Instructions for the Velociraptor Intelligent Motor Controller

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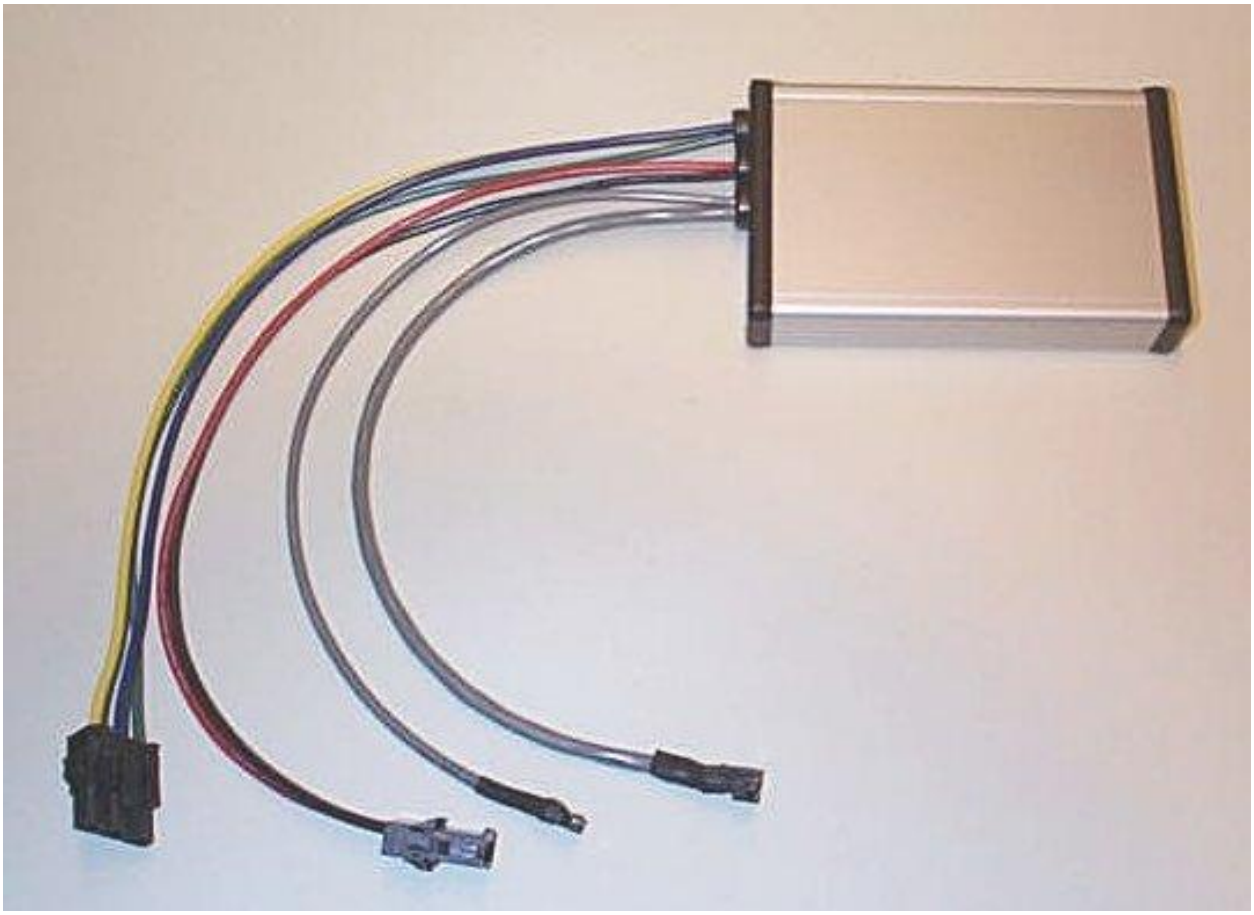
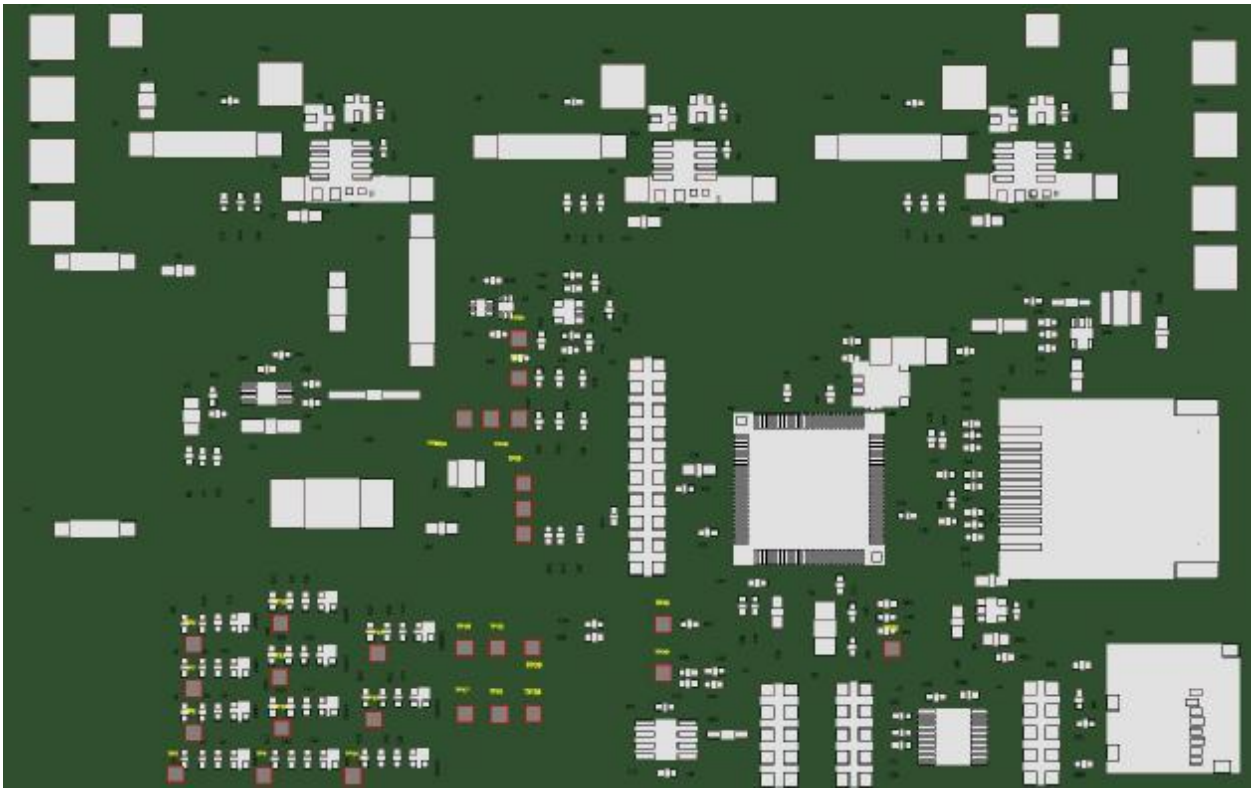




