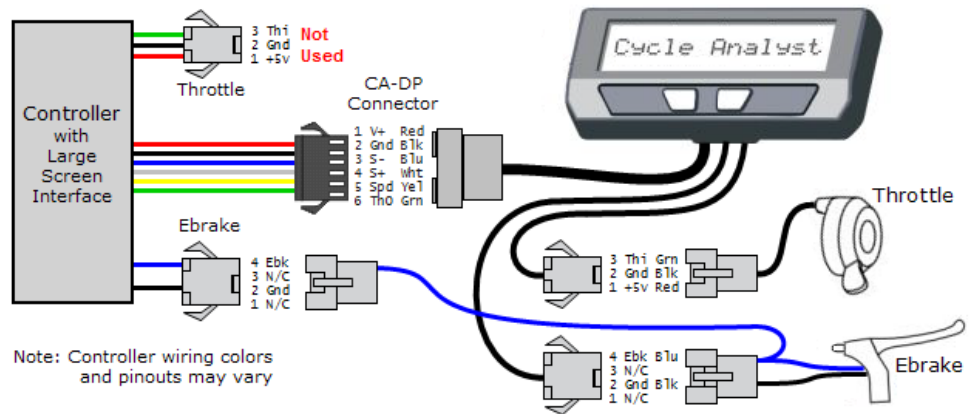
- a. **Case 1:** The CA provides simple throttle cutout or Grin Tech Proportional Regen and no controller features require ebrake input.

Ebrakes are run only to the CA.



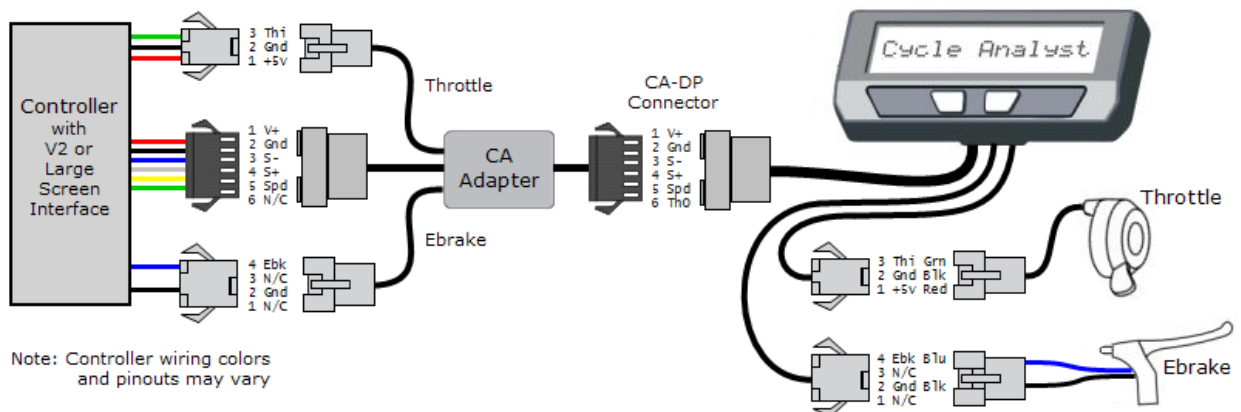
- b. **Case 2:** Both CA and controller features require ebrake input (e.g. conventional regen).

The ebrake signal is connected in parallel to both the CA **EBK** input and the matching controller ebrake input. A separate wire may be run or for a CA-DPS model, the yellow **Spd** wire of the CA-DP cable may be re-purposed to carry the signal. The controller ebrake **Gnd** connection is not necessary.



- c. **Case 3:** Both CA and controller features require ebrake input (e.g. conventional regen).

A CA Adapter Module on the CA-DP cable recovers an equivalent ebrake signal from the **Th0** signal on CA-DP pin 6 (see: [Install Using a CA Adapter Module](#) ). The module provides a throttle and ebrake connectors to directly drive the controller. This solution works for both 'legacy V2' and 'Large Screen Compatible' controller interfaces.



## 5.5 Auto-Cruise Control

1. **Operation:** Auto-cruise is a firmware-only feature that locks in the preset Throttle IN voltage until disengaged. This feature can be used with any throttle mode: *PassThru*, *Current*, *Power*, or *Speed*. For example, Speed Throttle selects a speed between 0-100% of **SLim->MaxSpeed** and so will maintain the 'set' Throttle IN speed regardless of terrain, as would an automobile cruise control.

Auto-cruise is enabled by setting **ThrI->AutoCruis** from **Off** to one of several preset hold times. This is a per-preset parameter that determines the period of time that the operator throttle must be held stationary to engage auto-cruise.



*Set AutoCruise Hold Time*

The global **ThrI->CruiseHld** parameter determines the allowable (+,-) voltage variation for the operator throttle in order for it be considered 'held stationary' for the **AutoCruis** period.



*AutoCruise Motion Tolerance*

When auto-cruise engages, a second (blinking) indicator appears on the throttle bar graph at the 'set' cruise level. The normal solid slider continues to move with the throttle. The appearance of the blinking slider gives a visual indication that cruise is engaged signaling that the throttle can be released. The 'In' label on the Diagnostic screen also blinks.



*AutoCruise Throttle Indicator*

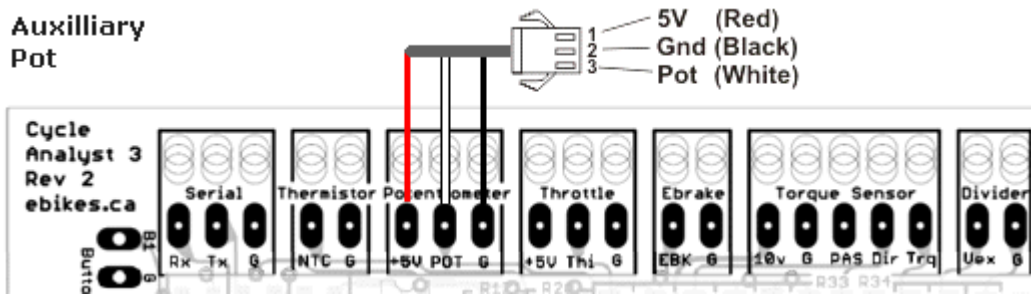
Auto-cruise disengages when ebrakes are applied or when the operator throttle is moved in the direction of WOT regardless of its present position.

**IMPORTANT:** Do not use the auto-cruise feature unless ebrakes are installed and wired to the Cycle Analyst **EBK** input. Using auto-cruise with the conventional ebrakes connection to the controller will not disengage auto-cruise when brakes are applied and may cause a potentially dangerous runaway situation as soon as the brakes are released.

2. **PAS Interaction:** If PAS is enabled, pedaling must be detected above **PAS->MxThrotSpd** for auto-cruise to remain active. When pedaling ceases, auto-cruise ceases to provide throttle but does not disengage – resuming pedaling will cause auto-cruise to resume the engaged throttle setting. Auto-cruise can be used as a means to provide an on-the-fly setting for PAS assist – see '[6.11 Auto-Cruise as an Adjustable PAS Level](#)'.
3. **Auto-Cruise Dropouts:** Sporadic dropouts in auto-cruise operation may be traced to a **ThI->MinInput** voltage offset that is too small. See '[4.7 Test Throttle and Limit Settings \(Interpreting Limit Flags\)](#)'.
4. **Conflict with Controller Cruise Control:** The conventional controller cruise control operates by controlling motor power by means other than the throttle input. Depending on Cycle Analyst configuration, this can have dangerous consequences as the Cycle Analyst attempts to make speed or power corrections via the throttle – which the controller is ignoring. If cruise control operation is desired, always use the Cycle Analyst functionality which provides properly integrated throttle control.

**IMPORTANT:** Do not use controller-based cruise control when a Cycle Analyst is attached in any but the most basic monitoring mode (e.g. only shunt and voltage connections) as potentially dangerous loss of throttle control may result.

### 5.6 Auxiliary Pot



The AUX Pot JST-3 is white to differentiate it from the black Throttle JST-3

1. **Grin Tech:** "The purpose of this input is to allow on-the-fly adjustments of one of the CA's limit values (i.e. the current limit, speed limit, or power limit). That can be accomplished either via a potentiometer, or for discrete settings with a multi-position switch and resistor dividers. A 0-5V signal range is allowed, and it defaults to 5V if left disconnected."

Alternatively, the Aux Pot input may be used with an external switch to select configuration mode presets (see ' 2.2 Mode Presets').

2. **Live Data Display:** The AUX Pot Setup preview screen provides a live data display of the **POT** input which can be used to dial in trimpots or inspect voltages as controlling switches/pots are manipulated.



Live Vpot %Limit Mode  
Aux Pot with 3-position Switch and Current Throttle

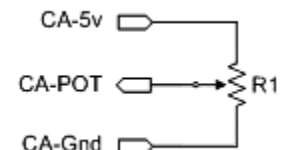
3. **Modes:** The AUX Pot input can operate in either of two modes determined by **Aux->Function**:
- **Limit:** The applied voltage scales a limiting parameter or
  - **Preset:** The applied voltage selects one of the available mode presets.
- a. **Limit Mode:** This provides a means to apply an external control voltage (max range 0-5V) to provide a 0-100% scale of the limiting parameter specified by **Aux->ScaleLim**.

Aux->ScaleLim	POT input controls 0-100% of parameter
Amps Lim	PLim -> Max Current
Power Lim	PLim -> Max Power
Speed Lim	SLim -> Max Speed
PAS Level	PAS->PAS Watts ( if PAS->PAS Mode = Auto PAS ) Trq->Asst Factr ( if PAS->PAS Mode = Torq PAS )

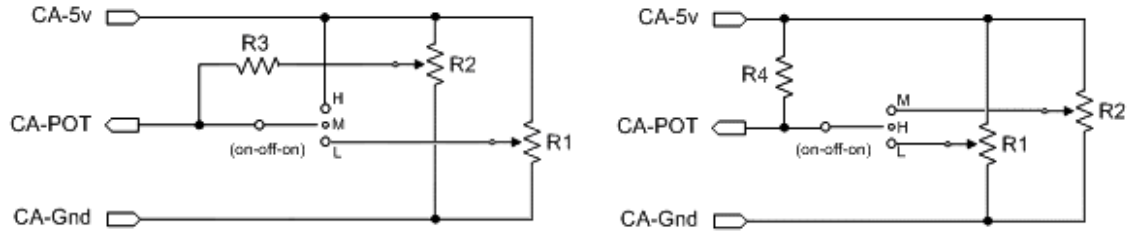
In this mode, an "AUX ADJUST" screen showing the new limit value is briefly displayed whenever the AUX Pot input voltage is altered. This provides a convenient means to dial in specific limit values.

Any device providing a voltage in the range of 0-5V may be used. Examples of external controls:

- **Potentiometer:** This is the most basic adjustment technique. R1 = 5K linear taper pot. To prevent contaminants from entering the device either use a 'sealed' type pot, enclose it completely, or seal it using a product like *Liquid Lectric Tape* or *Plasti-Dip*.
- **Throttle:** A resistive or hall effect throttle may be substituted for the potentiometer. For instance, a thumb throttle may be modified so that it stays in position when adjusted.

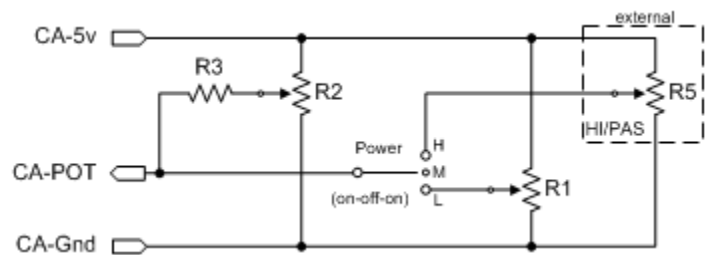


- 3-Position Switch:** This is the Cycle Analyst version of the conventional controller 3-position switch. The example implementations below provide three settings: Low, Medium, and High. The LMH version is better suited to rocker switches while the LHM version may be better suited to toggles where the center (high) position is a little fussier to achieve. R1 = R2 = 5K 20 turn trimpots, R3 = 7.5K, R4 = 10K.



Depending on the **Aux->ScaleLim** setting, these sample circuits may be used as a 0-100% PAS Assist knob, a 0-100% speed limit knob, a 3-position current or power limit control, etc. The examples can be combined. For instance, the illustration below shows the LMH switch above extended with an external 5K linear pot (R5) on the 'high' setting. The pot serves double duty in different presets as either a PAS level adjustment or when set to the high extreme, the 'High' setting of the LMH switch for throttle-based non-PAS operation.

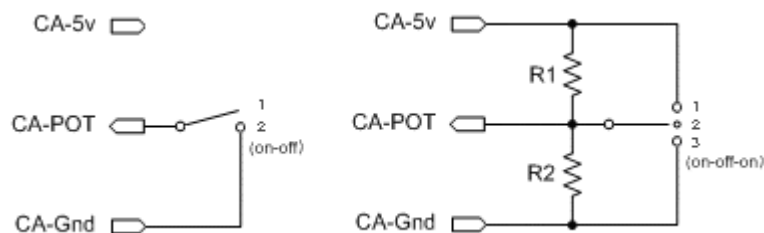
These particular sample circuits assume **Aux->MinAuxIn** = 0.0V and **Aux->MaxAuxIn** = 4.99V; other circuits may have different requirements. Devices like a hall throttle are best configured based on voltage measurements from the AUX Pot Setup preview screen.



- Preset Mode:** This provides on-the-fly preset selection using an external switch. The Cycle Analyst selects a mode preset by dividing the voltage range between **Aux->MinAuxIn** and **Aux->MaxAuxIn** into the same number of equally sized voltage bands as there are presets (1,2, or 3) and determining in which band **Vpot** lies. Input voltages below/above the configured min/max range are considered to fall within the adjacent lower/upper voltage band. The lowest voltage band is preset #1.

In this mode, the present preset is exclusively determined by the Aux Pot switch. Attempts to alter the current preset using the console buttons will prove ineffective.

When a new preset is selected, a "CHNG MODE PRESET" screen is briefly displayed.



The left diagram above will select from two presets. The right diagram uses R1 = R2 = 4.7K resistors and will select from three presets. These particular sample circuits assume **Aux->MinAuxIn** = 0.0V and **Aux->MaxAuxIn** = 4.99V although other circuits might use a different range.

**Note:** The Grin Tech 3-Position Switch is available as a plug-and-play solution for either Limit or Preset modes. Although this switch uses fixed resistors instead of trim pots, the selectable limit levels are configurable using Setup. 'Appendix G. Configurable Aux Pot 3-Position Switch Using Fixed Resistors' describes Limit/Preset mode configuration for both the Grin Tech switch and a similar DIY version.

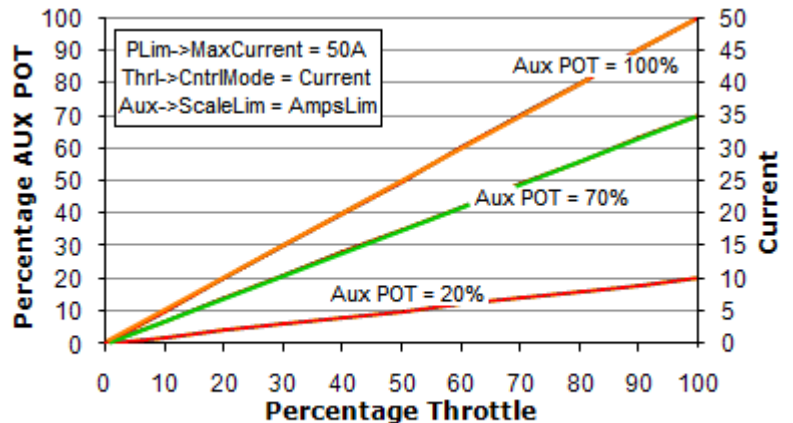
- 4. **Electrical Characteristics:** To avoid affecting external resistor dividers, the Aux POT input does not have pull-up or pull-down resistors on the PCB although there is a weak pullup internal to the processor port. The applied impedance should be no more than 10K for the A/D converter to achieve full 10bit accuracy, although realistically, full 10 bit accuracy is unnecessary for these external switch applications.
- 5. **Throttle Scaling:** Throttle scaling causes the throttle maximum to be limited by the **POT** input value instead of the configured limiting parameter maximum. For example, if **PLim->MaxCurrent=50A**, **POT** (min,max) is (0V,5V), and **POT** = 1.0V (20% of the 5V **POT** range), then Throttle OUT will be limited to 20% of 50A or 10A.

To obtain automatic throttle scaling, **Aux->ScaleLim** and **ThrI->CntrlMode** must be configured to use the same limiting type. This may not always be possible, for instance when using Current Throttle and PAS Aux Pot control, but mixed current and power limiting can be resolved to use one or the other limiting type exclusively. For the example above to work as described, **Aux->ScaleLim** and **ThrI->CntrlMode** must be set to matching values: *AmpsLim* and *Current* respectively.

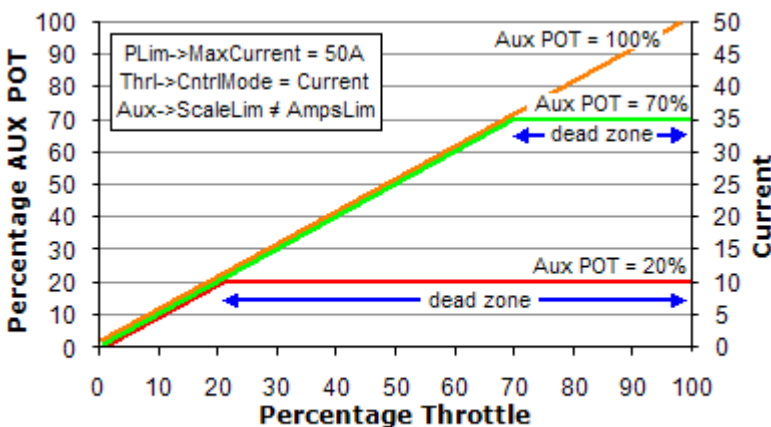
'Matching' limiting type values are shown above in the 'Throttle Mode Summary' table.

The sample plots to the left using matching limit types show the Cycle Analyst current limit vs 0-100% throttle rotation for three different Aux POT limit settings (20%, 70%, and 100%).

In each case WOT is scaled to the existing Aux POT limit and the throttle output is linear over the complete throttle rotation, ZERO to WOT. This is the preferred throttle behavior with a control such as a LMH switch.



Throttle Scaling - Same Throttle and Aux POT Limit Type



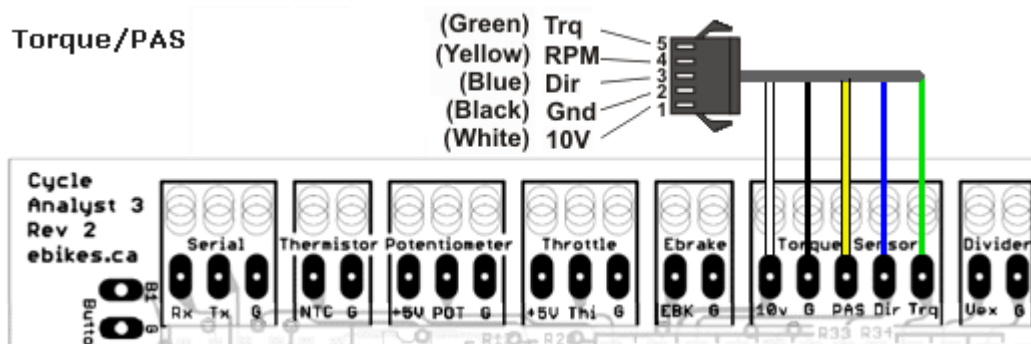
Dead Zones - Different Throttle and Aux POT Limit Types

In contrast, the plot to the right shows an example where throttle and Aux POT have differing limit types (e.g. current and power).

In this case there is no throttle scaling. Instead, the Aux POT limit imposes a ceiling above which further throttle rotation has no effect. These throttle 'dead zones' (flat sections of curves) are identical to that produced by the simple limiting of legacy mode (V2) operation.

In this particular example this behavior can be converted to the scaled behavior shown above by setting **Aux->ScaleLim** = *AmpsLim* so the Aux POT and throttle limits match.

## 5.7 Pedal Assist



### 1. **Grin Tech:**

**"10V:** This is an output pad specifically for supplying power to the THUN torque sensing bottom bracket. It can potentially be used as a low current power source by other PAS sensors too, however care must be taken as this supply is not fused or protected, and a short to ground will damage the CA. *Current draw from this line should be limited to 15mA max and only with 48V or lower batteries.*

**Pedal Sensor Input (RPM):** This is a digital input for a pedal cadence sensor. It has an onboard pull-up resistor, so it can work with an active hall effect device or a simple magnet and reed switch pickup.

**Pedal Direction Input (Dir):** This is used to distinguish between forwards and reverse pedal rotation for PAS sensors that provide this signal. It can support both a pure direction signal (e.g. 5V = fwd, 0V = reverse), or a quadrature type encoder such as on the THUN sensors.

**Torque Sensor (Trq):** This is a 0-5V input for a torque signal. The human pedal torque can be measured either via a torque sensing bottom bracket (THUN, FAG, TDCM), or via a DIY tension meter on the bike chain itself. The torque signal here is multiplied by the calculated pedal RPM signal to derive the human power on the CA, and to provide proportional torque assist."

2. **Supported Sensors:** The PAS signal interface is primarily designed for the THUN torque sensing bottom bracket but also supports similar units such as those from TDCM, Sempu, or Green Trans. It can also use a simple PAS cadence wheel providing a contact closure or 0V/5V pulse output. The direction input can be a Fwd/Rev level or a pulse waveform providing quadrature encoding in concert with the RPM signal. Grin Tech has custom PAS wheel sensors that are plug compatible with the CA-TRQ connector; these units utilize novel mounting techniques so the crank/BB do not require disassembly.

**Note:** PAS wheel sensors must have a pulse output. Sensors providing a throttle-compatible analog voltage output cannot be used. PAS wheels typically do not have a direction output to detect pedaling backwards although some may instead only send pulses pedaling forward which is equally effective. See '6.2 DIY PAS Sensor / Adding Direction Output to a PAS Wheel' for a means to optionally add a second pickup to PAS wheels to discriminate direction.

3. **Sensor Operational Overview:** PAS cadence sensors are 'pedaling detectors' and provide a means to activate a constant non-proportional power assist, that is, the assist is ON or OFF and does not vary with rider effort. PAS wheels are available with varying numbers of poles – typically 5 to 16. PAS wheels with many magnets are preferred because the larger number of impulses mean pedaling is detected sooner making the system more responsive.

