Endless-Sphere.com

Cycle Analyst V3.0
Unofficial User Guide

Beta Release – B22

teklektik

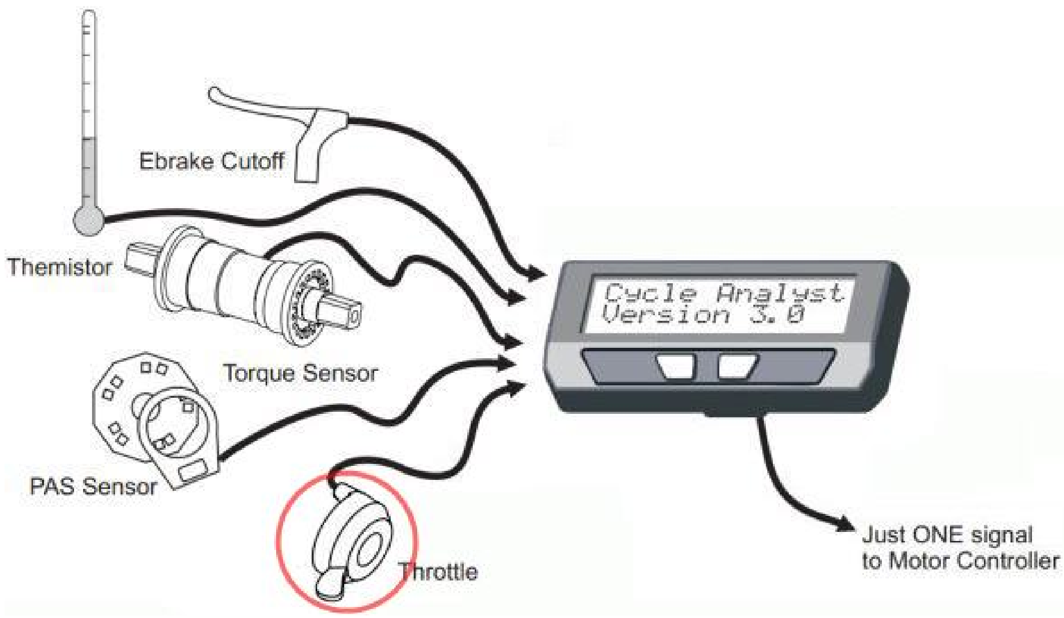
This is a 'best effort' work intended as a temporary measure until formal documentation is available. Selected text from the Grin Tech site is quoted in-line with colored background for reference. Please review the authoritative documentation on that site for more contemporary versions. Also see the Endless-Sphere.com thread "Cycle Analyst V3 preview and first beta release" from which much of this material has been drawn.

1.0 Overview

1.1 Concept

The Cycle Analyst V3 measures and displays detailed information about the battery, acts as a general purpose trip computer, records and calculates statistics on vehicle performance, monitors and displays data from optional input devices, and limits the motor controller based on the monitored and calculated data. This affords a single integrated solution to display and control vehicle operation with all control passing to the motor controller via a single throttle signal. This approach allows any motor controller to be upgraded with advanced features like torque-sensing PAS or over-temperature power rollback.

In the role as intermediary between controller and accessory devices, the Cycle Analyst also processes the operator throttle and combines it with other inputs to arrive at a single output throttle signal. This provides an opportunity to provide options to enhance operator throttle operation. These options can materially improve the driving experience by smoothing power application and mitigating uneven and quirky throttle response.



1.2 Features

1.2.1 User Configurable Presets

The V3 offers up to three *Battery Presets* that allow rapid reconfiguration when installing different battery packs. Battery statistics are associated with each preset so unique historical information is maintained for each individual pack.

Up to three additional *Mode Presets* are provided to allow easy selection of suites of preconfigured parameter settings. These may be used to switch between different power limitations (e.g. legal, off-road), to enable/disable assist modes, or to customize throttle behavior for different riding situations.

1.2.2 Pedal Assist

The Cycle Analyst supports both PAS cadence sensors and torque-sensing devices such as the Thun bottom bracket. These can be operated in a variety of modes that include simple PAS-only, combined throttle-PAS, and special 'no throttle without pedaling' modes to comply with various pedalec legal requirements.

1.2.3 Auto-Cruise Control

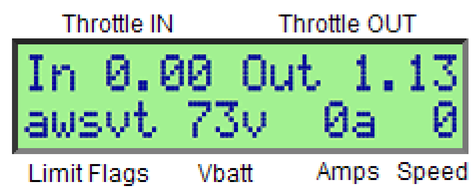
The Cycle Analyst can be configured to provide a firmware-only auto-cruise control capability that holds the present throttle setting if the throttle remains unchanged for a period of time. The delay to trigger the cruise control as well as the amount of throttle motion that will be ignored by the trigger logic are both configurable. Auto-cruise releases on ebrake input or throttle application.

1.2.4 Temperature Sensing

The Cycle Analyst provides a temperature sensor input that supports either NTC (Negative Temperature Coefficient) thermistors or linear 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.

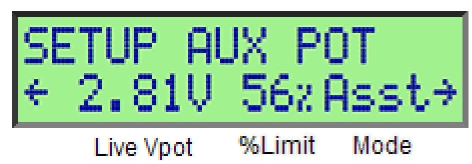
1.2.5 Diagnostic Displays

The Cycle Analyst has several displays designed to 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 presently in play and restricting controller power.



Diagnostic Screen

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. The display to the right shows the voltage from a custom external PAS assist level adjustment knob.



Aux Pot with PAS Limit Knob

1.2.6 Throttle Enhancements

The V3 provides three means to enhance throttle operation:

- throttle/controller voltage matching,
- throttle ramping, and
- alternative 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 match the requirements of these two devices without additional test equipment.
2. Configurable throttle ramping provides a means to ease the application and removal of controller power. 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 can safeguard drivetrain components.
3. Perhaps the most valuable throttle feature is the ability to employ one of three additional closed-loop feedback modes: *Current*, *Power*, or *Speed Throttle*. In these modes the operator throttle is not used for direct control but rather provides a 0-100% target level of the configured current, power, or speed limit for the Cycle Analyst to achieve. The V3 runs the controller independently, monitoring speed, shunt, and/or battery voltage and computing the necessary controller throttle voltage to achieve the operator target. This fly-by-wire approach masks quirky controller/motor behavior by making difficult controller throttle adjustment the responsibility of the CA, not the operator.

1.3 Input Summary

The V3 is housed in the same Large Screen console as the V2 but the offers expanded features with a new circuit board, more powerful processor, and increased memory.

The V3 provides these inputs:

Communication: There is an Rx / Tx and Gnd for hooking up a TTL->USB converter. This can be used for data logging, bootloading new firmware, or configuring setup parameters from a computer rather than by pushing buttons through the Setup menu.

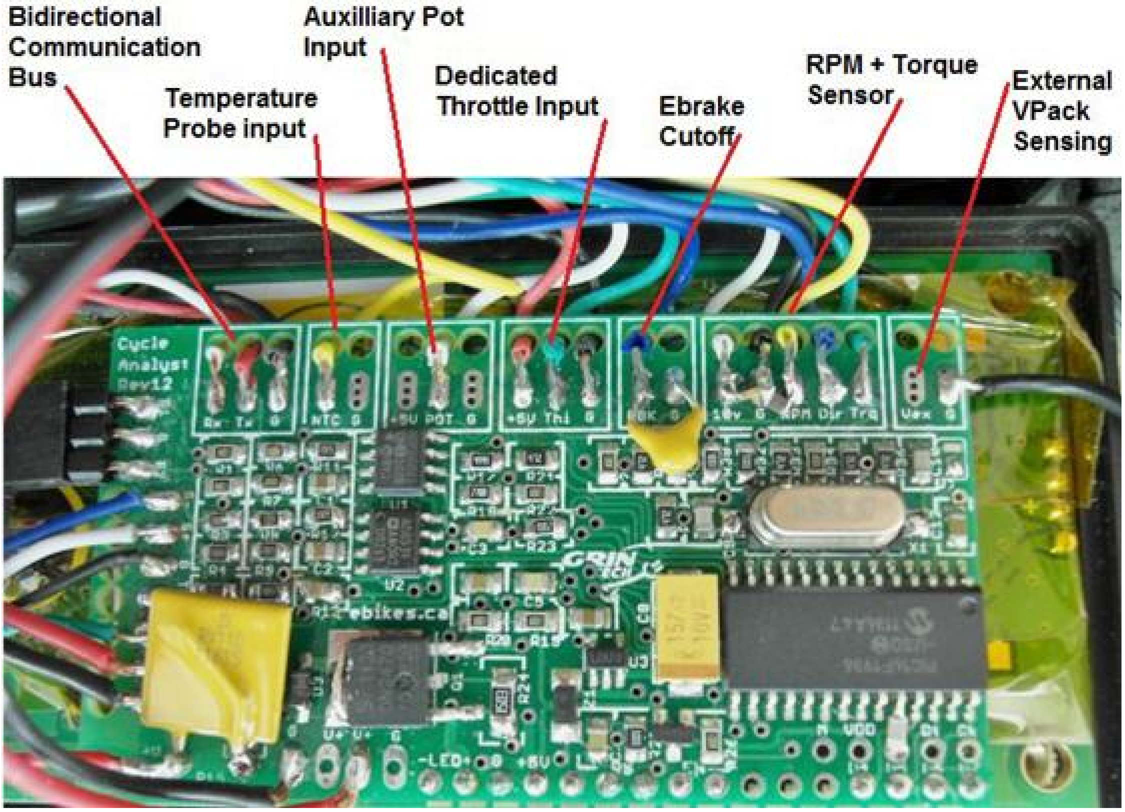
Temperature: This input can be either a 10K NTC thermistor, or a linear temperature sensing IC like the LMx35 series.

Aux Pot Input: This is a general purpose 0-5V input that can be used to support custom user inputs such as a PAS level knob, speed knob, 3 position switch, or 'preset switch' to externally select CA mode presets.

Ebrake Cutoff: Instead of running an ebrake brake signal wire back to the controller, it can go to the CA which in turn inhibits the throttle signal.

RPM / Dir / Trq: The pedal assist connector is laid out primarily with the THUN torque sensing bottom brackets in mind, but also supports regular PAS cadence sensors and other torque sensors such as those from FAG from Germany or GreenTrans from Taiwan.

External VPack: This input can be connected to a custom resistive divider to allow monitoring voltages different than the Cycle Analyst supply voltage. This gives the option to monitor battery packs up to 500v while the CA itself is powered from a separate low voltage source such as a 12v DC/DC converter.



2.0 Display Screens and Console Operation

2.1 Basic Button Navigation

1. Press right/left buttons to navigate Status or Setup Screens
2. Press/hold right button to reset trip statistics
3. Press/hold left button to enter Setup

2.2 Mode Presets

Mode and battery presets are configured in Setup and may be selected in Setup or at any time from the main status screens using both buttons in 'hot swap' mode:

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

Mode presets may also be selected by means of a custom external 'preset switch' (see *' 6.3 Auxiliary Pot'*). The CA can be configured to power up with the either a fixed default or the mode preset in effect when last powered down.

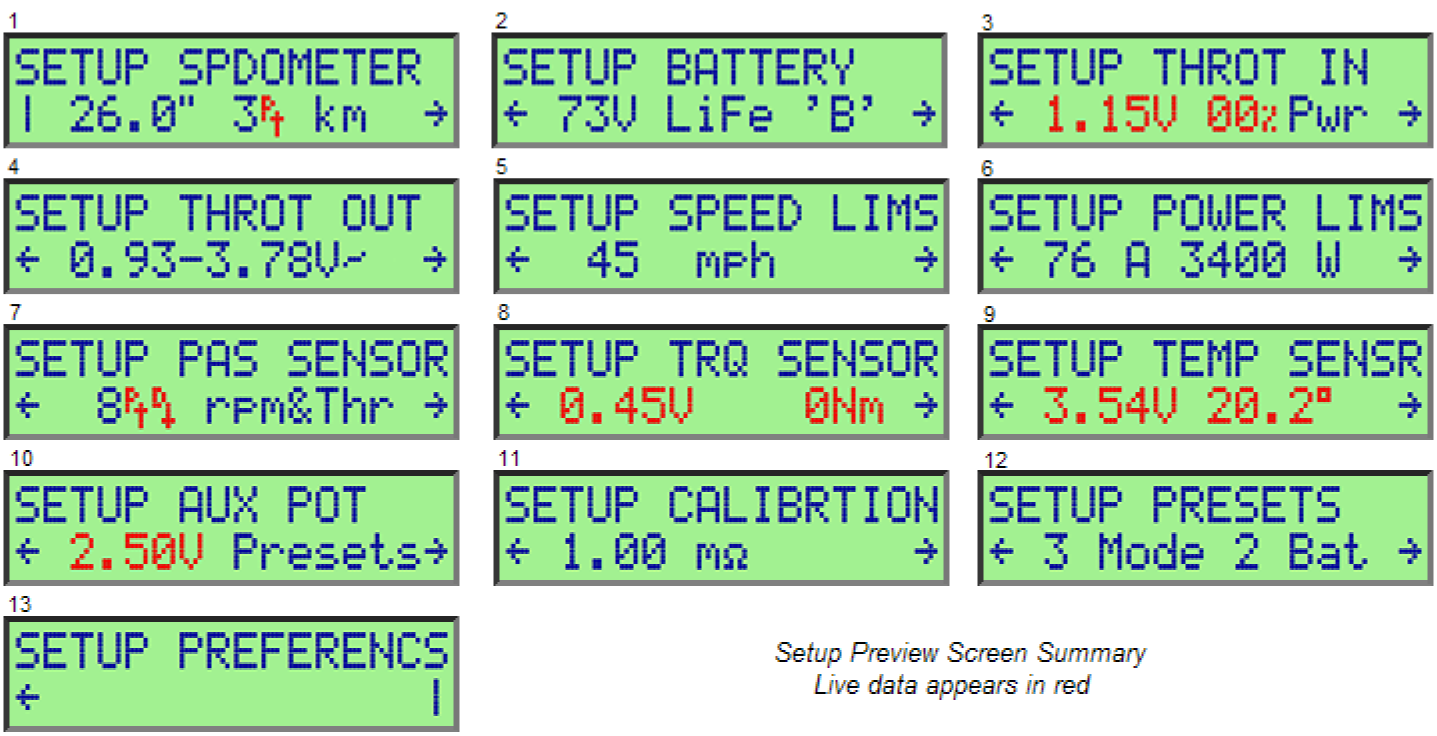
Historical battery statistics (see *'Status Screens'* below) are accumulated independently for each battery preset. By assigning a separate battery preset to each battery pack, unique historical data will be available for individual packs.

2.3 Screen Summary

Although the images in this section were accurate at the time of publishing, they may become dated because of firmware updates and are presented only to illustrate general content, style, and techniques.

2.3.1 Setup Screens

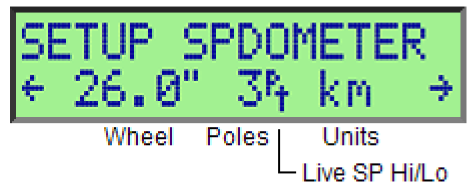
The setup screens are divided into sections, each prefaced with a section preview screen. The preview screens typically show an abbreviated summary of important parameters within the section.