(**EcoSpeed Velociraptor)**

Congratulations on your purchase of the EcoSpeed Velociraptor Intelligent Motor Controller, the worlds first fully programmable, software based digital motor controller for e-bikes. The EcoSpeed Velociraptor is one the world's most advanced digital motor controllers for three-phase brushless DC motors, and is designed specifically for throttle operated, electric-assist applications. It is the only electric-assist motor controller designed specifically to fit a wide variety of motor types, and differing battery systems.

The EcoSpeed Velociraptor has the following features :

1) Automatic battery voltage configuration. Detects battery voltage and configures internal parameters for optimal operation with that voltage. Operates with 24 to 48 volt battery systems. No jumpers to set, it just works.
2) Programmable battery chemistry support. Ships optimized for LiFePO4, but can be set upon request to work with any chemistry.
3) Programmable motor power limit. Can be set to allow in excess of 1000 Watts of power if the motor it's connected to can handle it.
4) Current mode throttle operation. More intuitive than conventional speed controls in that power is proportional to how far the throttle is pressed. Half throttle equals half power.
5) Intelligent battery interface. Detects how much power the battery can reliably supply and limits motor to just that amount.
6) Dual mode operation. A switch on the case selects between two operating programs. One is conservative and is designed to get the best battery life. The other is a power mode for maximum performance. Much more intelligent than a simple power/economy setting in that the power you get in each mode also depends on your battery. With a strong battery, even the economy mode will give strong performance.
7) Low voltage limiting, not cut off. Most controllers will either shut down completely if the battery voltage drops below a fixed limit or will force the battery BMS to shut down by drawing too much current when the battery in nearing the end of its charge. The Velociraptor will detect low battery voltage and automatically limit power to try and keep you going as long as possible with a low battery.
8) Automatic high temperature limiting. Again, most controllers will simply shut down if they get too hot. Usually it happens when you're climbing a steep hill on a hot day, exactly the worst time for that. The Velociraptor will slowly back off the power as it heats up. You can feel it lose power, but it keeps going, delivering as much power as it's able to under the circumstances. As it cools, power comes back. You could even give it a squirt from your water bottle if you are in need of a few extra amps.
9) Layered protection systems. Driving hundreds of pounds of bike and rider at high speeds or up steep hills in all weather is a lot to ask of a few transistors in a box weighing half a kilogram. That's why controller failures are so common. The Velociraptor sports multiple layers of protection from advanced thermal design to electrical protection devices to software that samples critical parameters hundreds of thousands of times per second. Like its namesake, Velociraptor is built to survive.
10) Built to be upgraded. We're not done with Velociraptor. It's built around a 32-bit Harvard architecture RISC processor that easily handles all the features we have today. We'll be adding features at a rapid clip. If you see something you want, we can simply reprogram your controller with the latest code. If there's any added hardware involved, we can add that too. Your Velociraptor won't be obsolete for a long time.

Cable Connection Instructions

Installation is simplicity itself. Connect the Hall Sense and Phase cables to your motor. Connect the power cable to your battery and finally connect your throttle to the throttle cable. Diagrams on succeeding pages show the connector details, but they are unnecessary unless you're adapting our controller to a non-EcoSpeed motor. All connectors are unique, so there's only one way to connect them.

Mounting Instructions

The controller is lightweight and may simply be attached to a pannier rack or frame using the included cable ties. If you purchased one of our battery cradles, the correct screws and spacers for attaching to that will be included.

Any of the screws visible on the outside of the case may be used as mounting points. The five M4 button head machine screws on the bottom of the case are especially strong, but are relatively short at only 6 mm (1/4"). They can be replaced with longer M4 screws as long as they don't penetrate more than 7.5 mm into the case when tightened. This is important as too long screws can contact the bottom of the circuit board and cause damage or failure.

Operation

Turn on the System

Turn on the main power switch on your battery to power up the system. The red LED on the Velociraptor case will turn on. It should be lit steadily after a second or two, blinking indicates a fault condition. See the fault code section later for details.

Press the throttle and your motor will turn on. If you look at the LED when you first press the throttle, you will notice it turn off briefly. This provides a quick check to see if your throttle connection is good. If you don't see the LED turn off, check the connections to your throttle.

Program Selection

The Velociraptor ships with two preprogrammed operating modes that are selectable via the case switch. Flipping the switch to the down (towards the screws on the underside of the case) position selects program 1. The up position selects program 2.

Program 1

Program one is optimized for long battery life. Peak power is restricted somewhat so you won't get the highest possible power. Battery voltage droop under load is tightly controlled. This means that if your battery is small or weak, the controller will back off motor power to avoid excessive voltage droop which is an indicator of a highly stressed battery. We recommend using program 1 as your normal operating mode unless you have an large battery system capable of continuous high currents.

On 1000 Watt systems, program 1 also selects a 50 US state legal 750 Watt power limit.

Program 2

Program 2 is optimized for best performance. Operating power is allowed to rise to whatever your motor can handle. Current is boosted slightly at high rpms for even more power when spinning fast. Battery voltage droop is only lightly restricted.

