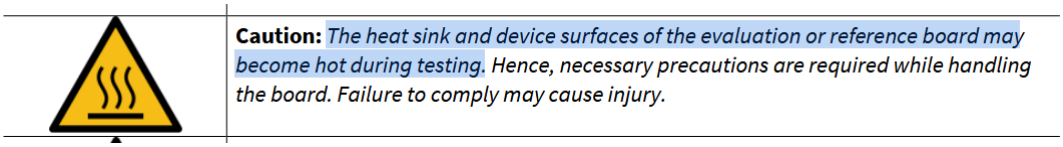
# 9 kg of "Trivial Pursuit"?

As an expert in PCB thermal management, I am always interested in posts featuring “Cool” and “Heat.” I read the post

https://www.linkedin.com/posts/bodo%C2%B4s-power-systems_powerelectronics-mosfet-solarenergy-activity-7341377481674752004-jAbp?utm_source=share&utm_medium=member_desktop&rcm=ACoAAB6UQegBCzzz-Ho-G88xGrvs4p7g_N6JCgM

with great interest and now want to shed some light on the thermal details.

This is our object



**Caution:** *The heat sink and device surfaces of the evaluation or reference board may become hot during testing. Hence, necessary precautions are required while handling the board. Failure to comply may cause injury.*

Figure 2 shows the completely assembled 6 kW HERIC reference design.

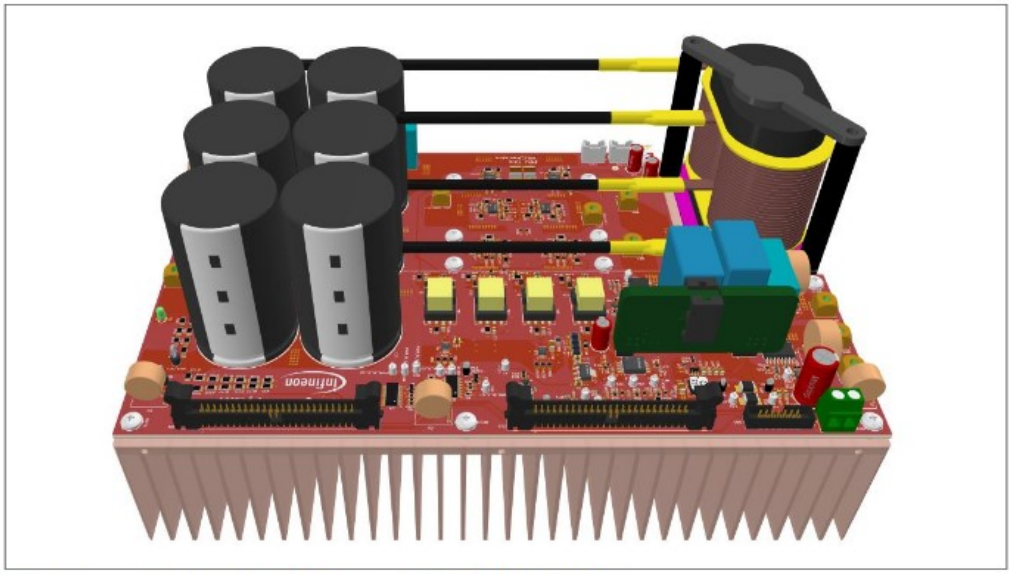


**Figure 2 Power conversion reference design REF-6KWHERIC**

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I obtained the Altium™ design files, the datasheet[1] (IMDQ75R016M1H), and the User Guide[2] (UG030541) ("UG") from Infineon.

## Datasheet:

### 2.1.1 Switching devices

The inverter stage is designed with the CoolSiC™ Power Device G1 MOSFET products IMDQ75R016M1H.

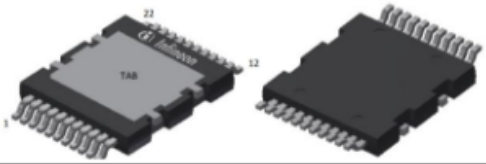


**Figure 8 IMDQ75R016M1H**

IMDQ75R016M1H belongs to the CoolSiC™ Power Device 750 V G1 family. The 750 V CoolSiC™ MOSFET offers excellent performance in this design due to its low switching losses, stable conduction loss overtemperature, and ease of thermal management. It is an ideal part for hybrid inverter applications which are typically passive cooled and sealed from the environment.

