Engineer shares how to build an electric vehicle from the ground up: Design choices

Steve Taranovich - July 06, 2011

Editor's note: In part 1 of this two-part series, we look at the core technology and design choices behind this electric vehicle. In part 2, we will discuss some mechanical and structural challenges and solutions, the specifications, road test results, and what will be next in improvements for this amazing HEV effort.

Electric vehicles (EV) and hybrid electric vehicles (HEV) are advancing rapidly. We see a parade of solutions including the Toyota Prius (the number-one-selling hybrid), Ford Fusion with 41-mpg city mileage, Chevy Volt with 35-mile stretches of all-electric driving, and the Nissan Leaf as the first affordable, mainstream all-electric, five-passenger car.

Now let me introduce you to yet another EV---the 1988 Pontiac Fiero "donor car." OK, in truth, only the front suspension and steering gear were used from the Pontiac donor car that has grown into John J Santini's ground-up design.

Santini is the vice president of engineering at TDI Power in Hackettstown, NJ, a company that has been in the power conversion industry for more than 50 years and has been providing power equipment in mobile, hybrid, and electrical vehicle applications for more than 25 years. Frustrated by fast-rising gasoline prices, Santini decided to turn his creativity and problem-solving skills toward developing his own EV.

Learn more in this video interview:

The goal

While Santini's original goal was to build a plug-in hybrid vehicle, the fast-falling cost of lithium-ion (Li-ion) batteries spurred the decision toward the end of the project to postpone the engine/generator and to add some weight back in as additional lithium ion batteries. As a result, the current vehicle is all-electric, although the space remains to add an engine-generator in the future. Doing so will increase the cruising range of the vehicle well beyond the 90-mile range of the current system. The total vehicle weight, with batteries, is now 2,050 lbs.

The project
The project is a lightweight, two-seat commuter car. The frame is a space-frame design, inspired by the Locost project cars and similar construction vehicles. Some background: A Locost is an economical, home built "clubman" style sports car based on the concept of the original Lotus 7. You construct a Locost by following Ron Champion's book *Build Your Own Sports Car for as Little as £250 and Race It!*, Second edition, or Keith Tanner's book *How to Build a Cheap Sports Car*.

Part of the inspiration also came from a Cornell University EV built in 1975.

The body is a custom design, fitted around the frame, made of one-inch-thick Styrofoam covered with one to three layers of 0.009-inch-thick fiberglass cloth and epoxy. Technically, it's a three wheeler, as the rear wheel is a solid assembly with two tires and the drive pulley in the center. The belt drive is more than 99% efficient, while even a simple two-speed transmission would likely incur losses of up to 10%.

**Battery charger**

The battery charger comprises a pair of TDI Mercury 54V, 80A chargers, one for the lower 48V and one for the upper 48V pack, with 120/240V AC input, two in series with battery center-tap to keep the batteries balanced (Figure 1).

![Figure 1: TDI's Mercury battery charging converter. Two are used in series with battery center-tap.](image)

So at 4.3kW, the TDI Mercury battery chargers perform a typical bulk charge in less than one hour and there is plenty of time to soak up a full charge during the day. The original chargers were only 1.2kW Mercury units that charged at 30A. Charging used to take all day at work, as four hours were just needed to just "top off" the battery.
Santini has also added a new circuit that detects battery current greater than 60A and turns the brake lights on. The regenerative braking is turned up pretty high, so when you fully back off the gas pedal, the braking is pretty strong. Santini rarely uses the hydraulic brake system, so he has noticed some surprised drivers very close to his car's rear end!

Plans are afoot to lower this to 30A so the twin rear brake lights and rear window brake lights go on under most all regenerative braking conditions---this is merely a modification of the threshold to an on-board comparator. He has also converted his tail lights to LED to be fast-acting, brighter, and to use less energy (Figure 2).

![Figure 2: Fast-acting LED brake lights are bright and energy efficient.](image)

The mechanical braking system in this car should last beyond 150,000 miles because they are mostly used when at a stop sign or traffic light on an incline, after regenerative braking has taken effect, to stop any rolling.

**AC motor**

The AC motor from ABM is rated at 18.7 kW, almost as much power as the old GE motor Santini had in his Electric Corvette design back in 1975. It weighs only 165 lbs and with an 84V input, it will operate at constant torque up to around 3000 rpm and then constant horsepower (hp) up to 6000 rpm. The drive uses a single 62-mm wide gear belt with a single reduction of around 6.3:1 (Figure 3).
AC motor controller

The Curtis AC motor controller is a new model that works well with a 96V nominal battery pack. It has all the features needed for a complete vehicle controller, including regenerative braking. It is rated at 60 kW (80 hp) with this battery/motor combination. The finned heat sink has ducted air through it from the body-side air intake in this all-air cooled vehicle. See Figure 4.
Continue reading: Lead-acid vs lithium-ion batteries

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About the Author

Stephen Taranovich has 40 years of experience in the electronics industry. He received his MSEE from Polytechnic University, Brooklyn, NY, and his BEEE from New York University, Bronx, NY. Steve is also chairman of the Educational Activities Committee for IEEE Long Island.