If you have a strong battery, you can leave the system in Program 2 and enjoy stellar performance all the time. If not, it's best to reserve this setting for occasional use. Frequent use will shorten your battery life.

Throttle Operation

Most, or maybe all, motor controllers built for e-bikes use the throttle as a speed controller. When you press the throttle it tells the motor to accelerate to a certain speed. The controller decides how much power to apply. The result is that you don't have accurate control over how much power the motor is putting out. Mostly that doesn't matter, but if you're trying to limit power while limping home with an almost dead battery or a mechanical problem, it can be an annoyance. It also puts unneeded stress on your

bike and battery.

Velociraptor uses true power control. How far you press the throttle determines how much power you get, just like the gas pedal of a car. You can operate the throttle gently most of the time for improved battery life and less wear and tear on the bike. When you need it though, full power is right there under your thumb.

Intelligent Power Features

The Velociraptor is an intelligent motor controller. It constantly samples various system parameters at rates up to a million times per second. Based on what it sees, it makes decisions on how much power it can safely allow the motor to output or whether to allow it to operate at all.

The Velociraptor design philosophy is to try to keep you going under almost any circumstance. To do that, if it detects abnormal conditions it will first try to operate the motor at reduced power for as long as possible. For example, if your battery is nearing fully discharged you will notice a decrease in power as the controller tries to keep the battery voltage high enough to avoid tripping the battery BMS* shutdown.

Similarly when climbing a steep hill or going fast on a hot day, Velociraptor will reduce motor power if it starts to get too hot. It does so in small steps so you may not even notice at first. But, even if it gets extremely hot, it will try to give you at least a little bit of power for as long as it can. A small amount of power is far better than being stuck on a steep hill from the sudden high temperature shutdown that is typical of most controllers. Also, Velociraptor won't wait until it cools down all the way before increasing power again. You get extra power immediately for each degree that it cools.

Most often, the Velociraptor will operate at reduced power to protect your battery. Program 1, above, operates the battery in a conservative manner to get the best possible battery life. It will vary the maximum allowed motor power to achieve that aim.

Multiple Voltage Operation

Velociraptor is designed to operate from either 24, 36, or 48 volt battery systems. Each time the controller powers up it reads the battery voltage and reconfigures itself to operate with that voltage. The means setting up current limits appropriate to the battery voltage and setting up battery parameters to protect the battery from being overstressed. Most controllers, if they have any battery protection at all simply have a fixed low voltage shut down. Velociraptor goes far beyond that.

As it ships from the factory Velociraptor is optimized for use with Lithium Iron Phosphate batteries in the common 8-cell (25.6V nominal), 12-cell (38.4V nominal), and 16-cell (51.2V nominal) sizes. If you wish to use the Velociraptor with a different battery chemistry, just ask and we can set it up for your favorite battery.

Battery Saving Features

The secret few in the young electric vehicle industry talk about is that how long your battery lasts is determined almost exclusively by its treated. The problem is that you, the battery owner, don't have a lot of control over that since it's the motor controller that is doing the treating.

Velociraptor gives you the power to decide how much battery life you want. Program 1 is set up to minimize stress on your battery for maximum life. If your battery is older and starting to weaken, or if it's small and just can't supply a lot of power, Velociraptor will adapt by running your motor at lower power. You'll get noticeably less performance, but it will still be more than adequate in most situations and you'll be able to stretch out the life of your expensive battery.

* BMS: Battery Management System. A piece of electronics that watches the cells inside a battery and shuts the battery pack off if the voltage of any one cell drops too low.

If you want to maximize your battery life, leave the controller in Program 1 most of the time. Reserve Program 2 for the occasional e-bike race or off-road adventure.

If performance is more important to you than battery life, leave it in program 2. This mode is programmed to push the battery harder, but still not abuse it as many high performance controllers will. What that means is that if you have a fresh battery that can supply the full current without excessive voltage drop, you'll get full power out of the motor. Typically that means you'll need at least a 350 Watt-hour (Wh) battery with a 700 Watt system or a 500 Wh battery with a 1000 Watt system.

