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Challenges of Junction Temperature Calibration of SiC MOSFETs for Power Cycling – a dynamic Approach

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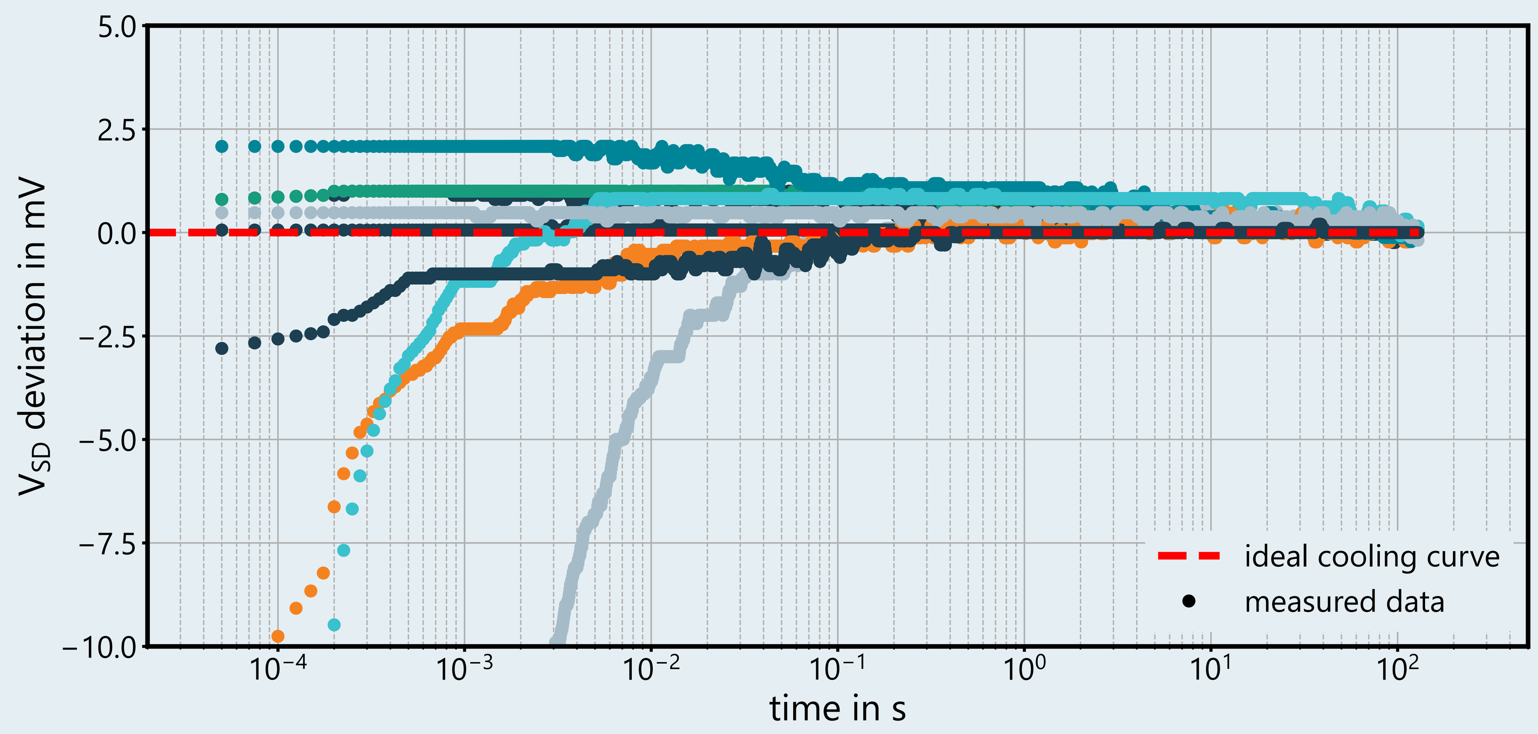
Motivation

For active power cycling tests (PCT) of SiC MOSFETs, the body diodes forward voltage V_{SD} is used as a temperature sensitive electrical parameter (TSEP). Advanced SiC MOSFETs from several manufactures show a transient response of V_{SD} after a gate bias switch, although a constant temperature is present. Using conventional static temperature calibration, this effect leads to a calculation error of T_{vj} in the range of 10 K close to the beginning of the cooling phase. As a critical parameter in PCT, this value lies outside the *AQG 324* specification [1] and might lead to an overestimation in lifetime prediction.



