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# A Study of Thermal and Electrical Multi-Domain Model of Aluminum Electrolytic Capacitors (First Report)

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Aluminum electrolytic capacitors are used widely for automotive electrical equipment. However, it is complicated to evaluate the lifetime for the actual operation condition varying ambient temperature and ripple current, due to the temperature dependence of the impedance and lifetime acceleration factor of aluminum electrolyte capacitors. To eliminate this complexity, we studied the multi-domain model that is combined the electrical model (Impedance Model) and the thermal model. As shown in Fig.1, these two domain models are connected via the element temperature: $T_e$, which is the parameter that the acceleration factor of the consumed lifetime of the aluminum electrolytic capacitor, too.

In this study, we proposed two types of models for the electrical impedance model. One is i) LCR model is given by the serial connection of the constant capacitance, the constant inductance (ESL), and the $T_e$ dependent resistance (ESR). The other is ii) the detailed model which is modified i) the LCR model to represent the impedance behavior in the low temperature and high-frequency range. As to the thermal model, two heat passes are considered. The heat generated by ESR and ripple current in the element flows toward PCB (Printed Circuit Board) land via the capacitor terminal, and to the surrounding air via the packaging aluminum case. Therefore, the thermal model contains two thermal resistances $R_{pin}$ (element to PCB land via lead wires) and $R_{ec}$ (element to the aluminum case). Since the aluminum electrolytic capacitor element and the sealing rubber have comparatively large thermal capacitance values to other constituent materials, we set two thermal capacitance for the element part and the packaging part. As these electrical models and thermal models are given by the lumped-circuit model, they can easily build up as SPICE models or described with VHDL-AMS. Furthermore, the VHDL-AMS model can contain the lifetime calculation as explained above.

To show the efficiency of the multi-domain model of the aluminum electrolytic capacitor, we prepared the simplified system model of the fuel injection on the system-simulator (PARTQUEST EXPLORER) where the multi-domain models of the targeting aluminum electrolyte capacitor are described in VHDL-AMS to install for the boost smoothing capacitors. The results of this fuel-injection system simulation confirm the following three items, i) Ambient temperature dependency of the dissipation and temperature rise of the boost capacitor, ii) Real-time output of the consumed lifetime of the boost capacitor and iii) Difference of the surge voltage between the LCR model and the detailed model in an extremely low-temperature range.

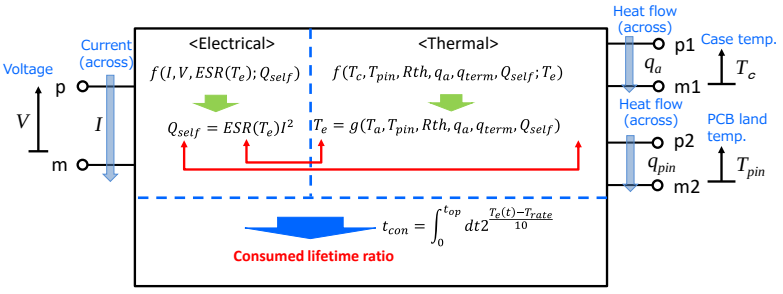


Fig.1 The diagram of the proposed multi-domain model of aluminum electrolytic capacitors