Setup Preview Screen Summary
Live data appears in red

Some preview screens display live data which can be identified by rapid blinking or flickering of the displayed value. These screens are generally self-explanatory, but certain display features warrant special mention.

1. The 'SETUP THROT OUT' screen (#4 above) shows the configured min/max output voltages followed by a small sloping line. The steepness of the slope reflects the relative rate configured for ***ThrO->UpRamp***.
2. The Speedometer and PAS preview screens use animated glyphs 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” points up/down according to the 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.



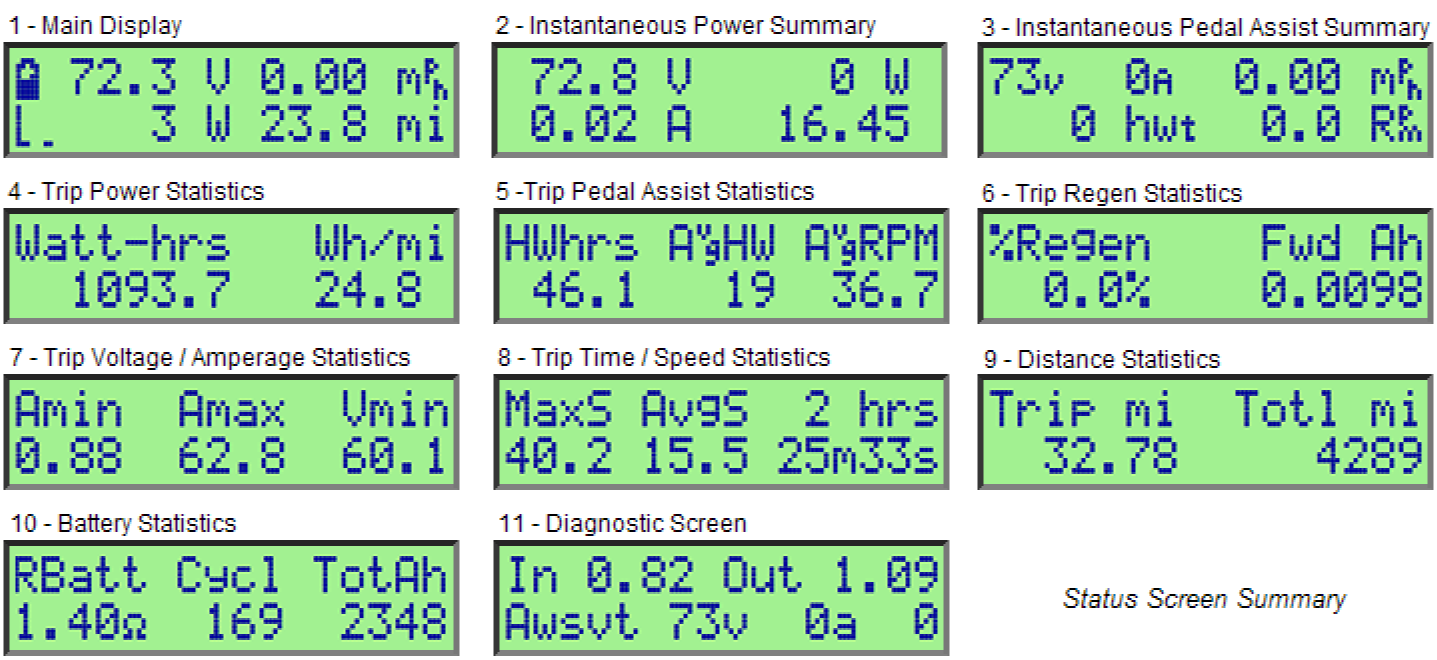
Speedometer Preview Screen

Press-hold the right button on any preview screen to enter the section and edit individual parameters. Each parameter is configured on an individual screen. Advance to the desired parameter screen and press-hold the right button to edit.

Note: Certain Setup parameters have *global* significance and are not part of any preset (e.g. tire circumference) while others are *preset-specific* (e.g. number of battery cells) and may be set differently in each preset. To determine if a parameter is global or preset-specific, see the most recent configuration summary file listed in this post. Individual Setup parameters are described in detail on the Grin Tech V3 web page.

2.3.2 Status Screens

There are eleven Status screens which display information grouped by function. Some information (e.g. speed, Amps) is displayed on more than one screen to give the operator a more comprehensive view without changing screens.

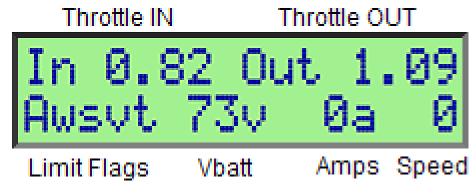


Status Screen Summary

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

1. In PAS screens (#3 and #5 above) 'HW' refers to generated 'Human Watts' measured by the CA.
2. 'Rbatt' on the Battery screen (#10 above) refers to the calculated battery resistance which will normally vary with temperature.

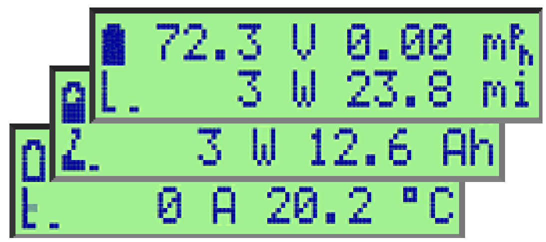
3. The Diagnostic Screen contains a character string of *Limit Flags*. A capital letter indicates that the limit is asserted and may be moderating power to some degree. More than one limit flag may be in play at once. When the throttle is configured for one of the closed-loop throttle modes, the associated 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).



Diagnostic Screen with Current Limit
Capital Limit Flag = Limit Asserted

4. The Main Status screen appears simple but displays the following status information in addition to the numeric values:

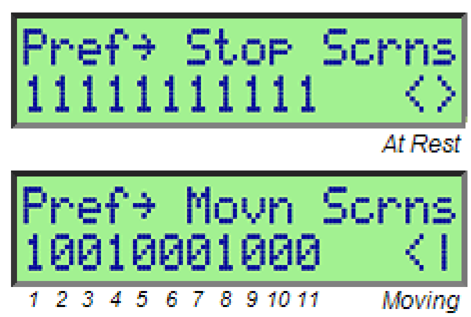
    1. the Battery Gas Gauge indicates battery SOC from Full to Empty,
    2. the Operator Throttle bar graph shows 0-100% of the configured Throttle IN range (far left on 2nd line),
    3. the Human Power bar graph shows measured torque from the torque sensor (adjacent to throttle graph),
    4. an animated ebrake lever glyph replaces the throttle bar graph when ebrakes are applied,
    5. the leftmost numeric value of the 2nd line may be configured to display either Watts or Amps,
    6. the rightmost numeric value on the 2nd line alternates display of distance, Amp hours, and if the sensor is enabled, temperature in degrees C,
    7. exceeding a limit causes the units to flash: '*V*' flashes if below LVC, '*kph*/*mph*' flashes if over the configured speed limit,
    8. the speed digits flash if the present speed is less than the configured *Start Speed*, and
    9. when auto-cruise is triggered a second blinking 'ghost' slider appears on the throttle bar graph at the selected 'cruise throttle' position. The normal throttle slider is unchanged and moves normally. Appearance of the blinking slider gives a visual cue that auto-cruise is engaged and it is no longer necessary to hold the operator throttle in place.



Main Status Screen Variations

Depending on the installed suite of accessories, certain status screens will be of negligible or limited value. The Preferences Setup section provides means to hide any of the eleven screens so only information of interest is accessible. The CA utilizes two such configurations to differently customize displayable screens when at rest and when underway. This allows use of an abbreviated screen set for rapid display navigation while in motion.

The strings of 1's and 0's are configured to enable/disable display of status screens in the order navigated by pressing the right button. In the sample screens to the right, all screens are visible at rest while all but three are hidden when underway – only screens 1, 4, and 8 are accessible.



Visible Screen Configuration

3.0 Basic Installation

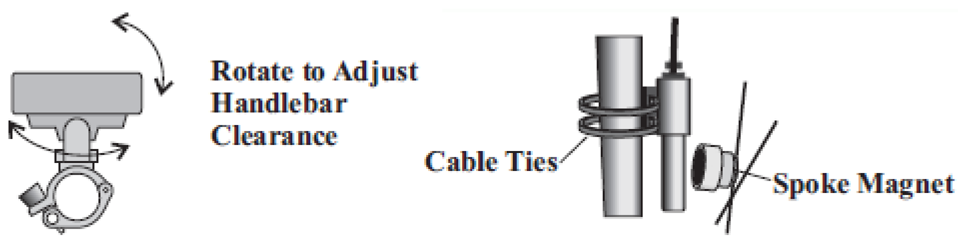
3.1 Install Hardware

1. If upgrading from a CA V2, record the value of the shunt on the existing system prior to removing the old CA.
2. Familiarize yourself with V3 components by briefly reviewing '*Appendix C. CA V3 Connector and PCB Images'.*
3. Mount the CA Console and Optional Wheel Pickup

   Grin Tech CA v2.23 User Manual:
   "The Cycle Analyst display box comes with a mounting bracket for installation on the handlebar of your bicycle. This bracket can rotate in two axis to adjust the display position. Use rubber shims as required around the tube if the clamp diameter is too large for your bar."

   In the case of the CA-SA, CA-DPS, and CA-HC models, there is also a speedometer pickup cable and spoke magnet. The pickup attaches to the fork with two cable ties, and must be mounted to pass within 2mm of the magnet for the speed readings to register. For systems like scooters or motorcycles that don't have spoked rims, a standard magnet can be attached with epoxy to a suitable location on the wheel."

   Multiple spoke magnets may be installed to improve low speed responsiveness when using closed-loop 'speed throttle' (see *' 6.1 Closed-Loop Throttle Modes'*). They need not be placed exactly evenly.

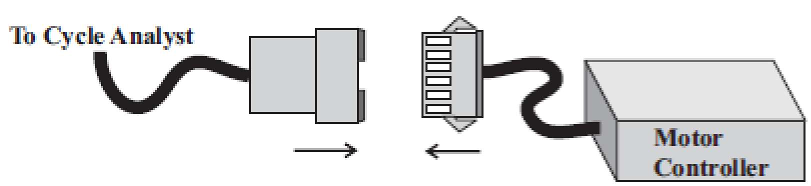


4. Connect the CA Console to Controller, Shunt, and Power

   This step will vary according to the particular model of CA, controller, and shunt.

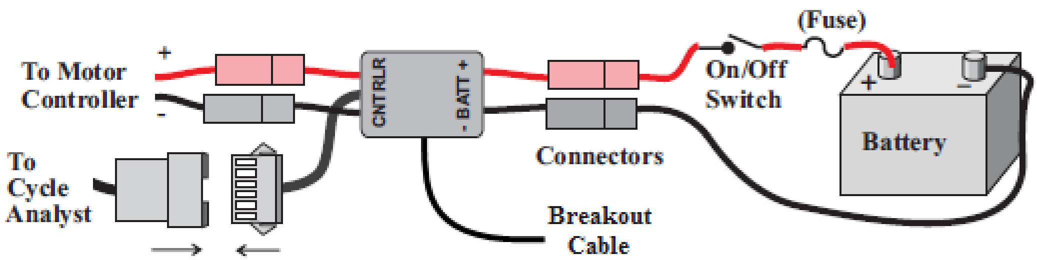
   1. Installation with CA-DP(S) and CA-Compatible Controller

      Grin Tech CA v2.23 User Manual:
      "With the Direct Plug models, simply plug the 6-pin connector of the CA into the matching 6-pin connector on the motor controller. Because there are large voltages present through this connector, it is a good idea to protect the pins with dielectric grease, particularly if it will be exposed to wet conditions."



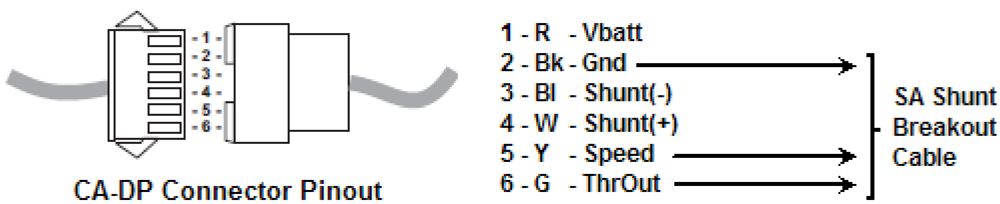
   2. Installation with CA-DP(S) and SA Molded Shunt Module

      Grin Tech CA V2.23 User Manual:
      "With the Stand Alone version, wire the molded shunt in between your battery and the motor controller. This is most conveniently done by attaching connectors on the shunt leads which match your battery connectors. If you have a switch in the system, it is best to wire the shunt after the switch so that the Cycle Analyst powers down."



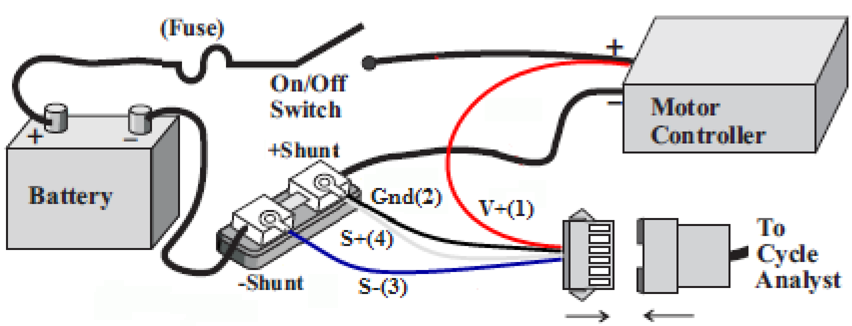
Connect the shunt and console CA-DP connectors as done with the controller connector in Step 1 above.

The optional Cycle Analyst external plug-in shunt comes with a short cable that breaks out the throttle, speedometer, and ground connections from the DP connector. These breakout connections are addressed in following steps.



3. Installation with CA-DP(S) and High Current External Shunt

Grin Tech CA V2.23 User Manual:
The High Current model attaches to a 3rd party shunt resistor and the positive battery lead. The shunt must be connected to the ground side of the battery; connection of the shunt to V+ can damage the circuitry.



Wire a male JST-6 connector as shown above.

The **CA Gnd** (CA-DP(2)) may be attached to either **+Shunt** or **-Shunt**, but the rule is to connect it such that **CA Gnd** is identical to **controller Gnd** to improve the quality of ground-relative signals (throttle). For external shunts, this means **CA-Gnd** should be tied to **+Shunt**. The optional CA-SA external molded shunt follows this same policy. Controllers with an internal shunt normally tie **controller Gnd** to **-Shunt** and so likewise tie **CA Gnd** of the controller CA-DP connector to **-Shunt**.

Connect the shunt and console CA-DP connectors as done with the controller connector in Step 1 above.

