



*Electric Mid-Drive™*  
*Electric Mountain Drive™*

Owners Manual, All Versions  
with

**VELOCIRAPTOR™**

Intelligent Motor Controller

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[http://www.ecospeed.com/docs/owners manual\\_rev\\_3.0](http://www.ecospeed.com/docs/owners manual_rev_3.0)

Revision 3.0

## **READ THIS FIRST**

### **USER AGREEMENT**

By installing an EcoSpeed Electric Mid-Drive (hereafter, EMD) or Electric Mountain Drive (hereafter, EMtnD) power assist unit on your bicycle, or purchasing a bicycle with such a unit already installed, whether from EcoSpeed, one of its dealers, or a third party, you consent to the following agreement. **If you do not agree and give your consent, you must return the product purchased for a full refund.**

1. Transportation devices, whether electric bicycles, cars, horses, or your feet expose their users to hazards which cannot be eliminated entirely no matter how diligent the manufacturer of said device. Such hazards include **SERIOUS BODILY INJURY, PERMANENT DISABILITY, PARALYSIS, AND DEATH**, as well as any minor injury that you can imagine. You agree to **FULLY ACCEPT AND ASSUME SUCH RISKS AND ALL RESPONSIBILITY FOR LOSSES, COSTS, AND DAMAGES ARISING THEREFROM.**
2. Mechanical and electrical failures are a fact of life for transportation products subjected to the rigors of the road. Tires go flat, chains break and jam, motors and batteries go dead, and any mechanical or electrical component can fail at any time. You agree to regularly and properly maintain your bicycle (by "bicycle", we mean all pedal powered devices whether bicycles, tricycles, quadracycles, or any other pedaled vehicle) and EMD or EMtnD unit to minimize such risks. You agree to regularly inspect your EMD or EMtnD unit and bicycle for hazards such as worn components, loose fasteners or electrical connections, or any other mechanical or electrical problem that could cause a safety hazard. Also, the extra weight and speed resulting from the installation of an EMD or EMtnD unit will result in faster brake wear. You agree to regularly inspect your brakes, rims, pads, discs, brake shoes, and all other braking components for wear and to replace them if they become unsafe. If you do not have the skills to perform maintenance tasks, you are responsible for finding a bicycle shop or other service facility or person to do it for you. You agree to **FULLY ACCEPT RESPONSIBILITY FOR MAINTAINING YOUR ELECTRIC BICYCLE IN A SAFE OPERATING CONDITION.** You further agree to **FULLY ACCEPT ALL CONSEQUENCES, DAMAGES, AND COSTS ARISING FROM ANY MECHANICAL OR ELECTRICAL FAILURE. THIS APPLIES EVEN IF SAID FAILURE IS A CONSEQUENCE OF NORMAL WEAR AND TEAR OR IF SAID FAILURE IS THE RESULT OF NEGLIGENCE ON THE PART OF ECOSPEED INCORPORATED** or any of the Releasees mentioned below.
3. Your bicycle may or may not have been designed by its manufacturer to accept an electric assist motor. While our motor and battery unit do not add any more weight than other common bicycle accessories, such as loaded pannier bags, and do not apply any more force to chains and sprockets than a strong rider can, it is possible that heavy and/or strong riders may exceed bicycle design limits for weight carrying and power applied to drive train components, resulting in unexpected failures. You agree **TO FULLY ACCEPT RESPONSIBILITY FOR ANY CONSEQUENCES, BOTH DIRECT AND INDIRECT, INCLUDING SERIOUS BODILY INJURY AND DEATH ARISING FROM YOUR INSTALLATION OF AN EMD or EMtnD UNIT ON YOUR BICYCLE.**
4. You **AGREE TO RELEASE, DISCHARGE, and COVENANT** not to sue EcoSpeed Incorporated or its dealers and their respective agents, employees, officers, directors, shareholders, affiliates, subsidiaries, and related corporations and assigns (the "Releasees") from all liability, claims, demands, damages, costs, claims for contributions, and claims for indem-

nity of any type or description whatsoever, even if caused by negligence of any of the Releasees.

