

## CONSUMER PRODUCTS AND RETAIL

# Trek Bicycle

Putting sound quality on the e-bike metric map with the award-winning Fuel EXe

### Product

Simcenter

### Business challenges

Create a high-end e-bike with quantified acoustics

Enhance the sound experience during rides

Reduce unpleasant noise from electric motor and gearbox systems

### Keys to success

Put sound metrics on the innovative map

Investigate industry-first acoustic metrics for the e-bike sector like tonality and the articulation index

Incorporate Simcenter testing tools in the e-motor design and e-bike development process

### Results

Put sound quality on the e-bike metric map with the award-winning Fuel EXe

Used Simcenter testing solutions to diagnose and improve e-bike motor acoustics

Developed the Fuel EXe, an award-winning e-bike that sounds five times more pleasant and nearly two times quieter than comparable e-bikes

### Trek Bicycle uses Simcenter testing solutions to diagnose and improve e-bike motor acoustics

Trek Bicycle (Trek) is based in Waterloo, Wisconsin and was founded in 1976. Trek designs and manufactures various types of bikes including electric mountain bikes, road/city bikes and other accessories. Trek aims to achieve continuous innovation and high-tech performance throughout its entire product range.

Trek Bicycle continues to innovate with the Fuel EXe bike, a pioneering line released in

July 2022. The Fuel EXe is a high-powered electric mountain bike designed to provide riders with a quieter riding experience. The Fuel EXe includes high-quality Trek design, high-standard components, a lighter-weight yet tough frame and a comprehensive e-motor designed to enhance the sound experience for riders. Trek put e-bike acoustics on the map and is known for its innovative bike engineering group, including experienced mountain bike (MTB) engineers and dedicated bike-minded analysts who bring measurements and quantitative insight into new performance metrics like acoustics.





**“We realized just how important sound quality is to the e-bike experience and how important tonality as a key metric is for quantifying the pleasantness of electric motor noise.”**

Paul Harder  
Principal R&D Engineer  
Trek Performance Research  
Group, Trek Bicycle

#### **E-mountain bike acoustics**

Trek is pioneering the concept of putting sound quality on the e-mountain bike metric map as it continues to be a hot topic in the industry.

“As Trek’s acoustics testing and analysis expert, which was not only a new role for me but a new type of role for the bike industry, we aimed to take Trek’s acoustics competency to the next level while applying new test and analysis methods to the Fuel EXe development cycle,” explains Paul Harder, principal research and development (R&D) engineer within the Trek Performance Research Group at Trek.

“It was quite the endeavor with a lot of firsts happening at the same time.”

The R&D engineers in Trek’s Performance Research Group tend to stay on the experimentation and simulation side of things, testing new prototype ideas and conducting experiments to seek out new knowledge in bike physics and human performance. This quest for new knowledge landed the team in the sound quality realm.

“Over the years, the industry has made a lot of progress to make e-bike motor and battery systems smaller, lighter, more integrated and more ‘natural’ to pedal,” says Harder. “But the inherent noise of electric motor and gearbox systems often remained a common downside. With the Fuel EXe, we had a unique opportunity to improve that last piece of the puzzle and make an e-bike that really has no downsides.”

To produce this e-bike, Trek partnered with Siemens Digital Industries Software to use Simcenter™ software as part of the design process to bring the Fuel EXe to life. Simcenter is part of the Siemens Xcelerator business platform of software, hardware and services.

Using Simcenter helped Trek design the Fuel EXe to sound five times more pleasant and nearly two times quieter than other popular e-mountain bikes.

### Inspired by EVs

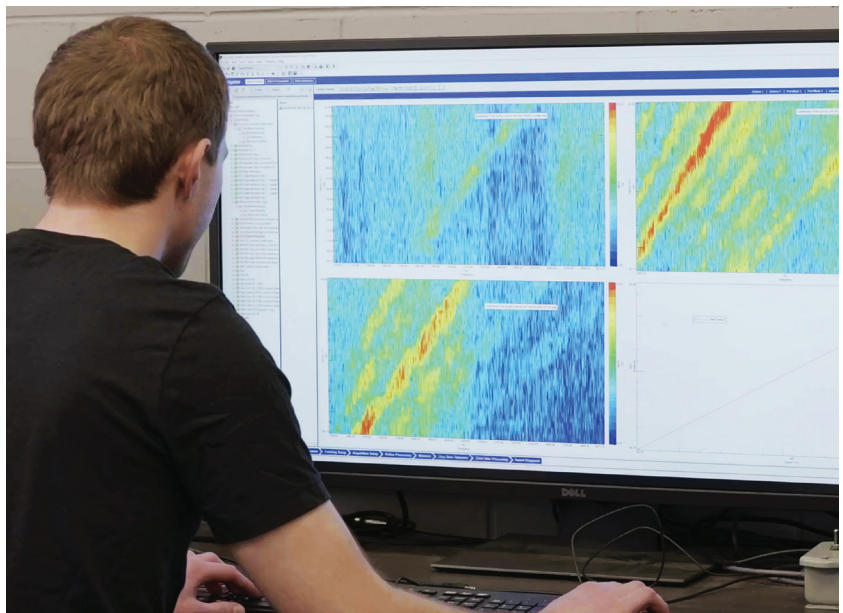
The team looked to the electric vehicle (EV) industry for inspiration. They realized that, like the early days of automotive EVs, the world of e-bike acoustics presented opportunities. The Trek team took acoustics full circle when investigating the options for the Fuel EXe in terms of the sound experience and unpleasant sounds. This included looking at industry-first acoustic metrics for the e-bike sector, like tonality and the articulation index.

