Novel Approach to Voltage Adjustment of Low-noise Signaling in Power over Coax Circuits

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***Abstract*—This paper proposes a power-supply-voltage adjustment method for low-noise signaling of in-vehicle high-speed communication systems involving cameras using a power over coax (PoC) circuit. We introduce a method of detecting the PoC filter degrading from the change in the equalizer parameters of serializer/deserializer (SerDes) LSIs and determine the appropriate set voltage value from their change points.**

***Keywords*—power over coax, SerDes, equalizer.**

I. Introduction

Autonomous driving technology has the potential to decrease traffic accidents and congestion, improve road safety, and reduce carbon emissions [1,2]. However, achieving reliable autonomous driving is still a very challenging task. With improvements in autonomous driving, more advanced recognition and judgment in the autonomous driving electronic control unit (AD-ECU) is necessary. One of the key technologies is a sensor system that takes in information from the outside world, and cameras play an important role in these systems [3,4].

Camera resolutions and frame rates tend to increase to improve the recognition performance of the target object. The signal speed of the transmission path connecting the in-vehicle camera and AD-ECU also increases. In addition, power over coax (PoC) circuits that transmit high-speed signals and supply currents over the same coaxial cable are common for reducing the weight of vehicle wire harnesses [5].

In a PoC circuit, the power-supply current is superimposed into the signal wiring via PoC filters, as shown in Figure 1. The PoC filter has a high impedance in the frequency range required for signal communication and does not adversely affect the signal quality. The design of this filter greatly affects transmission performance and vehicle-noise characteristics. We previously reported on packaging technology that improves filter performance for improving the transmission performance of high-speed signals [6]. In this report, we focus on the degradation mode during operation of a PoC filter. Specifically, we propose a power-supply-voltage adjustment method to avoid this degradation in filter performance, assuming that the filter performance decreases when the supply current exceeding the rated current of the filter component flows through the filter component.

II. Concept of Proposed Method

In this section, we explain the degradation mode of the PoC filter when the rated current of the filter component is exceeded, and the concept of the proposed power-supply-voltage adjustment method.

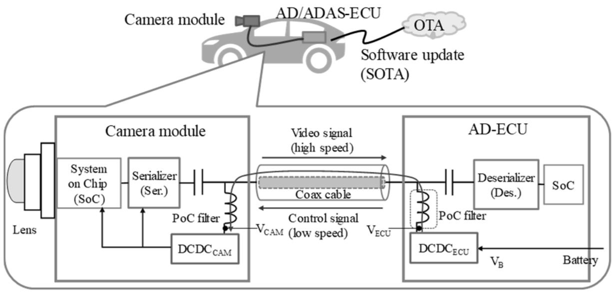
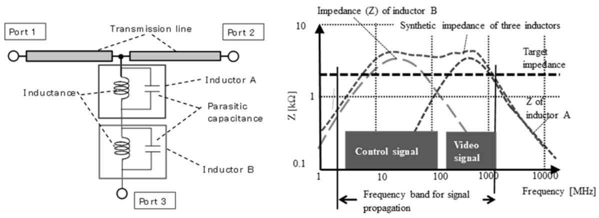


Fig. 1. System topology of power over coax (PoC) circuit.

Figure 2 shows the configuration of a typical PoC filter and its impedance profile. PoC filters typically consist of multiple inductor components. This is because PoC transmission communicates high-speed video signals and slow control signals in both directions and requires wideband filter characteristics to separate the two signals from the power-supply current on the frequency axis. As shown in Figure 2 (b), two inductors can maintain high impedance over a wide frequency range of 10 MHz to 1 GHz or more.



(a) Equivalent circuit of PoC filter (b) Impedance (Z) profile of PoC filter

Fig. 2. Equivalent circuit and its impedance profile of PoC filter.

Next, we describe the degradation mode of the PoC filter. Automotive software has been updated with over the air (OTA) during operation. Software updates OTA (SOTA) can change the way the camera is used, and the camera power consumption changes from the time the product is shipped. As shown in Figure 3, it is assumed that the power-supply current exceeding the rated current of the inductor of the PoC filter flows through the PoC filter due to an increase in the supply current. In this case, the effective inductance value of the inductor component that constitutes the PoC filter becomes lower than the specification value; as a result, the PoC filter performance deteriorates, and there is a risk that the noise performance deteriorates, as shown in Figure 3 (b).

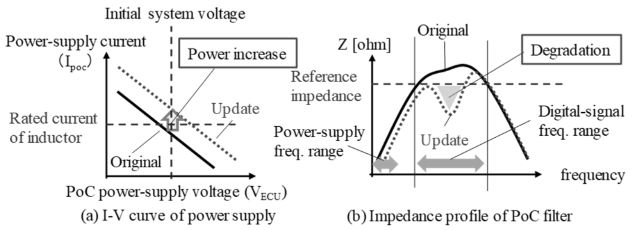


Fig. 3. Degradation mode of PoC filter by the power supply current increase.

