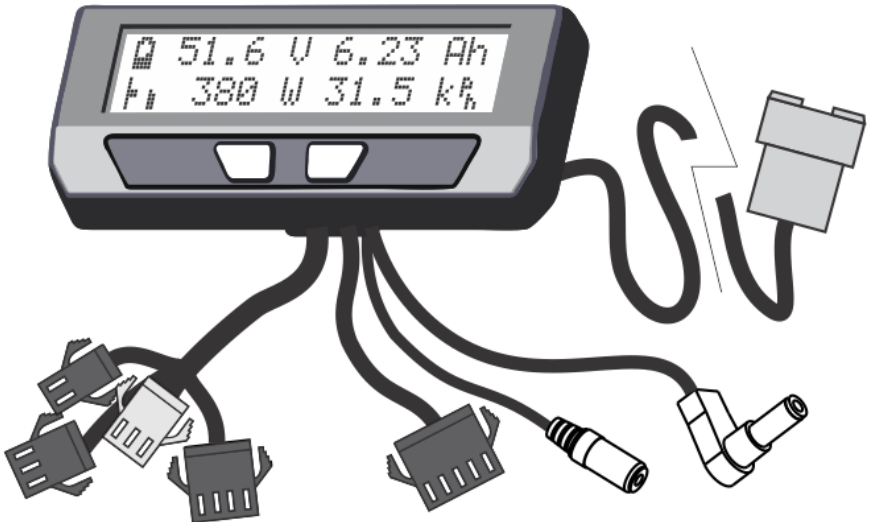




Cycle Analyst V3.1

Official User Manual



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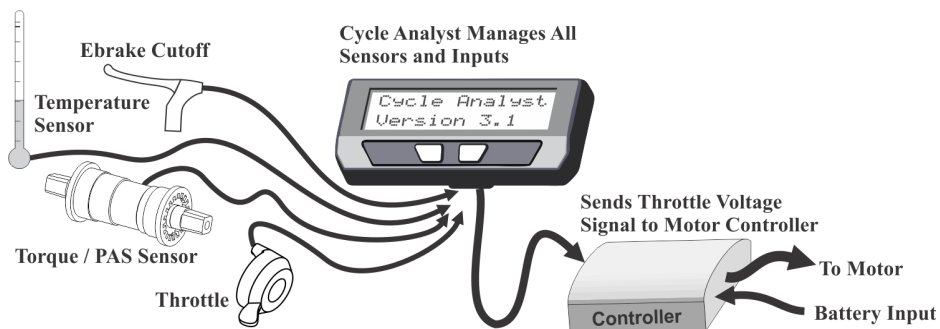
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1 Introduction

Thank you for the purchase of a V3 Cycle Analyst device, Grin's latest model of open standard display and control device for ebikes and other electric vehicles. This document should help you get reasonably familiar with the basic setup and operation of a CA3 as part of your vehicle system.

2 High Level Operation

The V3 Cycle Analyst is not like a typical ebike display interface that communicates with one particular model of motor controller. Instead the CA3 is designed as a more universal display and control unit. To achieve this universality, it reads existing signals already present in most EV drives to sense the power and speed of the vehicle, and then it regulates the motor power through a common throttle signal.

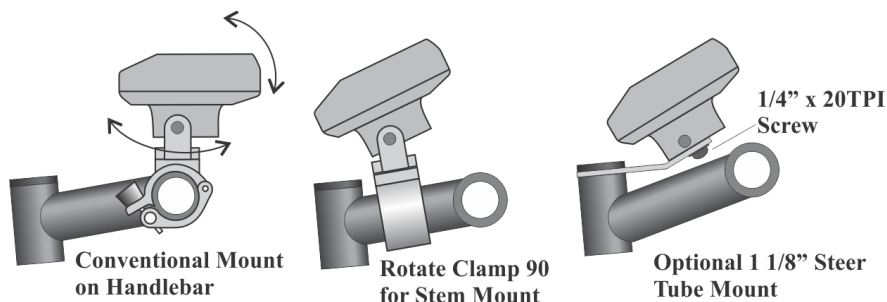


This is an important concept to understand; the CA3 does not "communicate" with your ebike in the same manner as proprietary display units. Rather it taps into analog signals already present inside a motor controller and interprets them. It then sends what it thinks is the most appropriate throttle voltage to your controller for generating a target amount of power from the motor.

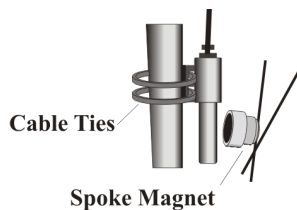
As far as your motor controller knows, the V3 Cycle Analyst is just a throttle device. The CA3 can't change any internal controller settings, or make the controller do anything more than what you could do via deft manipulation of a normal throttle.

3 Installation

The Cycle Analyst has an optional handlebar bracket that allows it to clamp on any tube from 21mm (7/8") to 40mm (1.5") in diameter. You can mount it directly on the handlebar, or you can swivel the base 90 degrees and clamp it to the stem for a more central display that doesn't consume bar real estate. There is also an optional steer tube mounting bracket and a 1/4" threaded insert on the bottom of the enclosure for improvised attachments.



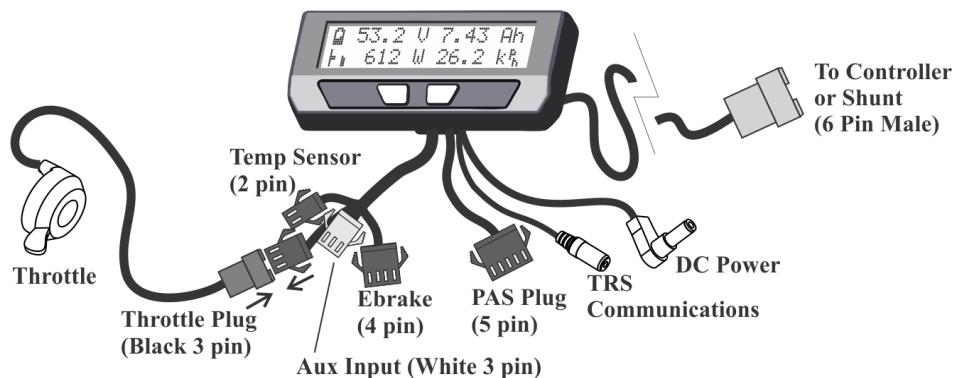
If you have a CA3-DPS device which uses an external spoke magnet and separate speedometer sensor, then you will need to screw the spoke magnet to your wheel and zip-tie the sensor pickup to your fork so that the magnet passes within about 5mm from the middle of the pickup sensor. To avoid glitches in the speed reading, the sensor body should be perpendicular to the direction of magnet motion.



3.1 Handlebar Wiring

It is important that you wire up your throttle to plug into the Cycle Analyst rather than directly to your motor controller. The CA3 has a short cable bundle for all accessories and the throttle input is the black 3-pin connector. Your throttle should be attached to this plug.

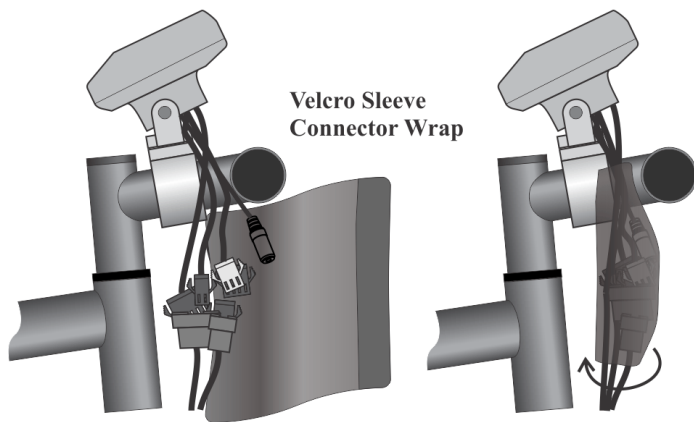
You can also connect ebrake cutoffs, auxiliary inputs, a temperature sensor, and Pedal Assist (PAS) or torque sensors if you have them to the appropriate connectors on CA3, but the throttle is the most essential for basic operation.



There are two additional short cables coming out of the Cycle Analyst. One is an 1/8" TRS communications jack that can be used for data logging or connecting to a computer for firmware updates and setting changes. The other is a DC Power cable that has full battery voltage for powering front ebike lights, DC-DC converters, and other peripherals that can run directly off pack voltage.

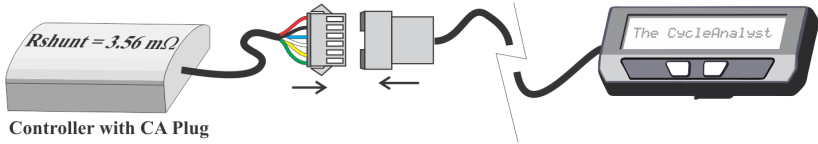
This DC power tap is fused internally and is limited to 1 amp. It is shipped with a rubber protective cap and you should leave this cap in place if you are not using the connector, as there is full battery voltage present on the exposed connector pin.

We include a stretchy fabric Velcro sleeve that lets you cover up the connector assembly for a clean finished look on the front of your bike once everything has been plugged in. This sleeve also provides a convenient place for bundling up any excess cable length.

