Guide to Making Motor Controllers that are CA3-WP Compatible

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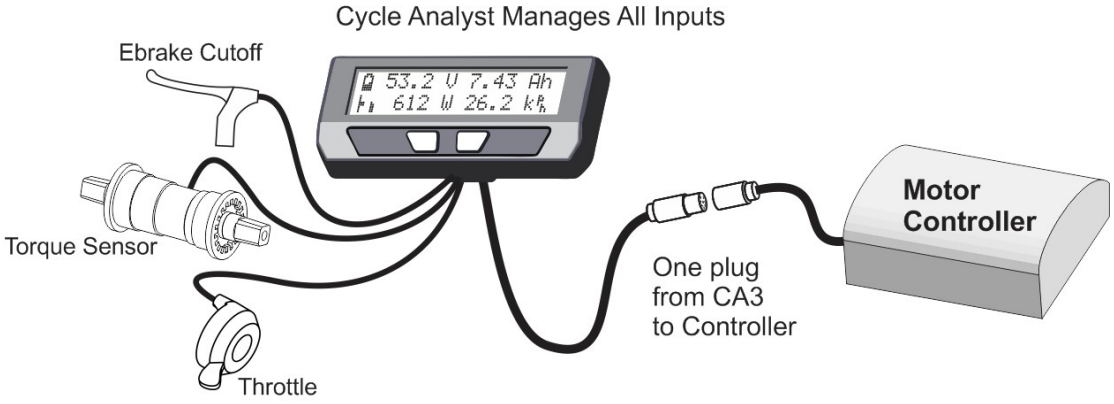
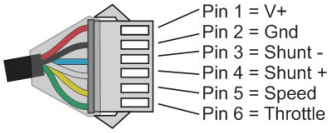
1 Introduction

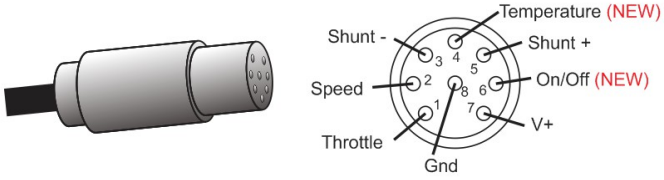
The Cycle Analyst is designed as a universal display device that can read the analog signals commonly available on any ebike system to infer the volts, amps, watts and speed of a vehicle. It can then modulate the throttle signal going to the motor controller in order to activate speed limits, power limits, pedal sensor control, and many other features. The Cycle Analyst does all of this without any communication protocol or special controller requirements, allowing for maximum compatibility with controller models both now and in the future.



In 2020, we updated our plug standard for the Cycle Analyst from the original 6-pin JST connector to the popular 8 pin waterproof HiGo Z812 style connector. The two two extra pins allow for both motor temperature sensing and on/off power control via the CA3 display.



Original CA-DP JST Plug
6 Pin



New CA-WP Plug
8 Pin

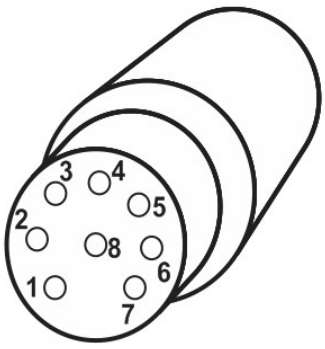
This guide goes over the process of making a 3rd party motor controller have a compatible CA3-WP plug.

2 Connector Details

The Z812 waterproof connector has been in use with Bafang and other popular ebike systems as the main signal connector between the motor controller the cable harness to display and sensors. The common Bafang pinout for this connection is shown in the table below on the left, compared to our Grin WP8 standard on the right.

Pin #	Bafang Z812 Standard		Grin WP8 Standard	
1	Blue	Throttle	Green	Throttle
2	Red	+5V	Yellow	Speed
3	Yellow	RX	Blue	Shunt-
4	White	Ebrake	Grey	Temperature
5	Green	TX	White	Shunt+
6	Orange	On/Off Key	Orange	On/Off Key
7	Brown	V+	Red (22g)	V+
8	Black	Gnd	Black (22g)	Gnd

For the CA3-WP devices, we keep the pin locations of the 4 common signals (V+, Key, Gnd, and Throttle) the same. However, the other signals are different. Instead of having TX and RX communication lines, these two pins now go to a common shunt resistor for sensing battery current flow. And instead of having 5V and Ebrake inputs, we use these signal lines for a wheel speed sensor and a motor temperature sensor.



