instructables

Build Your Own ELECTRIC MOTORCYCLE

by bennelson

OVERVIEW

The finished project is a 1981 Kawasaki KZ440, converted to electric. It is powered by four Optima Yellow Top sealed (AGM) lead-acid batteries, that drive a Briggs & Stratton Etek electric motor. The speed of the motor is controlled by an Alltrax brand "AXE" programmable controller that can run at up to 48 volts and 300 amps. Contrary to popular belief, and electric motorcycle is NOT silent, but is CONSIDERABLY quieter than a typical gas cycle.

The cycle is GEARED to 45 mph, has fairly good acceleration, no clutch or transmission. There's no oil to change, to mufflers to rust off, no air filter, no carbs to tweak, and no gasoline. I designed it for primarily city riding. The top speed and acceleration could be easily changed by swapping out a $20 stock sprocket.

The cycle recharges from the wall, through a renewable energy program, and if there is a blackout, I can actually run my house off my electric motorcycle! In the future, I hope to expand my system to include charging the cycle with photovoltaic solar panels. Real-world range per charge is 23-32 miles, and charging takes less than 10 hours for a full charge. (A different charger could charge them even faster - see details on the Batteries PDF)

In this Instructable, I'll walk you through the work required with the motor, batteries, controller, and mounting all components, including showing you some low-tech paper and cardboard "CAD" tricks.

Your Project
But what do you want? You might not even know yet.

I always encourage people to take a look at the EV Album. It's an on-line listing of mostly home-converted electric vehicles. Each listing shows the make and model of the vehicle, the cost to convert, the speed and range, and other specifics of each project. You can also search by type of vehicle or brand name.
For example, if you go to http://www.evalbum.com/type/MTCY , you'll see a wide variety of electric motorcycles. Different brand names, lithium and lead-acid battery types, and a wide range of costs of conversion. Likewise, if you want to see Scooters, Mopeds, and Minibikes, you can visit http://www.evalbum.com/type/SCMM

Give some thought to what cycle you would like to convert. Do you like sport bikes? Great! They have a lightweight and strong aluminum frame! Do you like standard? Great! There's lots of those out there and you can show off the motor and batteries. Hang out at biker events with your unique ride!

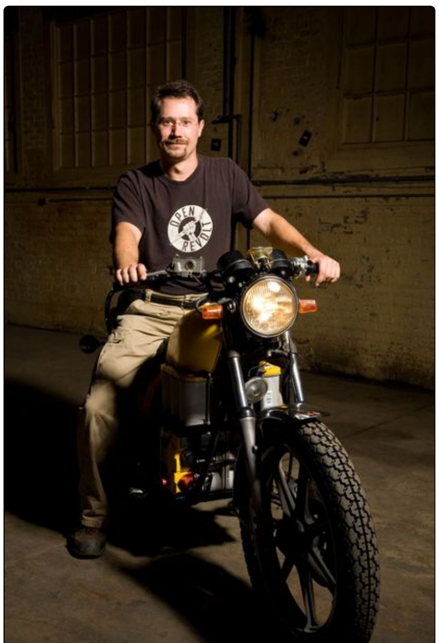
If you aren't sure what to expect in terms of range per charge and top speed, don't worry, online calculators can help you out.
EV RANGE/SPEED CALCULATOR Power Use at Speed Calculator
and of course, a
GEAR RATIO CALCULATOR

For more on my electric motorcycle, electric car, and other projects, swing by my blog at http://300mpg.org/

If you are interested in building your own electric motorcycle, but want even more information, more details, and hands-on style instruction, check out the INSTRUCTIONAL VIDEO DVD that I created to teach how ANYONE can Build Your Own Electric Motorcycle! As of January 2018, I've now posted the Instructional DVD, the entire 2 hours and 40 minutes of it, FOR FREE on YouTube. The DVD is broken down into shorter sections and available as a playlist. https://www.youtube.com/playlist?list=PLmHss3DBZUi...

//www.youtube.com/embed/0--IKZawMSQ?rel=0

1. Homebuilt 48 Volt Electric Motorcycle



1. Proud owner/builder on DIY electric motorcycle.
2. Proud owner/builder on his DIY Electric Motorcycle.

1. 300 amp ammeter is an instant power gauge, built into the former gas tank.
2. 300 amp ammeter is an instant power gauge, built into the former gas tank.
3. Power indicator lights up bright green when the cycle is ready to roll!

1. A photograph from a model shoot with my motorcycle as a prop.
2. Real sparks in the background were made with an angle grinder and scrap metal.

1. The motorcycle is powered by four off-the-shelf Optima Yellow Top spiral-wound AGM lead-acid batteries.
2. The motorcycle is powered by four off-the-shelf Optima Yellow Top spiral-wound AGM lead-acid batteries.

1. Motor controller
2. Briggs & Stratton Etek permanent magnet motor

Step 1: Safety

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It may be cliche, but every shop class, repair book, and seminar starts off talking about safety.

The reason why is because IT'S IMPORTANT! Any type of work always has some sort of risk to it. Minimize that risk, and protect yourself by thinking ahead and using proper safety equipment.

I'll hit a few of the basics here, as well as a few you may not have thought of that are particular to this project.

Personal Protective Equipment

Wear your safety glasses, work gloves, and hearing protection. If you already wear eyeglasses, the larger "boxy" type safety glasses work well over your eyeglasses. Otherwise, add side protectors to your existing glasses. If you don't wear eye-glasses, I like the the slimmer style that fit tight to the face. This is the same type some motorcycle riders wear out on the road. Heck, get yourself a nice pair, and they are multipurpose!

Wearing work-gloves will save your hands a lot of cuts and scrapes. Thick leather gloves are durable, but clumsy. Mechanics gloves give you much more dexterity. I prefer these, as I can leave the gloves on while using any type of tool. If you have to take gloves on and off to use a particular tool, it doesn't take long to give up on wearing gloves. Wear welding gloves when welding. Latex or other rubber gloves are sometimes handy for working with fluids or while painting.

Wear hearing protection. During any drilling, cutting, or grinding, you should be wearing hearing protection. Soft ear plugs are cheap and disposable, and pretty comfortable. I like the big "ear-muffs" because they are easier to take on and off than soft plugs are to take in and out. I like having "normal" hearing while I am not cutting and grinding.

Remove jewelry, or at least cover it up. Besides getting caught on a moving part, most jewelry is also extremely electrically conductive. Remove rings, wrist-watches, necklaces, wallet chains, and that big key chain hanging on your belt loop. Don't wear big conductive belt buckles that can also scratch paint-jobs. If you can't or won't remove a piece of jewelry (wedding rings, etc.), cover it up. Wearing work gloves will cover a ring, and a necklace can be tucked inside your shirt.

Clothing. I'm sure you've worked on enough projects that you know what appropriate clothing is. Typically, you want long shirt sleeves and long pants. Don't cuff your pants. Metal shavings, dirt, and possibly hot metal likes to get caught in there. Wear closed-toe shoes or boots, preferably leather, and safety toe if you have them. Natural fiber clothing is also preferable. In a bad situation synthetic fibers can melt (onto a person!) At least wear a cotton T-shirt under your fleece sweatshirt....

Now onto a few things that are more specific to this project.

Motocycles are powerful, heavy enough to hurt if they fall on you, have chains and sprockets, and run on electricity by the time we are done with it.

That brings up a few safety cautions of particular concern:

Pinch Points: Be really careful where the chain and sprockets come together! Always make sure you have the chain guard in place. Build a custom chain guard if the project requires it. I once got my finger pinched between the chain and back sprocket when I was adjusting the chain. YEOWCH! That was just with me turning the back wheel slightly by hand. I'd hate to imagine if the same thing happened with the motor running!

Electric Spark and Shock: Always keep covers on the battery terminals. Never work on the cycle with the power connected. Always have the real wheel off the ground when testing the vehicle. Keep conductive materials away from the batteries. 48 volts is right on the border of what is generally considered low-voltage or not. Risk of shock is fairly minimal, but all electricity should be taken seriously. SPARK is a greater concern. 48V short circuited has the potential to create large sparks that can melt battery terminals and propel molten lead. Always wear safety glasses when working on batteries and battery connections.

I recommend covering the handles of your battery wrenches with shrink tubing. You get a nice snug grip on your wrench and greatly increase its electrical resistance. You could also use electrical tape, but that's just going to make everything sticky eventually.

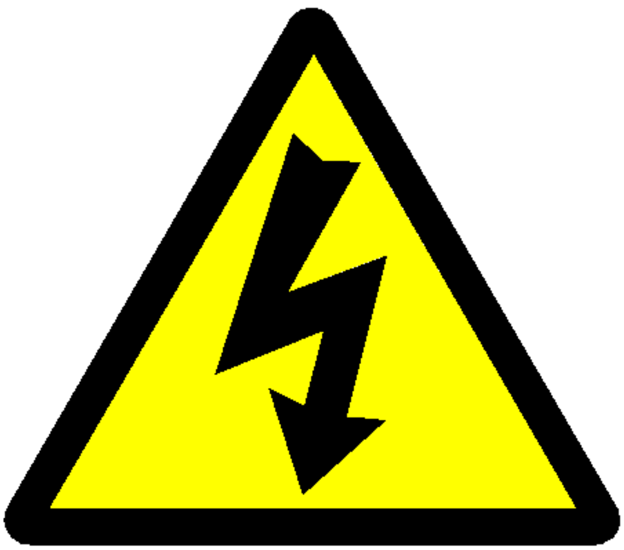
Lifting and Jacking: Chances are, you will want your cycle elevated. It makes it much easier to work on, as it prevents you from bending over, and working from floor level. I recommend a motorcycle lift. A small, sturdy table can also make a good stand, but it's challenging to get the cycle on and off that stand safely.

Whether using a lift, jack, or stand, make sure the cycle is SECURELY attached to it with straps or some other means. An elevated vehicle could easily become unbalanced while working on it, falling off the stand, damaging the motorcycle or landing on you, your other projects, or someone you love.

Use your multimeter correctly. Many typical multimeters allow for you to test voltage, amperage, and resistance. To test amperage, you have to physically move one of the probes to a different jack on the multimeter. MAKE SURE YOU MOVE IT BACK when you are done with the amperage test. Even if you flip the control on the multimeter back to voltage reading, but forget to put the probe back in the right connection point, the next time you go to test voltage, you will melt the tip of the one probe off in about one billionth of a second. And it scared the bejeezers out of me. I mean you. In theory, if that happened, it would really startle you. So make sure you use your multimeter right.

Don't smoke: Smoking is a fire hazard. Especially when you take the gas tank off.

Don't drink alcohol while or before working on the project. It impairs judgement, and you might do something stupid. Likewise, do not drink, smoke, or do other drugs while RIDING. Go for a ride, come back, and THEN have your beer.



Step 2: Legal, Insurance, and Registration

Isn't getting insurance the last thing you do before you go on the road?
Well, yes and no.

You do NOT want to go through all the time and expense of building an awesome electric motorcycle, only to find that you can NOT legally ride it!

Some legal reasons you may not be able to legally ride your cycle in your area may be due to Registration, Insurance, or License.
None of these things are that complicated, but you must comply with whatever the rules are in your area. (If you have a large private property, and will not be using this vehicle on-road, you may be able to ignore this.)

Registration:

Registering your cycle should be done exactly the same way any typical gasoline powered cycle would be done in your area. In some places, cars are required to pass a smog test, but motorcycles are exempt from that. A vehicle may also be exempt from certain tests or requirements if over a certain age (Classic or Antique) or primarily for show and exhibition or part-time use (Hobbyist.)
It seems that motorcycles are sold much more often WITHOUT a title than cars ever are. Make sure you get a title and bill of sale with the VIN - (Vehicle Identification Number) printed on it. If you do NOT get a title, make sure that you will be able to get one. This can sometimes require additional cost, paperwork, and/or vehicle inspection. Sometimes an inspection may require a matching number on the frame, engine, and transmission. Because of that, I recommend registering your vehicle as it is BEFORE removing the engine or transmission, even if it doesn't run.

A VIN is extremely important. I personally know somebody who built a pretty nice electric motorcycle from scratch. He made EVERYTHING on it, from the frame on up. He couldn't get it registered or insured. Without a VIN, registration may be possible (but lots of jumping through hoops) but extremely difficult. Without a manufacturer Make and Model, he couldn't get insurance. Eventually, he just took the cycle apart and used the parts on other projects.
By CONVERTING an existing motorcycle to electric, we have the VIN, Make, and Model to make the project fit "inside the box" for the government and insurance.

INSURANCE: One of the first things I did before really getting going on this project was to call my full-service insurance agent. I told her exactly what I wanted to do. Motorcycles are commonly modified and customized. This was really no different. I had no problems getting insurance. My insurance is about $100 a year and provided through Progressive. Before starting your project, talk to an insurance agent. The year, style, or engine size of the motorcycle frame may dramatically effect your rate. A 1500cc crotch-rocket is likely to cost more than a 250cc standard cycle. Since you are removing the engine anyways, just get a cycle that you like, with enough room in it for the motor and batteries.

License: If you don't already have a motorcycle drivers license, get one. I signed up for a course at my local college. Besides being excellent training for a first-time rider, the class also gave a benefit of streamlining the process (and reduced the cost!) of getting the motorcycle endorsement at the Department of Motor Vehicles. Even if you are a long-time rider, an electric motorcycle will perform slightly different than an engine powered machine. Some colleges and other training centers also offer advanced and specialized rider training.

I have heard of people converting a small to medium sized motorcycle to electric and getting it titled as a moped. In that case, you do not need a motorcycle endorsement, but you can't legally carry a passenger either. You may also be restricted to which roads you can ride on.

Once again, make sure you check AHEAD OF TIME on all the legal requirements in your area for vehicle operation. It's pretty exciting once your electro-cycle is completed, and you'll want to be ready to hit the road!

https://www.youtube.com/watch?v=NY1LUdk0BhM

1. Avoid the red tape. Make sure you have your ducks in a row with your vehicle properly registered, licensed, and insured.

https://www.youtube.com/watch?v=NY1LUdk0BhM

Step 3: Donor Bike & De-ICE-ing

Now that we made it through the basics of safety and legal, you want to start that search for your *"Glider"* or *"Donor Bike"*. You may already have something that's been sitting around with a bad engine or transmission. Otherwise start looking for your cycle. You may want to check out Craigslist, the local newspaper classifieds, or stop and see every motorcycle for sale on the side of the road.

Besides just overall style and finding something that fits your budget, here's what to look for in the donor bike.

OVERALL GOOD CONDITION

It might sound obvious, but get something that's in fairly good condition. You want to do a conversion, not a restoration! Make sure the turn signals and headlight work. The horn should work. It shouldn't be all rusted out. Get something that looks nice enough and will be fun to ride. If you happen to be somebody who regularly builds custom motorcycles and restorations, just ignore what I said. Go hog-wild instead. I do have to admit that the cycle I bought to convert to electric was not in very good shape. The price was right though. In the end, fixing all the little things on it took a fair amount of time and work. Looking back on it now, I would have preferred to spend a little more money and and have had fewer things to fix.

SAVE MONEY WITH A *BAD* ENGINE OR TRANSMISSION

In this conversion, the original engine and transmission are NOT used. If you buy a motorcycle that is in pretty good condition OTHER than a bad engine or transmission, you might be able to get a really good deal on it. Just make sure to keep the engine and transmission with for a while to confirm proper registration.

SAVE MONEY WITH A *GOOD* ENGINE AND TRANSMISSION

If you choose to buy a cycle in good running condition, make sure to carefully remove the engine and transmission. Keep all the parts together, label everything, and keep it out of the weather. Sell the engine and tranny to make some money back on the purchase of the cycle.

DRIVESHAFT, BELT-DRIVE, OR CHAIN

Most motorcycles are driven by a chain, but some use a belt or even a driveshaft. Get a donor bike with a chain. This will give you the most flexibilty and efficiency. Chains are cheap, don't slip, and are easy to change gear ratios by swapping out an inexpensive sprocket. Electric motorcycles CAN be built with a belt or driveshaft, but it is more of an advanced project and has other considerations.

BATTERY AND MOTOR SPACE

You will want a cycle with enough room in its guts for the motor and batteries. A too-small cycle will limit where you can put the motor and batteries, and how many batteries will fit. An extremely large cycle gives you plenty of room, but the frame may become heavy quickly. Popular choices include sport bikes and medium-size standard cycles.

Sport bikes typically have an aluminum frame (light-weight) and it is shaped with two supports over the engine, and two under it. This gives you a "box" to mount your batteries. Sport bikes also usually have some sort of plastic fairing over the engine. After conversion to electric, you can put the fairing back on, and look almost stock.

A medium-size "standard" will have two frame supports under the engine, which can be re-used as a base or tray for mounting the batteries. You will most likely want to avoid any cycle that has a single piece of frame above or below the engine. It just makes it more difficult to find a way to mount the batteries. You can always fabricate something custom, but it's best to start with a solid foundation.

GET THE BOOK

Most cycles have a mechanics repair manual available for them. You might be familiar with the Haynes or Chilton's brands for car repair. Find the book for your cycle. Although it won't cover the new custom electric system, it will tell you how to fix your brakes, align the chain, painting tips, general repair and maintenance, and have plenty of other useful information.

De-ICE-ing

Once you have your donor bike, you need to De-ICE it. ICE stands for Internal Combustion Engine. You'll be removing the engine, the transmission, and anything else related to that system. That includes the gas tank, the exhaust pipes, and a radiator if it has one. Remove these parts carefully, so you can re-sell them.

You will want to know where to put the electric motor for the conversion. The easiest way to do that is simply to put the electric motor exactly where the output shaft of the transmission was. Locate where the chain goes to on the transmission end and mark that location on the frame. Use a wax pencil or silver marker with a speed square to put a mark on the frame both vertically and horizontally from the output shaft of the transmission. You will later use these marks to position the electric motor.

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//www.youtube.com/embed/Q1evjQKO7tE?rel=0

1. My motorcycle as it was originally. Dented gas tank, one muffler missing, broken throttle cable, missing headlight, and rust.
In retrospect, I would have picked up a frame in better general condition.

1. Donor bike de-ICE'd.
2. Engine and transmission removed. They didn't work. I got a few bucks on Craigslist for them.
3. Notice that the cycle has twin lower frame members. This is a good start for a "tray" to mount the motor and batteries.
4. The upper part of the frame is a single tube down the center. It somewhat limits battery location.
5. Please note that I saved the gas tank. While an electric motorcycle doesn't NEED a gas tank, it looks much cooler with one!
6. The stock chain was but off and later replaced with one that fit standard machine sprockets.

1. Mark on the frame the position of the transmission's drive sprocket. This is where the motor will go. Here, I drew in two white lines in a graphics program, so you car read it better. In real life, I used a metallic silver Sharpie brand marking pen. It is permanent and shows up well on the black painted frame.

1. A custom motor mount puts the electric drive motor right where the transmission was.

Step 4: Electric Motor

To power your motorcycle, you're going to need a motor. But what type, what size, and where do you get it from!?

This project used a Briggs & Stratton Etek. It's a DC (Direct Current), brushed, pancake motor, rated at up to 48V and 150 amps continuous. I got it used, through Craigslist, from a college student who built those robots that battled each other. He was using this motor to swing a hammer, but it was too powerful, and he kept breaking hammer handles!

So why this motor?
DC - Direct Current
Direct current motors are very straight forward. They are easy to control the speed of. Also, batteries use direct current. By using a DC motor, there's no intermediate step of converting DC battery power to AC power to run the motor.

Face Mount
The Briggs motor has eight holes on the end (the "face") of the motor to make it easy to mount to a piece of flat steel or aluminum. Some motors have a "foot" on the bottom of them for mounting, which wouldn't have been as easy to use in this situation. electric bill.

In electric vehicle design, keep in mind that volts x amps = watts. Also, 1 Horsepower is roughly 746 watts. So, it's pretty easy to do some simple math to figure out the power of our motor.

By being connected to four 12V batteries in series, the system nominal voltage is 48V. The motor is rated at 150 amps continuous. 48 x 150 = 7,200 watts. Divide that by 746 (watts to horsepower) and you get about 9.6 horsepower. That doesn't sound like a lot. However, you can pull much higher amperage briefly through the motor - typically three or four times as much. My system amperage is limited by the fact that the motor controller maxes out at 300 amps. That still means we can get DOUBLE the power out of the motor compared to what you might think it can produce, just based on the numbers stamped on it.

Combine that with increased efficiency (by completely losing the transmission) and the fact that you have *FULL TORQUE* right off the line (a gas engine has to rev up to several thousand RPM to get into it's best power band) and even a compact electric motor has far better acceleration than you think it might.