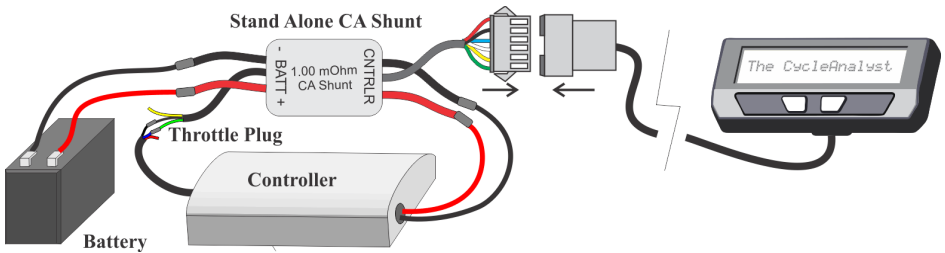


3.2 Shunt / Controller Wiring

For systems that have a CA3 compatible motor controller, the electrical hookup is simply a matter of connecting the 6-pin CA plug to the mating plug on the controller. This JST-SM connector standard has pins for the battery voltage, throttle signal, speedometer signal, and current sense resistor leads.



If your controller doesn't have a compatible CA plug on it, then you will need to use the Stand Alone Shunt wired inline with the + and – battery leads in order for the CA to see the battery current and voltage.



The Stand Alone CA3 Shunt has a short unterminated cable with 3 signal wires in it. The green signal wire is the throttle output of the Cycle Analyst, and that should be wired to the throttle input plug of your motor controller. Without this connection, the CA3 can monitor and display speed and battery consumption but has no way to regulate and control the motor power.

The CA3 turns on whenever there is voltage on the CA plug. With direct plug connections, if the controller has an on/off switch this would also turn the CA on and off. If the controller does not have an on/off switch or the Stand Alone CA shunt is used, then the the battery itself should have an on/off switch for turning the CA on and off.

Please refer to section 6.13 about setting the Cycle Analyst Rshunt value, especially if you are connecting the CA3 directly to a motor controller.

4 Display Screens

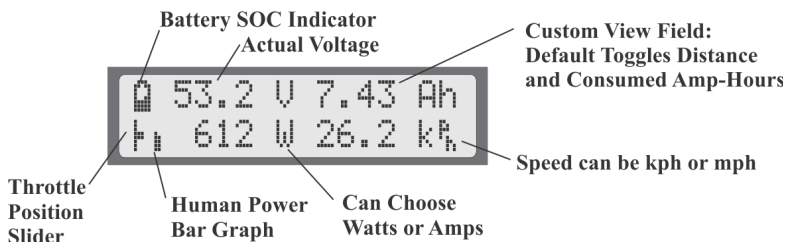
When the device is powered up you can scroll through numerous display screens by pressing the left and right buttons to show you things of interest:

Table 1: Summary of CA3.1 Display Screens

Display #1, Main Screen	Summary of battery level, speed, power, voltage, distance etc.
Display #2, Electrical Only	View of just the battery voltage, current, power, and amp-hours
Display #3, Human Power	Shows pedal cadence and human power if torque sensor installed
Display #4, Wh/km	Battery watt-hours and energy consumed per km or mile
Display #5, Human Stats	Average human power, pedal cadence, and total human energy output
Display #6, % Regen	Shows regenerative amp-hours and % by which it has extended your range
Display #7, Peak Stats	Shows peak current, peak regen current, and battery voltage sag
Display #8, Speed Stats	Maximum and average trip speed and total trip time
Display #9, Temp Stats	Shows current, average, and maximum temperatures if sensor is attached
Display #10, Odometer	Shows both current trip distance and lifetime odometer
Display #11, Batt Info	Charge cycle count, total kWh energy used, and Battery internal resistance
Display #12, Diagnostics	Live readout of throttle input/output voltages and active limiting flags

Most of the essential information you would want while riding is on Display #1.

4.1 Main Display



The battery State Of Charge (SOC) icon on the top left is a graphical indication of the charge level in your battery pack, inferred from a combination of the cell chemistry, pack voltage, and amp-hour consumption. This gauge will only be accurate if the battery type and series cell count has been set up correctly.

Next to that is the actual pack voltage. We recommend paying attention to your battery voltage and becoming familiar with the value that it shows on a full

charge, during use, and when the battery goes flat. This is often your first clue to anomalous behavior and provides very useful troubleshooting information.

The top right is a customizable display field. By default, this toggles between showing your accumulated amp-hours and distance since the last trip reset, but it can be configured to show other things like motor temperature, instantaneous wh/km, pedal cadence and so forth. You will eventually find the consumed amp-hours to be among the most useful and important pieces of information on the CA display, but only if you remember to do a trip reset each time there is a fresh charge on the battery pack.

The bottom left of the display has a throttle position that moves up and down with the user's throttle signal going into the Cycle Analyst. This is replaced by an animated brake lever if the ebrake cutoffs are engaged. Just beside this slider is an animated Pedal Assist bar graph, which is only active if you have a PAS sensor and visually indicates how fast or hard you are pedaling.

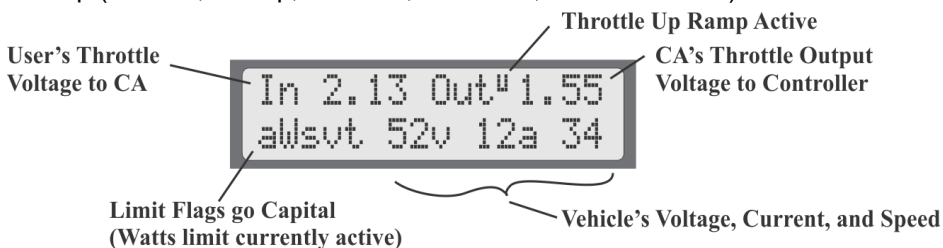
The bottom left numeric display by default shows the electrical power currently flowing through the system, and will go negative during regenerative braking. It is possible to change this to display amps instead of watts if you prefer.

Finally, on the bottom right is a readout of your current vehicle speed, in either kph or mph as chosen in the setup menu.

The left and right buttons will scroll through other display screens that show specific information that may be of interest. These screens are explained in detail on the CA3 web page and any of them can be hidden from view if desired. The diagnostics screen and watt-hour screen are of particular interest though.

4.2 Diagnostics Screen, Display #12

If you press the left button once from the main display, you will have the diagnostics display. This can be invaluable during any kind of system troubleshooting. The top line shows the actual throttle voltage signal going into the CA3, as well as the throttle voltage going out to your motor controller. If the rate of change of the throttle is being clamped, then the associated rate limit will show up (**F** = fast, **U** = up, **P** = PAS, **D** = down, see section 6.5).

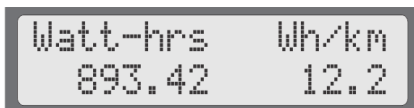


The bottom left shows if any of the limit settings are actively regulating the throttle output voltage. Letters **awvst** refer to the **A**mps, **W**atts, low **V**oltage, **S**peed, and **T**emperature rollbacks, and they become capitalized when active.

This display lets you easily identify if your input throttle is working correctly, if the CA itself is sending an output throttle to the motor controller, and if that output throttle is being clamped by any of the programmed limit settings.

4.3 Wh/km, Display #4

The 4th display screen shows the total energy in watt-hours taken from the battery, as well as the average watt-hours used per distance traveled, either wh/km or wh/mi. This is one of the most useful statistics to check as it is the equivalent of fuel mileage for your electric vehicle. You can see how different riding styles and terrains affect your energy usage, and you can compute how large of a battery will be required to travel a given distance.



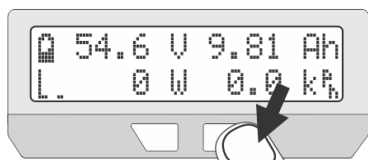
Total Consumed Energy
from Battery Pack

Regen Compensated
Consumption Rate

The other 9 displays are largely self explanatory and are more thoroughly covered on the [CA3 info page](#).

5 Resetting the Trip Counter

If there is only one thing to remember about using the Cycle Analyst, it is that you will want to make a habit of resetting the Cycle Analyst every time you have a fresh charge in the battery. Do this by pressing and holding the right button until the message "**RESET TRIP?**" shows on the screen. This allows you to see your consumed battery amp-hours on each trip and ensures that the battery cycle statistics are accurate.



Hold Right Button
1 Second to Reset



YES!

If you forget to reset, the trip amp-hour, watt-hour, and distance accumulators will eventually peg at their maximum values and you'll stop accumulating new statistics. You also won't get the benefit of seeing an accurate battery charge cycle count, seeing trip to trip variation in your wh/km consumption stats, and learning exactly how many amp-hours the battery is able to deliver.

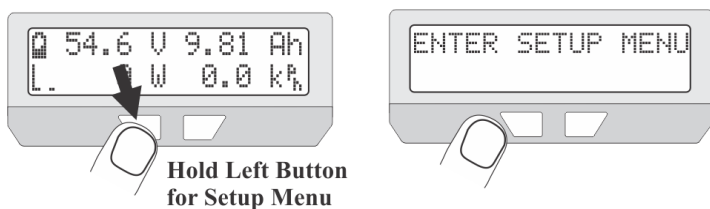
If you press the reset button on certain other display screens, it will reset just the statistics associated with that screen, like a reset of just the peak statistics or just the temperature data.

