

Lightning Motorcycles deliver a smooth 'magical feeling' even at 215mph!

Innovative modular power system design delivers an unequalled riding experience

"After the first ride I took on Skyline Drive in Woodside, Calif, I became convinced that electric motorcycles should be a business. The bike gives you a feeling of limitless torque with no vibration, no noise and no heat – there is almost a magical feeling to it."

That was the experience of Richard Hatfield, founder and CEO of Lightning Motorcycles Corp., which holds the land speed record for electric motorcycles: over 215mph. The San Carlos, California company was founded in 2007, just a few streets over from another electric vehicle pioneer – Tesla. San Carlos at that time was ground zero for electric vehicle development and collaboration.

Lightning strikes and breaks land speed record

Having cut his teeth on EVs in the late 1990s helping develop an electric Porsche for a U.S. race series, Hatfield, a lifelong motorcyclist, set his sights on creating a motorcycle that leverages the same technology. In the early days, lithium batteries were a scarce luxury item, but by 2005 he was able to source some of the



Figure 2 Minimally, electric motorcycles need to deliver 100 miles at 70 miles an hour per charge. Today Lightning's bikes range more than 170 miles/charge with the capacity to recharge to 80 percent in 10 minutes.

first iron-phosphate lithium cells, together with an industrial variable-frequency-drive inverter and an induction motor.

After developing early prototypes with his original EV motorcycle design, Hatfield

equipped his next bike with a Tesla motor, and Lightning was born.

"We took it to the Bonneville Salt Flats and broke a speed record that had stood for 35 years," Hatfield said. "We still hold the Bonneville record – an SCTA (Southern California Timing Association) sanctioned 215.962mph – in addition to 211.7 at the El Mirage dry lake bed. Then we raced it in the inaugural AMA (American Motorcyclist Association) zero-emission road racing series and won the North American championship."

Soon after, Hatfield produced Lightning's first production bike, the LS-218. As the speed and road racing trophies piled up, Hatfield used the momentum to bulk up Lightning's engineering prowess.

"That was our model," he said. "From the beginning we thought that, for electric motorcycles to be a compelling business, we had to provide performance and an experience that equaled or exceeded the best internal combustion bikes."

And exceed he did. In 2013, Lightning ran in the open class of the Race to the Clouds at the Pike's Peak International Hill



Figure 1 Lightning Motorcycles Corp. holds the land speed record for electric motorcycles, exceeding 215mph.

