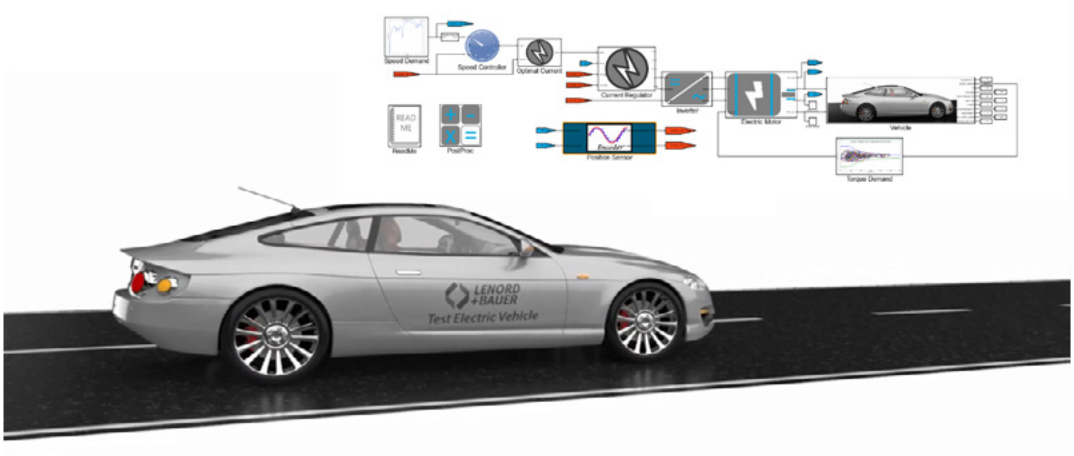
TECHNICAL DOCUMENT

THE INFLUENCE OF SENSORS ON E-MOTOR POWERTRAIN PERFORMANCE

High accuracy sensors and encoders are integral components of an e-motor drive, greatly impacting the quality and efficiency on the system. A purpose-driven simulation approach is needed to account for all the physical interdependencies within these complex multi-domain systems.



Model-based development (MBD) tools help drive faster development of electric powertrain systems. Simulating complex products as systems-of-systems allows e-motor designers to explore sensor design and controls and their impact on full vehicle-level noise and efficiency.
With MBD, mechanical models can be combined with electrical models and their controller configurations in 0D, 1D, or 3D environments, making them useful throughout the entire development cycle. Flexible multi-domain models can be deployed at the fidelity that best suits the development stage, from early concept design to detailed design to hardware-in-the-loop testing (HIL).

Challenges to EV Manufacturers

Electric vehicle manufacturers and suppliers must wrestle with a number of design challenges. Energy is limited, but customers put a premium on range and reliability. Noise factors contribute greatly to perceived quality. Finally, cost must be considered so that vehicles are both profitable for the manufacturers and affordable to the public.

"The comprehensive evaluation of sensor accuracy is key for electrically driven systems and requires for an integrated, multi-domain system simulation approach." - Ulrich Marl, Lenord + Bauer

LENORD +BAUER

e-Drive System Simulation with Lenord + Bauer

Lenord + Bauer is an international specialist in the field of motion sensors and integrated drive technology. They worked with Altair to develop a system simulation process for their high-accuracy encoders to understand their impact on the quality and efficiency of the system.

The key motivation of this project was to ensure high sensor resolution, accuracy, and precision, which contribute to:

- Noise reduction through improved field-oriented control (FOC)
- Improved e-motor reliability through reduction of torque ripple
- Battery cost reduction by maximizing torque and amplitude and increasing overall efficiency