6 Setup Menu

If you received your CA3 as part of a complete ebike kit package then it should be pre-configured with reasonable values for that setup and be ready to ride. There should be little need to change anything. If it was received as an independent device and not as part of a kit package, then there is a good chance that you will need to change a number of settings in the CA3's setup menu for it to function with accurate readings. Most essential would be the wheel size, battery details, and Rshunt value.

6.1 Accessing and Navigating the Setup Menu

The Setup Menu is accessed by pressing and holding the left button.



Once you are in the setup menu, the left and right buttons allow you to scroll through the options or toggle digits up and down. Pressing and holding the buttons has a special effect.

- Hold the RIGHT button to enter a menu or save a setting (like pressing enter on a keyboard).
- Hold the LEFT button to exit something (like pressing escape on a keyboard).

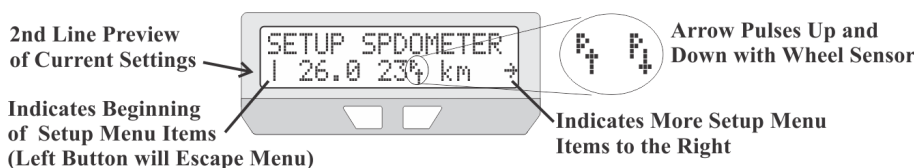
The setup page is organized with all the related settings grouped into sub-menus. Each of these high level menus is summarized in the table below.

Table 2: CA3.1 Setup Menu Organization

Setup Speedometer	Configure Speedometer Sensor (wheel diameter, #poles, metric/imperial)
Setup Battery	Configure Battery Details (chemistry, #cells, low voltage rollback etc)
Setup Throttle Input	Configure Input Throttle Mapping (min/max range, throttle mode, autocruise)
Setup Throttle Output	Configure CA's Output Throttle (min/max range, ramp limits, voltage/RC Pulse)
Setup Speed Limits	Set various Speed Limits and associated PID feedback parameters
Setup Power Limits	Set maximum power and current limits, and feedback gain parameters
Setup PAS Device	Set PAS or Torque Sensor parameters (#poles, fwd/rev direction, torque signal)
Setup PAS Configuration	Configure how the CA responds to pedal RPM and torque input from rider
Setup Temperature Sensor	Configure motor Temperature Sensor type and max temperature limits
Setup Analog Aux Control	Setup behavior of potentiometer or 2/3 position switch for Limit Control
Setup Digital Aux Control	Setup behavior of 2-button up/down Digital Limit Control
Setup Ebrake	Configuration of Brake Cutoff behavior and proportional regen
Setup Calibration	Calibration parameters for voltage scaling, zero offset, and Rshunt
Setup Presets	Enable up to three Mode Presets for quick access to pre-configured limits
Setup Display Options	Customize Display behavior, hide screens, choose custom views
Setup Miscellaneous	Other parameters like data log rate, display averaging, default saving
Setup Lifetime Statistics	Total Lifetime charge cycles, kilowatt hours, and odometer distance

6.2 Setting the Speedometer

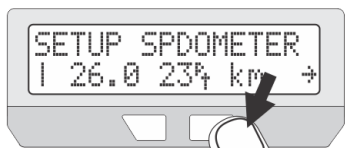
The first item in the setup menu is your speedometer configuration. The second line of the setup menu shows a preview of the configured settings, including the number of pulses per wheel revolution, the programmed wheel diameter, and your preference of metric or imperial display.



What you may not notice on this preview line is the small wheel sensor arrow beside the number of poles, which shows the signal going into the CA's speedometer input. With a spoke magnet and sensor this arrow should switch down whenever the magnet is right by the sensor. If you have a CA3-DP device

using the hall sensors for wheel speed, then it will toggle up and down many times as you turn the wheel. Most setup menus provide a preview of the related signals seen by the CA which can be valuable for setup and troubleshooting.

To change any of these settings, press and hold the RIGHT button to enter into the speedometer setup menu.



Hold Right Button to Enter Speedometer Submenu



First Item in Speed Setup Menu is Unit Choice

6.2.1 Metric / Imperial Units

The first item you may want to change in the speedometer setup menu is your preference for metric or imperial units. This is edited by pressing and holding the button, toggling to your preferred units, and holding the button again to save.



Hold Right Button to Change Units



Press to Toggle Between km and miles. Hold to Save

One small detail: if you do change between miles and km in the future, your total odometer distance will not automatically update. If there are 1000 miles present and the units are then switched to km, it will show 1000km rather than 1598km.

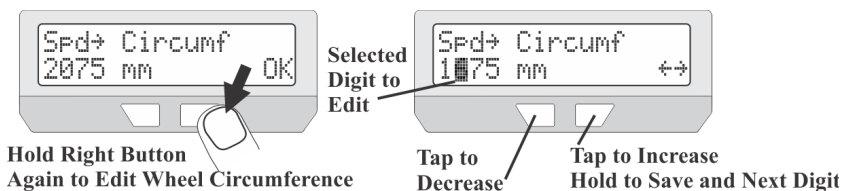
6.2.2 Wheel Circumference

Accurate speed readings require an accurate wheel size. The default value of 2075mm corresponds to a diameter of exactly 26.0", but a nominal 26" wheel is rarely going to be exactly 26" diameter. The table below shows the approximate value for a number of common wheel sizes, but for best accuracy you should simply measure your wheel circumference directly with a tape ruler, or compare the CA's trip distance with google maps distance and adjust accordingly:

Table 3: Approximate Tire Circumferences

Tire Size	Circumf	Tire Size	Circumf	Tire Size	Circumf
16 x 1.50	1185	24 x 2.12	1965	26 x 2.25	2115
16 x 1 3/8	1282	26 x 1 1/8	1970	26 x 2.35	2131
20 x 1.75	1515	26 x 1 3/8	2068	700 x 23	2097
20 x 1 3/8	1615	26 x 1 1/2	2100	700 x 28	2136
24 x 1 1/4	1905	26 x 1.5	1995	700 x 32	2155
24 x 1.75	1890	26 x 1.75	2035	700 x 38	2180
24 x 2.00	1925	26 x 2.0	2075	29 x 2.0	2273

To edit the circumference, press and hold the right button until you see **OK**. The digit you are editing will be flashing, and short presses of the left and right buttons will cause the value to increase or decrease.



When the digit is set how you like it, then press and hold the right button to save this and move over to the next digit. If you accidentally saved the wrong number, you can press and hold the left button to go back to the previous digit.

Once the last digit is entered, the new value will be saved and you will be back to navigating the speedometer setup menu.

6.2.3 Set Your Pole Count



The Cycle Analyst also needs to know how many times the speed signal will toggle up and down with each wheel rotation. With a CA3-DP device using a direct drive motor this will be the number of magnetic pole pairs in the hub.

For geared hub motors that have an internal speed sensor, the #poles should be set to the number of speed pulses on each turn of the wheel. Bafang and many other geared motor manufacturers seem to have standardized on 6 pulse internal speed sensors. If in doubt, simply count the number of times the 'P' arrow toggles when the wheel is turned one revolution.

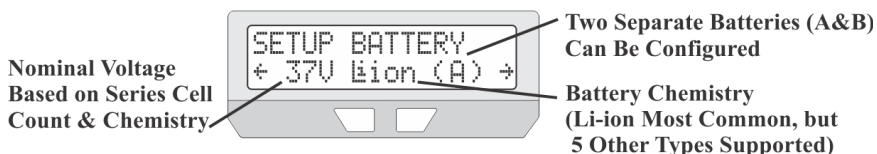
Table 4: #Pole Settings for Common Motor System

CA3-DP with Spoke Magnet	1 Pole
Bafang, Shengyi, GMAC, eZee, +Other Geared Motors with Internal Speed Sensor	6 Poles
Crystalyte 400 Series	8 Poles
Crystalyte 5000 Series	12 Poles
TDCM 5 Spd IGH Hub	16 Poles
Crystalyte NSM, SAW	20 Poles
Crystalyte 'H', Grin All-Axle, Nine Continent, MXUS, QS, and other 205mm DD motors	23 Poles
Nine Cont. 212mm DD motors	26 Poles
Golden Magic Pie	28 Poles

For CA3-DPS devices using an external spoke magnet and sensor, it would be set to the number of magnets on your wheel (typically 1, but there are some benefits to having multiple spoke magnets)

6.3 Setting Up the Battery

The next setup menu item is the battery configuration, which is used by the Cycle Analyst to generate an accurate State-Of-Charge (SOC) indicator. The setting information is summarized in the Battery setup menu.