Torque sensors provide the same 'pedaling detection' pulse signal as PAS cadence sensors but add an analog torque signal that varies with torque. In *TorqPAS* mode, the Cycle Analyst uses this torque signal to provide assist proportional to how hard the rider pedals. However, if the Cycle Analyst is instead configured in *AutoPAS* or *ThrotPAS* modes (see below) then the torque signal is ignored and the sensor operates as a simple PAS cadence sensor.

Assist is enabled in *TorqPAS* mode only if the rider is actually pedaling; simply standing on the pedals to generate a large torque signal is ineffective. In all modes, assist is enabled only if the direction signal indicates forward pedaling.



4. **Sensor Power:** The Thun, TDCM, and PAS wheel sensors from Grin Tech are plug and play compatible with the CA V3 and no special action is required to obtain power.

Other PAS cadence sensors may utilize hall sensors instead of reed switches and so require a +5V supply which can be obtained by various means:

- A +5V tap may be added to either mating JST connector for CA throttle or Aux POT.
- The white +10V power lead of the CA-TRQ/PAS connector may be re-purposed by relocating the connection to either of the Throttle or POT +5V pads of the CA PCB.
- A +5V tap may be added to the mating JST connector for the controller throttle.

**IMPORTANT: Sensor Power Requirements:** Pay particular attention to the current limit of the CA and choose an appropriate power strategy as described in '5.10 Powering Accessories with the CA' when adding any sensor or accessory to the CA.

#### 5. **PAS Configuration:**

- a. **PAS->PASpoles** determine the number of pulses per crank revolution. Although obvious (number of magnets) for simple cadence sensors, torque sensors are not so open to inspection. Go to the SETUP PAS SENSOR screen and count the number of times in a crank revolution the 'P' arrow switches to downward.
- b. **PAS->SensrType** identifies the interface as either 1-Wire (**Dir**) or 2-Wire (**Dir+RPM**). Proper setting may be determined by going to the SETUP PAS SENSOR screen, rotating the crank, and seeing if one or both of the 'P' and 'D' arrows alternate up and down. If one, it is a 1-wire sensor, if both it is 2-Wire.
- c. **PAS->DirPlrty** controls Fwd/Rev direction determination for both 1 and 2 wire sensor types.
- d. **PAS->PAS Mode** options:

In all modes, if throttle is applied even a small amount while pedaling, PAS assist is ignored and the throttle alone determines the output.

Set **SLim->MaxSpeed** to limit the maximum assisted speed. The throttle is enabled without pedaling at speeds up to **PAS->MxThrotSpd**, but requires pedaling at higher speeds; set **PAS->MxThrotSpd** to zero to *always* require pedaling or to a very high speed to *never* require pedaling. **SLim->MaxSpeed** in conjunction with **PAS->MxThrotSpd** can provide compliance with a variety of pedelec legal requirements.

1. **Auto PAS** – This mode provides fixed non-proportional PAS assist. It is designed for a simple cadence PAS wheel; the torque signal input has no effect even if present and enabled.
  - *Pedaling with no applied throttle* causes **PAS->PASWatts** of motor power to be applied. This provides a fixed 'background' assist - pedaling harder/faster does not affect the assist level. This assist level can be modified with **Aux Pot**.
  - Below **PAS->MxThrotSpd**, the throttle is enabled and if applied operates normally and disables PAS.
  - Above **PAS->MxThrotSpd**, if pedaling is detected, the throttle is enabled and if applied operates normally and disables PAS.
2. **Torq PAS** – This mode provides proportional PAS assist. It is designed for use with torque sensors such as the Thun X-Cell RT.
  - *Pedaling with no applied throttle* provides PAS assist power proportional to rider effort – pedaling harder/faster gives more assist. This assist level can be modified with **Aux Pot**.
  - Below **PAS->MxThrotSpd**, the throttle is enabled and if applied operates normally and disables PAS.
  - Above **PAS->MxThrotSpd**, if pedaling is detected, the throttle is enabled and if applied operates normally and disables PAS.

In Torq Pas mode, assist is computed using the greater of 55 rpm or the true pedal rpm. This ensures a workable minimum power delivery on getaway. The assist level scales with both increasing torque and rpm.

3. **Throt PAS** – This mode provides no PAS power assist. It is designed for a simple cadence PAS wheel; the torque signal input has no effect even if present and enabled.
  - Below **PAS->MxThrotSpd**, the throttle is enabled and operates normally.
  - Above **PAS->MxThrotSpd**, if pedaling is detected, the throttle is enabled.
- e. **PAS->StrtThrsh** and **PAS->StopThrsh** determine the pedal RPM at which the Cycle analyst detects that pedaling has started and stopped. In order for the CA to detect pedaling quickly on the first revolution and terminate assist power promptly after pedaling ceases, the start RPM is typically less than the stop RPM. PAS wheels with fewer magnets operate best with higher RPM settings.

Follow this procedure to configure these parameters:

1. Based on **PASpoles**, the CA provides default **StartThrsh** and **StopThrsh** values according to this table (may vary slightly). Use this table to restore default values if necessary.

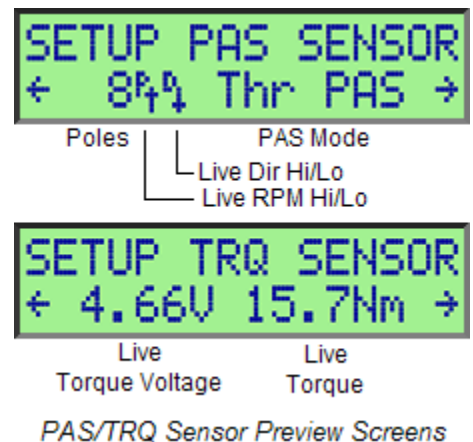
RPM	PAS Poles								
	4	5	6	8	9	10	12	15	16
<b>Start Thrsh</b>	20	16	13	10	9	8	7	5	5
<b>Stop Thrsh</b>	32	26	21	16	14	13	11	9	8

2. **StopThrsh** should be set to the minimum RPM to yield an acceptable power cutoff delay when pedaling stops. Adjust as needed.
3. **StartThrsh** should be set to the maximum RPM to yield an acceptable power application delay when pedaling begins or resumes. Adjust as needed.

**Note:** Routine pedaling at RPMs between the **StartThrsh** and **StopThrsh** can cause power dropouts so the range should be minimized. Ideally this range is transitioned only when starting and stopping.

- f. **PAS->PASWatts** determines the motor assist power when in Auto PAS mode. This value is superseded by **PLim->MaxPower** and so is typically set to the same or a lower value.
- g. **Torque Offst:** The nominal torque sensor offset voltage for zero torque should be set at installation time and may need to be zeroed again from time to time. **Trq->TrqOffst** operates much as does **Cal->ZeroAmps** – Press-Hold to store the present torque output voltage as the zero torque baseline.
- h. **Trq->AsstAvg** determines the number of torque sensor readings that are averaged when in **Torq PAS** mode. Larger values give smoother but less responsive operation. For example, for an 8 pole torque sensor (Thun), a setting of 16 averages readings over two full revolutions. From a standing start, averaging uses only as many samples as are available until the **AsstAvg** number of readings are accumulated, so start-up torque processing will be responsive even with a large setting.

6. **Live Data:** There are two Setup preview screens for PAS support: the PAS Sensor screen for the **RPM** and **Dir** inputs and a second screen for **Trq**, the proportional voltage torque input. Both show live data as in the illustrations to the right. The small up/down arrows on the PAS screen show the hi/low state of the **RPM** and **Dir** inputs. The torque input voltage and equivalent converted torque value are shown on the Torque Sensor screen. Pressing a pedal with the rear wheel blocked will show a torque voltage while turning the crank will show the small 'P' (**RPM**) arrow going up/down as magnets pass the sensor head. Depending on the PAS sensor, the small 'D' (**Dir**) arrow may or may not change.



In addition, the main display shows a bar graph of human Watts:

- in Auto PAS or Throt PAS mode, pedal RPM (0-120rpm)
- in Torq PAS mode, the number of Human Watts produced by pedaling (0-400W)

7. **Power Limiting:** *AutoPAS* and *TorqPAS* modes limit assist power using the same PID controller as Power Throttle; inspection of the Limit Flags on the Diagnostic screen will show Watts limiting always in effect for these modes. The power PID controller **PLim->WGain** parameter may be adjusted to smooth power application. This is a global parameter so compromise with other non-PAS presets may be necessary.
8. **External 'Assist Level' Control:** An external Assist Level adjustment knob may be added using the **AUX Pot** input – see '[5.6 Auxiliary Pot](#)'. This is configured differently for PAS and torque sensors.
  - a. PAS cadence sensors provide on/off control of a fixed assist level that is determined by **PAS->PASWatts**. To configure:
    - Set **Aux->Function** = Limits
    - Set **Aux->ScaleLim** = PAS Level.  
This causes the control knob to scale **PAS->PASWatts** from 0-100% of the configured value.
  - b. Torque sensors provide proportional assist and are also supported by **AUX Pot**. To configure:
    - Set **Aux->Function** = Limits
    - Set **Aux->ScaleLim** = PAS Level.  
This causes the control knob to scale **Trq->AsstFactr** from 0-100% of the configured value.

Please see '[6.6 PAS Assist Control without AUX Pot – DIY Virtual Torque Sensor](#)' for an alternate means to install an Assist Level control for PAS cadence sensors.

9. **PAS-only (No-Throttle) Operation:** Configure **ThrI->CntrlMode** = Off(0V) if there is no throttle installed or to deactivate operation of an installed throttle. This is a per-preset setting.
10. **Ebrake Interaction:** Ebrake application causes PAS assist to cease immediately (See '[5.4 Ebrakes](#)').

**IMPORTANT:** Some PAS power overrun may occur when pedaling ceases. Unsafe stopping situations may arise if ebrakes are not wired to the Cycle Analyst **EBK** input when PAS is installed.

11. **Thun Specifics:** Grin Tech provides a compatible Thun X-Cell RT digital bottom bracket with the proper connector to mate with the CA-TRQ/PAS JST-5. The connector wiring is as follows:

Thun Desc	Thun	CA-PAS	CA-PAS Pin	CA Desc
Power 7-16v	White	White	1	Power 10v
Gnd	Black	Black	2	Gnd
Cosine	Blue	Blue	3	Dir
Sine	Brown	Yellow	4	RPM
Torque	Grey	Green	5	Trq

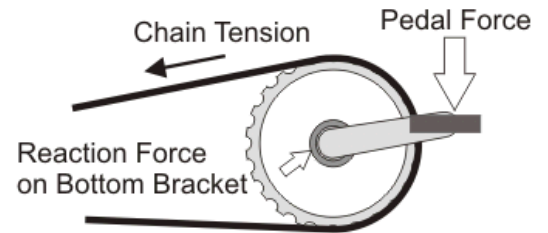
*Thun Cable to CA-TRQ/PAS Wiring*

The Thun X-CELL RT digital generates 8 pulses per rotation and has a power requirement of 7-16V at 20mA. The **RPM** and **Dir** signals are quadrature encoded as cosine and sine waveforms respectively. The nominal 0.0 Nm offset is 2.5V and the max (left,right) pedal torques of (-200Nm,+200Nm) generate output voltages of (0.5V,4.5V) respectively. The CA maps these outputs into (Fwd/Rev) pedal direction and positive pedal torque for both left and right side.

12. **Suggested Initial Thun Settings:**
  - **Plim->WGain** = 10 (adjust as needed)
  - **PAS->SensrType** = 2-Wire  
**PAS->PASpoles** = 8  
**PAS->DirPlrty** = Rev  
**PAS->StrtThrsh** = 10 RPM (adjust as needed)  
**PAS->StopThrsh** = 16 RPM (adjust as needed)  
**PAS->PASMode** = TorqPAS
  - **Trq->SensrType** = ThunBB
  - All other settings to default (adjust as required)

13. **TDCM Specifics:** The TDCM generates 12 pulses per rotation.

Unlike the Thun which measures actual crank torque, the TDCM sensor measures the backwards crank force produced by chain tension. This indirect measurement design makes it dependent on chainring size since a larger chainring produces less force (chain tension) for the same pedal torque. As a result, to adjust the measured TRQ signal voltage (V) to the actual torque value (Nm), the value for **Trq->TrqScale** (Nm/V) must be configured according to the chainring diameter. A nominal value of 50 Nm/V will work acceptably as an initial guess (the reported Human Watts may be off a bit) or a more exact value can be determined by experiment.



Typical values are in the range 30-80 Nm/V:

- Note the **TRQ** signal voltage on the Setup TRQ Section Preview Screen.
- Apply the back brakes and then apply a known mass (like 50lb) on the forward pedal to produce a known torque.
- Note the **TRQ** signal voltage on the Setup TRQ Section Preview Screen.
- Compute the torque scaling factor as:

$$\text{Trq->TrqScale} = (\text{testWeight}) * (4.44\text{N/lb}) * (\text{crank Length in m}) / (\text{Vweight} - \text{VnoWeight})$$

for example: using a 50lb weight and before/after voltages of 2.45V/3.1V with a 175mm crank

$$\text{Trq->TrqScale} = (50 \text{ lb}) * (4.44 \text{ N/lb}) * (0.175\text{m}) / (3.1\text{V} - 2.45\text{V}) = 59 \text{ Nm/V.}$$

14. **Suggested Initial TDCM Settings:**

- **PLim->WGain** = 10 (adjust as needed))
- **PAS->SensrType** = 2-Wire
- **PAS->PASpoles** = 12
- **PAS->DirPlrty** = Fwd
- **PAS->StrtThrsh** = 7 RPM (adjust as required)
- **PAS->StopThrsh** = 11 RPM (adjust as required)
- **PAS->PASMode** = TorqPAS
- **Trq->SensrType** = Custom
- **Trq->TrqScale** = 50 (adjust as needed or determine by experiment as described above)
- All other settings to default (adjust as required)

15. **Torque-based PAS – Operation:** The CA takes the BB torque voltage, subtracts **Trq->TrqOffst** to normalize the voltage relative to the zero-torque signal level, and multiplies the result by **Trq->TrqScale** to convert to Nm of torque. Using this torque with the larger of 55rpm or rider cadence, it calculates a baseline 1x 'Assist Watts'. It subtracts **Trq->AsstStart** from this baseline assist power and multiplies the result by **Trq->AsstFactr** to determine the final assist power to deliver. The determined assist level is used to control the motor using the Power PID controller which is configured by **PLim->MaxPower** and **PLim->WGain**.

An external switch or pot hooked to the **AuxPot** input gives adjustable assist by scaling **Trq->AsstFactr** 0-100% and so scales the final assist power range 0-100% as well.

16. **Torque-based PAS - Reported Human Watts:** The CA takes the BB torque voltage, subtracts **Trq->TrqOffst** to normalize the voltage relative to the zero-torque signal level, and multiplies the result by **Trq->TrqScale** to convert to Nm of torque. 'Human Watts' are calculated using this torque value and the actual rider cadence.

17. **Tuning Hints:** The default or suggested settings generally give workable behavior, but significant improvements in performance can often be obtained by further tuning. 'Good' behavior relies on rider preference, riding style, terrain, vehicle power/weight, etc so canned settings are not possible. Here are some hints to address common issues:
- a. Sporadic dropouts in PAS operation may be traced to a **ThI->MinInput** voltage offset that is too small. See '4.7 Test Throttle and Limit Settings (Interpreting Limit Flags)'.
  - b. Cyclic assist pulsing can occur with torque sensors because **Trq->AsstAvg** is too low. The CA applies assist based on the average torque over the last ( **Trq->AsstAvg / PAS->PASpoles** ) revolutions. While setting **AsstAvg** to a lower value improves responsiveness, very low values can make alternating left/right pedal strokes visible in the assist level.
  - c. Power surge on PAS re-engagement can be caused by:
    1. **PLim->WGain** is too high. PAS assist uses the power PID controller and high feedback gain can lead to aggressive throttle response. Try lowering the power gain to achieve more damped control (see 'Appendix E. PID Controllers and Gain Parameters').
    2. **Thro->xxRate** ramp rates are too high. Try adjusting the ramp rates downward to ensure that the changes to the Throttle OUT signal changes are limited to more modest rates.
  - d. Startup lag can be caused by:
    1. **PAS->StrtThrsh** is too high. Try lowering the rpm setting. Setting this to very low values will engage PAS with little crank motion, but it may do so when standing and manipulating the pedals. Once started, it takes a full crank revolution before the CA begins looking for stop delays so unwanted start ups can be unsettling.
    2. **PLim->WGain** is too low. PAS assist uses the power PID controller and very low feedback gain can lead to very sluggish software response. Try raising the power gain to achieve more tightly tuned power control.
    3. **Thro->xxRate** ramp rates are too low. Try adjusting the ramp rates upward to ensure that the changes to the Throttle OUT signal are not being unduly limited.
    4. **PAS->SensrType** is set to '1-Wire' for Thun or other sensors using quadrature encoding. The CA can operate 2-wire (quadrature) sensors in 1-wire mode, but the responsiveness is reduced. Be certain this parameter is set to 2-wire if the sensor is capable.
  - e. Cutoff lag is most often caused by **PAS->StopThrsh** too low. This parameter gives complete control over the cutoff delay – low values increase the delay, high values reduce the delay. However, too high values can cause unwanted assist dropouts simply because cadence has briefly slowed.

The CA cuts off assist if it does not see a pulse in 'CutOff Delay' seconds (i.e. a magnet does not move past the sensor). A cutoff delay of 0.2sec or so is a recommended lower limit. This delay is given by:

$$\text{Cutoff\_Delay} = 60 / \text{StopThrsh} / \text{PASpoles}$$

For example, for a PAS sensor with 12 poles and **StopTrsh** of 11 the delay will be

$$\text{Cutoff\_Delay} = 60 / 11 / 12 = 0.45 \text{ sec}$$

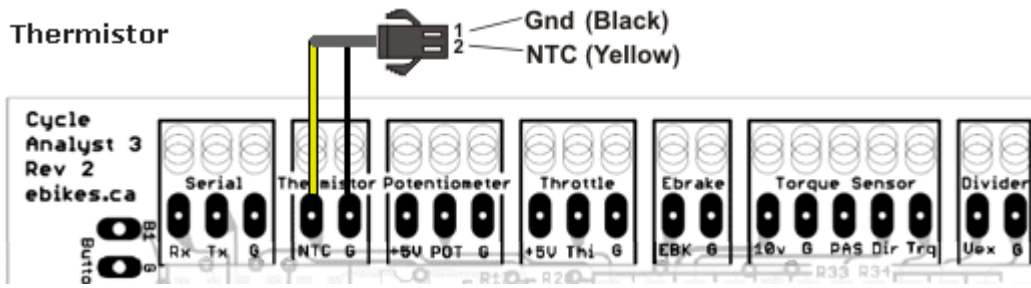
Increasing **StopTrsh** to 25 gives a delay of only

$$\text{Cutoff\_Delay} = 60 / 25 / 12 = 0.2 \text{ sec}$$

Watching the Diagnostic and Human Power screens can be very helpful to understand what is happening to cause a particular PAS behavior. The Diagnostic screen shows the OUT voltage applied to the controller while the Human Power screen shows rpm, human watts, and motor watts. Set **Pref->Averaging** to a lower value so that the display update is brisk and is not confused with delays in PAS control.

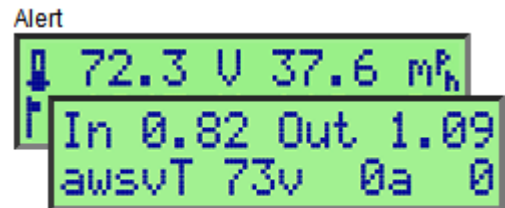
Since PAS uses the CA power PID controller, using Current instead of Power Throttle will leave **Wgain** dedicated to PAS adjustments and **AGain** dedicated operator throttle adjustment.

### 5.8 Temperature Sensor



1. **Grin Tech:** "This is the input for a temperature signal. The pad has a precision pull-up resistor to 5V, so it can be used with a simple 10K NTC thermistor between the pad and ground. Alternately, an actively driven signal from 0-5V (such as from an LM35 type IC) can be fed to this pad and scaled linearly into a temperature reading."

2. **Limiting Operation:** The CA limits *PLim*→*MaxCurrent* linearly 100-0% as the temperature rises in the configured danger range. Maximum current begins to be limited at *Temp*→*ThrshTemp* and is finally reduced to zero at *Temp*→*MaxTemp*. The *T Limit Flag* indicates that temperature limiting is in effect and the Main Screen SoC graphic alternates with a 'thermometer' Temp Alert graphic. The mercury level shows the 0-100% limit level.



Limit Flags  
Temp Alert Graphic + 'T' Flag

3. **Supported Devices:** This input can be supplied by either a 10K NTC (negative temperature coefficient) thermistor or a PTC (positive temperature coefficient) linear temperature sensing element such as an LMx35 ([datasheet](#)) that operates like a zener diode. Note that the LM35 ([datasheet](#)) is not part of this device family and is not formally supported. However, the LM35 may come pre-installed in some motors as the only option. In such cases, CA/LM35 electrical incompatibility can be remedied by minor modification of the Cycle Analyst PCB. See '6.7 Using LM35 Temperature Sensors'.

4. **NTC Thermistor Selection:** The CA firmware is calibrated for 10K NTC thermistors with a beta of 3900 but any beta in the 3800-4000 range is fine. Beta is can be viewed as the slope of the temperature-resistance correction curve where the thermistor has 10K resistance at 25degC. So - a beta of 4050 is 'outside spec' but still workable for this application although it will be off by a few degrees at high temperatures.

5. **Live Data:** If enabled, the temperature in degrees Celsius is displayed in alternation with other data on the Main Screen (see 'Main Status screen'). The temperature as well as the raw sensor voltage may also be viewed on the Setup Temperature Preview screen. The displayed temperature is averaged according to *Pref*→*Averaging* (see '2.6 Display Averaging').



Live Temp Voltage    Live Temp degC  
Temperature Preview Screen

6. **Signal Wire Routing:** For CA-DPS models, the **NTC** connection for the sensor may be routed by re-purposing the yellow pin 5 CA-DP **Spd** connection. This is the method used in EM3EV kits. A separate ground connection is not required if the sensor shares ground with the motor hall sensors. If not shared, the sensor ground can be tied to the CA-DP pin 2 to pick up CA ground, or more properly, tied to the CA PCB NTC Gnd pad.