**Table 3 Thermal characteristics**

| Parameter | Symbol | Values | | | Unit | Note / Test Condition |
|---|---|---|---|---|---|---|
| | | Min. | Typ. | Max. | | |
| Thermal resistance, junction - case | $R_{th(j-c)}$ | - | - | 0.39 | °C/W | Not subject to production test. Parameter verified by design/characterization according to JESD51-14. |

## User Guide:

**6 kW HERIC reference design user guide**
**REF-6KW HERIC design for solar photovoltaic solutions**
**Board layout**

### 5 Board layout

### 5.1 REF-6KWHERIC

**Table 11 Mechanical data**

| | |
|---|---|
| **Dimensions** | 250 mm x 155 mm |
| **No. of layers** | 6 |
| **Copper thickness** | 77.36 mil |
| **Weight** | 9.02 kg |

[1] www.infineon.com/dgdl/Infineon-IMDQ75R016M1H-DataSheet-v02_00-EN.pdf
[2] https://www.infineon.com/assets/row/public/documents/24/44/infineon-ref-6kwheric-usermanual-en.pdf

The geometric model of the assembly can be generated quickly and reliably from the Altium™ files using our software[3] in just two clicks. Finding the thermal conditions, however, is more work.

Quote: "This reference design is not a qualified and certified commercial product."

My goal is to make you aware of typical thermal issues. I want to reproduce the reported measurements via simulation.

## Data:

- In Fig. 2 of the UG, four prominent yellow blocks are visible. These are **not MOSFETs** but **transformers**.
- The six CoolSiC MOSFETs are located on the **bottom side of the board**.
- These CoolSiCs are optimized for **top-side cooling** (Rth_JC = 0.39 K/W, datasheet).
- Therefore, there are **no thermal vias**.
- A **9 kg (!) finned heatsink** is mounted on the bottom side to absorb heat from the component surfaces.
- The UG does not mention whether the heatsink baseplate is specially shaped or adapted, nor what type of thermal adhesive is used.
- The advantage of CoolSiC: "Using SiC MOSFETs enables switching at a higher frequency, resulting in a significant reduction in … heatsink size."
- To calculate anything related to temperature, we need the **power losses**. Unfortunately, the UG does not provide the watts generated by the CoolSiCs. It's a pity that the UG only focuses on electrical details!
- From a 6 kW line with ~98.5% efficiency, I assume losses of approx. 90 W (Tab. 8 @ 380 V), which I distribute evenly across Q1, Q2, Q3, and Q4.

[3] TRM3. www.adam-research.com

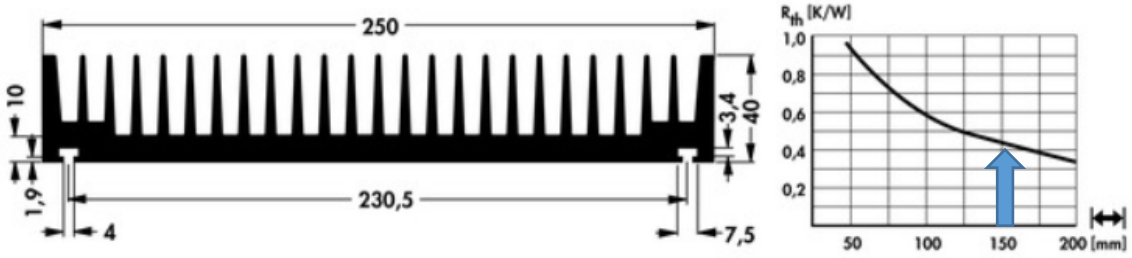
**Table 8 DC input voltage range**

| | |
|---|---|
| **Input voltages** | 380 $V_{DC}$, 445 $V_{DC}$, and 510 $V_{DC}$ |
| **PWM** | 50 kHz |
| **Output power** | 6 kW, $V_{out}$=230 $V_{rms}$/ 50 Hz |

**Table 9 Test data**

| Input voltage ($V_{dc}$) | Input Current ($A_{dc}$) | Input Power (kW) | Output Voltage ($V_{l\text{-}l\,rms}$) | Output Power (kW) | Output Current ($A_{rms}$) | PF | iTHD | Efficiency |
|---|---|---|---|---|---|---|---|---|
| 380 | 16.13 | 6.09 | 231.6 | 6.0 | 25.94 | 0.9993 | 1.62 | 98.65 |
| 445 | 13.79 | 6.1 | 230 | 6.0 | 26.14 | 0.9994 | 1.766 | 98.5 |
| 510 | 12.02 | 6.1 | 230 | 6.01 | 26.14 | 0.9992 | 1.764 | 98.45 |

- The contributions of other components is unknown and is not included in the calculation model. It would be useful to know how many watts Q5 and Q6 contribute.
- From Fig. 2 UG, I estimate the heatsink dimensions to be **width 250 mm, length 150 mm, height 40 mm**.
- From Fischer Elektronik GmbH catalog, I select **SK91 75 AL**[4] (unoxidized, suitable for outdoor installation) with these dimensions, giving an $R_{\Theta}$ of ≈ 0.4 K/W at 150 mm length.