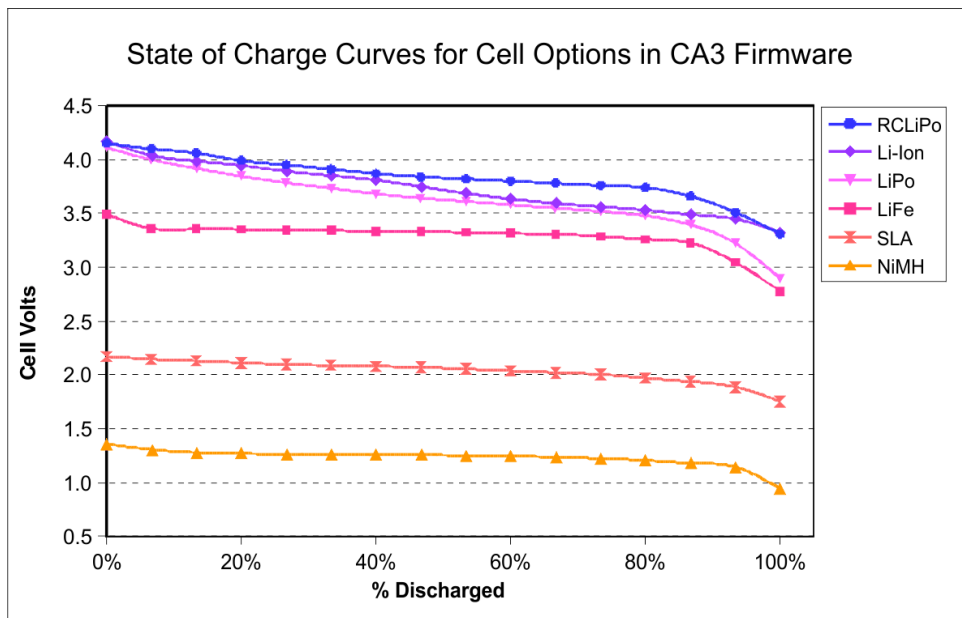
The three most important parameters to enter for an accurate SOC indicator are the cell chemistry, series cell count, and approximate capacity. Additional options let you choose if you want to display average cell voltage rather than pack voltage on the main screen, whether to activate a low voltage rollback feature, and whether to activate two preconfigured batteries (A&B) rather than just one. See the Presets section 6.14 for more information on this.

6.3.1 Set Your Chemistry

There are 6 options for the battery chemistry:

- **Li-Ion:** This is a catch-all lithium ion representative of most 18650 type lithium cells. The majority of ebike lithium packs are best represented by this option
- **LiPo:** This represents standard discharge rate ebike grade lithium polymer cells, which show a fairly steady drop in voltage as the battery is drained from 4.2V to 3.0 V/cell.
- **RCLiPo:** This is for high discharge rate polymer batteries typically used in radio controlled models. They have a much lower drop in voltage over the course of their discharge than regular ebike grade LiPo.
- **LiFe:** This is for Lithium Iron Phosphate batteries, be they pouch cells (like PING), or cylindrical cells (Like Headway, A123 etc). Iron phosphate cells have a very flat discharge curve, but at a lower voltage than other types of lithium (3.3V versus 3.7V nominal)
- **SLA:** This is for lead acid batteries, whether sealed or AGM etc.
- **NiMH:** This is for Nickel Metal Hydride or NiCad packs.

The majority of commercial lithium ebike batteries are represented with the standard Li-ion profile, but the LiPo profile can be used if the SOC icon shows a flat battery when there is still capacity remaining. The relationship between open circuit cell voltage and battery SOC for each type is shown in this graph.



6.3.2 Set Your Capacity

```
Batt+ Capacity
13.5 Ah ↔
```

Here you input the approximate amp-hours of your battery pack in order to help the battery SOC icon remain accurate at tracking changes during high discharge currents. The value does not need to be exact as the battery icon will always gradually readjust itself based on the voltage reading.

6.3.3 Set Your Series Cell Count

```
Batt+ String#
10 cells ↔
```

The nominal battery voltage is determined by the number of series cells in your pack. For lithium batteries each cell is about 3.7 volts, so a 36 volt pack has 10 cells in series. Lead cells are nominally 2.0V, so it takes 18 cells in series to make a 36V lead battery. And NiMH cells are just 1.2 volts each, so 30 of them are needed in series to make a 36V pack.

Most ebike batteries are configured in nominal 24V, 36V, or 48V modules. The following table shows the typical cell count for these nominal pack voltages, but it is increasingly common to see lithium packs not made in 12V multiples.

Table 5: # Cells Setting for Common Pack Voltages (brackets used occasionally)

Nom Volts	Li-ion	LiFePO4	SLA	NiMH
24V	7	8	12	20
36V	10	12	18	30
48V	13	(15) 16	24	40
50/52V	14	16	--	--
60V	(16) 17	20	30	50
72V	20	24	36	60

6.3.4 Low Voltage Cutoff

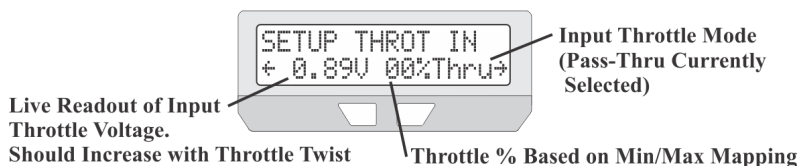
This optional feature allows the Cycle Analyst to automatically scale back power as the battery approaches a low voltage cutoff point. While lithium batteries have a Battery Management circuit (BMS) that will shut the battery off to prevent overdischarge, the experience for the rider is an abrupt loss of power with no warning. If the Cycle Analyst low voltage cutoff is set 1-2 volts higher than the BMS shutoff voltage, you'll have a gradual reduction in power instead, and will usually get more amp-hours and range from the pack.

When the CA is at the low voltage rollback mode, you will see the 'V' character flashing on the main display, and a capital 'V' on the diagnostics screen.

6.4 Throttle Input Settings

These settings allow you to modify how the throttle input signal coming into the CA3 device is mapped to a throttle output signal going to the motor controller. The default values (pass-thru input of 1.0-4.0V) generally work fine with a broad range of ebike systems using hall effect throttles and there is little need to change them in order to have a working setup. However, advanced users may want to tweak the throttle settings in order to achieve specific behaviors.

The preview screen on the Throttle Input setup menu shows the actual throttle voltage that is measured by the CA device, and as you turn the throttle you should see this number increase from 0.8-0.9V to 4.1-4.2V, and the percent throttle indicator should go from 0% to 99%.



6.4.1 Throttle Input Thresholds



Throttle Input Voltage for Start of Power



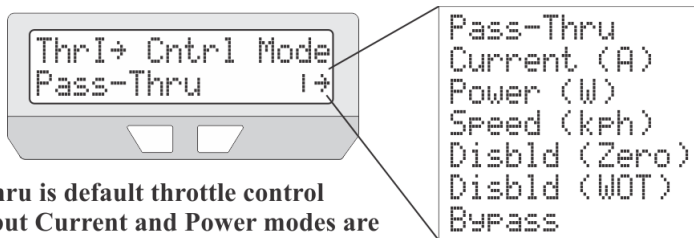
Throttle Input Voltage for Full Power

The Zero and Full throttle thresholds allow you to adjust the deadband at the start and end of your throttle motion. It is important that the throttle off voltage on the preview screen is at least 0.1V LOWER than the zero throttle threshold. You do not want to make these values identical, or a slight drift in voltage will cause the CA device to think you have the throttle slightly engaged all the time.

6.4.2 Throttle Mode

The throttle mode setting allows you to change the function of the input throttle. With most ebike controllers the throttle sets the unloaded RPM of the motor, so 50% throttle would result in the motor running at half speed. At higher RPM's there would be no more motor power, while at lower RPM's you will still have the

same power output as if it was full throttle. This is intuitive, although it means that the entire span from no power to maximum power can occur over a small portion of the total throttle motion.



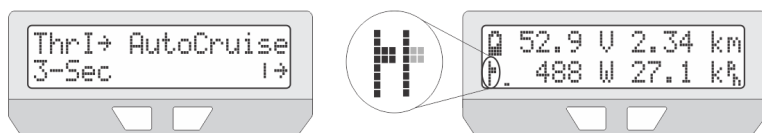
Pass-Thru is default throttle control mode, but Current and Power modes are also useful. Remaining options are for special circumstances only

With the CA3 you can change your input into an amps or power throttle, so that the throttle is directly controlling the power coming from the battery pack, and this will remain constant even as the vehicle speeds up or slows down. The benefit of a power or amp throttle is that the motor power is modulated over the full range throttle motion regardless of your speed, making it easier to maintain a given power level even as the bicycle speed increases and decreases with the terrain.

The proper use of a Power or Current throttle requires that the max current or max power limits described in section 6.7 are configured to values appropriate for your controller. The other throttle modes (Speed, Disabled, Bypass) have diagnostics usage or specialized applications and would not normally be used for controlling an ebike.

6.4.3 Input Throttle Autocruise

This setting allows a form of cruise control that is activated by holding the throttle steady at a fixed position for a minimum amount of time (2-8 seconds). Once the cruise hold time has been achieved, the throttle icon on the main screen will flash and the user can release the throttle and it will stay active at that value. It is cleared by a fresh application of throttle or squeezing the ebrakes.



Throttle AutoCruise Active. After 3 seconds, throttle indicator will blink indicating it can be released without losing power. Care must be taken when letting others ride the bike with this feature active.

This mode can be useful on long trips when holding fixed throttle level is tedious, but has largely been superceded by PAS sensors for those wanting throttle-free assistance.

6.5 Output Throttle Settings

The throttle output menu contains the configuration details for the signal that the CA3 sends to the motor controller, including the minimum to maximum voltage swing and the maximum rate at which the throttle signal can ramp up or down.