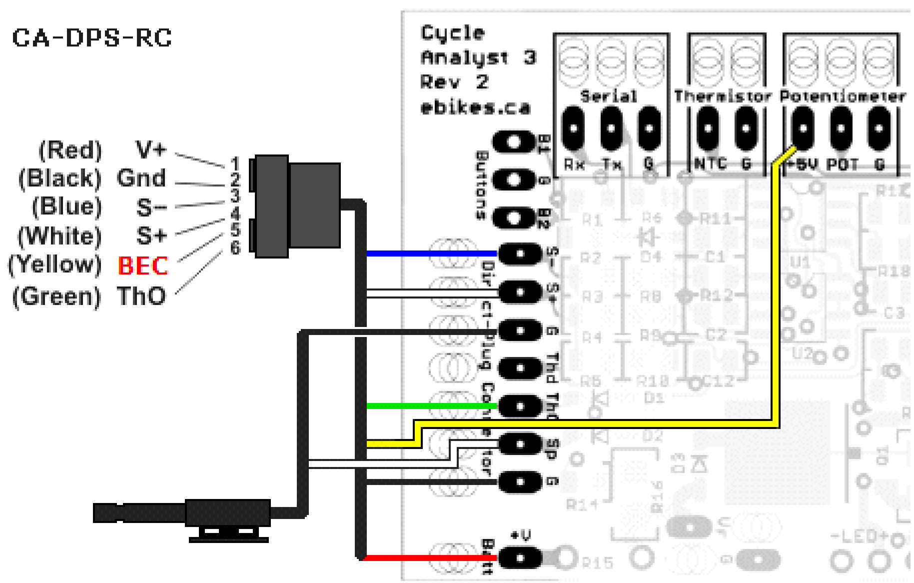
4. Installation with CA-DP(S) and RC ESC (Electronic Speed Controller)

   Wire the ESC using the preceding technique for an external high current shunt. If the current is 50A or less, the CA-SA molded shunt module may be used instead, in which case wire the ESC as in the preceding CA-SA section.

   In either case, also wire CA-DP(6) (**ThrO**) to the ESC Servo Pulse Input.
   This connection is available on the CA-SA molded shunt breakout cable as the green wire.

   If the ESC has no on-board BEC (Battery Eliminator Circuit), then the yellow CA-DP(5) connection for **SP** input can be re-purposed to utilize the CA 5v supply as the BEC.

   - 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.
   - 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

Note: The older V2 DP cable and speedometer pickup are essentially identical to those of the V3 and have the same cable color coding. The V2 shunt is a perfectly acceptable external shunt for V3 operation and the four wires of the V2 shunt have the same color coding as the V3 DP cable/molded shunt combination. This allows reuse of existing V2 wiring if desired. The new V3 molded shunt module has a breakout cable to make throttle wiring a bit easier, but this can be achieved by other means.

After this step the CA will have power and shunt connections but the throttle will require additional attention.

5. Hook up Throttle

Important: See *'Appendix D. Tips and Tricks'* if using a resistive (Magura) throttle.

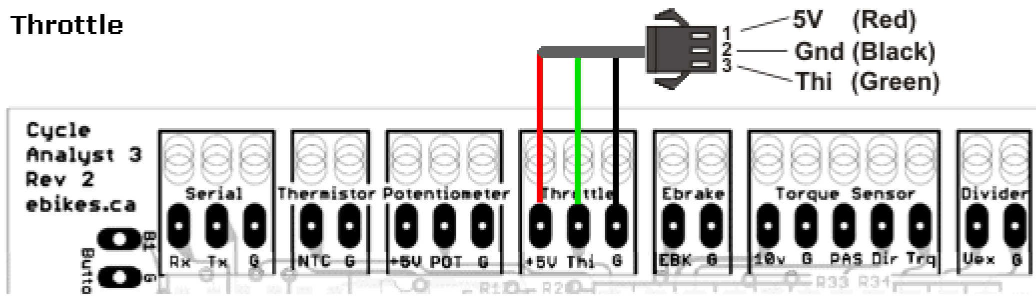
If using an RC ESC, the throttle was already connected in the previous section. Skip to Step 6. - *'Customize Speedometer Installation (Optional)'*.

Otherwise, there are two choices - relocate the operator throttle connections to the CA or use the legacy 'Throttle Override' mode with the throttle connected to the controller. Legacy mode is an easy 'first attempt' just to get the CA running without wiring changes if you are replacing a V2 with a V3, but it precludes access to new V3 throttle-related features.

1. **EITHER - New v3 Operation (CA Provides Throttle – Preferred)**

   To take advantage of the new throttle features, the throttle must be controlled by the CA.

   1. Connect the throttle to the CA using the provided connector.



   2. Hook the CA **Throttle OUT** connection to the controller using one of the following techniques:

      1. Use one of the approaches described in *'Appendix A. '*
      2. As of Dec 2012, the optional CA-SA external plug-in shunt comes with a short cable that breaks out the throttle, speedometer, and ground connections from the DP connector. Attach the green throttle wire to a mating connector matching your controller throttle-in connector.

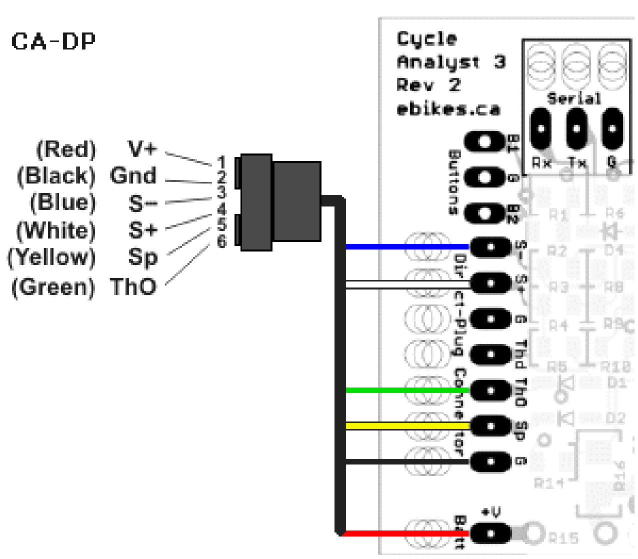
   Note: If the controller does not respond even though the V3 presents a proper throttle control voltage as measured at the controller throttle input pin, then the controller may employ a 'missing throttle' safety circuit. Certain controllers (e.g. Yiyun YK43) block operation if the throttle is unplugged as determined by the absence of current in the throttle connector (+/-) leads. If this symptom presents, simulate the presence of a throttle by adding a 1K resistor across the controller throttle (+/-) leads. To preserve the 'disconnect' safety feature, this is best done across pins of the mating throttle connector carrying the green CA **ThO** wire. This resistor is harmless although unnecessary for controllers lacking a safety circuit.

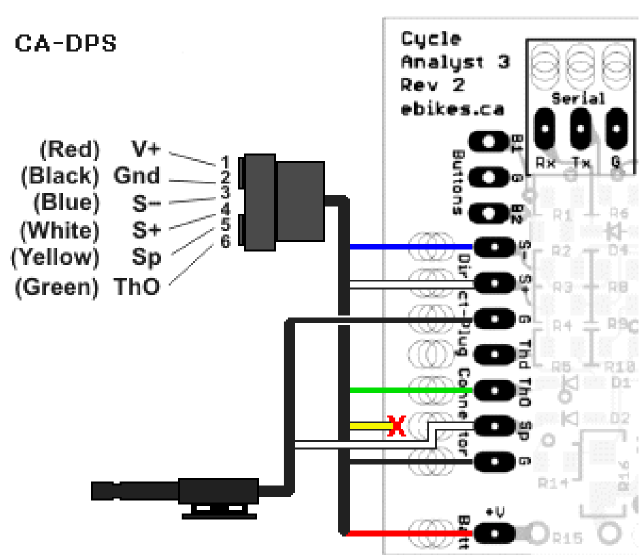
2. **OR - Legacy Operation (CA Limits Operator Throttle - Older v2.x style Operation)**

   Connect the throttle to the controller in the older V2 fashion (e.g. plug in the CA-DP cable).

6. Customize Speedometer Installation (Optional)

   The CA V3 comes in two forms: CA3-DP using speedometer signals from the controller (DD) and CA3-DPS with wheel pickup wired into the console (DD or gear motors).





If you have a CA-DPS (or older beta release version) and wish to eliminate the wheel pickup for DD installations, unsolder the pickup cable from the CA PCB and solder the loose yellow wire from pin 5 of the controller CA-DP connector to the **Sp** pad of the PCB (under the square brown polyfuse). Be sure to reconfigure the speedometer pole count appropriately in the steps below.

The optional CA-SA external molded plug-in shunt comes with a short breakout cable. This may be used in custom installations with a wheel pickup (yellow, black wires) or to route a hall signal (yellow wire) from the controller or controller DP connector.

3.2 Determine and Save Device-Specific Settings – Important!

1. Enter Setup and record the value of ***Cal->VScale*** which calibrates voltage measurements. This is specific to your CA and is set by Grin Tech during production.
2. Determine and save the value to used for ***Cal->RShunt*** which calibrates current measurements. This is one of:
   - 1 mOhm if using a new V2 or V3 external plug-in style shunt
   - the shunt value of your specific controller
   - the specific shunt value of your old V2 wired-in external shunt (value was saved above)
   - the value of some other custom or high power external shunt

3.3 Update CA with Most Recent Firmware

1. Download the most recent firmware from the Grin Tech Site if the CA splash screen does not show the most recent version.
2. Flash the new firmware as described on the Grin Tech Site. At this early stage of product maturity, it's best to order a programming cable (CA3-USB) with your CA. See *' 6.9 Serial Data Port'* for details.

   There are two ways to enter the CA bootloader mode when using the uploader application:

   - If '*Update Firmware*' is pressed with the CA powered down, the uploader will display a message: "Please power cycle the device...".
   - If 'Update Firmware' is pressed with the CA running normally, the CA will detect the uploader, display the screen to the right, and enter bootloader mode without the need for a manual power cycle.

Bootloader Serial Connection Screen

   As a matter of policy, using the most recently available uploader will ensure full feature functionality and will eliminate firmware installation difficulties.

Note: The settings in the Calibration section of Setup can be preserved during re-flash by using the 'NoCal' firmware hex file version. However, flashing erases all 'non-Calibration' settings. When performing subsequent firmware updates, first record all non-Calibration settings so that you may restore them when the re-flash is complete. The configuration summaries located in this post each contain a printable form to assist you.

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

1. Configure Current Range, Voltage Scaling, and Shunt

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

   Cal->Range differs from other Setup parameters and should not to 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 may be necessary.

1. If Maximum Amps < 100A …
   1. Set ***Cal->Range = Lo (W)***
   2. Set ***Cal->VScale*** and ***Cal->RShunt*** as determined above
   3. The flashed ***PLim->AGain*** and ***PLim->WGain*** values provide suitable defaults. (e.g. for v3B22 (AGain,WGain) = (150, 050))
2. If Maximum Amps >= 100A ...
   1. Set ***Cal->Range=Hi (kW)***
   2. Set ***Cal->VScale*** and ***Cal->RShunt*** as determined above
   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 (e.g. for v3B22 revise (AGain,WGain) = (999, 500))

   Important: The value of ***Cal->Range*** is not preserved when flashing and is instead reset to Lo. If you are using the Hi setting and flash, always reset ***Cal->Range = Hi*** as the first configuration item immediately after flash. This will ensure that other preserved calibration values are properly interpreted and that entry fields are correctly displayed.

2. Verify Zero Current Calibration

   With ZERO throttle the CA should show a current reading in the neighborhood of 0-5A due to the controller idle current. If you have large readings, the shunt voltage offset may need correction. Enter Setup and navigate to the **Calibration** section, select ***Cal->ZeroAmps*** and press-hold the right button. This will re-calibrate the present current as 0.0 Amps.

   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.

3.5 Set Up Baseline Configuration

Only a few parameters are required for basic operation; enter Setup and configure only the following items. Other necessary settings are addressed below - do not enable or configure more advanced features until basic setup is successfully completed.

```
(The 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
      3. Spd -> #Poles  = [1]

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 }
```

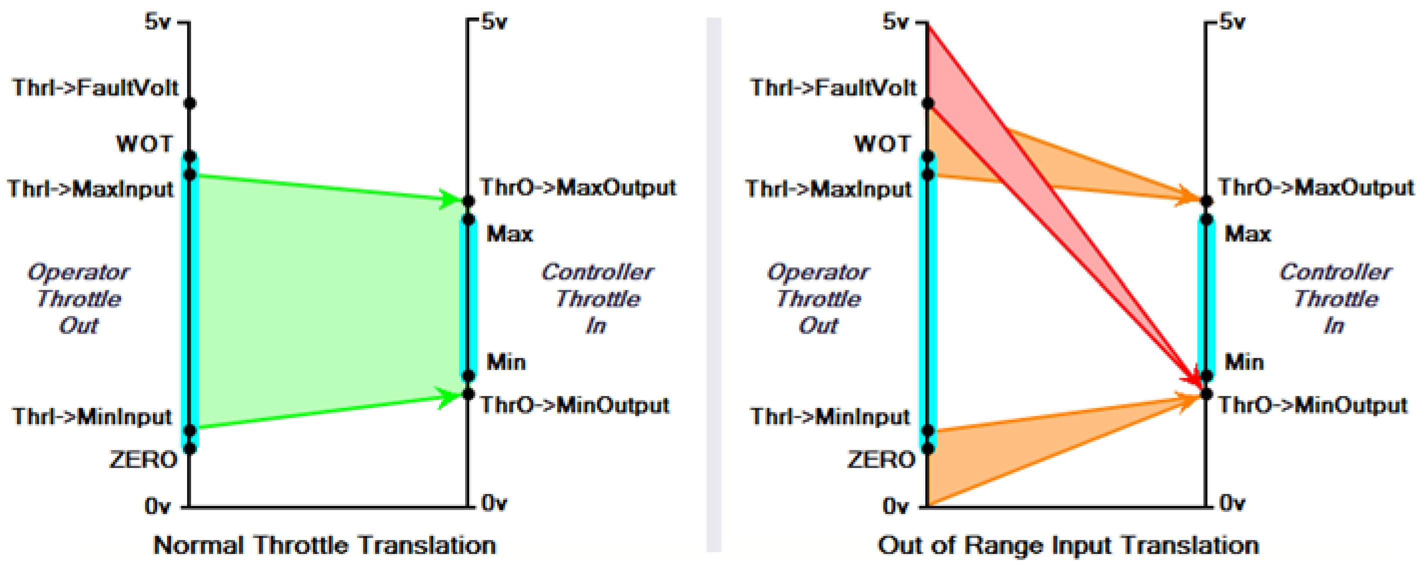
```
5.SETUP SPEED LIMS
      1.SLim -> Max Speed = [99.0] kph


6.SETUP POWER LIMS
      1.PLim -> Max Current = [99.0] Amps
      2.PLim -> Max Power   = [9900] watts

7.SETUP PREFERENCES
      1.Pref -> Main Disp = { Watts | Amps }
      2.Pref -> Vshutdown = [10.0] Volts
```