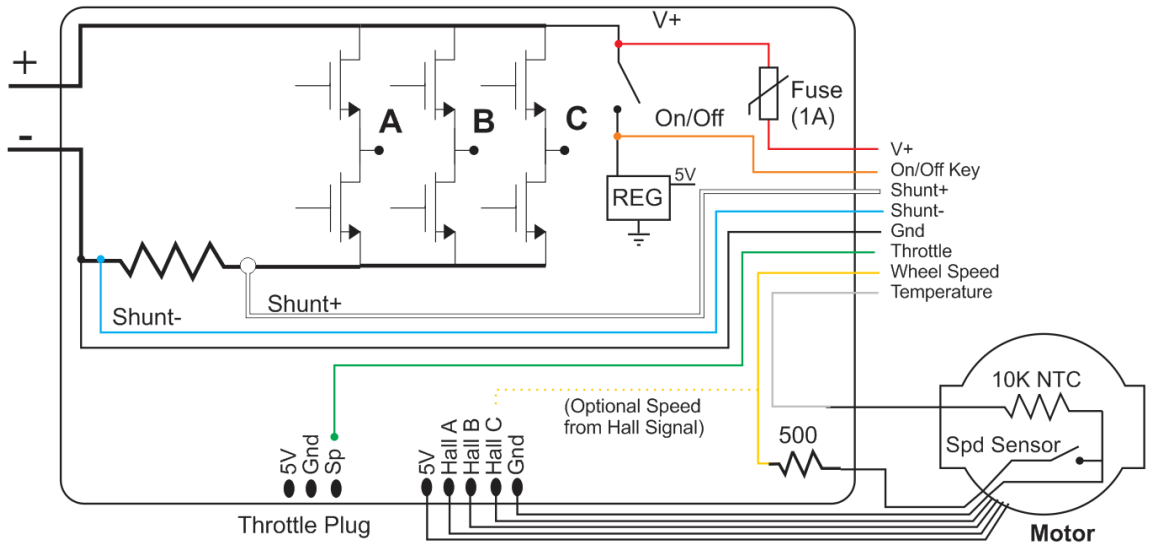
3 Differences between our WP8 and HiGo812 Cables

For the CA3 cables and plugs produced by Grin, we have used a different colour coding for each wire in order to have consistency with the colours used in the original 6-pin JST plug standard. We have also customized the wire gauges so that V+ and Gnd wires are heavier than the 6 signal lines to support higher current draw from bike lights and other accessories.

This cable is produced from Cusmade and is available for purchase directly from them (WH-A003-CA002 RevA2) or from Grin (WP8_F). Although it is possible to use the Higo Z812 plug to make a CA3 connection, we recommend the using the Cusmade cable when possible for consistent cable colours and higher current capabilities with the power wires.

4 Connection Schematic

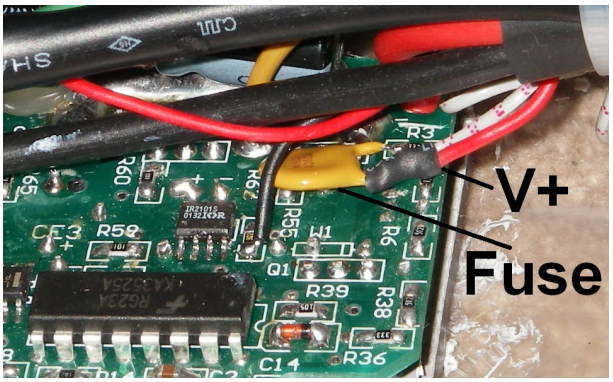
The diagram below shows the wiring hookup of the CA3-WP plug to a typical motor controller. The connector taps into the battery V+ and Gnd for power and pack voltage sensing, it taps into either side of the existing current sensing shunt resistor for measuring the battery current draw, and it connects to the throttle input plug as well. Other signals like the wheel speed sensor and motor temperature sensor typically pass through directly from the motor cable.



5 Details of Each Pin

The wire colour references are for the Cusmade WP8 cable.