Many users with powerful setups will want to take advantage of throttle output ramp limiting to provide smoother acceleration and less kick on throttle engagement. Up Ramp values of 0.3 to 1.0 V/sec will smooth out the start, while higher rates like 6-8 V/sec give immediate responsiveness.

The separate PAS Ramp Rate allows a slower/smooth power engagement when pedaling, while still having a fast and punchy response to the throttle.



Example setup with fast throttle response and more gradual power engagement from pedal sensor

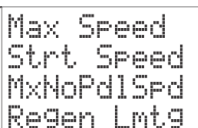
It is also possible to configure the Throttle Output to be a 1-2mS pulse style of signal instead of a varying voltage signal, which provides compatibility with RC speed controllers.

6.6 Setup Speed Limits

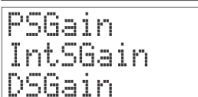
The speed limit menu contains settings relating to the Cycle Analyst limiting power based on the vehicle speed. This includes a maximum assist speed, a minimum speed for power to work, and even a maximum speed that only applies when the rider is using the throttle without pedaling.



Speed Limit Setup Menu



Speed Limit Options and Parameters



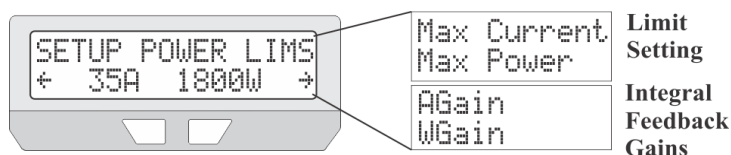
PID Feedback Loop Gain Settings

These features are most often used to make setups comply with local ebike regulations that stipulate maximum speed for motor assistance, and sometimes a different limit when pedaling versus just using the throttle. A 3 term PID control algorithm is employed in firmware to enable a smooth rollback of motor power as target speed is reached without oscillation. The default feedback settings work well for most ebike systems with common PWM controllers, but they may need to be decreased for powerful ebikes, or increased by a factor of 2 or 3 for ebikes running a torque-based controller like the Phaserunner or Baserunner.

The use of regen speed limiting is a useful feature for those who want a speed governor behavior when riding downhill. It enables the system to automatically enter proportional regen mode when the speed limit is exceeded without needing to activate ebrakes.

6.7 Setup Power Limits

There are many reasons for using a Cycle Analyst to limit the power of an ebike beyond the controller's native limits. This can be done to reduce stress on a battery cells for better cycle life, to extend the range you are able to get on a charge, to prevent inadvertent overcurrent tripping of a BMS circuit, to limit the risk of motor overheating, and to reduce mechanical stress to drivetrains on mid-drive systems.



Power can be limited either with a battery current limit in amps, or a power limit in watts. Both have similar effect, though with an amps limit the power will decline as the battery depletes and drops in voltage, while with a watts limit it remains constant. In general, the use of an amps limit is most appropriate when the goal is protection of the battery pack, while a watts limit makes most sense when you are wanting to protect the motor or mechanical drivetrain.

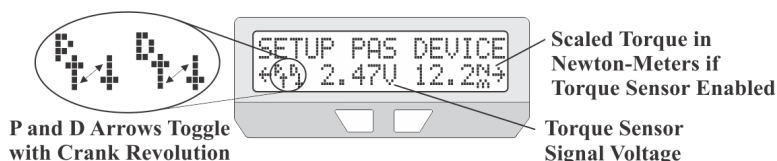
When the CA device is limiting power because one of these limits is active, the diagnostics screen will capitalize the associated **a** or **w** limit flag. If the power output becomes jerky and oscillates at this point that it is a sign that the associated feedback gain term needs to be adjusted downwards until the behavior is smooth via the WGain and AGain feedback terms.

If no limiting is desired, then these limits can be left at their default high values (99 Amps and 9990 Watts) where they will not come into play.

6.8 Setting Up PAS or Torque Sensors

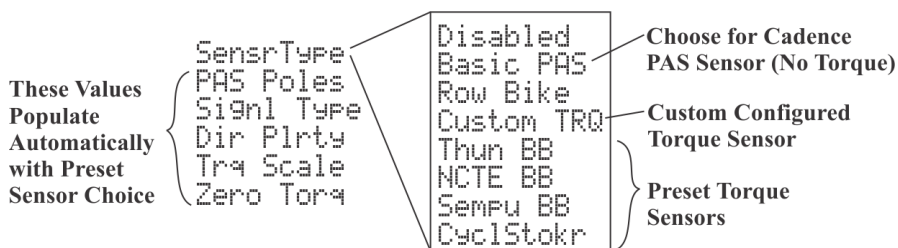
The setup of a PAS sensor involves telling the CA3 details of both the type of PAS device that is connected, as well as how to respond to pedal input.

The Setup PAS Device preview screen shows the state of both the digital PAS signals, with an arrow beside the letters 'P' and 'D'. When you rotate the cranks, either one or both of these should toggle up and down. If only the 'P' arrow toggles you have a 1 wire PAS sensor, while if both the 'P' and 'D' alter in succession you have a 2-wire (quadrature) sensor. The number of PAS poles should equal the number of times this signal toggles in one complete crank revolution.



The preview screen also shows the voltage coming from the torque sensor. On most torque devices this will sit somewhere between 1-2.5V, and then either increase or decrease as you apply force on the pedals. With no torque sensor attached the voltage will rise to nearly 5V.

Configuring a basic PAS device involves setting the number of PAS poles and the fwd/rev direction sense. The correct setting for the Direction Polarity varies with installation, depending on whether the sensor is installed on the left or the right crank. If the CA shows a human RPM reading when the cranks are spun backwards and not when spun forwards, then the direction polarity setting needs to be flipped.



With a torque sensor, the CA also needs to know the voltage when there is no torque on the pedals, and how this voltage increases with applied pedal torque.

Without that it will not show an accurate measure of the human power input, nor will it be able to scale the rider's pedal effort into a proportional motor power.

Fortunately there are a number of preconfigured torque sensor devices in the CA3.1 setup menu which will preload appropriate default values for that sensor type. Most users can simply select their sensor type from the menu without knowing the specific signal details.

6.9 PAS Configuration

The Setup PAS Configuration menu determines how the CA3 responds to the pedal sensor input signals. There are three basic types of PAS control available.

- **Basic (Pwr):** In this mode, the CA3 attempts to produce a constant power output in watts when pedaling is detected, and this power can be scaled to increase or decrease with pedal RPM as well. This is the most common mode of PAS assistance with basic PAS sensors.

```
PAS → Strt Level
+ 600 W          ↔
```

Basic PAS Power Mode with
600 Watts Baseline Assist

```
PAS → Scale Fctr
+ 5.00 W/rpm    ↔
```

Above 50rpm Assist Power
Increases with Cadence by 5 W/rpm

- **Basic (ThO):** This is a somewhat different approach to PAS where the CA3's throttle output voltage is held constant rather than the target power level. With normal PWM motor controllers this mode results in each PAS set point having an approximate wheel speed rather than motor power.

```
PAS → Strt Level
80 %            ↔
```

Basic PAS Throttle Mode, Set %Throttle Rather Than Power

```
PAS → Scale Fctr
+0.00 %/rpm    ↔
```

- **Torque:** This mode is only available if a torque sensor is configured in the PAS device setup. When selected, the CA3 attempts to mirror the human power on the pedals with motor power on the wheel, giving proportional torque control. The assist level is set by a multiplier on the human power, and for most riders a max setting of 2X to 4X the human power level is about right. The Start Level parameter in this case sets a minimum human effort requirement before the motor kicks in.

```
PAS → Strt Level
+ 80 HWatts     ↔
```

80 Watts Human Power
Required for Torque Assist

```
PAS → Scale Fctr
4.00 W/HWatt   ↔
```

Above 80 Watts, Motor Adds
4 Watts for each 1 Watt Human Power

In all 3 PAS modes you can control the timing when PAS kicks in as you start pedaling, and how long it lingers after you stop pedaling. This is done by editing the PAS Start and Stop Thresholds.

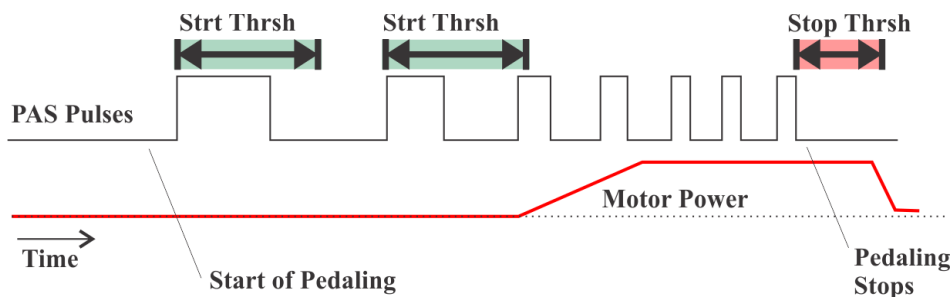
```
PAS → Strt Thrsh
0.40 sec      ↔
```

```
PAS → Stop Thrsh
0.25 sec      |→
```

Timing thresholds between PAS pulses controls the responsiveness of the CA3 to the starting and stopping of pedal rotation.

The Cycle Analyst does not sense your actual pedal speed in a continuous manner, rather it sees a signal pulse every time a new PAS magnet passes the sensor. The faster you pedal, shorter the time between these pulses.