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
```

3.6 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 as illustrated below. This minimizes throttle dead zones, ensures that 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.



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

The left figure above illustrates how the CA parameters are set near but not exactly equal to the related throttle/controller values to ensure effectiveness in case of small mechanical and electrical variations with time and temperature. For instance, ***ThrI->MaxInput*** and ***ThrO->MaxOutput*** are adjusted so the CA detects max operator throttle slightly before true WOT and accordingly delivers a bit more than the maximum controller input.

The right figure above illustrates the mapping of out-of-range inputs which can be caused by broken throttle connections.

- Breaks in the throttle Sense or 5v+ connections send the **Throttle IN** to 0.0v which the CA maps to ***ThrO->MinOutput***.
- 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->MinOutput***.

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 are required. Please postpone alterations to these recommended settings until the entire throttle adjustment procedure is complete and fully operational.

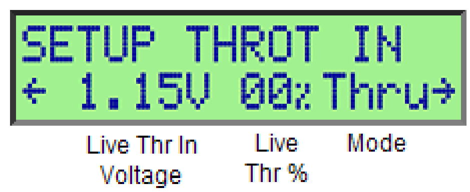
Note: The following adjustments are best undertaken with the bike on a stand so the motor can be run to speed safely. Use care in making these adjustments since it is possible for high motor speeds to be accidentally applied during the adjustment process.

1. **EITHER - New v3 Operation (CA Provides Throttle)**

    1. Set ***ThrI->CntrlMode = Pass-thru***
    2. Jot down the default settings for ***ThrO->UpRamp***, ***ThrO->DownRamp*** , and ***ThrO->FastRamp.***

        To avoid delayed response during adjustment, set these parameters to 0.00 Sec/Vlt
        (the display may change after data entry to the actual allowable minimum values).
    3. Tune ***Thrl->MinInput*** and ***Thrl->MaxInput*** to match the actual throttle voltage range.

        1. Use the live Throttle In voltage display on the bottom of the **Setup Throt In** screen to determine the voltages at ZERO throttle and WOT.
        2. Transfer these readings to ***Thrl->MinInput*** and ***Thrl->MaxInput*** . Increase/decrease the Min/Max settings respectively by 0.05-0.10V over the actual readings to ensure full throttle range e.g. if read
        (min,max) = (1.12, 3.93) then set instead to (1.17, 3.88)



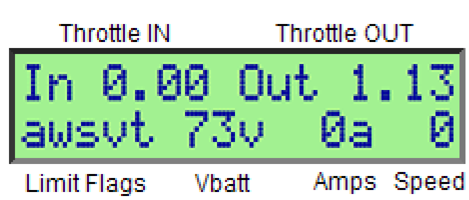
Throttle-In Preview Screen

    4. 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 ~= 4.5v.
    5. Adjust ***ThrO->MinOutput*** and ***ThrO->MaxOutput*** 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 min/max 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 shutdown from an input voltage fault. Slowly ramp the throttle up until the controller shuts down from throttle overvoltage fault; note the **OUT** voltage when this occurs and in the next steps ensure that ***ThrO->MaxOutput*** is at least 0.25V less than this value.
        Disregard this test if the controller does not shut down (it may lack this feature).



Diagnostic Screen

        4. Transfer these readings to ***ThrO->MinOutput*** and ***ThrO->MaxOutput***. Decrease/increase the Min/Max settings respectively by 0.05-0.10V 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 (1.35, 3.95) instead.

5. If necessary, fine tune the ***ThrO*** settings so there is very small 'dead zone' at zero throttle and WOT.

   Verify 'dead zones' by watching Watts on Main Display while moving throttle near/at zero and WOT - Watts will not change in dead zones.

6. Restore ***ThrO->UpRamp, ThrO->DownRamp***, and ***ThrO->FastRamp*** to the default settings recorded earlier.

2. OR - Legacy Operation (CA Limits Operator Throttle)

1. Set ***ThrI->CntrlMode=Disabled***
2. In legacy mode, ***ThrI->MinInput*** and ***ThrI->MaxInput*** have no effect; these parameters may be left at the default settings.
3. In legacy mode, ***ThrO->MinOutput*** and ***ThrO->MaxOutput*** are equivalent to the CA v2.x parameters ***ITermMin*** and ***ITermMax*** respectively. To paraphrase sections 8.11 and 8.12 of the CA v2.23 Manual:

> “***ThrO->MaxOutput*** 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->MinOutput*** 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. Range is from 0 to 4.99V, and must be less than ***ThrO->MaxOutput***.”

   These values are ideally 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 non-legacy mode, there is no way 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 and adjust for more optimal limiting operation later if necessary.

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

3.7 Test Throttle and Limit Settings

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 pronounced dead zone and no motor creep.
     Otherwise, revisit the ***ThrI->MinInput*** and ***ThrO->MinOutput*** adjustments above.
   - Verify that at WOT there is no pronounced dead zone and that the bike delivers maximum power.
     Otherwise, revisit the ***ThrI->MaxInput*** and ***ThrO->MaxOutput*** adjustments above.
2. Verify Limit Configuration

   If the throttle is correctly adjusted and the bike still fails to achieve full power, then some Limiting Parameter may be unexpectedly coming into play. Use the 'Limit Flag' display on the Diagnostic Screen to identify any limits in effect (see table below). Upper case flag characters indicate which Limiting Parameter is presently moderating throttle output and so may require adjustment. Gain Parameters are discussed in the next section.

   In legacy mode, 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->MaxOutput*** may be set too low causing limiting to accidentally be in effect in spite of Limit Flag indications. Temporarily adjust ***ThrO->MaxOutput = 4.99***. If this remedies the problem, then take throttle voltage measurements to more accurately determine the minimum voltage necessary to achieve maximum unloaded motor speed at WOT. Alternatively, reset ***ThrO->MaxOutput*** to the default then iteratively increase the value by 0.1v and test until no further WOT speed improvement occurs.

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 you actually exceed the limit. There are other aspects of the speed control logic that can lead to limiting or speed oscillations (next section) but that are difficult to evaluate as causing a problem. As a result, there can be a speed-related issue with no 'S' Limit Flag.

At this point the throttle and basic limiting adjustments are complete. It remains only to adjust throttle ramping and, if necessary, to adjust gains to minimize power oscillations.

4.0 Throttle Ramping Adjustments

Throttle ramping is not available in legacy mode.

Throttle ramping affects Throttle OUT universally and so plays a role in operator throttle, closed-loop throttle, PAS, auto-cruise, etc. The ramping logic appears as a clamping mechanism to moderate the rate of throttle change. It only participates when the the rate of Throttle OUT change exceeds configured limits – at lower rates it has no effect. Although adjusting these settings to achieve desired behavior is a matter of personal preference, ramping can have an effect on the stability of controller current and speed limiting logic. It is best to configure ramping as close as possible to final desired values before gain adjustments are undertaken. This policy allows conservative ramping adjustments to be made later with little likelihood of stability impact.

Adjust ***ThrO->UpRamp, ThrO->DownRamp***, and ***ThrO->FastRamp*** as appropriate to achieve the desired throttle response. All ramp settings are in sec/V (inverse rate) so larger values yield longer ramp times.

UpRamp is a limit controlling the maximum rate at which power can be applied – lower rates are unaffected. This slows power application giving smoother getaways without harsh acceleration. Gear motors, mid-drives, and powerful DD motors may benefit from higher values to moderate power on dead starts.

FastRamp is similar to ***UpRamp*** and is set to a faster rate. The CA uses ***FastRamp*** when current is less than 2A to allow the motor to quickly come to speed if the vehicle is already underway. The CA switches to ***UpRamp*** when current is 2A or greater (load is detected) to apply slower ramping.

DownRamp is a limit controlling the maximum rate at which power can be reduced – lower rates are unaffected. This generally should be set to the default or faster so closing the throttle has a fairly immediate effect. Certain types of drive systems may benefit from slower ramp times. Ebrake application bypasses ***DownRamp*** and always has immediate effect.

ThrO->UpRamp is the only preset-specific parameter so all other ramping adjustments will be shared across presets.

5.0 Gain Adjustments: Minimizing Surging or Speed Oscillations

Control overshoot and power oscillations may occur whenever the Cycle Analyst provides current, power, or speed limiting. Alternate closed-loop throttle modes (e.g. Current Throttle) where the throttle sets a limit so limiting is always in effect are just special cases of classic 'maximum value limiting' (e.g. ***MaxCurrent***).

The Cycle Analyst utilizes PI (proportional-integral) and PID (proportional-integral-derivative) controllers for current/power and speed limiting respectively. The behavior of this controller logic is determined by gain settings that affect the degree of feedback from measurements of battery voltage, shunt current, and speed. These gain settings allow the Cycle Analyst to be tuned for proper operation across a wide range of vehicle powers and weights. Although the default gain settings will prove suitable for many low to moderate powered builds, some vehicles will 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 table in preceding section). 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. The Limit Flag(s) changing state in synchronization with the surging will indicate the gain settings of interest.

All gain settings are global parameters and so will be shared across presets.