Permanent Magnet
Permanent Magnet motors tend to be very compact. They create rotational energy (torque) by pushing two magnetic fields against each other. The one magnetic field is produced by current from the batteries (an electro-magnet). The other magnetic field is from mineral permanent magnets. These magnets are much more compact than a second electro-magnet would be, allowing for an overall powerful, yet small motor. The limiting factor in the design is the strength of the permanent magnetic field. Many permanent magnet motors spin equally well in either direction. Just swap the positive and negative battery cables for it to spin the other way. The permanent magnets are ALWAYS magnetic! So don't drop a washer near one of the vent slots, or it will get sucked in and you have to take the whole thing apart to get it out! Since then, I made sure ALL washers are stainless steel (not only are they corrosion-resistant, but they are non-magnetic as well.)

I chose this motor knowing that many other people had used the same one in their electric motorcycle designs. http://www.evalbum.com/mtrbr/BRIG

Permanent magnet motors are generally designed to spin equally well in either direction. If the motor spins the opposite direction of what you intended, all you have to do is swap the two cables. On a large motorcycle, you could take advantage of this with a reversing contactor to have a reverse gear.

It's not all about horsepower....
Electric motors are rated differently than gas engines are in terms of their power. A gas engine is rated in horsepower with the engine running at nearly maximum speed and fuel consumption (full-out!) An electric motor is rated at how much power is can put out continuously - for hours at a time. So, a horsepower rating between an engine and an electric motor is not apples to apples.

More and more engines are also now being rated in Watts. A watt is a unit of power used. Most people understand watts, as in that a 100-watt light bulb uses more power than a 75-watt lightbulb. It puts out more power (as light and heat) but also costs more on your

I later had my cycle tested on a dynometer at a large Harley-Davidson gathering. The cycle "officially" clocked-in as 12hp. But when the guy first went to ride the cycle up to the dyno, he almost threw himself off with how quick it accelerated!

Other Options
What other motors might you use in your electric motorcycle? Besides permanent magnet DC motors there are also Series-Wound and Brushless DC motors as well as some new AC motors. Series-wound motors are similar to permanent magnet DC motors. They are bulkier, but produce fantastic torque! You could use a series-wound drive motor out of a junked electric forklift. Do not use a pump motor. Those typically do not have a male driveshaft. Same goes for electric golf cart motors. They may otherwise sound like a good motor for a cycle, but unless you have a way to easily connect a standard sprocket to the motor, they will be a lot of tinkering to make work for your project. *(A friend of mine is currently working on designing a kit with a specialty part allowing anyone to build their own electric motorcycle using an off-the-shelf golf cart motor. Look for that in the future.)*

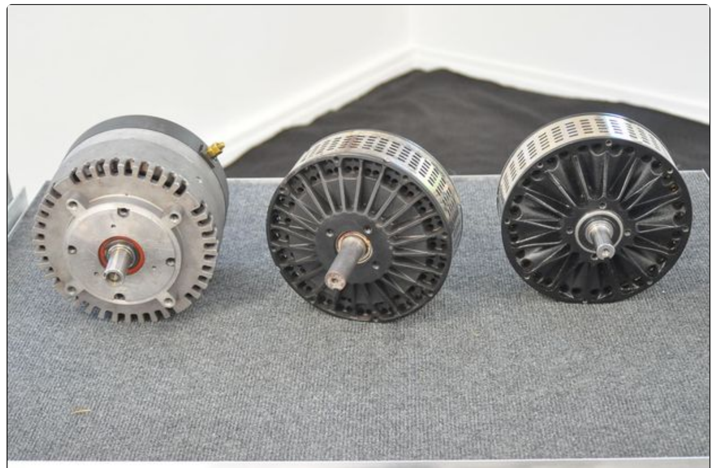
Brushless DC and AC motors are very similar. They require dedicated controllers designed specifically for them. If you go that route, buy your motor and controller as a matched set through a reputable dealer.

in general, all these motors are air-cooled, so you don't need a motorcycle with a radiator on it.

For planning purposes, you want to know that your motor will FIT in the motorcycle before you buy it! Made sure to measure the space you have and the physical size of the motor before you buy. If the motor is not in front of you in person, don't worry, most mainstream manufactured motors have diagrams that you can download, that include the physical dimensions. (See Etek_Diagram PDF file attached below.)
Besides the diagram showing physical dimensions, it also lists important information on torque, voltage, RPM, etc. That helps you plan out your cycle design

as well.

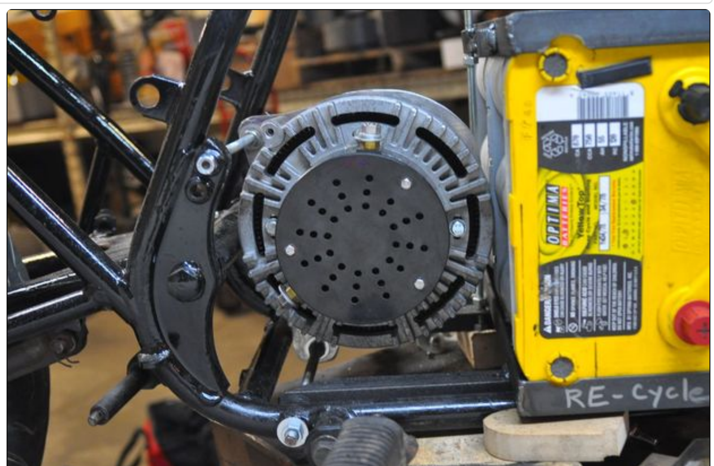
1. A Mars motor, similar to the Etek that I used on the cycle project.
2. Notice that there are two sets of face-mount bolt holes. Gives flexibility in mounting.
3. A male drive-shaft of standard diameter will allow for off-the shelf use of standard sprockets and easy gear changes.
4. A permanent magnet motor has two power connectors on it. Reversing the two power cables makes the motor spin the opposite direction.
5. Ruffles Have Ridges! Some motors have "fins" to assist in passive air cooling.
6. This is the other power connector.



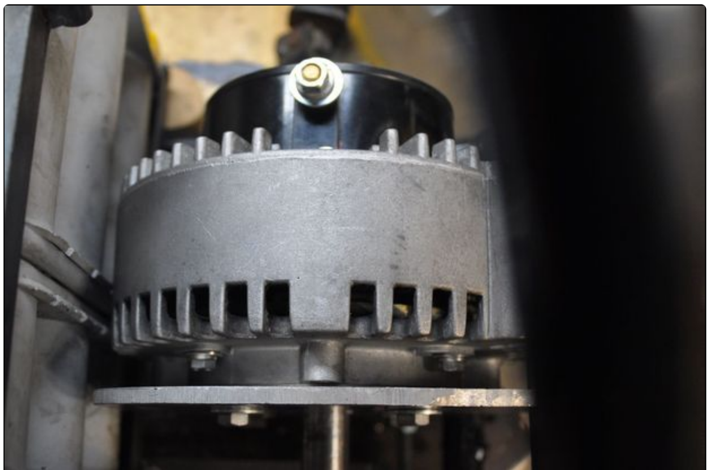
1. Mars brand motor. These are now under the Motenergy brand name.
2. Drive end side of motors. Notice that they all have male drive shafts of standard diameters, such as 7/8".

https://www.youtube.com/watch?v=YRikg0NOfLI

1. Commutator end of motors. Here, you can see each brand is a little different in how they do their power connectors.



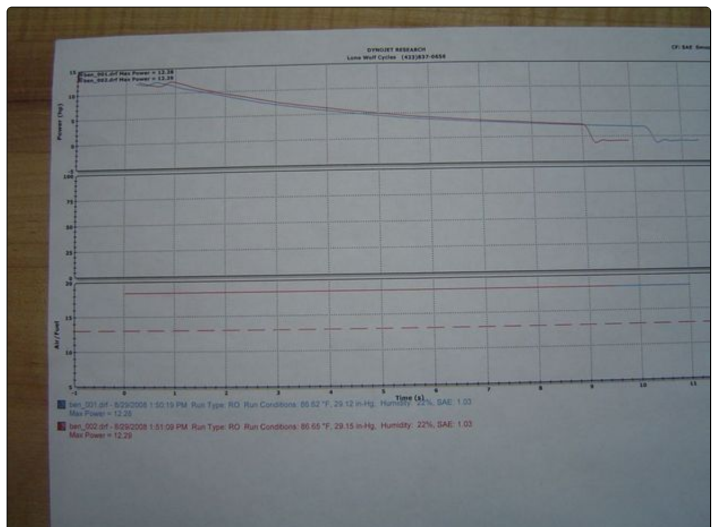
1. Motor in position. Showing brush/commutator end of motor.
2. Some parts of the motorcycle are salvaged material, including this piece of steel for the battery rack. That was written with a Sharpie Silver Metallic Marker - a great way to write on black metal.



1. Top view of the electric motor.
2. The ridges and air vents for cooling are easily seen from this angle.
3. Heat-sinking fins on back of motor.
4. Power connector. Notice that it's oriented so that it will be easy to cable the batteries to the motor when I get to that step.

1. Briggs & Stratton Etek electric motor in position, without brush-holder.
2. A ratchet strap is a handy item to secure the cycle to a lift or workbench.

1. Motorcycle testing on a dynometer.
2. Motorcycle being tested on the dynometer. Although my cycle "officially" tested at 12hp, I had no problem tailing 1500cc cycles while leaving the event.



1. Test results show it as a 12hp motor. Notice that the line starts at the TOP of the chart! Gas engines start at the BOTTOM of the chart and have to work their way up. This chart shows the INSTANT power of an electric motor, but does not fully reflect its torque.
2. This chart was for fuel/air ratio. The cycles uses no gasoline fuel, so it's blank.
3. I think this chart was for tailpipe emissions. Notice that it's blank. The cycle has no tailpipes nor emissions at point of use.

1. This series-wound motor (from a forklift) would also work well to drive a motorcycle. This one is being repurposed to drive an electric car.
2. This series-wound motor is mounted to a custom adapter plate using 6 bolts into the facemount holes. It's big enough that the back end of the motor will be held up by an additional mount. On a pancake motor, just the adapter plate can hold the entire weight of the motor.
3. Series-Wound motors have FOUR power connectors - one pair for each of the two magnetic fields. A cable or buss-bar connects the two middle power connectors so that the same current flows in series through both sets of electro-magnets. Some series-wound motors only have two exposed power connectors. The other two ends are internal to the motor. Those ones are only designed to spin one direction. The ones with four exposed power connectors are much easier to reverse.

Download

http://www.instructable…

Step 5: Motor Mounting Plate

Once you have your motor selected and in-hand, you need some way to physically mount the motor where you need it to go in the motorcycle.

To do this build an "Adapter Plate" or "Motor Mounting Plate".
I built mine from a piece of scrap 1/4" aluminum plate that I had around. The plate needs to have a hole in the middle of it for the driveshaft to pass through and four holes in the appropriate locations for the bolts to mount the motor to the plate.

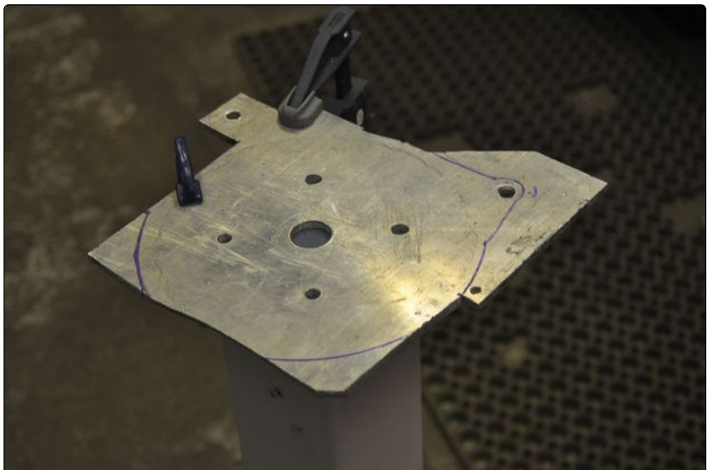
The plate also needs mounting points to connect it to the frame of the motorcycle. On this project, I re-used the existing mounting points in the frame of the cycle where the engine and transmission originally bolted in place. Those holes are already just about where I needed them and it meant I didn't have to make any new holes in the frame.

MAKE IT REAL
Rather than making a template from scratch, or drilling holes based on careful measurements of the motor, I simply made my own paper template based on the PDF file that I already had of the mechanical drawing of the motor. In a graphic design program, I simply made sure that the measurements on the diagram matched up to 100% actual scale, and printed it out on paper. The motor is compact enough that the whole image fit on one 8.5x11" sheet.

I cut out the piece of paper and then glued it (rubber cement) to the aluminum plate. Using a drill press, I simply drilled holes of the appropriate size (the size is marked right on the diagram!) right through the crosshairs on the piece of paper. That gave me a plate of aluminum with a central hole for the driveshaft, and four holes to mount the motor to the plate. I test-fit the plate in place on the motorcycle, with the drive-shaft hole lining up with the marks on the frame indicating where the chain originally went. I then sketched right on the plate "tabs" of where the plate would extend to the existing mounting points on the frame - one on the bottom and one on the high side of the back. I will later add another attachment point on the front with an angle bracket.

At that point, I could just put the motor and plate together to confirm that all the holes lined up. I also traced the outline of the motor on the plate.

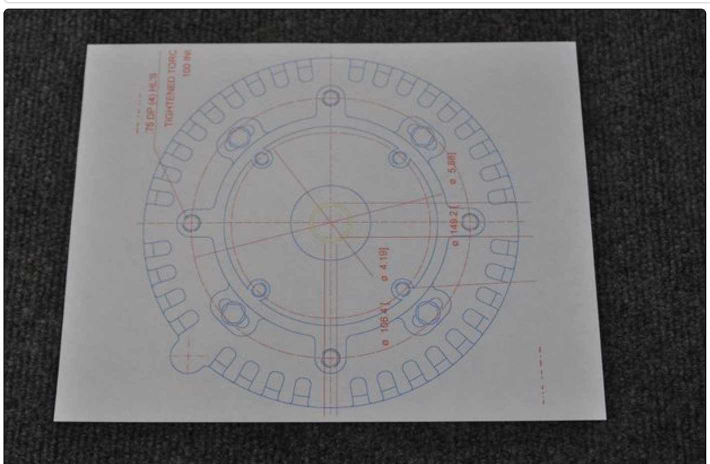
Once I rounded off all the edges, I put the plate in the motorcycle, and ran threaded rods (3/8" and 5/16", which matched the holes in the frame) through the frame attachment points, through the plate, and through the matching attachment point. Stainless steel nylock nuts and washers went on both sides of the adapter plate and on the outsides of the motorcycle frame. If I ever need to adjust the position of the motor side-to-side, I can loosen the nuts on either side of the plate and move it one direction or the other.



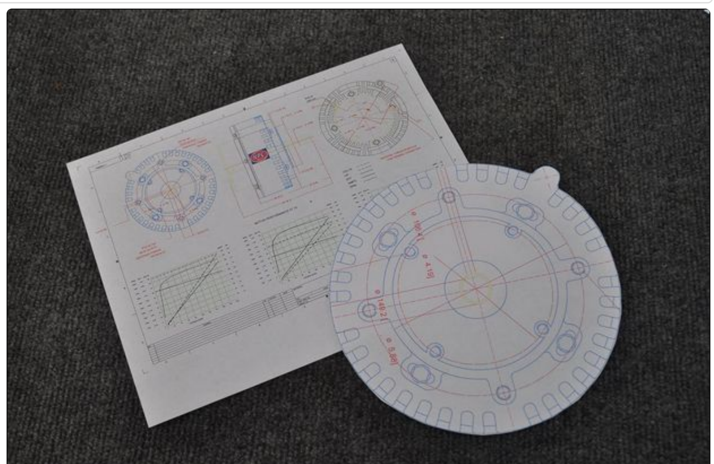
1. Clamping down your work makes your life safer and easier. It allows you to use BOTH hands on the jigsaw, sander, or other tool being used.
2. This is a "mounting tab". This part of the plate connects to the frame of the motorcycle, NOT the motor.
3. This mounting tab is the bottom one. It will connect the bottom of the motor adapter plate to the frame of the cycle.
4. This is nothing. It was already a hole in the piece of scrap plate I was using.
5. Notice that something is missing here. I should have at least 3 points to mount the plate to the frame of the cycle. At that point in time, I wasn't sure how to do it, because I knew a battery was going to be right there.
6. I later decided that about here would be the best spot for mounting point number three. I drilled a hole in the plate, and connected it to the frame with a stout angle bracket.
7. Hole for the drive-shaft.
8. One of the four face-mount mounting holes. A bolt will go through each of these holes directly into the motor to mount it to the plate.

1. The mounting plate, flipped upside down from the last photo. Now with the corners cut and sanded to a rounded shape.

https://www.youtube.com/watch?v=Jzo6K8EeTV8



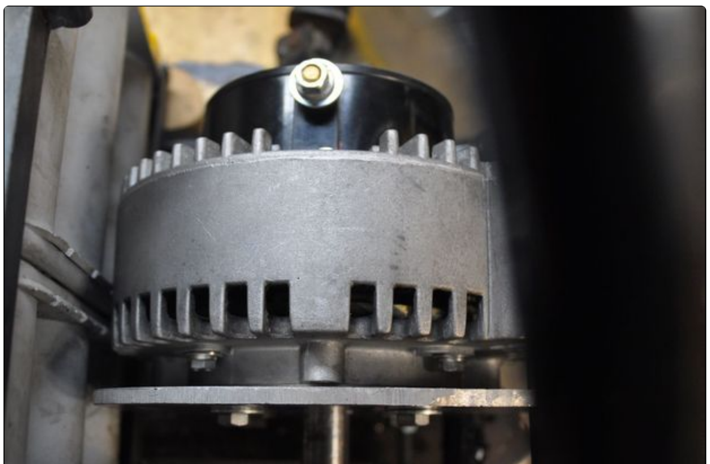
1. Image of the motor, scaled to 100% actual size, and printed out on a home ink-jet printer. The motor was exactly small enough to fit on one sheet of paper.



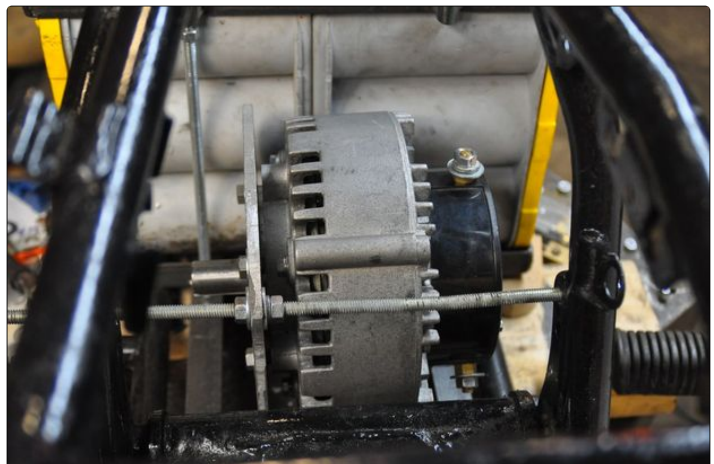
1. Print-out cut to shape with a scissors, ready to become the paper-template for the motor plate.
2. In a graphics program, I scaled this part of the image to 100%, and cropped everything else out. It was originally a high-resolution image, so I had plenty of detail to work with.

1. Threaded rod goes through this hole and through the motor plate to hold it in place.
2. Threaded rod goes through this hole in the frame and the mounting plate to hold it in place.
3. Existing holes in frame are re-used to attach the battery rack.

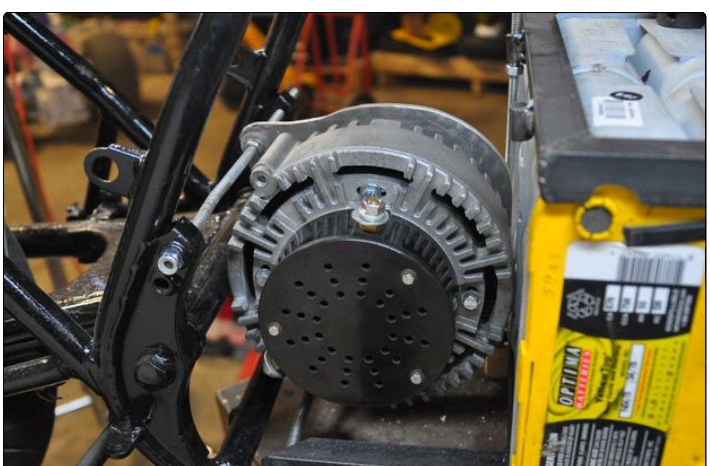
1. These two bolts are part of what holds the engine and transmission in place. Those holes in the frame can be re-used to mount the electric motor.
2. Frame mounting points to re-use to mount the batteries.
3. Another point to attach the motor mounting plate.



1. Motor mounting plate. (Top View)
2. Stainless steel bolts go through the plate into the face of the motor to hold it in position.