7. **Ground Reference:** Ideally the temp sensor ground should be tied to the CA PCB NTC **Gnd** pad and not shared with the CA proper or other devices. This minimizes unwanted voltage offsets in the sensor ground resulting in offset measured sensor voltages. As a practical matter, however, this effect has negligible impact except in cases of high current CA accessories which raise the CA ground reference slightly above that of the controller ground. For example, small temperature errors may occur where the temp sensor shares ground with motor hall sensors and a high current headlight is run from the CA external power jack.

- 8. **Electrical Characteristics:** The NTC input is pulled up to 5V via a 5K resistor. This value provides forward current for devices like the LM335 to give reliable linear response while giving good sensitivity for 10K thermistors in the 80-100 degC temperature range.
- 9. **Using Linear Devices:** The 'Linear Mode' of operation allows use of a PTC device (voltage or resistance increases with temperature) and is calibrated with two parameters:
  - **Temp->0°Volts** (Volts at 0°C)
  - **Temp->TScale** (Deg/V)

The first value defines the voltage at 0°C and the second value scales other voltages to temperatures based on that reference point. These settings can be derived from the available datasheet for the particular sensing device. Data for zener type devices such as the LM135 are already in terms of voltage while resistive devices require a little calculation taking into account the V3 5K pullup resistor.

**a. Example Using a Zener Device (LM-135)**

The TI LM-135 datasheet specifies parameters of:

Output Voltage at 0°K = 0V and  
 Output Voltage Temperature = 10mv/°C = 10mv/°K.

The voltage at 0°C (273°K) is 273°K x (10mv/°K) = 2.73V and the inverse scaling factor is 1/(10mv/°C) = 100°C/V. The V3 can be configured with:

**Temp->0°CVolts** = 2.73 V  
**Temp->TScale** = 100 Deg/V

**b. Example Using a Resistive Device (KTY81-210)**

The NXP KTY81-210 is a 2K PTC device that can be found in Crystalyte motors. The datasheet presents the required information in a convenient tabular form – an excerpt is shown below. The resistance at 0°C can be taken directly from the table and we need only pick another arbitrary temperature to use in calculating a scaling factor.

As shown by the increasing error with temperature, the R/T curve is not quite linear. To get the best accuracy we choose a temperature close to the area of interest at the high end. Based on the default 0% and 100% limiting temperature values of **Temp->ThrshTemp** = 90 Deg and **Temp->MaxTemp** = 130 Deg we use an upper calibration temp of (90°C+130°C)/2 = 110°C, although anything in the neighborhood is fine.

Ambient temperature		Temperature coefficient (%/K)	KTY81/210			Temperature error (K)
(°C)	(°F)		Resistance (Ω)			
			Min	Typ	Max	
0	32	0.85	1603	1630	1656	±1.91
25	77	0.79	1980	2000	2020	±1.27
50	122	0.73	2383	2417	2451	±1.91
100	212	0.63	3318	3392	3466	±3.46
110	230	0.59	3523	3607	3691	±3.93
130	266	0.44	3901	4008	4114	±6
150	302	0.20	4153	4280	4407	±14.63

From the datasheet the resistance at 0°C is 1.63K. Considering a nominal CA regulated voltage of 4.96V and the 5K pullup resistor, the voltage at 0°C is:

$$V_0 = R_0 / ( 5K + R_0 ) * V_{cc} = 1.63K/(5K+1.63K) \times 4.96V = 1.22V$$

From the datasheet the resistance at 110°C is 3.607K. The voltage at 110°C is:

$$V_{110} = R_{110} / ( 5K + R_{110} ) * V_{cc} = 3.607K/(5K+3.607K) \times 4.96V = 2.08V$$

The scaling factor is then:

$$Scale = (T_{HI} - T_{LO}) / (V_{HI} - V_{LO}) = (110°C - 0°C) / (2.08V-1.22V) = 127.9 °C/V$$

The V3 can be configured with:

**Temp->0°CVolts** = 1.22 Volts  
**Temp->Scale** = 127.9 Deg/V

### 5.9 Powering the CA / High Voltage Vehicle Support

- Power Requirements:** The Cycle Analyst nominally draws 10mA for the PCB proper plus whatever current is required for accessories (throttle, PAS sensor, 3-position switch, etc). The CA requires 12V – 150V supplied to PCB pad **+V** which by default is connected to pin 1 of the CA-DP cable. However, when supplying additional current to operate accessory devices, the maximum allowable supply voltage must be de-rated to avoid overheating the PCB regulators (see ' 5.10 Powering Accessories with the CA').
- Low Voltage Behavior:** When the **+V** voltage falls below **Pref->Vshutdown**, the CA terminates normal operation, saves current trip statistics to EEPROM, and displays a 'Low V' message on the console. If the **+V** voltage rises above **Pref->Vshutdown**, the CA boots as on initial power up. This operation is separate and distinct from LVC functionality which protects the battery from over-discharge (see ' 5.1 Battery Low Voltage Cutoff (LoVGain)').
- High Voltage Vehicle Operation:** The CA can monitor a single voltage source up to 500V and by default monitors its **+V** power supply voltage (max = 150V). However, the PCB may be modified to instead monitor an alternate external source by redirecting voltage measurement from the PCB **+V** pad to the **Vex** pad. This special **Vex** configuration is required in any application where the CA is powered from a supply different than the monitored (traction) battery.

Modification:

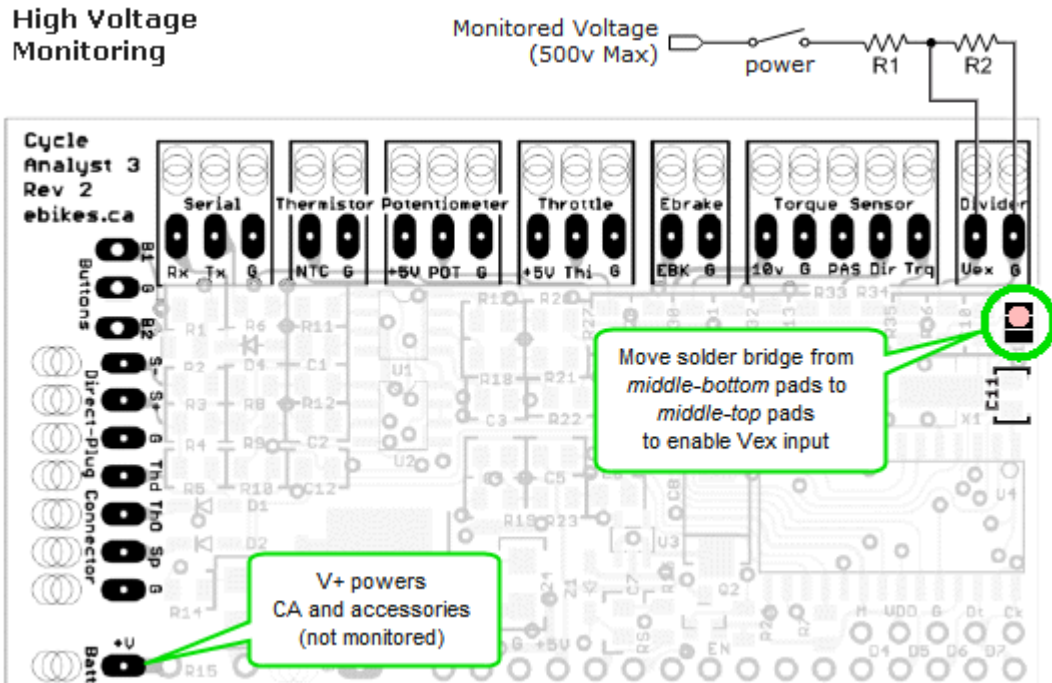
- Locate the three adjacent solder pads shown below and relocate the solder bridge from the [middle + bottom] pads to the [middle + top] pads. This modification re-directs the voltage sense input from [+V and the on-board resistor divider] to [**Vex** and an external divider].

**Note:** Early Rev 2 boards may have an SMD capacitor hand-soldered from C11 to the middle/bottom 'bridge' pads. This capacitor is not critical and may be removed if necessary to relocate the solder bridge.

- An external resistor divider must be provided as shown to scale the monitored voltage to 0-5V with R1 in parallel with R2 limited to no more than 10K. For this situation  $R1 || R2$  (i.e.  $R1 \cdot R2 / (R1 + R2)$ ) is roughly equal to R2 so limit R2 to no more than about 9-10K. Set **Cal->VScale** to the voltage scaling ratio  $(R1 + R2) / R2$ .

For instance, if (R1, R2) = (220K, 4.7K) then **Cal->VScale** =  $224.7 / 4.7 = 47.81V/V$  yielding a maximum monitored voltage of  $5V \times 47.81V/V = 239.05V$ .

Fine tune **Cal->VScale** as needed so the CA console voltage reading matches that of an attached DMM.





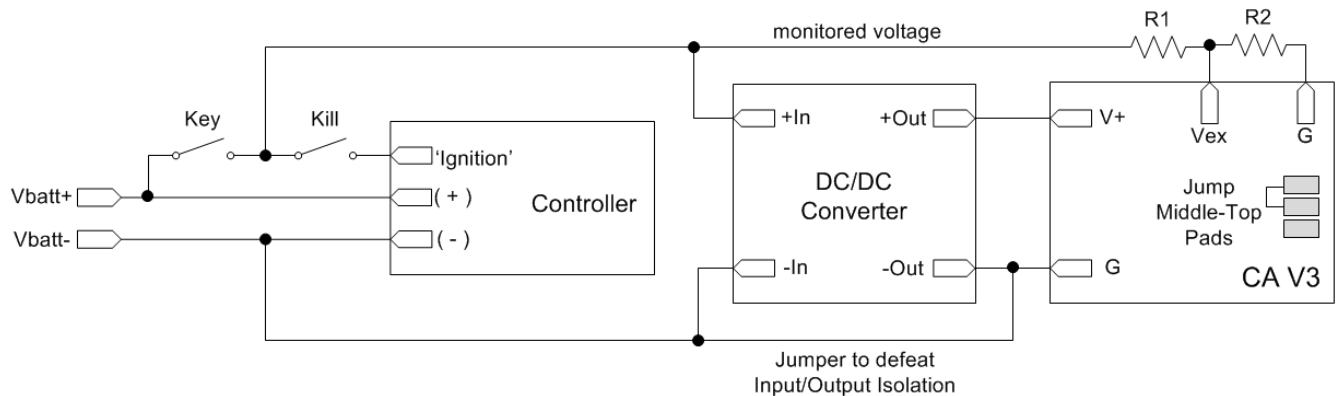
**Note:** Although the ADC input has clamping diode protection, R1 and R2 should be chosen so that **Vex** does not exceed 5V which translates into choosing a scaling factor that yields a maximum 'monitored voltage' safely in excess of the anticipated battery maximum voltage (e.g. design for a monitored max of 200V for an actual battery max of 150V).

The ADC voltage measurement has a maximum error of approximately +/- 0.05% which gives more than acceptable accuracy even if the maximum 'monitored voltage' is quite high (e.g. an error of +/- 0.3V if the maximum monitored voltage is 600V). A minimum 'monitored voltage' design margin of 20% over the anticipated battery maximum voltage is reasonable to help keep **Vex** in safe limits.

**IMPORTANT: Non-Isolated CA Power Supply:** The CA V3 design requires that the CA power and monitored voltage share a common ground. This presents a potential safety hazard for HV vehicles.

High voltage vehicles normally isolate the 12V accessory system (lights, etc) as a safety precaution. To preserve isolation in such cases, it is recommended that the Cycle Analyst be powered from a second low voltage supply isolated from the 12V accessory supply but sharing ground with the monitored battery.

4. **Operating the CA from a DC/DC Converter:** Even if the traction battery voltage is 150V or less, it may be desirable to operate the CA from a low voltage DC/DC converter to increase the current the CA can supply to accessories such as throttle, PAS, etc (see ' 5.10 Powering Accessories with the CA' and ' 6.1 DC/DC Converters'). In these cases, the **+V/Vex** modification described above must be made and any converter isolation must be defeated by tying the CA **Gnd** (converter negative output) to the traction battery ground (**Vbatt-**). This fulfills the requirement that the CA supply and monitored voltage share a common ground.



Typical ebike remote sensing configuration with Cycle Analyst powered by a DC/DC converter

5. **IMPORTANT: Forcing a Data Save:** Data is saved to EEPROM when the monitored voltage falls below **Pref->V Shutdown**. When a voltage is monitored via **Vex**, turning off the vehicle must so reduce **Vex** as to trigger a data save and orderly CA shutdown prior removing power from **+V** and incapacitating the processor.

A simple strategy when powering the CA from a DC/DC converter is to tie the external divider *Monitored Voltage* line to the switched power supplying the CA DC/DC converter as shown above. However, in such cases, the voltage appearing on **Vex** may be held high by capacitors in the equipment long after the converter has shut down and the CA has been rendered inoperable – making a data save impossible. In the example above, filter capacitor voltage on either the converter input or on the internal controller 5V regulator (appearing on the 'ignition wire') may cause this effect.

This problem in the order of falling **Vex** and **+V** voltages can be remedied by setting **Pref->Vshutdown** higher than the *minimum converter input voltage* and safely below **Batt->VltCutoff** so the CA will have time to save data and shut down before the converter output collapses.

For instance, if the illustration above employs a 79V LiFePO4 battery and a 15V converter with a minimum input of 45V, then it might use settings of: **Pref->Vshutdown** = 55V and **Batt->VltCutoff** = 64V.

### 5.10 Powering Accessories with the CA

The CA can provide power to other devices by three means:

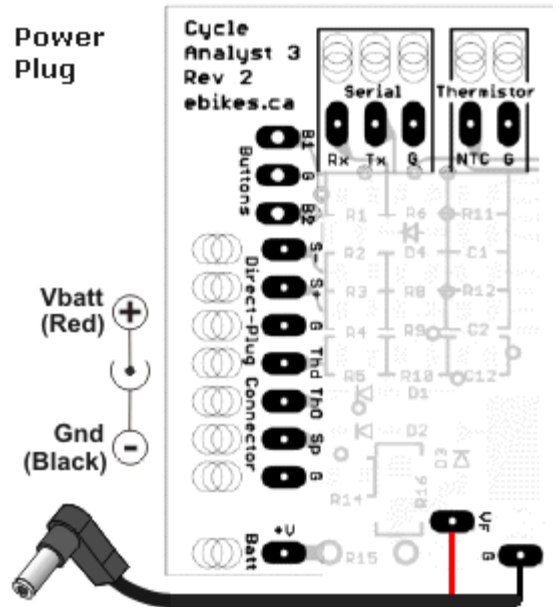
1. The regulated +5V voltage available on PCB pads is unfused and can supply power to the throttle, custom Aux POT switches, etc.
2. The regulated +10V voltage available on PCB pads is unfused and is primarily intended for use with PAS and torque sensors.
3. The external DC Power Plug is attached to **V<sub>F</sub>** and supplies unregulated +**V** via a 1A auto-resetting polyfuse.

The maximum regulated current available to power all external accessory devices for cases 1 and 2 above is the sum of the individual device current requirements regardless of whether they require +5V or +10V. Case 3 deals with unregulated power and is not a consideration.

The maximum total accessory current (**I<sub>acc</sub>**) decreases with increasing voltage. Sample limits are summarized in the following table according to:

$$I_{acc} = (\text{total regulated current}) - (\text{PCB internal current reqmt})$$

$$I_{acc} = ( 1500\text{mw}/(\text{V}_{\text{batt}}-10\text{V}) ) - 10\text{mA}.$$



+V	Iacc	+V	Iacc	+V	Iacc	+V	Iacc	+V	Iacc	+V	Iacc	+V	Iacc
12	740.0	32	58.2	52	25.7	72	14.2	92	8.3	112	4.7	132	2.3
14	365.0	34	52.5	54	24.1	74	13.4	94	7.9	114	4.4	134	2.1
16	240.0	36	47.7	56	22.6	76	12.7	96	7.4	116	4.2	136	1.9
18	177.5	38	43.6	58	21.3	78	12.1	98	7.0	118	3.9	138	1.7
20	140.0	40	40.0	60	20.0	80	11.4	100	6.7	120	3.6	140	1.5
22	115.0	42	36.9	62	18.8	82	10.8	102	6.3	122	3.4	142	1.4
24	97.1	44	34.1	64	17.8	84	10.3	104	6.0	124	3.2	144	1.2
26	83.8	46	31.7	66	16.8	86	9.7	106	5.6	126	2.9	146	1.0
28	73.3	48	29.5	68	15.9	88	9.2	108	5.3	128	2.7	148	0.9
30	65.0	50	27.5	70	15.0	90	8.8	110	5.0	130	2.5	150	0.7

Table of Maximum Total Accessory Current (Iacc) in mA vs Supply Voltage on PCB Pad +V

5V or 10V Accessory	mA
generic hall sensor	5.00
hall throttle	5.00
Magura Throttle (5K)	1.00
Thun BB	20.00
TDCM BB	28.00
typical PAS wheel (2 hall)	10.00
typical PAS wheel (reed sw)	1.00
5k aux potentiometer	1.00
typical preset sw (two 5K resistors)	1.00
typical 3-pos sw (trimpots)	2.50
Grin Tech 3-pos sw (fixed resistors)	0.35
DIY 3-pos sw (fixed resistor - see Apdx)	0.53

**I<sub>acc</sub>** may be estimated using typical accessory current requirements shown in the table to the left.

For instance, an installation with a hall throttle, Thun BB, DIY 3-position switch, and two hall ebrakes requires:

$$I_{acc} = 5\text{mA} + 20\text{mA} + 0.53\text{mA} + (2 \times 5\text{mA}) = 35.53\text{mA}$$

The '+V vs Iacc' table above shows this configuration can be supported by the Cycle Analyst for +**V** voltages up to 42V.

**Iacc** may also be determined by temporarily hooking up all accessories to the CA and powering it from a low voltage source that according to the preceding '+V vs Iacc' table has ample capacity (e.g. use a battery balance lead at 24V). Use a DMM to measure the total CA current at the CA-DP connector and exercise switches and accessories to draw maximum current. Subtract the 10mA used by the CA PCB proper. The result is **Iacc** which can be applied to the preceding table as done with the estimated **Iacc** value above.

Either of two strategies may be applied for battery packs above the computed maximum **+V** voltage:

1. **Power one or more accessories from an alternate source**

Additional 5V power can drawn from the controller throttle connector to power hall sensors, etc. If there is a Thun BB or similar 10V sensor and a large current shortfall, then an external DC/DC converter can be used to power such devices. In those cases, the accessory power (+) connection is redirected to the alternate source but the ground and device output signal lines run to the CA connectors normally.

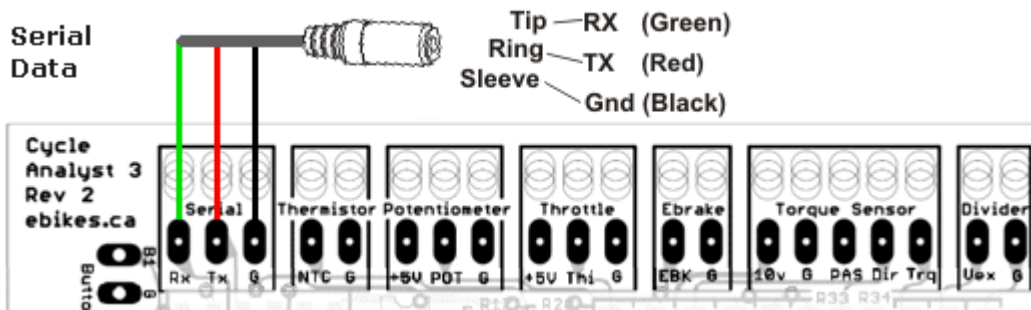
2. **Power the CA from a lower voltage source to raise the available current it can supply**

**Vbatt** is stepped down via a DC/DC converter and used to reduce **+V** to the extent that the V3 can supply the needed accessory current requirements itself. Since the CA is no longer powered by **Vbatt**, it is configured as if in a high voltage environment, driving **Vex** from **Vbatt** via an external resistor divider.

For details see '[5.9 Powering the CA / High Voltage Vehicle Support](#)'.

Determine the required current capacity of a DC/DC converter to run the CA and accessories by finding **Iacc** as described above and then adding 10mA for the CA PCB proper and any current drawn from the external DC Power Plug (headlight, etc). Increasing the final capacity by 10-20% as a safety margin is recommended.

### 5.11 Serial Data Port



1. **Encoding/Signal Levels:** The Tx/Rx serial ports operate at 9600 baud with 8 bits, 1 Start bit, 1 Stop bit, no parity, and no handshake at 0V/+5V TTL levels.
2. **Live Data Stream:** In normal operating mode log data is transmitted from the serial port. This stream may be captured by a [Cycle Analogger](#) or similar device (there is no handshake) and contains TAB-separated data as described in the following table. The data rows are sent periodically at the rate configured by **Pref->DataRate**.

Col	Heading	Description
1	Ah	Amp hour
2	V	Voltage
3	A	Amperes
4	S	Speed
5	D	Distance
6	Deg	Temperature degC
7	RPM	PAS RPM
8	HW	Human Watts
9	Nm	PAS Torque Newton-meters
10	ThI	Throttle In Voltage
11	ThO	Throttle Out Voltage
12	Acc	Acceleration
13	Lim	Limit Flag Characters 1/2/3 = Preset # X = Throttle Fault B = Brake A = Amp Limiting W = Watt Limiting T = Temp Limiting V = Low Volts Limiting S = Speed Limiting s = Low Speed Limiting

3. **Interface Cable:** The standard Grin Tech CA V3 programming cable (pn: CA3-USB) is best ordered with the CA V3 to facilitate firmware updates. The [FTDI](#) cable pn: TTL-232R-5V-AJ is a good substitute. See the [Grin Tech site](#) for USB->TTL converter cable ordering and device driver download information.
4. **External Memory Access:** Using the bootloader, all of the V3 EEPROM may be accessed externally via the serial interface. This supports loading new firmware as well as external inspection and configuration of Setup parameters. See '[Appendix H. Updating CA Firmware and Saving/Restoring Settings](#)' and the [Grin Tech site](#) for details on operation of the updater application.