5. You FURTHER AGREE that if, despite this release agreement, you, or anyone else acting on your behalf, makes a claim against any of the Releasees, you WILL INDEMNIFY AND HOLD HARMLESS EACH OF THE RELEASEES FROM ANY LITIGATION EXPENSES, ATTORNEY'S FEES, LIABILITY, DAMAGE, OR COSTS, which might occur as a result of such claims. You further agree that any such claim will be governed by the laws of the State of Oregon and any claims will be filed in a court within the City of Portland, Oregon.
6. You agree that if any portion of this agreement is held to be invalid, the other portions shall be in full effect.
7. If you sell, transfer, lend, or otherwise allow a third party use of your EMD or EMtnD unit or bicycle equipped with same, you AGREE TO ASSUME ALL LIABILITY unless said third party agrees to this agreement as a condition of use or purchase. Transferring this owners manual to said third party and offering to refund any purchase price if they do not agree will meet this condition. Copies may be requested from EcoSpeed or downloaded from our web site at the URL given on the cover of this document.
8. We have no doubt that a sufficiently clever lawyer can find a way around this agreement, but you get the idea — there is a serious breakdown in our sense of personal responsibility in the US at this time which makes it difficult for companies that make anything more challenging to use than paper clips to do business. We do our very best to make safe, quality products. We just don't want one disgruntled person to sue us out of existence thus depriving the whole world of what we do.



**Electric Mid-Drive™**



**Electric Mountain Drive™**

Congratulations on your purchase of EcoSpeed's Electric Mid-Drive for certain recumbent bicycles or Electric Mountain Drive for almost everything else. The Electric Mid-Drive and Electric Mountain Drive are the world's best multi-speed, throttle operated, electric-assist conversion. With our Exact Fit Technology™ it is also the only assist that uses precision machined mounting components to minimize stress on your bicycle frame.

To install your EMD or EMtnD kit, refer to the accompanying installation instructions. There will be one set of instructions for the drive unit itself and one for the battery pack.

Installation will take a few hours, since there are several steps and you will want to go slowly and do everything carefully. Don't worry though, every step is easy and help is just a phone call or e-mail away: 1-866-EcoSpeed or [support@ecospeed.com](mailto:support@ecospeed.com).

### ***Maintenance Warnings***

**WARNING:** Use only dry lubricants on chains. If you have been using oil to lubricate your chain, you must either replace it with a new chain, or clean it thoroughly and switch lubricants. See Maintenance section.

**WARNING:** Be sure that the unit is switched off when not in use to avoid draining and possibly damaging the battery. BMS equipped batteries will shut down to prevent damage, but may leave you stranded. Our EcoSpeed Velociraptor controller will automatically go into a low power state if left unused for a period of time with the bike stationary.

### ***Power Switch***

If you purchased a battery system from us, the power switch is located on the side of the battery case. On two position switches, UP is ON and DOWN is OFF. UP is considered to be towards the side of the case with the carrying straps.

An optional switch has 3 positions: UP is ON; MIDDLE is OFF; and DOWN is the PRECHARGE position. The Precharge position is *momentary*, meaning it is spring loaded and won't stay in that position.

The Precharge position is for use with BMS (Battery Management System) equipped batteries, that are sensitive to the high inrush currents of typical motor controllers. When a battery is switched on, the controller filter capacitance will look like a short circuit to the BMS. That can cause the BMS to protectively shut down the battery. The Precharge position charges the capacitance through a resistor and prevents the BMS from tripping.

If your BMS shuts when you turn on your battery, press the power switch to the Precharge position for a split second before switching it to ON. If you forget to do that, it won't cause any harm but the motor may not always start. If that happens, just turn it off, wait a few seconds, and use the Precharge position.

### ***Program Switch and LED***

The Velociraptor controller used on you EcoSpeed system has a switch on the case that selects between two operating programs. One is a conservative program (program 1) that reduces maximum power slightly and enforces easy on your battery operation. We recommend you normally ride on this setting.

