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学 位 論 文 題 名	Time Dependent CAN Error Mitigation for EMI Noise of Switched-Mode Power Supplies （スイッチング電源の EMI に起因する CAN 通信エラーの低減手法）
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【論文の内容の要旨】

Electromagnetic compatibility (EMC) is a major concern in modern electrical applications, such as EVs and industrial robots, where switched-mode power supplies (SMPSs) and serial communication networks operate in conjunction. SMPSs have gradually employed high-frequency and high-speed switching operations with the advent of wide bandgap semiconductor devices, which has resulted in the generation of more electromagnetic interference (EMI) noise. Moreover, for serial communication systems, high-speed and wide-bandwidth data transmission are common requirements for applications such as telecommunication, transportation, and industrial systems. To achieve the technical requirements under the robust operation, the noise immunity of communication systems is a significant concern. Hence, a large amount of effort has been implemented into suppressing electromagnetic disturbance on serial communication systems. In this context, SMPSs have been recognized as the main EMI sources that causes electromagnetic disturbance on communication systems. Therefore, this thesis covers a comprehensive study on EMC of a buck converter and controller area network (CAN) communication.

Chapter 1 presents the background and motivations for the research. After technological problems of EMC between SMPSs and serial communication systems are r

eviewed, Chapter 2 reviews the literature related to EMC of SMPSs and communication systems. First, the EMI noise of power electronics converters is reviewed, focusing on the conducted noise of a buck converter. State-of-the-art EMI reduction approaches for the conducted noise are described. Second, the overview of CAN summarizes the specification of standard CAN protocol and recent EMI research. Subsequently, case studies of the disturbance on serial communication systems concretize EMI problems and the potential risks are discussed.

Chapter 3 describes the time-domain analysis of the disturbance caused by a buck converter on CAN communication. As an experimental platform, the noise injection system is developed. The system consists of a buck converter and a CAN bus and it enables to perform experimental studies with high repeatability. within addition to experimental studies, simulation modeling methodologies are also discussed. In particularly, two types of parasitic impedance remain undeveloped regarding simulation modeling: parasitic impedance of an electrolytic capacitor and OFF-state MOSFET impedance. Accordingly, experimental and simulation studies were performed to develop simulation models. Subsequently, simulation and experimental waveform comparisons of the noise injection system were performed to verify the modeling approach and unveil the mechanism of EM disturbance, followed by the CAN failure analysis.

Chapter 4 describes the time series control using an active gate driver to balance the EM disturbance reduction and converter performance. The active gate driver is one of the key technologies in controlling a switching speed of power semiconductor device. By suppressing the switching speed of the device, an EMI reduction can be achieved. However, this increases the switching power loss and results in lowering the conversion efficiency. That is, balancing the EMI reduction with the converter performance would be a technical challenge. The time series control of the active gate driver realizes an effective EMI reduction on CAN data transmission. For low-bus-traffic applications, the control method balances the EMI reduction and the conversion efficiency, which was studied experimentally.

Chapter 5 presents the timing-shift control of the buck converter that reduces the EMI using converter control. Unlike the conventional EMI reduction methods, the control scheme aims to prevent communication errors even if the buck converter induces a noise to the communication line. Despite the control suppressing the EM disturbance, shifting a switching timing potentially undermines the converter control stability. A duty compensation method is used to improve the stability.

Chapter 6, in contrast to the timing-shift control on the converter side, proposes the digital denoising technique that enables a CAN processor to digitally remove error signals. The denoising method can be applied to the communication system independently of the converter. To implement the denoising method to the noise injection system, a field programmable gate array (FPGA) is integrated with the CAN controller. The denoising process occurs on the FPGA, and the CAN controller receives the processed signals. Owing to the CAN sampling rule, modifying the communication protocol is not required. Finally, experimental results validate the denoising method. Chapter 7 provides the conclusions and future outlook of this research.