[4] https://www.fischerelektronik.de/web_fischer/de_DE/VA/SK91150SA/datasheet.xhtml

## Measurements:

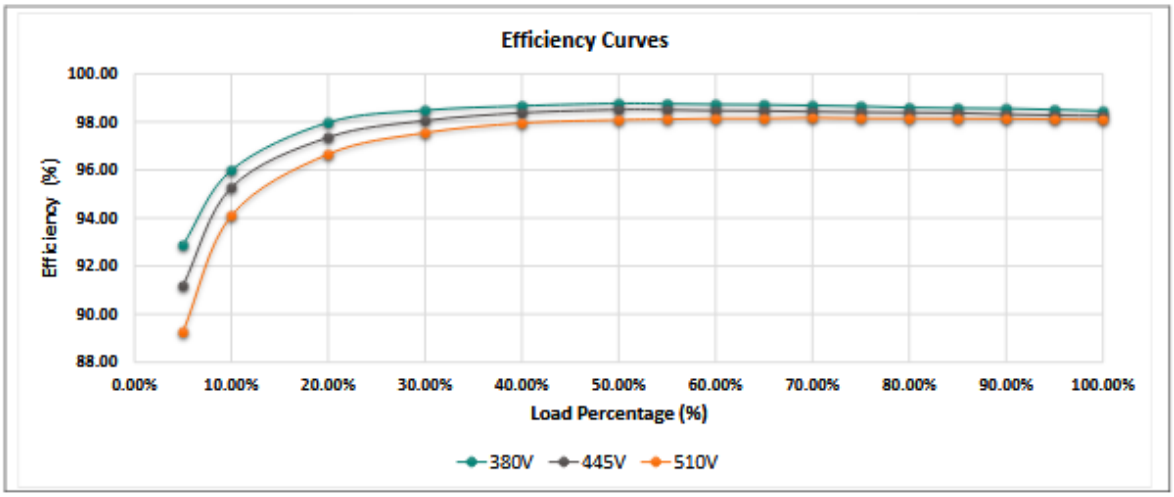



**Figure 52** **Efficiency of the inverter power stage**

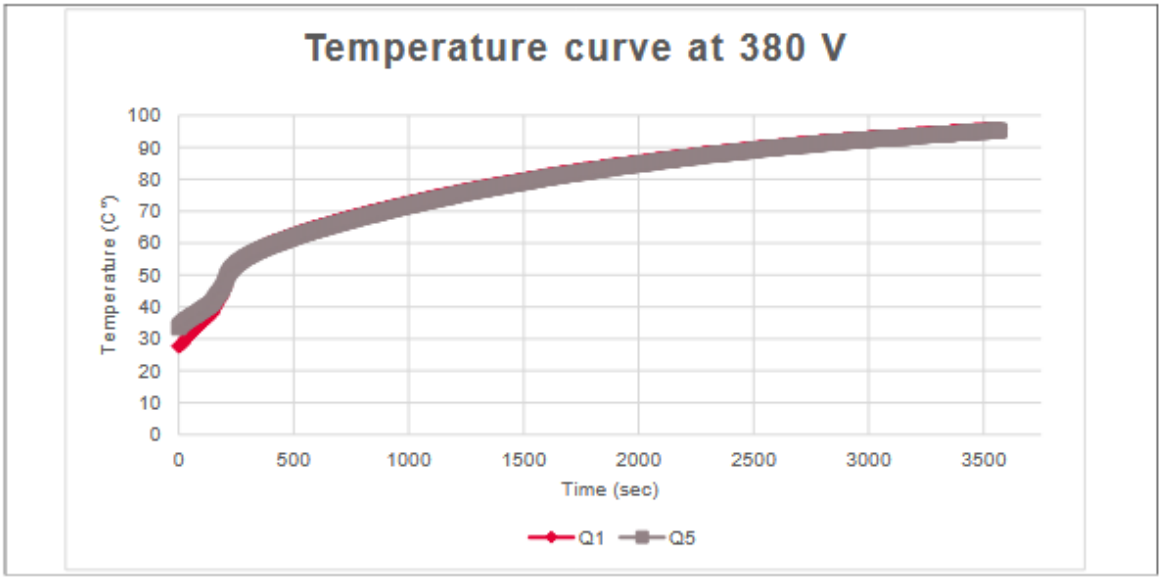



**Figure 53** **Temperature curves at 380 V**

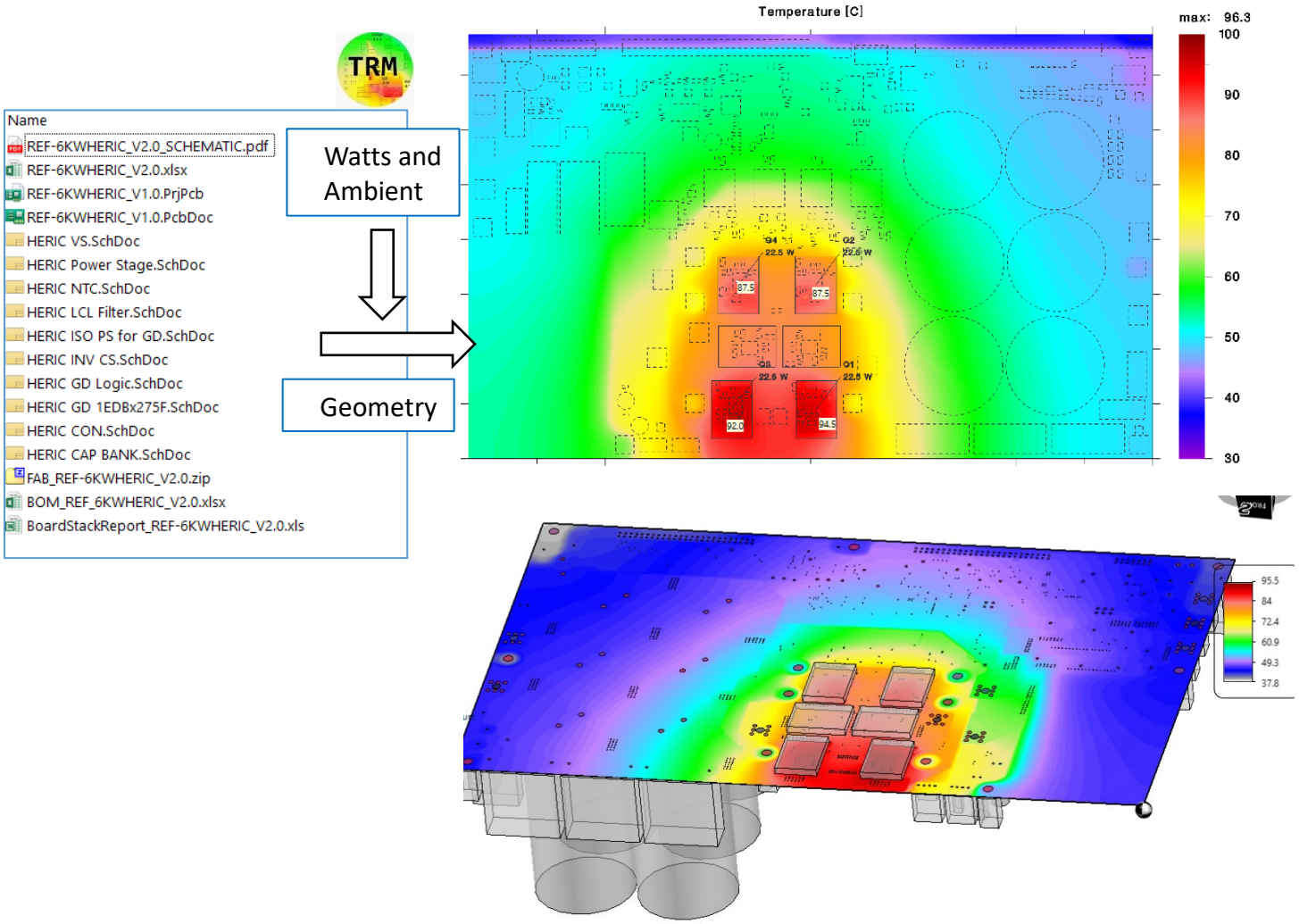
- The UG does not show how or where measurements were taken.
- Fig. 53: Measured temperature is approx. 100 °C in steady state @ 380 V.
- Fig. 53: Ambient temperature appears to be approx. 30 °C.

## Simulation results:

- TRM simulation results for temperature are around 90 °C:
  - Q1: 93 °C
  - Q2: 85 °C
  - Q3: 94 °C
  - Q4: 86 °C

Not bad at all, considering the many assumptions and the fact that not all heat sources are known and are not included.

- Q1 and Q3 are too close to the edge of the heatsink. It's generally recommended to position the hottest components as centrally as possible.



## Summary:

- The temperature of the CoolSiCs strongly depends on the effectiveness of the heatsink.
- Therefore, the UG should also provide better information about the thermal losses of the circuit.
- If the assembly is to weigh less than 9 kg, alternatives like a fan or water cooling should be considered.

Trivial pleasure? For me, it was real.

For more information:

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