## 6.0 Tips and Tricks

### 6.1 DC/DC Converters

Builds involving the Cycle Analyst may require a DC/DC converter to either power accessories or the CA itself. An ordinary AC switching power supply can be viewed as a DC/DC converter with an EMI filter and full wave bridge on the front end. These will run nicely on DC. AC supplies are typically rated 90-240Vac but the voltage specification reflects standard mains international voltages not the actual limits at which the supply will operate; reliable operation at 50Vdc and lower is not uncommon. Because of production volume, these supplies provide an economical source of fully isolated wide range DC/DC converters.

Automotive/motorcycle '12V' accessories actually expect 13.8V and will operate without difficulty 10-16V. This makes 15V power supplies an ideal choice although 12V models are acceptable at the lower end with some reduction in light brightness. Choosing a supply to power the Cycle Analyst or Thun that is also compatible with automotive components allows secondary use for LED lighting, GPS, and phones, however, sharing the automotive accessory power with the Cycle Analyst is not recommended for high voltage vehicles (see '[5.9 Powering the CA / High Voltage Vehicle Support](#)').

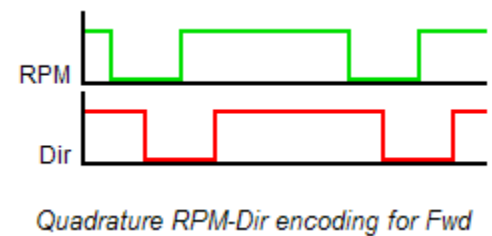
Common netbook and laptop supplies have waterproof packaging and are available for about \$10. For example, the Toshiba ADP-60RH laptop supply provides 15V at 4A. Netbook supplies are smaller and are a good choice where only an ampere or so is required. Conventional switching supplies are available off the shelf from suppliers like Mouser for about the same price.

When using these isolated AC supplies it is necessary to jumper the output negative connection to **Vbatt-** to defeat the isolation and provide the common ground required by the Cycle Analyst.

### 6.2 DIY PAS Sensor / Adding Direction Output to a PAS Wheel

An effective PAS cadence sensor can be fabricated by affixing magnets to the front sprocket and placing two speedometer wheel pickups next to one another. Wire the pickups to the Cycle Analyst **RPM** and **Dir** inputs.

Similarly, adding a second reed switch or hall pickup to a simple one-hall PAS wheel will provide direction information. To determine pedaling direction the two pickups must provide a quadrature signal similar to that of the Thun BB. Arrange the pickups so that the **RPM** and **Dir** signals have the relationship shown to the right when the crank is turned in the forward direction.



The hi/lo signal states can be determined by using the PAS Preview screen and examining the small arrows as the crank is rotated ( see '[2.4.1 Setup Section Preview Screens](#)').

### 6.3 Opening the Cycle Analyst Case

The Cycle Analyst case is held closed with four screws located in the corners of the rear case half. The PCB is sandwiched between aligned sets of four screw bosses in the front and rear case halves with the extra small gap between the opposing front and rear bosses taken up with four small o-rings around the four screws. Removing the screws and opening the case halves frees the tiny o-rings to escape.

To open the case without losing the o-rings, unscrew the four screws until the threads disengage but leave them in place in the rear case half so the screw ends are touching the opposing threaded bosses and continue to engage the o-rings. Separate the case halves and push the screws home into the rear case while pushing the o-rings all the way up the screw threads. This will hold both the screws and o-rings in place in the rear case half until re-assembly which is a matter of closing the case halves together and running down the screws.

### 6.4 Extending Cables

The supplied Cycle Analyst cables may be extended either by splicing or by adding intermediate connectors. This includes the 6-conductor CA-DP cable which carries the shunt connection, the 2-conductor speedometer pickup, or cables for accessories such as the Thun bottom bracket.

## 6.5 AutoTorqPAS – AutoPAS with RPM-Proportional Assist

This technique uses the *TorqPAS* setting with a simple PAS wheel to achieve rpm-proportional assist.

The Cycle Analyst has a pull-up on the **Trq** signal line so that with no torque sensor attached it receives a signal of approximately 5V which indicates the maximum crank torque. The default torque offset (voltage at which there is zero torque) is 2.5V which is correct for the Thun. From this the CA calculates (Trq Voltage) - (**Trq->TrqOffst**)  $\sim$  5V - 2.5V = 2.5V of normalized torque signal. The configured value of **Trq->TrqScale** is used to convert this to Nm of torque, so for example, if **Trq->TrqScale** = +10 Nm/V, the result is 25Nm of torque. This 'apparent' torque is fixed and results only from the pull-up resistor and configured values. The CA uses this calculated torque and the RPM to figure out 'Human Watts', then multiplies that by **Trq->AsstFactr** get the assist in 'motor Watts'.

By choosing the proper **Trq->TrqScale** value and configuring the CA for *TorqPAS*, when pedaling is detected the CA will convert the fixed voltage (torque) from the pull-up resistor into Watts and apply it as assist - just like *AutoPAS*.

However, when doing Assist Watts calculations in *TorqPAS* mode, the CA assumes a baseline cadence of 55rpm. If the rider pedals faster than 55rpm, *the assist wattage scales up with increasing cadence* – exactly what we want.

Configured as described below, *TorqPAS* mode (with no torque sensor) will work like *AutoPAS* to give fixed assist up to 55rpm, then above that cadence it will give additional rpm-proportional assist.

Configuration:

- **PAS->PASMode** = TorqPAS
- **Trq->SensrType** = Custom
- **Trq->AsstAvg** = 1

The following two tables show the settings to achieve the Assist Watts (similar to **PAS->PASWatts**) at two different rpm levels: 55rpm (column 1) and 90rpm (other columns). The first column gives no power increase as cadence increases, while columns further to the right yield greater assist power as cadence increases. Each cell of the tables contain the target assist level in Watts at 90rpm and three values that must be transferred to Setup:

- **Trq->TrqScale**
- **Trq->AsstFactr**
- **Trq->AsstStart**



Stored Offset  
Voltage

Live TRQ  
Input Voltage

Begin by examining the stored **Trq->TrqOffst** voltage in Setup (see to right).

1. Use the first following table if you have the default **Trq->TrqOffst** of about 2.5V.

For example, for 175W of assist @55rpm and 455W of assist @ 90rpm, locate the 175W row and the desired 455W column, then set:

- **Trq->TrqScale** = 38.2
- **Trq->AsstFactr** = 1.00
- **Trq->AsstStart** = +265

2. A **Trq->TrqOffst** voltage close to 4.99V indicates that a Press-Hold operation has been done on **Trq->TrqOffst** which stored the pull-up voltage as the zero torque baseline. As a result, the pull-up resistor will now appear to be applying zero torque voltage so the resulting calculated torque will be zero.

This situation can be remedied restoring the default 2.5V offset voltage using the Software Setup Utility or with a one-time calibration using a jumper plug to set the offset to 0.00V:

To calibrate **Trq->TrqScale** = 0.00V: Make up a 5 pin JST that just jumps the **Trq** input (pin 5) to **Gnd** (pin 2), install this jumper plug on the CA Trq/PAS connector, and do the Press-Hold to set **Trq->TrqOffst** to 0.00V. Remove the jumper plug, and restore the regular PAS sensor connector. With this 0.00V calibration in place, use the second following table to select the appropriate settings as described for case (1). If a programming cable is in available, this 0.00V offset can also be achieved with the Setup Utility.

Watts at 55rpm	Watts Multiplier from 55 rpm to 90 rpm										
	1.00	1.20	1.40	1.60	1.80	2.00	2.20	2.40	2.60	2.80	3.00
100	100 0.0, -100 1.00	120 2.7, -69 1.00	140 5.5, -37 1.00	160 8.2, -6 1.00	180 10.9, 26 1.00	200 13.6, 57 1.00	220 16.4, 89 1.00	240 19.1, 120 1.00	260 21.8, 151 1.00	280 24.6, 183 1.00	300 27.3, 214 1.00
125	125 0.0, -125 1.00	150 3.4, -86 1.00	175 6.8, -46 1.00	200 10.2, -7 1.00	225 13.6, 32 1.00	250 17.1, 71 1.00	275 20.5, 111 1.00	300 23.9, 150 1.00	325 27.3, 189 1.00	350 30.7, 229 1.00	375 34.1, 268 1.00
150	150 0.0, -150 1.00	180 4.1, -103 1.00	210 8.2, -56 1.00	240 12.3, -9 1.00	270 16.4, 39 1.00	300 20.5, 86 1.00	330 24.6, 133 1.00	360 28.7, 180 1.00	390 32.7, 227 1.00	420 36.8, 274 1.00	450 40.9, 321 1.00
175	175 0.0, -175 1.00	210 4.8, -120 1.00	245 9.6, -65 1.00	280 14.3, -10 1.00	315 19.1, 45 1.00	350 23.9, 100 1.00	385 28.7, 155 1.00	420 33.4, 210 1.00	455 38.2, 265 1.00	490 43.0, 320 1.00	525 47.8, 375 1.00
200	200 0.0, -200 1.00	240 5.5, -137 1.00	280 10.9, -74 1.00	320 16.4, -11 1.00	360 21.8, 51 1.00	400 27.3, 114 1.00	440 32.7, 177 1.00	480 38.2, 240 1.00	520 43.7, 303 1.00	560 49.1, 366 1.00	600 54.6, 429 1.00
225	225 0.0, -225 1.00	270 6.1, -154 1.00	315 12.3, -84 1.00	360 18.4, -13 1.00	405 24.6, 58 1.00	450 30.7, 129 1.00	495 36.8, 199 1.00	540 43.0, 270 1.00	585 49.1, 341 1.00	630 55.3, 411 1.00	675 61.4, 482 1.00
250	250 0.0, -250 1.00	300 6.8, -171 1.00	350 13.6, -93 1.00	400 20.5, -14 1.00	450 27.3, 64 1.00	500 34.1, 143 1.00	550 40.9, 221 1.00	600 47.8, 300 1.00	650 54.6, 379 1.00	700 61.4, 457 1.00	750 68.2, 536 1.00
300	300 0.0, -150 2.00	360 4.1, -103 2.00	420 8.2, -56 2.00	480 12.3, -9 2.00	540 16.4, 39 2.00	600 20.5, 86 2.00	660 24.6, 133 2.00	720 28.7, 180 2.00	780 32.7, 227 2.00	840 36.8, 274 2.00	900 40.9, 321 2.00
325	325 0.0, -163 2.00	390 4.4, -111 2.00	455 8.9, -60 2.00	520 13.3, -9 2.00	585 17.7, 42 2.00	650 22.2, 93 2.00	715 26.6, 144 2.00	780 31.0, 195 2.00	845 35.5, 246 2.00	910 39.9, 297 2.00	975 44.3, 348 2.00
350	350 0.0, -175 2.00	420 4.8, -120 2.00	490 9.6, -65 2.00	560 14.3, -10 2.00	630 19.1, 45 2.00	700 23.9, 100 2.00	770 28.7, 155 2.00	840 33.4, 210 2.00	910 38.2, 265 2.00	980 43.0, 320 2.00	1050 47.8, 375 2.00
375	375 0.0, -188 2.00	450 5.1, -129 2.00	525 10.2, -70 2.00	600 15.3, -11 2.00	675 20.5, 48 2.00	750 25.6, 107 2.00	825 30.7, 166 2.00	900 35.8, 225 2.00	975 40.9, 284 2.00	1050 46.0, 343 2.00	1125 51.2, 402 2.00
400	400 0.0, -200 2.00	480 5.5, -137 2.00	560 10.9, -74 2.00	640 16.4, -11 2.00	720 21.8, 51 2.00	800 27.3, 114 2.00	880 32.7, 177 2.00	960 38.2, 240 2.00	1040 43.7, 303 2.00	1120 49.1, 366 2.00	1200 54.6, 429 2.00
450	450 0.0, -225 2.00	540 6.1, -154 2.00	630 12.3, -84 2.00	720 18.4, -13 2.00	810 24.6, 58 2.00	900 30.7, 129 2.00	990 36.8, 199 2.00	1080 43.0, 270 2.00	1170 49.1, 341 2.00	1260 55.3, 411 2.00	1350 61.4, 482 2.00
500	500 0.0, -167 3.00	600 4.5, -114 3.00	700 9.1, -62 3.00	800 13.6, -10 3.00	900 18.2, 43 3.00	1000 22.7, 95 3.00	1100 27.3, 148 3.00	1200 31.8, 200 3.00	1300 36.4, 252 3.00	1400 40.9, 305 3.00	1500 45.5, 357 3.00
600	600 0.0, -200 3.00	720 5.5, -137 3.00	840 10.9, -74 3.00	960 16.4, -11 3.00	1080 21.8, 51 3.00	1200 27.3, 114 3.00	1320 32.7, 177 3.00	1440 38.2, 240 3.00	1560 43.7, 303 3.00	1680 49.1, 366 3.00	1800 54.6, 429 3.00
700	700 0.0, -233 3.00	840 6.4, -160 3.00	980 12.7, -87 3.00	1120 19.1, -13 3.00	1260 25.5, 60 3.00	1400 31.8, 133 3.00	1540 38.2, 207 3.00	1680 44.6, 280 3.00	1820 50.9, 353 3.00	1960 57.3, 427 3.00	2100 63.7, 500 3.00
800	800 0.0, -267 3.00	960 7.3, -183 3.00	1120 14.6, -99 3.00	1280 21.8, -15 3.00	1440 29.1, 69 3.00	1600 36.4, 152 3.00	1760 43.7, 236 3.00	1920 50.9, 320 3.00	2080 58.2, 404 3.00	2240 65.5, 488 3.00	2400 72.8, 571 3.00

Table Cell =  
Watts@90rpm  
TrqScale, AsstStart  
AsstFactr

Case of:  
TrqSensor = 4.50v  
TrqOffset = 2.50v

Watts at 55rpm	Watts Multiplier from 55 rpm to 90 rpm										
	1.00	1.20	1.40	1.60	1.80	2.00	2.20	2.40	2.60	2.80	3.00
100	100 0.0, -100 1.00	120 1.2, -69 1.00	140 2.4, -37 1.00	160 3.6, -6 1.00	180 4.9, 26 1.00	200 6.1, 57 1.00	220 7.3, 89 1.00	240 8.5, 120 1.00	260 9.7, 151 1.00	280 10.9, 183 1.00	300 12.1, 214 1.00
125	125 0.0, -125 1.00	150 1.5, -86 1.00	175 3.0, -46 1.00	200 4.5, -7 1.00	225 6.1, 32 1.00	250 7.6, 71 1.00	275 9.1, 111 1.00	300 10.6, 150 1.00	325 12.1, 189 1.00	350 13.6, 229 1.00	375 15.2, 268 1.00
150	150 0.0, -150 1.00	180 1.8, -103 1.00	210 3.6, -56 1.00	240 5.5, -9 1.00	270 7.3, 39 1.00	300 9.1, 86 1.00	330 10.9, 133 1.00	360 12.7, 180 1.00	390 14.6, 227 1.00	420 16.4, 274 1.00	450 18.2, 321 1.00
175	175 0.0, -175 1.00	210 2.1, -120 1.00	245 4.2, -65 1.00	280 6.4, -10 1.00	315 8.5, 45 1.00	350 10.6, 100 1.00	385 12.7, 155 1.00	420 14.9, 210 1.00	455 17.0, 265 1.00	490 19.1, 320 1.00	525 21.2, 375 1.00
200	200 0.0, -200 1.00	240 2.4, -137 1.00	280 4.9, -74 1.00	320 7.3, -11 1.00	360 9.7, 51 1.00	400 12.1, 114 1.00	440 14.6, 177 1.00	480 17.0, 240 1.00	520 19.4, 303 1.00	560 21.8, 366 1.00	600 24.3, 429 1.00
225	225 0.0, -225 1.00	270 2.7, -154 1.00	315 5.5, -84 1.00	360 8.2, -13 1.00	405 10.9, 58 1.00	450 13.6, 129 1.00	495 16.4, 199 1.00	540 19.1, 270 1.00	585 21.8, 341 1.00	630 24.6, 411 1.00	675 27.3, 482 1.00
250	250 0.0, -250 1.00	300 3.0, -171 1.00	350 6.1, -93 1.00	400 9.1, -14 1.00	450 12.1, 64 1.00	500 15.2, 143 1.00	550 18.2, 221 1.00	600 21.2, 300 1.00	650 24.3, 379 1.00	700 27.3, 457 1.00	750 30.3, 536 1.00
300	300 0.0, -150 2.00	360 1.8, -103 2.00	420 3.6, -56 2.00	480 5.5, -9 2.00	540 7.3, 39 2.00	600 9.1, 86 2.00	660 10.9, 133 2.00	720 12.7, 180 2.00	780 14.6, 227 2.00	840 16.4, 274 2.00	900 18.2, 321 2.00
325	325 0.0, -163 2.00	390 2.0, -111 2.00	455 3.9, -60 2.00	520 5.9, -9 2.00	585 7.9, 42 2.00	650 9.9, 93 2.00	715 11.8, 144 2.00	780 13.8, 195 2.00	845 15.8, 246 2.00	910 17.7, 297 2.00	975 19.7, 348 2.00
350	350 0.0, -175 2.00	420 2.1, -120 2.00	490 4.2, -65 2.00	560 6.4, -10 2.00	630 8.5, 45 2.00	700 10.6, 100 2.00	770 12.7, 155 2.00	840 14.9, 210 2.00	910 17.0, 265 2.00	980 19.1, 320 2.00	1050 21.2, 375 2.00
375	375 0.0, -188 2.00	450 2.3, -129 2.00	525 4.5, -70 2.00	600 6.8, -11 2.00	675 9.1, 48 2.00	750 11.4, 107 2.00	825 13.6, 166 2.00	900 15.9, 225 2.00	975 18.2, 284 2.00	1050 20.5, 343 2.00	1125 22.7, 402 2.00
400	400 0.0, -200 2.00	480 2.4, -137 2.00	560 4.9, -74 2.00	640 7.3, -11 2.00	720 9.7, 51 2.00	800 12.1, 114 2.00	880 14.6, 177 2.00	960 17.0, 240 2.00	1040 19.4, 303 2.00	1120 21.8, 366 2.00	1200 24.3, 429 2.00
450	450 0.0, -225 2.00	540 2.7, -154 2.00	630 5.5, -84 2.00	720 8.2, -13 2.00	810 10.9, 58 2.00	900 13.6, 129 2.00	990 16.4, 199 2.00	1080 19.1, 270 2.00	1170 21.8, 341 2.00	1260 24.6, 411 2.00	1350 27.3, 482 2.00
500	500 0.0, -167 3.00	600 2.0, -114 3.00	700 4.0, -62 3.00	800 6.1, -10 3.00	900 8.1, 43 3.00	1000 10.1, 95 3.00	1100 12.1, 148 3.00	1200 14.1, 200 3.00	1300 16.2, 252 3.00	1400 18.2, 305 3.00	1500 20.2, 357 3.00
600	600 0.0, -200 3.00	720 2.4, -137 3.00	840 4.9, -74 3.00	960 7.3, -11 3.00	1080 9.7, 51 3.00	1200 12.1, 114 3.00	1320 14.6, 177 3.00	1440 17.0, 240 3.00	1560 19.4, 303 3.00	1680 21.8, 366 3.00	1800 24.3, 429 3.00
700	700 0.0, -233 3.00	840 2.8, -160 3.00	980 5.7, -87 3.00	1120 8.5, -13 3.00	1260 11.3, 60 3.00	1400 14.1, 133 3.00	1540 17.0, 207 3.00	1680 19.8, 280 3.00	1820 22.6, 353 3.00	1960 25.5, 427 3.00	2100 28.3, 500 3.00
800	800 0.0, -267 3.00	960 3.2, -183 3.00	1120 6.5, -99 3.00	1280 9.7, -15 3.00	1440 12.9, 69 3.00	1600 16.2, 152 3.00	1760 19.4, 236 3.00	1920 22.6, 320 3.00	2080 25.9, 404 3.00	2240 29.1, 488 3.00	2400 32.3, 571 3.00

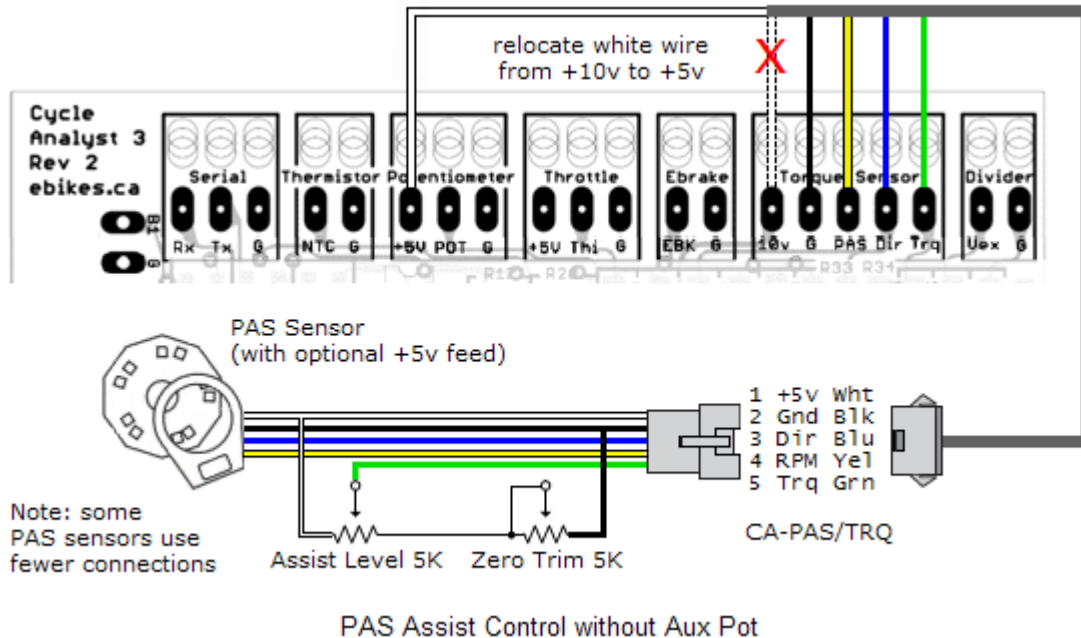
Table Cell =  
Watts@90rpm  
TrqScale, AsstStart  
AsstFactr

Case of:  
TrqSensor = 4.50v  
TrqOffset = 0.00v



## 6.6 PAS Assist Control without AUX Pot – DIY Virtual Torque Sensor

Using **AUX Pot** to provide variable Assist Level is very desirable when installing a PAS cadence sensor, however, this is problematic for builds where a preset or 3-position power level switch is also desired. Ideally, both controls would be available for separate independent use.