The other program (program 2) allows full power operation and uses the battery more aggressively, though still providing considerable abuse protection. Continuous use of this program will probably reduce your battery life somewhat, but is the setting of choice for maximum performance.

When the switch is flipped to program 1, the LED on the controller case will flash once. Flip the switch to program 2 and it will flash twice. The LED also turns off briefly when the throttle is pressed with the

motor stopped as a quick check for a good throttle connection. For other LED codes refer to the appendix.

## **Charging the Battery**

Lithium iron phosphate batteries, like those we recommend, will typically arrive nearly fully charged. Still, it's best to do a quick top-off charge before riding, just to be sure.

All chargers have an indicator light that indicates whether or not the battery is fully charged. Usually a red or yellow LED glows to indicate that the battery is being charged. The LED switches to green when charging is complete.

## **Operation**

Both our Electric Mid-Drive and Electric Mountain Drive are designed for optimal power output and efficiency at speeds that match a rider's normal pedal cadence – about 40 to 120 crank revolutions per minute. That means all you have to do is pedal normally and the motor power will be there whenever you need it, in any gear, at any speed.

### *Throttle Use*

Whenever you would like a boost – going up a hill, accelerating away from a stop, or just wanting to go faster – gently press the throttle lever and the motor will spin up and propel you on your way. Avoid mashing the throttle lever quickly so that you're not surprised by the sudden power. Starting from a dead stop in low gear on bikes with a rearward weight bias it's possible to lift the front tire off of the ground with the sudden application of power. So unless you want to impress your friends by popping wheelies (and we don't want to know, if you do!), go easy on the throttle.

### *Shifting*

Derailleurs are designed to be shifted under load. That doesn't mean it's a good idea though. Shifting the rear derailleur while pedaling with the motor engaged will put considerable strain on your cassette and chain. Your drive train will last longer if you back off the throttle and reduce pedal pressure while shifting.

### *EMD Shifting*

For bikes with triple front chainrings, the EMD is geared for highest speed when you're in the middle chainring on the front gears. Shifting down to the small front chainring will cause the motor to turn slower for a given cadence. This increases the torque that the motor can supply – great for slogging up steep climbs. The motor is less efficient while turning slowly and will eventually get hot, so shift up as soon as possible.

If you shift to the largest front chainring the motor will turn faster for a given cadence. A bit less power will be available at these higher speeds, but the motor will operate more efficiently over the full range of throttle settings. This is perfect for relaxed, fast cruising.

On bikes with all the gears in the rear, shifting is the same as with the EMtnD below.

### *EMtnD Shifting*

The EMtnD drives your triple crankset directly so the motor rotational speed is always the same multiple of your cadence no matter what gear you are in. With the EMtnD you shift as you would a bike without assist. Shift to a smaller front ring and/or a larger rear sprocket for hill climbing and the reverse for high speed.

Because the motor spins faster as your cadence increases and because it produces more power at higher rpms, you will go faster and climb steeper grades by shifting to keep your cadence high.

### *Proper Shifting Technique*

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 Velociraptor 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 grip shift 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.

### *Hill Climbing*

Conventional wisdom among bikers is to "spin" while climbing hills. That is, use a high pedal cadence, 100+ RPM, and relatively little pedal pressure. That advice still works with the EMD or EMtnD in use and is the most efficient (least battery power used) way to climb. It also uses more of the rider's aerobic output and can be tiring on long climbs.

### *EMD*

If you want to climb in a more relaxed way or climb fast, shift onto the middle front chainring and use a relaxed, low cadence -- 60-80 RPM, and whatever pedal pressure you're comfortable with. In this speed range the motor is putting out its maximum power. For fastest climbing pick the highest rear gear where you and the motor can hold the 70 to 90 cadence.

### *EMtnD*

To climb in a relaxed fashion with the EMtnD, pick a gear where the motor is not straining and your cadence is comfortable. The way you can tell that the motor is not straining is that the throttle is not fully depressed and the motor can still accelerate the bike.