5.1 V+ (Red for WP8 – Brown for Z812)



This is the positive battery voltage line, and it both supplies power to the Cycle Analyst and provides the sense for voltage measurement. This connection should be fused with a re-settable polyfuse device rated for at least 1A of hold current to protect against short circuits of the power bus. It is wired directly wired to the positive battery rail, before any on/off key switch contact.

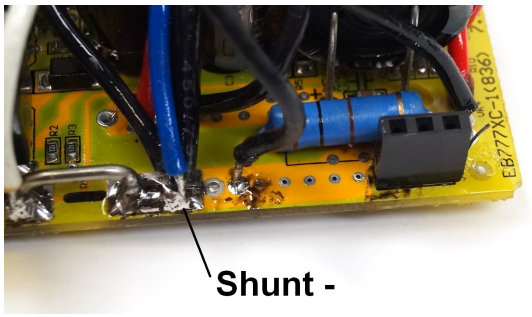
5.2 Key (Orange)

This wire hooks up to the on/off key switch input of the motor controller which returns battery V+ voltage to power the controller's logic circuitry. If the controller does not have a key switch input this wire can be left unterminated, in which case the Cycle Analyst will not be able to turn the controller off and on. Instead power would be turned on and off via the main battery power to the controller.

5.3 Gnd (Black)

This is the ground reference for the Cycle Analyst and is the point of return current for the Cycle Analyst power. Normally it would be connected to the same ground point as the battery reference, although in certain situations you can attach the ground to the bus connected to S+, in which case the CA will also show accessory current draw.

5.4 Shunt- (Blue for WP8 – Green for Z812)

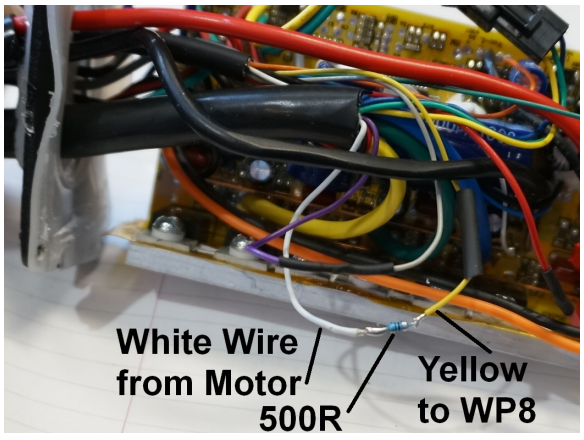


This is a the negative current sensing lead of the shunt, on the side closest to the battery return. It should be soldered as near as possible to the base connection of the shunt resistor for best accuracy and consistency in the readings. Do not think that because the negative side of the shunt is on the same trace as the ground pads of the PCB that you can hook up the blue wire to any available ground connection, as that will result in false current readings on the CA3 as a result of variations in the ground potential from current flow on the motor controller.

5.5 Shunt+ (White for WP8 – Green for Z812)

This is the positive current sensing lead of the shunt, on the side that is closest to the mosfet return bus. It should also be soldered as near as possible to the shunt resistor itself in order for accurate and stable current sense readings. If it is located further down the bus bar, it will have higher drift with temperature.

5.6 Speed (Yellow for WP8 – Red for Z812)

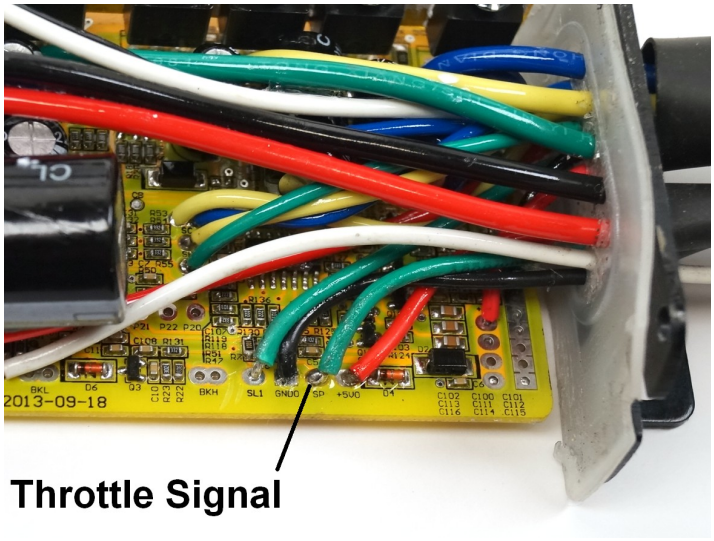


The Cycle Analyst computes vehicle speed based on pulses present on the speed signal that are timed with the wheel rotation. Most geared hub motors have built in speedometers with between 1 to 6 magnets in the motor shell which is present on the white wire of the motor cable. This can be directly wired to the Speed line of the WP8 plug, although better rejection of noise and glitches is achieved with an inline resistor of approximately 500 ohms.

