| 講演番号 | 077 |
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# Electro-Mechanical Coupled Simulation-Based Conducted Noise Analysis of High-Precision IC and MOSFET Models


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**KEY WORDS**: **SPICE, VHDL-AMS, electromagnetic interference (EMI) Model, Gate Driver, MOSFET, H-Bridge** [E1]


The rapid electrification and functional integration of automotive systems have imposed increasingly stringent requirements on electronic control units (ECUs), including higher power density, faster switching speeds, and improved reliability. As a consequence, electromagnetic interference (EMI), particularly conducted noise, has become a critical issue that can degrade system-level performance and hinder compliance with automotive electromagnetic compatibility (EMC) regulations. To address these challenges at an early design stage, model-based design (MBD) and front-loading simulation approaches are gaining importance, enabling virtual verification prior to hardware prototyping.

In previous work, high-precision semiconductor models for gate driver ICs and power MOSFETs were developed and validated through transient electrical and thermal analyses under actuator operating conditions. Building on these results, this study extends the application of these models to conducted noise analysis using an electro-mechanical coupled system simulation. The objective is to establish an effective methodology for evaluating conducted noise characteristics in automotive motor drive systems at the ECU level.

The target system is a DC brushed motor drive circuit employing an H-bridge configuration. The simulation model integrates a system-level gate driver IC model optimized for fast computation, high-precision SPICE models of power MOSFETs that capture nonlinear capacitance and switching behavior, and a Cauer-type RC thermal network to evaluate transient junction temperature characteristics. In addition, a DC motor model derived from measured characteristics of a commercial motor and a mechanical load model consisting of friction and inertia components are incorporated, enabling electro-mechanical coupling.

Transient simulations are performed under typical automotive body-system conditions, including a supply voltage of 12 V, a PWM switching frequency of 20 kHz, and an ambient temperature of 25 °C. The results demonstrate stable H-bridge operation and realistic switching waveforms. Voltage and current responses exhibit overshoot and ringing associated with MOSFET switching, which are potential sources of conducted noise. Transient thermal analysis further reveals gradual junction temperature rise with periodic temperature ripple synchronized to the PWM frequency, confirming the capability of the coupled model to capture electrical–thermal interactions.

To evaluate conducted noise characteristics, the supply voltage (VB) current waveform obtained from transient simulation is converted to the frequency domain using fast Fourier transform (FFT) analysis. The resulting frequency spectrum clearly shows components corresponding to the PWM switching frequency and its harmonics, as well as noise components appearing in the AM and FM radio frequency bands. These results indicate that the proposed model can effectively reproduce conducted noise behavior arising from the interaction of the gate driver IC, power MOSFETs, and motor load.

The proposed simulation framework provides valuable insight into conducted noise generation mechanisms and enables early-stage evaluation without reliance on physical prototypes. Owing to the use of a fast system-level IC model, the approach is well suited for initial design exploration and comparative studies. Future work will focus on experimental validation using an evaluation board and correlation with measured conducted noise to further improve model accuracy and applicability to practical ECU design.

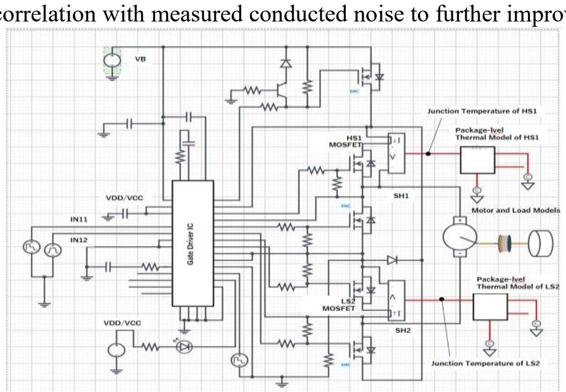


**Fig.1 Detailed Configuration of the Simulation Circuit**

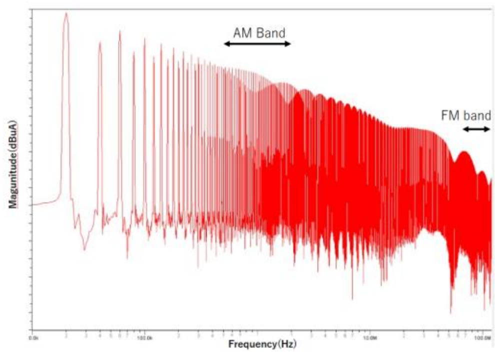


**Fig.2 FFT Analysis of the Supply Voltage (VB) Current Waveform**




2026 JSAE Annual Congress (Spring) - Summarized Paper

Issued on May 22, 2026