### *Optimizing Range*

The first or second question everyone asks about a hybrid pedal-electric bike is "How far will it go on a battery charge?" The correct answer is "100,000 miles". Really, it totally depends on how much you pedal.

A 15Ah, 38 volt lithium battery contains over 500 Watt-hours of energy. Heavy or continuous use of the motor and high speed operation can use over 25 Watt-hours per mile. Conservative use can be less than 5 Watt-hours per mile. Twenty mph cruising with continuous motor use can be less than 15 Watt-hours per mile with moderate pedaling. This corresponds to ranges between 20 and 100 miles for that battery.

You get to decide how far you want to go. If you've got a short errand to run, go ahead and use the motor a lot. If you're touring, and it's a long way to the next town, only use the motor on the steepest hills. For everything in between, experience is the best teacher. You'll quickly learn what your personal range is.

### *Starting from a Stop*

The most important consideration is which gear to start in. Pick a fairly low gear but one higher than what you would start in if you didn't have the motor. Too low a gear actually reduces your acceleration away from a stop as the motor quickly reaches its top RPM. Too high a gear lugs the motor resulting in lots of heating in the motor windings but relatively little mechanical power to the wheels. **WARNING:** Don't start in so high a gear that the motor stalls and doesn't start turning immediately. Stalling for more than a fraction of a second will cause the Velociraptor to shut down to protect itself.

Use lower gears for starting on hills than on the flats, just as when pedaling. If you're a tall rider and have the seat way back over the back wheels be aware of the possibility of lifting the front tire off of the ground if you use too much power starting on a hill.

If you're a clipless pedal user, you will find that you can clip one foot in, start using only the motor, and clip in the remaining foot while accelerating away.

Starting out using only the motor is also a good technique for novice riders. You can start with your feet almost touching the ground and then put them on the pedals as speed increases and the bike begins to feel more stable.

### *Riding in Traffic*

If you are already familiar with riding your bike in traffic, be aware that the EMD or EMtnD will give you enough extra speed that car drivers may be confused by you. They may pull out in front of you or try to pass without enough passing distance because they expect you to be slow. Be aware of this and plan accordingly.

The extra speed may also tempt you to mix in with traffic that you might otherwise avoid. At that point you are essentially operating as a motorcycle and should ride with that in mind. Install a mirror or mirrors and ride with 360-degree awareness, paying attention to everything that's happening around you. Always keep enough distance in front of you to stop and have a place to go if a car comes towards you.

Bicycle and even motorcycle safety courses are a good idea. There's more to learn about riding on two wheels than we can cover here. Wear a helmet and be safe out there.

### *Riding on Bike Trails and Near Pedestrians*

Be aware that the higher speed potential of EcoSpeed equipped electric bikes may not mix as well with pedestrian or slower bike traffic on bike trails and paths. It's best to go slow near pedestrians (a good idea on a regular bike as well) so that they will not feel as if they're walking in high speed traffic. Slow to pass other bikes so that you are going only slightly faster than they are. Note that some areas prohibit motor use on trails, though it's generally OK to ride using only the pedals.

### *No-Pedal Operation*

Riding using only the motor is possible, though we don't recommend it. It not as efficient as moderate pedaling and doesn't give you any exercise. That said, there's nothing wrong with doing it occasionally. Just be sure to shift as if you were pedaling, i. e. don't just leave the bike in top gear. Pick gears that let the motor spin at a high RPM and start easily from a stop.

## Changing Gear Ratios

It's possible to tune the performance of the EMD or EMtnD to your riding style by changing gear ratios.

### *EMD*

If you're a strong rider, you can increase top speed by switching to a larger mid-sprocket. Switching to a smaller mid sprocket will improve hill climbing.

If you like to pedal at a faster cadence and want the motor to be producing peak power at that higher cadence, *decrease* the size of the front chainrings. To pedal at a more relaxed pace with full motor power, either increase the size of the front chainrings, or decrease the size of the mid-freewheel.