Lenord + Bauer rotor position encoder kit

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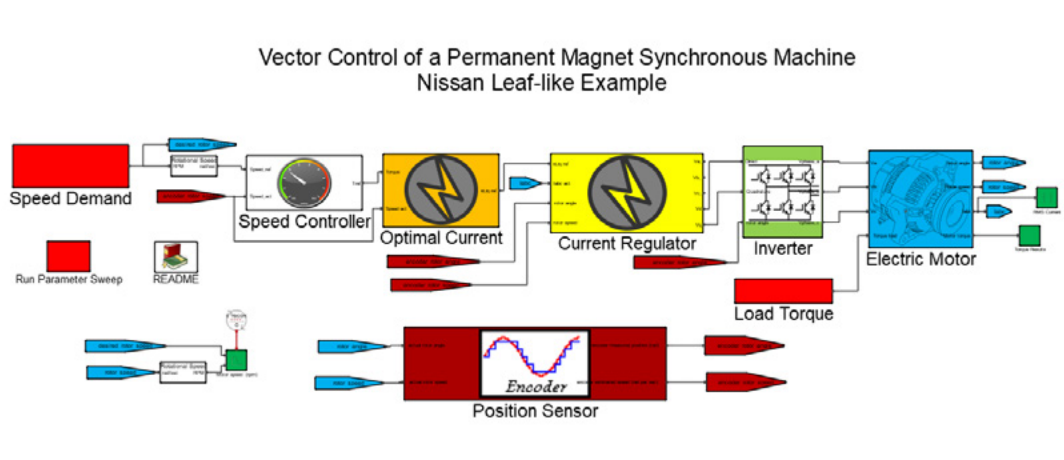
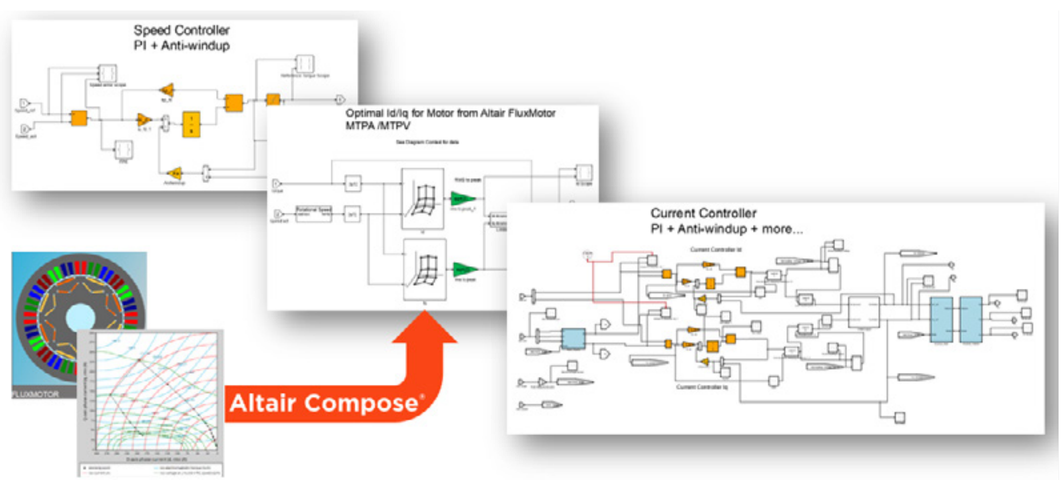


An object-oriented modeling of the topology and functional behavior of an e-drive system. The system consists of an electric motor, power electronics components, controls, and a Lenord + Bauer sensor.

To represent their high-accuracy encoders and the e-drive as a whole, Lenord + Bauer needed to combine simulation results in multiple fidelities.

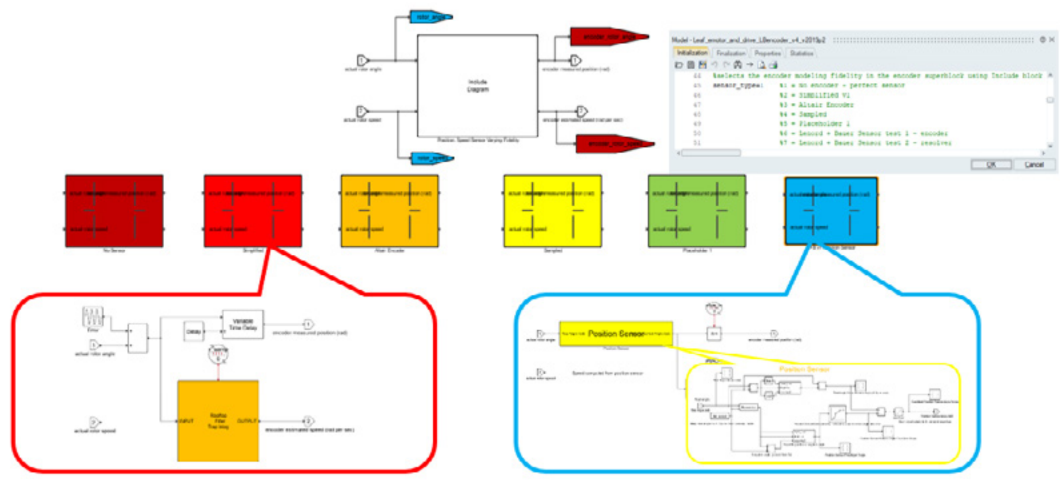
First, a sub-system model was created to represent the speed controller, which compares desired and actual speed of the motor and generates a torque demand. This data was converted to tabular format to be used in Altair's MBD tool [Altair Activate](). The process was partially automated via Altair's math and scripting software to convert 3D motor results into a reduced fidelity model suitable for system simulation. Automated script generation allowed these simulation results to easily be linked to the current controller block and to the global model-based system simulation.

Interested in math and scripting process automation? **Learn more about Altair Compose**



Cascaded control structure consisting of a speed controller and current controller blocks.

Model blocks were also created to represent the inverter and e-motor. Altair Flux™ allowed Lenord + Bauer to produce high-fidelity 3D representations of the e-motor's electromagnetic, thermal, and structural performance. This tool also facilitates the creation of Reduced Order Models (ROM), which are appropriate for 1D system simulation. High-fidelity co-simulation was used for the detailed motor design phase and to validate inverter signals, and lower-fidelity equations or table-based models could be used at the controller level.