The illustration above shows how the **Trq** input can be used to support the second control. This is a simple extension of the technique described in section '[6.5 AutoTorqPAS – AutoPAS with RPM-Proportional Assist](#)'.

In this approach the fixed voltage from the CA pull-up resistor on the **Trq** input is replaced with a variable voltage from a 5K linear pot. In concert with the PAS wheel, this yields the approximate electrical equivalent of a Thun BB. The potentiometer output substitutes for the rider torque signal and delivers an adjustable but constant torque voltage. The Cycle Analyst is configured for a torque sensor and so converts the artificial torque voltage into a proportional assist level. As with a true torque sensor, the CA will not apply this assist until pedaling is detected.

**AUX Pot** is not required and may be used for another purpose. The throttle operates as for any torque sensor BB.

In the illustration above, the white +10V lead is re-purposed to carry +5V by relocating it to the **AUX Pot** +5V PCB pad although +5V could instead be picked up externally from the Throttle or AUX Pot connectors. This voltage is required for the potentiometer and may also be used to power hall sensors in the PAS unit. The suggested potentiometer configuration gives a **Trq** input range of 0-4.99V.

The optional 'Zero Trim' trimpot is set to zero when **Trq->AsstStrt** = 0W but is increased for larger start values. This eliminates a 'dead zone' at the beginning of the Assist Level pot that would otherwise reflect the pot rotation needed to reach **Trq->AsstStrt** watts before pedal assistance was applied.

Configuration:

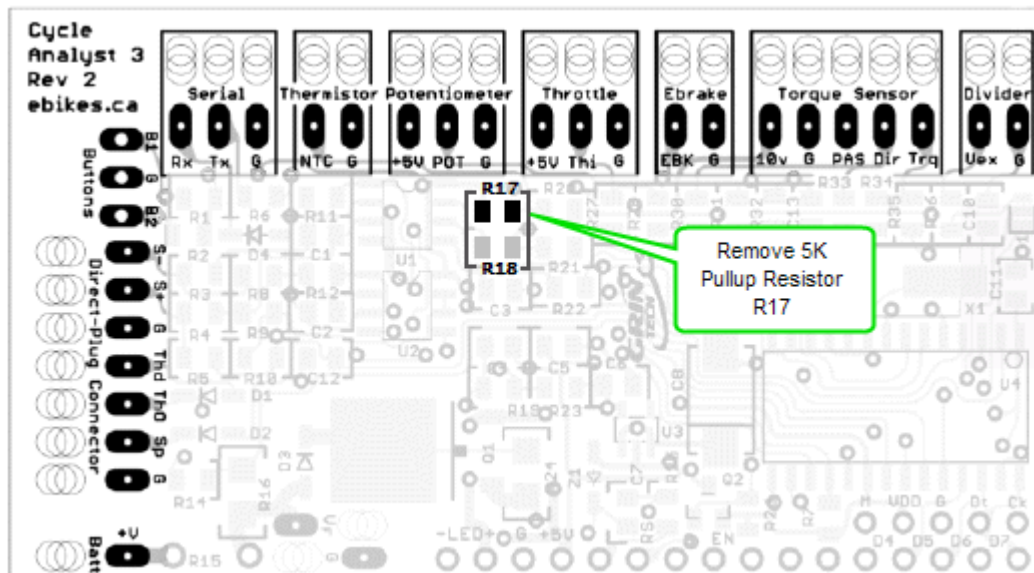
- Turn the Assist Level and Zero Trim pots to minimum, go to **Trq->TrqOffset** in Setup, then right Press-Hold to set the voltage baseline for 'zero torque'. The left displayed voltage should go to zero.
- Follow the configuration steps in '[6.5 AutoTorqPAS – AutoPAS with RPM-Proportional Assist](#)' using the second configuration table (for **Trq->TrqOffset** = 0.00V).
- With the Assist Level pot at minimum, increase the Zero Trim pot until assist just begins, then back off somewhat. Increasing the Assist Level pot slightly above minimum should now cause assist power to be applied. This is a one-time adjustment.

As with a real Thun BB, assist is rpm-proportional above 55rpm. If desired, the Zero Trim pot can be further adjusted to yield zero assist at 'normal' cadence with the Assist Level pot set to zero.

## 6.7 Using LM35 Temperature Sensors

Certain motor vendors utilize LM35 sensors ([datasheet](#)) because the temperature can be displayed in Celsius with a simple DMM. The LM35 is typically powered from the hall sensor +5V and Gnd leads and the LM35 output lead is routed out of the motor for monitoring. Although this device is incompatible with the Cycle Analyst, it can be accommodated with a small PCB modification and external resistor.

1. Locate 5K pull-up resistor R17 and remove it – the SMD PCB pads are identified in the illustration below.
2. Add a 470 ohm resistor from the LM35 output lead to Gnd. This is best done as close to the LM35 as possible: inside the motor is best but at a connector just outside the motor is suitable as a second choice. As a last choice, it can be added across the PCB thermistor **NTC** and **G** pads.
3. Configure **Temp->Sensor** = LinearType, **Temp->0Deg** = 0.00 Volts, and **Temp->TScale** = 100.0 Deg/V



## 6.8 Operation in Wet or Cold Conditions

### **Grin Tech CA v2.3 User Manual:**

The Cycle Analyst enclosure contains a clear sealed window to protect the circuitboard and LCD from water exposure. There is generally no problem using the meter in light rain or heavy rain, so long as the meter is upright if the cables exiting downwards. The open holes in the bottom allow the device to breath to prevent condensation issues.

That said, there have been occasional instances of water ingress into the button keypad circuitry that has caused the buttons to misbehave. If this happens, please contact your dealer for a replacement front enclosure casing. Also, if the enclosure is ever opened up, it is important to re-apply a bead of silicone sealant around the seam so that it is properly waterproofed again on reassembly.

The LCD screen is specified to operate between -10°C to 50°C. At the colder end of the temperature range, the response time of the LCD segments is slow, and so rapidly changing digits and screen changes will appear as a blur. The underlying operation of the internal circuitry is unaffected. At high temperatures in direct sunlight, the display characters may become quite dark, but will return to normal once the unit has cooled off.

## 6.9 Displaying Wheel RPM

Set the wheel circumference to 1666 mm and the display units in Km. The speed indicator will display in 10's of RPMs, so for instance 345 RPM will display as 34.5 kph. Of course, the distance displays will be inaccurate with this configuration, but for motor/wheel bench testing, rpm readings are likely of greater value than those for imaginary distance.

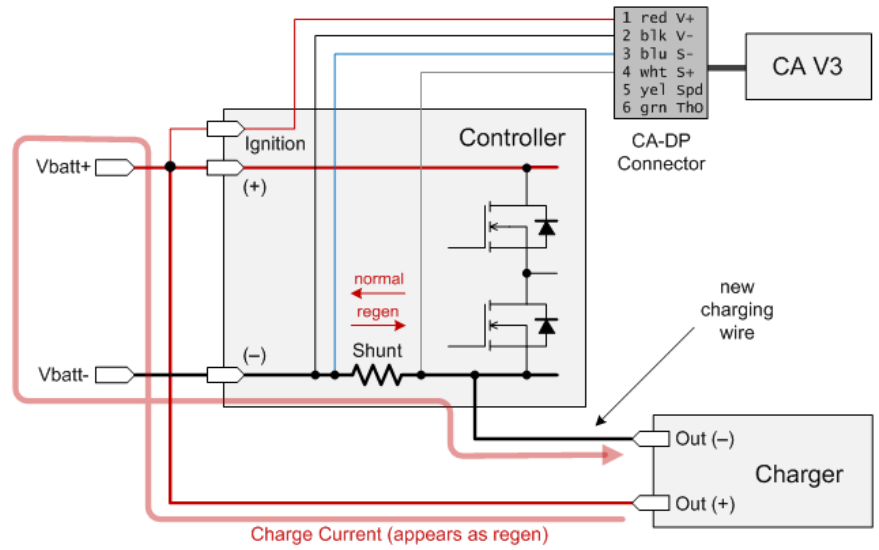
### 6.10 Monitoring Charge Current

By using a modified charger hookup that routes charge current through the shunt in the reverse direction, the CA can monitor and track Ah added when charging in the same manner as it does during regen. This allows the CA to give correct State of Charge statistics even with partial recharge cycles. The required connections can be easily added to external shunt configurations and require a single added internal controller connection if using the internal controller shunt. This extra connection is optionally available by special order on the Grin Tech PhaseRunner.

#### 6.10.1 Modifying a Controller for Charge Monitoring

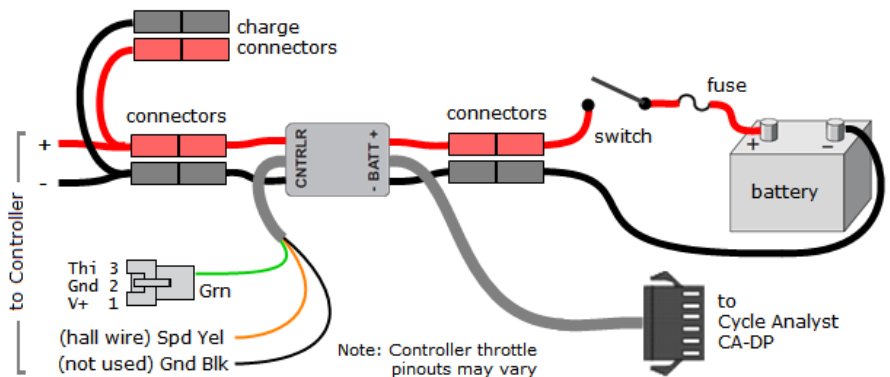
The controller modification adds a negative charger wire of suitable gauge to the internal controller wire of suitable gauge to the FET side of the shunt as shown to the right. The charger positive lead is either attached to the large internal controller power trace shared by the capacitors and FETs or is externally spliced into the controller positive **Vbatt** lead.

This configuration runs the charger current to the battery through the controller positive lead and returns it to the charger through the shunt in the 'regen' direction. The controller electronics are not participating in the charging process but the controller remains powered up via the ignition wire since this indirectly powers the CA by the standard CA-DP plug hookups.

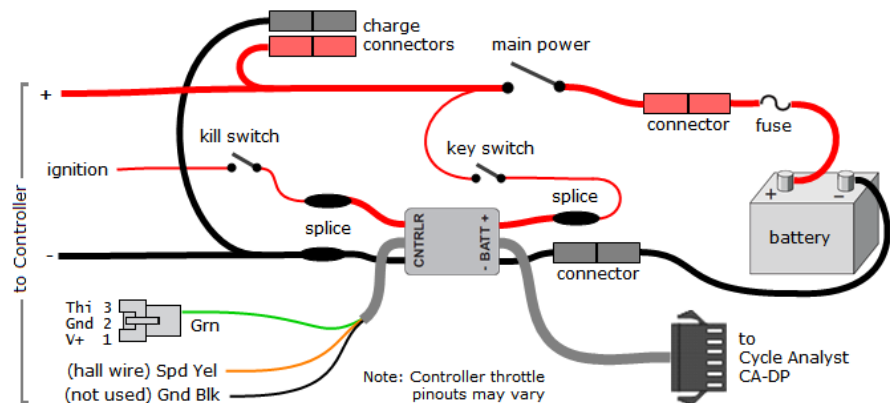


#### 6.10.2 Monitoring Charge with an External Shunt

The illustrations to the right show the same strategy applied to external shunt installations.



The lower illustration shows a conventional key and kill switch installation. This setup allows the controller to be switched off during charging with the kill switch leaving the CA active to monitor charge current.



## 6.11 Auto-Cruise as an Adjustable PAS Level

Auto PAS mode relies on the standard speed, current, power limit parameters to set the assist level. Unfortunately, in the absence of an Aux POT control, PAS assist level can only be altered by manually adjusting one of these limit parameters in Setup. However, with PAS enabled, auto-cruise requires pedaling to remain active at speeds above **PAS->MxThrotSpd** and will automatically resume the preset throttle value if pedaling is suspended then resumed. This behavior can be exploited to easily set assist level without using Aux POT.

Enable auto-cruise, set **PAS->PASMode** = ThrotPAS and set **PAS->MxThrotSpd** = 0. While pedaling, adjust the throttle to the desired assist level and allow auto-cruise to engage. ZERO the throttle and continue pedaling with auto-cruise providing the assist. If pedaling stops, the assist will also stop and but will recommence at the previous level as soon as pedaling resumes.

## 6.12 Determining Tire Circumference

Use this table for an approximate initial configuration of **Spd->Circumf** (from the Grin Tech CA 2.3 User Manual):

Tire Size	Circumf (mm)	Tire Size	Circumf (mm)	Tire Size	Circumf (mm)
16 x 1.50	1185	24 x 2.125	1965	26 x 2.25	2115
16 x 1-3/8	1282	26 x 1-1/8	1970	26 x 2.35	2131
20 x 1.75	1515	26 x 1-3/8	2068	700c x 23	2097
20 x 1-3/8	1615	26 x1-1/2	2100	700c x 28	2136
24 x 1-1/4	1905	26 x 1.5	1995	700c x 32	2155
24 x 1.75	1890	26 x 1.75	2035	700c x 38	2180
24 x 2.00	1925	26 x 2.0	2075	700c x 2.0	2273

A more accurate value can be found by placing a blob of typewriter correction fluid, paint, or nail polish on the tire and riding (not rolling) the bike forward. Use a tape measure to find the distance between the trailing edges of two dots. Measuring across multiple rotations will yield improved results. Convert measurements in inches to mm by multiplying by 25.4mm/in.

## 6.13 Determining External Shunt Resistance

High current external shunts are specified in terms of the voltage drop across the shunt at the rated current – for instance, 50mv at 200A. However, the Cycle Analyst requires a resistance in mOhm so a bit of math is required. For this example:

$$\begin{aligned} \text{Resistance} &= \text{Voltage} / \text{Current} \\ \text{Resistance} &= 0.050\text{V} / 200\text{A} = 0.000250\text{Ohm} = 0.25 \text{ mOhm} \end{aligned}$$

If the shunt resistance is less than 0.763 mOhm, then the CA must be configured for Hi Range (see '4.5 Calibrate Current and Voltage Measurements (Make Device-Specific Settings)').

## 6.14 Determining Pole Count

Pole counts of common motors are shown below. If your motor is not shown, align the tire valve with the fork or seat stay and count the number of times the small arrow on the 'SETUP SPDOMETER' screen changes to down-pointing as the wheel is rotated one revolution.

Motor	Poles
Crystalyte 400 series	8
Crystalyte 5000 series	12
Crystalyte NSM, SAW	20
Crystalyte 'H', Crown; 9C; MXUS	23
Golden Motor Magic Pie	28

## 6.15 Logging Cycle Analyst Data with Phone or PC

Although the [Cycle Analogger](#) is the classic turnkey solution for data logging, the basic non-GPS Analogger is a simple serial data recorder. The serial interface is standard, is configured to require no program intelligence for flow control, and simply picks off the data bytes as they arrive. The data stream itself is already formatted in CSV format by the CA and is ready for use by Excel or similar free spreadsheet applications (Apache OpenOffice, LibreOffice, etc).

Logging data then requires two parts: (1) a hardware adapter to convert the TTL interface and (2) some device or program to record the serial data stream – no other processing is required.

### 6.15.1 A 'Free' Hardware Adapter

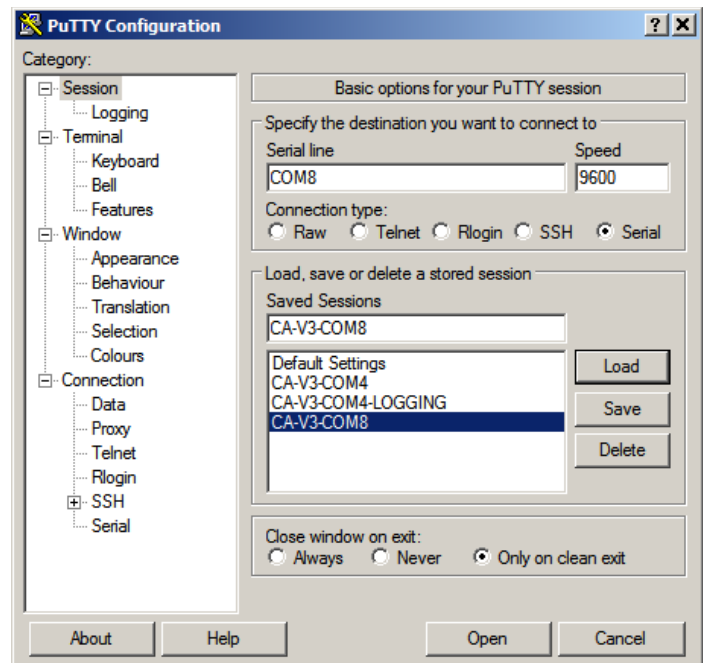
The same serial interface used for data logging is also used to download firmware and update Setup configuration by means of a bi-directional USB-to-TTL serial cable. This means that the existing download cable can also be used to provide the logging data via USB connection to any device that has an FTDI USB driver. Other TTL-to-USB cables using Prolific or similar chipsets will work as well if suitable drivers are available in the receiving device. No special configuration of the CA is necessary regardless of chipset type.

### 6.15.2 PC Data Logging

On Windows, the FTDI USB cable driver installed with the Setup Utility makes the CA data appear on a conventional (virtual) COM port. There are many free applications available that can capture and analyze serial port data, however, for simple data logging it's really only necessary to capture the stream - not analyze it. A 'serial terminal emulator' similar to the old Windows 'hyperterminal' is a good choice since these typically provide session logging as an option – which saves the input data stream to a file as it arrives.

The Unix utility 'putty' is an easy choice if running Linux and is also available for Windows as '[PuTTY](#)'. PuTTY supports saving session/port configuration so you can open the CA connection and begin logging with a couple clicks.

A PC is an easy solution for bench testing and a laptop stuffed in a backpack is perfectly workable for a few data collections on a frequently used route or to test controller or motor changes. Many investigations are one-time affairs and the inconvenience of a laptop is inconsequential compared to obtaining the data.



### 6.15.3 Android Phone/Tablet Logging

Android phones can be hooked up using the same strategy as the PC technique: plug in the CA USB cable and run a serial terminal emulator. Rooting the device is not required.

The tiny mini or micro USB connector on the phone or tablet simply needs a straight-through adapter to allow connection of the standard CA programming cable. These are readily available as USB OTG (On the Go) cables for about \$5 on [Amazon](#), etc. They have no electronics and just change the connector sex with a short adapter cable. Plug the standard TTL-to-USB programming cable into the USB OTG cable and the hardware aspect is addressed.

Next choose a USB terminal emulator - one free example is '[USB Terminal](#)' from the Play Store which supports FTDI cables. Install and launch the app, enable logging, configure the data protocol options (see '[5.11 Serial Data Port](#)'), then turn on the Cycle Analyst. Log data will begin scrolling down the screen and to the log file. This particular example app does not display the CA <tab> column separator properly on the screen, but importantly, it is passed through to the data log file. Log data can be retrieved in the same fashion as photos, etc.: either transfer the files to a cloud drive, pull the SD card, or use a conventional USB cable to connect to a PC and extract the files device-to-device.

## Appendix A. Calibrating the Cycle Analyst RShunt Value

### A.1 The Calibration Correction Factor

The Cycle Analyst can use either the internal controller shunt or an external shunt such as the CA-SA external molded shunt. While the external shunts are typically of known value, the exact resistance of controller shunts can vary from controller to controller and even within the same manufacturer batch. Typically:

- 6 mosfet Infineon controllers.....5.0 - 6.0 mOhm,
- 12 mosfet controllers.....2.5 - 3.5 mOhm.
- Crystalyte controllers.....1.1 - 2.6 mOhm.
- eZee controllers.....1.3 - 1.6 mOhm.
- Controllers with custom modified shunts.....unknown, but half the values above for a doubled shunt

'Calibrating' the **RShunt** setting means adjusting CA for a specific shunt so the CA measures current according to a known (precision) standard. For practical purposes this is the same as determining the resistance of the shunt except that it accommodates any inaccuracies in the CA electronics (which are typically of no consequence). Ideally, a known reference current is passed through the shunt and the Cycle Analyst readings are compared with those of a precision ammeter. A correction factor is calculated and applied to the nominal CA **RShunt** value to arrive at a new corrected setting (Corrected Shunt Value) = (Old Shunt Value) x (CA Current Reading) / (DMM Current Reading). For instance:

- If the Cycle Analyst reads 27A and the current reference shows 19A,  
then (Correction Factor) = (CA Current Reading) / (DMM Current Reading) = 27A/19A = 1.421.
- If the present **RShunt** value is 1.000 mOhm,  
then the corrected **Rshunt** value will be 1.000 mOhm x 1.421 = 1.421 mOhm.

The accuracy of the calibration with this procedure is limited by the accuracy of the test equipment.

### A.2 Calibration Without Instruments

In the absence of an Amp or Amp-hour meter, a serviceable calibration can be obtained based on built-in controller current limiting. Proper controller limiting relies on the shunt matching the value stored in the controller firmware which makes this technique useful only where the shunt is unmodified but of unknown value.

Examine the continuous amperage draw while riding at low speed at full throttle i.e. up an incline so the motor is heavily loaded ensuring controller current limiting is in effect. If the CA reads 53 amps and the motor controller is limited to 20 amps, then a fair estimate for the correction factor is 53A/20A = 2.65. Apply this correction factor to **RShunt** as shown above. Verify the calibration by repeating this procedure and make a second adjustment if necessary.

