

# Development of a simple evaluation method for abnormal heat generation phenomena in automotive ECUs under high temperature environments

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The increasing performance and density of automotive electronics have made thermal design and reliability increasingly important. Random component failures may cause abnormal heating, potentially affecting surrounding circuits or leading to ignition. Because these effects depend on the ECU's initial temperature and heat-dissipation conditions, evaluation under high-temperature conditions is necessary. However, temperature-controlled chambers may restrict observation and ignition testing. This study therefore proposes an open radiative-heating method using far-infrared heaters. A thermal-balance model was experimentally calibrated to estimate the heater conditions and time required to achieve a target ECU temperature.

Fig.1 shows the proposed heating method. Two far-infrared heaters were arranged opposite each other, with the ECU positioned between them. Heating both broad faces was intended to reduce the front-to-rear temperature difference and form a more uniform temperature distribution in the case and internal PCB. Temperatures were measured using three thermocouples on the ECU case, three on the PCB, one on the heater heppat source, and one for ambient air. Eq.1 represents the transient heat balance for one irradiated face of the ECU, and Table 1 defines the parameters.  $\sigma$  is Stefan-Boltzman constant. Effective model parameters incorporating radiative transfer, convection, geometry, and equivalent heat capacity were identified from measured case, heater, and ambient-temperature histories. Experimental data not used for parameter identification were then employed to assess the model.

$$C_{eff} \frac{dT}{ds} = K_{rad} \sigma A (T_h^4 - T^4) - hA(T - T_a) \dots Eq. 1$$

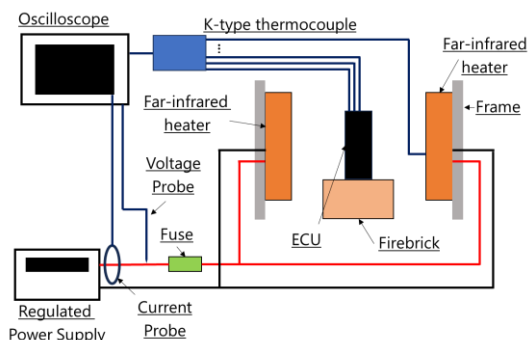


Fig. 1 Schematic Diagram of the Experimental Setup

Figure 2 compares the measured ECU case-surface temperature at a heater voltage of 120V with the temperature calculated using the thermal-balance model under an experimental condition excluded from parameter identification. The maximum temperature difference was 2.21 °C, and the overlapping curves indicate that the model reproduced the overall time-dependent temperature response. The model was also used to inversely determine the heater conditions required for the target ECU temperature. The calculated heater temperature was 369.2 °C, which was 12.8 °C higher than the measured value of 356.4 °C. The calculated heater voltage was 121.9 V, which was 1.9 V higher than the applied voltage of 120 V. These results show that, within the calibrated experimental configuration, the heater conditions for a target ECU temperature and the time-dependent approach toward saturation can be estimated. The identified parameters are specific to the tested ECU, heater arrangement, distance, orientation, and ambient conditions; recalibration is required when the configuration changes.

Table 1 Parameters in the thermal-balance model

| Symbol    | Definition                       | Unit                               |
|-----------|----------------------------------|------------------------------------|
| $C_{eff}$ | Equivalent heat capacity         | J/K                                |
| $T$       | ECU temperature                  | K                                  |
| $T_h$     | Heater temperature               | K                                  |
| $T_a$     | Ambient temperature              | K                                  |
| $K_{rad}$ | Effective radiative coefficient  | W/(m <sup>2</sup> K <sup>4</sup> ) |
| $h$       | Effective convective coefficient | W/(m <sup>2</sup> K)               |
| $A$       | Effective area                   | m <sup>2</sup>                     |

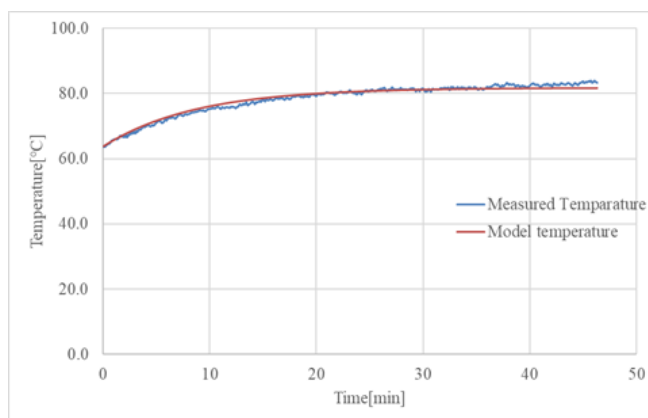


Fig. 2 Measured Temperature and Model Temperature