In legacy mode, slow limiting correction can also occur if ***ThrO->MinOutput*** or ***ThrO->MaxOutput*** are set far from the desired values described earlier (i.e. default settings may work, but suboptimally). This can cause correction delays as the CA limiting voltage takes time to change across the 'dead zone' between the actual and optimal settings. This problem mode can be identified by examining the Throttle OUT voltage on the Diagnostic Screen and watching if there is excessive change with no apparent effect on bike power - followed by the desired correction. If necessary, adjust the ***ThrO*** parameters as described above.

5.1 Current and Power Limiting (Current and Power Throttle)

For these modes, reducing the related gain setting minimizes overshoot and dampens oscillation, while excessive reduction leads to sluggish response. Adjustment is straightforward. 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.

5.2 Speed Limiting (Speed Throttle)

Here is a summary of the three speed-related gain adjustments:

Grin Tech V3 web page:
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.

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.

DSGain: Differential feedback term for speed control loop. This is used to dampen oscillations from speed limiting.

Because the speed PID controller tries to anticipate limiting situations before they occur, the some vehicles may experience cutouts during hard acceleration. The problem arises as the vehicle rapidly accelerates toward the speed limit and the Cycle Analyst preemptively reduces the throttle to avoid overshoot – even though the limit has not yet been reached. This cutout symptom is an indication 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.

The more complex PID controller employed for speed limiting is of a type that classically presents a greater adjustment challenge. 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 B. Tuning Speed Control Gain Parameters*'.
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*** = 1, ***PSGain*** = 0, ***DSGain*** = 0.

6.0 Advanced Features

The following sections describe features that can be utilized once basic setup is complete.

6.1 Closed-Loop Throttle Modes

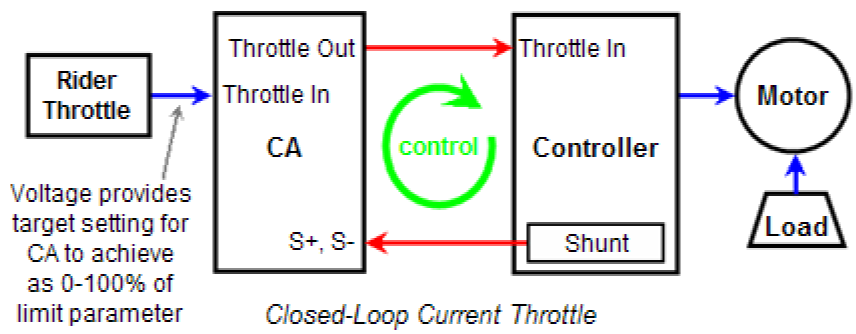
Selecting 'Current Throttle' Mode

1. ***Overview:*** If in non-legacy mode, the CA offers three additional closed-loop throttle modes that can give substantially improved throttle control:

   - Current Throttle
   - Power Throttle
   - Speed Throttle

   These are 'fly by wire' modes where the operator throttle is not passed through to the controller but rather 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 how well it has done 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. Because the load is reflected through the motor back to the shunt, the CA will maintain the target current regardless of changes in terrain.

   In this mode any unpleasant non-linearities in the controller-motor curves are of little consequence as adjustments to achieve the desired output are exclusively the responsibility of the CA, not the rider.



Closed-Loop Current Throttle

   For example, in the case of 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 (i.e. set as true max safety limits) so only the single throttle limiting parameter is generally in play.

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

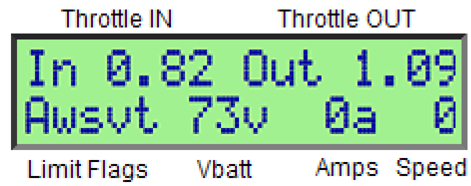
   Note that the CA Speed Throttle is completely different than the Infineon controller throttle logic which is often referred to as a 'speed throttle'. The CA Speed Throttle is a true closed loop control system that measures the bike speed and corrects for variations. In contrast, the Infineon throttle 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; this results in varying speed with load and terrain.

   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 *' 5.0 Gain Adjustments: Minimizing Surging or Speed Oscillations'.* Existing ramping settings are 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 long linear magnet or resistive throttles like a Magura will yield the best results.



Current Throttle = 'A' Limit Flag

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:

   1. 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.

   2. 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 good results. Additional magnets may be ordered from Grin Tech.

6.2 Auto-Cruise Control

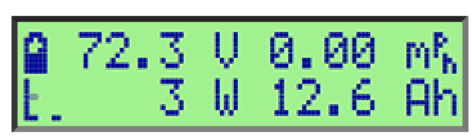
The cruise control feature is firmware-only. The option is enabled by setting ***ThrI->AutoCruis*** from ***Off*** to one of several preset hold times. This is a preset-specific parameter that determines the period of time that the operator throttle must be held stationary to engage auto-cruise.

Set AutoCruise Hold Time

The ***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 'ghost' 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 and the throttle can be released.

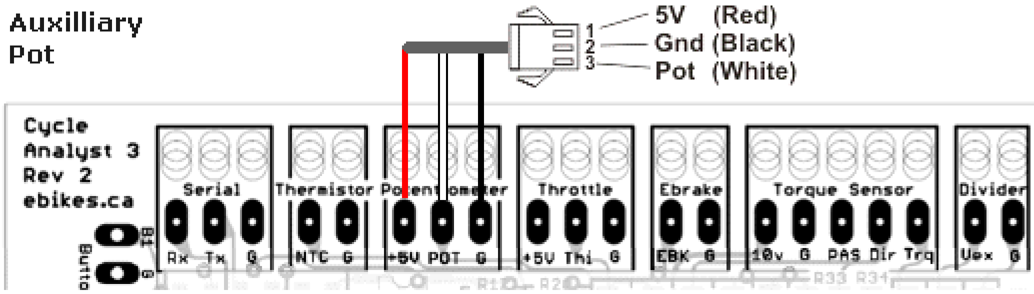


AutoCruise Throttle Indicator

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

Auto-cruise can be used with any throttle mode: *PassThru, Current, Power, or Speed*.

6.3 Auxiliary Pot



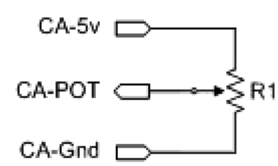
1. ***Grin Tech:***
   "The purpose of this input is to allow on-the-fly adjustments of one of the CA's limit values (i.e. the current limit, speed limit, or power limit). That can be accomplished either via a potentiometer, or for discrete settings with a multi-position switch and resistor dividers. A 0-5V signal range is allowed, and it defaults to 5V if left disconnected.**"**
2. ***Modes:*** The AUX Pot input can operate in either of two modes determined by ***Aux->Function***:
   - **Limits**: The applied voltage scales a limiting parameter or
   - **Presets**: The applied voltage selects one of the available mode presets.

   1. ***Limits 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	Trq -> Asst Level

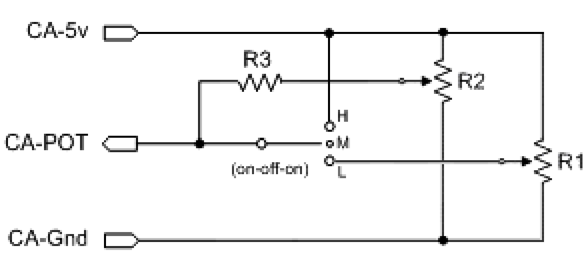
Any device with a voltage output in the range of 0-5v may be used. Examples of external controls:

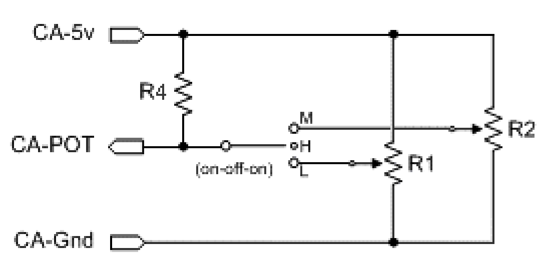
Potentiometer: This is the most basic adjustment technique. R1 = 5K linear taper pot. To prevent contaminants from entering the device either use a 'sealed' type pot, enclose it completely, or seal it using a product like *Liquid Lectric Tape* or *Plasti-Dip*.



Throttle: A resistive or hall effect throttle may be substituted for the potentiometer. For instance, a thumb throttle may be located on the left side and be modified so 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 position is a little fussier to achieve. R1 = R2 = 5K 20 turn trimpots, R3 = 7.5K, R4 = 10K.

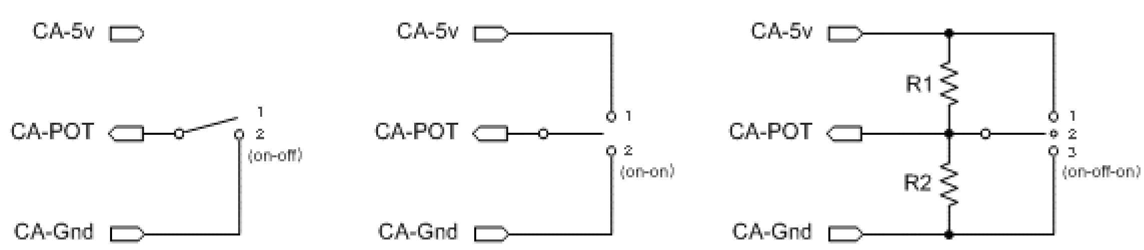




Depending on the ***Aux->ScaleLim*** setting, these sample circuits may be used as 0-100% PAS Assist knob, a 0-100% speed limit knob, a 3-position current or power limit control, etc. These examples can be combined. For instance, the 'Low' trimpot of the 3-position switch might be replaced with a 5K linear pot to add an adjustable low setting or to do double duty as a PAS Assist Level in a different preset.

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 measurements from the AUX Pot Setup preview screen - see below.

2. ***Presets Mode:*** This provides on-the-fly preset selection using external switch control. The mode preset is selected 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 respectively. The highest voltage band is preset #1.

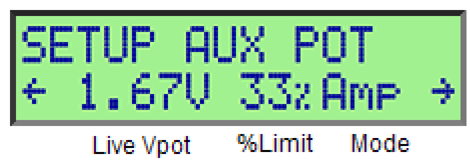


When a new preset is selected, a “CHNG MODE PRESET” screen is briefly displayed.

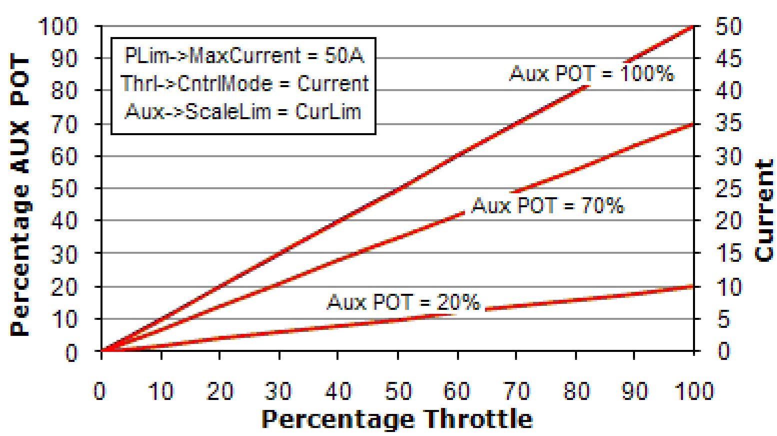
The left and middle diagrams above will select from two presets with the middle circuit being perhaps a bit more noise immune. The right diagram uses R1 = R2 = 4.7K resistors and will select from three presets. These particular sample circuits assume ***Aux->MinAuxIn*** = 0.0v and ***Aux->MaxAuxIn*** = 4.99v although other circuits might use a different range.

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

4. ***Throttle Scaling:*** When using both closed-loop throttle and Aux POT features it is important to configure ***Aux->ScaleLim*** and ***ThrI->CntrlMode*** to use the same limiting type to obtain automatic throttle scaling. Throttle scaling causes the throttle maximum to be limited by the **Vpot** value instead of the configured limiting parameter maximum. These matching settings are shown above in the *'Throttle Mode Summary' table.*



Aux Pot with 3-position Switch and Current Throttle

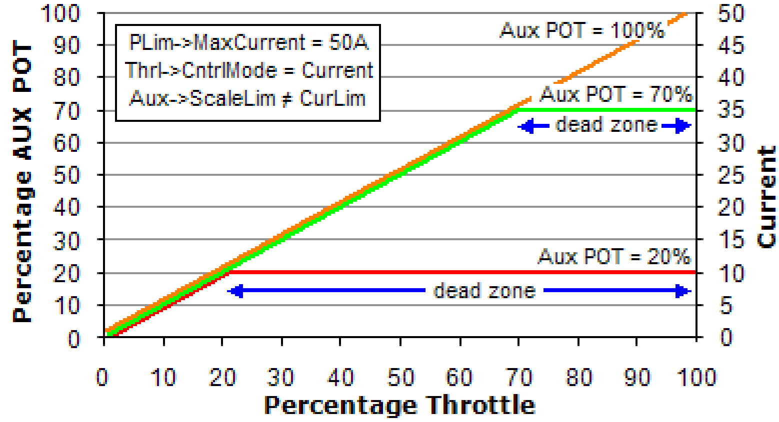


Throttle Scaling - Same Throttle and Aux POT Limit Type

For example, if ***PLim->MaxCurrent=50A***, ***Aux->ScaleLim=AmpsLim***, ***ThrI->CntrlMode=Current***, **Vpot** (min,max) is (0v,5v), and **Vpot** = 1.0v (20% of 5v), then the controller will be limited to 20% of 50A or 10A.

The sample plots to the left show the controller 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 effect is linear, ZERO to WOT.

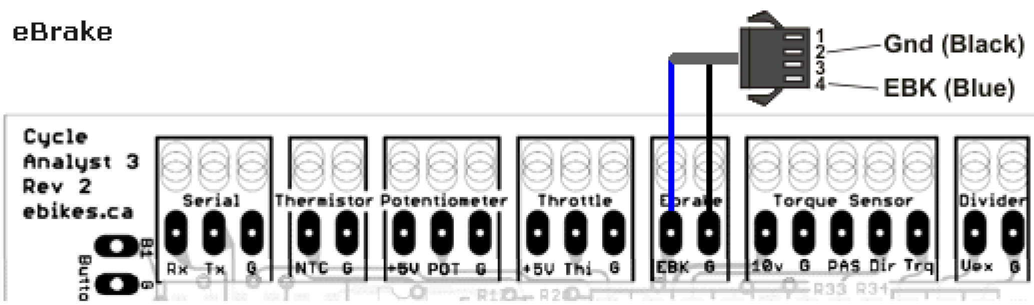
In contrast, the plot to the right shows an example where throttle and Aux POT have differing limit parameters (e.g. current and power). In this case there is no throttle scaling; instead, the separate Aux POT limit imposes a ceiling above which further throttle rotation has no effect. This causes an operator throttle 'dead zone' identical to that produced by the simple limiting of legacy mode (V2) operation.



Dead Zones - Different Throttle and Aux POT Limit Types

5. ***Electrical Characteristics:*** To avoid affecting external resistor dividers, the Aux POT input is the only input that does not have a pull-up or pull-down resistor on the PCB. The applied impedance should be no more than 10K for the A/D converter to achieve full 10bit accuracy.

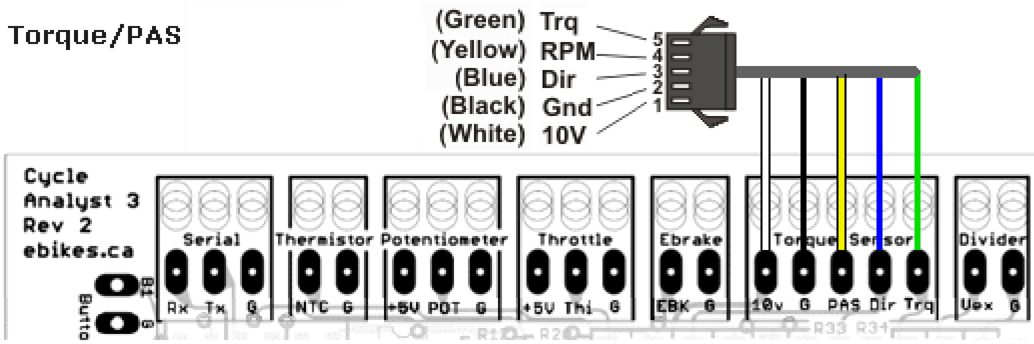
6.4 eBrake



1. ***Grin Tech:***
"This input has an onboard 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 and forces the CA's throttle output to 0V."
2. ***Device Connection:*** If you have simple throttle cutout on ebrake, then you may connect your ebrake to the Cycle Analyst using the connector illustrated above. This will work in either new or legacy modes. However, if you are using controller regen or auto-cruise that rely on direct ebrake input, then you must run the ebrake connection to the controller instead of the Cycle Analyst.