“Since I almost always ride with other people, any noise that distracts from the ability to converse bothers me. This relates to the articulation index,” adds Harder. “Using tonality as our key metric for unpleasantness came from quite a bit of exploration and research into the many sound quality metrics that are commonly applied to electric motors.”

### Integrating sound science with advanced engineering

Harder and the MTB engineering team at Trek knew the acoustic experience for the Fuel EXe depended heavily on the e-motor. The team was working with TQ’s HPR120 motor, which is a powerful but fairly loud motor. The team was looking for a smaller, quieter version of the motor. They found that TQ’s harmonic pin ring technology with minimum moving parts and unique gear meshing could play a role in making a new, quieter motor.

“We have an exclusive partnership with our e-motor OEM, TQ, so that means we can effectively collaborate when creating specs and testing our e-motors,” says Harder. This collaboration resulted in the HPR50 e-motor that’s in the Fuel EXe and Domane+”.



The team at Trek counted on Simcenter Testlab to help define what ‘sounded really good’ meant from an acoustics testing and engineering standpoint.



#### **Making a great first impression**

After the usual back and forth between Trek and TQ, the prototypes with the HPR50 were ready to hit the test trails. The Trek test riders thought the prototypes with the HPR50 e-motor sounded really good. This was great news, but Harder knew they would have more work to do.

“Our team had developed solid acoustics test and analysis capabilities, but we still needed to figure out how to quantify what

‘sounded really good’ meant in the context of an e-bike,” explains Harder. “We had acoustics as a key goal for the new TQ motor and we used the analysis to quantify that, understand it and track it as we decided between the many prototype iterations throughout the development process.”

#### **From subjective opinions to objective measurements**

The team started by measuring loudness and found out that Fuel EXe was nearly two times quieter than other e-bikes but the test riders subjectively thought this understated how much better it sounded.

“At this point, we realized just how important sound quality is to the e-bike experience and how important tonality as a key metric is for quantifying the pleasantness of electric motor noise,” says Harder. “We knew we had to get a little bit smarter about how we quantified these sound descriptions. So, we moved to the sound quality aspect, which has a ton of options. We looked closely at the EV acoustic space where we knew that tonality was a best practice.”

#### **Executing the test on the trail and the sound studio**

After the initial test rides, the team needed more concrete acoustic data to work with. They headed to the sound studio at the Trek factory headquarters in Waterloo, Wisconsin, which is where Trek’s private mountain bike trails are, to run more exploratory acoustic analyses. This included sound power and sound quality metrics such as loudness, tonality and articulation index using Simcenter testing solutions, like the portable, Simcenter SCADAS™ XS hardware and Simcenter Testlab™ Neo software, the next-generation software platform for multidisciplinary test-based performance engineering.

// Using Simcenter SCADAS XS and Simcenter Testlab Neo software let me focus less on how to get correct answers and more on what those answers were teaching me.”