To solve this problem, our proposed voltage-adjustment method uses the equalizer setting parameters. Figure 4 shows the circuit configuration of our proposed method. It has a voltage-adjustment instruction function ((a) in Figure 4) from the system on chip (SoC) side to the power supply integrated circuit (IC), a function for reading the equalizer parameter setting after voltage adjustment ((b) in Figure 4), and voltage-determining function ((c) in Figure 4) by comparing the saved threshold with the read parameter setting. Using this configuration, the process of determining a voltage that does not exceed the rated current is illustrated in Figures 5 and 6.

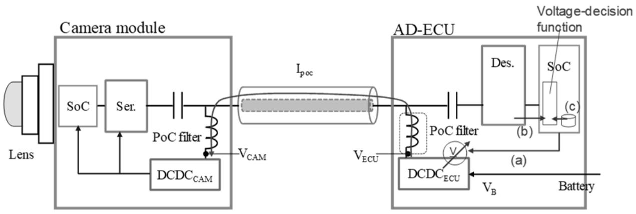


Fig. 4. Proposed circuit configuration for voltage adjustment.

Figure 5 shows the relationship between the power-supply voltage and power-supply current and equalizer parameters of serializer/deserializer large scaled ICs (SerDes LSIs). By lowering the power-supply voltage, the power-supply current increases. When a current exceeding the rated current of the PoC filter component flows, the signal waveform is disturbed due to deterioration in filter performance, so the equalizer parameters are optimized to recover the signal integrity. By determining the change point where the equalizer parameters change occurs, it is possible to determine the appropriate voltage setting.

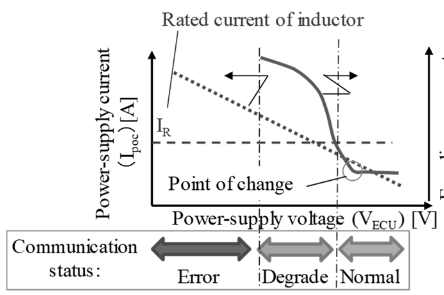


Fig. 5. Power-supply-voltage dependency on power-supply current and equalizer parameters.

Figure 6 shows the flow of determining the voltage setting using the circuit configuration in Figure 4. First, the voltage is set to maximum and the equalizer parameters are read. Then, the equalizer parameters are read and stored in the storage area while lowering the voltage by a certain voltage step, ΔV. This is done until a communication error occurs. The relationship between the amount of change in the last collected equalizer parameters and set voltage is determined, and the voltage exceeding the rated current is estimated from this relationship when there was a large change in the equalizer parameters, and the output voltage is determined.

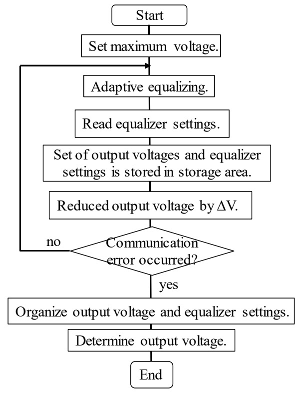


Fig. 6. Flow chart of voltage adjastment

III. SIMURALTION RESULTS FOR PRINCIPLE VERIFICATION

In this section, we explain the principle verification results of the proposed method through simulation. Specifically, we discuss the feasibility of reading the change in the filter performance from the change in the equalizer parameter setting.

We consider a PoC filter composed of two inductors (A, B) as shown in Figure 2. In this study, the bias current dependencies of inductance in inductors (A, B) were assumed as shown in Figure 7. The rated current of inductor A and inductor B are about 300 mA and about 800 mA respectively.

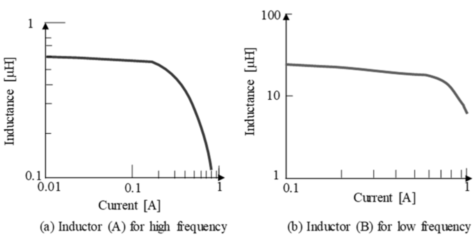


Fig. 7. Bias current dependencies of the inductor components.

Figure 8 shows the current dependence of the electrical characteristics of a PoC filter composed of the above two inductors. Figure 8 (a) shows the bias current dependence of the impedance characteristics of the PoC filter. Dips are generated in several hundred MHz bands when the rated current of inductor A is exceeded. Figure 8 (b) shows the bias current dependence of the insertion-loss characteristics of the transmission line connected to the PoC filter. Dips are also generated in the insertion loss at the frequency at which the dips are generated in the impedance of the PoC filter.