### *EMtnD*

You gear the EMtnD just like you would a regular bicycle, i. e. smaller front rings and bigger rear cogs for climbing and carrying loads, bigger front rings and smaller rear cogs for high speed. Note that as you go to higher (bigger front + smaller rear) gear ratios, you will eventually find a ratio that gives you the maximum possible speed. Any higher gearing will actually reduce your top speed.

## Maintenance

Your Electric Mid-Drive and Electric Mountain Drive require little regular maintenance. It is important though that the rest of the bike be well maintained. The EMD and EMtnD put extra stress on the entire bike – brakes, chain, sprockets, frame, etc. So pay special attention to proper maintenance and adjustment.

The motor drive chain on the EMD or EMtnD should be inspected and lubricated whenever you lubricate the regular bike chains. **WARNING:** Use only “dry” lubricants to lubricate the motor chain. It's also best to use dry lubricants on the bike chains, though oil is acceptable if you clean your chains frequently. Dry lubricants are wax or PTFE (Teflon™) based and leave no oil film on the outside of the chain. Oil films allow grit to adhere to the chains where it can be carried into the interior of the motor gearbox and cause premature failure. **Use of oil lubricants on the motor chain will void warranty.**

Check the adjustment of the motor chain every few months. EMD units allow you to move the entire drive spindle forward or back to adjust the motor chain. Loosen the 5 bolts on the left side of the motor plate and move the spindle to take up slack. Be sure and torque the 5 bolts that hold the spindle to 55 inch-lbs.

On the EMtnD, there are four nuts and bolts that secure the plate that supports the motor/gearbox unit. Loosen the bolt and nut pairs and move the motor/gearbox unit to take up chain slack. Tighten the bolts and nuts securely.

The chain should be adjusted the that it has a small amount of slack. You should be able to move the chain up and down about 1/4 inch when the slack is properly set. It's OK for it to be a bit looser or tighter than this, but if the chain skips, it's too loose, and if it's taut, it's too tight. After adjusting the chain, rotate the spindle or crankset through a full 360 degrees and make sure the chain never gets too tight.

About once a year in normal use, detach the motor from the gearbox and remove the planetary gear and roller clutch for cleaning and re-lubricating. On the EMD, the motor is held in place by three bolts. Remove them and the motor can be pulled free. The planetary gear is held in place by 4 screws. Remove them and the planetary gear can be removed. The roller clutch will be visible behind the planetary gear and can be removed by hand.

On the EMtnD, remove the motor chain, then remove the motor/gearbox unit and supporting plate by removing the four bolts and nuts used to adjust chain tension. Disassemble the unit to get at the gearbox internals.

The roller clutch consists of two pieces, a shaft and the clutch and sprocket assembly. Clean these two pieces along with the planetary gear in a solvent or with soap and water (be sure to dry thoroughly) . Re-lubricate using a non-EP grease (if the container doesn't say EP, it's not). Re-assembly is the reverse of disassembly.

## **Batteries**

### ***EcoSpeed Batteries***

See the documentation that came with your battery system.

**IMPORTANT: You must read your battery documentation before use. Doing otherwise can damage your battery and void its warranty.**

**WARNING: All EcoSpeed lithium batteries contain BMS electronics that continuously draw a small amount of current. You must charge your battery at least once every 2 months to prevent over discharge by the BMS. Failure to do so may kill your battery and void the warranty. Leaving the battery on the charger when not in use will prevent this happening.**

### ***Batteries from other sources***

You may use batteries from sources other than EcoSpeed. The Velociraptor motor controller will automatically adjust itself to use any size battery from 24 to 48 volts nominal. 36 volt batteries work best with EMtnD systems and 48 volt batteries are best with EMD systems. 48 volt batteries are also acceptable for EMtnD systems.

### ***Battery Life Cycle and Recycling***

Rechargeable batteries inevitably wear out. How long they last depends mostly on how they're treated. Your Velociraptor controller is designed to minimize stress on your battery. Refer to the Appendix for details.

Batteries normally age by losing capacity slowly until at some point the weakest cell in the battery fails completely. So, it's normal for your battery to lose capacity as it ages.

Plan on replacing your battery occasionally as just a normal operating expense. Lithium batteries should last several years and up to 20 thousand miles in normal use.