Battery life in program 2 won't be as good as in program 1, but will still be better than with most high performance systems. Note that if your battery can't meet the current and voltage requirements of program 2, the control will still reduce motor power as in program 1 to avoid abusing your battery.

If you want both the best possible battery life and maximum performance, the way to do that is with a large battery system. We recommend at least 500 Wh and preferably 750 Wh for 700 Watt systems and 750 to 1000 Wh with 1000 Watt systems. This assumes typical lithium iron phosphate e-bike batteries. Some smaller batteries, such as the ones used on power tools, can supply the needed current though the trade off is more weight for a given capacity.

Proper Shifting with Multi-speed Drives

EcoSpeed EMD and EMtnD electric drive systems utilize a bike's gear system to match motor speed to bike speed for best performance. On such systems, getting good reliability from your controller is partly dependent on knowing how to shift gears properly.

You want to avoid situations where the motor is trying to accelerate the bike from a stop in the highest gears. This puts extreme stress on the controller power stage, momentarily drawing hundreds of amps through transistors that are only rated for a fraction of that. Trying to climb an extremely steep grade in a low gear with the bike not moving or moving very slowly does the same thing.

Velociraptor is designed with multiple layers of protection to avoid failure when treated this way, but that doesn't mean it's a good idea to rely exclusively on that protection. Better to think of it as a backup plan should you unthinkingly do something dumb.

If you're not familiar with gearing terminology, *high* means a harder gear to pedal and *low* means easier. The small cogs in the rear are *high* and the big rings in the front are *high*. On flat ground start out with the middle size or larger cogs in the rear (these are the *lower* numbers on your shift grip or lever).. Use smaller rear cogs if you're in the biggest front ring. On hills use the smallest rear cogs and use the smallest front rings on the steepest hills.

LED Flash Codes

The LED on the Velociraptor case is more than just a simple power on indicator, as is common. It will flash to indicate various normal and abnormal operating conditions. During normal operation the LED stays on but turns off briefly to indicate certain operations. If there is a problem with the system, the LED will turn off and then repeatedly flash brief codes to indicate the problem.

The following are the LED flash codes:

Normal, LED continuously on, these codes flash only once.

1) Continuous on: Normal operation
2) Off for 3/4 second: Throttle pressed.
3) One on-off flash: Program 1 selected.
4) Two on-off flashes: Program 2 selected.

Fault Indications, LED continually off, these codes repeat.

1) Single short flash: Battery voltage too high to start *(Overvolt Start)*.
2) Double short flash: Battery voltage too low to start *(Undervolt Start)*.
3) Triple short flash: Battery voltage dropped too low while running *(Undervolt Run)*.
4) Long flash, pause, short flash: Motor current too high. *(Overcurrent)*.
5) Long flash, pause, two short flashes: Possible short circuit or heavily loaded motor *(Soft Fuse)*.
6) Long flash, pause, three short flashes: Stalled motor detected. (*Motor Stall)*
7) Long flash, short flash, pause, short flash: Controller temperature too high *(Overtemp)*.
8) Long flash, short flash, pause, two short flashes: Possible shorted throttle *(Throttle Rate)*.
9) Long flash, long flash, pause, short flash: Motor emergency stopped *(Emergency Stop)*.
10) Long flash, long flash, pause, two short flashes: Unexpected software problem *(Watchdog Timer)*.

Long flashes are 3/4 second, short are 1/4 second.

What to Do If You Get a Fault Code

Overvolt Start

Battery voltage is over 60 volts. The Velociraptor can be safely connected to a DC voltage source of up to 64 volts. It will not allow the motor to start however if the input voltage is over 60. If you get this code, make sure you are using a battery that's in the right voltage range.

Undervolt Start

Battery voltage is less than 14 volts. The controller will not allow the motor to start if it sees less than 14 volts at any time. The least the controllers internal power supply will operate on is 12 volts. Below that the controller may not respond at all. This fault may sometimes happen on power up if the battery voltage rises too slowly. If you know that your battery voltage is OK, just ride. The fault will clear as soon as you press the throttle the first time.