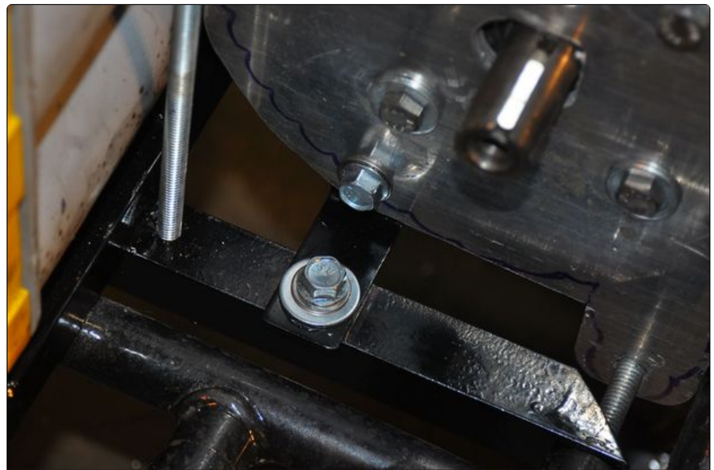


1. Existing frame mounting point.
2. Existing frame mounting point. (Not Visible.)
3. Threaded rod goes through plate with nut and washer on both sides of it. This allows for a side-to-side adjustment if needed.



1. Threaded rod goes through frame. Kept in place with nut and washer.
2. Threaded rod goes through "tab" on the mounting plate.

1. Motor with drive sprocket in place.
2. Bottom tab with threaded bolt going through it into the frame.



1. Angle bracket is the third point of contact between the motor mounting plate and the frame of the motorcycle.

Step 6: Batteries

This motorcycle is powered by four off-the-shelf batteries. They are *Optima Yellow-Tops*, rated at 55 amp-hour capacity, and cranking current of nearly 900 amps. They are AGM - absorbed glass matt. That's a style of lead-acid battery that is sealed up and the electrolyte is soaked into coils of fiberglass matting. They cannot leak, spill, or slosh around.

While there are other types of batteries available, this seemed to be the best combination of price and performance for my project. "Flooded" lead-acid batteries are really not acceptable for a motorcycle. Besides being challenging in adding water, the movement and possible tipping-over of a motorcycle would not be good for flooded batteries.

Sealed lead-acid batteries (VRLA) would also be fine, as would gels. However, neither of those can crank the power as well as an AGM can, which is what gives the cycle good acceleration. Lithium batteries are excellent for weight, capacity, and power, but are currently only for those with higher budgets. If you use lithium batteries, everything else about the project is the same, except for a different battery charger and a battery management system.

Figuring Range

Going back to some simple math, we can get an estimate of motorcycle range. I have four batteries, each of which is 12 volts, but they are wired up in one series string of all four of them, so it's really 48V in total.

The batteries are rated at 55Ah.

So, in theory, 48V x 55AH = 2640 watt-hours capacity. 100 watt-hours per mile is a typical ball-park number for energy consumption per mile on an electric motorcycle. (Of course that does vary by weather, speed, riding style, etc.) But this is just a rough estimate.

2640/100 = 26.4miles

Just a real rough estimate, but it's good enough to say "Will this vehicle meet my needs? Will it perform the way I want it too?"

In this case, yes. I only live a couple miles outside town, and the next town is ten miles away. I can use this cycle to drive all over locally, and head to the next town over and back on one charge.

In real-world driving tests, the single-charge range of zones.

Mock-ups and CAD

Lead batteries are NOT light. It helps to make a mock-up from foam or cardboard, so that you have a LIGHTWEIGHT, easy-to-handle version of the battery to experiment with. I like to think of this as the poor-man's C.A.D.

If you are into computer design, there are many great programs out there to help you create 3D images and think in three-dimensional space. Google Sketchup seems to be getting fairly popular. Still, you really can't beat an actual, physical object in your hands. I just prefer something that weighs less than lead.

In my earliest version of the cycle, I had three batteries in it. Then I moved up to four (for more range and higher top-speed.) I was never sure how to fit four inside the frame in a way that fit well and looked good. By using cardboard mock-ups, I was able to experiment with various arrangements of batteries until I found one that I liked. In this case, the fact that I could mount these batteries turned on end allowed me to come up with a configuration that I liked.

Once the size and number of batteries are decided on, they need to be physically mounted inside the motorcycle, and solidly connected to the frame.

//www.youtube.com/embed/2f3yZpHzKv8?rel=0

Edit: Please note - Battery technology has been changing rapidly the last few years, largely in thanks to commercially-built electric cars. Lithium cell modules are SIGNIFICANTLY less expensive than when I built the Electric Kawasaki. At this point, if I were building an electric motorcycle, I would go directly to lithium cells. Please keep in mind that with Lithium, you need some sort of BMS (Battery Monitoring or Battery Management System,) and it needs to be charged appropriately. Please visit a web forum for the latest availability and best practices with Lithium Batteries.

the cycle came to 23 miles if I drove full-tilt, and 32 if I was doing easy acceleration and in the city 25 mph

1. "Side Posts" visible, covered by rubber battery boots.
2. Power cables follow the frame and connect the lower and upper batteries.
3. One of the original engine mounting points that now holds the battery rack in place.

1. This photo shows the finished vehicle, including the final battery arrangement.
2. Note that all electrical connections are covered.
3. The lower batteries use the "side posts" for the power connections, which face towards the front.
4. The top batteries use the top, automotive post power connections. They are covered both by rubber boots and the shell of the old gas tank.
5. Because these top posts still face outside and are accessible, I can use them for individual testing and charging as needed.
6. Completed battery rack is hardly noticeable. It's painted black to match the frame. You hardly even really see it.

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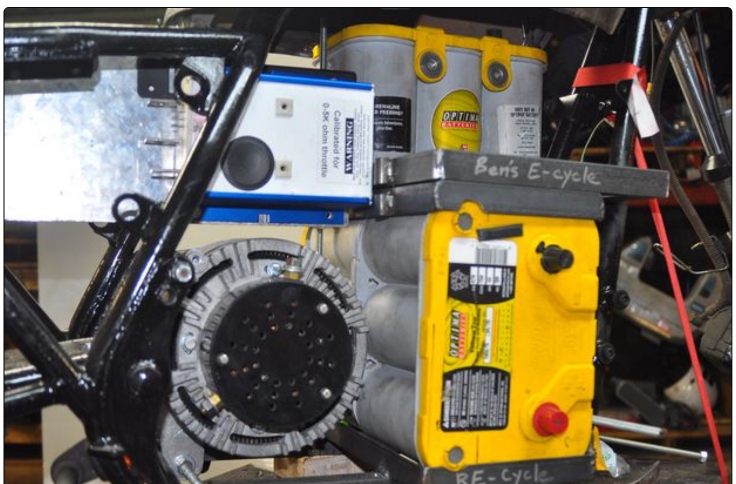
https://www.youtube.com/watch?v=jbykYNoXgqU

1. Cranking amps is how much OOOMF! the batteries can put out. 870 amps is a lot! The motor controller maxes out at 300 amps.
2. This is the capacity of the battery, listed in Amp-Hours. 55 is somewhat on the low side, but the batteries physically fit in the cycle, have high cranking amps, and can be mounted sideways.
3. These numbers typically refer to a specific size and shape of a battery. For example, a "Group 31" battery has the same dimensions no matter which brand name. You can look up common sizes of batteries and see which would be best for your project.
4. Make sure you use a battery marked as a "Deep Cycle". "Marine" is also a good code-word for this as well. In the Optima line-up, those are the Blue-Tops.

1. All four batteries mounted in the frame. Notice that the top two are in a typical position, but the bottom two (you can only see the near one) are oriented vertically.



1. Automotive Post Negative
2. These batteries can be mounted any direction except for upside-down.
3. This ratchet strap ties the cycle frame to a work table it was on. It's a safety item to prevent the frame from shifting and falling off the table, especially while test-fitting heavy lead-acid batteries.
4. Motor controller.

Download

http://www.instructable…

Step 7: Battery Rack

Rack 'em up!

The batteries need to be securely mounted to the frame of the cycle.
This is typically done with a box shape or angle iron.

You do also want to keep in mind that the batteries are the heaviest part of the motorcycle. Ideally, they should be kept as close to the center of the cycle for front/back balance, and as *LOW* as possible for best center of gravity. Fortunately, that describes the big hole left by the removal of the engine and transmission.

The trick is to design a rack that fits in that space and holds the batteries.

A simple start.
In the earliest, experimental version of the motorcycle, I played around with something as basic as a "tray" put across the bottom two frame members. Small batteries could just sit right on top of that in a single layer. The larger batteries could only fit two there, so the others would have to be mounted in some other way. I experimented with "unistrut" - a slotted C-channel material available at building supply stores. It worked well in holding the batteries, but I didn't like the looks. The batteries stuck out the sides a bit in a way I didn't like.

Cut, Grind, Weld, Paint.
While the early version of the cycle was functional, I really wanted to get it cleaned up and looking nice. I had been practicing welding, and it was time to build a welded rack to hold the batteries.

The rack consisted of 1" steel angle, cut to make frames that fit around the batteries, and tabs that would reach from the battery frame to an existing engine mounting point on the frame of the motorcycle. It would be made of several "layers", because of the arrangement of the batteries - two on the bottom, and two mounted above them.

Essentially, there were four pieces:

1. Bottom piece. Connects to the bottom of the frame of the motorcycle. The two bottom batteries sit on top of it.
2. Lower-middle piece. This sandwiches down to hold the bottom batteries in place and connects to the front of the cycle frame.
3. Upper-middle piece. Holds up the top two batteries and connects to the front of the cycle frame. Sits directly above the Lower-Middle piece.
4. Top-Straps. These are just two pieces of steel that go over the top of the top two batteries to hold them down. Threaded rod goes through the ends to tie them down to the other parts of the battery rack. This is very similar to a typical tie-down for a car battery. (The top straps are insulated and don't go near the top posts of the top batteries.)

Besides just being a square ring under the bottom two batteries, the bottom piece also had to directly connect to the bottom of the frame. To do that, I ran two pieces of angle iron the length of the cycle's engine bay, so that it bolted right to the frame, again, through existing mounting points. It might be a little overkill, but gave me plenty of new attachment points for threaded rod to hold down the batteries, and another connection point for the motor mounting plate.

To figure the size of each rack piece, I simply put the batteries together the way they would fit, and measured them. I added just a little more to the measurement to give me some wiggle-room, and account for some thin weatherstripping to go between the batteries and rack when finished.

The tabs to mount the battery rack components to the frame were just flat steel - 1" wide. I put the batteries and rack parts into the frame and test fit the spacing between the rack and the frame and clamped them in place. Then

I removed everything and welded the tabs.

On the back of the rack parts, I welded some short bits of steel pipe, just a little larger diameter than the threaded rod I was using. These are "holes" that the threaded rod goes through to align all the parts and sandwich them together.

All rack parts were were painted with Rustoleum gloss black paint and the assembled into the cycle.

The finished rack looks nice and holds the batteries securely. The battery arrangement keeps them inside the body of the cycle. I was originally hoping to be able to just exactly clear the gas tank. In the end, the pieces of angle iron added up to too much total thickness. I notched the edge of the gas tank to make it clear the top batteries. The gas tank is hollow and covers the top posts of the batteries.

//www.youtube.com/embed/rOcXFWdaAs4?rel=0

//www.youtube.com/embed/R8j4KbNufBY?rel=0

//www.youtube.com/embed/XEX8m49I99g?rel=0

1. Bottom piece. The long rails on it connect it to the frame and provide a place for the vertical threaded rod to go it. It also gave me a place to connect the third mounting point of the motor adapter plate.
2. These two scrap pieces were cut to length and had a hole drilled in either end for the threaded rod tie-downs. They already happened to be covered with a non-conductive powder-coat finish.
3. Middle rack piece.
4. The other middle rack piece.
5. The battery rack is semi-complicated-looking due to the unusual configuration of the Optima batteries, and their rounded shapes. For more typical rectangular batteries, building a rack is very straight-forward.

1. Bottom two batteries. I set them on the bench like this and measure them to see what size I needed to make the first rack piece.

https://www.youtube.com/watch?v=JgMIAOUN_RA

1. Typical wrench to show scale.
2. I welded the OUTSIDE corners. If I built up too much of a bead on the inside, the battery might not fit well. Also, it's hard to get an angle-grinder on the inside corners to "fix" too much of a weld.

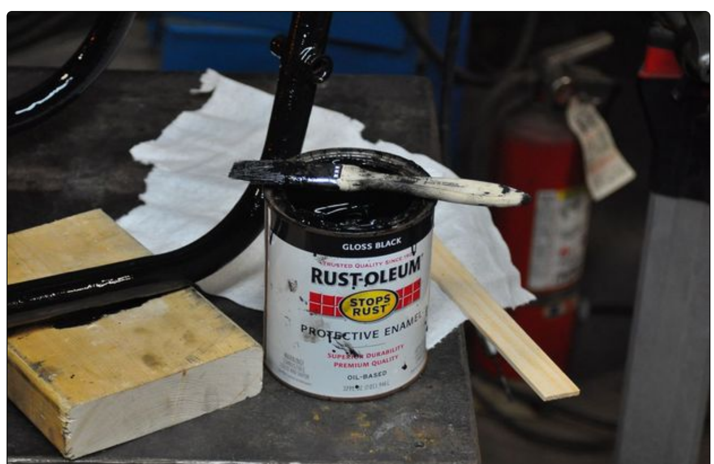
1. Lower-Middle piece test-fit on top of lower batteries.
2. Please note that I was never WELDING NEAR THE BATTERIES. They are plastic and don't like hot sparks! Hydrogen gas shouldn't be an issue near SEALED batteries, but let's not press our luck...

1. This is a support to hold up the middle of the two bottom batteries.
2. Because of the curve of the frame of the motorcycle, I had to notch out the front of the battery rack here. The curve of the batteries fits this perfectly.
3. Notch in the battery tray to account for the curve of the cycle frame.
4. These engine mounting holes will be re-used to support the battery rack.

1. Smile indicates happiness of results. (Thanks for your help Tim!)

1. The square rack piece had to be notched to fit around the curve of the cycle frame. The rounded side of the battery curves to match the cycle frame perfectly.

1. New support piece welded in to go around the cycle frame.



1. Black gloss paint almost perfectly matches the existing black paint job of the cycle frame. I used this paint to touch up the frame and paint the battery rack.

1. Scrap pieces used to temporarily support the upper two batteries to insure that everything is still lining up.

1. The bottom piece bolts to the frame in several places.

1. Tabs connect lower battery rack to frame of cycle.

1. Rack tab to frame.

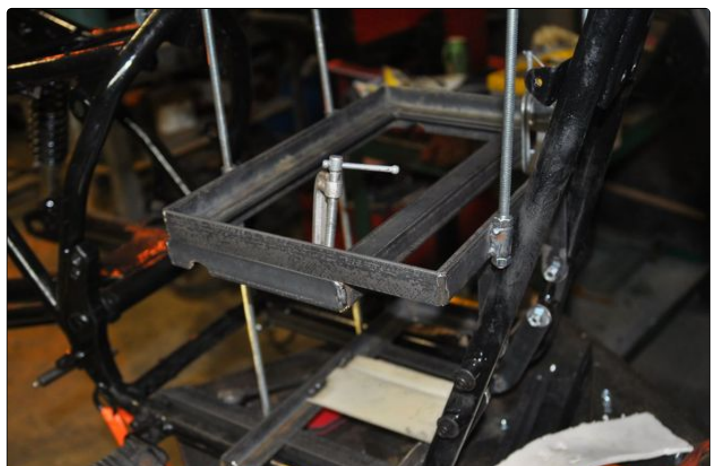
1. I cut short pieces of pipe and welded them to the back of the rack parts as a guide and mounting point for the threaded rod.

1. Tab connects the middle rack part to the frame of the cycle.

1. Back side of the battery rack. Threaded rod lines up all the components and sandwiches them together.

1. Pipe bits welded to rack component.
2. Threaded rod goes through bottom rack piece, which is bolted to the frame. Not seen is a stainless steel washer and nylock nut on the bottom.

1. On the front, shorter threaded rods will sandwich the top straps down to the middle section of rack.



1. This is what the battery rack would look like WITHOUT the batteries in it.

Step 8: Charger

If you have batteries, you are going to need to charge them.

Chargers are fairly simple, but there are a few things to think about. Will you use one 48V charger, or 4 12V chargers? Will the charger mount on the cycle, or will you keep it in the garage? What about solar or other ways of charging?

12 vs 48
An electric vehicle is typically charged one of two ways, either one charger that charges *ALL* the batteries, or one charger for *EACH* battery.

An off-board charger is NOT with you while you are out and about. That can be a good thing too. While you can't "opportunity charge", you also don't have the weight of the charger, nor do you need to have the SPACE on your cycle for the charger. In addition, some chargers are rather large and heavy, and you simply wouldn't want to try to lug one with on your motorcycle. You might also be able to get a really good price on purchasing an off-board charger. Also, an off-board charger is typically available for use on other things, such as recharging your car battery.

I originally started with a very compact 5-amp 48V

It would be pretty simple to hook up one twelve-volt charger to each of the four batteries. (Or even just use one 12V charger to charge a battery, wait for it to charge, move it to the next battery, wait for it to charge.....WAY too time-consuming though....)
In my setup, the top two batteries aren't real easy to access to connect and disconnect battery chargers to. It would be fairly easy though to PERMANENTLY leave battery chargers connected to it.

There is some space under the hollowed-out gas tank, that could fit a battery charger.

To use a series-charger, ONE SINGLE charger of a higher voltage (48V in this case) charges all the batteries. You simply connect the positive cable to one end of the string of batteries, and the negative cable to the opposite end of the string of batteries.

A 48V charger has an advantage in that ONE charger tends to take up less space than FOUR chargers. Higher voltage chargers tend to be more expensive in general that 12V chargers (They just mass-produce so many 12V chargers that they are cheaper.) However, 48V is a common voltage for golf carts, forklifts, and electric scooters. Ebay and on-line electric scooter companies are great places to get 48V chargers.

Onboard vs Offboard
Where do you want your charger to go? My original 48V charger permanently mounted on the motorcycle, under the gas tank. It's plug was right on the frame of the cycle, and I would just plug an extension cord into it from the wall. The cycle would automatically start charging. A charger that's left always mounted to the vehicle is called an "on-board" charger.

On the other hand, you might have a charger that you just leave in your garage. It would have either alligator clips (similar to jumper cables) or an Anderson disconnect (a popular, fairly standard power quick disconnect.) When you park the cycle at home, you either plug in the connector or clamp on the alligator clips from the charger to the battery pack.

Both on-board and off-board chargers have their benefits.

On-board chargers are always with the vehicle. If you

scooter charger that I kept on-board of the cycle. Unfortunately, it was a poor quality off-brand that eventually quit working. After that, I put an Anderson disconnect on the cycle so that I could quickly connect and disconnect a variable-voltage off-board charger. That charger is big and heavy, and stays in my garage. It is variably voltage, so I can charge anywhere from 12-72 volts. When I am not using it to charge the cycle, I can charge my 12V car battery, or my 36V electric riding lawn mower. If I upgraded my motorcycle to 72V, I could still use the same charger and just turn the knob another two clicks!

How big of a charger?
People commonly ask how long it takes to charge an electric vehicle. Or the may ask how "big" my charger is. What they are really referring to is the *rate of charge,* which is measured in amps. Battery capacity is measure in amp-hours. When you want to know how long it takes to charge a battery, it depends on the capacity of the battery (and how far it is discharged) and the amp rate of the charger.

The basic math is pretty simple though. Lets say that you have a battery that is rated at 100AH, and it's half-empty. That means that you need to charge it with 50AH. If you have a charger rated at 5 amps, that will take 10 hours, or overnight. If you have a 10-amp charger, it will take 5 hours to charge, which might mean you could get a full charge while at work!

Consult your battery information. Battery manufacturers provide information on the preferred rate of charge and voltage points for their batteries. Get a charger that matches what your battery manufacturer recommends. In addition, some chargers are either pre-programmed or have a specific setting for a particular type of battery. If your charger has a setting for "Flooded" and another for "AGM", make sure you use the correct setting.

For a nice, short "rule of thumb" get a charger that has an amp-rating of 1/10th the capacity (in AH - amp-hours) of the battery. Mine are rated at 55AH, so a 5 amp charger will always recharge it in 10 hours or less.

I'm now using an off-board charger which is selectable between 5 and 10 amps. I added an Anderson connector to the battery charger and the motorcycle to make charging as easy as plugging in ride over to a friend's house, or have access to an electric outlet at work, you can ride there, plug-in, and charge the cycle the whole time you are there. Your charger is always with you. You can top off the batteries any time you want, even if they are just partly discharged, or even if you know you will only be charging for a little while. This is called "opportunity charging", and is a good way to extend your range and keep your batteries happy.

motorcycle to make charging as easy as plugging in the connector, and flipping the charger switch to On.

There are other ways to recharge batteries as well. See the end of this Instructable for thoughts on Solar and Grid-Tied Battery Backups.