V_{SD} vs. time after gate bias switch of recent SiC MOSFETs from ten different manufactures at constant temperature

Novel dynamic calibration method

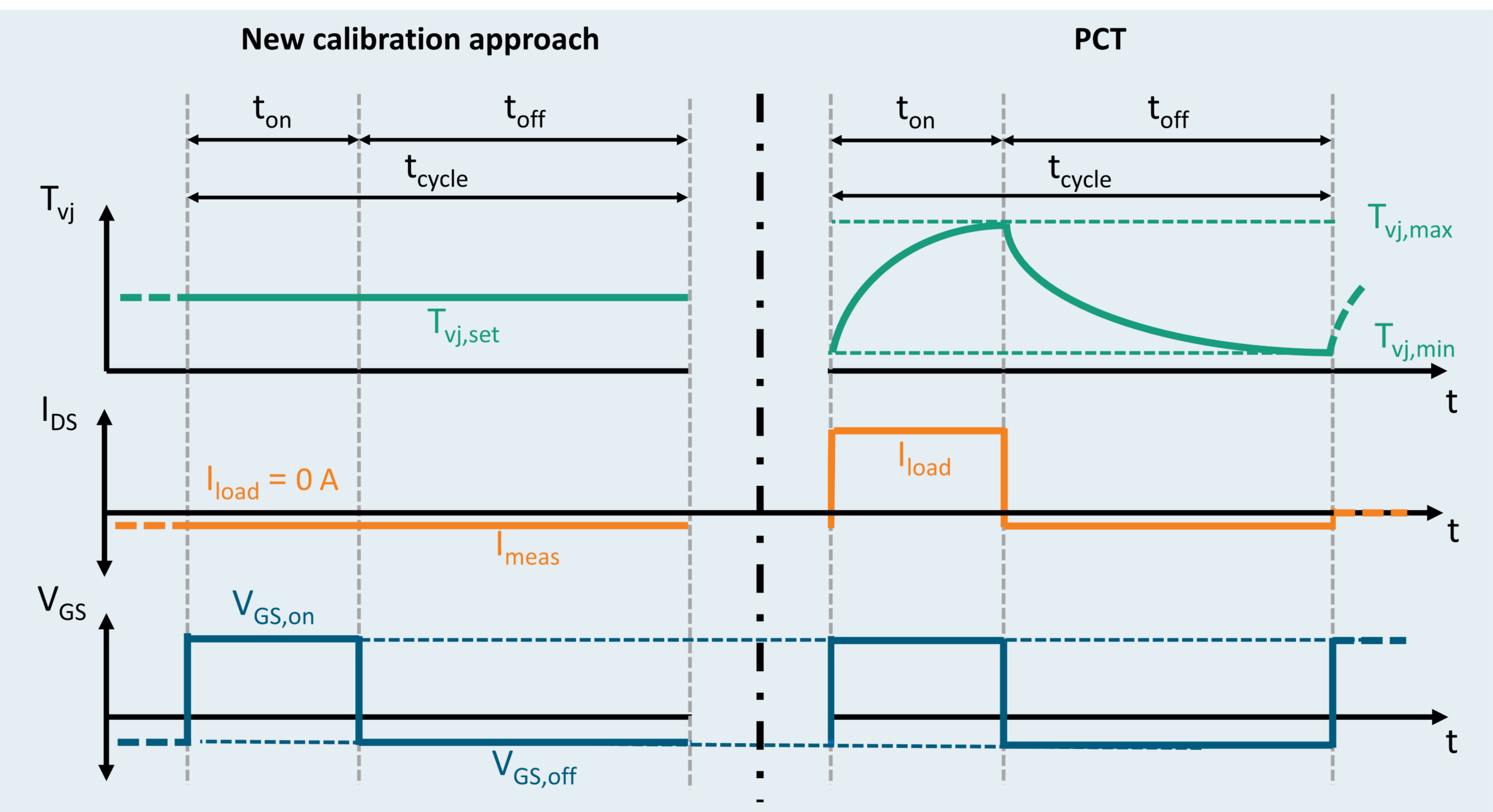
To account for the observed transient effect, time as a variable is included for the calibration. V_{SD} is measured at several temperatures T and fixed discrete time steps t_i, corresponding to those in the cooling phase yielding $V_{SD}(t_i)|_T$

Step 1: Apply the measurement current I_{meas}

Step 2: Apply the first temperature with V_{GS} = 0 V applied to the device and wait for thermal equilibrium state