3. ***Operation:*** The Cycle Analyst **EBK** input is asserted when low. This causes **ThO** to be driven to 0.0v; no other operation reduces **ThO** lower than ***ThrO->MinOutput*** making it possible for an external circuit to examine the **ThO** level to discriminate between throttle ZERO and ebrake application.

   Ebrake application also suppresses ***ThrO->DownRamp***, sending **ThO** to 0.0v immediately.
4. When **EBK** is asserted, an animated eBrake graphic replaces the Throttle Gauge on the main display (see *'Main Status screen'*).
5. ***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 makes a suitable sensor.

6.5 Pedal Assist



1. ***Grin Tech:***
   "<u>10V:</u> 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. *<u>Current draw from this line should be limited to 15mA max and only with 48V or lower batteries.</u>*

   <u>Pedal Sensor Input (RPM):</u> 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.

   <u>Pedal Direction Input (Dir):</u> 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.

   <u>Torque Sensor (Trq):</u> 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), 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. ***Sensors:*** The pedal assist connector is primarily designed for the THUN torque sensing bottom bracket but also supports similar units from FAG from Germany and GreenTrans from Taiwan. Alternatively, it can use a simple PAS cadence sensor providing a 0-5v pulse output. The direction input can be a Fwd/Rev level or a pulse input providing quadrature encoding in concert with the RPM signal. PAS rings are available with varying numbers of poles - typically less than 12. The more magnets or pulses per wheel rotation, the faster the CA can detect and react to start of pedaling.

   Note: The PAS sensor 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. See *'Appendix D. Tips and Tricks'* for a means to add a second pickup to simple PAS wheels to discriminate direction.

3. ***Sensor Power:*** Certain PAS cadence sensors utilize hall sensors instead of reed switches. These sensors require a +5v supply which may 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.

   <u>IMPORTANT: *THUN Power Requirements:*</u> Please pay particular attention to the current limit of the CA +10v supply when powering a Thun or similar sensor. Higher battery voltages require the use of an external DC/DC converter to power either the THUN or the Cycle Analyst.

   Please inventory the total CA current requirements and choose an appropriate power strategy as described in *' 6.8 Cycle Analyst as a Power Source'* when adding any sensor or accessory to the CA. This is particularly important for torque sensors or dual hall effect PAS sensors because of the higher current requirements.

4. ***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 constant regardless of pedal RPM. Torque sensors provide the same signals as PAS sensors but add a torque signal that varies linearly with torque. This variable signal can be used to provide proportional assist according to applied rider effort. If the Cycle Analyst is configured to ignore the torque signal, a torque sensor will operate as a simple PAS sensor.

   The simple on/off nature of assist from a PAS sensor warrants no special logic beyond enabling assist only when the optional direction signal indicates 'Fwd'. In the case of torque sensors, the Cycle Analyst logic requires that the rider actually be pedaling to enable assist. Simply standing on the pedals to generate a large torque signal is ineffective. Measured rider torque is averaged over each full pedal rotation rather than over a specific time period. This eliminates undulation from aliasing of the average rate with pulsating pedal torque.

5. ***PAS Configuration:*** Individual parameters of the Setup ***PAS*** and ***Trq*** sections are described on the Grin Tech Site. Although configuration is generally straightforward, the following presents detailed information about select parameters.

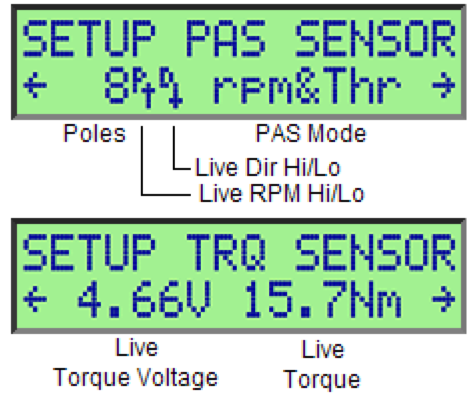
   1. ***PAS->Plrty*** controls Fwd/Rev direction determination for both level (**Dir**) and quadrature (**RPM/Dir**) signal types.
   2. If there is no quadrature sensor, then ***PAS->Quadrtr*** <u>must</u> be disabled. If there is a quadrature sensor then ***PAS->Quadrtr*** may be either enabled or disabled. If ***PAS->Quadrtr*** is disabled then only the falling signal transitions are used to detect pedaling, whereas both rising and falling edges are used if it is enabled. This improves pedaling detection responsiveness by doubling the number of indications per revolution.
   3. Details of ***PAS->PAS Mode*** parameter values:

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

      1. <u>“OR” Modes</u> – PAS and throttle are always enabled and either provide power. ***PAS->MxThrotSpd*** has no effect in these modes.
         1. ***RPM | Throt***
            - *Pedaling without throttle* causes full throttle to be applied until a limiting parameter comes into play. In this mode the standard limit parameters ***PLim->MaxCurrent***, ***PLim->MaxPower***, or ***Slim->MaxSpeed*** serve as adjustments for assist level.
            - *If throttle is applied,* it operates normally and disables PAS.
              Since the same limits remain in force, WOT gives the same assist as PAS.
         2. ***Trq | Throt***
            - *Pedaling without applied throttle* results in proportional PAS assist power according to ***Trq->AsstLevel*** times the detected torque.
            - *If throttle is applied*, it operates normally and disables PAS.
      2. <u>“AND” modes</u> – The throttle is enabled without pedaling at speeds up to ***PAS->MxThrotSpd.*** At higher speeds, pedaling is required to enable the throttle. These modes in conjunction with ***PAS->MxThrotSpd*** can provide compliance with a variety of pedalec legal requirements.
         1. ***RPM & Thot*** – in this mode there is no PAS power assist
            - Below ***PAS->MxThrotSpd***, the throttle is enabled and operates normally.
            - Above ***PAS->MxThrotSpd***, if pedaling is detected, the throttle is enabled.
         2. ***Trq & Throt***
            - *Pedaling without applied throttle* results in proportional PAS assist power according to ***Trq->AsstLevel*** times the detected torque.
            - 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.

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 ('yes' for Thun, 'no' for PAS wheels).

7. ***Torque Offset:*** 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->TrqOffset*** operates much as does ***Cal->ZeroAmps -*** Press-Hold to store the present torque output voltage as the baseline for zero torque.



PAS/TRQ Sensor Preview Screens

8. ***External 'Assist Level' Control:*** An external Assist Level adjustment knob can be added using the **AUX Pot** input – see *' 6.3 Auxiliary Pot'*. This is configured differently for PAS and torque sensors.

    1. PAS cadence sensors provide on/off control of a fixed assist level that is determined by the standard current, power, and speed limit parameters. To configure:
        - Set ***Aux->Function*** = Limits
        - ***Set Aux->ScaleLim*** = one of { PowerLim | AmpsLim | SpeedLim }. This will cause the control knob to scale one of ***PLim->MaxPower***, ***PLim->MaxCurrent***, or ***SLim->MaxSpeed*** respectively from 0-100% of the configured value. By this means PAS assist will encounter the reduced limit and hold assist to that level.
        - Since the throttle is also affected by these limits, it may be best create a dedicated PAS preset with a reduced limit so that less restricted throttle output is readily available in other presets.
    2. Torque sensors provide proportional assist and are specially supported by **AUX Pot**. To configure:
        - Set ***Aux->Function*** = Limits
        - Set ***Aux->ScaleLim*** = Pas Level. This will cause the control knob to scale ***Trq->AsstLevel*** 0-100% of the configured value of Watts per Newton-meter, reducing the number of assist Watts provided for each Nm of torque.

    Please see *'Appendix D. Tips and Tricks'* for an alternate means to install an Assist Level control for PAS cadence sensors.

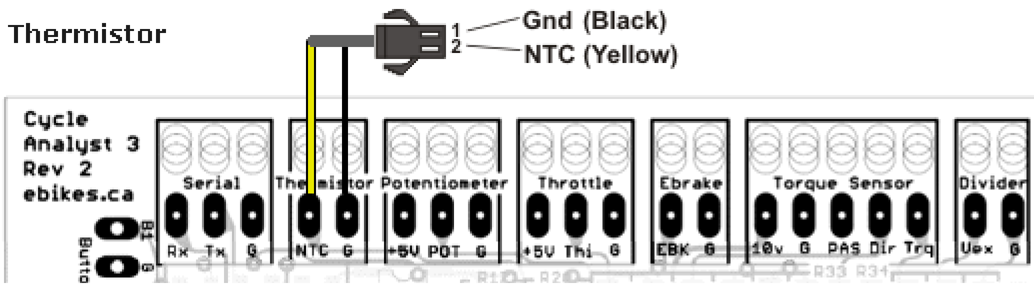
9. ***Thun Specifics:*** Grin Tech provides a compatible Thun X-Cell RT digital bottom bracket with the proper connector to mate with the CA-TRQ/PAS JST-5. The connector wiring is as follows:

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

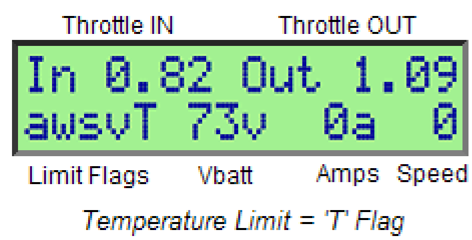
The Thun X-CELL RT digital generates 8 pulses per rotation and has a power requirement of 7-16v at 20ma. The nominal zero Nm offset is 2.5v and the max (+) torque is 200Nm at 4.5v. The **RPM** and **Dir** signals are quadrature encoded as cosine and sine waveforms respectively.

6.6 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 Cycle Analyst limits ***PLim->MaxCurrent*** linearly 100-0% as the temperature rises in the configured danger range. Maximum current begins to be limited (100%) at ***Temp->ThrshTemp*** and is finally reduced to zero (0%) at ***Temp->MaxTemp***. The ***T*** *Limit Flag* indicates that temperature limiting is in effect.



3. ***Supported Devices:*** This input can be supplied by either a 10K NTC thermistor or a linear temperature sensing IC 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. Unfortunately, the LM35 may come pre-installed in some motors as the only option. In such cases, CA/LM35 electrical incompatibly can be remedied by minor modification of the Cycle Analyst PCB. See *'Appendix D. Tips and Tricks'*.

4. ***Thermistor Selection:*** The present firmware has a hard coded calibration for 10K NTC thermistors with a beta constant of 3900. This gives workable accuracy for beta values of 3800 - 4000.

5. ***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.

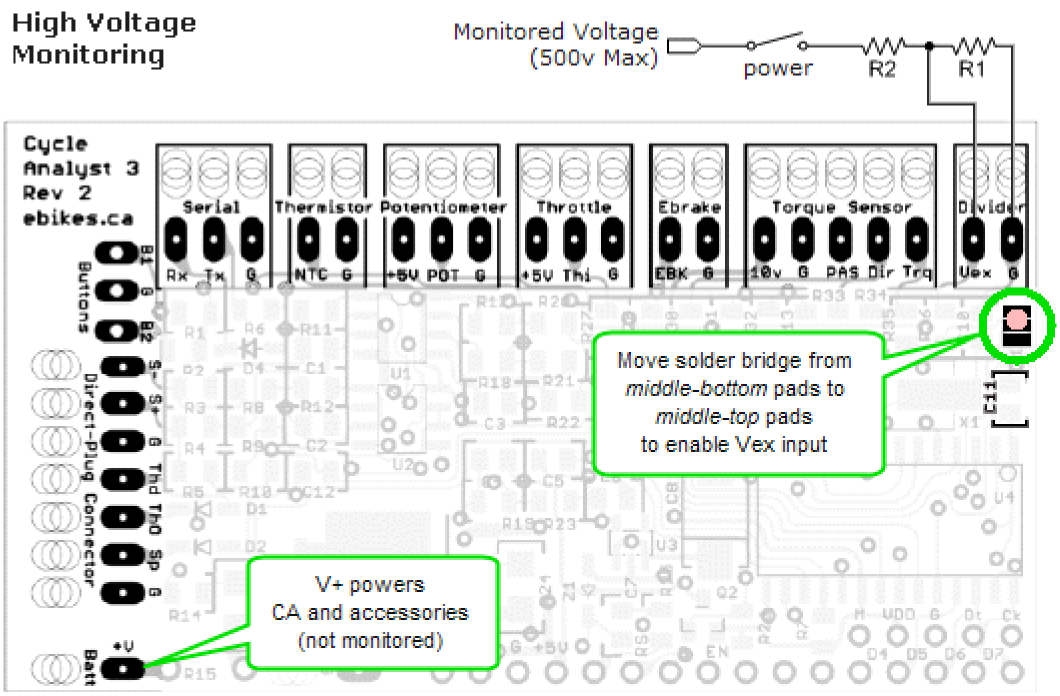
6. ***Ground Reference:*** It is recommended that the thermistor ground be tied to the provided CA PCB Gnd pad and not be shared with other devices. This policy minimizes unwanted voltage offsets between the CA and thermistor grounds which will affect the measured sensor voltage. For example, temperature errors can occur where a motor temp sensor shares a Gnd lead with hall sensors (controller Gnd) and a high current headlight is run from the CA external power jack causing the CA ground reference to rise slightly above that of the controller.