Direct drive motors do not typically have a separate speed sensor as the motor hall signals can serve the same purpose. If the controller is being used with a direct drive motor and with a connector standard that doesn't include a speed signal hookup, then the speed signal can be wired directly to one of the 3 hall signals instead.

5.7 Throttle (Green for WP8 – Blue for Z812)

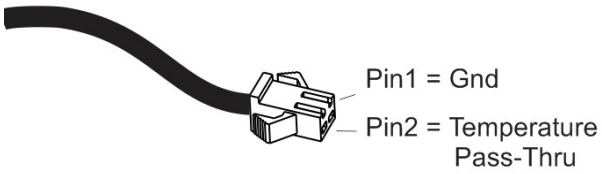
The V3 Cycle Analyst is expected to send its own throttle signal to the motor controller, with the user throttle hooked up to the CA3 instead of the motor controller.



If the controller is designed for the CA3 to to be optional, then there will also be a separate direct throttle plug on the motor controller. We recommend putting a 1kOhm resistor in series with the throttle signal to avoid conflict when both the CA's throttle and an external throttle are wired to the motor controller.

5.8 Motor Temperature (Grey for WP8 – White for Z812)

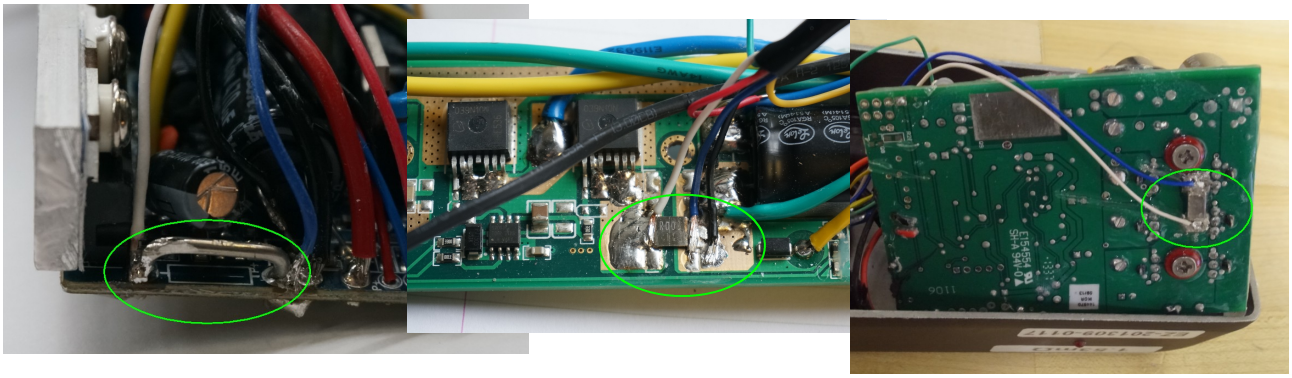
The grey wire of the WP8 plug is intended to measure the motor winding temperature. This allows the Cycle Analyst to sense and display the motor temperature directly and activate thermal rollback if the motor gets too hot. Most often this signal will come directly from the motor cable and will loop back out to the WP8 plug without connecting to the motor controller PCB.



If the connector between the motor and controller does not include a temperature sensor, we recommend bringing out this wire via a 2-pin female JST-SM plug to allow the hookup of an external temperature sensor into the system.

6 Controllers Without a Shunt

The majority of motor controllers use a shunt resistor between the negative mosfet bus and battery ground to detect battery current flow. These shunts are usually in the form of a resistive metal wire hoop or strip, and are generally between 1-5 mOhm of resistance. The Cycle Analyst taps into this same shunt resistor for sensing the amperage flow as well.



However, some field oriented motor controllers sense current flow with hall transducers on the motor *phase* wires rather than the battery return. In these controllers there is no onboard shunt suitable for the Cycle Analyst, and it must be added externally. Grin Tech offers a precision 1.000 mOhm shunt that can be crimped onto the negative battery lead and used in these scenarios.