Undervolt Run

Battery voltage dropped below parameterized limit. When the controller detects the battery voltage at startup it picks an absolute minimum voltage limit to protect the battery. If the battery voltage drops below this limit the controller shuts down the motor. This is intended as a backup to the battery BMS which should shut the battery down before the voltage drops this low. If you see this fault, stop using the system and check or charge your battery.

Overcurrent

Motor current has exceeded a limit chosen based on battery voltage and motor power. Normally this should never happen, but might occur when lugging the motor in too high a gear. The first time you see this fault, simply turn the system off then back on. If it occurs repeatedly and you are operating the system normally, have the system checked.

Soft Fuse

This is a backup to the over current protection. The controller samples motor current over 200,000 times per second. If it detects a current spike that's beyond safe limits, it can shut down the motor drive within tens of microseconds, far faster than an electrical fuse. The first time you see this fault, simply turn the system off then back on. It is usually caused by a heavily loaded motor pulling in too high a gear It can also be caused by a fault in the wiring between the motor and controller or a problem in the motor. If it occurs repeatedly and you are operating the system normally, have the system checked.
Motor Stall

This most often happens when attempting to start at full power in too high a gear. Stalling the motor on steep climbs will also cause this. The motor does not have to be completely stopped to be considered stalled. High current at very low speed for more than a very short time is considered stalled. Downshift if you're not in lowest gear, otherwise use light throttle application until you get rolling.

Overtemp

As the controller heats up it first tries to run at reduced power. Normally this will work and the controller will stop heating up at a certain power level. If for some reason the controller still gets too hot, it will shut down with an over temperature fault. If you see this fault, check the mounting location of your controller. It may be located in a place where it can't get airflow over the case that it needs to stay cool. Otherwise, turn it off and wait for it to cool a bit. The controller can be turned on again at reduced power as soon as it has cooled only a few degrees.

Throttle Rate

This is a safety feature intended to catch the situation where an electrical defect in the throttle or its cable causes power to short to the throttle signal wire. This is a very rare occurrence but, if it does happen, it forces the motor instantly to full power, which is obviously a safety hazard. This feature works by constantly checking the rate at which the throttle voltage changes. In normal operation it changes slowly. If a short occurs, it typically changes very rapidly and trips this fault. If you see this fault, shut down the system and have your throttle checked before using the motor again.

SAFETY NOTE: Throttle failures are very rare, but they do happen. Normally they fail turned off, which is not a problem. Sometimes though, a failure happens that causes the throttle to request full power. This feature will catch many of those and safely shut down the motor, but not all. **If your throttle sticks at full power, don't fumble trying to reach the power switch unless it is readily at hand. Just apply your brakes firmly and stop. Well maintained brakes can easily overpower the motor even at full power.** And, of course, you do keep your brakes well maintained, don't you?

Emergency Stop

All faults cause the controller to emergency stop the motor. If an emergency stop happens for some other reason, this fault code is displayed. The first time you see this fault, simply turn the system off then back on. If it occurs repeatedly and you are operating the system normally, have the system checked.

Watchdog Timer

This fault indicates a problem with software. Most likely a transient glitch of some sort, such as momentary low battery voltage, caused the Velociraptor control program to crash. Just turn the system off then back on again. If the fault occurs repeatedly, have the system checked.

Firmware and Upgrading

Determining Your Firmware Version

The Velociraptor is a software based motor controller. As such it ships with the latest version of its control program, EMCA (EcoSpeed Motor Control Application) that's available as of its ship date. Over time, we will make improvements and feature additions to EMCA. Should you want to upgrade your controller to take advantage of the improvements or new features, that's easily done.

The firmware version your controller is programmed with is found on a sticker on the inside of the cover that has the switch and LED. Loosen and remove the four screws holding the cover plate. Gently pull it off being aware that there are wires attached to the switch and LED that are soldered to the circuit board.

The firmware sticker will read something like “emca.b330.1.bmc1k”. The digits following the “b” refer to the software build number, the “.1” is a particular parameter set, and “bmc1k” refers to the motor it is programmed for, in this case the BMC 1000 Watt. The firmware version is the build number.