7. ***Jitter:*** Some display jitter is not unexpected but does not adversely affect measurement accuracy or limiting functions. The jitter is due in part to the absence of display averaging in firmware through B22.

   Excessive jitter may be reduced by soldering a monolithic 0.47uf capacitor across the thermistor NTC and Gnd pads. However, firmware alterations planned for B23 should eliminate visible jitter and make the capacitor fix unnecessary.

6.7 High Voltage Vehicle Support

1. ***Grin Tech:* "**Battery Power (V+): This is the V+ supply of the battery pack, used both to power the CA and also to sense the battery voltage. The maximum supply voltage with no accessories is 150V, but this must be derated if there are other devices (Torque Sensor, Input Throttle etc) also drawing power from the CA.*"*



2. ***High Voltage Operation:*** Voltages up to 500vdc may be monitored by redirecting the CA voltage measuring functionality from the power supply **+V** PCB pad to the **Vex** pad. The **+V** pad continues to supply CA power.

   Locate the three adjacent solder pads shown above and relocate the solder bridge from the [middle + bottom] pads to the [middle + top] pads. With this modification, the **+V** pad only supplies power while the voltage sense input is taken from [**Vex** and external divider] instead of [+**V** and on-board divider].

   Note: Rev 2 boards may have an SMD capacitor hand-soldered from C11 to the middle/bottom 'bridge' pads. Remove this capacitor.

   An external resistor divider must be provided as shown to scale the monitored voltage to 0-5v with R1 limited to no more than 10K. Set ***Cal->VScale*** to the voltage scaling ratio (R1 + R2)/R1.
   For instance, if (R1, R2) = (4.7K, 220K) then ***Cal->VScale*** = 224.7/4.7 = 47.81v/v for a maximum monitored voltage of 5v x 47.81v/v = 239.05v. Fine tune ***Cal->VScale*** as needed so the V3 voltage reading matches that of an attached DMM.

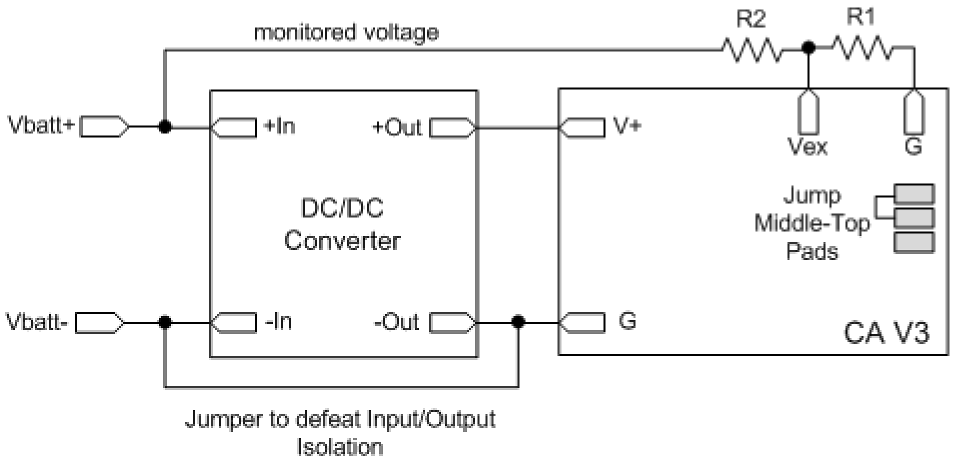
3. **IMPORTANT: *Non-Isolated CA Power Supply:*** The CA V3 design requires that the CA power and monitored voltage share a common ground.

   High voltage vehicles normally isolate the 12v accessory system as a safety precaution. Because the V3 voltage sensing circuit shares a common ground with the monitored high voltage (motor) power, it is recommended that a separate small DC/DC converter be driven by the high voltage source and used to power the V3. The converter must be capable of supplying 10ma plus power for accessories (THUN, etc).

   When a DC/DC converter is used, the converter ground must be common with the CA ground. If the converter is isolated, the isolation must be defeated by tying the converter negative output to **Vbatt(-)**.

4. **IMPORTANT: *Forcing a Data Save:*** Data is saved to EEPROM when the monitored voltage falls below ***Pref->V Shutdown.*** Since the voltage monitor is now divorced from **+V**, turning off the vehicle must both remove power from the CA as well as so reduce **Vex** as to trigger a data save prior to CA shutdown.

   A simple approach is to tie the external divider *Monitored Voltage* line to the switched high voltage power supplying the CA DC/DC converter. Opening the switch will allow R1 to pull down **Vex**, forcing the save.

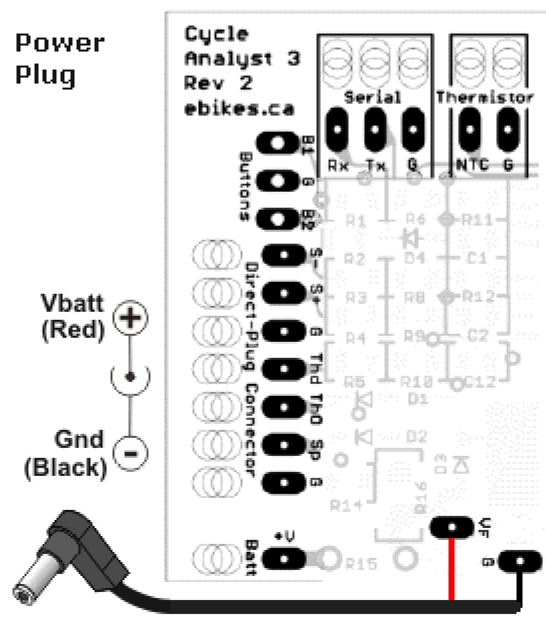


Typical remote sensing configuration with alternate Cycle Analyst power

6.8 Cycle Analyst as a Power Source

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

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



The CA V3 uses stacked 10v and 5v regulators so the current limit is calculated by summing current for all 5v and 10v accessories together instead of addressing two separate limits. 'Accessories' are any devices drawing power from the PCB excluding the external DC Power Plug.

The CA V3 can supply current to accessory devices as shown in the table below according to:

Max = (1500mw/(Vbatt-10v)) – 10ma.

The current limit decreases with increasing battery voltage.

V+	Imax	V+	Imax	V+	Imax	V+	Imax	V+	Imax	V+	Imax	V+	Imax
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 for CA Supply Voltage Applied to Pad V+

5v or 10v Accessory	ma
generic hall sensor	5.0
hall throttle	5.0
Magura Throttle (5K)	1.0
Thun BB	20.0
PAS wheel (2 hall)	10.0
PAS wheel (reed sw)	1.0
typical CA 3-pos sw	2.5
typical 5k aux pot (5K)	1.0
typical CA preset sw	0.5

Typical accessory current requirements are shown in the table to the left.

For instance, an installation with a hall throttle, Thun BB, preset switch, and two hall ebrakes requires:

5ma + 20ma + 0.5ma + (2 x 5ma) = 35.5 ma

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

Either of two strategies may be applied for battery packs above this maximum voltage:

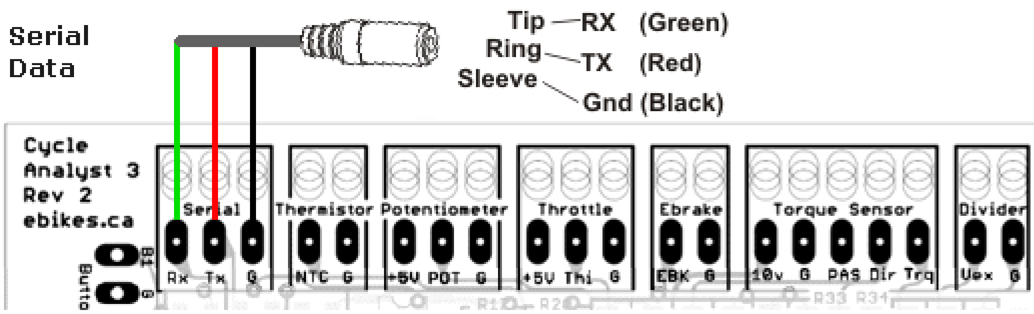
- power one or more accessories from an alternate source, or
- power the CA from a lower voltage source to raise the available current it can supply.

1. In the first case, 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 the device(s). In these 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. In the second case, **Vbatt** is stepped down via a DC/DC converter and used to reduce the CA power supply 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 *' 6.7 High Voltage Vehicle Support'*.

Whenever a DC/DC converter is used, the converter ground must be common with the CA ground. If the converter is isolated then the negative converter output connection must be tied to **Vbatt(-)** to defeat the isolation.

See *'Appendix D. Tips and Tricks'* for additional DC/DC converter information.

6.9 Serial Data Port



1. ***Encoding/Signal Levels:*** The **Tx/Rx** serial ports operate at 9600 baud with 8 bits, 1 Stop bit, and no parity at 0v/+5v TTL levels.
2. ***Live Data Stream:*** In normal operating mode a serial data stream 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->RS232***.

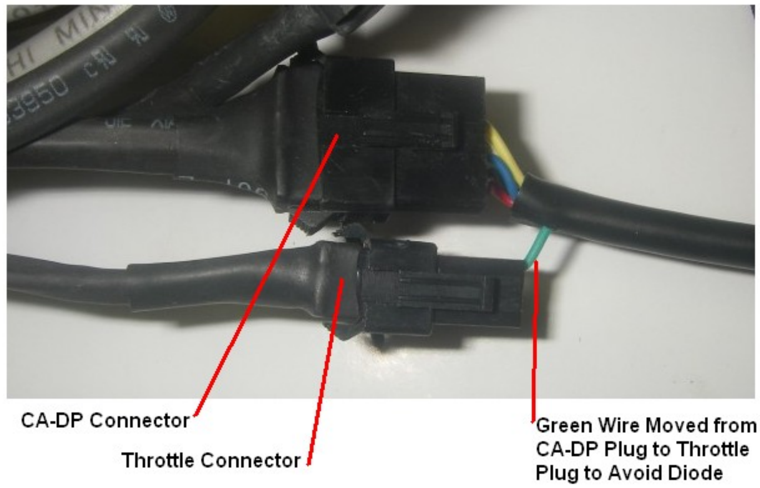
Col	Heading	Description
1	Ah	Amp hour
2	V	Voltage
3	A	Amperes
4	S	Speed
5	D	Distance
6	Deg	Temperature degC
7	RPM	PAS RPM
8	HW	Human Watts
9	Nm	Thun Newton-meters
10	ThI	Throttle In Voltage
11	ThO	Throttle Out Voltage
12	Acc	Acceleration
13	Lim	Limit Flag Characters

3. ***Interface Cable:*** The standard Grin Tech CA V3 programming cable (pn: CA3-USB) is an FTDI TTL-232R-5V-AJ and is best ordered with the CA V3 to facilitate firmware updates.
   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 these posts [**1**, **2**] for bootloader protocol and EEPROM parameter layout. For operation of the updater application see *'Update CA with Most Recent Firmware'*.

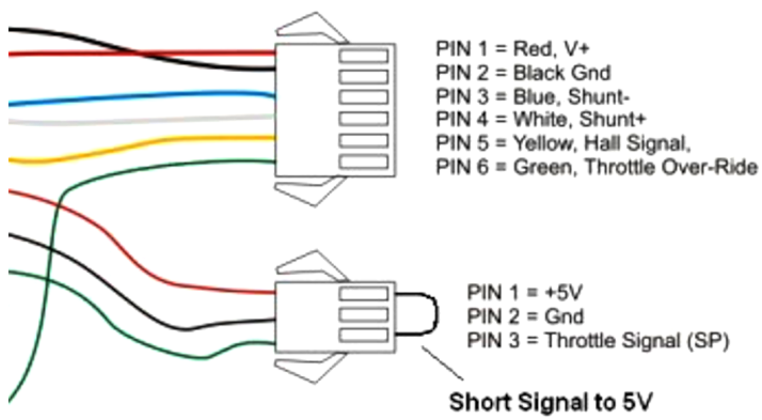
Appendix A. CA V3 Throttle OUT to Controller Connection

Justin on Endless-Sphere.com: "With the V3 CA devices, the functionality of the CA now includes not just throttle limiting, but actually driving the controller's throttle signal directly, and this is NOT possible if there is a diode inline with the throttle signal. So, if you have a CA-DP compatible controller and want to use the CA-V3 device as your new throttle, you will need to do a bit of modification. Here are 3 approaches:

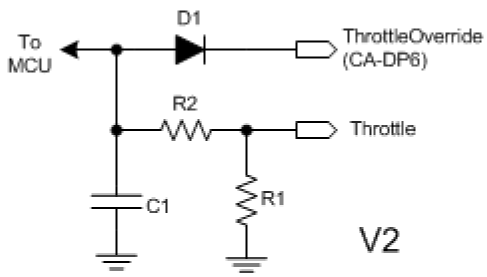
1. Swap pins around so that the green wire from the CA-DP goes into the controller's regular throttle input. You can either do this at the CA-DP plug end as shown, or you could do it on the controller end.

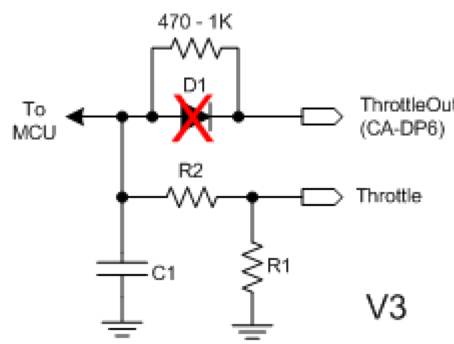


2. Insert a short between 5V and your throttle signal. This way the throttle signal is being pulled high by the short circuit, and so the CA only needs to pull the signal down from there which it can do via the diode. This method is easiest for sure, however, <u>it is crucial that you only do it if your controller has a proper over-throttle voltage fault</u>. Otherwise, if you unplug the CA then the controller will take off full tilt as the throttle input is at 5V. You want to be sure that the controller treats this situation as a fault and shuts down.



3. Open up the controller and replace the diode with a ~500-1000 ohm resistor. Depending on where your controller is from, the diode may be a surface mount device on the PCB or a clearly obvious inline diode to the green CA wiring.
<u>While you could in principle completely short out or bypass the diode, this isn't recommended as then the CA will usually be directly connected to the microchip which can be an issue if your ground connection fails.</u> A 500 to 1000 ohm resistor will provide some protection."





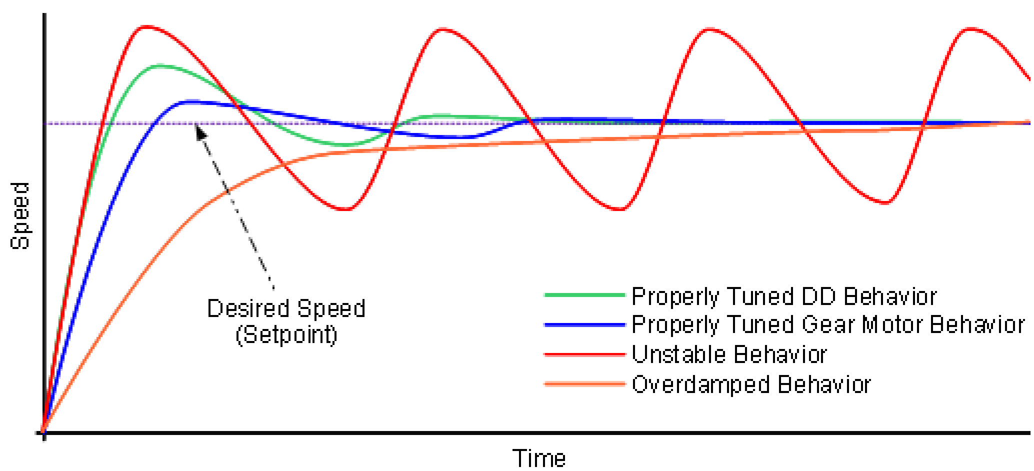
Appendix B. Tuning Speed Control Gain Parameters

The Cycle Analyst speed limiting is implemented as a classic PID (proportional-integral-derivative) controller. There are three interacting gain parameters that can make configuration somewhat challenging. The procedure presented below should give a good working configuration without trial and error. Bikes with high power to weight ratios may benefit from additional tuning using this configuration as a baseline.

The table below shows the three gain parameters and the effects of increasing each individually. 'Setpoint' refers to desired or limiting speed.

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 plots below illustrate some typical behaviors on getaway with Speed Throttle. Some initial overshoot is normal and desirable - the idea is to achieve a responsive initial rise time, minimum overshoot, reasonably rapid settling time, and stable (non-oscillating) behavior. These are interacting features, so achieving balance is the goal.



The red plot shows an unstable underdamped oscillating response that may never converge on the setpoint. In this case there is likely either to much ***PSGain*** and/or not enough ***DSGain*** - the controller is continually overshooting the setpoint. The orange plot shows an overdamped case where ***PSGain*** and ***IntSGain*** are too low – the response converges on the setpoint but only after a long delay with a very slow rise time – the controller has too little gain.