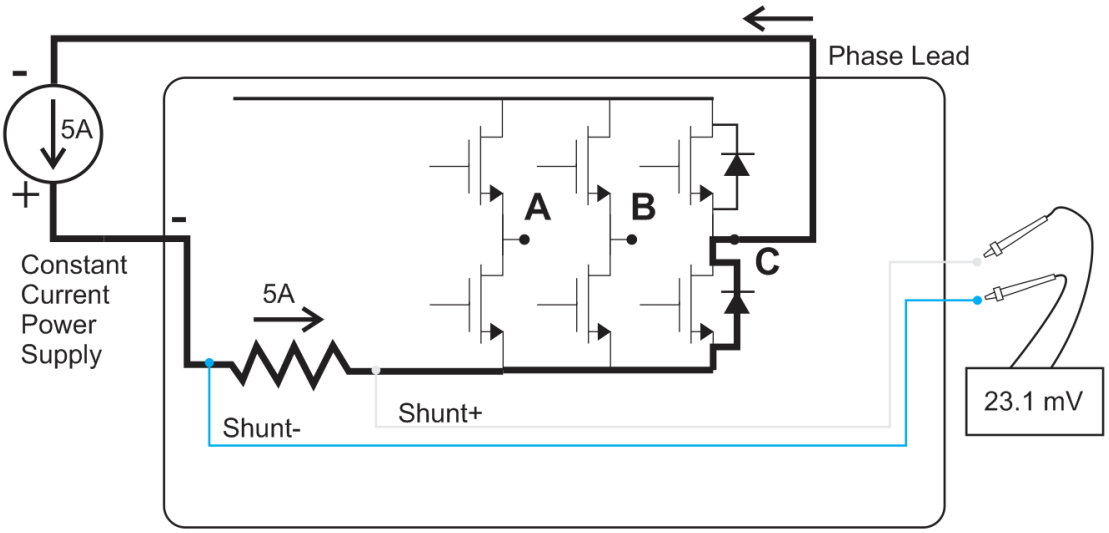
1.00 mOhm Inline Shunt

7 Controller RShunt Label

The Cycle Analyst will only display accurate power and amp-hour readings if it knows the actual shunt resistance inside the controller. Wire hoop shunts often vary by over 10% from one controller to the next and commercial surface mount shunts can vary by up to 5% as the nature of the solder job will affect the observed resistance.

We recommend that every controller has the actual measured and calibrated shunt resistance printed on the controller label so that the user can input this value into their CA device for accurate readings.

The shunt resistance can be measured by forcing current from a regulated DC power supply through the motor phase lead and out the negative battery lead and measuring the voltage drop across the Shunt- and Shunt+ wires with a multimeter. The resistance is then calculated with ohms law.



So for instance, if the power supply is injecting 5.0 amps of current, and you measure 23.1 mV on the multimeter, the shunt is 23.1mV/5.0A = 4.62 mOhm

For a more convenient and portable measurement solution, Grin manufactures a precision RShunt resistance tester that is self powered with a lithium battery and shows the shunt resistance directly to the nearest 0.001 mOhm with the push of a button.

8 Common Mistakes

Hopefully the details are clear enough. Historically we have seen several mistakes in 3rd party CA plug integration.

1. **Assuming the S- is just like Gnd**: Just because the ground line and the negative shunt line are electrically equivalent does not mean that you can hook the S- line up to any convenient ground pad. The ground return has actual currents flowing through it, and a difference of a few mV in ground potential can show up as several amps of erroneous current reading on the CA screen. Make sure that the blue S- wire is soldered immediately adjacent to the shunt itself.

2. **Assuming all Shunt Resistances are the same**: We have seen some vendors use a blanked shunt resistance, like 1.3333 mOhm, when actual measurements on these controllers vary by more than 10% from this value. Unless you can guarantee a 3% or better accuracy on the sense lead, we recommend measuring and labelling each controller uniquely.

9 Additional Help

If you are a controller manufacturer or OEM and are looking for additional help or confirmation, please contact Grin Technologies. In many cases it is possible to ship Grin a sample controller (without potting of conformal coating on the PCB) and we will be able to make an example modification with the CA plug on it as a reference.

Similarly, if your controller does not have a suitable onboard shunt for current sensing, then contact us about our crimpable 1.000 mOhm shunt devices.