## **Service and Warranty**

The Electric Mid-Drive and Electric Mountain Drive are warranted for one year on all mechanical and electrical parts except normal wear on standard bike parts. The warranty is for parts only if you choose to service it yourself or have someone do it for you. If the EMD or EMtnD is shipped back to the factory for service, the warranty includes labor as well.

Any unauthorized modifications to your EcoSpeed system will void the warranty. This includes use of any motor controller other than one supplied by EcoSpeed. We do want to support creative use of our products so we can and will make exceptions to this on a case by case basis. You'll have to get in touch with us and give us details of what you're planning to get an exception.

All EcoSpeed lithium batteries are warranted for 1 year. This warranty includes parts, labor and return shipping to customers within the continental US. If you fail to keep your battery properly charged or if it simply wears out in less than 1 year due to heavy, hard use, it is not covered.

If you prefer not to service the unit yourself, remove it from your bike, call or e-mail us for authorization, and then ship the unit back to: EcoSpeed Inc., 1525 SE Powell Blvd. Portland, OR 97202 USA. We will repair it promptly and ship it back to you.

As the years wear on and the warranty expires parts do inevitably wear out. Our commitment to our customers is not to obsolete our products. We design our products with longevity in mind and plan on having parts readily available for all of our products for years to come. We also attempt to use standard parts that are available from multiple sources whenever possible, giving you, the customer, greater choice.

This warranty only applies to Electric Mid-Drives and Electric Mountain Drives in private, non-commercial, non-governmental use. This warranty also specifies the minimum that we will commit to in writing. We reserve the right to do more.

To order parts or to arrange to ship a unit back to the factory for service contact us at 1-866-EcoSpeed (866-326-7733) or by e-mail at [service@ecospeed.com](mailto:service@ecospeed.com).

## Specifications

### Motors

#### *Small Frame*

Motor Type: 3 phase permanent magnet brushless DC. Out runner magnets.  
Hall effect speed sensing.

Motor Constant: 84 rpm/volt

Peak Output Power\*:  
700 watts

Weight: 1.6 kg (3.5 lbs)

#### *Large Frame*

Motor Type: 3 phase permanent magnet brushless DC. Out runner magnets.  
Hall effect speed sensing.

Motor Constant: 84 rpm/volt

Peak Output Power\*:  
1000 watts

Weight: 2.2 kg (4.8 lbs)

### Controller

#### *EcoSpeed Velociraptor Intelligent Motor Controller*

Type: 3 phase BLDC controller.

Current Limit: Self adjusts based on battery voltage and other conditions.

Operating Voltage Range:  
19 volts to 60 volts

*see Appendix for full details*

### Gearing

#### EMD Reduction Gearing:

Planetary Gear: 4.79:1

54T #25 sprocket: 2.84:1

48T #25 sprocket: 2.53:1

Overall: 13.6:1 (54T) or 12.1:1 (48T) from motor to mid-sprocket

spindle

#### EMtnD Reduction Gearing:

Planetary Gear: 4.79:1

85T #25 sprocket: 4.47:1

Overall: 21.4:1 from motor to crankset

**EMD Mid-Freewheels:**

18T standard  
16T to 22T optional

**EMD Mid-Sprockets:**

24T standard  
any 74mm 5-bolt sprocket optional (24T to 32T)

**EMtnD1 (uprights) Sprocket size range:**

24T to 48T

**EMtnD2 (boom mount) Sprocket size range:**

24T to 58T

**Battery System Requirements**

*Velociraptor Controller*

**Recommended Chemistries:**

*Any<sup>^</sup>*

**Nominal Battery Voltage:**

24 to 52 volts

**Peak Battery Voltage: 60 Volts**

**Rated Continuous Current\* :**

12 amps @ 24 volts, 8 amps at 36 volts, 6 amps at 48 volts minimum. <sup>^</sup>

or **Rated Power\* :** 250 Watt minimum, 1000 Watts for full power operation <sup>^</sup>