When pedaling from a standstill the cranks start off spinning quite slowly and the time between pulses can be pretty long, resulting in a delay before the motor power engages. The longer the PAS Start Threshold time, the more likely that even the first few pulses will start power assist. However, if the value is too long then incidental twitches or bumps on the pedals can cause short bursts of unintended motor power even when the cranks aren't being turned. A Start Threshold value of 0.25-0.4 seconds works well for most setups.

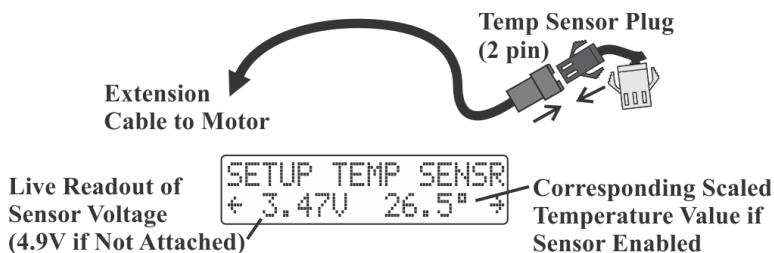


When the system is under power with the rider spinning the cranks, the CA3 needs to know for how long it should continue powering the motor while waiting for the next PAS pulse to occur. This is controlled with the Stop Threshold setting. A short time value will result in a nice immediate cutout in motor power, but too low will cause unintended cutouts when pedaling at low RPMs. Stop Threshold values of 0.15-0.3 seconds work well for most setups.

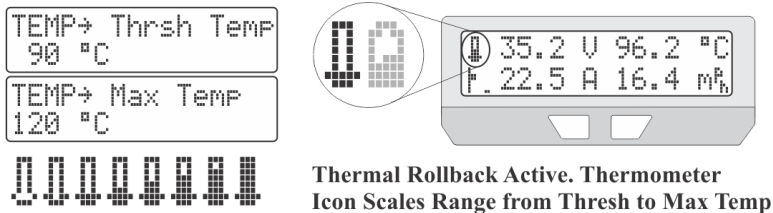
In all cases, higher pole count PAS sensors have the advantage for allowing the shortest delays in response to pedaling.

6.10 Temperature Sensor

The Cycle Analyst has a 2-pin input intended for motor temperature sensing. Many motors supplied by Grin have a 10K NTC thermistor (Beta constant of 3900) prewired into the stator which can hook up to the CA3 through a 2-wire extension cable. The firmware also supports most linear temperature sensor IC's through a custom offset and scale factor.



The Cycle Analyst automatically reduces output power of the system when the temperature is higher than the threshold temperature. It does this by scaling the current limit from the maximum set point down to zero amps as the motor temperature increases from the threshold to the maximum temperature.



When thermal rollback is active a flashing thermometer icon will alternate with the battery SOC icon on the main screen, and the T flag will be active on the diagnostics screen.



In general most hub motors can withstand core temperatures of up to 150 °C for short times without suffering insulation damage or demagnetization, but it's advisable both for headroom and motor efficiency to keep motor core temperatures below about 110-120 °C.

6.11 Setup Auxiliary Control Inputs

The auxiliary input on the Cycle Analyst allows for the rider to adjust settings on the fly without going into the Cycle Analyst setup menu. This is popular on bikes that have PAS or Torque sensors on them in order to adjust the assist level while riding.



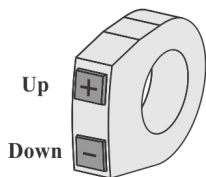
Digi Aux Set for 8 Levels of PAS Assist. Currently on Level 3 (38% of Max)

Live Readout of Aux Voltage

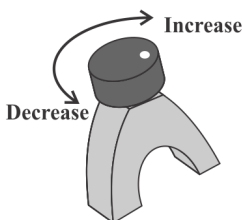


Analog Potentiometer Set for Adjusting Max Speed Limit.

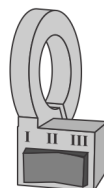
There are three types Auxiliary input available which plug into the white 3-pin CA3 connector. A digital button arrangement for up-down adjustment, an analog potentiometer for continuously variable setting adjustment, and a 3 position switch for three discrete settings.



DigiAux Up/Down Button Control



Analog Potentiometer Dial for Continuous Adjust



Three Position Analog Switch

Low = 1.6V
Med = 2.5V
High = 3.3V

Each of these auxiliary inputs can be configured to adjust the vehicle's speed limit, power limit, amps limit, max throttle output, or pedal assist level. When the Aux input is adjusted while riding, a pop-up window shows the new adjustment value to the rider, before returning to the normal display.

AuxD+ Function
PAS Level

↑ Off
Presets
Amps Lim
Speed Lim
Power Lim
↓ Thr0 Lim

List of Functions Controllable from Aux Inputs



Main Screen Temporary Aux Display on Change:
Dx = DigiAux
Ax = AnalogAux



Pop-Up Window on Other Displays

With the Digital Aux input, you can set the number steps as well as the percentage corresponding to the first step in case you want the lowest setting to be above zero.

AuxD+ Max Levels
5 steps

AuxD+ Min Prctnt
50 %

These settings would result in 5 even steps from 50% to 100% of the limit. If the AuxD Function was set to Amps Limit and the Max Current was 40A, the result would be current limits of 20A, 25A, 30A, 35A, and 40A.

With the Analog Aux input, the adjustment parameters depend on whether the control is a 2 or 3 position switch, or a continuously adjustable potentiometer. The CA3 assumes that each switch position produces a voltage in the following range.

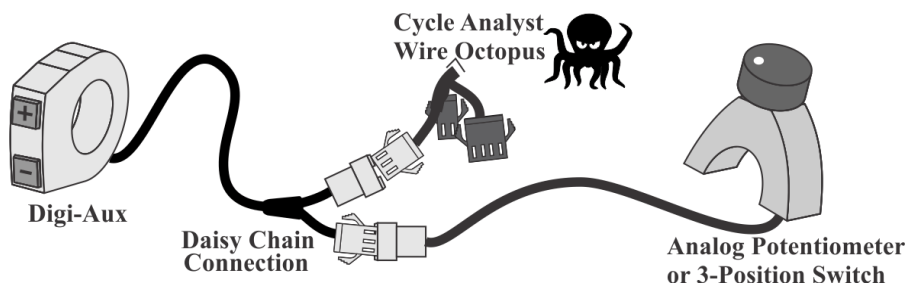
AuxA+ Cntrl Type		
Pot	2-Pos Sw	3-Pos Sw
0-5V Adj	I < 2.5V II > 2.5V	I < 2V II ~ 2.5V III > 3V

AuxA+ Low Sw Lvl
30 %

AuxA+ Med Sw Lvl
80 %

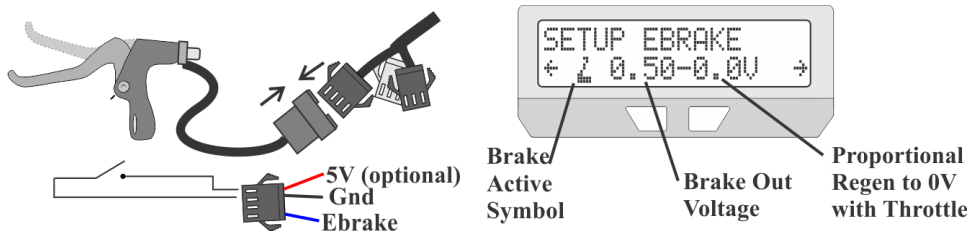
The potentiometer mode automatically scales the limit from 0 - 100%. With 2 or 3 position switches, the analog voltage range is mapped to switch positions, and the corresponding limit percentage is user settable.

The Digital Aux buttons feature both male and female 3-pin connectors which allow daisy chaining an analog potentiometer or a 3 position switch at the same time as the digital buttons. This provides the ability to independently control two different limit settings from the handlebars, one with the digital control and another with the analog control.



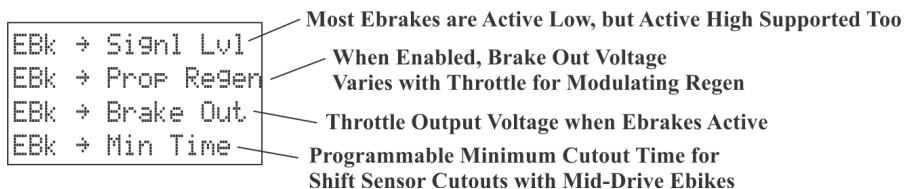
6.12 Setup Ebrakes and Regen.

The 4-pin ebrake plug of the Cycle Analyst supports digital ebrake cutoff sensors. Most sensors are 2-wire normally open switches that close when the brake levers are pressed, though some are powered hall sensor devices and require 5V too. The CA supports both types and also allows for ebrakes with reversed normally closed switch logic, which is often easier to implement with DIY cutoffs.



When the brake levers are squeezed, the throttle slider on the main screen will instead show an animated brake lever, and the throttle output voltage to the controller will drop down to the programmed Brake Out voltage, effectively cutting power to the motor.