1. Two colored LEDs indicate that the vehicle is charging, and when it's done.
2. This charger has a cooling fan built-in.
3. This cable has two wires inside. Each of the two wires goes to the positive and negative ends of the battery pack.
4. This end is the typical electric cord that you would expect. It plugs into any standard electric outlet.
5. This charger is 48V and 5amps. It worked well as an on-board charger, but was poor quality and eventually quit working. It's worth your time and money to get a good name brand.
6. Wherever you mount a charger, make sure it has good airflow. Chargers can make a fair amount of heat while in operation

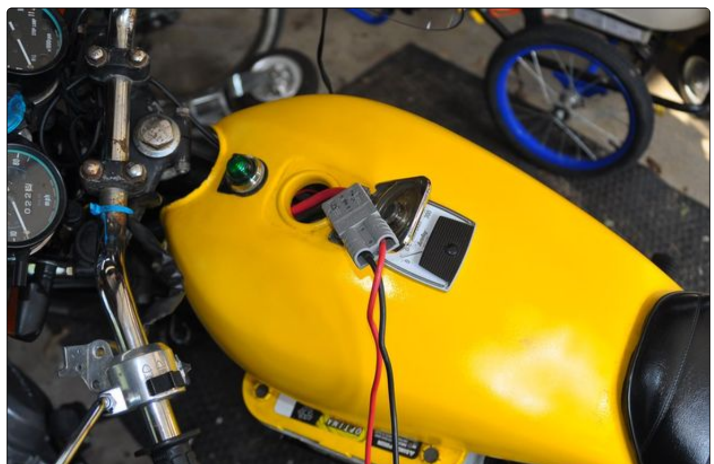
1. This battery charger is adjustable in both voltage and current (amperage.) It's perfect for mounting on-board in an electric car, but is a bit bulky for a motorcycle.
2. This charger has a 50-amp Anderson disconnect to be able to quickly connect and disconnect it to an electric vehicle.

https://www.youtube.com/watch?v=5pZ9Q3xhdgk

1. This is an industrial, 36V forklift charger. If was dirt cheap, but not very efficient, and big and heavy! It only does just one voltage. Something this size puts out fairly high current, which is only good for LARGE battery packs. Too high of a current can damage your batteries. Although something like a golf cart or forklift charger might sound like a good deal, check to see if it's appropriate for your batteries or not. Most likely, it won't be.
2. This charger features a large Anderson disconnect - that's standard on most electric forklifts for quickly connecting to the charger.
3. These pieces of foam are the same size and shape as the batteries I used in my electric car project. They worked well as mock-ups so I could try different battery configurations without having to lift actual batteries.

1. This charger is variable voltage from 12-72 volts. It's a good all-purpose charger to have around.
2. The charge rate is selectable between 5 or 10 amps.
3. Ammeter shows how much current your battery pack is drawing. The amp rate lowers as the battery pack charges and its voltage increases.
4. This is a variable voltage charger very similar to the one I'm now using as my off-board charger.
5. Alligator clips work fine, but for a charger that you are going to connect and disconnect often, a dedicated Anderson connector is the way to go.

1. An Anderson connector is a popular way to quickly connect and disconnect a charger. It's "keyed" so that you can't plug it in backwards. The mating connector looks the same as this one.



1. I added an Anderson disconnect to the cycle to make it easy to plug in to the off-board charger.
2. The other Anderson connector goes to the off-board charger in my garage.

Step 9: Motor Controller and Throttle

With the motor and batteries in place, they could be cabled up, and the motor would spin, but how would you control the speed?

an electric car is about $1500. If you built your own, you could have the best of both worlds - a high power controller at an affordable cost. But where would you start? How about right here on Instructables! In fact, That's what the motor controller does.

Direct Current (DC) motor controllers typically all work the same way. They "chop" the current from the batteries to the motor. Essentially, they are a big fancy switch that turns power to the motor on and off very quickly, typically thousands of times per second. The controller varies how long the circuit is on vs. off, depending on the signal it gets from the electronic throttle, or *"potentiometer".*

The technique of turning the motor full on and off quickly is called PWM or Pulse Width Modulation. Besides controlling the speed of DC motors, it's also used to dim LEDs on sports scoreboards and digital billboards, and is also used in many other facets of industry and electronics.

By always providing the full voltage to the motor, but turning it on and off quickly, the motor has full torque (OOOOOMF!) at any speed. The speed of a DC motor is directly proportional to the voltage provided to it. More voltage (such as having more batteries in series) makes the motor spin faster. With PWM, the AVERAGE on/off of the pulse width modulation controls the speed. But there's still full voltage, and voltage times amperage = HORSEPOWER. Using a modern electronic PWM controller gives an amazing effect of all the power you want at even very low speeds.

There are other ways to control speed on battery powered DC motors. One older technique was to mechanically switch the series/parallel connections of the batteries to the motor in such a way that that it might be 12/24/48 volts. A bit like having "3-gears". These systems made a lot of clacking noise, and the contactors (heavy-duty power switches) needed maintenance somewhat regularly. The speed control was fairly basic. Vehicles like the Citicar made use of this type of system.

Voltage to the motor could also be controlled by running the current through a variable resistor. Trouble is, you need a BIG resistor! They get hot, and would need a LOT of forced air cooling. It would be a very inefficient means of control, as the only time all of the power goes to the wheels would be when you were driving full speed. (The rest of the time at least part of the current is being wasted as heat.)

here's a controller anyone can build themselves that's good for up to 100 electric horses.
https://www.instructables.com/id/Homemade-100-HP-Motor-Controller-for-an-Electric-C/
That's the motor controller that currently powers my homemade electric car.

Mounting the controller
The motor controller needs to be mounted solidly to the frame of the cycle, near the batteries and motor. It does produce a small amount of heat, so ideally the controller should be either out in the airflow, or if you have an aluminum frame, just pressed right up against that.

On my cycle, the best place for the controller was behind the batteries and above the motor. This kept the power cables short and everything was still easily accessed. It also shows the controller off nicely, as people often ask me how the vehicle works, and it's nice to point out the various components.

I used a scrap aluminum plate to the mount the controller. Aluminum makes a nice heat-sink, and it's lightweight and easy to cut and drill. The controller has four mounting holes on its base. I marked and drilled matching holes on the mounting plate, and attached the controller with typical nuts and bolts. Adding that plate to hold the controller also gave me room on the OTHER side of the plate to mount the *"balance of system"* components.

Throttle
The throttle is a "potentiometer" - a variable resistor that sends a signal to the controller, based on its rotation.
I used a Magura Twist-grip, a popular throttle that replaces the right-hand grip on a scooter or motorcycle. On my cycle frame, the original throttle was rusted and the throttle cable was broken. I removed the original throttle and slid on the Magura Twist-Grip. It easily installs just by sliding it on and then tightening a pair of screws to snug it onto the handlebar. (Had my original throttle been in good condition, I could have just connected the throttle cable to a different style of potentiometer, such as a PB-6.)

The throttle comes with three bare wires, but there are only two connections for throttle on the controller!

PWM is a nice and efficient means of controlling speed, conserving energy, AND giving you excellent speed control. If it sounds complicated, don't worry, there's a PWM controller in nearly every electric golf cart out there.

In fact, a used golf cart motor controller from E-Bay might be a great place to start! Golf cart controllers are typically 36-48 volt, and are so mass produced, that they tend to be rather affordable. You will want to make sure to get one that has a high enough amperage rating to make the cycle fun.

Choosing a Controller

The two most popular brands of motor controllers are Curtis and Alltrax. I'm using an Alltrax AXE 4834 controller.

Because the motor controller is wired up between the batteries and motor, it is common for it to be one of the limiting factors of your electric vehicle's performance. The model of controller you want will depends on your system voltage (how many batteries you have) and the current you want to be able to pull. You typically want to minimize current while cruising, so that you are "sipping" power from your batteries, and in turn have a long range per charge. However, you want to have high current available to you for quick acceleration (half the fun of an electric motorcycle!) and powering up hills.

My motorcycle has a 48V system, so I purchased a motor controller that can run on anywhere from 24-48 volts. If you want to build a motorcycle at 48V and think you MIGHT want to upgrade in the future to 72V, you could get a motor controller that will operate from 48-72V, but it will cost you a little more up front. My motor controller can pass up to 300 amps of current to the motor. The motor is only rated for 150 amps continuous, but can briefly take much more than that. The batteries themselves can produce nearly 900 amps (briefly), but the electric motor simply can't pull that much power.

If you just want a moped type vehicle for around town use, a 175 amp used golf cart controller will be fine. If you want to have good acceleration, get a 300 amp controller. A 450 amp controller should give enough acceleration to keep pretty much anyone happy!

What do you do!? Well, since you just mail-ordered this part, you can call the dealer and ask which two wire you use. Otherwise, you can test them with the OHMs setting on a multimeter. Potentiometers have three connectors or wires. The center one is the "wiper" which changes as you turn the potentiometer. The other two wires are the "ends" of the range the potentiometer covers. One is high and one is low. Connect the Ohmmeter to two of the wires, and twist the throttle and see if the reading changes. When it reads 0 ohm when just connected, and 5000 ohms when fully twisted, you got the right two wires. Crimp a 1/4" insulated spade connector to those two wires. Cut or fold back the third wire and cover it with electrical tape or shrink tube.

Route the throttle cable from the handle-bars, along the body of the cycle (leave slack for steering!) and back to the controller. Plug both wires into the connectors marked THROTTLE. Polarity doesn't matter, plug either wire onto either connector. Make sure they are on securely. As a safety feature of the controller, if the throttle ever becomes disconnected, the controller shuts down.

Wiring up the controller power cables to the motor and batteries is fairly straight forward. The motor controller comes with a manual that includes the wiring diagram. The Alltrax Document Depot is a great resource for all sorts of information on controllers, batteries, and motors.

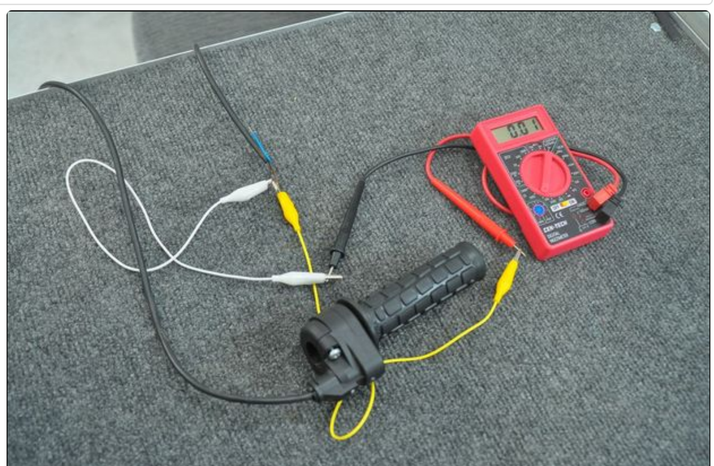
After the cycle is completely finished and test-driven, you will want to tweak the controller. Some controllers have small potentiometers on the side that are adjusted, and others are computer reprogrammed. The Alltrax AXE lineup has a computer port. You simply plug a cable from the controller to your computer, download a small program, and change parameters through a simple interface. On most controllers, you can control throttle response, limit maximum amperage, and control voltage shut-off points. On an electric motorcycle the "feel" of the throttle is based on how the controller is tweaked.

Once you get into higher voltage and amperage, controllers start to get expensive. A popular one for

1. A typical DC motor controller.
2. This programmable controller has a rubber plug that covers a computer serial port. You can plug the controller into a computer to reprogram several parameters.
3. The heavy buss-bars are for the cables to the batteries and motor.
4. Smaller connectors are for power to operate the logic of the controller and for the throttle connections.
5. The holes in the base are for the physical mounting of the controller.

https://www.youtube.com/watch?v=LigtdIn2qa4

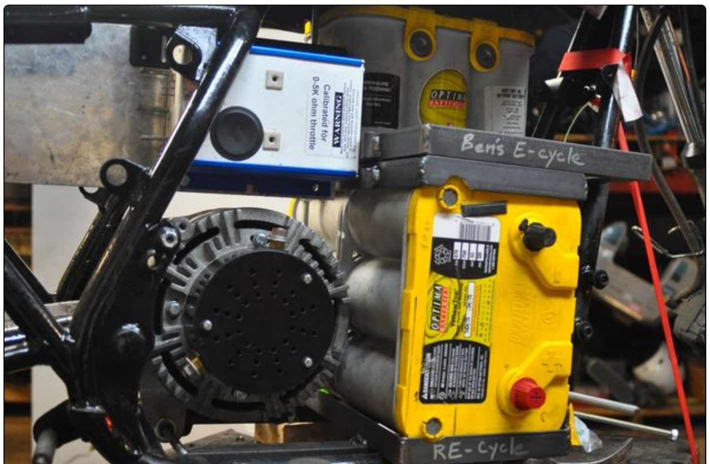
https://www.youtube.com/watch?v=A2uj1S40iIs



1. Testing the throttle with a multimeter. On a 0-5Kohm throttle, it might not go all the way to 0 or to 5K. That's fine, the controller accounts for that and doesn't apply throttle until a couple hundred Ohms, and maxes out a bit before 5Kohms.
2. Twisting the throttle will change the ohm reading on the multimeter.
3. Alligator clip leads are your friends. It's really hard to hold all these wires and also twist the throttle at the same time!
4. After sliding the throttle onto the handlebar, this screw is tightened to secure it in place.

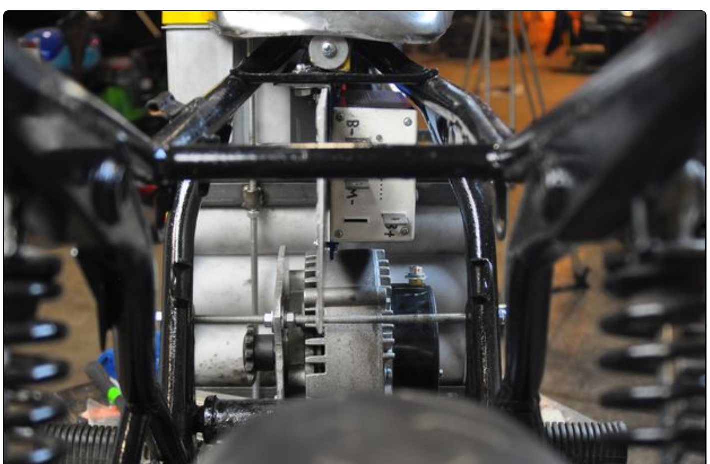
1. Tread plate attaches to back of battery rack here.
2. Tread plate attaches to cycle frame here.

1. Area for mounting the motor controller. Controller mounts on the right-hand-side of the plate, leaving room on the left side for other components.

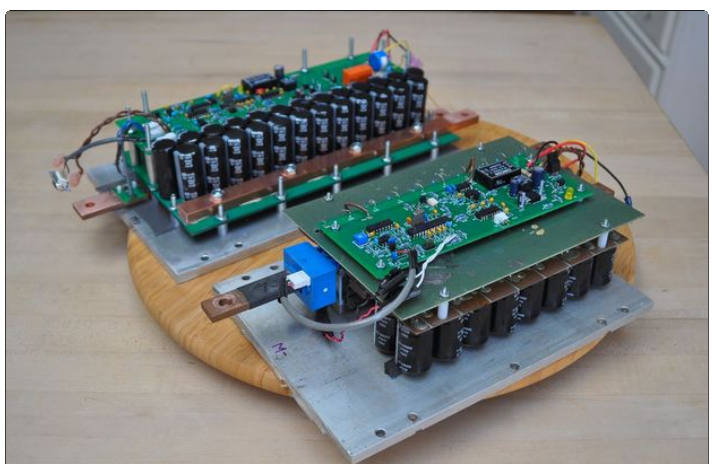


1. Alltrax AXE motor controller in position.
2. Plenty of room left over here to connect the power cables.

1. One battery removed for a better view of the controller and other parts.
2. Motor controller is partly under the gas tank, and partly under the seat. This way, the power cable terminals are hidden behind a plastic cover, but it shows off the front end of the controller.

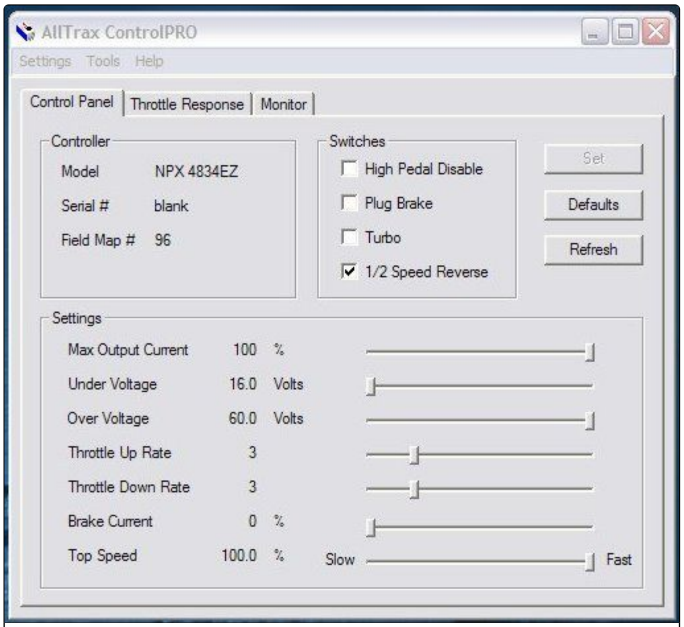


1. Motor controller mounted to a scrap metal plate.
2. The space on the opposite side of the controller is available for the remaining components of the system.

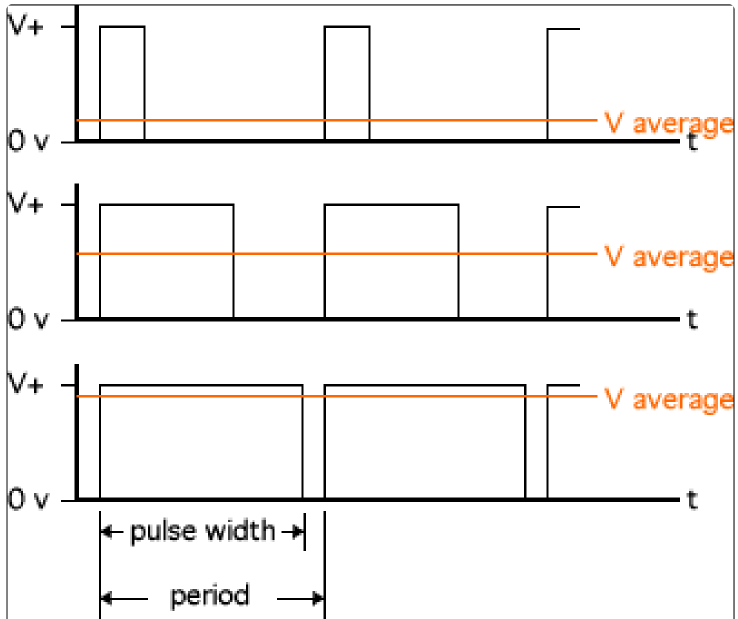


1. Open Source motor controllers like the "Open ReVolt" allow you to build your own controller with better features at a better price. Unlike commercial controllers, you can also fix, improve, and tweak them to your heart's delight.
2. The original 500 Amp Open ReVolt controller. Can run up to 144 volts.
3. This 1000 amp Open ReVolt motor controller could take full advantage of the 870 cranking amps the Optima Yellow Tops can put out.

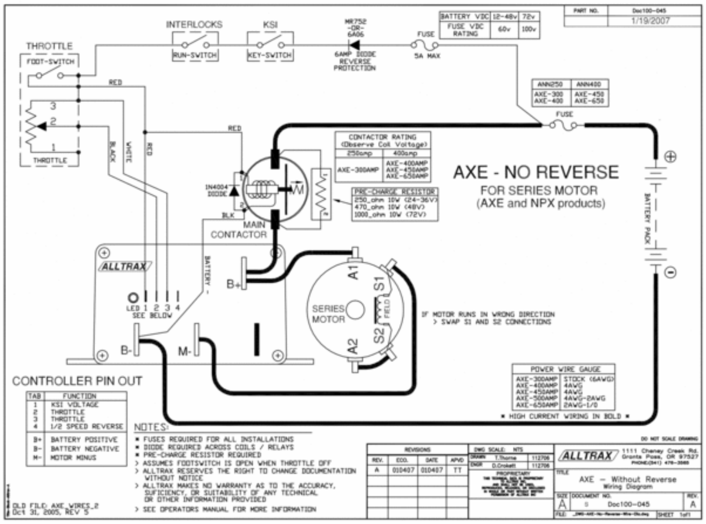
4. These controllers are shown without their covers, so that you can see the cool guts. Commercial controllers are typically filled with epoxy, which totally weather-proofs them, but also means they can't be opened up, taken apart, or repaired.
5. I would LOVE to see a motorcycle running one of these open source controllers. If anyone does it, please let me know!
6. Controllers like these can be built from scratch, using the open source information and wiki, or built from a kit. Visit Ecomodder.com for more info on these controllers.