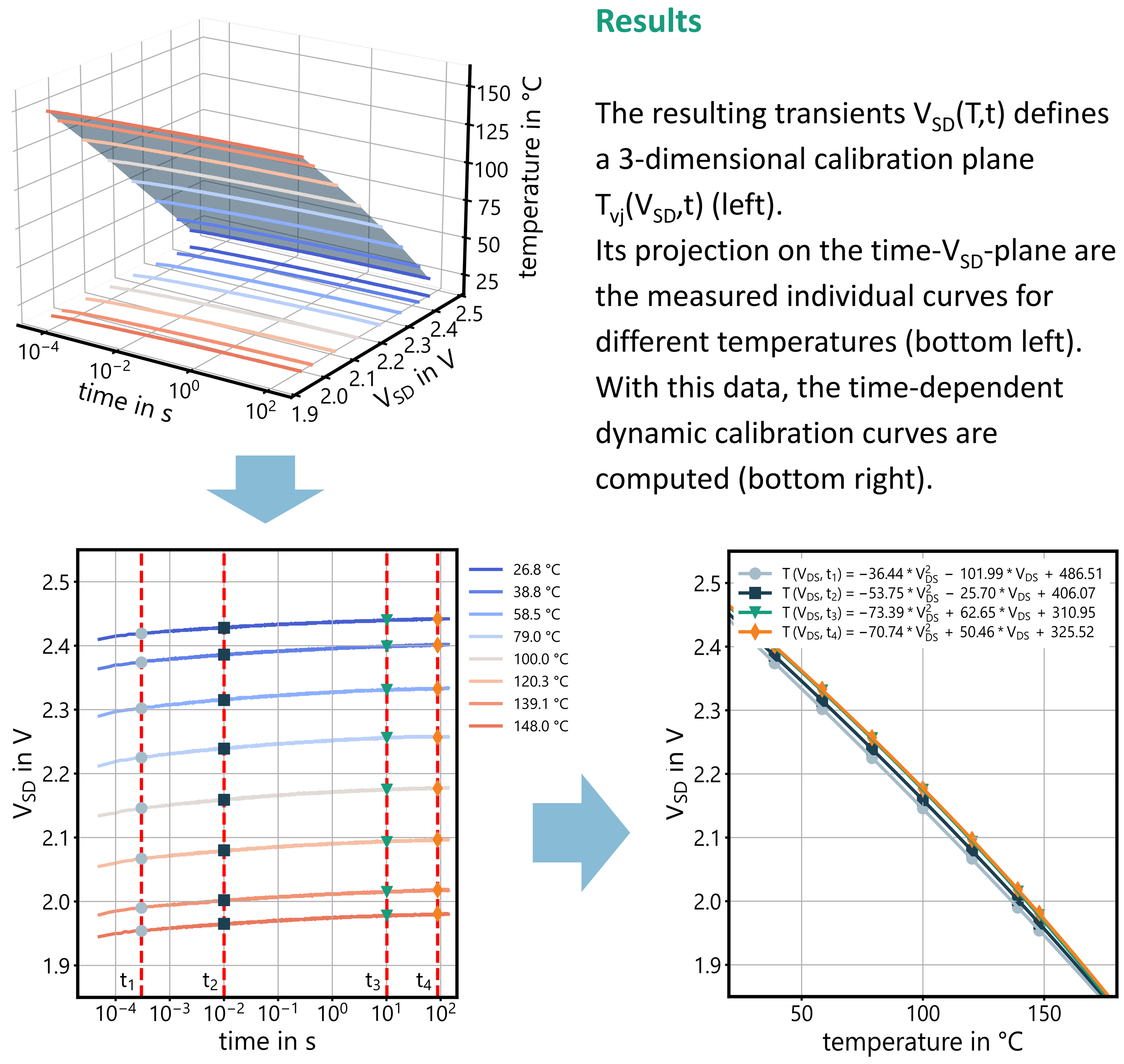
Step 3: Perform a power cycle with I_{load} = 0 A as described in figure below. Run as many cycles as needed to reach a steady state operating point

Step 4: Set the next temperature level while V_{GS} = 0 V and repeat with step 3 until all temperature levels are done