With Grin and certain third party controllers, the throttle signal range from 0.0V to 0.8V is mapped to do proportional regenerative braking. This mapping allows the CA3 to regulate motor braking behavior on the same throttle output signal. When the proportional regen feature is enabled, the Brake Out voltage sets the baseline braking force when levers are squeezed, and the throttle can further modulate this to maximum braking (equivalent to an output of 0.0V)



There is also a Min Brake Time parameter which supports using the brake lever as a shift sensor cutout for mid-drive systems. It's possible to hook up a shift sensor product directly to the ebrake plug, or briefly tap the brake lever before shifting. The CA will keep the motor cutout active for the minimum time setting in order for the gear shift to complete before power is reapplied.

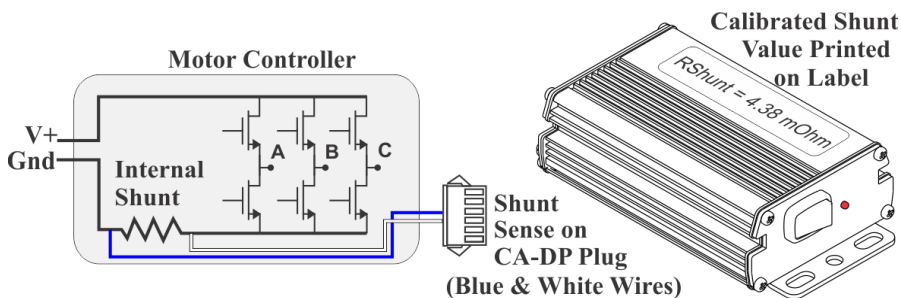
6.13 Set Current Sense Shunt Resistance

The Cycle Analyst detects the current and power flowing through your system by looking at the small voltage drop across a shunt resistor. This allows it to work over a very broad range of power levels, from small 200 watt pedalecs to 50kW electric cars. It is essential to set the RShunt value in the CA to match the connected sense resistor for accurate watts, amps, and amp-hour readings.

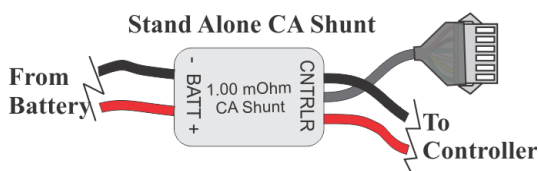
The shunt resistance is configured in the calibration setup menu and the current value is shown on the preview screen.



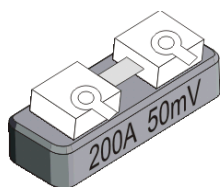
For systems that are directly plugged into the motor controller, the calibrated Rshunt value should be printed on the controller label.



Typical imported 6 mosfet controllers have ~3-6mOhm shunts, while larger 12 mosfet controllers are usually 2-3 mOhm. Ezee controllers are about 1.5 mOhm and the Grin Phaserunner / Baserunner are both 1.0 mOhm. If you leave RShunt at the default value of 1.000 mOhm on controllers that have a higher actual resistance, then the amps and watts readings will be way too high.



The Stand Alone shunt that we offer for controllers lacking a 6-pin CA plug is exactly 1.000 mOhm, which is conveniently the default value in the CA.



High current shunt resistors for larger EV's do not typically list their rating in mOhm. Instead they are characterized by the current which will produce a full scale reading on a 50mV (most common) or 100mV galvanometer. To calculate the RShunt from one of these devices, divide the mV full scale value of the shunt by the amps rating. For instance, a 200A 50mV unit has an RShunt value of:

$$50\text{mV} / 200\text{A} = 0.250 \text{ mOhm}$$

It's worth noting that shunt resistors are large blocks of metal that can handle significantly more current for short times than their "rated" current. Don't be concerned if you have a 75A shunt but draw 150 or 200A peak currents, in general this is fine.

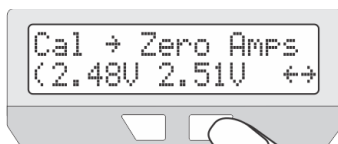
Most high current shunts will be less than 0.8 mOhm and the Cycle Analyst must be set to High Range (0.1A) mode to accommodate them. The High Range mode will show power in kilowatts instead of watts, and current to the nearest 0.1A instead of 0.01A.

6.13.1 Zero Amps

If the Cycle Analyst consistently shows a small positive or negative power even when the motor is not running, it means that the amps offset needs to be zeroed to recalibrate the no-current reference point.



Time to Zero the Amps!



Press and Hold
to Save Current Offset

This is done by pressing and holding the button on the "Zero Amps" setup routine. The screen shows the actual output voltage from the two current sensing amplifiers, and they should both be approximately 2.50V. If the resulting voltages are widely different from this, it usually indicates a bad connection on either of the shunt sensing wires (S+ and S-, white and blue respectively).

6.14 Using Presets

Mode presets are useful for riders wanting a shortcut to quickly switch between up to three preconfigured groups of power limits, speed limits, and PAS / throttle mode settings. This is commonly used for bike setups with street legal and off-road modes, or to switch between various economy and high power levels.

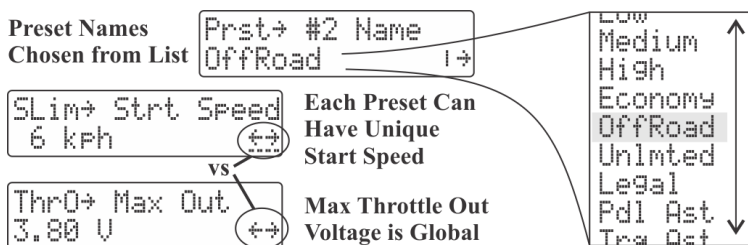


3 Presets Active.
Currently in Preset #1
called 'Economy'



Hold Left While Tapping Right
Button to Change Preset

Settings which can be uniquely customized for each preset are identified by the four dashes under the navigation arrows in the setup menu. Settings without these dashes are global and apply to all presets. An optional name from a selection list can be given to each preset to for ease of identifying them.



Once enabled, the rapid switching between presets can be achieved in two ways:

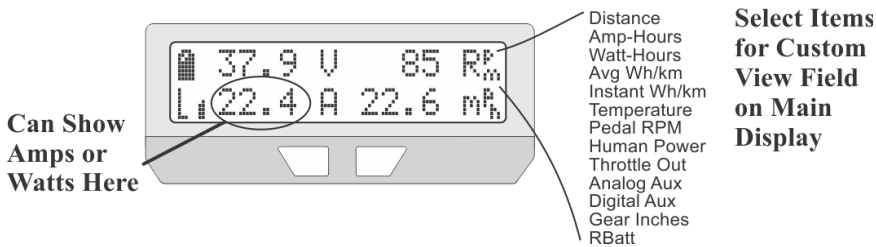
1. Hold the left button down on the CA3 and then tap the right button. Each tap of the right button will cycle through to the next preset. Release the buttons when you are at the desired preset.
2. Configure either a 3-position switch or the digi aux input for preset control. This will allow you to change presets from the handlebars.

You can similarly activate two battery presets (A&B) from the Battery setup menu. To swap batteries, simply hold the *right* button while tapping the *left*.

It is important to remember that when editing certain settings in the setup menu, you are only editing the value on the currently selected preset. To edit the values in the other presets, you need to switch to the desired preset first.

6.15 Display Customization

The CA3.1 provides many options for customizing the screens to display only information that is pertinent to a given setup and user. Any of the 12 display screens can be hidden from view while in motion or while stopped. Many fields on the main screen can be user set, and it's possible to enable an automatic return to the main display after a short time without needing to navigate home.



```
Disp→ Mvng Scrns
@0000@000000@ ←|
```

Only the 1st, 4th, 6th, and 12th Display Screens Visible while Moving

```
Disp→ Auto Main
Enabled ←→
```

Return to Main Display Automatically After 12 Seconds of No Button Presses

```
Disp→ Cust Views
Wh, km, Wh ←→
```

Custom View Will Cycle Through Watt-Hours, Distance, and Wh/km

7 Data Logging

The Cycle Analyst sends out a constant stream of serial data on the TRS jack that can be used for trip logging, displaying on alternate screens, and performance analysis.

This information is output as a 0-5V TTL level serial data stream at 9600 baud. On power-up the CA transmits a header line showing the meaning of each data column, and then either once or ten times a second (as set in the Miscellaneous->Data Rate setting) it outputs a matching data row.

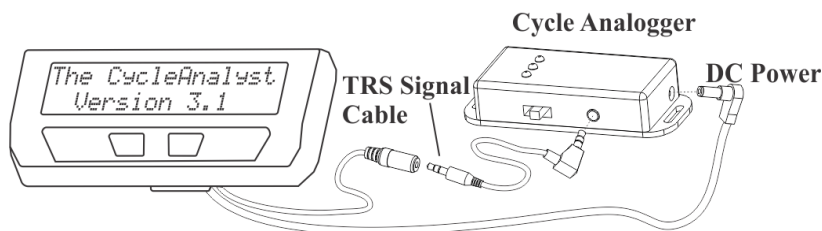
Ah	V	A	S	D	Deg	RPM	HW	Nm	ThI	ThO	AuxA	AuxD	Flgs
5.542	37.28	0.05	0.00	11.58	31.2	0.0	0	0.2	0.82	1.00	82.4	75.0	1
5.542	37.28	0.05	0.00	11.58	31.2	0.0	0	0.2	0.82	1.00	82.4	75.0	1
5.542	37.28	0.05	0.00	11.58	31.2	0.0	0	0.2	0.82	1.00	82.4	75.0	1
5.542	37.28	0.05	0.00	11.58	31.2	0.0	0	0.2	0.82	1.00	82.4	75.0	1
5.542	37.28	0.05	0.00	11.58	31.2	0.0	0	0.2	0.82	1.00	82.4	75.0	1

The Flags column on the end starts off with the current mode preset (#1 in this example) and then uses letters (A,W,s,S,V,T) to show any active limits like on the diagnostics screen, as well as 'B' to indicate if ebrakes are pressed and X to indicate a throttle fault.

