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Improving EMC Performance of Digital Cluster for Electric Vehicle using Power Integrity Analysis

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Abstract. With the production of many plug-in hybrid electric vehicles and electric vehicles, the degree of integration is increasing for electronic components used in steering, braking, suspension, infotainment, BMS and instrument panel systems. Consequently, the possibility of malfunction due to the mutual interference of electromagnetic waves generated from the systems has increased, and the system design should consider resistance to electromagnetic wave generation and interference based on the electromagnetic wave standards. Power integrity refers to the stabilization of power supply system in the PCB design process, and integrity signals can be composed by strengthening the power supply, which is vulnerable to noise. This allows us to predict, modify, and solve the structural problems of circuits before producing the PCB, thereby minimizing the redesign of PCB. As a result, we can shorten the development time, save the cost, and improve the reliability of electromagnetic waves for systems.

Keywords; Digital Cluster; Power Integrity; EMC; resonance; decoupling capacitor

1. Introduction

Recently, automotive manufacturer are developing plug-in hybrid electric vehicles and electric vehicles that use environmentally friendly energy. As a result, many electric and electronic components that have not been mounted in conventional vehicles are

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mounted in new vehicles [1]. Consequently, the possibility of malfunction due to the mutual interference of electromagnetic waves generated from the steering, braking, suspension, infotainment, battery management, and instrument panel systems has increased, and the system design should consider resistance to electromagnetic wave generation and interference based on the electromagnetic wave standards [2][3]. In particular, the automotive cluster is a device that delivers vehicle information needed for driving to the driver and incorrect information delivery by malfunction caused by electromagnetic interference from other systems can lead to serious accidents. Therefore, the electromagnetic interference from the systems must be designed to be lower than the levels specified in OEM or domestic and international standards or the systems must be designed not to be affected by external electromagnetic waves.

In this paper, power integrity (PI) analysis is applied to digital cluster for electric vehicles. PI analysis is a computer aided engineering (CAE) method that can predict, modify, and minimize signal malfunctions and EMC (electromagnetic compatibility) problems in system design process [4]. Simulations were performed using ANSYS SIwave to propose a method for reducing the PCB (Print Circuit Board) design cost and improving the reliability of electromagnetic waves by predicting and improving the electromagnetic wave performance. The organization of this paper is as follows. Chapter 2 describes the proposed technology. Chapter 3 explains the result of applying the PI analysis. Finally, Chapter 4 presents the conclusions and future tasks.

2. Methods

PI starts with resonance analysis to find structural resonance between the power supply of PCB and the ground, and the electromagnetic field analysis method is used for structural analysis. In the first step, resonance analysis is performed to calculate the resonance between power plan and ground plan. A large resonance waveform indicates that the corresponding part is vulnerable to voltage noise. In the resonance analysis results, the actual resonance frequency is indicated by “Re. Frequency” and the Q value can be used to determine the sharpness of resonance. In the second step, impedance analysis is performed to verify the impedance change by frequency after adding a port for measurement in the area where resonance occurred. A sharp increase in impedance at a specific frequency indicates a large resonance at the point. Even a small current noise can develop into a voltage noise by being multiplied by impedance. Therefore, the target impedance is required to improve noise by lowering the impedance of a specific frequency, and the pattern is changed by adding the decoupling capacitor and via with the target impedance as the goal. The equation for obtaining the target impedance is as follows:

$$Target\ Impedance = \frac{Supply\ Voltage \times AllowalbleRipple}{Maximum\ Current} \quad (1)$$

In the third step, the decoupling capacitor connects the power with the ground and plays the role of connecting the self-resonant frequency (SRF) to the ground. This process can remove noise by sending all the resonance energy of a specific part to the ground. Finally, this process is repeated until the impedance becomes lower than the target impedance through modification of decoupling capacitor and layout. In this case, the decoupling capacitor must be located at a position where the resonance can be suppressed and the impedance can be stabilized. Through this process, clean signals can be composed by improving the places that are vulnerable to noises and it is possible to theoretically find and solve problems that are difficult to discover through measurement.

3. Results

Table 1 shows one of the resonance frequency between 10MHz~1GHz and Fig. 1 shows the position where the resonance occurred. If noise signals occur at positions ① and ② in Fig. 1, EMI and PCB noises are generated. A port is added to the part where resonance occurred, the impedance is measured and the target impedance is determined. If the input voltage of the digital cluster for electric vehicles is +12 V, allowable ripples are 5%, and the used current is 1 A, the target impedance becomes 0.6Ω by Eq. (1).