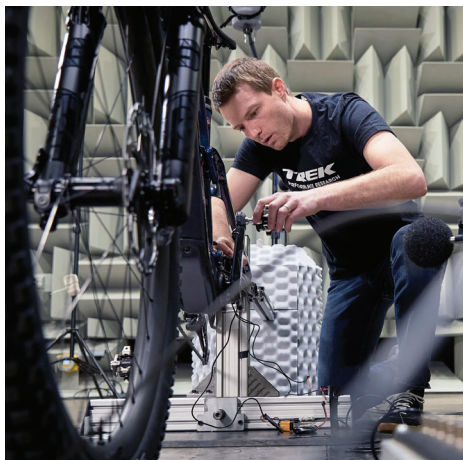
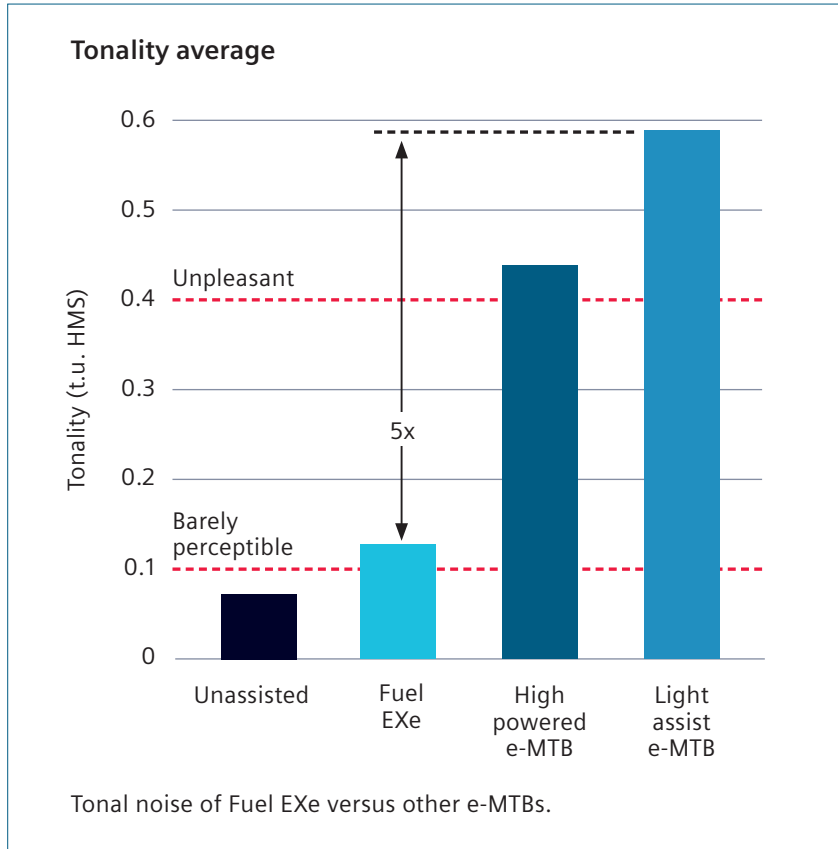
Paul Harder  
Principal R&D Engineer  
Trek Performance Research Group, Trek Bicycle

“Using Simcenter SCADAS XS to perform field testing is pretty easy because it fits in a bike jersey pocket, integrates seamlessly with the binaural headset and can be controlled wirelessly with the Simcenter Testlab Scope App on a tablet outside,” adds Harder. “During the trail tests, we also used a GPS and action camera to visualize the data in Simcenter Testlab Neo.”

The lab test setup included the Simcenter SCADAS XS, professional microphones, an acoustically-isolated stationary trainer set to 300W total resistance and, of course, the Trek Fuel EXe adjusted to maximum assist mode. The Trek team used Simcenter Testlab Neo according to the ECMA-74:2019 standard to calculate tonality.

“After researching various sound quality metrics, it became clear that tonality was the most representative of what our riders were hearing,” says Harder. “Thanks to using Simcenter Testlab, we could easily explore other relevant metrics like prominence ratio and articulation index. Nothing is worse than coding an algorithm by hand for a couple of days only to realize it’s not a useful metric for this test.”

Harder and team provided feedback throughout the prototyping process and ended up creating an advanced set of methods to diagnose and improve e-bike motor acoustics. As a final step, they verified the field and lab results on the final production motor for two days in an anechoic chamber. The final results proved that using Simcenter helped them design the Fuel EXe to sound five times more pleasant and nearly two times quieter than other popular e-mountain bikes.



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### Solutions/Services

Simcenter Testlab  
siemens.com/simcentertestlab

Simcenter Testlab Neo  
siemens.com/  
simcenter-testlab-neo

Simcenter SCADAS XS  
siemens.com/simcenterscadas

### Customer's primary business

Trek Bicycle (Trek) is based in Waterloo, Wisconsin and was founded in 1976. Trek designs and manufactures various types of bikes including electric mountain bikes, road/city bikes and other accessories.  
www.trekbikes.com

### Customer location

Waterloo  
Wisconsin



The Simcenter SCADAS XS was used in the field tests as well as the lab test setups.

### The future of e-bike acoustics

As the HPR50 and Fuel EXe rolled into production, the Trek Performance Research Group realized that they were working on cutting-edge e-bike acoustics.

"Quantifying human sound perception is extremely complicated", says Harder. "Using Simcenter SCADAS XS and Simcenter Testlab Neo software let me focus less on how to get correct answers

and more on what those answers were teaching me. The ability to quickly test different metrics and interactively visualize, filter and playback data led to much quicker and more confident insights than we could have gotten otherwise." Harder says, "The really exciting thing is that we can now leverage these tools and acoustic knowledge in even earlier stages of future e-motor and e-bike R&D projects."

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