1. The controller used on this project is programmable with a basic Windows program.
2. Throttle response was one of the most important settings to tweak the feel of the cycle.
3. This is a fun setting to change before letting someone else ride your cycle. I suppose you could also use it to avoid speeding tickets...
4. You can also use the software to monitor information from the controller. A small devices that can run windows emulation could be used to make a real-time digital display for the cycle. I know a guy who used a Palm Pilot and null-modem cable to do this.
5. You can program the controller to stop working at various voltages. Calculate your minimum voltage based on how far you want to discharge battery pack. The controller will stop working at that point to protect your batteries.



1. PWM at low duty would make the motor spin slower.
2. Medium PWM would make the motor spin at half its full-speed.
3. With PWM, the voltage is either at full (48V in my cycle) or at zero. The AVERAGE amount of on vs. off time translates into the average voltage, and the speed of the motor. It sounds weird but works great.



1. The motor controller will include with it a wiring diagram, and other detailed information that you will find useful in hooking up your electric motorcycle.

Step 10: Balance of System

Balance of System is a fancy term that refers to "and everything else".

In an electric vehicle, you already know about the main components, like the motor and batteries, but it can sometimes be the little things that people don't talk about, and can be the most confusing.

In this case, we will talk about the on/off key, main fuse, contactor, battery disconnect key, pre-charge resistor, shunt and ammeter, instrumentation, power indicator light, and DC/DC converter. Most of these components are shown right on the wiring diagram, along with their specs.

On/Off Key
When I got my cycle frame, the ignition key was broken. I replaced it with a simple keyed electrical switch. It's a "double-pole, double-throw" switch, which means that it completes two separate circuits at the same time. That's great, because with one switch, I can turn on both the 12V accessory system and the 48V drive system at the same time.
I built a mounting bracket by cutting down a piece of metal from a recycled computer case. I drilled a hole activates the main contactor. The contactor is now a less resistive path, and when you twist the throttle, high current can not go from the batteries, through the contactor, controller, and motor, and drive the cycle. Pre-charging the controller also prevents any arcing internal to the main contactor and prolongs its life.

Ammeter and Shunt
The ammeter is a display of how much current (measured in amps) that you are using at any given moment. Think of it as a real-time energy meter. In general, you want to minimize amperage while cruising (to maximize range and battery life) but it would also be nice to know how much power you use for burn-outs and powering up hills.
This is usually a matched set. The Ammeter is the display itself, mounted on the handlebars or other location for easy viewing, and the shunt, which is a calibrated piece of metal that the current flows through. Two wires (one on either end of the shunt) go to the ammeter. The needle on the ammeter varies directly with the amount of current through the shunt.

My ammeter is a 300 amp meter, mounted in a hole in the former gas tank. The shunt is mounted out of to mount the key switch, two holes for bolts to mount the bracket to the cycle frame, and painted it black. The switch gets two sets of wires to the back of it, both with small crimp-on ring terminals. One set goes to the DC/DC converter to run the 12V accessory system, and the other pair activates the main contactor for the 48V drive system.

On a motorcycle that has an existing, working ignition key, you can route 12V power from the key to activate a relay that will turn on the main contactor and motor controller.

Battery Disconnect

The battery disconnect is just a big kill switch. It completely disconnects the batteries from the rest of the system. It's an easy way to disconnect power for when you are working on the cycle, and acts as an emergency backup in case the main contactor ever failed. Both the On/Off Key and the Battery Disconnect are mounted on the left side of the motorcycle, not far from where the "Emergency Reserve" switch would be on a typical cycle's gas tank. Since there is no clutch or other left hand control, these are mounted on the left side in easy reach of the rider.

The batteries are connected or disconnected with a removable red "key" plunger. Make sure to get a disconnect rated for high amperage. The full current of the vehicle goes directly through this component. All battery cables, fuses, connectors, shunts, shut-offs, and anything else carrying current needs to be sized correctly. Since I'm using a 300 amp motor controller, sizing everything to 300 amps makes sense.

Main Fuse

The bike needs a fuse that will blow and protect the system if anything shorts or otherwise draws too much current (such as a blown motor controller.) I used a fancy-looking fuse holder with a 300 amp fuse in it. Make sure to mount this in such a location that the fuse is easy to access and replace. (If you want to get really wild, make it so it can be easily replaced on the side of the road, in the middle of nowhere, at 4AM in a rainstorm. Because you just KNOW that's when you are going to have a problem....)

Main Contactor

the way, near the contactor and battery disconnect. I strapped the gas tank down to a drill press with a hole saw in it to cut a hole just slightly larger than the ammeter. Since the gas tank doesn't hold gas anymore, there's no reason not to cut holes in it and mount instrumentation in there.

I recommend an ANALOG ammeter. A needle sweeping back and forth is easy to quickly read. Although a digital display may be more accurate, it's not as useful and it's difficult to read digital numbers that are constantly changing.

Power Indicator Light

On an electric motorcycle, there is no engine noise or vibration to indicate to the rider or anyone else that the motorcycle is on. You simply flip a switch, and it's instantly ready to go. Although the headlight is on when the cycle is on, the rider typically can't see that during the day. I wanted a great big, bright indicator to tell me when the vehicle was on. I decided that a green light mounted towards the front of the tank would work well. I found some switches, lights, and other components on an old instrument panel. One light had a sign on it saying "Power" and another one had a green lens. Both lights were for AC power, not DC power. I grabbed the components and put together the green lens, the power sign, and removed the small transformer on the bottom of the light socket so I could instead run 12V DC straight to the bulb. The bulb holder was installed through the gas tank, and 12V wiring run to it from the cycle's 12V fuse panel.

Powering the 12V system

On a typical gasoline motorcycle, there is a 12V battery to start the engine and run the headlamp and other electrical. The battery gets recharged by the engine, through the alternator, and it is what really powers all the 12V electrical.
Without an engine and alternator, you will need some other way to run the 12V electrical.

With a 12V battery

If you mostly just use the cycle for very short trips and errands, you could just use a plain, sealed, 12V battery. That battery would need its own charger, so that every time you are done with a ride, the 12V accessory battery gets recharged right away. The battery will take up some space, add some weight, The Main Contactor is a large, remotely-activated, high-power relay. When I turn the on/off key, it sends 12V to the main contactor, which closes, and completes the 48V drive circuit. The contactor is spring-loaded, so that if it no longer gets that small amount of 12v power, it opens and shuts down the cycle. This works well as a safety feature. For example you could wire a switch in series with the 12V power to the contactor from the kickstand. If the kickstand is down, the main contactor won't close, and you can't turn the cycle on.

Pre-charge resistor
Most motor controllers require a "pre-charge resistor". That's a way to allow power to slowly go into the motor controller to charge up the capacitors. If power was suddenly applied to the motor controller (such as just flipping a switch) the capacitors internal to the controller would suck up power almost instantly. Do that too many times and the capacitors will blow and wreck the controller. If you called the manufacturer for warranty work, the first thing they will ask you is about the pre-charge resistor.
The resistor simply bypasses the main contactor. When the battery disconnect is turn on, current will flow from the batteries, through the resistor, and into the controller. As it does, the voltage internal to the controller will raise to match that of the batteries. Once it does, you can turn the key to on, which

and you would most likely want the charger for it left right on the cycle as well, using up even more space. It does work, and is simple, but not ideal.

With a DC/DC converter
Instead of a dedicated 12V battery and charger, you could use a DC/DC converter. The converter is an electronic device that takes one DC voltage in, and gives a different DC voltage out. It's a very efficient way to use a trickle of power from all four of the large drive batteries, convert the 48V to 12v, and run the headlight and other accessories.

The DC/DC converter was a computer component purchased from e-Bay for $10. It's two-inches square by half an inch thick - very compact and lightweight. This saves considerable bulk and weight over a medium-sized battery and dedicated charger. 48V from the drive batteries is wired to the input end of the converter. The output end of the converter takes the place of a 12V battery. The + goes to the cycle fuse panel, and the - goes to the motorcycle frame ground.

The output of the converter is adjustable into the range of CHARGING a 12V battery, so another option is to use BOTH a DC/DC converter and a small lead-acid battery. The converter provides power to the battery as a trickle-charge, and the battery acts as a reservoir in case you suddenly pull more power than the converter can provide, or in case it quit working.

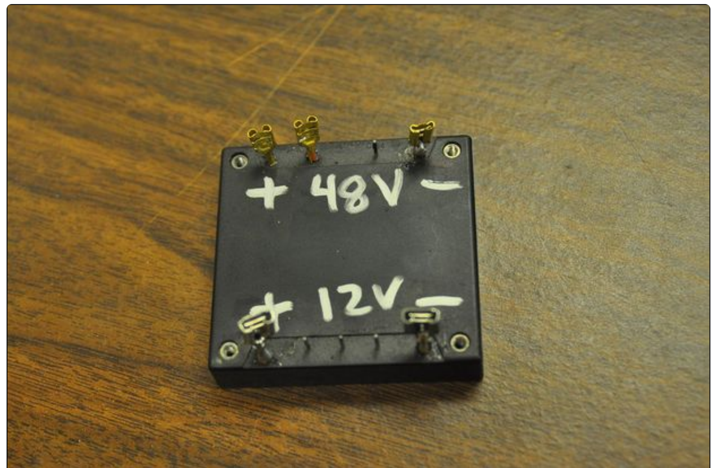
This DC/DC Converter is rated for 100 watts. The headlamp draws 55, leaving plenty of power for the tail-lights, turn signals, and other 12V accessories.

I crimped and soldered 1/4" spade connectors on the converter to make it easier to quickly connect the wiring. The converter already has mounting holes in it. I mounted it with small screws to the same plate that the motor controller is mounted to.

All over these various components serve important roles. Even though the motor and batteries are the first things we think of on an EV, make sure you understand the balance of system to properly and safely operate your vehicle.

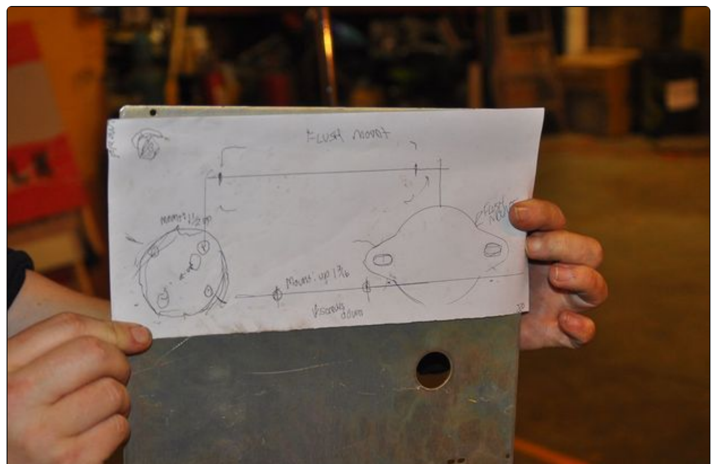
https://www.youtube.com/watch?v=EblaQllex8A

1. Green power indicator light showing that the cycle is ready to go!



1. 48 volts goes in...
2. ...and 12 volts comes out!
3. A Sharpie brand silver metallic marker writes great on black metal motorcycle frames or black electronic parts.

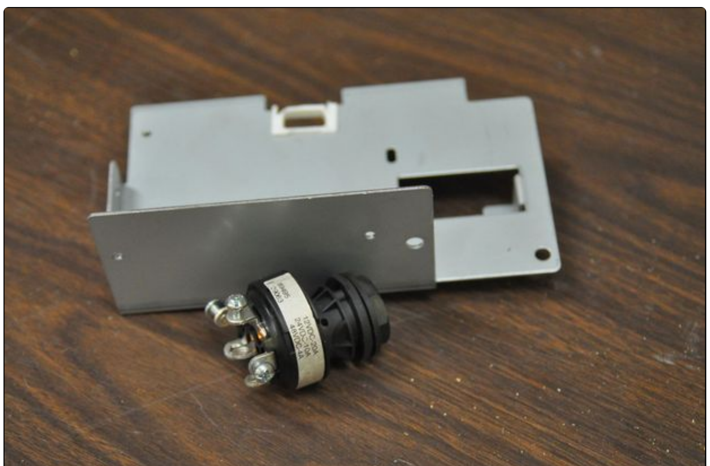
1. This DC/DC converter will take the 48 volts from the main batteries and convert it to 12V to run the headlight, taillights, horn, and other 12V items on the motorcycle.
2. This DC/DC converter is 2" square by 1/2" thick, and replaces weight and bulk of a separate 12V battery and charger.



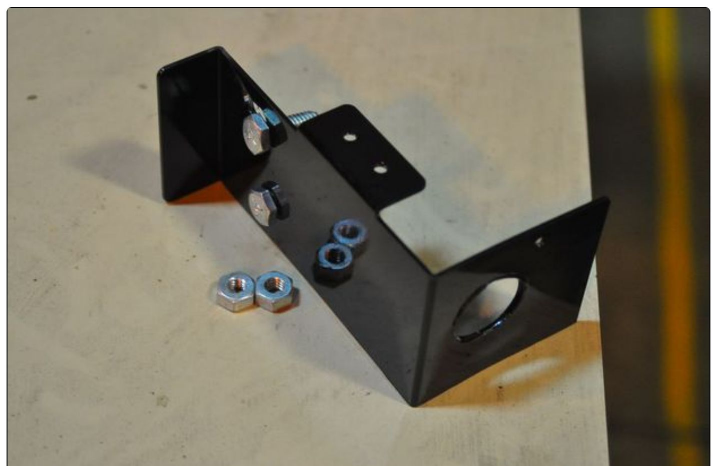
1. Using a pice of paper, I could hold it up to the space in the motorcycle and mark how much room I had to work with. I then outlined the components I wanted to fit there directly on the paper. After than, I found an appropriate piece of scrap metal that would work as a mounting plate.

1. Keyswitch
2. Main contactor
3. Main fuse in a fuse-holder
4. Battery disconnect
5. Ammeter shunt
6. All of these "Balance of System" components had to fit in a small area on the motorcycle. I spread them out on the floor to experiment with how they would need to be connected. Once I figured that out, I traced the objects on a paper template, and made a mounting plate from that. I drilled all the holes and mounted the items to that plate, and then mounted the entire plate at once into the motorcycle.
7. The hunk of wood and hammer were the only tools I had to bend a piece of sheet metal to make a support for the battery disconnect, which needed to be spaced away from the mounting plate.

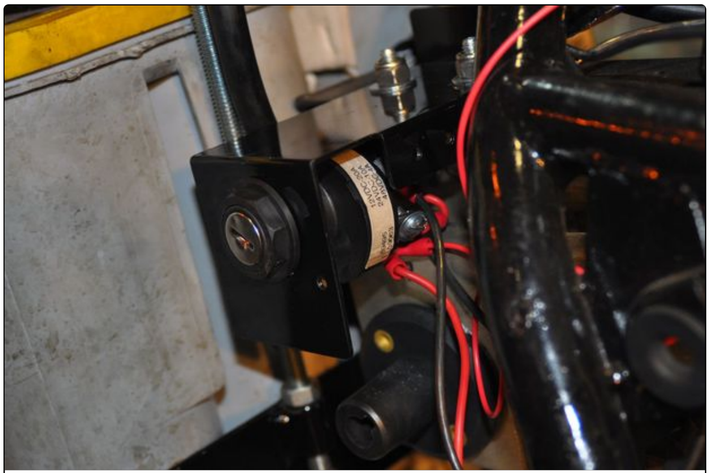
1. Battery disconnect key.
2. Main fuse.
3. Main contactor
4. Main components of the balance of system were all assembled on the workbench on a small mounting plate. Then, that whole assembly was mounted into the motorcycle. The limited space inside a motorcycle frame makes it difficult to drill and mount small individual pieces separately.
5. The DC/DC converted is mounted on the other side of the plate.



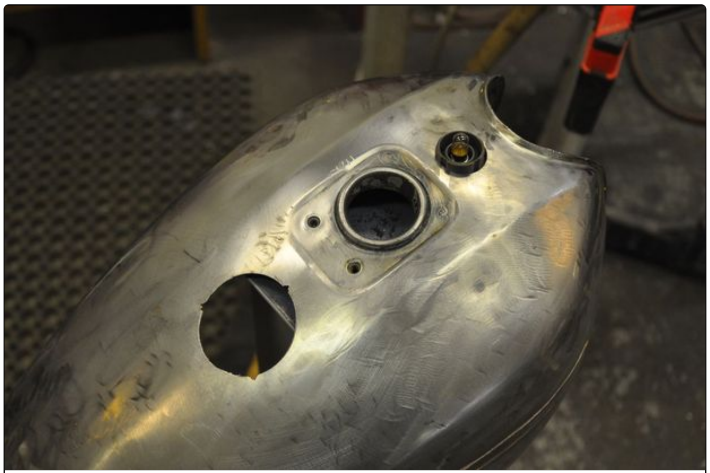
1. Keyed 12/48v switch. Note that there are TWO sets of power connectors on the back of it. This switch will turn TWO circuits on and off at the same time. It's rated for 12-48v.
2. This piece of metal from some recycled computer equipment already had a nice 90 degree bend in it. I cut it down to size to make a bracket to hold the key switch. I then drilled a hole in it the diameter of the front of the switch for it to pass through and mount on the bracket.



1. Hole I drilled to mount the key switch.
2. Black gloss spray paint sure made this look nice. Look at the reflection of the nuts in the paint job. This is AFTER the paint dried!
3. Two bolts will hold this bracket to the frame of the motorcycle.

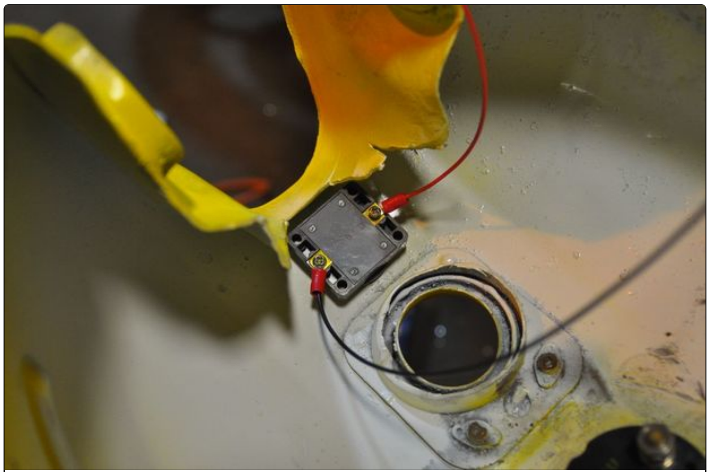


1. Key switch mounted in place on the motorcycle. Two pairs of wires come out of the back of it. One pair turns on the 12v system, and the other powers up the 48V electric drive system.

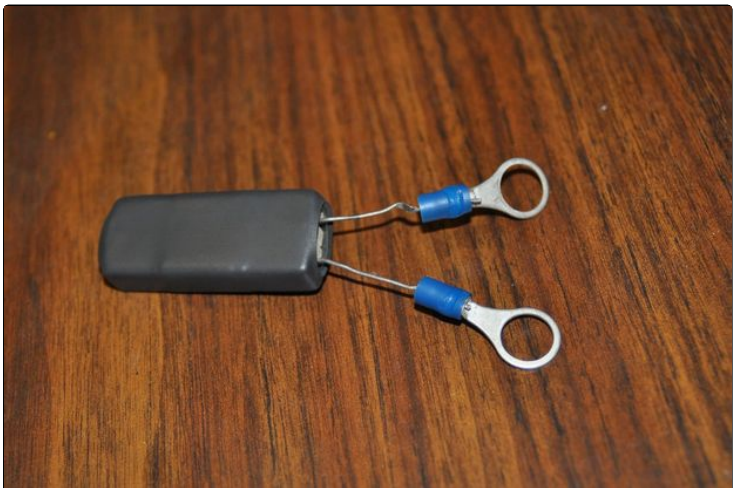


1. Hole drilled in the tank for the ammeter.
2. Fuel opening. Instead of adding gas here, this is where the battery charger will connect.
3. Hole drilled to mount a power indicator light.

1. 300 amp analog ammeter in place.
2. Power indicator light.



1. The power indicator light was installed in a hole drilled through the gas tank.
2. The two red wires are powered by the existing standard 12V electric system of the motorcycle.
3. Back side of the ammeter.



1. Ring terminals were the easy way for me to connect the resistor to the main contactor.
2. Pre-Charge Resistor. The rating of the resistor required is on the motor controller wiring diagram. Typical would be something like a 10 watt, 600 ohm resistor. I didn't have one of those, so I put two resistors together to make one.
3. The pre-charge resistor bypasses the main contactor allowing a trickle of power to go to the charger before you complete the main circuit by turning on the key.

Step 11: Driveline, Sprockets, and Gear Ratios!

I bet by now that you want to make the cycle go!