Upgrading Firmware

We’re not ready to risk releasing EMCA onto the web (where anyone can copy it), so for now you’ll have to ship your controller back to us to have the firmware upgraded. The process is quick, so we’ll be able to turn your controller around and ship it back to you in a day or two. Your first upgrade is free, after that we charge a $10 upgrade fee to cover the costs of opening the case and restoring the weather seals when we’re done. Any upgrades that fix problems with earlier versions will always be free.

Hardware Upgrades

Some new features will require the addition of additional hardware such as added signal cables or sensors. These will also be available to Velociraptor owners at a nominal cost depending on the complexity of the upgrade.

Repairs

In keeping with EcoSpeed’s philosophy of not building disposable systems or components, Velociraptor can be repaired if there’s a problem. Repairs are handled at our factory by the same skilled workers who build them in the first place, so you can be assured that it will be done correctly.

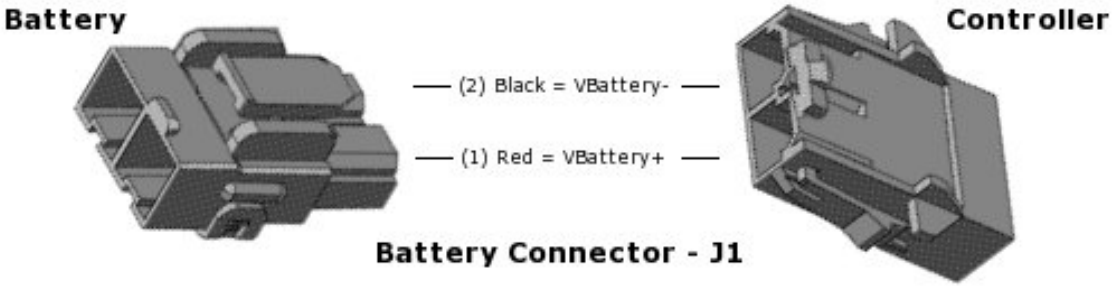
Just ship failed controllers back to us and we’ll take care of the rest.

Warranty

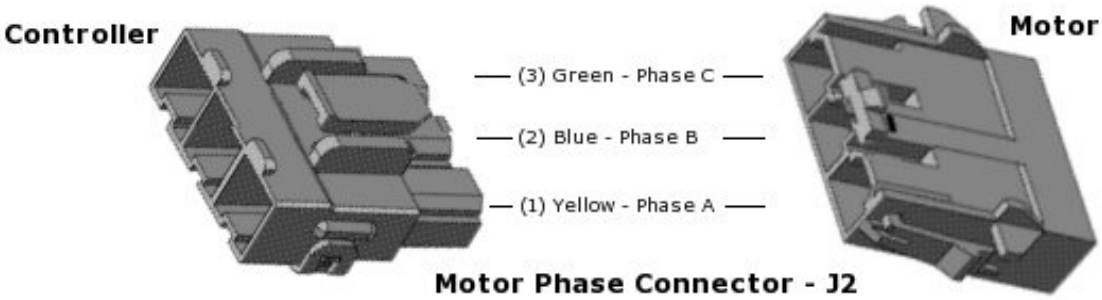
Velociraptor is covered by the same warranty as our drive systems, one year parts and labor for controllers sent back to us for repair or replacement for systems not in commercial or government use. Velociraptor doesn’t have any parts that are field replaceable so they must be returned to us for warranty service.

The Velociraptor is not warranted for use on non-EcoSpeed motors except by permission.

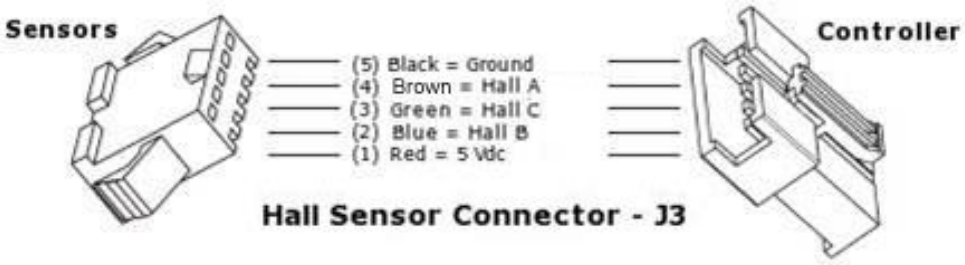
EcoSpeed Velociraptor Connection Diagrams