**Minimum Voltage at Rated Current and 90% discharged:** *Any<sup>^</sup>*

**Recommended Continuous Current for 700 W operation:**

23 Amps at 36 volts nominal  
17 Amps at 48 volts nominal

**Recommended Continuous Current for 1000 W operation:**

33 Amps at 36 volts nominal  
25 Amps at 48 volts nominal

*\* Some battery suppliers specify a maximum continuous current and some specify a recommended power output or a motor size that the battery is to be used with. Use whichever spec is appropriate to your battery source.*

*<sup>^</sup> The EcoSpeed Digital Controller can adjust its operation to accommodate a wide range of battery chemistries and specifications. It does so by adjusting its power output downward to whatever the battery can reliably supply. To get peak power from your motor, use a battery that meets the recommended specifications.*

## ***Appendix: Velociraptor Intelligent Motor Controller***

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 is 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.

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 the 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 con-

troller. 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 service.

## Specifications

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

### ***Program 1***

#### *48 Volt Battery System:*

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

#### *36Volt Battery System:*

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

#### *24Volt Battery System:*

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

### ***Program 2***

#### *48 Volt Battery System:*

<i>Minimum Bus Voltage :</i>	<i>38.4 Volts</i>
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*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.*

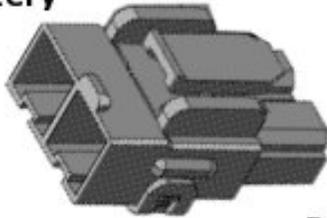
*§ This is the nominal maximum current. Actual maximum current will vary according to battery voltage and voltage limits and may be somewhat higher or lower.*

*† 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.*

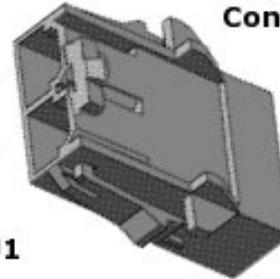
## EcoSpeed Velociraptor Connection Diagrams

**Battery**



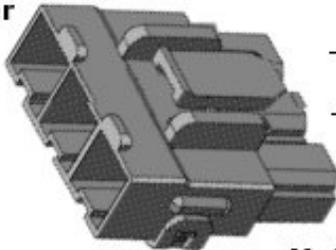
- (2) Black = VBattery- —
- (1) Red = VBattery+ —

**Controller**



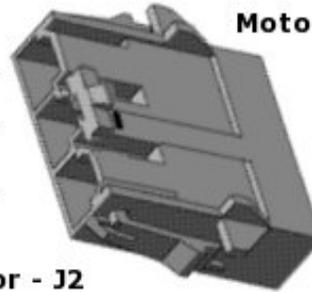
**Battery Connector - J1**

**Controller**



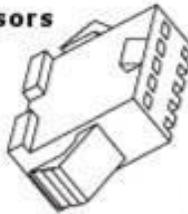
- (3) Green - Phase C —
- (2) Blue - Phase B —
- (1) Yellow - Phase A —

**Motor**



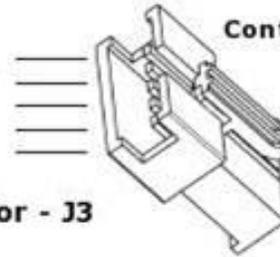
**Motor Phase Connector - J2**

**Sensors**



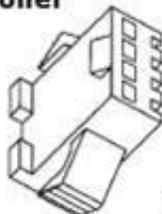
- (5) Black = Ground —
- (4) Brown = Hall A —
- (3) Green = Hall C —
- (2) Blue = Hall B —
- (1) Red = 5 Vdc —

**Controller**



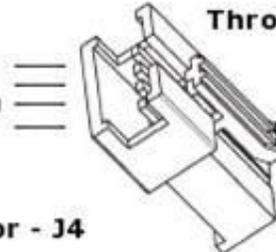
**Hall Sensor Connector - J3**

**Controller**



- (4) Green = —
- (3) Black = Ground —
- (2) White = Throttle AIN —
- (1) Red = 5 Vdc —

**Throttle**



**Throttle Connector - J4**