So, it's time to talk about the driveline.

This motorcycle is about as simple and efficient as you can get. It's more or less the same as a single-speed bicycle.
The motor has a drive sprocket, which connects to a chain, which turns the back wheel. That's it!

Drive Sprocket
The motorcycle uses a standard machine sprocket. I simply went to a farm store, which had a decent tractor repair aisle and located parts for the sprocket and chain. I bought a 14-tooth sprocket and a hub with a 7/8" center hole to match the motor's drive shaft. These are two parts, bought separately, which allows greatest flexibility in driveshaft diameter and sprocket tooth count. The sprocket and hub had to be welded together. In the earliest version of my cycle, that was the only welding done on the entire project. It was only later, when I had some welding experience that I tackled the welded battery rack. On

(Somebody asked about the sprocket being aluminum, and that this is a high-wear item. The black finish on this sprocket is a wear-resistant coating. The sprocket manufacturer highly recommend at least that for protecting the sprocket. I've been very happy with it, and wear on the sprocket has been minimal overall.)

Gear Ratios
After all of my riding, I believe that I COULD have kept the original stock rear spocket. It would have given me a higher top speed, poorer acceleration, and cause the motor to draw more amps. Most of my riding is in the city, so I would gladly have a lower top speed in exchange for better acceleration and less amp draw. By having the larger rear sprocket, I can always change out the inexpensive front sprocket to change gear ratios. If I kept the smaller stock rear sprocket, I wouldn't have had that flexibility.

My current setup is a 14-tooth front drive sprocket and a 72-tooth rear driven sprocket for a 5.14:1 gear ratio. On my cycle, I'm very happy with the

the original sprocket, I just had somebody else weld those two pieces together for me. They were inexpensive - under $20 for both parts. If I want to change the gearing on the cycle, all I need to do is spend another $20 at the farm store and get a sprocket with a different number of teeth. These same parts could also be mail-ordered from a dealer such as Grainger or other industrial supplier.

The sprocket slides onto the end of the motor driveshaft, and is held in place by a keyway, square key, and set screws.

Chain
The chain is #40 chain from tractor aisle. Cost about about $10 for ten feet, and a few dollars for a master link. It is a popular size chain, so there is a wide variety of sprockets that match.

Driven Sprocket
I did not use the stock sprocket on the back wheel of the motorcycle. Electric motors tend to work best spinning faster than gasoline engines, and geared down a bit more. This gives you plenty of power, without constantly running high current through the motor.
There are many on-line motorsports companies that will make custom rear sprockets. I used one called Sprocket Specialists. You simply tell them what motorcycle you have, what chain you want to use with it, and how many teeth you want on it. They custom make them on CNC equipment and send it to you in the mail.

I got an aluminum sprocket for a Kawasaki KZ440 for #40 chain and 72 teeth. It has a black protective finish. The larger aluminum sprocket weighs less than the stock steel one did. (Saving weight is always a good thing for electric vehicles.) I removed the rear wheel, unbolted the stock sprocket, and replaced it with the custom one. Consult the cycle's repair manual to make sure to bolts are torqued correctly, and that the back wheel is re-installed right.

combination of range, acceleration, and top speed. On a fresh charge, I have just enough power to do a minor burn-out. Acceleration away from a stop for city use is very nice. There's no clutch to slip or engine to rev, so the cycle just GOES the moment you twist the throttle.

Tweak the Driveline
Once I had the sprockets on, I wrapped the chain, checked it for length, cut it to length, wrapped it on to both sprockets, and closed it up for a brand new master link. (Make sure the clip on the master link faces the right direction. It can work its way off if you put it on backwards.)

The original chain guard still fit over the new (larger) rear sprocket, but just barely. I simply bent it a tad to make sure it had clearance.

On the front end, the transmission would normally have an integral cover over the chain and drive sprocket. Without the tranny, it meant I had to make a custom chain cover. It could have been made from almost anything - metal, plastic, wood, but I wanted to show off how the cycle works, so I went with plexiglass. I roughed out the shape required with some cardboard and a pencil, and then cut the plexiglass to fit the space. A straight piece of plexiglass covers the top of the chain. I used a scrap of an aluminum rail as a spacer between the motor mounting plate and the plexiglass to hold it in position.

With everything in position. The chain needs to be tightened and aligned as per the user manual.

While I had the rear wheel off, I also used the opportunity to put on new tires. (Bought on sale during a close-up sale!)

https://www.youtube.com/watch?v=o70j1I_WkZU

1. Brand-new custom rear sprocket mail-ordered from Sprocket Specialists.
2. Bolt pattern matches my existing KZ440 sprocket.
3. Black finish keeps the aluminum from getting that icky aluminum corrosion on it. Custom colors were available, but cost more.
4. Large diameter gives a mechanical advantage to the electric motor, geared for city use.
5. Is it just me? Or does this photo remind anyone else of the movie KRULL?

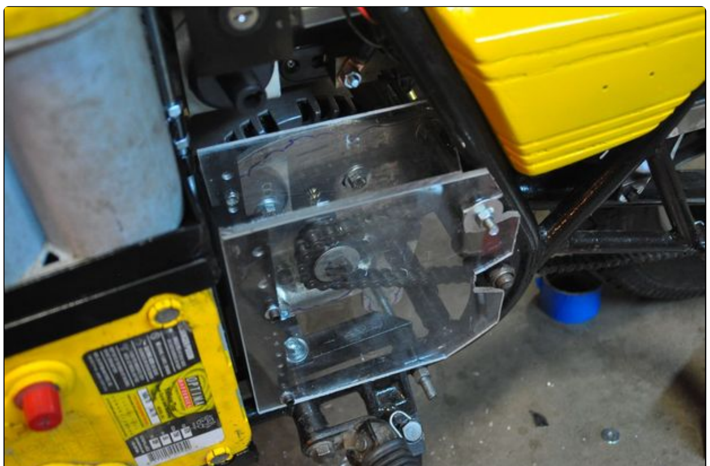
1. New sprocket exactly clears original rear chain guard.

1. 14-tooth drive sprocket. Still needs key and set-screws.

1. I hand polished the rims with a green scrubby pad. It was messy hard work, but they looked great when done!
2. A friend who is big on motorcycles helped me put the new tires on. Here's the old back tire, which I used as a rest while polishing the rims.

1. New custom rear sprocket.
2. New rear rubber.
3. Safety strap ties cycle frame to the work table and keeps it from falling on and crushing me.

1. This aluminum piece already had threaded holes in it and spaces out even to the outside of the cycle frame. It also protects the battery from any gunk flying off the chain. It is bolted to the motor mounting plate.
2. I added a spacer to hold the other edge of the sprocket cover.



1. Plexiglass cut to shape to fit flat against the black aluminum bracket and the frame of the motorcycle.
2. Top clear cover/guard is just a straight piece of plexiglass.

1. Finished chain guard.

1. Rear wheel removed for sprocket swap.

Step 12: Cabling It Up

Wiring up the power system of the motorcycle is fairly straight-forward. It just requires using thick power cables that are connected with nuts on the motor and batteries, and nuts and bolts on the motor controller.

Cable Type
You will want to use what's known as welding cable. Welding cable has many fine strands of copper cable inside. It's designed to carry high current, but it is also very flexible, making it easy to work with. Other types of copper cable are very stiff, may not have the right type of insulation, and aren't as easy to crimp to. Welding cable is available at welding suppliers, good full-service hardware stores, and some building supply stores.

Cable Thickness
The thicker the cable, the more current a cable can pass through it without heating up. Cable is commonly rated by American Wire Gauge. That measurement is a number wherein the higher the number, the skinnier the wire, and the lower the number, the THICKER the wire. Typical household electric wiring for 15 amps might be 14 ga, but electric vehicle cabling might need to be able to handle hundreds of amps. The motorcycle uses 4 gauge cable. It's thick enough to carry the required current, but still be affordable. Thick cable can get pricey fast.

Lugs
Get crimp-on power lugs that match the size of the cable you are using. They are available at the same place you got the welding cable from. 4 gauge is common enough to find locally. Make sure that the bolt hole in the lug is the right size to match up with the power connectors on the motor, the controller, and the batteries. If the various connectors are different sizes, get the appropriate number of lugs required so that you have enough lugs to fit all system components correctly.

Crimpers
You will need a mechanical crimper designed specifically for these heavy lugs. They usually come in two styles - "bolt-cutter", and hydraulic. purchased fairly affordable at import tool stores like Harbor Freight.

Making Cables
To make power cables for the cycle, you need to know how long each cable is. Measure the distance between the two components using a flexible table measure or a piece of string (it's almost NEVER a straight line between anything) You might want to account for having cables follow the shape of the frame or all be on the same side. In general keep cables as short as possible.

Cut the cable to length. Thick power cable usually can't be cut with a small wire cutters. A bolt cutter will work fine, but the best tool I have used is a Sears Robo-Cutter. Any other type of large, sheering cutter will work fine.

On the end of the cable, slide on a piece of shrink tube, large enough diameter to go around the lug, and about an inch or so long. Then, cut back the insulation of the cable so that the lug can fully slide on, without having any left over bare wire.

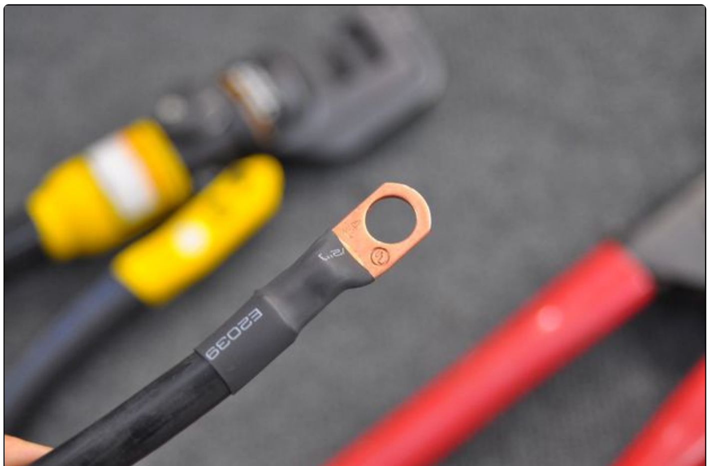
Crimp the lug on with the crimper of your choice. On some styles of hydraulic crimpers, they won't release until you have FULLY crimped the lug. On "bolt-cutter" style crimpers, certain sizes require you to crimp twice.

Slide the heat shrink tube forward to cover the crimped part of the lug and the beginning of the cable insulation. Hit it with a heat gun or hair dryer set to hot so that it shrinks into place.

Physically connecting the cables
Connect all the cables, following the diagram provided in the motor controller manual. All four batteries in series - one to the next to the next to the next. Batteries to the controller. Controller to motor. Without the main power turned on, the only concern electrically is that the batteries themselves always have power and that anything attached to them can carry current. Do not touch any power cables to the frame of the cycle, as that is the easiest accidental

The ones that look like large bolt cutters (long handles, small, jaw, almost always painted red for some reason....) work well and are fast and easy. They can be a bit pricey to purchase. They can sometimes be rented from full-service hardware stores. I borrowed one from a friend.
Hydraulic crimpers are typically hand-held with a small cylinder like a mini bottle jack. You pump the handle repeatedly to make hydraulic fluid crush the lug onto the cable. They have interchangeble jaw inserts for various diameter cables. The can be short-circuit. (Wear safety glasses whenever working with batteries and power connections.)

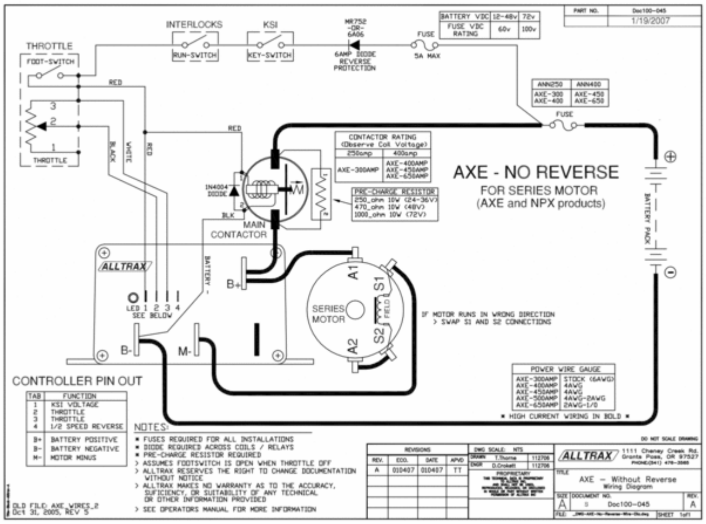
Once the cycle is cabled up, you only have to check things over and test it all out before you can go for a ride!



1. Heat-shrink tubing.
2. 4 gauge cable.
3. 4 gauge copper power lug, with hole of correct size to go to the motor.
4. A hydraulic crimping tool.
5. A mechanical crimping tool.

1. I borrowed this tool from a friend. That saved me the cost of buying or renting one.
2. This tool has a rotating jaw set. It has various sized indents. You rotate the correct one into position, depending on the size cable you are crimping.
3. The doubled set of levers and fulcrums gives this tool an amazing mechanical advantage. Even though it's just a hand-tool, it makes powerful crimps.

https://www.youtube.com/watch?v=VI-pXsoG0h8



1. Recommendations on cable size.
2. Motor.
3. Controller.
4. Your motor controller will have with it diagrams to follow to connect your cables.
5. The thick black lines represent the high-power cables.

http://www.instructable…

Download

Step 13: Test and Ride

Testing
Before you go for your first ride, you must test the vehicle.

Make sure all chain guards and any other safety features are in place.

With the rear wheel OFF the ground, turn on the main battery disconnect and the key. Gently twist the throttle. The motor will start to spin, and along with it, the chain and back wheel. *(If it doesn't, power down the cycle, disconnect the batteries, and follow the motor controller troubleshooting guide. It may be something as simple as a loose throttle connection. Most controllers have a troubleshooting indicator light on them to help you.)*

Having an assistant turn the throttle will more easily allow you to inspect the cycle with the motor running. Visually inspect the chain alignment and the front and rear sprockets.

Everything else should also work on the cycle, the light, horn, turn signals, etc.

If there is anything else you need to do (chain alignment, torque bolts, etc.), power down the cycle and disconnect the batteries before working on it.

Test Ride
Make sure to take it easy on your very first ride. An electric motorcycle will behave a bit different than a typical gasoline cycle. Empty parking lots and lightly traveled roads are good for your first ride. As you ride, take note of anything unusual. The cycle should be very quiet and have almost no vibration, other than the bumps in the road. On my first ride out, I noticed that I didn't like the way the throttle responded. It was too touchy. Any tiny twist of the throttle would instantly begin accelerating.

When back from your test ride, check the cycle over again. Make sure nothing has loosened up, that the motor isn't hot, or anything else unusual. At this point, you might want to adjust the controller so that the throttle better suits your riding style.

If everything checks out, and the throttle is how you want it, CONGRATULATIONS! *You just built your own electric motorcycle!*

//www.youtube.com/embed/HK65FFJqnOY?rel=0

1. Known as an "EV Grin", you can't help but smile driving an electric vehicle.

1. An electric motorcycle's view of the road. Shot with a wide angle camera mounted near my right foot.

https://www.youtube.com/watch?v=Rrdv7cKj57I

Step 14: Other Notes

In the list of "odd things nobody ever tells you about....."
I found a few quirks while working on this project.

Rear Brake Spring Bracket
When I was getting the cycle all back together and testing to make sure everything was working right, I had to hook the rear brake back up. On a motorcycle, the rear brake is activated by a right-foot pedal. A spring pulls that pedal back up when you release it. But here's the weird part.... I couldn't figure out where that spring connected to on the frame of the motorcycle. I consulted the repair manual, and found out that the spring hooks on THE MUFFLER!

By converting my motorcycle to electric, I no longer had a place to connect my return spring! So, I built a little tiny, custom bracket, just for the spring to go to. On your project, you might come across some other odd quirk like this. It's not a big deal, it just gives you the opportunity to be creative and come up with your own solution!

The Gas Tank
Some of the most common questions I get about an electric motorcycle are about the gas tank. Typical is *"If it doesn't have any gasoline, why do you have the gas tank?"* and *"Why don't you just STUFF that gas tank full of batteries!?"*

The short answers are that motocycles just don't look like motorcycles without the gas tank, and you really can't fit batteries in there anyways.

When I got the motorcycle, the tank was already rusted and dented. It was completely bone dry, but I still left it open for a few days before cutting off the bottom with an angle grinder, so I could beat out the dents from the inside. Then I stripped the existing paint, and gave it a new paint-job. The top part of the motorcycle frame is a tube that goes straight through the gas tank. The tank is almost like a saddle-bag that hangs over that bar. The tank is also curved and batteries are nearly always big rectangular things. So, between the frame and shape of the tank, you just AREN'T going to cram batteries in there (That would also raise the center of gravity on the cycle as well.) The tank does make an excellent cover for over the batteries. It would also be a good place to mount the motor controller or a battery charger, as long as you make sure they have enough ventilation.

Some electric vehicle enthusiasts will even make a FAKE gas tank from foam, fiberglass, or plastic. It gives the cycle that cool look, but since it's custom, can be designed to accomodate batteries or other components. Remember, on some cycles today, the "gas tank" really isn't. On Goldwings, the "tank" is just a filler port, but the actual fuel tank is elsewhere on the vehicle. The "tank" makes a nice box for gloves, goggles, and maps.

LOUD PIPES SAVE LIVES
One myth of an electric motorcycle is that it's silent. It isn't - it makes some noise, but it is SIGNIFICANTLY quieter than a gas motorcycle, especially one with modified tailpipes. Should the need arise for my cycle to be loud, I have a horn and am not afraid to use it.

Even though most car drivers today have their windows rolled up, with the air-conditioning cranked, and the radio blaring, (so they can't hear a thing anyways) some people still think that a motorcycle being obnoxiously loud is a safety feature. After the millionth time that I heard that "loud pipes save lives" (mostly from NON-motorcyclists), I wondered if there was a way I could play with that in a way that an electric motorcycle could be BETTER than a gas one when it came to making noise.

I connected an MP3 player to my computer and downloaded some various motorcycle sound effects. I then attached self-powered computer speakers inside the hollowed gas tank and bungie-corded the MP3 player to the handlebars. I could now sound like a Harley, a Kawasaki, a 50cc scooter, or the George Jetson flying car!
See details on that here on Instructables.
https://www.instructables.com/id/Add-Sound-Effects-to-your-Electric-Motorcycle/

Training
If you haven't already, take a riders safety class. Motorcycle riding is a skill. It should be learned and practiced. Make sure to always "get the hang of it" again in the spring after pulling the cycle back out of winter storage. Come to think of it *winterizing* should be covered here as well.

Winter Storage
When I looked through the cycle manual on winter storage, I was surprised at how much work it was to store a gas cycle for the winter! You have to change the oil, run the tank dry, and doing a surprisingly-long list of other things! When back out of storage in the spring, you are supposed to change the oil (again!) and have another laundry list.

On my electric motorcycle, here's how I put it away for the winter.

1. Charge the batteries
2. Pull out the battery disconnect
3. Ignore the cycle for the rest of the winter (I just keep mine in the back corner of the garage.)

In the spring, it's

1. Charge the batteries (they will self-discharge a bit over the winter)
2. Check the air in the tires.
3. Put in the battery disconnect, turn the key, and ride the cycle!

LED Lighting
A vehicle becomes more efficient the lighter and more aerodynamic it is. You can also help make it more efficient by reducing electrical loads. For example LED lights consume less power than incandescent ones. On my cycle, I replaced the stock taillight with an LED light from the autoparts store. They are mass-manufactured, DOT-approved, and affordable.
I'd like to have a low power-draw headlight, but at this time there are only a few DOT-approved LED headlights available on the market, and they are rather expensive. I'd like to get one when the price comes down, or possibly build my own.

The turn signals on the cycle are still incandescent, as they use nearly no power at all (how often are turn signals on!?) It didn't make sense for me to spend the money to upgrade them to LED. If I were building a new, custom motorcycle, I would install LED lights all the way around right from the start.

300 Miles per Gallon!
Another really cool thing about electric motorcycles is how crazy efficient they can be! After my first ride on a fully charged battery, I recharged the battery, tracking how much energy was used (with a Kill-a-Watt energy monitor) and divided it by how many miles I traveled (using the trip odometer.) I used electric-to-gasoline-conversion numbers from MIT to calculate what the equivalent "miles per gallon" would be. It came out to over 300 mpg!

Is it fair to use MPG when talking about electric vehicles? No, not really. Gasoline can't be made from wind turbines or photovoltaic panels, and there aren't nearly as many gas stations as there are electric outlets. When talking about electric vehicles, we might use "MPGe" or miles per gallon equivalent. It's not a perfect analog between gas and electric, but it gives people who have lived in a world of miles per gallon a better sense of the efficiency of an electric vehicle. Keep in mind that heat, noise, and vibration are all signs of POOR efficiency. An electric motorcycle doesn't have a hot engine, with noisy exhaust that needs mufflers, and it doesn't shake from engine vibration.