Table 1: Result of Resonant Mode

Re. Frequency(MHz)	Im. Frequency(MHz)	K	Wavelength(m)	Q
28.476	0.277	0.597	10.528	51.364

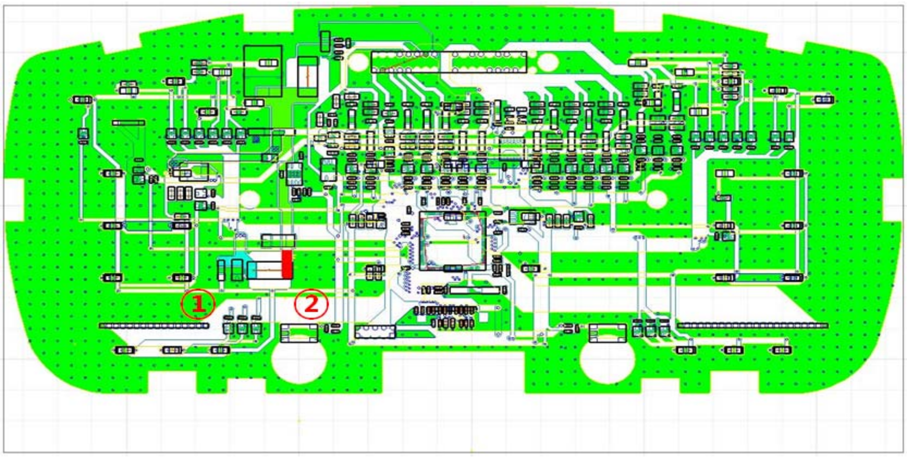

Fig. 1 Result of resonance analysis at 28.476MHz

Fig. 3 shows that the impedance of the 28.476 MHz band exceeds 0.6 Ω (blue line) at 120 MHz or lower. To reduce the overall impedance, the GCM32ER71E106 KA01(10uF) decoupling capacitor that has impedance characteristics was added at the part where resonance occurs as shown in Fig. 2. After adding the decoupling capacitor, the impedance of the 28.476 MHz band (green line) became lower than the target impedance and the resonance was removed.

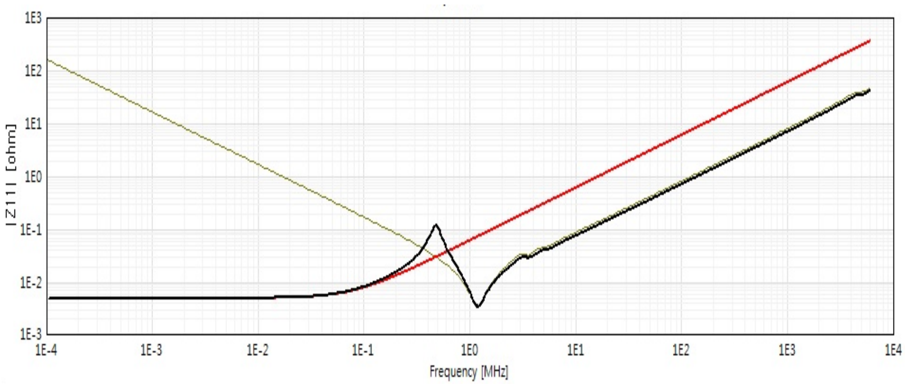

Fig. 2 Impedance characteristic of GCM32ER71E106KA01

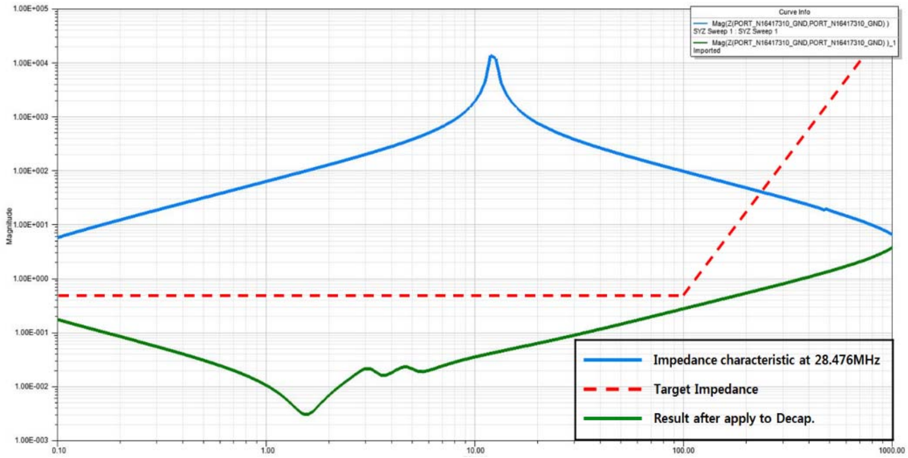

Fig. 3 Impedance characteristic after apply to GCM32ER71E106KA01(10uF)

Conclusion

In this paper, the resonance and impedance characteristics of the frequency band that has a problem in the design process of digital cluster for electric vehicles and the system was improved by adding a decoupling capacitor. The proposed method will save the design cost and improve the reliability of electromagnetic waves for the system by predicting, modifying and improving the signal malfunctions and EMC problems that can occur in the design process.

In our future study, we will analyze the resonance and impedance characteristics of other frequency bands that were not dealt with in this study and solve problems. The results of this study are expected to contribute to the development and mass production of digital clusters for electric vehicles in accordance with the OEM or domestic and international standards.

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