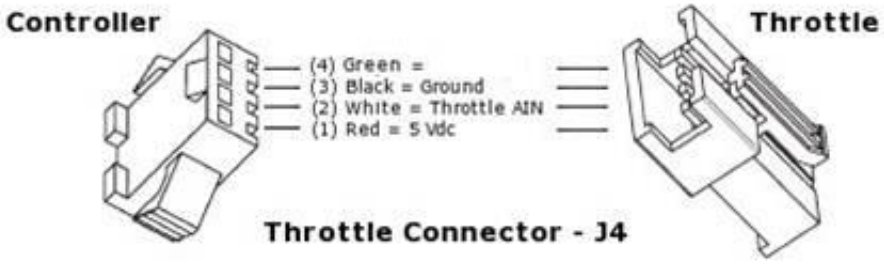
Battery Connector - J1



Motor Phase Connector - J2



Hall Sensor Connector - J3



Throttle Connector - J4

Specifications

Voltage Range, Running:	14 to 60 Volts*
Voltage Range, Safe to Connect:	0 to 64 Volts
Nominal Maximum Operating Current:	47 Amps at 24V, 38 Amps at 36V, 29 amps at 48V
Throttle Voltage Range:	0 to 5 volts.
Startup Throttle Voltage:	1.2 Volts
Full Power Throttle Voltage:	3.9 Volts
Controller Type:	3-phase, brushless DC, sensored
Speed Sensors:	Hall Effect, inverted or non-inverted (programmable)
Sensor Timing:	20 degree advanced (BMC motors) (programmable)

Program 1

48 Volt Battery System:

Minimum Bus Voltage :	*42.4 Volts*
Maximum Voltage Droop:	*4.8 Volts*
Current Limit (700 Watt)§:	*19 Amps*
Current Limit (1000 Watt)§:	*27 Amps*

36Volt Battery System:

Minimum Bus Voltage :	*31.8 Volts*
Maximum Voltage Droop:	*3.6Volts*
Current Limit (700 Watt)§:	*25 Amps*
Current Limit (1000 Watt)§:	*37 Amps*

24Volt Battery System:

Minimum Bus Voltage:	*21.2 Volts*
Maximum Voltage Droop:	*2.4 Volts*
Current Limit (700 Watt)§:	*32 Amps*
Current Limit (1000 Watt)§:	*48 Amps*

Program 2

48 Volt Battery System:

Minimum Bus Voltage :	*38.4 Volts*
Maximum Voltage Droop:	*9.6 Volts*
Current Limit (700 Watt)§:	*20 Amps*
Current Limit (1000 Watt)§:	*29 Amps*

36Volt Battery System:

Minimum Bus Voltage :	*28.8 Volts*
Maximum Voltage Droop:	*7.2Volts*
Current Limit (700 Watt)§:	*27 Amps*
Current Limit (1000 Watt)§:	*39 Amps*

24Volt Battery System:

Minimum Bus Voltage:	*19.2 Volts*
Maximum Voltage Droop:	*4.8 Volts*
Current Limit (700 Watt)§:	*32 Amps*
Current Limit (1000 Watt)§:	*47 Amps*

Both Programs

Minimum Power†:	*150 Watts*
Cutoff Voltage (48V nominal)&:	*33.6 Volts*
Cutoff Voltage (36V nominal)&:	*25.2 Volts*
Cutoff Voltage (24V nominal)&:	*16.8 Volts*

** Program dependent. Will not allow motor to run below programmed minimum bus voltage or above programmed maximum.*

§ This is the nominal maximum current. Actual maximum current will vary according to battery voltage and voltage limits and may be somewhat higher or lower.

† Minimum useful power. Once power drops to this value, the controller will stop enforcing minimum voltage or maximum temperature limits.

& Controller shuts down if battery voltage drops to this level even momentarily.