Regenerative Braking

Many people are now familiar with the concept of regenerative braking, due to the mainstream popularity of hybrid cars. So, of course they ask if my cycle has it as a feature. No it doesn't. Although a DC permanent magnet motor can make a fine generator, adding regenerative braking adds to cost and complexity of the project. Also, most braking is done on the FRONT of a vehicle. On the cycle, the motor is connected to the back wheel, where it would be less effective for regen. Also, overbraking on the rear of a cycle can lead to a uncontrolled skid. Many "hypermilers" get better fuel economy by avoiding braking in the first place, using simple eco-driving techniques, such as "timing lights".

Budget

We wouldn't want to finish talking about this project without mentioning what it cost to build. First, let me start off by saying that any project like this can have WIDE VARIATION in the cost of the components and the final budget. On my project, some of the parts, like the ammeter, power indicator light, and battery charger were items that I already had or were salvaged materials.

Here's a basic run-down of the project budget.

- Donor bike - $62 (bought it for $100, sold scrap parts for $38)
- Motor - $500
- Motor controller - $300
- Twist Throttle - $50
- Batteries - $700
- Drive Sprocket - $20
- Chain - $10
- Custom Rear Sprocket - $100
- Fuse, holder, battery cut-off, and cabling - about $100
- Repair Manual - $20
- Main contactor - $50ish

Add it all up, and the project came out to right around $2000. If a person already had some other parts, tried used batteries, or installed an inexpensive forklift motor, the price could come down. (See Russ' cycle photo in the last step! He built his for nearly nothing!)

On the other hand, if it was all brand-new parts, with a high-end motor and controller, and lithium batteries, the project could easily be $10,000. (Check out Tony's cycle in the last step!)

On the electric car project, I was a bit smarter about money, creatively used salvaged parts, and built an entire electric car for about $1300 total.

Cost of charging

Electric motorcycles are efficient and have smaller battery packs than electric cars. My cycle usually costs about a penny a mile to charge. That will vary a little bit depending on what electric rates in your area are. Electric rates are much less volatile than gasoline prices.

If you have solar, you can charge your cycle for "free"!

In some areas, a "Time of Day" plan is available. You pay double the price of electricity during "peak load" times and you pay HALF the price during "off-peak" times, usually at night. Check with your local power company. By recharging your vehicle only at night, you can cut your electric "fuel" costs in half!

Simplicity

Lastly, I'd like to mention that even though I went into a lot of detail on this project, Electric Motorcycles are SIMPLE. They really are just about cleanest, most straight-forward transportation possible. Knowing what I know now, I could build an electric motorcycle in a three-day weekend.

I know one guy who I mailed a photo of my motorcycle to. When I saw him the next week, he had already built an electric motorcycle almost exactly like mine!

//www.youtube.com/embed/tM9VWmIF3_Q?rel=0

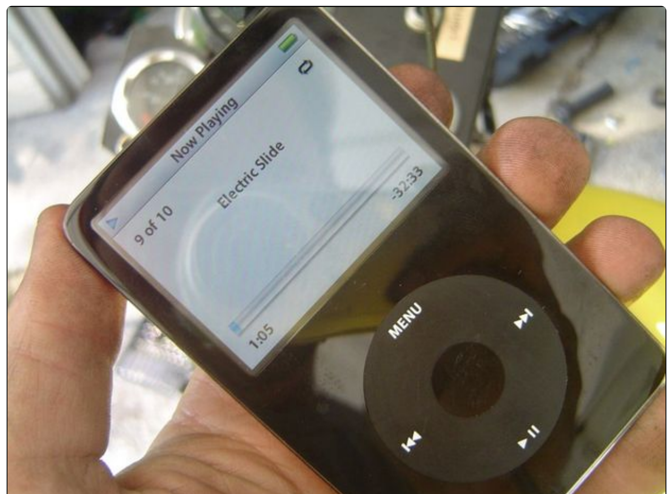
1. LED bulbs are bright, but also conserve energy. As an added bonus, they tend to have an extremely long life.
2. The stock incandescent bult was replaced by a high-efficiency LED bulb.

1. Inexpensive DOT-approved LED tail light bulbs are now available at auto parts stores.

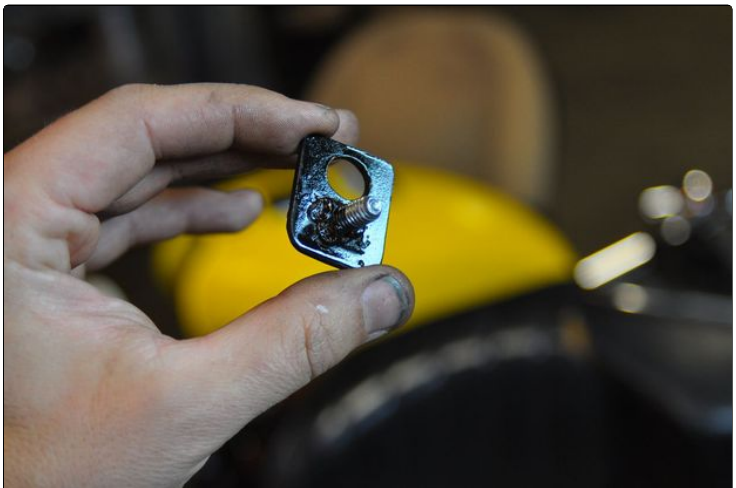
1. I loved the look of the tank with the paint stripped off! Unfortunately, it would be blinding to ride on a sunny day! I ended up having to repaint the tank more than once to get good results. Had I started with a nicer cycle, I wouldn't have had to do all that work.

1. My brother lent a hand by using body-filler to smooth out the last of the dents and cover indents in the side that originally held the motorcycle brandname.

1. The finished tank with ammeter and power indicator light. I'm really happy with the results.



1. Enjoy the peace and quiet of an electric motorcycle, or crank up the MP3 player with sound effects to sound like any motorcycle you want!



1. Because the rear brake lever return spring normally connected to the muffler, I had to build a custom bracket, just for the spring.

Step 15: Power Your House in a Blackout With Your Electric Motorcycle

We now have a completed electric motorcycle. That's great for practical local transportation, but what about the 22 hours a day that the motorcycle is just parked there!? Isn't an electric vehicle just a big battery pack with wheels? Wouldn't it be great to in some other way make use of that?

A lot of very clever people think so. They are working on something called *"The Smart Grid",* in which electric vehicles only charge up at a time that little power is being used, and the EV PROVIDES it to everyone else when too much power is being used. It's just theory right now, and requires a lot of standardization of components, fancy computer controls, and vehicle owners agreeing that everyone else can "borrow" their power. It's a really neat concept, but I don't think it will happen anytime soon.

Could some of those same ideas be used on a personal level?

The Poorman's Smart-Grid
One use that would be fantastic for an electric vehicle is for home blackout protection. Instead of purchasing a gasoline or diesel generator for use in a power-outage, just run your house off your electric motorcycle!

Instead of electricity going OUT from the breaker box there, it would input to the breaker box there. This is called a "load-side connection".

(*If you have specific electrical codes, or are required to use only licensed and certified electricians, don't mess around in your breaker box. High-voltage AC power is potentially fatal. Don't screw around if you don't know what you are doing!*)

The new power inlet is a "twist-lock" connector. It is physically different than anything else in my garage, so a person can't plug anything else in there by accident. It is also labeled as UPS POWER INLET on the connector and in the breaker panel.

I built a custom cable with two male ends. One is a 20-amp plug (one blade is turned 90 degrees from a typical 15 amp plug) and the other is the twist-lock connector, which is rated for up to 30 amps.

I connected the cable from the UPS to the twist lock wall "inlet". On the breaker box, the mains circuit breaker is manually turned off, and the 20-amp breaker for the UPS blackout protection is turned on. That allows power from the motorcycle batteries to go through the UPS, get converted to AC power, and feed all the other circuits in the breaker box. My

UPS delivers for you

You might be familiar with a UPS (Uninterruptable Power Supply.) People often have their computer at work plugged into one. In a brief blackout, the UPS switches power over to an internal battery, allowing you to finish what you are doing and save your work. When the power comes back on, the UPS switches seamlessly back to regular wall power and recharges the internal battery.

While most basic UPSs are 12V, larger ones, such as for computer server rooms, often run on 48V. Hmmmm - that's the same voltage as the electric motorcycle. I spoke with a local computer recycler and asked if he ever gets 48V UPSs coming through his facility. He said that he did, but I wouldn't want it, as the batteries are always bad. I told him that not having batteries was no problem! It wasn't long until I got a call saying that a salvaged 48V UPS was in. I was able to get the salvaged UPS at no cost to me.

I mounted the UPS in a cabinet in my garage. It had been a while since my cheap, imported onboard battery charger had quit working, and I was using a basic off-board charger since then. Because of that I already had an Anderson quick connection on the motorcycle. I wired the UPS connection that would normally go to internal batteries to instead go to a matching Anderson connector. That way, I could quickly connect and disconnect the cycle from the UPS.

Keep in mind that a UPS is actually two things, a *battery charger*, AND a high-quality *power inverter*. By simply plugging the UPS into the cycle, it begins to recharge, and acts as a typical 48V battery charger.

If AC wall power is cut off from the UPS (such as happens in a blackout) it stops charging the batteries, and instead takes DC power from them and converts it to 120V AC power as is typical in American homes and businesses. The back of the UPS has several 15 and 20-amp outlets. That would be fine if I only wanted to power a few items directly plugged into the UPS. What if I wanted to run the whole garage off it, or my entire house!?

To do that, I first added an additional 20-amp circuit to feed all the other circuits in the breaker box. My garage is now "off-grid"! I've run the radio, garage door opener, lights, and shop vac, and other power tools from the UPS. The UPS is rated for 2200 watts, enough to run any heavy corded drill or other shop tool.

The UPS only outputs 120V power, NOT 240V power. I do not have any 240V appliances (such as an electric oven or water heater) in the garage or the house. The garage only has two circuits, and both of those are on the same "leg" as the UPS.

If I wanted to run power to the house from the garage. I would turn off the main power to the house from the grid, and turn the circuit breaker (100 amp, 240V) from the garage to the house back on. It is illegal and dangerous to provide power to your house with it connected to the grid when grid power is down. Solar "grid-tie" connections have "anti-islanding" features, and generators use an "automatic transfer switch" to disconnect a residence from the power grid during a blackout. This manual system could be upgraded in the future with an automatic transfer switch or an appropriately designed system of relays.

So far, I have tested the system many times, both charging the motorcycle with the UPS and running my entire garage on just battery power. I haven't yet optimized my house circuits to put all the critical circuits (furnace, well pump, refridgerator, main living space lights) onto just one power leg, but we haven't had any blackouts yet either!

An IDEAL Poorman's Smart Grid would also have PV (photovoltaic) solar panels, a solar charge controller, an AC grid-tie, and device to switch from charging the 48V batteries, to running power back into the grid when the batteries are fully charged. 48V is a common voltage for many solar panels and solar charge controllers. With an electric vehicle connected to a garage power hub, the solar panels will charge the batteries, and the UPS will be available for household power backup. All of this could be done for only several hundred dollars in off-the-shelf parts.

PS: For more on this, I did produce an Instructable just on this aspect of the project
Poor-Man's Smart-Grid

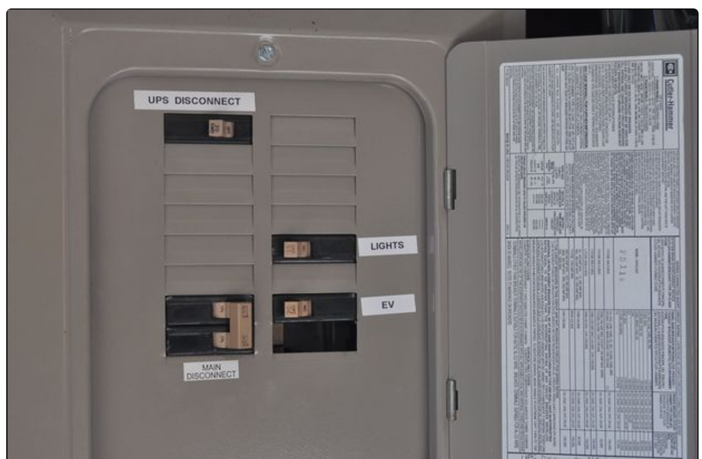
my garage circuit breaker box. (The garage is separate from the house and has its own dedicated 100-amp, 240V breaker panel.) Connected to that circuit, I added what would become a power "inlet".

https://www.youtube.com/watch?v=-ydKipDPgQE

1. 2200 watt, 48VDC to 120AC UPS battery backup. Typically used for back up of computer servers.
2. 4 small 12V batteries would normally be installed inside the UPS. Instead, four much larger batteries are installed in the motorcycle.
3. Indicator shows if batteries are charging, level of charge, and whether or not the UPS is in charge mode or making AC power.
4. UPS bolts right into a salvaged computer server rack.

1. 15-amp outlets.
2. 20-amp outlets. The cord from the UPS to the wall connects to a 20-amp outlet to carry maximum power.

1. Yea! A place to charge my EV! Makes it look more official!

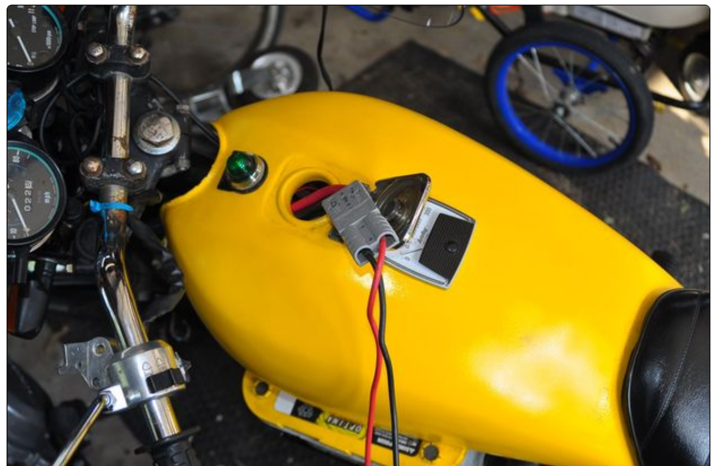


1. 20-amp circuit braker for connection to the UPS.
2. Circuit dedicated for electric vehicle charging.
3. Garage circuit for the lights and the 15-amp electric outlets.
4. Mains breaker - connects or disconnects to the house to take my garage "off-grid".
5. Just below here, details are written on what each circuit does, including special notes on the UPS power inlet.

1. Dedicated connection for the UPS blackout protection circuit. It's a locking connector and can't be confused for a standard electric outlet.
2. 20-amp GFI-protected outlet for electric vehicle charging.

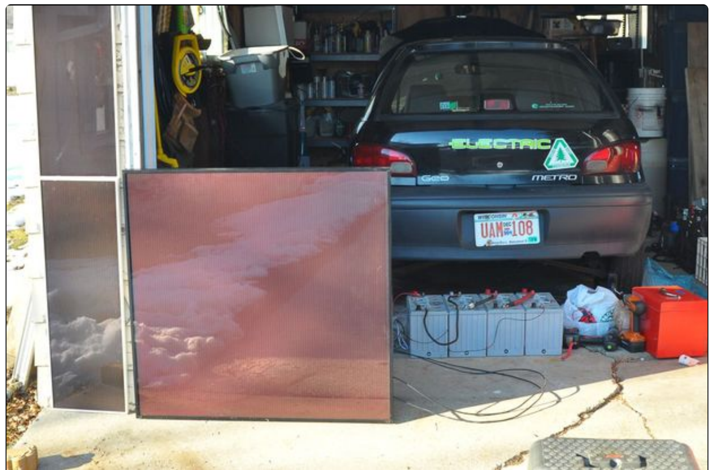
1. Custom cable built to connect the UPS to the breaker box.
2. 20-amp plug goes to back of the UPS.
3. Twist-lock connector plugs into the wall to connect to the breaker box.

1. This plug originally went to the four batteries internal to the UPS.
2. I added a plug to match the Anderson disconnect on the motorcycle.
3. This is nothing more than an extension cord to connect the UPS to the motorcycle. It's about ten feet long and made from very thick cable.



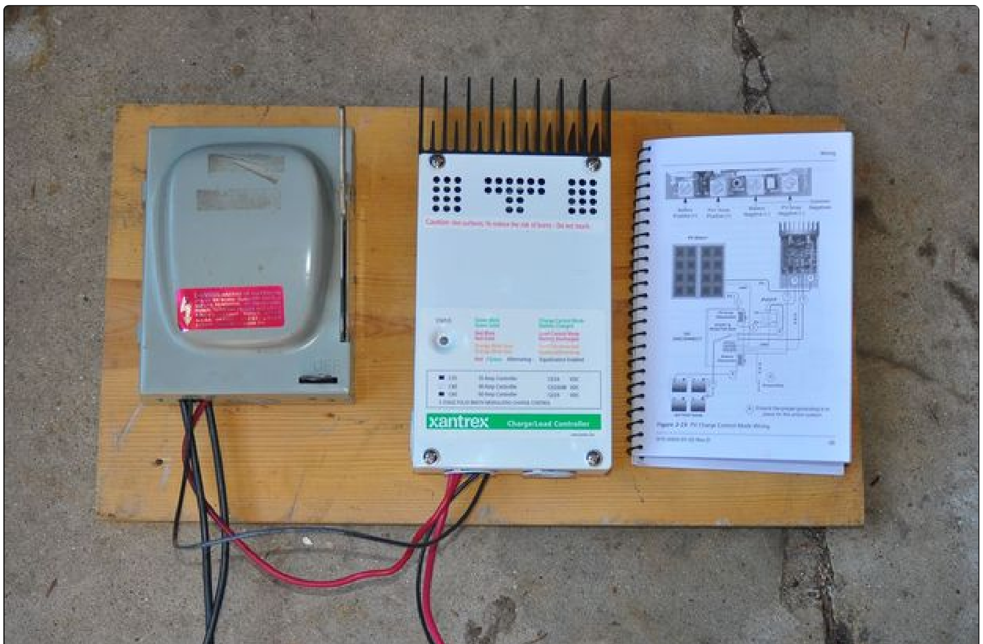
1. An Anderson plug connects the motorcycle's batteries to the UPS.

1. A typical cheap inverter plugs into a car's 12V accessory jack.
2. A cheap inverter only creates "Square-Wave" AC power, not good for computers, electronics, and some appliances. It can only provide a peak of 300 watts. The big UPS for the Poorman's Smart Grid provides up to 2200 watts with a better AC waveform than what I get from the power company.



1. This is a 48V nominal PV solar panel. Several of these mounted on the roof of the garage could charge an electric motorcycle or the electric car you see behind it.
2. These four batteries are connected in series for 48V and are being charged by the solar panel to the left of it.
3. An electric vehicle is really just a battery bank with wheels!

1. This Xantrex C-40 can run 12, 24, or 48V solar charging systems. On a sunny day, it would become the charger for the 48V motorcycle.
2. This device can operate in several modes, including one as a "dump charge". Once the batteries are fully charged, the load controller instead sends the power to another source, typically a heater of some sort to waste the electricity. If it was instead routed to a grid-tie inverter, the solar power would either reduce your electric bill or or send your solar power out to your neighborhood.



1. Power disconnect switch
2. Charge controller temporarily set up to test various configurations.
3. The manual shows how to use the device to charge batteries with solar power OR reroute power to another source when the batteries are full.

Step 16: Now You Make One!

Ok, I showed you what I made!
Now YOU build one! Make sure you post some photos when you are done.

If you want a high-speed, long-range vehicle, everything I've talked about here still applies, but you will need to use lithium batteries, which will add considerably to the budget. That said, they are fantastic, and lithium cycles are an absolute BLAST to ride!

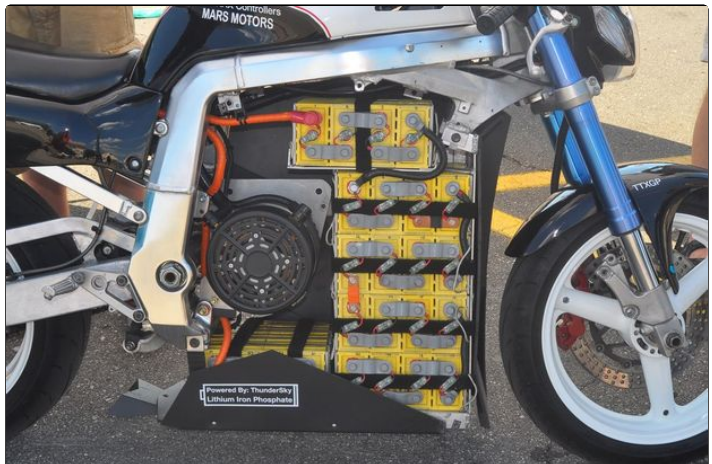
If you have any questions about my project, please leave a question or comment below, or swing by my clean transportation blog.