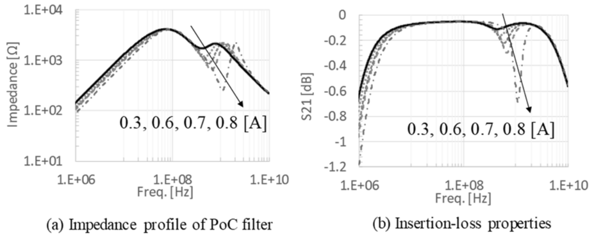


Fig. 8. Power-supply-current dependency on electrical properties of PoC circuit.

Next, using this PoC filter for the circuit configuration in Figure 4, we simulated the transmission system between serializer and deserializer LSIs and examined the feasibility of detecting the characteristic degradation of the PoC filter by equalizer parameters. We used the ADS™ of Keysight technology as a simulator, 2-tap feed forward equalizer (FFE) for the serializer (Tx) side, and 5-tap decision feedback equalizer (DFE) for the deserializer (Rx) side. We also carried out automatic compensation of the signal waveform using the adaptive equalizer option. Figure 9 shows a representative example of the result of reading the tap coefficient of the equalizer when the current bias condition was changed and plotting the amount of change. As shown in this figure, the change in the DFE setting can be read near 0.3 A, which is the rated current of inductor A. This suggests the feasibility of the proposed method. We think that the reason the change in the FFE setting is small and the change to the set DFE appears greater is that the deterioration due to the bias current of the PoC filter contributes to the loss deterioration of a specific frequency. The FFE is effective for compensating for waveform degradation when insertion losses deteriorate in a wide frequency band. While the DFE is effective in compensating for degradation in specific frequencies such as reflections [7]. It is considered that the difference in the characteristics of these equalizers appears as the difference in the amount of change in the tap coefficients. To clarify the correlation between the degradation mode and the equalizer parameter changes, further studies will be needed in the future.

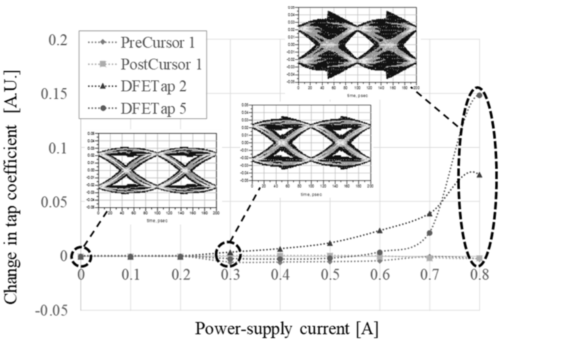
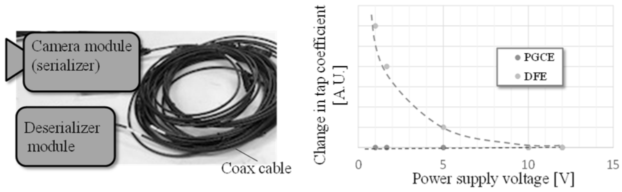


Fig. 9. Power-supply-current dependency on the change in tap coefficient of equalizer of TX/RX.

IV. Experimental Verification

In this section, we present the verification results using the experimental setup. In this verification, the change in the equalizer parameters was observed while changing the set value power-supply voltage to the camera-module side and connecting the cable between the camera module and module equipped with the deserializer. In the SerDes LSIs used in this experiment, programable gain control equalizer (PGCE) and DFE were installed on the deserializer side as equalizing functions.

Figure 10 shows the amount of change in the equalizer parameter setting when the measurement system setup and bias voltage were changed. As shown in Figure 10 (b), the changing point of the DFE was determined at a voltage below 10 V. This voltage corresponds to that calculated from the power consumption of the camera module and the rated current of the filter. This suggests that the proposed method is effective for an appropriate voltage setting that does not cause noise in PoC communication.



(a) Experimental setup (b) Equalizer settings vs. power-supply voltage

Fig. 10. Experimental setup and results of power-supply-voltage dependence on change in tap coefficient of equalizer

V. Conclusion

In this paper, we proposed a power-supply-voltage adjustment method for low-noise signaling of in-vehicle high-speed communication systems involving cameras using a power over coax (PoC) circuit. Due to the change in power consumption from the change in the operation of the camera module, the PoC filter performance deteriorates when the rated current of the PoC filter component is exceeded, deteriorating signal quality. To avoid this deterioration, we also introduced a method of detecting this change from the change in the equalizer parameters of serializer/deserializer (SerDes) LSIs and determine the appropriate set voltage value from their change points. In the future, further studies will be needed to clarify the correlation between the degradation mode and the equalizer parameter changes.

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