### A.3 Instrumented Calibration Using an Ah/Wh Meter

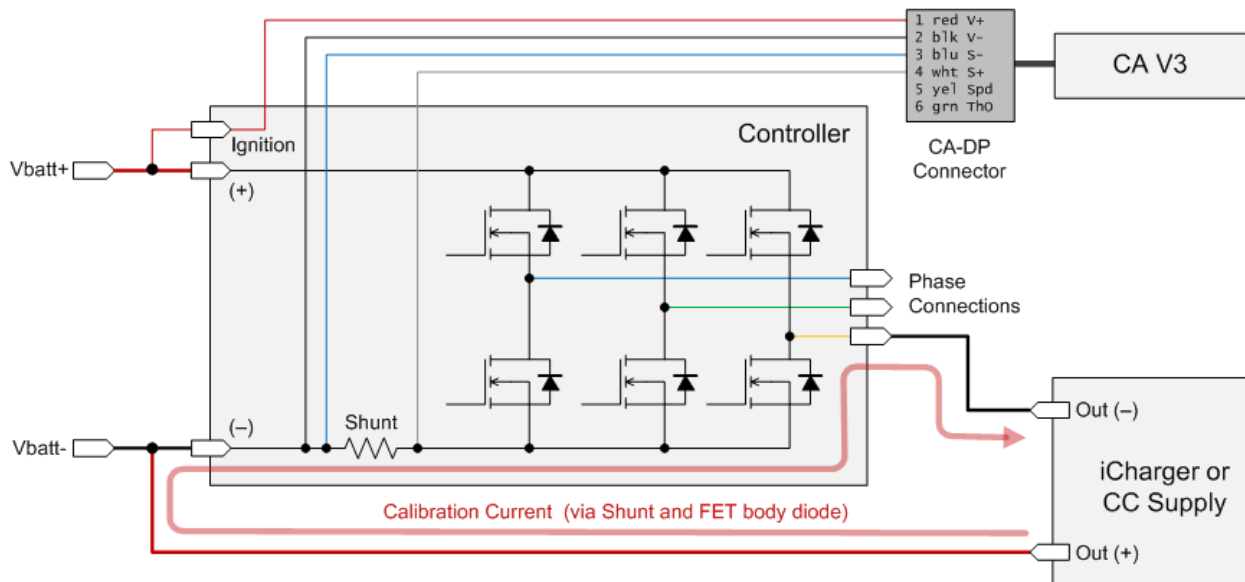
This procedure uses a *Watts Up* or similar Amp-hour/Watt-hour meter for calibration. Perform the calibration with a fully charged battery.

1. Wire the meter between the battery and controller taking care to exclude all other current drains (lights, etc) from the current path through the meter.
2. Perform a Trip Reset on the Cycle Analyst
3. Ride the bike. The more Ah consumed, the more accurate will be the calibration.
4. Compare the meter Ah or Wh with the corresponding reading from the CA and compute a correction factor as described above in section A.1 – either:
  - (Correction Factor) = (Cycle Analyst Ah) / (meter Ah) or
  - (Correction Factor) = (Cycle Analyst Wh) / (meter Wh)
5. As in section A.1 apply the correction factor to the nominal **RShunt** setting to determine the corrected value.
6. Verify the calibration by repeating this procedure and make a second adjustment if necessary.

## A.4 Instrumented Calibration Using a Current Controlled Charger/Power Supply

This technique drives a known constant calibration current through the controller shunt allowing an accurate CA **Rshunt** setting to be calculated from the reference and CA-displayed current values. The current may be provided by any constant current supply, although the following procedure utilizes the popular *iCharger* in "foam cutting" mode (constant current). The calibration current is arranged to flow in the reverse direction so that it can be routed through a FET body diode without requiring that the FET be in an active ON state. The controller electronics do not actually participate - power is applied to the controller only to route power to the Cycle Analyst via the CA-DP connector.

1. Plug the CA into the controller DP connector.
2. Attach a power supply or battery to the controller **Vbatt(+)** and **Vbatt(-)** connections. If present, also wire the controller 'ignition' wire to **Vbatt(+)**. Any voltage within the controller and CA operating ranges is suitable.
3. Set the *iCharger* to Foam Cutting mode with a constant current of 20A. For safety in case of a connection error, set the voltage to 2 volts - this value is not critical.
4. Attach the *iCharger* (+) output to **Vbatt(-)**. **NOTE POLARITY!**
5. Attach the *iCharger* (-) output to any one of the controller phase leads (do not connect the motor).
6. Power up the controller to supply power to the Cycle Analyst.
7. Power up the *iCharger* to drive the configured constant current through the controller shunt and FET diode. The *iCharger* may display a transient 'Reverse Polarity' message. Ignore.
8. Read the CA displayed current. This current will be negative because the calibration current is flowing in the reverse direction through the shunt and so appears as regen current.
9. Power down the *iCharger*.
10. Determine the correction factor and revised **Rshunt** value as described in section A.1 using the Cycle Analyst reading and the actual *iCharger* reference current of 20A.
11. Update the Cycle Analyst with the new **Rshunt** setting.
12. Verify the calibration by repeating steps 7-10. Ideally, the *iCharger*/CA current measurements and new/old **Rshunt** should differ by no more than a percent. If necessary, repeat step 11 then re-verify.

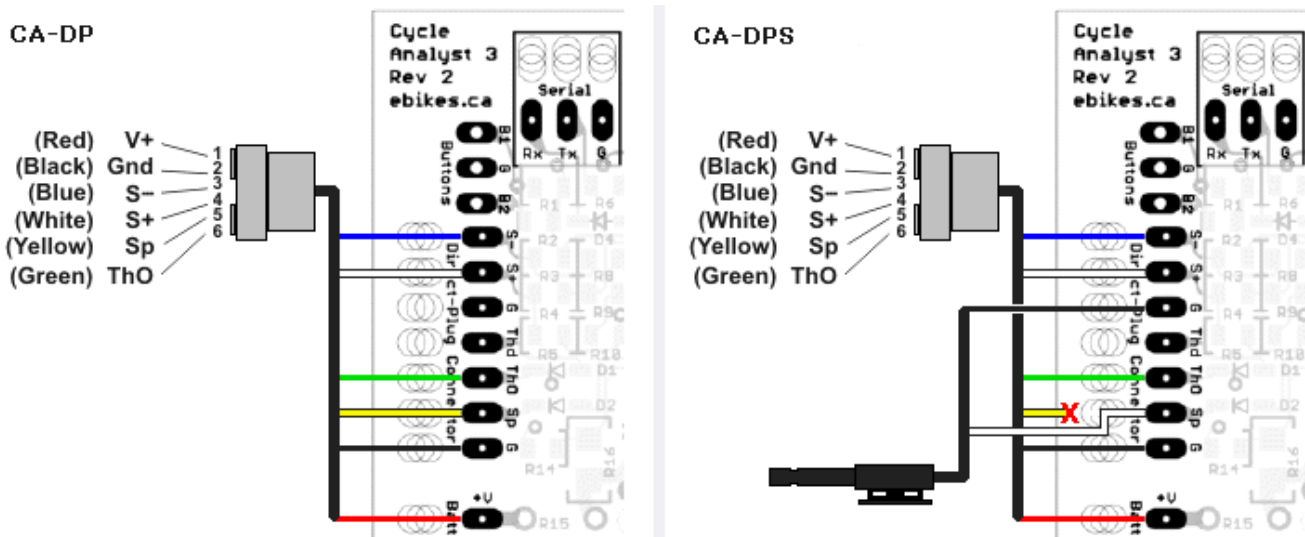


## Appendix B. Add/Remove Wheel Speed Pickup Sensor

The CA V3 comes in two forms: 'CA3-DP' using speedometer signals from the controller (DD motors) and 'CA3-DPS' with wheel pickup wired into the console (DD or gear motors). These models are identical in all aspects of electronics and firmware and differ only in the wiring of the CA-DP cable and optional wheel sensor.

Either CA-DP or CA-DPS model may be converted to the other as follows:

1. Open the case (see '[6.3 Opening the Cycle Analyst Case](#)') and expose the **Sp** PCB Pad by gently bending the square brown polyfuse upright.
2. Do one of the following conversions:
  - a. **Convert to CA-DP**
    - remove black/white pickup wires and solder the yellow wire from the CA-DP cable to the PCB **Sp** pad.
  - b. **Convert to CA-DPS**
    - remove the yellow CA-DP cable wire from the **Sp** pad.
    - Thread the pickup cable through the back of the console case and add a strain relief to the cable inside the case to prevent it from being pulled free (e.g. a band of heatshrink, a small cable tie, or multiple turns of waxed dental floss).
    - Attach the white/black pickup wires to the **Sp** and **G** pads respectively.
3. Reposition the brown polyfuse and close the console case.



The unused yellow wire shown above in the CA-DPS model may be used to route a signal to/from the CA (e.g. a rear-mounted wheel pickup, ESC BEC +5V supply, or temp sensor signal).



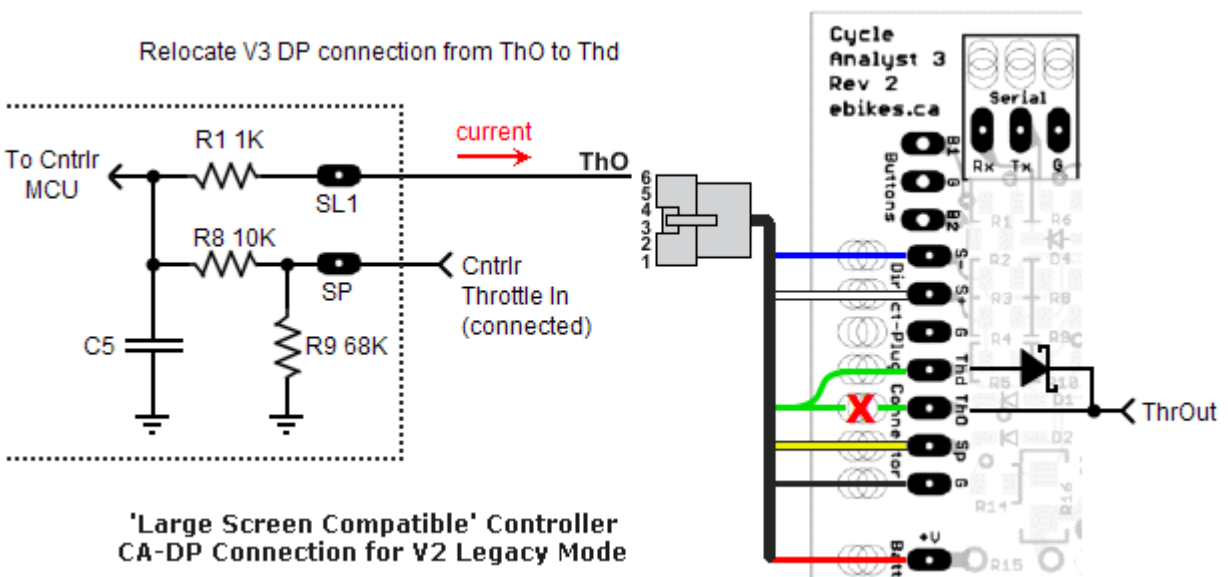
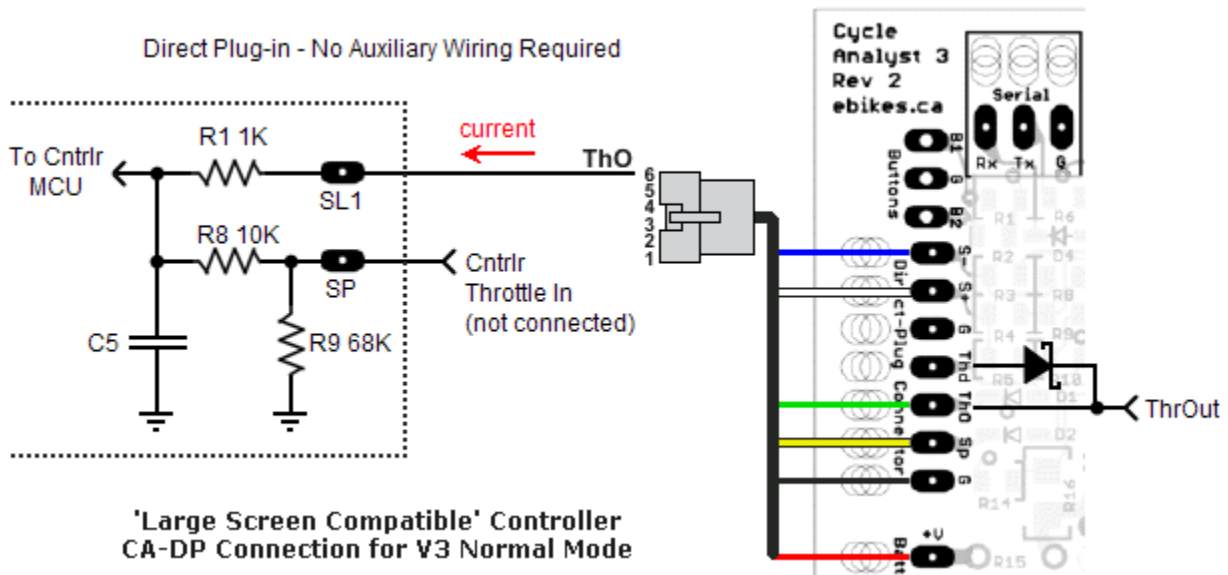
## Appendix C. Summary of CA-DP Wiring for Controllers with Old/New Interface Types

Sample circuit excerpts for Grinfineon controller interfaces are illustrated below; other controller types have similar diode/resistor input configurations. Regardless of the controller CA-DP interface type, these hook-ups ensure that:

- for 'normal mode' there is only a series resistance in the path from CA ThrOut to controller MCU input (CA continuously supplies controller throttle voltage level), or
- for 'legacy V2 mode' there is a series diode in the path from controller MCU input to CA ThrOut (operator throttle supplies controller voltage level and CA limits that level only when a limit is exceeded).

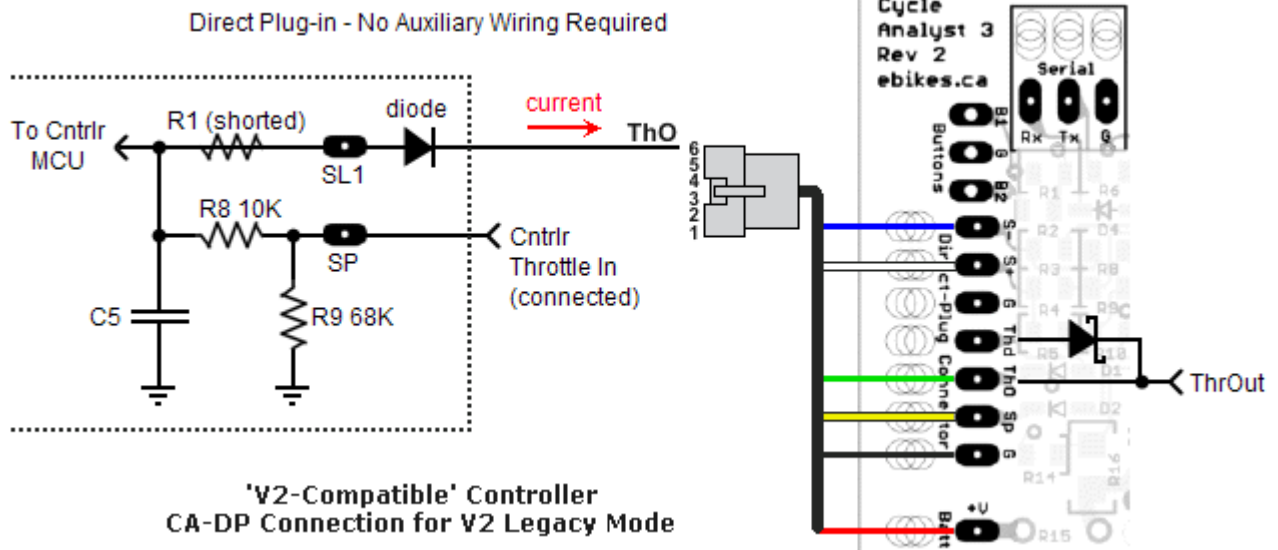
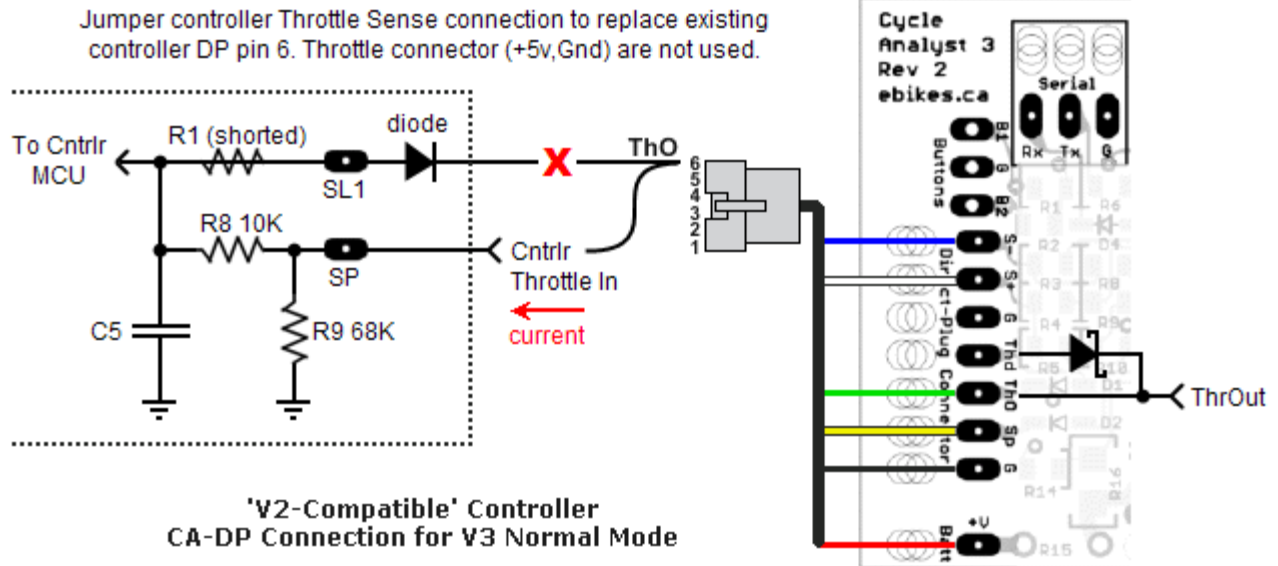
### C.1 “Large Screen Compatible” Controllers

This newer style controller interface has been available since mid-2013. The first illustration outlines the preferred 'normal' mode of operation. Note that the solder pad labels are specific to the Grinfineon and may differ from those of other Infineon (Xie Chang) controllers.



### C.2 "V2 Compatible" Controllers

If wired as shown below, controllers with this older interface design will provide the same functionality as those with the newer interface. The first illustration outlines the preferred 'normal' mode of operation.

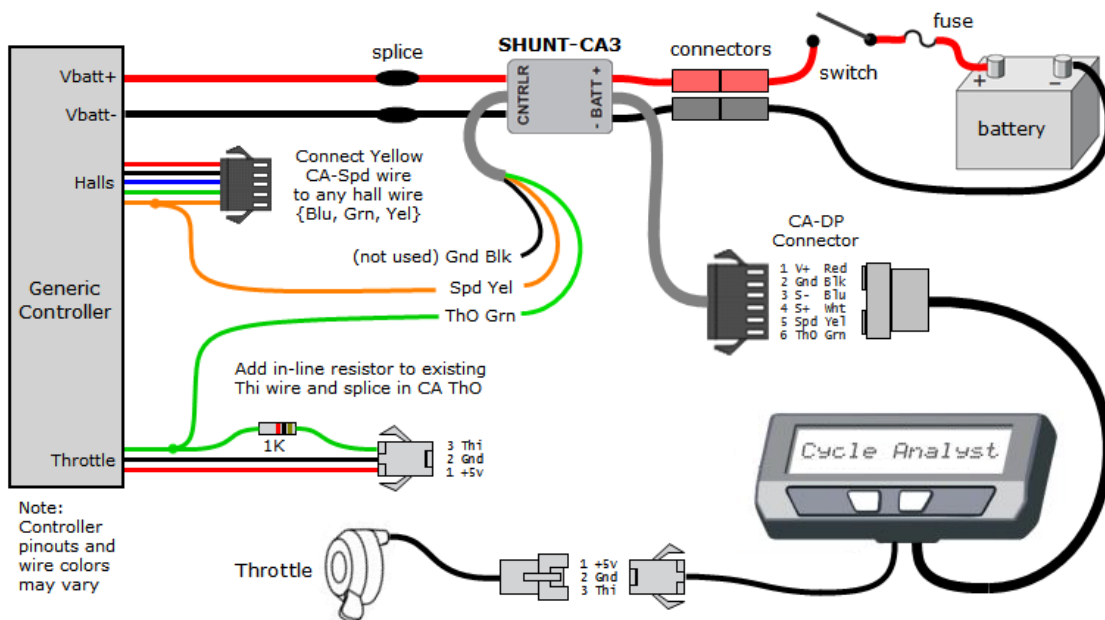


### Appendix D. Adding a CA-DP Connector to a Generic Controller

A CA-DP connector may be added to a generic controller by opening the controller, adding connections to access power and the internal controller shunt, and making minor wiring modifications to implement throttle override. That strategy can yield a very finished looking conversion but requires more time, skill, and risk than necessary. Identical functionality can be obtained using only basic wiring skills and without opening the controller.

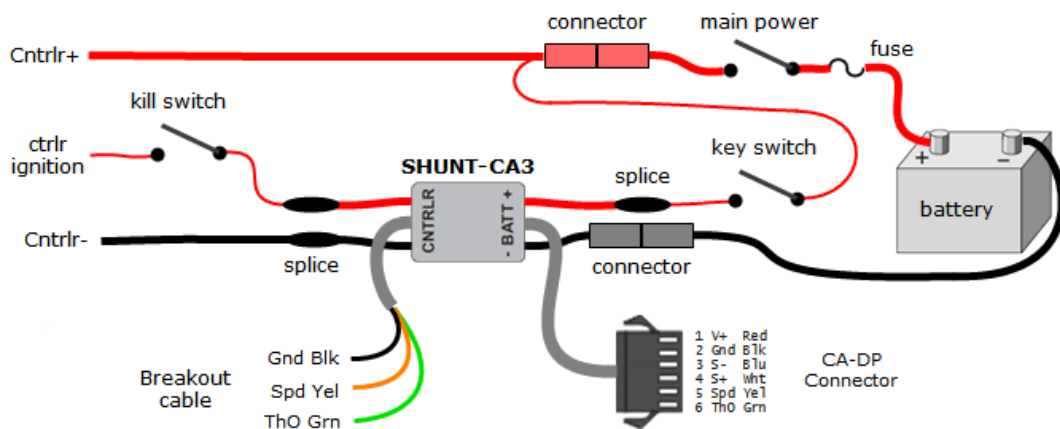
The illustration below is a combination of a standard external shunt installation and a 'normal mode' throttle hook-up as described in earlier sections. This combination effectively adds a 'Large Screen Compatible' CA connector (the shunt connector) to a generic controller. The new connector is plug and play with either a CA V3 (throttle plugged into the CA) or 'Large Screen' V2 with PCB rev 11 or greater (throttle plugged into the controller).