For even more inspiration, take a look at these photos of electric motorcycles built by my friends.

You can read more about the lithium cycle shown here at Tony's blog. For information on Russ' no-budget DIY cycle, please visit his web page.
For more on my electric motorcycle and other projects, including ordering the BUILD YOUR OWN ELECTRIC MOTORCYCLE instructional video DVD, please visit 300MPG.org

//www.youtube.com/embed/DzZ0gvJbm4s?rel=0

1. Tony's 72V lithium race cycle
2. My 48V Lead-Acid motorcycle.



1. Lithium batteries. Sure, they are expensive, but man are they fun!
2. This Mars brand permanent magnet motor is designed to run at up to 72V.

1. Tony shows off his cycle at a local EV club meeting.

1. Dave's 48V Goldwing.

1. 48V Goldwing

1. Tom's electric Harley-Davidson roadster, the SPARKSTER!
2. My electric motorcycle.
3. Retro, 1970's electric Citicar. 100% street-legal. Plastic body and aluminum roll-cage frame.
4. My home-built electric Geo Metro.
5. Experienced Harley rider checks out this electric motorcycle.

1. 60V Harley electric motorcycle.

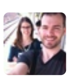
1. This low-budget electric trike is built with parts from a motorcycle, ATV, and forklift.
2. Series-wound electric forklift motor and custom motor-mount
3. Curtis brand PWM DC motor controller.
4. Driven sprocket is on the other side of the back wheel.
5. Trike design not only looks cool, but also gives a bigger frame to more easily add more batteries.
6. Trike design not only looks cool, but also gives a bigger frame to more easily add more batteries.

1. My 1981 Kawasaki KZ440, converted to electric.
2. Another guy's electric motorcycle. It's the same make, model, and year as mine. He built it in about a week after seeing my motorcycle.

1. Chris' Steel Wheels is a work in progress. Part electric motorcycle, part art metals class project.

1. Showing where the rear fender will go. This motorcycle is powered with a driveshaft, instead of a chain.
2. Showing where the rear fender will go. This motorcycle is powered with a driveshaft, instead of a chain.

1. Russ on his ultra-low budget forklift motorcycle "Volt-Zilla".



Ben your instructable was a huge help to me in figuring out my own electric motorcycle conversion project, so thanks for sharing! I thought you might be interested to see the instructable I just posted for my project: https://www.instructables.com/id/Engineer-Your-Own-...

if your converting a bike with or without a title it might be better or required to get a specially constructed vehicle title.

"Any vehicle that is built for private use from various parts of different makes and models, and has not been constructed by a licensed manufacturer, is considered to be a specially constructed vehicle."

"A motorcycle constructed from various parts.

Even if all the parts used are from a Honda motorcycle, it will need a specially constructed vehicle title because the vehicle was not assembled by the original manufacturer.
"

I would love to do this and getting a untitled donor cycle is the cheapest route especially if it doesn't run. but getting the original title is considered a hassle and a half. this is another option to that. I'm not sure on difficulty or cost as of yet. but its possible for those who cannot get one on the standard route. you will get a new vin and everything.

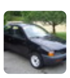
source:

https://www.dmv.org/buy-sell/new-cars/specially-co...

The VERY FIRST thing you want to do with your project is to make sure you will be able to legally ride it when you are done!
Check with your local laws and requirements, and make sure to comply with them. These rules vary quite a bit from state to state and country to country.

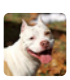
Hey all, Great instructable Ben!

I am wondering if anybody knows a reputable place and possibly a wholesaler that sells lithium batteries? or if other batteries are better than AGM lead acid batteries? that wont cost an arm and a leg :)



I haven't ever ordered lithium batteries, but the prices are continuing to fall. Another advantage of an electric motorcycle is that the battery pack is smaller than an electric car. So, if you DO want to pop for lithium batteries, it's always going to be more affordable than a car.

The Electric Auto Association is also a good place to start for general info, including some vendor links.
http://www.electricauto.org/?page=EVinfo



Hey bennelson, great job on the bike and car conversion. About the batteries, you could always use batteries pulled from laptop battery packs and build your own pack. this guy on jalopnick or something, converted an old vw combi into an EV, running on salvaged lithium batteries for old laptop battery packs. Maybe another instructable for another day perhaps??

Great DIY ever. I love it

I've finished an EV bike of my own, however, I cannot find a drive sprocket and no guide talks about what sprocket they used. I am running an eTek motor with a 7/8" output shaft and a 3/16" keyway on a 520 chain, likely a common setup... what sprocket did you use? Where did you get it? My project is sitting in the garage until I find one :(

Which will give more efficiency.. Series connection or parallel connection?

It's not really that one or the other - series or parallel - connections are more efficient than each other. In series connections, voltage increases. In parallel connections, current or capacity increases. However, with DC motors, speed is proportional to voltage. Therefore, connecting your batteries in series is the preferred way to go. You get a higher voltage, thus higher top speed from your motor. Also, higher voltage means lower current draw for the same amount of power. Lower current means that you can use thinner cabling, which is less expensive, easier to work with, and saves weight.

I'm living in an hilly area. So will a 36 volt help me.. And will it charge my battery when going down hill..

The motor wont natively charge as you ride down hill. In some cases you can use a second motor to charge batteries, but it's easier to do with an alternator of some sort. Either way, though, you need a way for the whole unit to only engage when you when you are going downhill; if you don't you'll be using your drive output from the batteries to turn it. 36v may work for you, but it may not. with a hilly area you want something that is going to put out a reasonably high amount of torque (you can play with this a little bit with the ratio of your drive sprocket to wheel sprocket). Some motors (like those used in off-road winches) are super high torque, and don't spin very fast, but they only require 12v to go. Others are relatively low torque, but relatively high horsepower (which directly affects top speed) and can be 24v-72v or more. With one from a winch you could, in theory, use a gigantic drive sprocket and a tiny wheel sprocket to compensate for the slow speed of the motor. It depends on how in depth you really want to get with this build. I recommend researching the physics involved and figuring out what requirements you will need to deal with your hills and then comparing with the specs of different motors on the market.

Thank you somuch mr.bennelson for your keen support for youngsters, who try to live without pollute our environment.

Wow this is one of the best electric bike tutorials I've found! Thanks for putting so much detail, definitly helps a lot!

Looks amazing . I am trying to learn more about diagnosing issues I am having with my electric DIY cargo bike build. Should the three phase wires running from the controller to the hub carry full voltage under WOT? I am running a 48V system with a brushless direct drive rear BMC hub. Reading 54V under a full charge 15 ah battery. Reading 11.88 V at each phase wire, not changing under throttle movement.

Appreciate it !!

Great Build and info! I have a DIY cargo bicycle that I am trying to diagnose a failure on. If I run a 48 V system producing 54 V under a full charge should I see that on the three phase wires coming from the controller running to the brush-less direct drive rear hub as you twist the throttle? Appreciate your time !

Donny

Where I live (NL) scratchbuilding anything to drive is illegal, unless you have a company that specialises in it, plus you need to give the government at least 3 models for crashtesting and safetytesting and you will have to pay for getting them recycled and/or scrapped and transport and for the testing itself, plus however many more they require but never more than 12. Motorcycle tests are fewer so maybe you can get away with only 2 or so but they will be wrecked. They will run them into crastest dummies to test pedestrianfriendlynes in case of accident and rate it accordingly. So if your homebuilt cycle fails you are done for.

Putting batteries on something also will open you up for testing for leaks and accidents, so likely crashtest to test what happens with the battery if it hits a truck.

is there a way for batteries of higher voltage to be used on a motor of lesser voltage where the motor will only take its recommend amount. This question is based on long distance travel where highway and city driving are necessary,

This is my first time on this post. I read a lot of the posts and a lot of interesting info. I have built a couple of Electric KTM dirt bikes, and am now building a Yamaha Steeel frame electric with a gearbox. A lot of the questions that every posted are good, and I have worked thru most of them. My KTM is a 2008 250SX-Fframs and running gear, a Motoenergy ME1004 48V 200-400A motor. I have been using the Kelly controller. I bought over what I needed 72V 500AMP with Regen. I am using a Magura 5k throttle and it works fine. My batteries are CALB 40AH x 16 cells to give me 48V 40AH (about a 2KW battery pack)

I get 6 hot laps on the motocross track or 15 miles on the street, I was able to make it street legal in California since it was converted to electric. I did not modify the frame so I could put the motor back on, but I love the electric aspect of the bike.

It is on EV Albums " 2008 KTM Electric" under Motorcycles

To answer a few questions , the Kelly controller has been very reliable, and the Regen Braking turns the motor into a Generator, which works great on this bike. At a motocross track you rely on engine braking, with electric you don't have any, regen braking is the answer and you can program in as much in as you want, or you can vary it with a rheostat

The bike has been very reliable , and a lot of fun . It is neat have and play with it. It is encouraging to see all the people on here interested in electric build of there own

Dcoxryton

Would it work if I put it all in a mini moto ??

I just recently saw a Trail Buddy converted to electric. It was really cute, and an all the electric components were really well packaged. I didn't see it on their home page, but it was built by these guys. http://www.trail-buddy.com/home.html

You can pretty much build any size electric motorcycle you want, However:
1) If you build it really big, you will need a very powerful motor and high capacity battery pack.
2) If it's a very SMALL motorcycle, you will have very limited room in the frame for all the components, and will only be able to fit smaller batteries.

A mini motorcycle sounds like a lot of fun. You could probably get away with using the style of lithium batteries used by high-end RC Car enthusiasts.

I recently obtained an old 1950s Harley Davidson frame from a friends junkyard. It does not have a VIN# because this was from a time before they put VIN#'s on frames. The odd thing about it, is the DRF XXXXX number on it. Does this mean it was stolen? Will I ever be able to register this old of a motorcycle frame before I start building on it?

Thanks for any help.

Depending on your state laws you will probably be able build it as a new custom. My suggestion is to sell that frame to a collector and buy a complete bike with a blown motor. Old Harley frames are heavy and parts are expensive.

I think the last sentence you said kind of sealed the deal for me.
Looks like I'll need to find a Collector!

Thanks again
-TM

I've built a 72 volt version from a Suzuki 600 Katana. weights about 500 pounds.

This was built in about 1 week give or take a few days. the current picture is Version 3. the first version was a 48 volt 75 Ah system. Version 2 was 72 Volt 75 Ah version, but the final version was 72 volt 101 Ah version. current version gets between 30-40 miles per charge depending on driving conditions. only an estimate since it is only 22 miles to work @ 50 mph and i recharge it everyday at work, so i never really never had a chance to kill the batteries that much.

This version has a dual laptop battery pack for the light and a 72 volt battery pack for the Drive motor. all lights are custom built L.E.D. lighting that i made my self from 12 5050 L.E.D. strips.

This version uses about 50- to 65 amps at 50 mph.

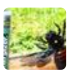



I like your electric scooter selling service..
http://www.billelectricscooter.com/

great

First of all, thank you for putting so much time into such an awesome instructable! This is really helpful. Secondly, I have a question. I'm looking at doing this for a 2001 Yamaha R1. It's perfect as the engine is in good nick and the transmission is busted, but I'm wondering if it's too heavy for the electric motor you used. I'm new to EL motors and trying to make a go of it with this project. What do you think? Could it work?

Cheers!



Hi!
Put in few words, with same motor and more amps-hour (more energy stored), go farther.
Readequate motor (to get more power - more watts), more amps-hour, more speed depending on gearing. Same range. It's not so simple, you have to equate all variables for your goal.
Usually motors with higher voltage can develop more power.
Of course the correct is that you have a target power, say 750W (~1 HP), for sake of simplicity: 75V x 10A to feed the beast. Or, 32,5V x 20A. Or 150V x 5A. And it goes on. Higher voltage also allows thinner wiring (to hold less current)if you manage to have a motor that runs this figures at 12V, you would need to provide 62.5 Amps. Imagine the wiring for this now. Research motors, batteries, weight, your goals and spreadsheet it to find your personal solutions having in mind what you want. :)

Wow what A dream bike..
I want to build my own like yours.
does it become a 96v18ah battery if i connect two 48v9ah batteries?
This is what I found on alibaba website

http://www.ebike-bmsbattery.com.cn/product/690588130-215068276/e_bike_48v_lithium_ion_battery_ups_battery_48v_lithium_ion_battery.html
Lifepo4 48v9ah E Bike Battery,e-bike battery,ebike battery
Item No. Voltage Capacity battery type Lifespan
BMS
Option
Charger
Option
Dimensions Weight
G-BP4809A 48v 9ah lifepo4
>2000
cycles
15Amps 3Amps 69*148*360mm 4.9kgs

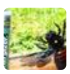
48v 9ah electric bike li ion battery Characteristics
a. Very Security: No fire,no explosion,no leakage ;
b. Portable handle and hidden charging port;
c. Aluminium alloy Back rack(Silver and Black for option);

d. Well die-casting slide board and lock, for easy installation and theft-prevention.
c. 30A Fuse and smart BMS are included for protection

Pictures and detaild data sheet

Model G-BP4809A
Norminal voltage 48V
Rated capacity 9Ah @0.5 C3A, 20°C
Operating current 15Amps(can be customized)
Peak current 30Amps(can be customized)
Charge voltage 58.4V
Standard charge current 3Amps
Cycle life >2000times
Dimensions 69*148*360mm
Weight 4.9kg
Battery box material aluminium alloy
Built in battery cells 3.2V 9AH polymer lifepo4 cells
Assembly 16 cells in series
Operating temperature - 20 °C to 60 °C
Charge temperature 0 °C to 45 °C

it weights about 12 pounds.
What do you think? No one can answer my question.



Hi.

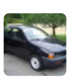
Batteries Voltage adds up when in series, but current does not. If you put 2 batteries in parallel, you will get same voltage but will add the current. This is very very basic electricity.

To achieve your 96/18 figures you need 4 batteries, putting 2 pairs of 48/9 parallel batteries in series. I mean take a pair and mount in parallel - call it now pack 'A'. You now have a 48/18 pack. Then take 2 of this packs 'A' and put in series then you have your 96/18.

Best regards

Lissandro

Thanks. Sorry for bothering you but if you dont mind i ould like to ask you one more question. Would my bike run faster and run farther if only current(AMPS) goes up? I think there is extra space for a pair. in that case a pair becomes 48v/18ah?



No, current has nothing to do with range or speed. On a DC system, speed is determined by voltage and gearing. RANGE is primarily through battery CAPACITY, which is measured in AH - amp-hours. Being able to draw more current can get you to your top speed quicker (better acceleration) but won't change the top speed.

If you add additional batteries in parallel, this will increase the capacity of the pack, and give you better range. Current is only related to range in that batteries will give you less total range at high current than low current. Also, if batteries are the limiting factor in how much current you can draw, adding more in parallel will allow you to draw more current.

Remember that current (measured in amps/ampres/A) is flow, it is a RATE of power use. Amp-Hours (AH) is a measure of capacity.

Questions:

1. Why a drive between the motor and the wheel? Why not have the motor in the wheel hub? Wouldn't this be more efficient?

2. Do you still use a gearbox? If so, why? Cant you use direct acceleration?

3. Why have a braking system, once the vehicle is stationary, wont it only move if you apply power?

4. Could you use this same system to make an electric cruiser?

5. Where can i get an high efficient high speed motor?

Hi Alexander!

Answers:
1: Chaining the motor to the back wheel allows for both adjustable gearing (by changing the sprockets) and for placing the motor where I would like it. Hub motors of the right power ARE now available for motorcycles, but have not always been the best thing for high top speed. Direct drive also doesn't usually give you the same "oooomf!" that you can get with a chain drive. Also, a hub motor increases "unsprung" weight, which isn't as good for handling. My project as of spring 2015 is a Vectrix, which DOES use a rear hub motor, but it also has planetary gearing to overcome some of the limitations of hub motors.
(http://300mpg.org/2015/03/02/vectrix-maiden-voyage/)

2: Please see step 11. https://www.instructables.com/id/Build-Your-Own-ELE... It clearly shows that there is no transmission. The motor is chained to the rear sprocket. Yes, it is more efficient than with a transmission, there's fewer moving parts, it also saves space!

3: Brakes! Yes, of course I have brakes! The cycle came with brakes, I did not change them. Why would I want to remove the brakes! Yes, once at a stop, the cycle doesn't move, unless on a hill. Brakes are most important when you are moving and want to slow down! The vehicle doesn't have "regenerative braking" or any special system other than the stock regular motorcycle brakes.

4: Yes, you could build an electric motorcycle similar to the say I did, but build it as a standard, a cruiser, a sport bike, a scooter, or whatever style of motorcycle you like. Sport bikes are popular for conversions because of their light-weight aluminum frames.

5: There are many mail order companies on the web that sell electric vehicle parts. Just do a web search for them. The Electric Auto Association also has some nice links on their web page. http://www.electricauto.org/?page=EVsForSale Scroll about half way down on that page to "EV Converters, repairs, & kit or component suppliers", you can order parts, including motors from those places.

Dear Ben,

I have a 1972 honda dirt/trail bike whose engine seems to me not worth restoring, and I have toiling with the idea to convert to electric for the longest time, refreshing my parts wishlist from time to time.

At last I've seen the Enertrac 18" hubmotor, and its the ideal motor in my opionion. However, as with any electric application, battery technology seems to let us down in various combinations of cost, weight, size, and amperage (cost in particular).

I have seen your batteries on your Kawa and its damn huge (and heavy). I am thinking of using LiPO batteries from hobbyking (those used in large scale electric RC) - just need your two cents on this opion.

Tks,

Aszman.

Hi ErfanA1,

Yes, you are right, lead-acid batteries ARE heavy. In fact, right now, I'm upgrading my Kawasaki to NiMH batteries I got out of an old Ford Escape Hybrid! (Nickel is still heavy, but it's better, and the salvage yard price was GREAT!)

Hub motors are becoming practical for EV motorcycles, and have already been used on many EV Scooters.

Lithium batteries are great. You might want to see about going on the Endless Sphere web forum. Those guys are into electric bicycles, but have GREAT knowledge to share about using small lithium batteries.

Good Luck!

SUH-WEEEET-AH!!!

So 'ok...you've got the info I needed and explained clearly...more clearly /less cluttered than most other related instructables! Now can you answer me this...the wires coming from the controller to the throttle.....could an arduino replace the throttle? this would be for remote or programmed motor "control" ie: instead of a human hand turning a physical throttle...an arduino sending signals to the controller as though it (arduino) IS the throttle...? make sense?...others have jumped all over me for this...but I think the 2 wires can act as the potentiometer..? yeah?

On my motorcycle setup, the throttle is a 0-5Kohm twist potentiometer. To replace this style throttle with an Arduino, you would need the Arduino to be able to create a variable resistance in that range. I haven't played around with Arduinos very much at all and would have no idea how to do that, but I'm sure somebody could figure it out.

There are also motor controllers that use a variable voltage of 0-5 volts as their input. Voltage can be varied by PWM, and I know that can be done by Arduinos. So, it may be an easier approach to use a controller with that style input.

Due to safety considerations, I would NOT create any kind of "experimental" throttle for an on-road vehicle, but if it is for some sort of stationary machinery, just follow typical safety precautions and have fun!

YES!! thats the numbers I was lookin' for!!! I'm just starting arduino as well but, if I'm not mistaken 5v is exactly what the arduino needs /handles.

I'm sure a resistor or two would make it a little safer I think? arduino pros?

the applications of this could be for giant remote control cars, a stationary sculpture...anything an arduino could influence via...PIR sensors..bluetooth phone remote control...timers etc.

Much Thanks Bennelson!!

I have lots of bikes but I have this 74 cb 360,I took this cbr 600 that I had ,it was from a police chase and it was never picked up from the cops after its rider got away after it slide own on a golf course so I got it after it sat at the tow company for a couple of years..never could get a title for it so I sold its engine and took off its rear swing arm and front forks which bolt directly ODDLY to the

74 cb..I welded on the rear swing arm to make this cafe bike....but Id like to convert it to electric since I have 3 more bikes including the 75 cb 550....which will be cafe also but still a gas burner..I want an electric motor that goes faster than 45 mph..any suggestions?Im going to run lithium batteries Im thinking.

For high speed/performance, it's best to go with the highest voltage motor you can. 72V is pretty popular for a fun lithium bike. Motenergy has some good motors. Check them out.
http://www.motenergy.com/

Can you use the existing transmission system of the bike??

On most motorcycles, the engine and transmission are really a single, integrated unit. It's very difficult to remove the engine, but keep the transmission. You CAN build an electric motorcycle with a transmission, but the tranny takes up space that might better be used by having more batteries.

What a transmission in general really does is convert engine speed into torque. Electric motors tend to have HIGH torque at LOW speeds, so you don't neccessarily need a transmission.

For a commercially-built EV cycle WITH a transmission, take a look at the Brammo Empulse.