1D models of different sensor types incl. Lenord + Bauer's specific encoder.

Altair Activate then helped Lenord + Bauer combine these mixed-fidelity simulation results with their 1D sensor models to execute multi-disciplinary system simulation. They used Activate to both optimize the design of the sensor itself and run comparisons of performance based on sensor positioning. With the 1D sensor diagrams, engineers could easily switch between sensor types to understand their influence on the whole system.

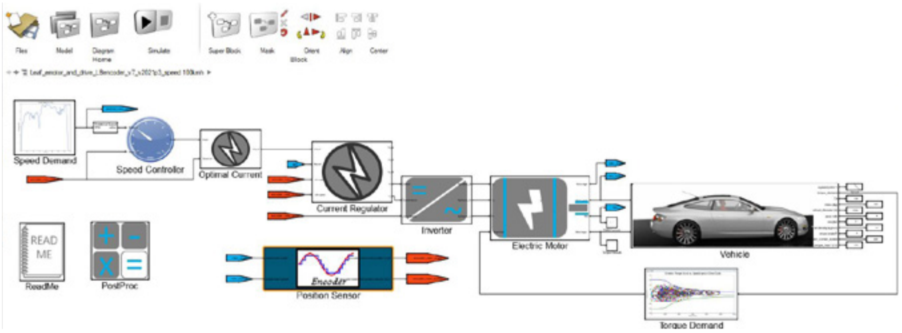
Influence of Sensor Resolution, Accuracy, and Precision

Sensors that offer higher resolution enable engineers to better measure the level of sensor accuracy; how close the measurements come to the physical test reference points, and sensor precision; the ability to produce consistent, repeatable measurements. To determine whether a sensor is both accurate and precise, proper resolution is needed to verify the simulation's adherence to real-world measurements.

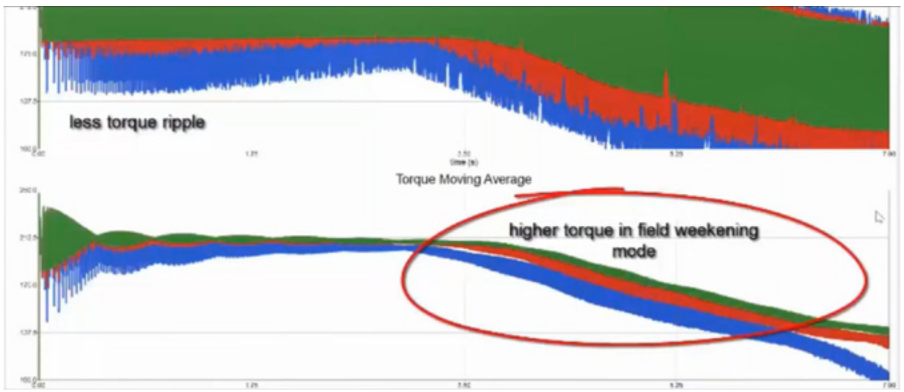
Speed resolution is a critical metric for vehicle powertrain developers. The speed resolution depends on the resolution of the sensor (number of distinguishable positions) and the sampling frequency of the inverter. By increasing the sensor resolution at the same inverter frequency, system simulation shows a reduction in torque ripples as the powertrain is able to provide a smoother distribution of power, which also requires less overall energy consumption.

The resolution of sensors and encoders is so important because of their influence on noises, reliability, and efficiency. Vibrations caused by inadequate speed control lead to noises and unpleasant sound, which hamper driver comfort. High resolution and accurate sensors lead to better FOC, which reduces vibration-induced noise. Vibrations can also permanently damage the engine and negatively influence vehicle reliability. Finally, higher efficiency can be achieved with vibration-reducing high-resolution sensors. Achieving lower drive cycle energy consumption (higher torque per amp) allows designers to use smaller, lighter, and more cost-efficient batteries to drive down vehicle cost without sacrificing range.

A speed test was performed to compare sensors of varying rotor position accuracy using Altair Activate. The system simulation found that as rotor position accuracy increased, acceleration was improved. Additionally, sensor accuracy contributed to a reduction in torque ripple and higher overall torque, especially in field week weakening mode. The Altair workflow enabled Lenord and Bauer to reduce torque ripples by 50% compared to conventional resolvers, ensuring sensor accuracy.



Altair Activate modeling of rotor position accuracy on maximum acceleration.



Torque ripple results from speed test. Blue represents poor accuracy,
red is medium accuracy, and green shows good accuracy.

Want to learn more?
Watch the Webinar Series

Working with Altair

Delivering e-Mobility to the masses is not only a huge investment, but a significant operational undertaking. As OEMs, suppliers and emerging vehicle manufacturers invest billions to develop innovative electric vehicles, and optimize development and production processes, they are looking for a strategic partner to help realize their vision. Altair technologies are changing the way electric passenger, off-highway and autonomous vehicles are designed, enabling them to accelerate product development, enhance energy efficiency, and optimize integrated system performance.

Learn more at altair.com/e-mobility