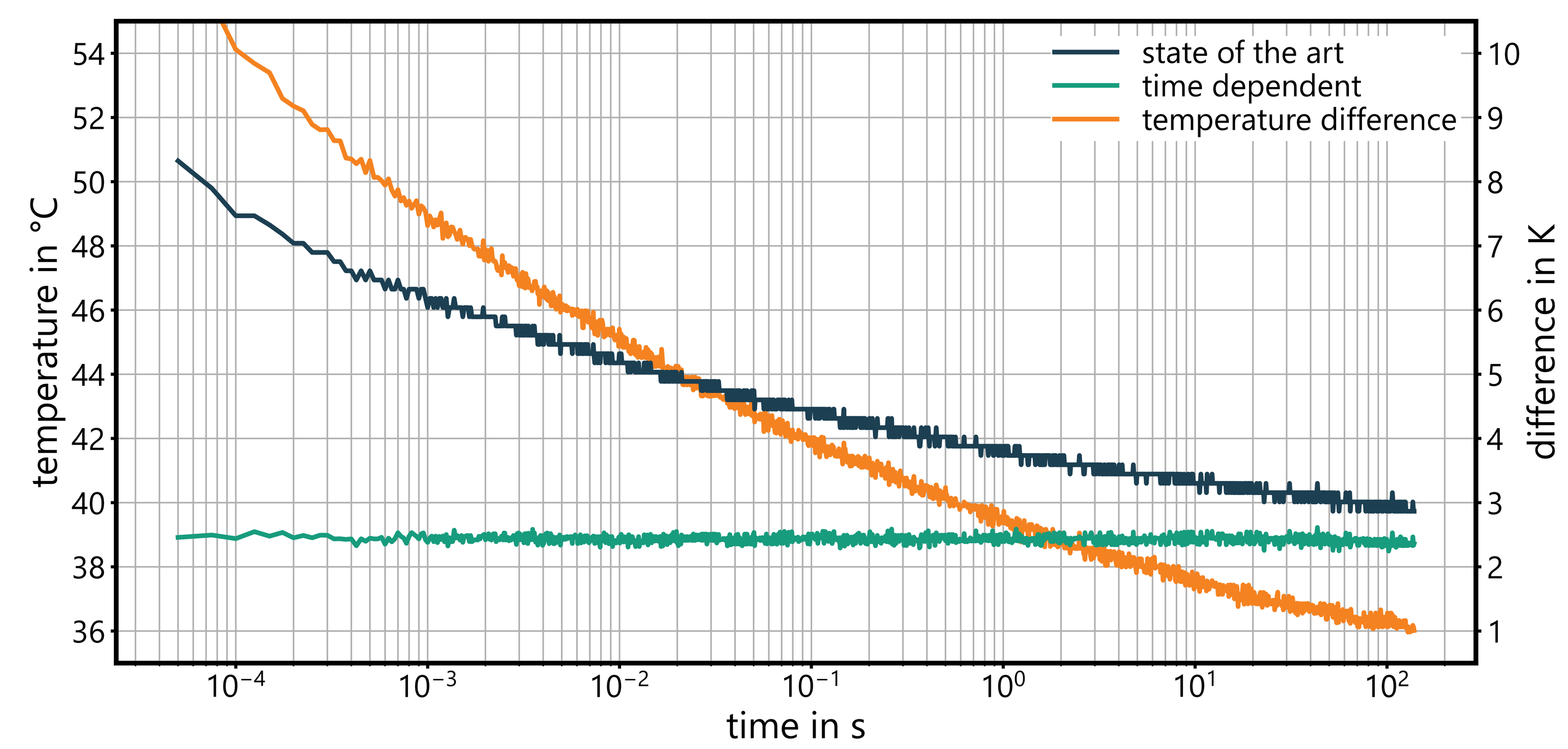
Results

The resulting transients $V_{SD}(T,t)$ defines a 3-dimensional calibration plane $T_{vj}(V_{SD},t)$ (left).
Its projection on the time-V_{SD}-plane are the measured individual curves for different temperatures (bottom left).
With this data, the time-dependent dynamic calibration curves are computed (bottom right).



Comparison of different calibration methods

The new method is suitable to compensate the transient behavior and the calculation error of approx. 10 K. The resulting cooling curve is flat as expected for a cycle with no applied load current and therefore no temperature change.



Conclusion and Outlook

- Novel dynamic temperature calibration can reduce the temperature calculation error in the cooling phase of PCT
- Resulting matrix $V_{SD}(T,t)$ with discrete values for each time step
- Further investigation on the impact of I_{load}, I_{meas}, $V_{GS,on/off}$, settle time as well as the cause of the transient effect and therefore the underlying semiconductor physics is needed

[1] *ECPE Guideline AQG 324: Qualification of Power Modules for Use in Power Electronics Converter Units in Motor Vehicles*, 03.1/2021, ECPE European Center for Power Electronics e.V., May. 2021