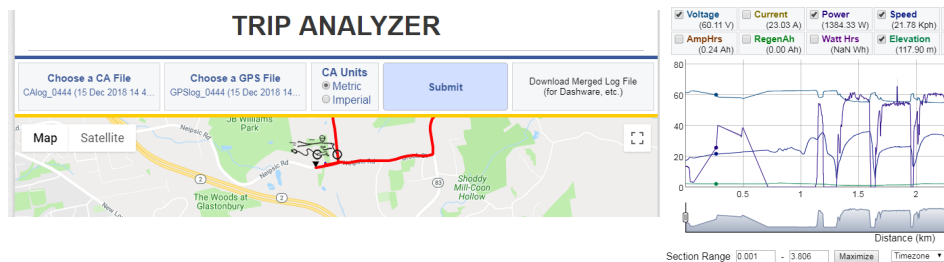
Each line of data is sent out in tab delimited ASCII format making it easy to view the data in a text editor or spreadsheet. The transmitted values are the same averaged data that is presented on the CA's display screen. When using the fast 10Hz log rate, it is recommended to set the Display Averaging parameter to 0.08 seconds so that each logged data value is unique and not repeated.

Grin offers a USB→TTL adapter cable to transmit this information directly to a computer with a terminal program or to a USB OTG enabled smartphone. Alternately any serial converter cable with a matching TRS pinout should work as well, as would a serial to bluetooth converter.

We do not currently produce any software applications designed for the realtime logging and graphical display of this information, although free terminal programs are available on all platforms to display and log serial data. Grin does produce a product (the Cycle Anologger) that is plug and play with CA devices and conveniently logs data directly to an SD memory card along with optional GPS data.



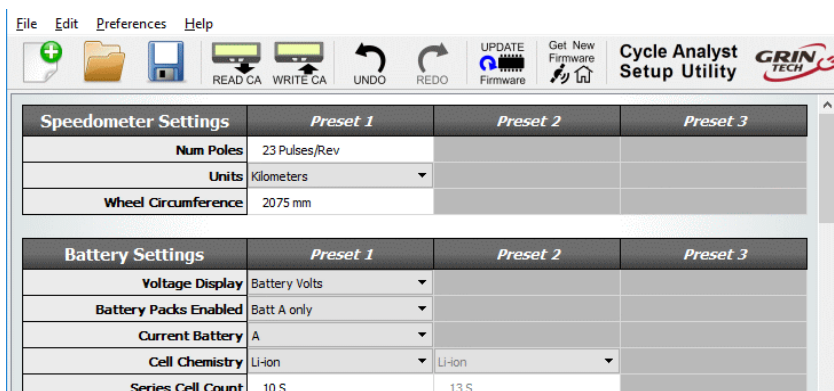
Recorded CA data (whether logged with the Anologger or any other means) can then be analyzed and visualized online with our [Trip Analyzer](#) web application.



This web application also has the ability to upload and merge a corresponding NMEA encoded GPS file to show your consumption at various points on a trip.

8 Software Setup Utility

The Cycle Analyst [Setup Utility software](#) is available for Windows, MacOS, and Linux, and it lets you edit all the CA3 parameters by computer rather than through the two button interface. The software also allows you to update and reflash the firmware on the Cycle Analyst, and load various special purpose firmwares like the Solar CA code or GPS code.



The software suite and instructions for using it are both on the CA3 info page <https://www.ebikes.ca/product-info/cycle-analyst-3.html>

Even if the software utility is not used for flashing new settings on your device, it is still useful as a reference for learning in greater detail the function of each and every setting on your CA. There is a detailed tooltip that will show up when you hover the mouse over any setting of interest, and these can be seen all in one file by going Help->Help

Min Start Speed	0.00 km/hr	0.00 km/hr
Max No-Pedal Speed	99 km/hr	99 km/hr
Proportional Speed Gain	1.01 V/kph	
Integral Speed Gain	[SLim->PSGain]	
Differential Speed Gain	Proportional (P) feedback term for the speed PID control loop and displayed in terms of Volts / (mph or kph). If set to 0.5V/kph, the throttle output will immediately drop by 0.5V for each km/hr the bike exceeds the set speed limit. This adjusts the correction for the 'present' speed error.	
Power Limit Settings		
Current Limit		

There are certain items that can't be changed from the device and do require the software tool. These are in the OEM category, and include the ability to hide items inside the setup menu itself and also set a total upper bounds for the maximum power, speed, and current limits that the user can configure.

9 Common Mistakes

The Cycle Analyst is pretty rugged and (we like to think) pretty self-explanatory. But there are several user errors that have come up more often than others and it is best to bring attention to these common mistakes upfront.

- 1. Connecting throttle to controller and not the CA3:** If the throttle is left plugged into the controller, then the CA's throttle output will be at the minimum output and will over-ride the connected throttle. This results in no power or very little power when the throttle is turned.
- 2. Hooking up a PAS sensor not able to handle 10V:** The power on the 5-pin PAS plug is 10V in order to be compatible with torque sensor models. The Grin supplied PAS sensors have all been modified to handle 10V power, but most third party PAS sensors can't. Hooking them up without adding an inline 5V regulator will typically fry the PAS sensor. It can also damage the CA too, if while failing it draws excessive current from the 10V power bus.
- 3. Connecting a programming header to PAS plug:** Certain models of 3rd party motor controller use a 5-pin JST plug for controller programming, and when this is mistakenly plugged into a Cycle Analyst PAS plug it shorts out the 10V bus and damages the CA similar to item 2.
- 4. Using a torque sensor on a high voltage system:** Even though the CA on its own can handle up to 150V, this voltage needs to be derated when accessories are plugged in which draw significant current. Most torque sensors consume at least 20mA from the CA's 10V power bus, and that usually correlates to no more than 52V nominal battery packs. A torque sensor can be used with a high voltage ebike system if the power for the torque sensor is supplied externally and not through the 10V on the PAS plug.
- 5. Not reading the web page, manual, software tooltips, or our YouTube videos and making a bunch of random ill-informed changes:** Yeah, this happens pretty often too. Luckily in the V3.1 firmware it's possible to restore all settings back to factory defaults in the Miscellaneous setup menu. Choose *Misc->Defaults* and then select *Restore*.

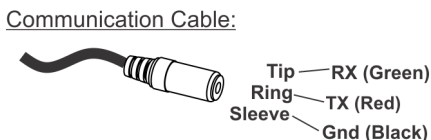
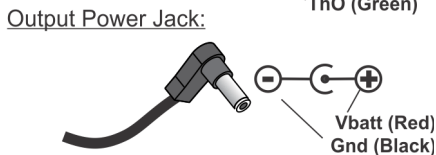
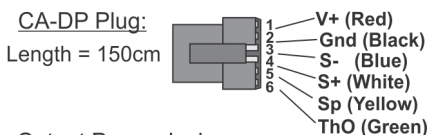
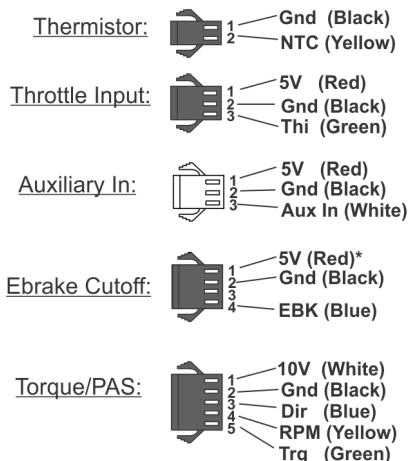
10 Enjoy your Ride and Remember to Reset

That's it! After 34 pages of study, we hope that this Version 3.1 Cycle Analyst lets you not only achieve the performance behavior you want from your ebike, but that in using it you gain a new level of understanding on how ebike systems in general work and operate. That more than anything is our mission with this product.

And please don't forget to *RESET YOUR CA* every time you have a fresh full charge on the battery. That's essential to get the most from this device, and you want to make it a second-nature habit.

11 Specifications

11.1.1 Cables and Connectors



*5V Pin on Ebrake plug new since Dec 2016. Earlier units just had EBK and Gnd

JST-SM connector series for signal lines. DC Power is 5.5x2.1mm.

11.1.2 Electrical

Voltage Range	10-150V, but derated by accessory current draw. With common torque sensors on PAS plug, 60V max.
Voltage Resolution	0.1V
Device Current	10mA
Current Sense Range	±240 mV/Rshunt. For instance, with a 2mΩ sense resistor, the maximum current is 120 amps. With a 0.5mΩ resistor, up to 480 amps, and so forth
Current Resolution	0.01A in low range mode, 0.1A in high range mode

11.1.3 Mechanical

Dimensions	129 x 57 x 25 mm
Weight	270 g

11.1.4 Certifications

	This device is CE compliant for use with 60V or lower ebike systems
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