"Lithium Lounger" Electric-Human Hybrid Conversion Details

The process started after I test-drove nearly all of the available 2 and 3-wheeled recumbent bicycles at the Hostel Shoppe in Steven's Point, Wisconsin. The best combination of precise and stable handling, extreme comfort, low weight and wind drag, and speed I could find at the time was the 2006 Catrike "Road". The other factors considered, since I wanted a machine capable of commuting and long-distance touring over rough and steep roads were:

a) A fairly upright (35-45°) seat angle for better visibility and head comfort over bumps
b) Easily found and uniform tire size, available in wider widths for gravel, but at the higher pressure needed to reduce rolling resistance on smooth roads

The Catrike Road's base price was $2250, but the same shop now (2008) sells 3 comparable trikes at a lower cost. These are the Catrike "Trail" at $1750, and the Terratrike "Zoomer" at $1799 or "Zoomer Elite" at $2199.

The selection of the electric motor took a lot of web research and, eventually, a number of very technical phone calls with Dave, the engineer, at ElectricRider.com (also known as EV Depot in Lawrence, Kansas). They had a fair number of possible motor set-ups, but after owning a Zap tire-drive unit, and after seeing the Currie chain-and-sprocket drive, I set my sights on a hub motor. The side-loaded front hubs on the trike made rear wheel drive the easiest choice. And looking at the various power outputs, the speed/acceleration curves, and the choice of a cheaper, more simply controlled, "brushed" DC motor or the more costly, but more efficient and maintenance-free "brushless" 3-phase motor, I finally came to a decision.

I was trying to climb extreme hills on rough surfaces at a reasonable speed, yet I wanted good cruising speed on flat smooth roads. The Crystalyte 'Phoenix" series hub motor is available in 3 windings:

a) The "Brute" for maximum hill-climbing torque at lower speeds
b) The "Racer" for the opposite traits, and
c) The "Cruise" as a compromise between the two

Since the Phoenix uses a 40-amp controller at either 36, 48, or 72 volts, any of these controllers would provide plenty of horsepower. But since I wanted to use the 36-volt lithium batteries from DeWalt (more on these later) and power a 20-inch wheel, this already limited my speed. The 72-volt option, running the DeWalt batteries in series, would yield nearly highway speeds, but range would suffer unless I used lots of batteries, and I didn't want to go THAT fast. I settled on the Racer, controlled at 36 volts, giving me loads of hill torque and a top speed, without pedaling, of 24 mph.

Fitting the pre-built hub-motor-wheel to the trike was the next challenge. First, hub motors all rotate a wheel by twisting against the axle. This either requires some massive axle lock-nuts, a steel frame to keep the drop-outs from spreading open, a torque arm (as used on coaster brakes) to spread the torque out into the frame, or some combination of all three. Since the trike had an aluminum frame, I first bought some thick stainless steel "star" washers. Then I ordered EV Depot's "R2" torque arm, made for front wheel motors and forks. I simply added a piece of strap steel to mate their part to the frame angles I had in the rear.

Next, the hub motor's axle was a tiny bit thicker than the space in my drop-outs. So I pulled out a chainsaw file and a micrometer to remove a little bit of aluminum from both sides of each drop-out, making sure that the stock wheel was still a snug fit, just in case I wanted to switch back. Then I found that the 135mm width of the hub motor axle was 5mm wider than the Catrike's width. So, using some 3/8-inch threaded rod along with washers and nuts, I made a crude but secure frame-spreader. While this isn't normally recommended on aluminum frames, the combination of unyielding stiffness in the Catrike's oversized tubes and my inability to spread the frame by hand made it necessary. Most frames would just bend open further or be made a tiny bit wider, but not this one! I found that by widening the opening to 155mm, the width when I relieved the pressure was 135mm. Whew! I got the wheel in and snugged down with the washers, and the torque arm strapped to the frame tube.

Mounting the batteries on the trike presented more challenges:

a) The batteries had to be accessible but still "out of the way"
b) The wheel-to-battery connection should be as short as possible to limit electrical resistance and unnecessary cable clutter
c) Limiting EMF exposure for the rider was important, and
d) Battery weight had to be either minimized, used to best effect for traction, or spread out more evenly over the entire wheelbase

The battery research I had done indicated that nothing available at the time could outperform DeWalt's 36-volt lithium nanophosphate batteries, made using A123 System's cells, developed at M.I.T. The reasons were:

a) Highest energy density (watt-hours/weight)
b) Highest power output (up to 60 amps per battery, more if wired in parallel)
c) Best safety (no fires, explosions, toxic leakage, or other hazards)
d) Life expectancy (highest "cycle-life")
e) Charge-state insensitivity (run it "dead", charge it much later if necessary), and
f) Warranty (3 years!)