On the other hand, the green and blue plots show desirable DD and gear motor responses. In both cases there is some initial overshoot followed by settling to the setpoint. The curves differ slightly because of the freewheel clutch in the gear motor which gives a more pronounced asymmetrical control effect – the Cycle Analyst can speed the vehicle up, but it rolls freely and slows down of its own accord. The same is true to a lesser extent for the DD case. Because of this, the speed controller for the gear motor is adjusted to have a more damped response (less gain) to minimize overshoot. This slows the initial rise time and the overall settling time is slightly longer.

As mentioned in an earlier section, ramping logic can have a destabilizing effect on the control logic, particularly if it is suddenly engaged and introduces unexpected behavior into the feedback loop. Whenever possible, it is best to satisfy slower ***UpRamp*** requirements with more conservative (***PSGain***) adjustments so the controller has a nominal responsiveness in line with overall needs rather than imposing throttle ramping to restrain tuning with unnecessarily rapid response. As a bonus, tuning for a more damped response is somewhat easier. Slower response can be achieved in the following tuning procedure in step (4) by further reducing ***PSGain*** beyond the recommended factor (2 or 4 depending on the driveline type).

Note: Please be certain to have proper 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 driveline stress and potentially dangerous riding situations.

Tuning Procedure Under Test

Planned Release
in
B23 Version of UUG

Here are some common symptoms and likely causes if 'wing it' adjustments are made instead of the procedures outlined above:

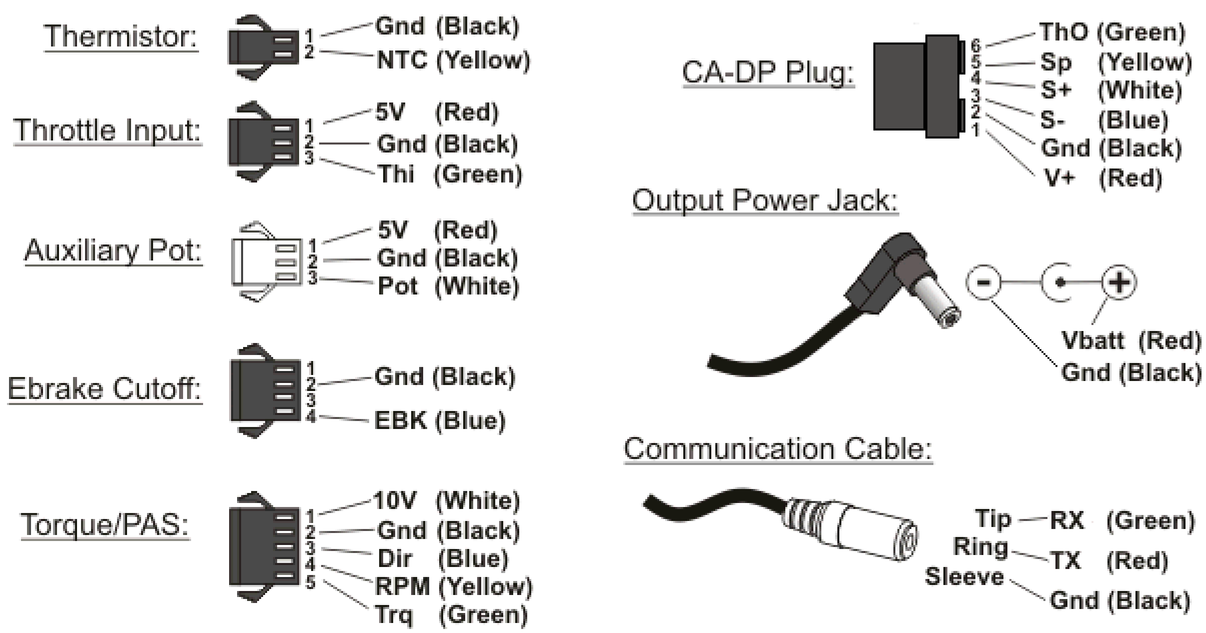
1. If there are (decaying) oscillations centered about the setpoint, ***IntSGain*** is probably okay but either ***PSGain*** is too high or ***DSGain*** is too low. Try increasing ***DSGain***. If this leads to jittery power or does not reduce the oscillations, then restore ***DSGain*** and instead reduce ***PSGain***.
2. If the rise time is slow and the output 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, ***PSGain*** and ***IntSGain*** are too low.
4. If there are cutouts when accelerating, ***DSGain*** is too high. Repeat the adjustment of step (6) above.

Appendix C. 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.

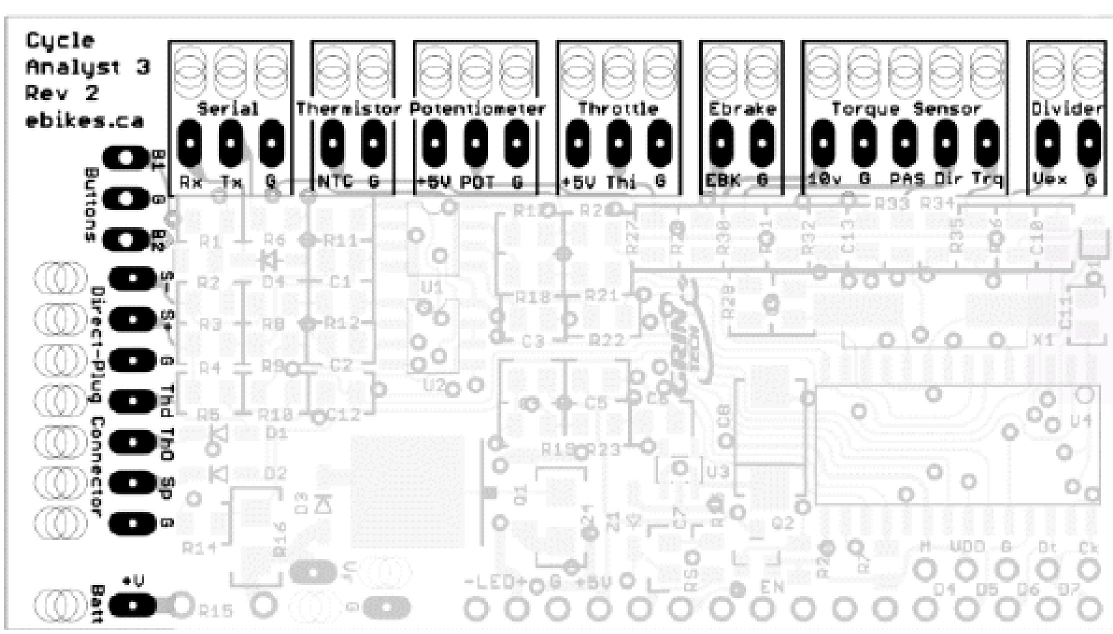
B.1 Connector Pinout

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:



B.2 Pad Descriptions

The following shows the solder pad locations on the circuit board for anyone who is doing their own custom wiring harness directly into the Cycle Analyst enclosure:

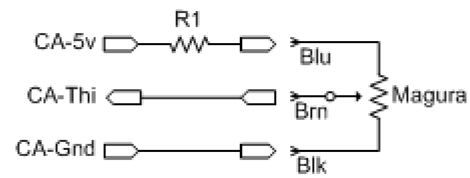


Appendix D. Tips and Tricks

C.1 Using Resistive (Magura) Throttles

The Cycle Analyst fault voltage safety feature uses Setup parameter T***hrI->FaultVolt*** which has an allowable range of 0.00-4.99v. This parameter is intended to be set between 5v and the maximum input voltage as determined by ***ThrI->MaxInput***. However, for resistive throttles such as the Magura, **Throttle IN** max is already at or very near 4.99v making a higher setting for ***ThrI->FaultVolt*** problematic. Also, since ***ThrI->FaultVolt*** cannot be set higher than 4.99v, it is not possible to deactivate the auto-shutdown feature – the throttle always appears to be in fault mode.

A simple workaround is to introduce a small resistor as shown to slightly reduce the actual max throttle voltage. Loss of the Gnd connection will still raise the **CA-Thi** input to approximately 5v. Figuring a small safety margin of 10% (5% above and below ***ThI->FaultVolt***) and a nominal Magura resistance of 5K, a 470 ohm resistor is suitable. This value is arbitrary; use any resistor 470ohm-3.3K to keep Throttle **IN** max > 3 volts. Since the throttle range of motion delivers the full but slightly reduced ***ThrI->MinInput*** to ***ThrI->MaxInput*** range, normal throttle operation is unaffected.



Magura Throttle Mod for ThI->FaultVolt

The resistor can be soldered directly to the (+5v) pad adjacent to the **Thi** pad of the CA PCB in-line with the (+5v) lead of the throttle cable and then entirely sleeved with heat shrink.

C.2 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 quality wide range DC/DC converters.

Automotive/motorcycle '12v' accessories actually expect 13.8v and will operate without difficulty 10v-16v. This makes 15v power supplies an ideal choice although 12v models are acceptable at the lower end. 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. (This strategy of sharing the automotive accessory power with the Cycle Analyst is not recommended for truly high voltage vehicles – see *'High Voltage Vehicle Support'*).

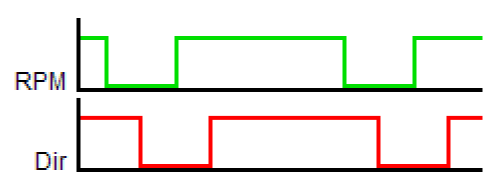
Common netbook and laptop supplies have waterproof packaging and cost about $10. For example, the Toshiba ADP-60RH laptop supply provides 15v at 4A. Netbook supplies are smaller and are a good choice where only an ampere or so is required. Conventional switching supplies such as the Mean Well APV-12-15 (15v 0.8A) 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.

C.3 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 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.

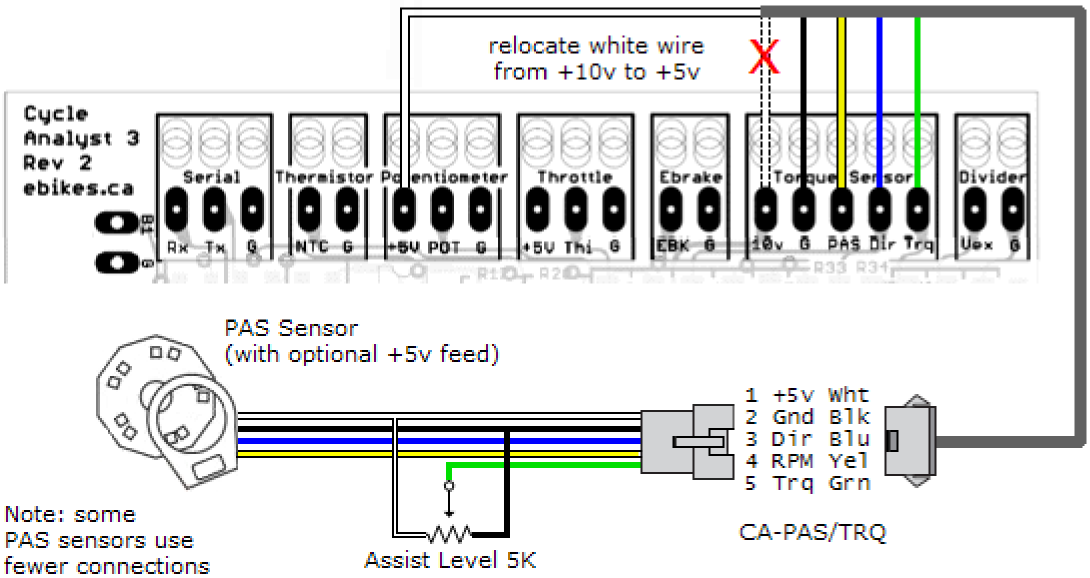


Quadrature RPM-Dir encoding for Fwd

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 *'Setup Screens'*). Configure ***PAS->Quadrtr*** = Enabled.

C.4 PAS Assist Control without AUX Pot – DIY Virtual Torque Sensor

For ease of use, an **AUX Pot** limiting knob is almost a requirement when installing a PAS cadence sensor. This is problematic for builds where use of **AUX Pot** for a preset or 3-position switch is desired. Additionally, since a PAS sensor can only be limited by reducing normal current, power, or speed limits (***Aux->ScaleLim = PAS Level*** applies only to torque sensors), the throttle is necessarily limited to the PAS level. This means the throttle cannot be used to apply more power than is otherwise available by PAS. Ideally, the throttle would work normally and could be scaled by a 3-position switch while the PAS assist level would be unrelated and adjustable by a second dedicated control. This would give flexible control and would allow advancing the throttle to sprint faster than PAS assist.



PAS Assist Control without Aux Pot

The illustration above shows how this can be accomplished. A 5K linear pot is added to any PAS sensor to provide an artificial torque signal yielding 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. The normal CA torque sensor logic will not apply this assist until pedaling is detected. **AUX Pot** is not required and may be used for another purpose. Throttle operation is unaffected since none of the current, power, or speed limits need be reduced to limit the PAS assist.

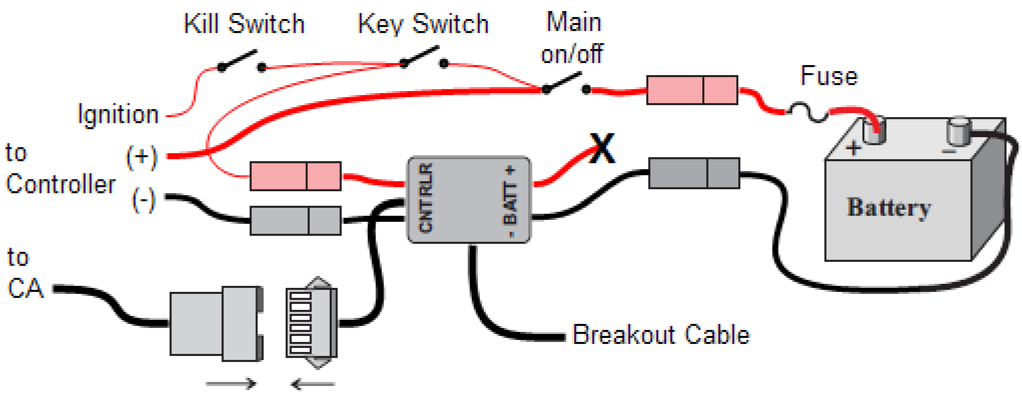
In the illustration above, the white +10v lead is re-purposed to carry +5v by relocating it to the **AUX Pot** +5v PCB pad. This voltage is required for the potentiometer and may also be used to power hall sensors in the PAS unit if necessary. This configuration gives a 0-5v range for the **Trq** input.

1. Turn the Assist Level pot to minimum and use ***Trq->TrqOffset*** to set the voltage baseline for 'zero torque'.
2. Set ***Trq->SensrType*** = Custom.
3. Set ***Trq->TrqScale*** = 20 Nm/V. This yields *MaxAssistTorque* = 5V x 20 Nm/V = 100Nm.

   Trq->TrqScale is an arbitrary value for the 'virtual torque sensor' and is used only to obtain a maximum virtual torque value that is required to compute ***Trq->AsstLevel***. 100Nm is an easy to use divisor...
4. Choose a maximum assist power in Watts then set ***Trq->AsstLevel*** = *MaxAssistPower/MaxAssistTorque.* For instance, for *MaxAssistPower* = 500W, set ***Trq->AsstLevel*** = 500W/100Nm = 5W/Nm.
5. Set ***Trq->AsstOffst*** = +0 to disable the feature since any offset setting > 0 will only serve to produce a dead zone at the bottom of the Assist Level control.
6. Configure all PAS parameters appropriately for the particular PAS sensor but set ***PAS->PASMode*** to either **Trq|Throt** or **Trq&Throt** instead of an RPM option.

C.5 Key Switch and the Cycle Analyst Molded External Shunt

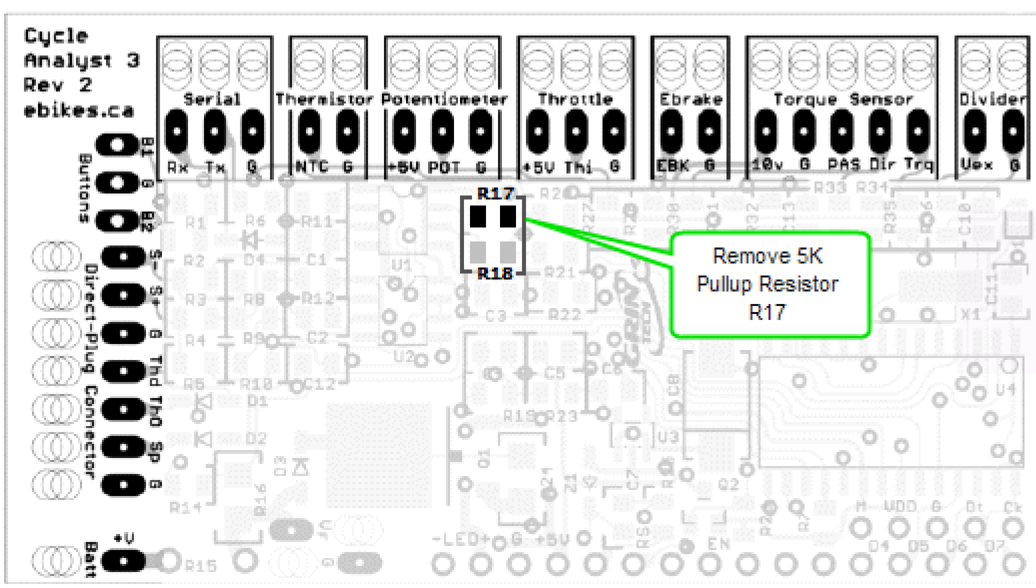
The shunt resistor of the CA molded external shunt is in the negative power path. In contrast, the heavy red positive leads actually need not carry the primary controller power, this is merely a convenient means for the CA to pick up **Vbatt(+)** for power and monitoring. If a key switch is desired, then the controller **Batt(+)** can bypass the shunt module and be wired directly to the battery or breaker. A light gauge wire is then run from **Batt(+)** through the key switch to both the controller 'ignition' wire and either of the the shunt module heavy red *Batt* or *Cntlr* leads; the other heavy red module lead need not be connected or can be used as a pass-through to a DC/DC converter, etc.



C.6 Using LM-35 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.
3. Configure ***Temp->Sensor*** = LinearType, ***Temp->0Deg*** = 0.00 Volts, and ***Temp->TScale*** = 100.0 Deg/V



C7. Operation in Wet or Cold Conditions

Grin Tech CA v2.23 User Manual:
The Cycle Analyst enclosure contains a clear sealed window to protect the circuit board and LCD from water exposure. There is no problem using the meter in light rain. However, in cases of prolonged exposure to wet conditions, it is possible for moisture to enter the box though the back cover which is not sealed. This can cause the window to fog up in cold conditions and render the display difficult to read. Should this occur, simply remove the back cover so that the moisture can escape and let the unit dry thoroughly indoors. When it is reassembled, you may consider using a sealant around the lip and screw holes to render the box fully waterproof.

The LCD screen is specified to operate between -10oC to 50oC. 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.

C.8 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 haves 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 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.