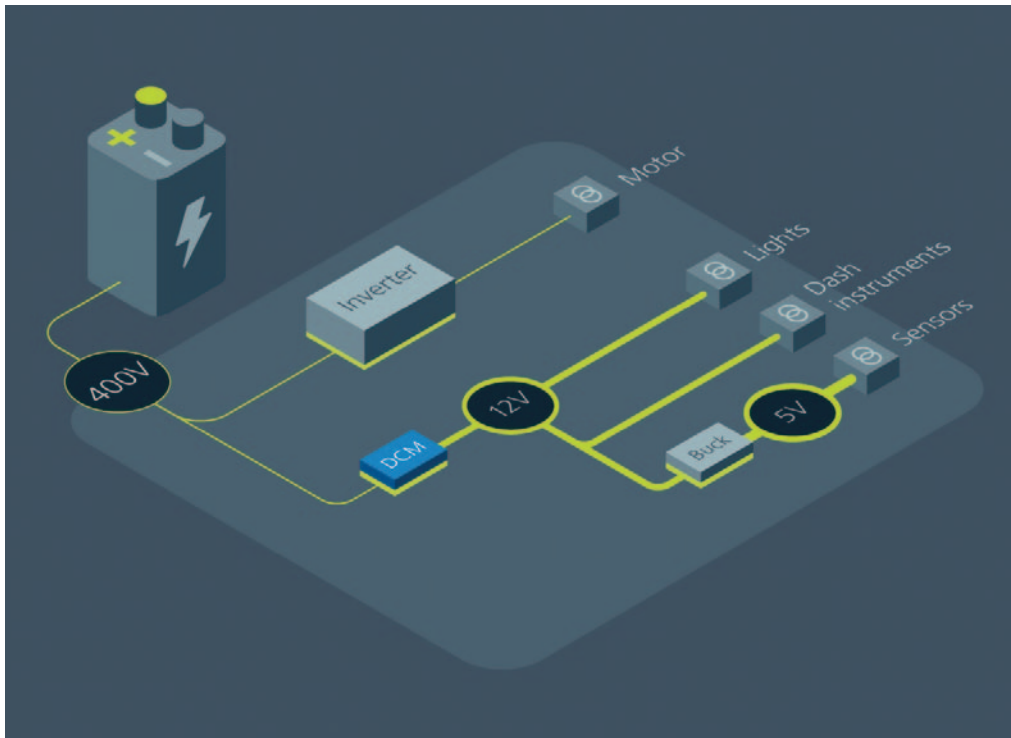


Figure 3 Lightning uses Vicor DCM power modules to convert the high voltage battery down to 12V to power the bike's control electronics including dash instrumentation, lighting, and sensors. The DCM4623 is a power-dense, light-weight and cost-effective DC-DC converter that generates a clean 12V supply from a very wide high voltage input range.

Climb. Hatfield's LS-218 EV motorcycle out-scrambled the entire field, winning the event by more than 20 seconds over the fastest gas bikes.

Honing a world class riding experience

Lightning's goal from day one was to deliver a one-of-a-kind electric riding experience. To a large extent, that came down to assuaging two customer concerns: range and charging time. Initially, Hatfield confided, it was a challenge to build a bike that could deliver 100 miles at 70 miles an hour. Lightning's bikes now range more than 170 miles with the capacity to recharge to 80 percent in 10 minutes.

Lightning's latest battery packs replace the typical graphite anode with silicon anodes, which have energy density in the 300-watt-hour-per-kilogram range – higher than most automotive EV OEMs can achieve, according to Hatfield. Silicon anode cells also charge exceptionally quickly and are able to charge sustainably over 100 kilowatts, whereas competing EV bikes push to get to 20 kilowatts even for a brief time.

The cell battery pack lifespan also generally exceeds that of most EV motorcycles. Even shorter-life cells pull about 800 to 1,000 zero-to-100 cycles. Lightning batteries are also modular and

upgradeable, meaning that as better technology becomes available, new batteries can be swapped onto the bike.

Power modules the easy choice for top performance

As Lightning's bikes became more sophisticated, the electronics onboard demanded more power, but not weight. Managing electrical noise in a vehicle that's extremely compact and lightweight is always a challenge. From the early stage, Lightning adopted Vicor DC-DC power modules in all its products, a decision Hatfield attributed to their superior reliability, low noise, high power density and easy thermal management.

Lightning uses Vicor DC-DC converters to power the bike's 12V control electronics as well as lighting, dash instrumentation and sensors. Lightning began commercial production using the DCM4623TC8G16F0T00, which is power-dense, lightweight and a very cost-effective solution.

The input range of the DCM4623 is wide enough to support different voltages from commonly used battery chemistries. For example, it offers flexibility to switch between Lithium-Iron-Phosphate packs, which provide 200 – 400V, and Nickel-Manganese-Cobalt or Nickel-Cobalt-Aluminum Oxide chemistries, which typically range between 250 – 420V.

One early issue was how to connect the battery and apply its voltage to the DCM. The problem is one that all DC-DC converters face: the transient voltage step ($V/\mu s$) from a battery when turning on and off is so fast that it's not actually possible

to connect and immediately apply the battery's 400V. There were also mechanical relays that connect the battery to the loads such as actuators and the motor, where noise can damage the DC-DC converter and other electronics. To address both problems, Vicor designed a pre-charge circuit and input filter to allow stable operation when turning ON and OFF.

Vicor was instrumental in supporting Lightning's technical needs as the power systems evolved.

What's down the road for Lightning

Hatfield is planning to return to the El Mirage dry lake beds in southern California to see if his team can break its own record. They also have aspirations of racing at Bolivia's Salar de Uyuni, which is the largest salt flat in the world and covers almost 4,000 square miles at 12,000 feet. So far, 15 of the world's elite teams have been invited to compete in what is the world's premiere land-speed event.

For Hatfield, while the records are important, it's the poetry of riding an EV motorcycle that is most satisfying.

"It's just a more advanced feeling," he said. "You don't need a transmission, you don't have to shift, and you have limitless torque all the way across the power band. We hear that a lot from our customers. Most of them are lifelong motorcyclists, but they don't ride their gas bikes so much anymore because of the experience they get from the Lightning."

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