I found them on E-Bay for under $115 each, <u>far</u> under retail price. Since the DeWalt, 1 horsepower, cordless drill draws about 23 amps from this battery, I figured that 2 would be sufficient to power the 40-amp controller. But after some e-mail discussions with other electric bike enthusiasts, I bought 4 batteries, wired in parallel. This reduces the load on each battery and increases "range" to 300 watt-hours. So after spending about $3680 (stock trike = $2250, tax and trike upgrades = $250, hub motor wheel kit = $720, and batteries = $460) I still needed to mount the batteries <u>on</u> something.

The 4 batteries weigh 10 pounds. I figured that adding this to the hub-motor-wheel weight of 20 pounds would provide plenty of traction on the rear driving wheel. So I bought a pair of $10, powder-coated, steel baskets made to fit a pre-fab shelf system. I mounted these on either side of the Old Man Mountain "Sherpa" rack that fits the trike. I then did a bit of custom fabrication in wood, aluminum, plastic, and copper to come up with battery bays that would hold all of the "electricals" and nicely fit the baskets. The holders bolt to the baskets, lock the batteries in place yet allow easy removal, and hold the controller and an extra water bottle. After wiring in the included keyswitch and 50-amp fuse, the stock controller cables were shortened considerably by cutting, soldering, and "shrink-tubing" them.

I still needed some way to cover all of the electrical parts. On the first trike I converted, for my wife Larisa, I simply fitted a rain cover made from a discarded yellow vinyl raincoat. On the second trike I got more creative. We were charging the trikes from the same PV (photovoltaic, solar) panels that supply our home's electricity. By using series/parallel switching, I could choose to tap power from all of the panels at 12 volts for the house, 3 of the panels at 36 volts to charge the lead-acid batteries in our electric garden tractor, or 2 panels at 24 volts for the trikes and electric mower. To charge from the house PVs, I switch two of the panels into series, sending “24 volts” to the bike shed. I then unplug the battery to controller connection on the trike and plug in the supply cord from the PVs. I then turn on the trike’s keyswitch and a breaker on the wall. That’s it! An ammeter and voltmeter on the breaker box show the progress of the charging. Wait, you say, how does 24 volts of PV charge 36-volt batteries?

Nominal 12-volt, multi-crystal PV panels actually have an “open-circuit” voltage of around 20 volts. Two of them wired in series yield 40 volts. The current they’ll provide using two 120-watt panels tops out at about 7.1 amps, dropping to nearly zero amps at 40 volts. Since the recommended maximum charge voltage for the DeWalt batteries is 38 volts and the maximum allowable is 42 volts, the match is nearly perfect without having to use any sort of charge control. This method, in miniature, sounded like an easy, lightweight, safe way to make the trike self-fueling while on the road.

While browsing the vendor booths at the Midwest Renewable Energy and Sustainable Living Fair in Custer, Wisconsin, I found some multi-crystal, 24-volt PV panels made by Innovative Energy Solutions. They had thick stainless steel backs, thick plastic top sheets, and each supplied 10 watts. I bought two, adding another $150 to the project. Mounting them within some thin aluminum angle and square stock, they are “zip-tied” (plastic cable ties) to the top of the bike rack. Wired in parallel, they supply power directly to the batteries through a small diode mounted in their output cable. When the sun shines I’m charging. When it rains the electronics stay dry.

To finish things off, mounting the grip controls is pretty straightforward if you’ve done much bicycle remodeling. The only dissatisfying remnant was the gearing. The stock trike wheel had 9 speeds and an 11-tooth “high” gear. The stock freewheel from EV Depot was a cheap 14-28T Shimano. A web search uncovered a new Shimano Hyperglide freewheel called the “MegaRange”. As a 7-speed, it was available as an 11-34 tooth for under $30. Again I bought two, one for each trike. I thought that running a 7-speed cluster with a 9-spped SRAM derailleur would cause problems, but in actual use it rarely chatters or jumps gears. And with the electric drive I don’t shift as much anyway. I usually just pick a gear for the flats, jump from middle to big chainring on the crankset for downhills, and use the electric motor for an uphill boost, locking in the cruise control when my thumb gets tired.

So the true total cost for this project, discounting any sundries like wire, solder, zip ties, or other stuff I had lying around, was $3680 + $150 + $30 = $3860. That’s pretty pricey when compared to the $5500 (+ new tires) that we spent for our recycled, scrapyard Prius. But this buggy burns no gas, is fueled by the sun, and handles like a fancy sports car. In every way it’s just more fun to drive, and I think it was a great, future-proof investment!