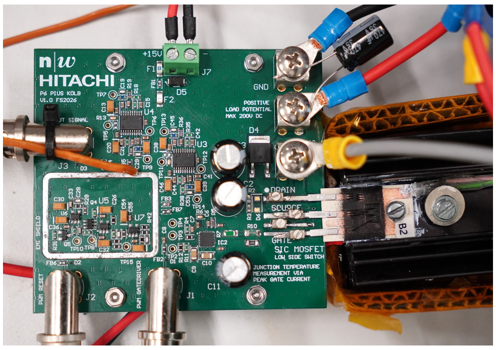
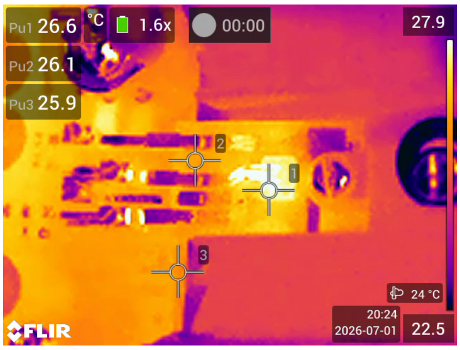
Junction Temperature Measurement

This project investigates a non-invasive SiC MOSFET junction temperature (T_j) measurement method. Various measurements validated the measured peak gate current as a linear and reliable indicator of the T_j.



Measurement PCB with a bare die MOSFET as a DUT



Thermal camera image of a bare die MOSFET during sinusoidal modulation

Problem

The wide adoption of the highly efficient Silicon Carbide (SiC) technology is currently limited by long-term reliability issues. Degradation mechanisms, such as gate-oxide instability and bond wire lift-off, lead to increased internal losses and rising T_j. Precise monitoring of T_j during operation is essential to predict the health state of the MOSFET to prevent failures, e.g. for predictive maintenance of railway traction converters. Existing measurement methods use external sensors placed close to the junction; hence, the result is always only an estimation and not the actual T_j.

Method

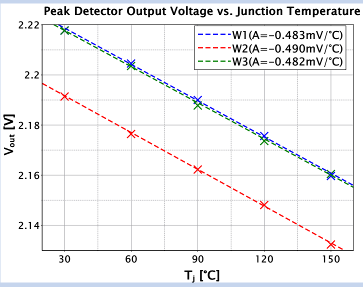
The internal gate resistance (R_{Gint}) is temperature-dependent, resulting in a temperature-dependent peak gate current (I_{Gpeak}). The I_{Gpeak} can be calculated by detecting the peak voltage drop across an external gate resistor with an analog circuit including a difference amplifier and a peak detector. The measurement circuit was integrated into a custom-made measurement PCB. A Python script acquires the output voltage from the connected oscilloscope in every switching cycle of the MOSFET up to 90 kHz.

Measurements

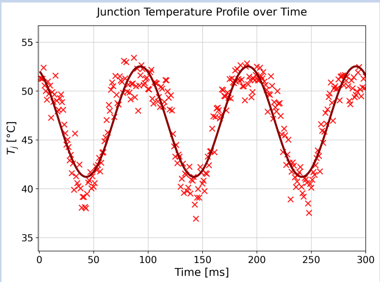
The device under test (DUT) was heated by a heating resistor while switching a drain-to-source current (I_{DS}) up to 12 A. In another configuration, the I_{DS} was modulated as a sine wave, and the T_j profile was recorded. Different MOSFETs have been tested, including a bare die MOSFET without packaging to measure the T_j directly with a thermal camera. A linear dependency between the I_{Gpeak} and T_j was observed. The different MOSFETs have a similar slope but differ in their offset. This requires calibration of each device for accurate T_j estimation.

Results

- DUT: C3M0016120K1 from Wolfspeed (W1, W2, W3 are three MOSFETs of the identical type)
- Linear output voltage sensitivity: $\approx -0.485\,\mathrm{mV\,°C^{-1}}$
- Junction temperature swing during sinusoidal modulation: $\approx 12\,°\mathrm{C}$



W1, W2, W3: T_j sweep 30 °C to 150 °C, $I_{DS} = 0$ A



W1: $f_{sine} = 10$ Hz, $f_{switch} = 1$ kHz, $I_{DS} = 12$ A

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