Current monitoring and throttle override are provided by a stock external (SHUNT-CA3) from Grin Tech and a 1K resistor. (Note that although the resistor power requirement is tiny, choosing a higher wattage part (1/4W – 1/2W) will give more robust leads for in-line connection – a purely mechanical consideration.) As always, if the CA is a DPS type using a wheel sensor, the yellow Spd connection to the hall may be omitted and the wire re-purposed for a temp sensor, etc.



Adding Large Screen V2/V3 CA-DP Connector to Generic Controller Using SHUNT-CA3

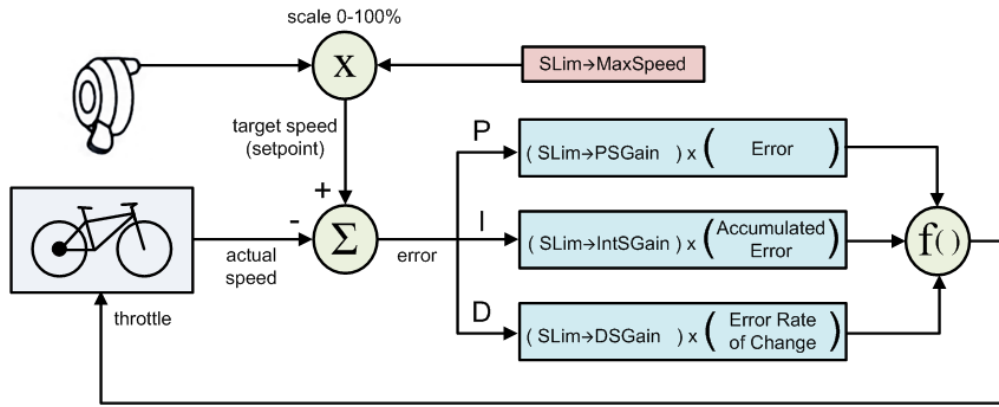
If the controller has an 'ignition' wire, the power portion of the circuit above might be modified as shown below to add key and kill switches. Note the use of light gauge wire for the added switch connections.



Alternate Power Configuration for Key and Kill Switches

## Appendix E. PID Controllers and Gain Parameters

A PID (proportional-integral-derivative) controller is a feedback-based control system that continuously adjusts a control signal to minimize the error between the desired and the actual values of some metric. The Cycle Analyst implements several feedback controllers to limit/control current, power, speed, etc by comparing measured and configured values and then correcting differences by adjusting the motor controller throttle. The CA Speed Throttle controller shown below is an example of a classic PID controller.



PID Controller Overview – Speed Throttle

In this example, the target speed of the system is determined by **SLim->MaxSpeed** as scaled by the operator throttle and is compared with the actual measured speed to determine the error. This raw error is used to develop three different values with past, present, and future views of the error:

- used directly as the immediate error (this allows immediate correction 'proportional' to the error),
- summed over time as an accumulated or 'integral' (integrated) error (this allows larger corrections to be applied as time passes if the error is not diminishing), and
- used to calculate the 'derivative' or rate of change of the error (a high rate of change may warrant adjustment to a correction that might potentially cause overshoot).

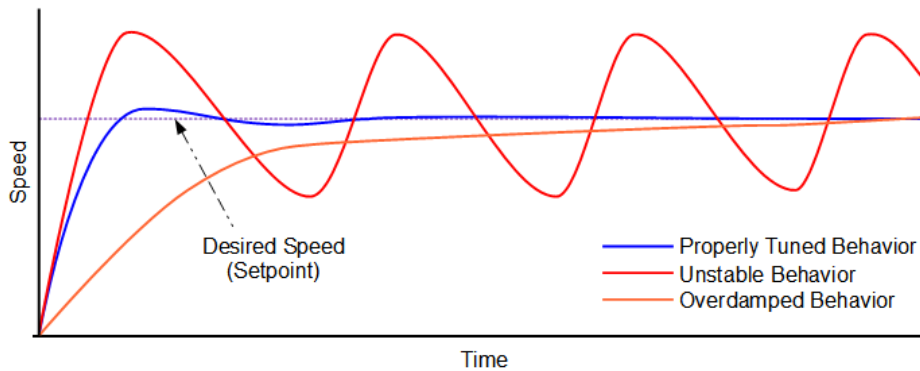
Each of these error terms is multiplied by a different constant or *gain* (like the gain of an audio amplifier) to determine the strength of the associated correction component and its importance relative to the other error terms. The three derived terms are combined to create a new adjusted throttle value intended to reduce the error on the next pass through the loop. The loop is operated continuously producing ongoing throttle adjustments. Although this example shows the means for direct control of speed (Speed Throttle), a minor change to the logic allows the same mechanism to instead simply limit the throttle to avoid exceeding **MaxSpeed** while the throttle is otherwise controlled by the operator or another PID controller.

The table below shows the effects of increasing each gain parameter individually. As above, the term 'Setpoint' refers to the target speed. The 'Error' column shows how the terms contribute corrections focused on differing time views.

Parameter	Feedback	Error	Initial Rise Time to Setpoint	Setpoint Overshoot	Settling Time	Stability
IntSGain	Integral	Accumulated Past	decreases	increases	increases	degrades
PSGain	Proportional	Present	decreases	increases	small change	degrades
DSGain	Derivative	Projected Future	small change	decreases	decreases	improves for small values then degrades

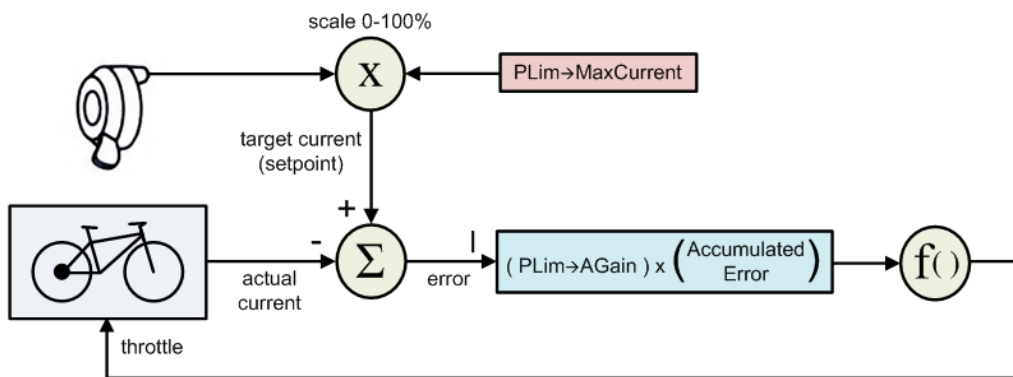
The following plots illustrate typical PID behaviors. In this example, these would be for a standing getaway with Speed Throttle. Some initial overshoot is normal and generally unavoidable - the idea is to achieve a responsive initial rise time, minimum overshoot, reasonably rapid settling time, and stable (non-oscillating) behavior.

- The red plot shows an unstable underdamped oscillating response that will never converge on the setpoint. In this case there is likely either too much **PSGain** and/or not enough **DSGain** - the controller is continually overshooting the setpoint. In the case of ebike operation this appears as 'surging' or 'hunting'.
- The orange plot shows the overdamped case where **PSGain** and **IntSGain** are too low - the response converges on the setpoint but only after a long delay with a slow rise time - the controller has too little gain so the correction per iteration is very small. In the ebike example, this is slow or sluggish rise to the target speed.
- The blue plot shows a desirable response - there is some initial overshoot followed by rapid settling to the setpoint.



Unfortunately, tuning the gain parameters for PID controllers is something of an art form. The gain settings typically interact and achieving rapid settling and stable behavior can be challenging. Fortunately, the CA uses a full PID controller only for speed control where the more complicated design better addresses the long response delays as error corrections alter the speed of the entire vehicle. By comparison, other control situations experience almost instantaneous response to corrections (e.g. controller current). All controllers except 'speed' are therefore simple integral controllers with only an integral term and single gain parameter (e.g. AGain, WGain, LoVGain) - the proportional and derivative terms are absent. The single parameter and inherently rapid response make these simplified controllers much more forgiving and much easier to tune.

The illustration below shows the simpler construction of the Current Throttle controller. The same general feedback diagram applies to the controller shared by Power Throttle and PAS. The same design is again used for the LVC controller, albeit without the throttle scaling.



Integral Controller Overview – Current Throttle

## Appendix F. Speed Gain Adjustment Procedure

The Cycle Analyst speed limiting and control is implemented as a classic PID (proportional-integral-derivative) controller as discussed in '[Appendix E. PID Controllers and Gain Parameters](#)' (review of that section is recommended before proceeding here). There are three interacting gain parameters that can make configuration somewhat challenging - tuning PID controllers is more art than fixed procedure. That said, this section presents a 'best effort' procedure to help tune higher powered bikes that experience surging and oscillation. It is, however, experimental and is strongly affected by individual vehicle characteristics. If speed overshoot cannot be achieved in step (3), then this procedure is likely unusable (see very experimental alternative in that step). A tested procedure for tuning lower powered bikes is not yet available.

**Note:** Whenever possible, it is best to satisfy slower **UpRate** requirements with more conservative (**PSGain**) adjustments so the controller has a nominal responsiveness in line with overall needs. This will give better stability than imposing throttle ramping to restrain controller tuning that has an unnecessarily aggressive response due to high gain settings. As a bonus, it is somewhat easier to tune for a more damped response. Slower response can be achieved in the following procedure in step (4) by further reducing **PSGain** beyond the recommended factor.

**Note:** Please be certain to have effective ramping values in place before proceeding. This is of particular importance for gear motors, mid-drives, and powerful DD motors since full throttle may be applied off the line resulting in drive line stress and potentially dangerous riding situations.

Begin by setting **SLim->MaxSpeed** to a conservative test speed e.g. 15mph (25kph). Set **ThrI->CntrlMode** to the throttle mode where difficulties have occurred (e.g. Speed, Current, or Power Throttle – use Power Throttle for PAS issues). In the following tests, run the same stretch of level or very slightly inclined test road and apply and hold WOT off the line to achieve consistent test conditions.

Follow this procedure:

1. Set **IntSGain** to 1 and **DSGain** to zero
2. Calculate initial **PSGain** =  $6 \times (\text{ThrO->MaxOut} - \text{ThrO->MinOut}) / (\text{SLim->MaxSpeed})$ .
3. Increase **PSGain** to the point where a single modest overshoot occurs before the speed settles.

If no setting produces overshoot, this procedure is not appropriate (bike power too low). However, in such cases some success has been reported by setting **PSGain** to the initial value from step (2) and skipping to step (4) - this is a largely untested and experimental strategy for low power tuning.

4. Reduce **PSGain** to 1/2 of its value.
5. Increase **IntSGain** until oscillations die out with no more than 1 or 2 additional upswings after the initial overshoot.
6. Increase **DSGain** until settled operation is just jittery (power feels rough or ratty), then reduce 30%.

This procedure should give workable settings. However, subsequent incremental adjustment iterations can benefit from starting with pre-adjusted values compared to those of the initial untuned state; this is particularly true for bikes with high power to weight ratios. To iterate,

1. note the time from getaway to settled speed, then
2. increase **PSGain** somewhat (e.g. from original 50% to 60%) and repeat steps 5 and 6.
3. Compare the new time to settled speed. Repeat until no time improvement occurs, then restore settings from the previous iteration (i.e. back up a bit).

This second tuning phase should yield the fastest rise time with the the fastest overall settling time. This procedure may improve responsiveness, but is not strictly necessary – as mentioned earlier, for many situations (PAS) a slightly damped response may be more desirable.

When tuning is complete, restore the desired **SLim->MaxSpeed** and **ThrI->CntrlMode** settings.

Here are some common symptoms and likely causes to aid in ad hoc adjustments:

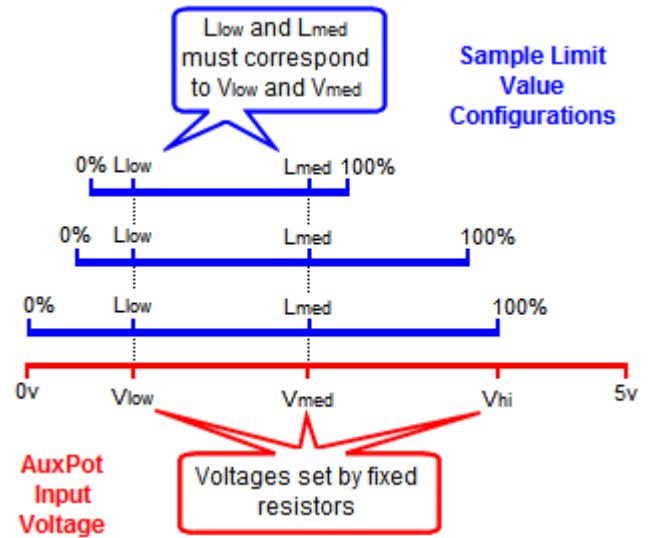
1. If there are (decaying) oscillations centered about the setpoint, then **IntSGain** is probably okay but either **PSGain** is too high or **DSGain** is too low. Try increasing **DSGain**. If this leads to jittery power or does not reduce the oscillations, then restore **DSGain** and instead reduce **PSGain**.
2. If the rise time is slow and speed is on the average below the setpoint until it has settled, then **IntSGain** is too low.
3. If the initial rise time is too slow or there is negligible overshoot and oscillation, then **PSGain** and **IntSGain** are too low.
4. If there are cutouts when accelerating, then **DSGain** is too high. Apply the adjustment of step (6) above.

## Appendix G. Configurable Aux Pot 3-Position Switch Using Fixed Resistors

The somewhat counter-intuitive idea of 'adjustable' limit points in a 3-position switch built with fixed resistors can be realized by sliding the input range around the limit points instead of by moving the limit points within the range. Shifting the endpoints of the allowable Aux Pot input voltage range in Setup causes the intermediate limit points to appear to have different relative values even though the corresponding voltages remain fixed – it's a matter of point of view...

In this technique the switch selects one of three percentages of the configured limiting parameter: (low, med, high) = (*Llow*, *Lmed*, 100%) e.g. (33%, 66%, 100%). The high setting is always equal to 100% of the Aux Pot limiting parameter e.g. **PLim->MaxCurrent** or **PAS->PASWatts**.

1. In the illustration to the right, the lower (red) scale shows the physical Aux Pot voltage range and several voltages determined by fixed resistors.
2. The upper (blue) scales show different possible logical working ranges (0-100%) of the **POT** input as determined by (**AuxMinIn**, **AuxMaxIn**). Although limits *Llow* and *Lmed* are bound to fixed voltages, the overall scale can be shifted left or right or expanded or compressed by moving the endpoints - this changes the effective percentage values of *Llow* and *Lmed* within that range.
3. The fixed voltages impose certain limitations on the possible Limit Value configurations – the endpoints can only be shifted so far. The trick is to pick voltages that will allow a range of commonly useful limit settings.



Although this approach lacks the convenience of trim pots to dial in the desired voltage, the tables on next pages make the one-time setup fairly easy.

### G.1 Grin Tech 3-Position Switch (Fixed Resistors)

This scheme is used by the Grin Tech 3-position switch which gives a convenient plug and play solution. The fixed voltages are (L, M, H) = (1.66V, 2.50V, 3.33V) and the maximum current is 0.35mA.

Follow this setup procedure using the table on the following page:

1. Set appropriate Setup limit parameter (e.g. **PLim->MaxCurrent**, **Pas->PasWatts**) to desired maximum value.
2. Set **Aux->Function** = Limits
3. Set **Aux->ScaleLim** = {AmpsLim | SpeedLim | PowerLim | PASLevel } as appropriate
4. Determine  $LowLimit\% = (LowValue/MaximumValue)*100$ .  
Determine  $MediumLimit\% = (MediumValue/MaximumValue)*100$ .
5. Locate proper cell in table at (col,row) = (*LowLimit%*, *MediumLimit%*)
6. Transfer cell values to **Aux->AuxMinIn** and **Aux->AuxMaxIn**.
7. Go to Setup Aux Pot Section Preview screen and verify switch settings (L, M, H) display the desired limits of (**LowLimit%**, **MediumLimit%**, 99%).
8. If the limits are not exactly as desired, then locate the appropriate adjacent cell and modify both **AuxMinIn** and **AuxMaxIn** toward those new cell values.

**Note:** Altering the maximum limit value (e.g. **Pas->PasWatts**) will result in proportional changes to the medium and low limits.



For example, to set up the switch for PAS Assist at levels (250W, 500W, 750W):

1. Set **PAS->PASWatts** = 750W
2.  $LowLimit\% = 250W/750W \times 100 = 33\%$   
 $MedLimit\% = 500W/750W \times 100 = 66\%$
3. Look up row 66%, column 33% in table.  
Use the nearest cell (66,32) and get (0.88, 3.31)
4. Go to Setup PAS section
  - a. Set **AuxMinIn** = 0.88  
**AuxMaxIn** = 3.31
  - b. Go to PAS section preview screen and operate the switch - Asst% should show (32%, 66%, 99%)



**Live Vpot**      **%Limit**  
 Fixed Sw Voltages      Selected Switch %  
 (1.66, 2.50, 3.33)      (Low%, Med%, 99%)

The Grin Tech switch can also be used as a 3-position Preset Switch by setting (**AuxMinIn, AuxMaxIn**) = (1V, 4V).

MinIn MaxIn	Low Limit %																											
	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50		
Medium Limit %	50	1.65																										
		3.31																										
	52	1.65	1.62	1.58																								
		3.24	3.27	3.31																								
	54	1.65	1.62	1.59	1.55	1.51																						
		3.18	3.21	3.24	3.27	3.31																						
	56	1.65	1.62	1.59	1.55	1.52	1.47	1.43																				
		3.13	3.15	3.18	3.21	3.24	3.27	3.31																				
	58	1.65	1.62	1.59	1.56	1.52	1.48	1.44	1.39	1.34																		
		3.08	3.10	3.12	3.15	3.17	3.20	3.23	3.27	3.31																		
	60	1.65	1.62	1.59	1.56	1.53	1.49	1.45	1.40	1.35	1.30	1.24																
		3.03	3.05	3.07	3.09	3.12	3.14	3.17	3.20	3.23	3.27	3.31																
	62	1.65	1.63	1.60	1.56	1.53	1.49	1.45	1.41	1.37	1.32	1.26	1.20	1.13														
		2.99	3.00	3.02	3.04	3.06	3.08	3.11	3.13	3.16	3.19	3.23	3.27	3.31														
	64	1.65	1.63	1.60	1.57	1.54	1.50	1.46	1.42	1.38	1.33	1.28	1.22	1.16	1.09	1.01												
		2.95	2.96	2.98	2.99	3.01	3.03	3.05	3.08	3.10	3.13	3.16	3.19	3.22	3.26	3.31												
	66	1.65	1.63	1.60	1.57	1.54	1.51	1.47	1.43	1.39	1.34	1.29	1.24	1.18	1.12	1.04	0.96	0.88										
		2.91	2.92	2.93	2.95	2.96	2.98	3.00	3.02	3.04	3.07	3.09	3.12	3.15	3.18	3.22	3.26	3.31										
68	1.65	1.63	1.60	1.57	1.54	1.51	1.48	1.44	1.40	1.36	1.31	1.26	1.20	1.14	1.07	1.00	0.92	0.83	0.72									
	2.87	2.88	2.89	2.91	2.92	2.94	2.95	2.97	2.99	3.01	3.03	3.06	3.08	3.11	3.14	3.18	3.21	3.26	3.31									
70	1.65	1.63	1.60	1.58	1.55	1.52	1.48	1.45	1.41	1.37	1.32	1.27	1.22	1.16	1.10	1.03	0.96	0.87	0.78	0.67	0.55							
	2.83	2.84	2.86	2.87	2.88	2.89	2.91	2.92	2.94	2.96	2.98	3.00	3.02	3.04	3.07	3.10	3.13	3.17	3.21	3.26	3.31							
72	1.65	1.63	1.60	1.58	1.55	1.52	1.49	1.45	1.42	1.38	1.34	1.29	1.24	1.19	1.13	1.06	0.99	0.91	0.83	0.73	0.62	0.50	0.35					
	2.80	2.81	2.82	2.83	2.84	2.85	2.87	2.88	2.89	2.91	2.93	2.94	2.96	2.98	3.01	3.03	3.06	3.09	3.12	3.16	3.20	3.25	3.31					
74	1.65	1.63	1.61	1.58	1.55	1.52	1.49	1.46	1.43	1.39	1.35	1.30	1.26	1.21	1.15	1.09	1.02	0.95	0.87	0.78	0.68	0.57	0.44	0.30	0.13			
	2.77	2.78	2.79	2.80	2.81	2.82	2.83	2.84	2.85	2.86	2.88	2.89	2.91	2.93	2.95	2.97	2.99	3.02	3.05	3.08	3.11	3.15	3.20	3.25	3.31			
76	1.65	1.63	1.61	1.58	1.56	1.53	1.50	1.47	1.43	1.40	1.36	1.32	1.27	1.22	1.17	1.11	1.05	0.98	0.91	0.83	0.73	0.63	0.52	0.39	0.24	0.06		
	2.74	2.75	2.76	2.76	2.77	2.78	2.79	2.80	2.81	2.82	2.83	2.85	2.86	2.88	2.89	2.91	2.93	2.95	2.98	3.00	3.03	3.06	3.10	3.14	3.19	3.24		
78	1.65	1.63	1.61	1.58	1.56	1.53	1.50	1.47	1.44	1.41	1.37	1.33	1.29	1.24	1.19	1.14	1.08	1.01	0.94	0.87	0.78	0.69	0.58	0.47	0.33	0.18		
	2.71	2.72	2.73	2.73	2.74	2.75	2.76	2.77	2.78	2.79	2.80	2.82	2.83	2.84	2.86	2.88	2.89	2.91	2.93	2.96	2.99	3.01	3.05	3.09	3.13			
80	1.65	1.63	1.61	1.59	1.56	1.54	1.51	1.48	1.45	1.41	1.38	1.34	1.30	1.26	1.21	1.16	1.10	1.04	0.98	0.91	0.83	0.74	0.64	0.53	0.41	0.28		
	2.69	2.69	2.70	2.70	2.71	2.72	2.72	2.73	2.74	2.75	2.76	2.77	2.78	2.79	2.80	2.81	2.82	2.84	2.86	2.87	2.89	2.92	2.94	2.97	3.00	3.03		
82	1.65	1.63	1.61	1.59	1.56	1.54	1.51	1.48	1.45	1.42	1.39	1.35	1.31	1.27	1.22	1.18	1.12	1.07	1.01	0.94	0.87	0.79	0.70	0.60	0.49	0.36		
	2.66	2.67	2.67	2.68	2.68	2.69	2.69	2.70	2.71	2.71	2.72	2.73	2.74	2.75	2.76	2.77	2.78	2.79	2.80	2.82	2.83	2.85	2.87	2.89	2.92	2.95		
84	1.65	1.63	1.61	1.59	1.57	1.54	1.52	1.49	1.46	1.43	1.40	1.36	1.32	1.28	1.24	1.19	1.14	1.09	1.03	0.97	0.90	0.83	0.74	0.65	0.55	0.44		
	2.64	2.64	2.65	2.65	2.65	2.66	2.66	2.67	2.67	2.68	2.69	2.69	2.70	2.71	2.72	2.72	2.73	2.74	2.76	2.77	2.78	2.79	2.81	2.83	2.85	2.87		
86	1.65	1.63	1.61	1.59	1.57	1.54	1.52	1.49	1.46	1.43	1.40	1.37	1.33	1.30	1.25	1.21	1.16	1.11	1.06	1.00	0.93	0.86	0.79	0.70	0.61	0.51		
	2.61	2.62	2.62	2.62	2.63	2.63	2.64	2.64	2.65	2.65	2.66	2.67	2.67	2.68	2.69	2.69	2.70	2.71	2.72	2.73	2.74	2.76	2.77	2.78	2.80			
88	1.65	1.63	1.61	1.59	1.57	1.55	1.52	1.50	1.47	1.44	1.41	1.38	1.34	1.31	1.27	1.23	1.18	1.13	1.08	1.03	0.96	0.90	0.83	0.75	0.66	0.57		
	2.59	2.60	2.60	2.60	2.61	2.61	2.61	2.62	2.62	2.63	2.63	2.64	2.64	2.65	2.65	2.66	2.66	2.67	2.68	2.69	2.70	2.71	2.72	2.73	2.74			
90	1.65	1.63	1.61	1.59	1.57	1.55	1.53	1.50	1.47	1.45	1.42	1.39	1.35	1.32	1.28	1.24	1.20	1.15	1.10	1.05	0.99	0.93	0.86	0.79	0.71	0.62		
	2.57	2.57	2.58	2.58	2.58	2.58	2.59	2.59	2.59	2.60	2.60	2.61	2.61	2.61	2.62	2.62	2.63	2.63	2.64	2.65	2.65	2.66	2.67	2.68	2.69			

High Limit = 99%      switch voltage (L,M,H) = (1.66v,2.50v,3.33v)      for preset switch (AuxMinIn,AuxMaxIn) = (1v,4v)

Grin Tech 3-Position Switch Adjustment Table

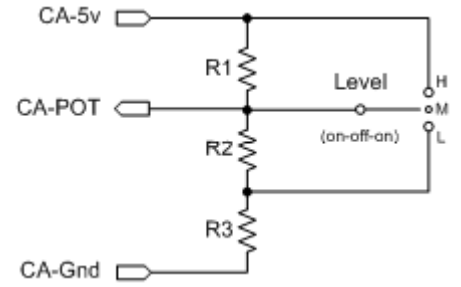
### G.2 Custom DIY 3-Position Switch (Fixed Resistors)

A similar custom switch can be fabricated using the 3-resistor circuit shown here. This is slightly different than the Grin Tech implementation and offers a slightly expanded adjustment range.

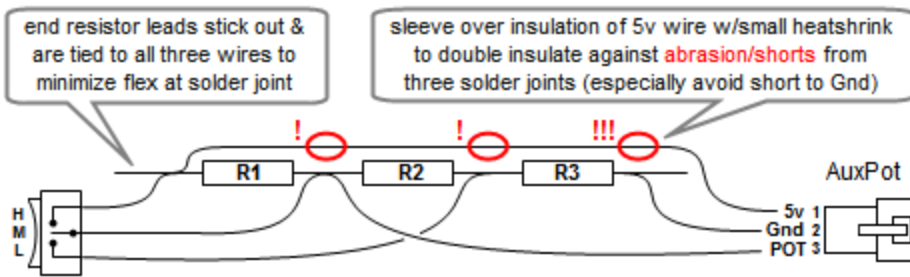
The fixed voltages are (L, M, H) = (1.60V, 2.42V, 4.99V) and the maximum current is 0.53mA.

The switch can be any center-off SPDT toggle or rocker switch or any of the commercially available ebike 3-position switches. Current is very low - resistor wattage can be anything available (1/8W, etc).

- R1=10K
- R2=4.7K
- R3=4.7K



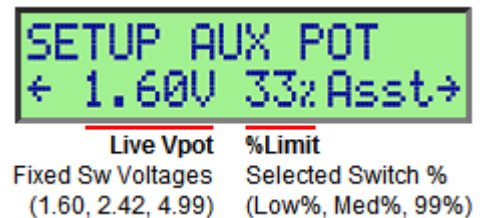
This can be fabricated many ways, including squeezing the resistors into the side cover of common 3-speed ebike switch. However, an easy technique is to cut the cable of an ebike 3-speed switch and splice the resistors in-line. Choose some part of the cable run that is relatively straight and will not be subject to flex. Leave the end resistor leads a little long and spiral wrap the resistors and wires down and back with waxed dental floss (DIY cable lacing twine) out to the end of the resistor leads so they are bound to the insulated cable wire for strength. Sleeve with a couple of layers of heatshrink.



Before adding the outer heatshrink, verify the pin-to-pin resistances below with a meter for the three switch positions. If resistances check out, plug the cable into the CA, navigate to the Setup Aux Pot Section Preview screen and check that the voltages are as shown in the table for the three switch settings. If all is well, apply the outer heatshrink.

Resistance	Pins	Low	Med	High
5v to Gnd	1, 2	14700	19400	9400
5v to Pot	1, 3	10000	10000	0
Gnd to Pot	2, 3	4700	9400	9400

AuxPot Voltage	3	1.60	2.42	4.99
----------------	---	------	------	------



Calibrate this custom switch exactly as with the Grin Tech switch in the previous section, but use the table on the following page.

This switch can be used as a 3-position Preset Switch by setting (**AuxMinIn, AuxMaxIn**) = (2V, 3V).

MinIn	Low Limit %																										
	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	
Med Limit %	26	1.59	1.52																								
		4.73	4.92																								
	28	1.59	1.52	1.45																							
		4.51	4.67	4.86																							
	30	1.59	1.53	1.46	1.38																						
		4.31	4.45	4.60	4.79																						
	32	1.59	1.53	1.47	1.40	1.31	1.21																				
		4.14	4.26	4.39	4.54	4.72	4.93																				
	34	1.59	1.53	1.48	1.41	1.33	1.25	1.14																			
		3.99	4.09	4.20	4.33	4.48	4.65	4.86																			
	36	1.59	1.54	1.48	1.42	1.35	1.27	1.18	1.07																		
		3.86	3.94	4.04	4.15	4.27	4.42	4.58	4.78																		
	38	1.59	1.54	1.49	1.43	1.37	1.29	1.21	1.11	0.99	0.85																
		3.74	3.81	3.89	3.99	4.09	4.21	4.35	4.52	4.71	4.94																
	40	1.59	1.54	1.50	1.44	1.38	1.31	1.24	1.15	1.04	0.92	0.77															
		3.63	3.69	3.77	3.85	3.94	4.04	4.15	4.29	4.45	4.63	4.86															
	42	1.59	1.54	1.50	1.45	1.39	1.33	1.26	1.18	1.08	0.97	0.84	0.69														
		3.53	3.59	3.65	3.72	3.80	3.88	3.98	4.10	4.23	4.38	4.56	4.77														
	44	1.59	1.55	1.50	1.46	1.40	1.35	1.28	1.20	1.12	1.02	0.90	0.77	0.60	0.41												
		3.44	3.49	3.55	3.61	3.67	3.75	3.83	3.93	4.04	4.16	4.31	4.48	4.69	4.95												
	46	1.59	1.55	1.51	1.46	1.41	1.36	1.30	1.23	1.15	1.06	0.96	0.84	0.69	0.52	0.31											
		3.36	3.41	3.45	3.51	3.56	3.63	3.70	3.78	3.87	3.98	4.10	4.24	4.41	4.61	4.86											
	48	1.59	1.55	1.51	1.47	1.42	1.37	1.31	1.25	1.18	1.10	1.00	0.89	0.77	0.62	0.44	0.22										
		3.29	3.33	3.37	3.42	3.47	3.52	3.58	3.65	3.73	3.82	3.92	4.04	4.17	4.34	4.53	4.76										
	50	1.59	1.55	1.51	1.47	1.43	1.38	1.33	1.27	1.20	1.13	1.04	0.94	0.83	0.70	0.55	0.36	0.13									
		3.22	3.25	3.29	3.33	3.38	3.43	3.48	3.54	3.61	3.68	3.77	3.86	3.98	4.11	4.26	4.45	4.67									
52	1.59	1.55	1.52	1.48	1.44	1.39	1.34	1.28	1.22	1.15	1.07	0.99	0.89	0.77	0.63	0.47	0.28	0.04									
	3.16	3.19	3.22	3.26	3.30	3.34	3.38	3.44	3.49	3.56	3.63	3.71	3.80	3.91	4.04	4.19	4.37	4.58									
54	1.59	1.55	1.52	1.48	1.44	1.40	1.35	1.30	1.24	1.18	1.10	1.02	0.93	0.83	0.71	0.56	0.40	0.20									
	3.10	3.13	3.16	3.19	3.22	3.26	3.30	3.34	3.39	3.45	3.51	3.58	3.66	3.75	3.85	3.97	4.11	4.28									
56	1.59	1.56	1.52	1.49	1.45	1.41	1.36	1.31	1.26	1.20	1.13	1.06	0.97	0.88	0.77	0.64	0.50	0.32	0.11								
	3.05	3.07	3.09	3.12	3.15	3.19	3.22	3.26	3.30	3.35	3.40	3.46	3.53	3.60	3.69	3.79	3.90	4.04	4.20								
58	1.59	1.56	1.53	1.49	1.46	1.42	1.37	1.33	1.27	1.22	1.16	1.09	1.01	0.92	0.82	0.71	0.58	0.43	0.25	0.03							
	3.00	3.02	3.04	3.06	3.09	3.12	3.15	3.18	3.22	3.26	3.31	3.36	3.41	3.48	3.55	3.63	3.72	3.83	3.96	4.12							
60	1.59	1.56	1.53	1.50	1.46	1.42	1.38	1.34	1.29	1.24	1.18	1.11	1.04	0.96	0.87	0.77	0.65	0.52	0.36	0.17							
	2.95	2.97	2.99	3.01	3.03	3.06	3.08	3.11	3.15	3.18	3.22	3.26	3.31	3.37	3.43	3.49	3.57	3.66	3.77	3.89							
62	1.59	1.56	1.53	1.50	1.46	1.43	1.39	1.35	1.30	1.25	1.20	1.14	1.07	1.00	0.91	0.82	0.71	0.59	0.45	0.29	0.10						
	2.90	2.92	2.94	2.96	2.98	3.00	3.02	3.05	3.08	3.11	3.14	3.18	3.22	3.27	3.32	3.37	3.44	3.51	3.60	3.70	3.82						
64	1.59	1.56	1.53	1.50	1.47	1.43	1.40	1.36	1.31	1.27	1.21	1.16	1.10	1.03	0.95	0.86	0.77	0.66	0.53	0.39	0.22	0.03					
	2.86	2.88	2.89	2.91	2.93	2.95	2.97	2.99	3.02	3.04	3.07	3.10	3.14	3.18	3.22	3.27	3.32	3.38	3.45	3.54	3.63	3.74					
66	1.59	1.56	1.53	1.50	1.47	1.44	1.40	1.37	1.32	1.28	1.23	1.18	1.12	1.05	0.98	0.90	0.82	0.72	0.60	0.48	0.33	0.16					
	2.82	2.84	2.85	2.87	2.88	2.90	2.92	2.94	2.96	2.98	3.01	3.03	3.07	3.10	3.13	3.18	3.22	3.27	3.33	3.40	3.47	3.56					
68	1.59	1.56	1.53	1.51	1.48	1.44	1.41	1.37	1.33	1.29	1.25	1.19	1.14	1.08	1.01	0.94	0.86	0.77	0.67	0.55	0.42	0.27	0.09				
	2.79	2.80	2.81	2.83	2.84	2.85	2.87	2.89	2.91	2.93	2.95	2.97	3.00	3.03	3.06	3.09	3.13	3.17	3.22	3.28	3.34	3.41	3.49				
70	1.59	1.56	1.54	1.51	1.48	1.45	1.42	1.38	1.34	1.30	1.26	1.21	1.16	1.10	1.04	0.97	0.90	0.81	0.72	0.62	0.50	0.36	0.20	0.02			
	2.75	2.76	2.77	2.79	2.80	2.81	2.83	2.84	2.86	2.87	2.89	2.91	2.94	2.96	2.99	3.02	3.05	3.08	3.12	3.17	3.22	3.28	3.35	3.43			
72	1.59	1.56	1.54	1.51	1.48	1.45	1.42	1.39	1.35	1.31	1.27	1.23	1.18	1.12	1.07	1.00	0.93	0.85	0.77	0.67	0.56	0.44	0.30	0.14			
	2.72	2.73	2.74	2.75	2.76	2.77	2.78	2.80	2.81	2.83	2.84	2.86	2.88	2.90	2.92	2.95	2.98	3.01	3.04	3.08	3.12	3.17	3.22	3.28			
74	1.59	1.56	1.54	1.51	1.49	1.46	1.43	1.40	1.36	1.32	1.28	1.24	1.19	1.14	1.09	1.03	0.96	0.89	0.81	0.72	0.62	0.51	0.39	0.24	0.08		
	2.69	2.70	2.71	2.72	2.73	2.74	2.75	2.76	2.77	2.78	2.80	2.81	2.83	2.85	2.87	2.89	2.91	2.93	2.96	2.99	3.03	3.07	3.11	3.16	3.22		
76	1.59	1.56	1.54	1.52	1.49	1.46	1.43	1.40	1.37	1.33	1.29	1.25	1.21	1.16	1.11	1.05	0.99	0.92	0.85	0.77	0.68	0.58	0.46	0.33	0.18	0.01	
	2.66	2.67	2.68	2.68	2.69	2.70	2.71	2.72	2.73	2.74	2.75	2.77	2.78	2.80	2.81	2.83	2.85	2.87	2.89	2.92	2.95	2.98	3.02	3.06	3.10	3.16	
78	1.59	1.56	1.54	1.52	1.49	1.47	1.44	1.41	1.37	1.34	1.30	1.26	1.22	1.18	1.13	1.07	1.02	0.95	0.89	0.81	0.73	0.63	0.53	0.41	0.28	0.13	
	2.63	2.64	2.65	2.65	2.66	2.67	2.68	2.68	2.69	2.70	2.71	2.72	2.74	2.75	2.76	2.78	2.81	2.83	2.85	2.88	2.90	2.93	2.97	3.00	3.05		
80	1.59	1.56	1.54	1.52	1.50	1.47	1.44	1.41	1.38	1.35	1.31	1.28	1.24	1.19	1.15	1.10	1.04	0.98	0.92	0.85	0.77	0.68	0.59	0.48	0.36	0.22	
	2.61	2.61	2.62	2.62	2.63	2.64	2.64	2.65	2.66	2.67	2.68	2.69	2.70	2.71	2.72	2.73	2.74	2.76	2.77	2.79	2.81	2.83	2.86	2.88	2.91	2.95	
82	1.59	1.57	1.54	1.52	1.50	1.47	1.45	1.42	1.39	1.36	1.32	1.29	1.25	1.21	1.16	1.11	1.06	1.01	0.95	0.88	0.81	0.73	0.64	0.54	0.43	0.31	
	2.58	2.59	2.59	2.60	2.60	2.61	2.61	2.62	2.63	2.63	2.64	2.65	2.66	2.67	2.68	2.69	2.70	2.71	2.72	2.74	2.75	2.77	2.79	2.81	2.84	2.86	
84	1.59	1.57	1.54	1.52	1.50	1.48	1.45	1.42	1.39	1.36	1.33	1.30	1.26	1.22	1.18	1.13	1.08	1.03	0.97	0.91	0.84	0.77	0.69	0.60	0.50	0.38	
	2.56	2.56	2.57	2.57	2.58	2.58	2.59	2.60	2.60	2.61	2.61	2.61	2.62	2.63	2.64	2.65	2.65	2.66	2.66	2.69	2.70	2.71	2.73	2.75	2.77	2.79	
86	1.59	1.57	1.55	1.52	1.50																						

## Appendix H. Updating CA Firmware and Saving/Restoring Settings

### H.1 Hardware Requirements

The Cycle Analyst need not be fully installed to flash software or alter settings; it requires only that power is supplied via the CA-DP connector; throttle and other input devices need not be attached. See '[5.11 Serial Data Port](#)' for details on the necessary programming cable.

**IMPORTANT:** The CA-DP connector can give the CA control of the controller throttle creating the possibility of unexpected motor operation during CA installation. For safety the bike should be placed on a stand until CA firmware is installed, parameters are brought to defaults, wiring is finalized, and settings are adjusted for the particular vehicle.

### H.2 The Cycle Analyst Setup Utility

The Setup Utility is available for download from the [Grin Tech CA V3 web page](#) for Windows and other platforms. This application provides a means to save and restore CA settings, restore settings to factory-fresh defaults, and load new firmware. Always use the most recent Setup Utility to obtain the most recent default settings and ensure newer firmware files are recognized and installed properly.

Detailed documentation for the utility is available from Grin Tech, but a few features are called out here as they relate to installation. Some variations in the instructions below may arise with release of newer utility versions.

### H.3 Third Party Vendor Kit Configuration

If the Cycle Analyst has been supplied as part of a kit or conversion package then the CA may have been pre-configured for proper out-of-box operation with the provided kit components. In these situations it is strongly recommended to save the 'as delivered' CA settings to a file using the Setup Utility before modifying them so the CA can later be restored to this original condition.

**IMPORTANT:** Vendor-supplied Setup parameter settings may not be the normal CA 'defaults' and may not be available from any source, including the vendor.

### H.4 Restoring Factory Default Parameter Settings

This guide assumes that the true CA factory default settings are in place at the outset of the installation procedure. There are many settings that may interact in unexpected ways and this 'defaults' policy is a means to ensure the CA is in a known state will operate in a known way. There are two means to restore factory defaults:

1. Use the Setup Utility to load the default setup file
2. Use the Setup Utility to re-flash the firmware + default settings in a single step

#### H.4.1 Loading the Default Setup File

Launch the utility and select '*File/Open Setup File*'. When the file chooser pop-up is displayed, navigate into the data/default directory and select the file named *V<version\_number>.hex*. Use the utility to load these settings into the CA. This will erase and replace all configuration settings except those in the Calibration Group.

#### H.4.2 Flashing Firmware with Default Settings

Launch the utility and select '*File/Update Firmware*'. In the 'Select Firmware' menu, choose the file named: '*CA<version\_number>\_firmware.hex*'. This file contains both the firmware and factory-fresh settings. When installed, it erases and replaces all user settings except those in the Calibration Group. Select the proper COM port and install.

### H.5 Updating Firmware Without Altering User Settings

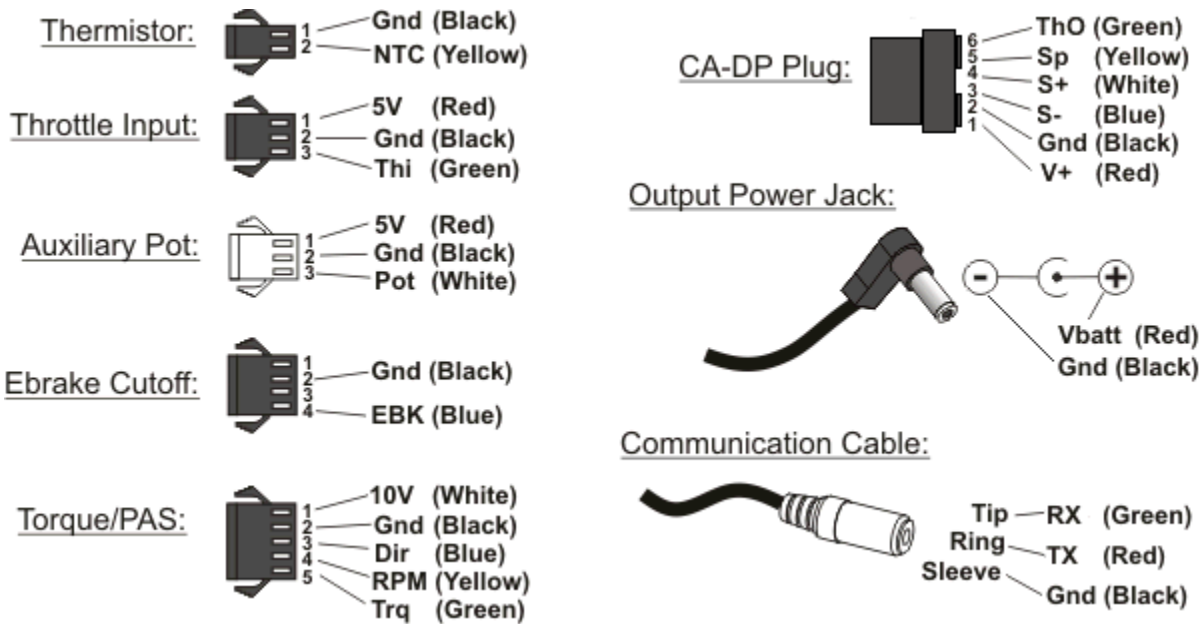
Most new firmware releases are compatible with existing user configuration settings. To preserve existing settings, follow the instructions in section '[H.4.2](#)' but instead use the file '*CA<version\_number>\_firmware\_NoEeprom.hex*'. This will update the CA with new programming but will leave all existing configuration data unaltered.

## Appendix I. CA V3 Connector and PCB Images

This material was excerpted on 2012-12-31 from the [Grin Tech Site](#) which is the authoritative source for V3 information. Please see the site for contemporary versions of this information.

### I.1 Connector Pinout

The V3 CA device has a cable bundle bringing out all the signal wires into suitably terminated JST-SM plugs. The following shows the standard CA V3 wiring harness connector details for all cables coming out of the V3 CA:



### I.2 Pad Descriptions

The following shows the solder pad locations on the circuit board for anyone fabricating a custom wiring harness running directly to the the CA PCB:

