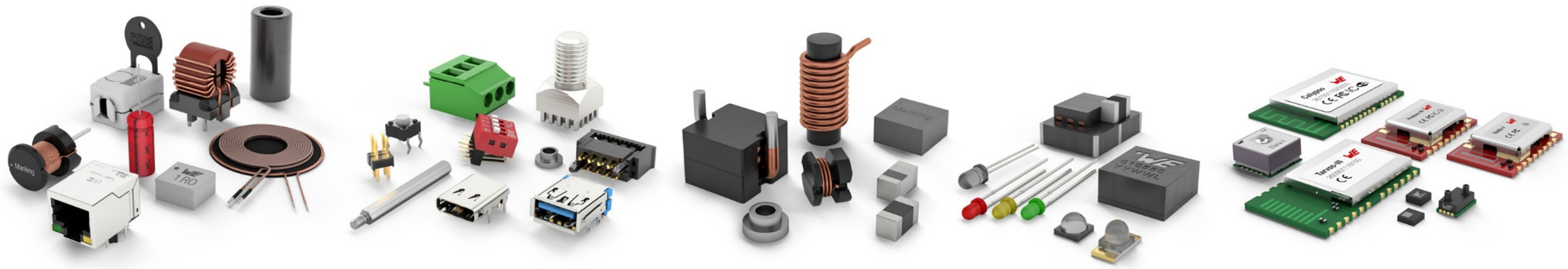

EMC CHALLENGES WITH THERMAL INTERFACE MATERIALS

Raf Vleugels

ENERGY STORAGE

Power Electronics & Energy Storage event

27 juni 2023 | 1931 Congrescentrum 's-Hertogenbosch

THE WÜRTH ELEKTRONIK GROUP

Employees: 8,000
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Agenda

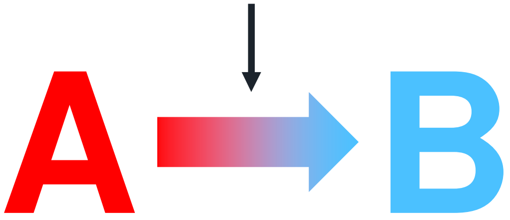
EMC challenges with thermal interface materials

- Introduction thermal management
- Application example
- EMI aspects
- LTSpice simulations
- Summary
- Q&A

Introduction

The Strategies

Thermal Management Solutions



Heating Element

- One hot component
- Multiple hot components
- Back side of a PCB
- Processing units
- Transistors, IGBTs
- Memory ICs
- Battery cells
- …

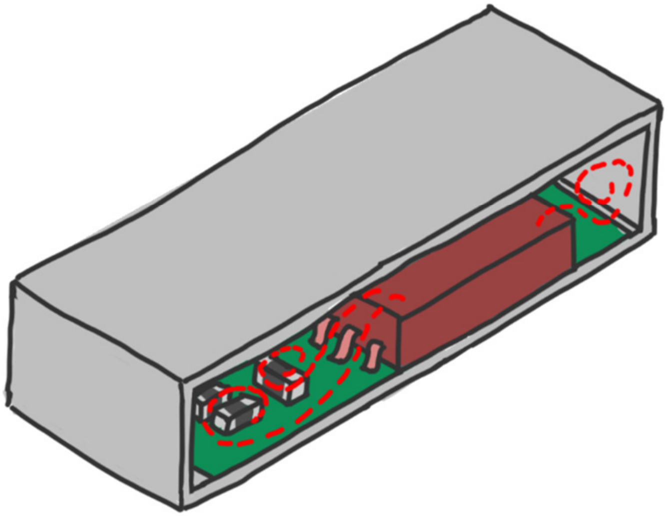
Cooling Assembly

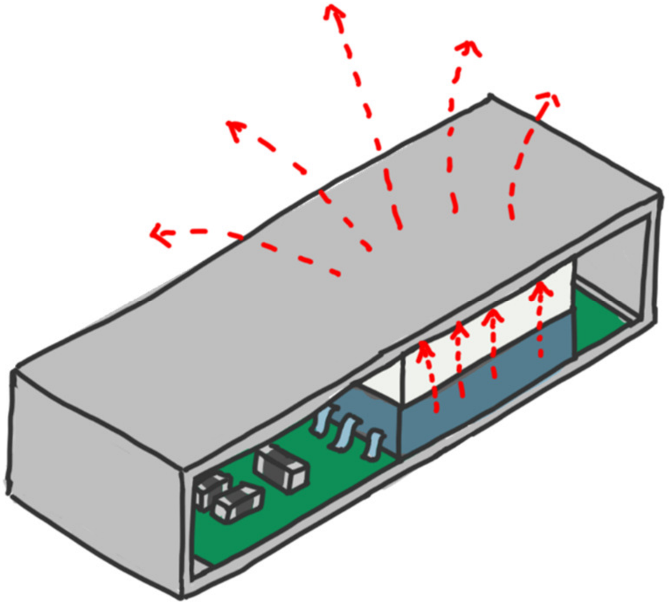
- Heatsink
- Metal housing
- Cooling plate
- Radiator
- …

Introduction

The Strategies

- Vertical heat transportation, realized by **thermal interface materials** (TIM) or **gap fillers**

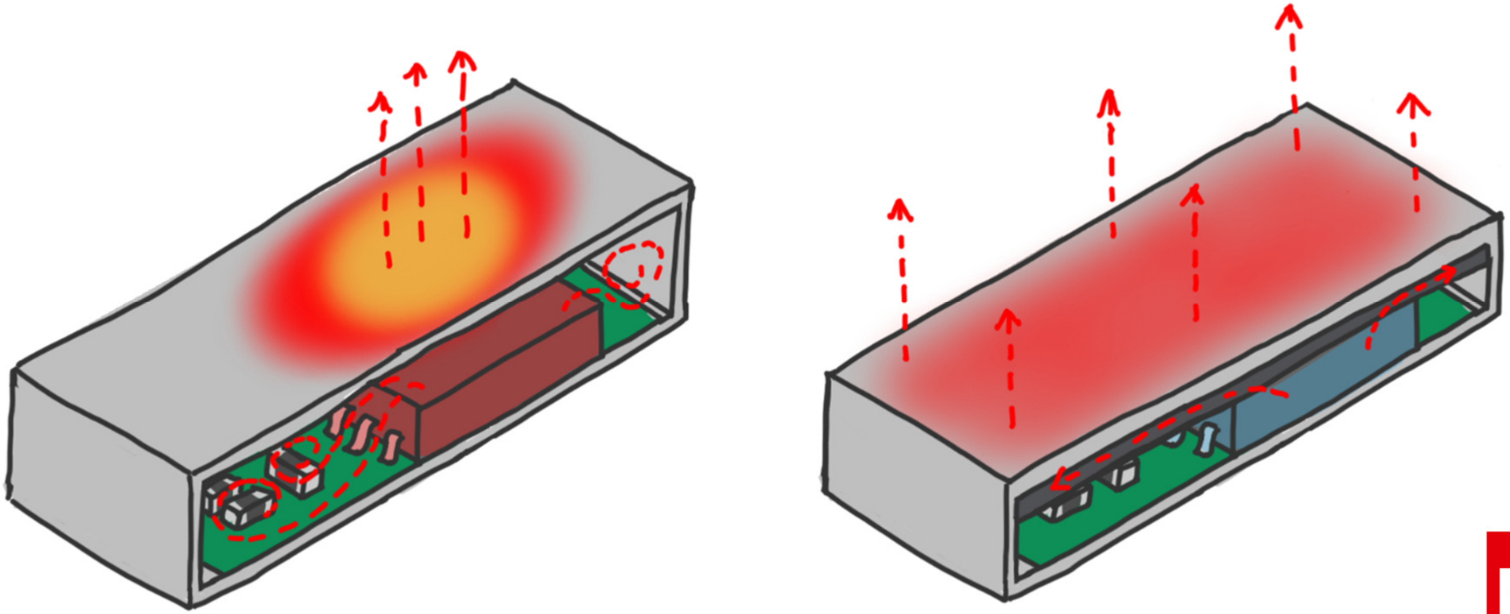




Introduction

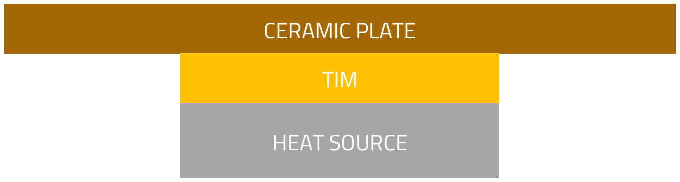
The Strategies

- Horizontal heat transportation, realized by **heat spreaders**



Application Example

Heat Spreader to enhance *Heat Spreading*

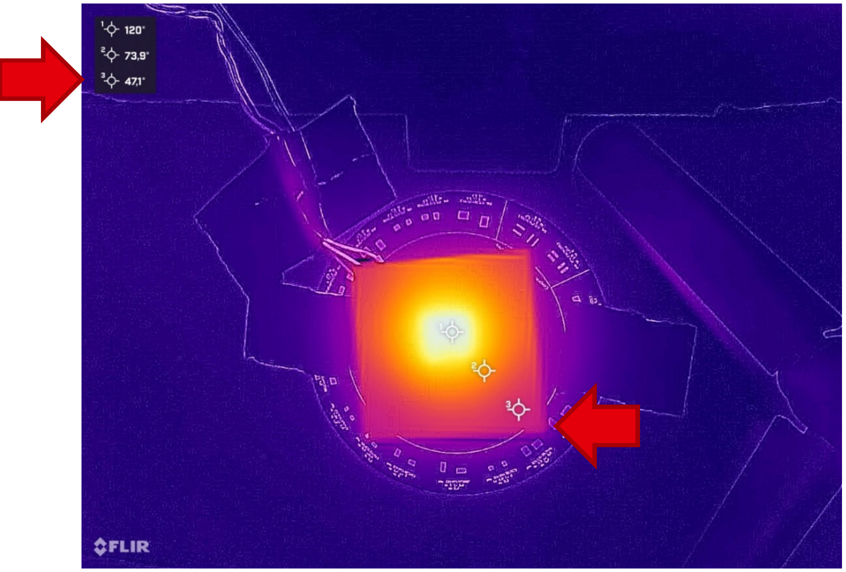


CERAMIC PLATE

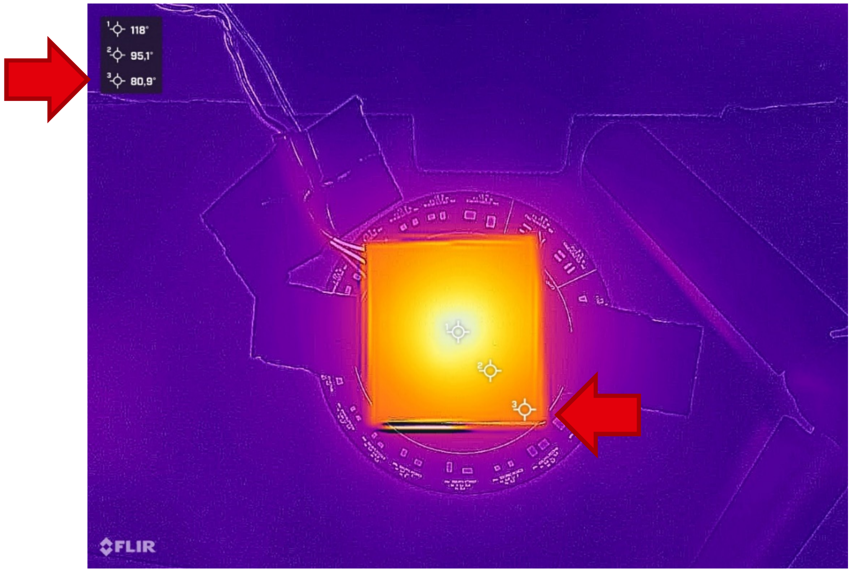
TIM

HEAT SOURCE

Without heatspreader



With heatspreader)

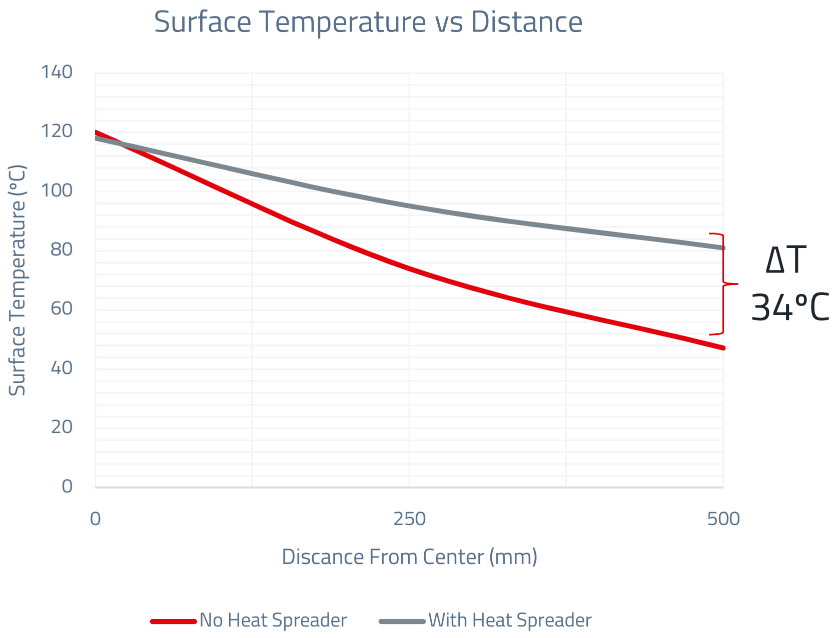


*Both images have been scaled as follows: 120°C (max), 20°C (min)

Application Example

Heat Spreader to enhance *Heat Spreading*

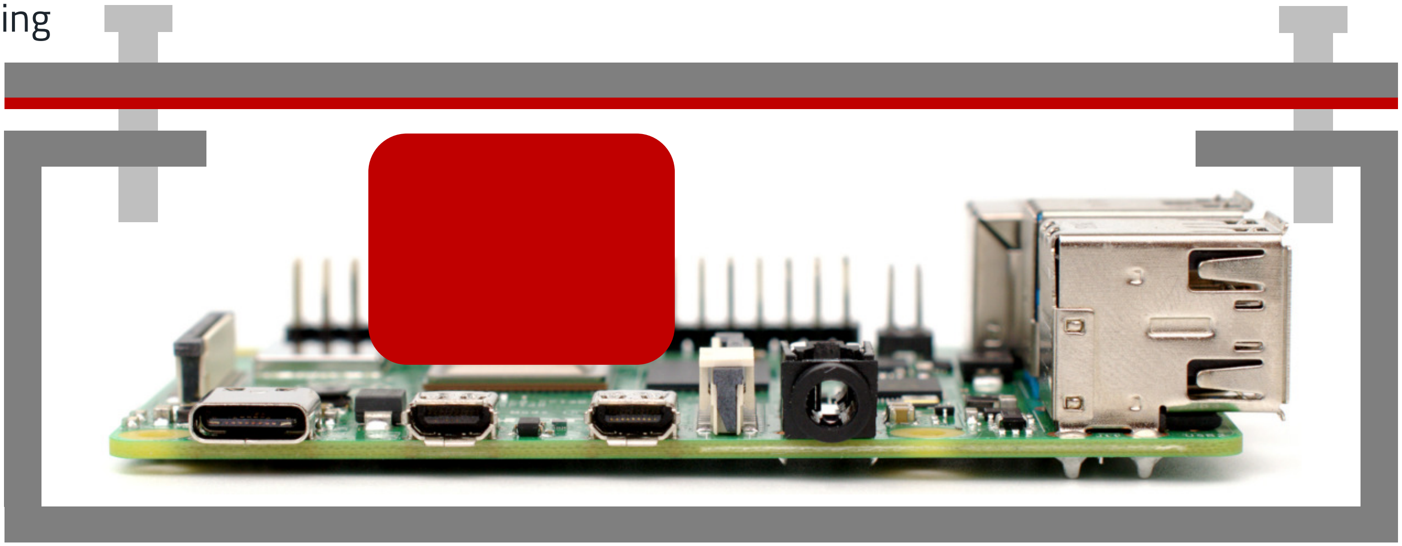
- By applying the heat spreader the temperature vs distance gradient is reduced.
- Larger hot surface is directly related to higher thermal transfer to cooling assembly
- Actual transfer value would require simulation



Application Example

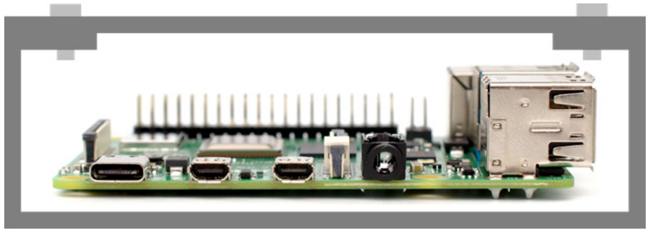
Finding the optimal solution to cool an embedded system

- Thermal Interface Materials & Heat Spreaders can **both** work together to tackle thermal issues
- We will evaluate different combinations of TIMs and Heat Spreaders to find the optimal solution
- Raspberry Pi in a box scenario, how we measure the effect of the TIMs:
  - CPU Temperature
  - CPU Clock Speed → Nominal is 1800 MHz, any decrease implies that the CPU is decreasing speed to avoid overheating

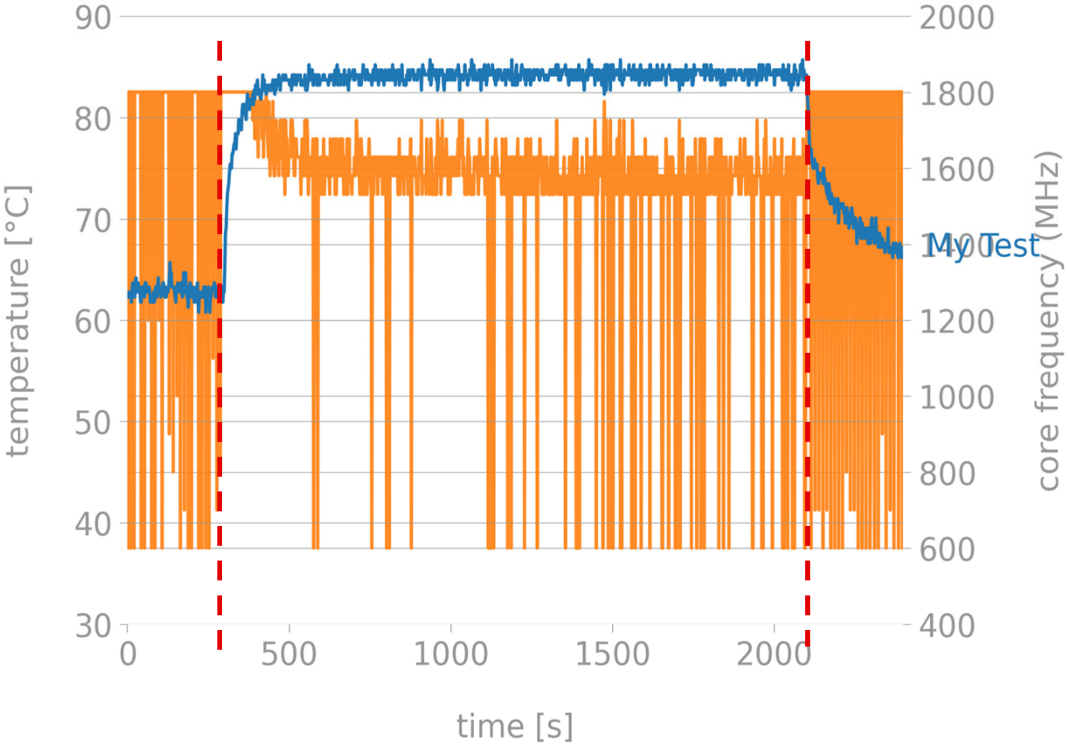


Application Example

Finding the optimal solution to cool an embedded system



- Benchmark - no thermal interface materials or Heat Spreaders

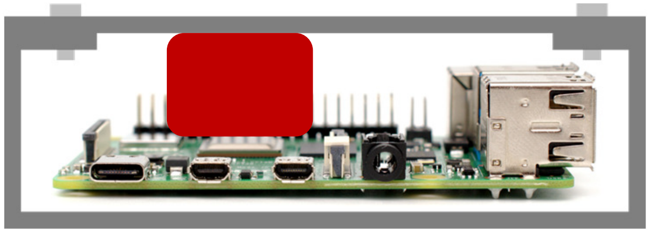


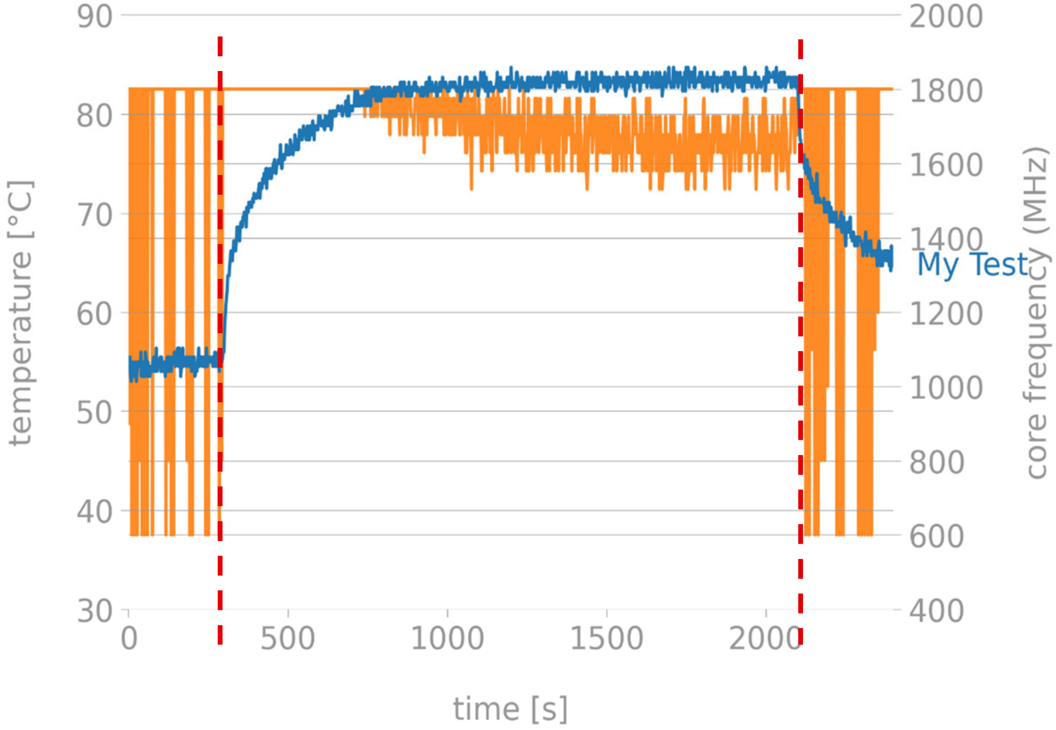
20% Thermal Throttling
Max CPU Temp: 85°C

Application Example

Finding the optimal solution to cool an embedded system

- Applying a thermal interface material for vertical heat transportation



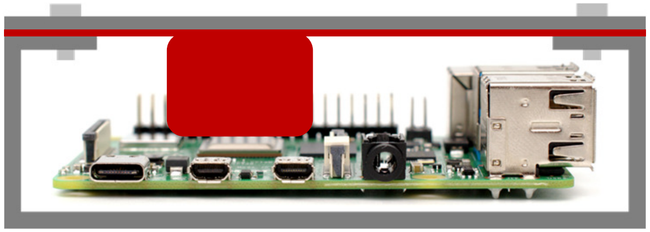


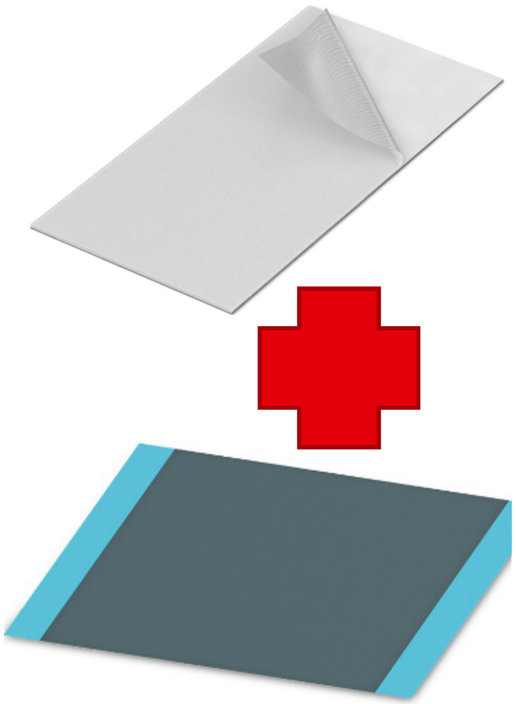
15% Thermal Throttling
Max CPU Temp: 85°C

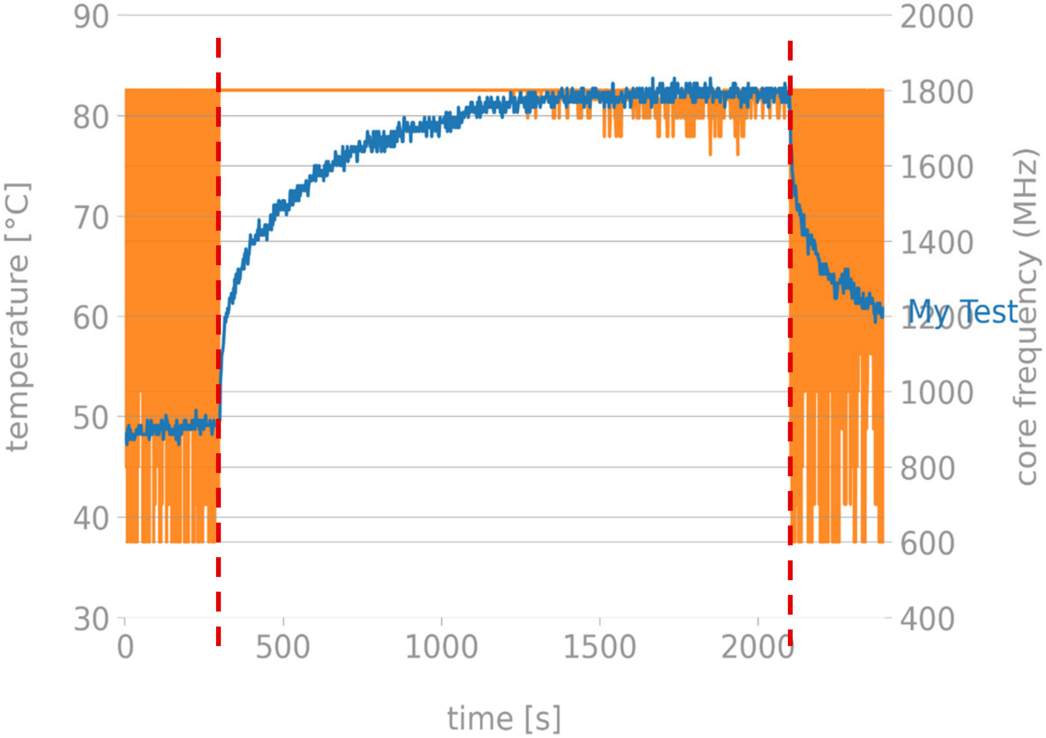
Application Example

Finding the optimal solution to cool an embedded system

- Adding a heat spreader for horizontal heat transportation





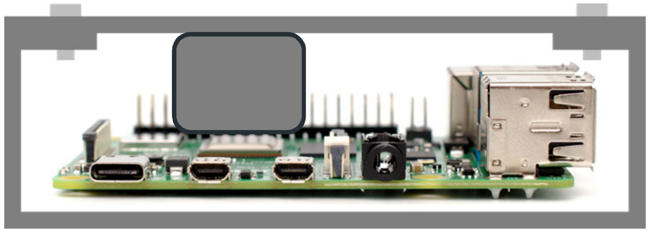


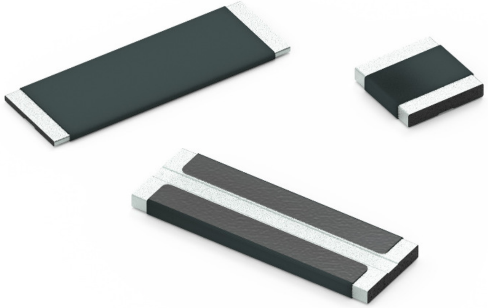
5% Thermal Throttling
Max CPU Temp: 85°C

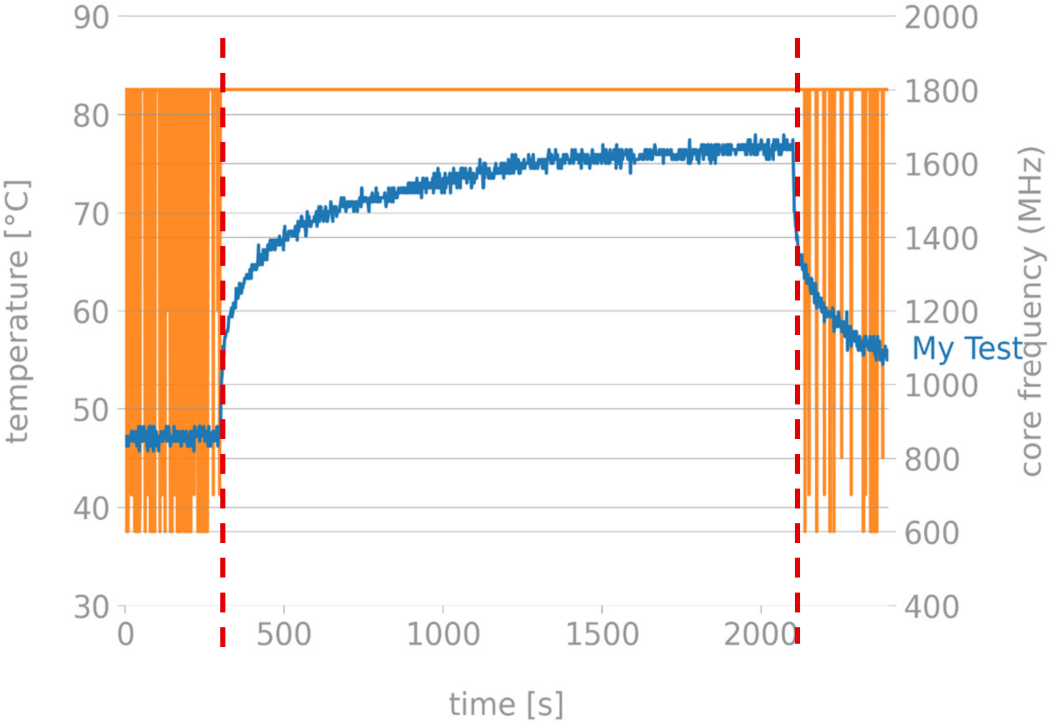
Application Example

Finding the optimal solution to cool an embedded system

- Improving vertical heat transportation without heat spreader
- Silicon free



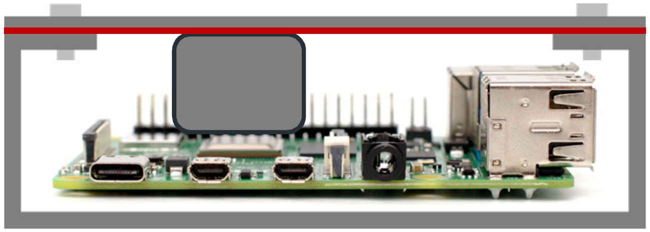




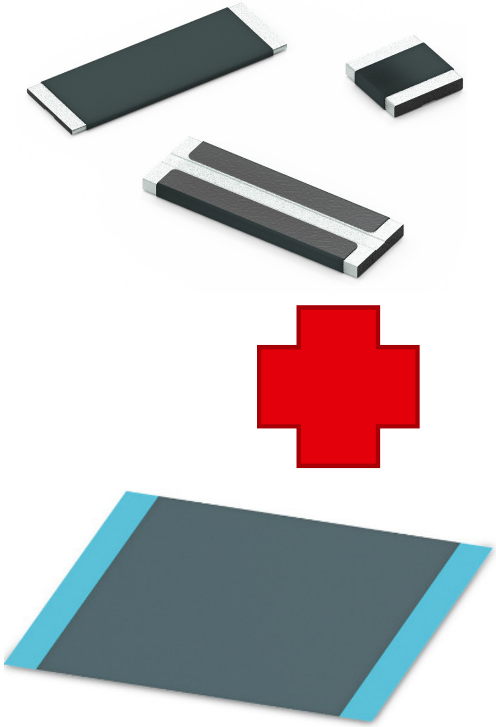
0% Thermal Throttling
Max CPU Temp: 76°C

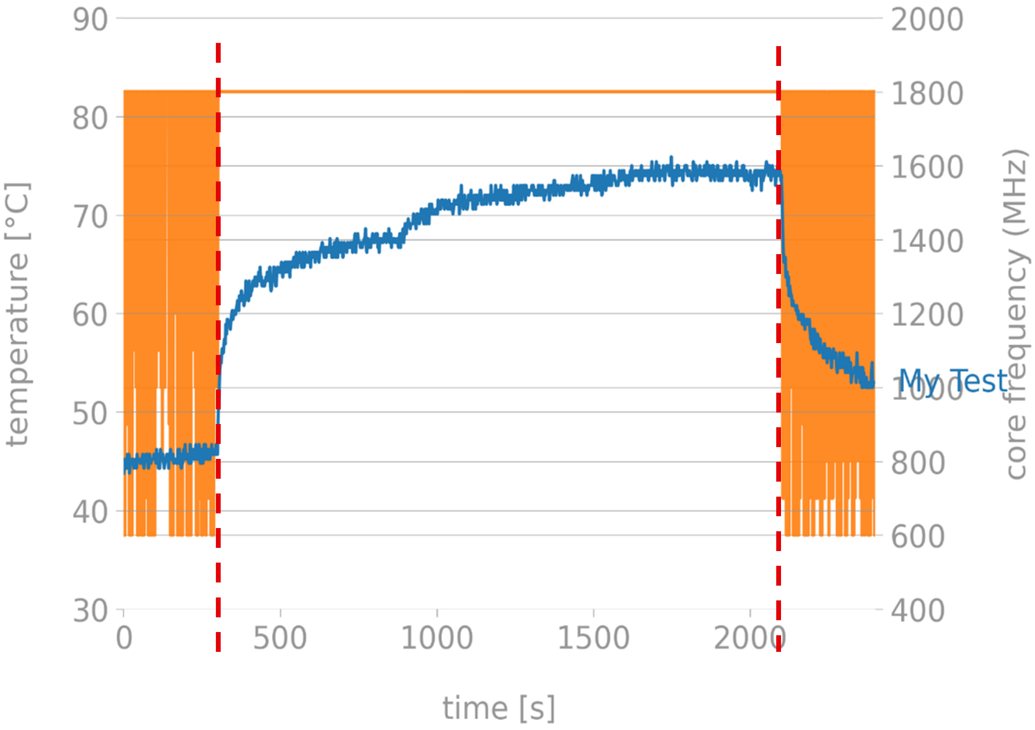
Application Example

Finding the optimal solution to cool an embedded system



- Adding a heat spreader for horizontal heat transportation





0% Thermal Throttling
Max CPU Temp: 74°C

Application Example

Finding the optimal solution to cool an embedded system

- Summary:

	No TIMs	No Heat Spreader		Heat Spreader	
		WE-TGF	WE-TGFG	WE-TGF	WE-TGFG
Max. CPU Temperature	85°C	85°C	76%	85°C	74°C
Thermal Throttling	20%	15%	0%	5%	0%

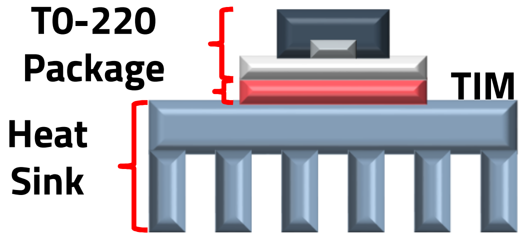
EMI Aspects

Thermal Performance versus EMI

Thermal

- Thinner TIM = Better thermal performance
  - Please make sure TIM is thick enough to fill the gap

$$R_{th} = \frac{l}{\lambda \cdot A} = \left[\frac{K}{W}\right]$$



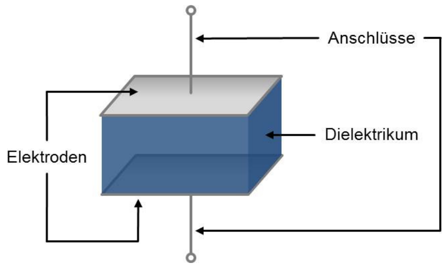
$$\Delta T = Temperature\ difference[K]$$

$$\lambda = Thermal\ conductivity\left[\frac{W}{m.K}\right]$$

EMI

- Thicker TIM = Better EMI performance (less CM noise)

$$C = \varepsilon_0 * \varepsilon_r * \frac{A}{l}$$

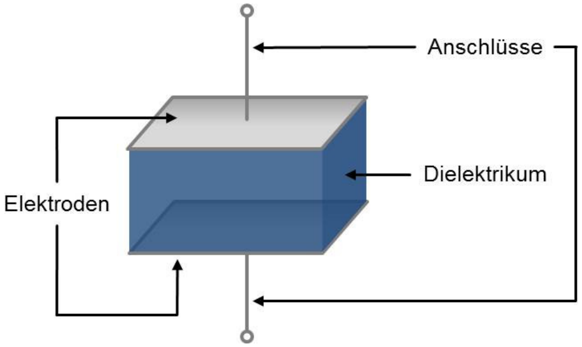


$$l = Material\ thickness[m]$$

$$A = Cooling\ overall\ surface[m^2]$$

EMI Aspects

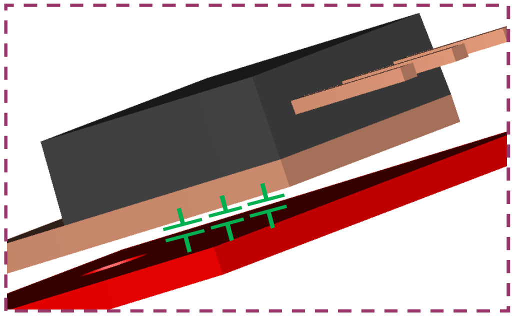
Parasitic Capacitance



Example: TO220 with TIM WE-PCM 1,6W/m*K

$$C = \varepsilon * \frac{A}{d} = \varepsilon_0 * \varepsilon_r * \frac{A}{d}$$

C – Capacitance [F]
A – plate area [m]
d – plate distance [m]
εr – relative permittivity TIM
ε0 –absolute permittivity : $8{,}85 \times 10^{-12} [\frac{As}{Vm}]$



Example for TO220 10x10mm (TIM d=0,2mm):

$$C_{para} = \frac{1 \cdot 10^{-4} m^2}{0{,}2 \cdot 10^{-3} m} \cdot 8{,}85 \cdot 10^{-12} \left[\frac{A \cdot s}{V \cdot m}\right] \cdot 4 = \mathbf{18pF}$$

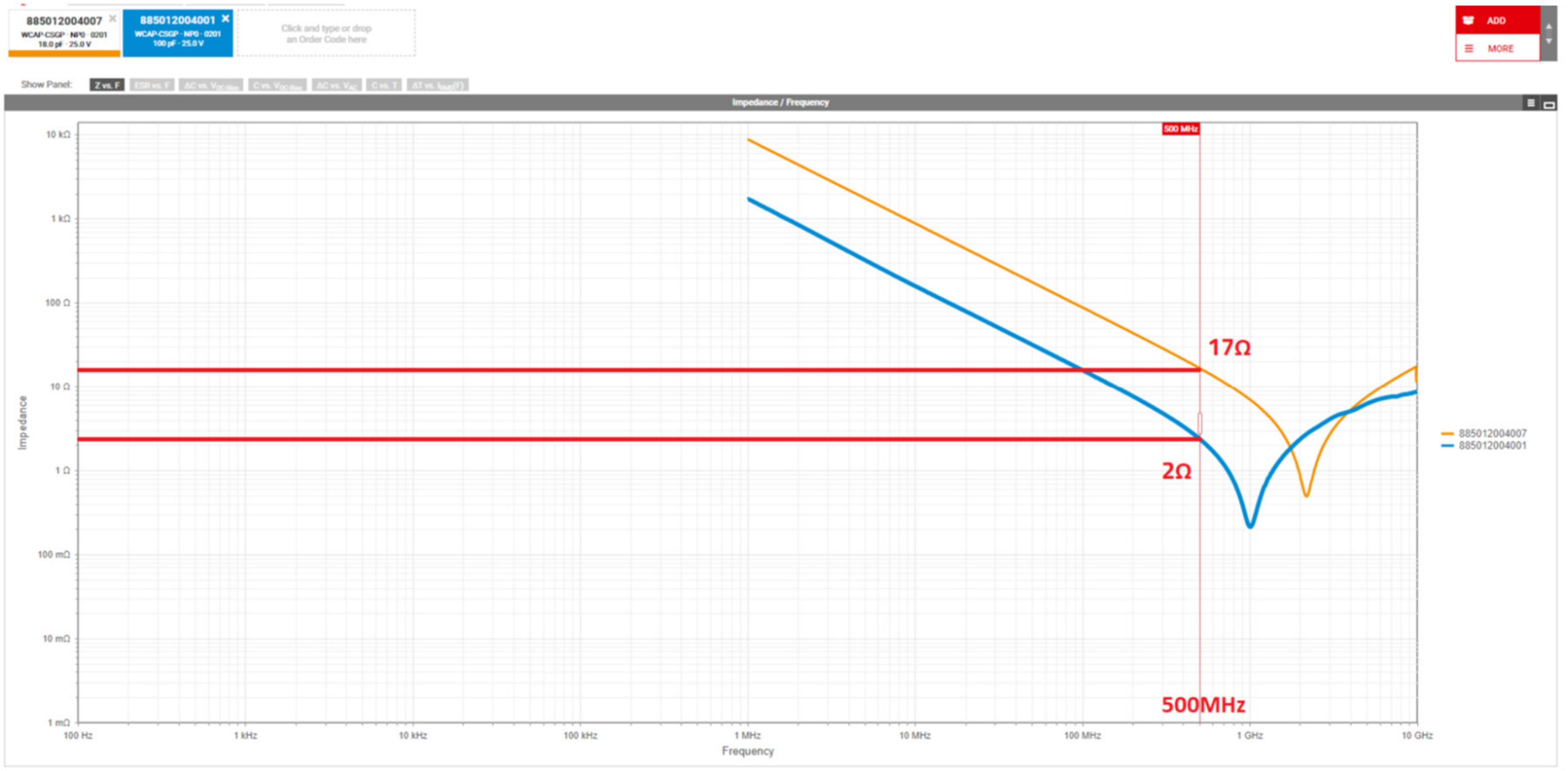
$$I_{cm} = C_{TIM} \cdot \frac{\Delta V}{\Delta t}$$

- 10mmx10mm cooling surface & 0,2mm thick TIM

EMI Aspects

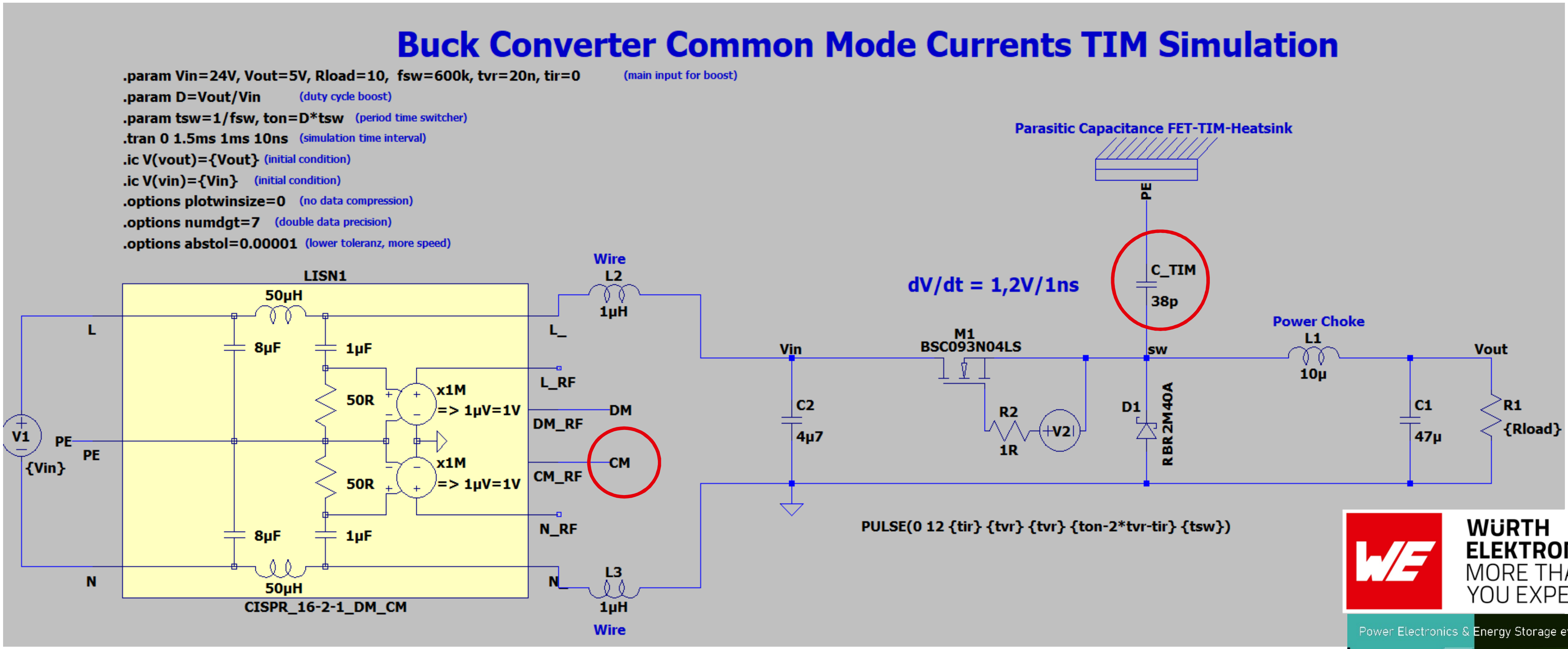
Parasitic Capacitance

- https://we-online.com/re/5o7RrAiN - 18pF / 100pF



EMC Aspects

LTspice Model for Common-mode Noise Level Prediction

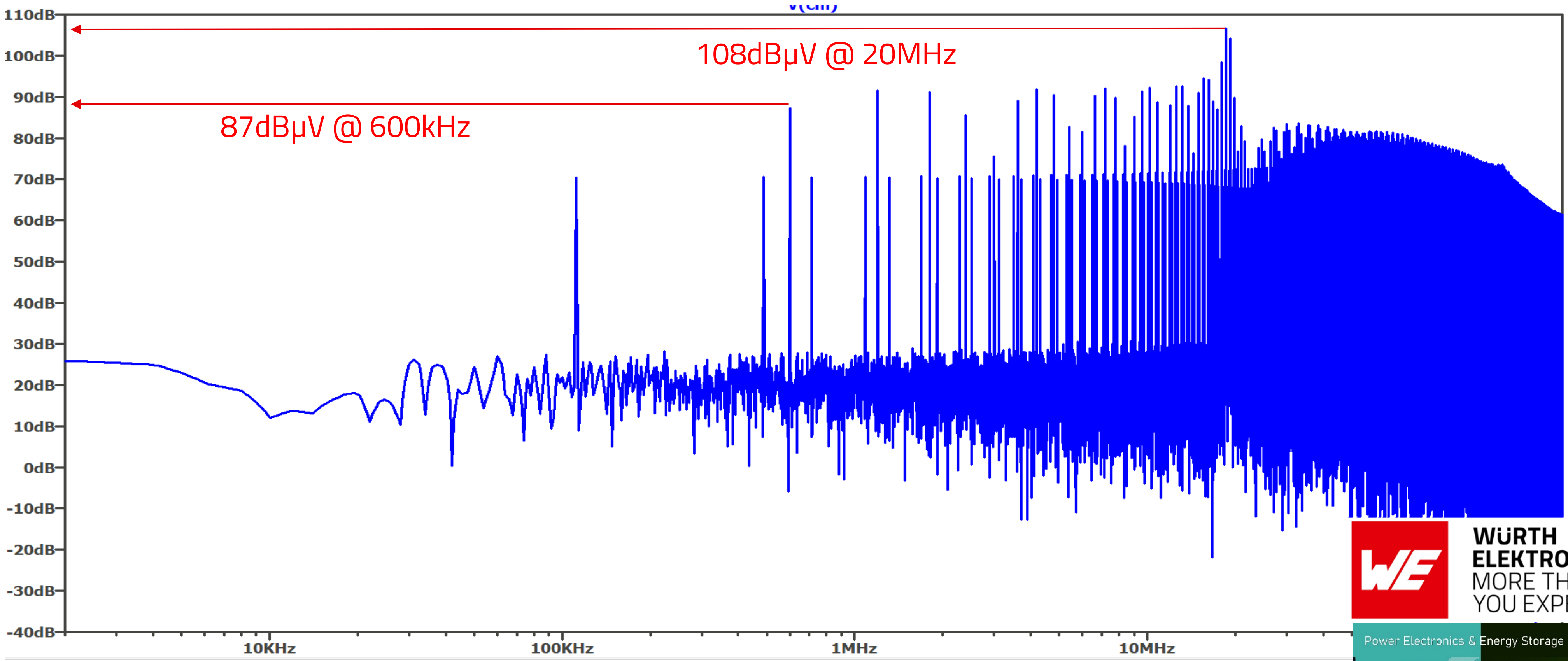


Buck Converter Common Mode Currents TIM Simulation

```
.param Vin=24V, Vout=5V, Rload=10,  fsw=600k, tvr=20n, tir=0        (main input for boost)
.param D=Vout/Vin       (duty cycle boost)
.param tsw=1/fsw, ton=D*tsw   (period time switcher)
.tran 0 1.5ms 1ms 10ns   (simulation time interval)
.ic V(vout)={Vout} (initial condition)
.ic V(vin)={Vin}   (initial condition)
.options plotwinsize=0   (no data compression)
.options numdgt=7   (double data precision)
.options abstol=0.00001  (lower toleranz, more speed)
```

EMC Aspects

LTspice Model for Common-mode Noise Level Prediction



108dBµV @ 20MHz

87dBµV @ 600kHz

EMC Aspects

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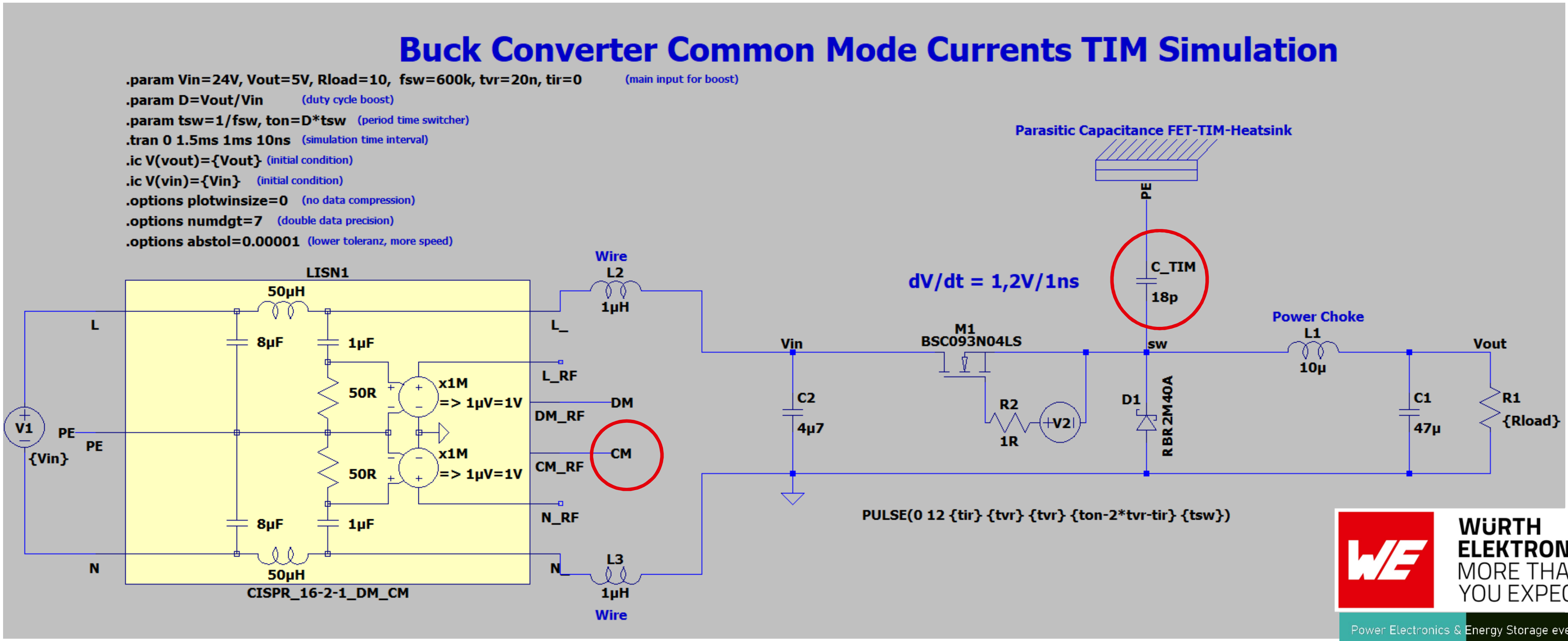

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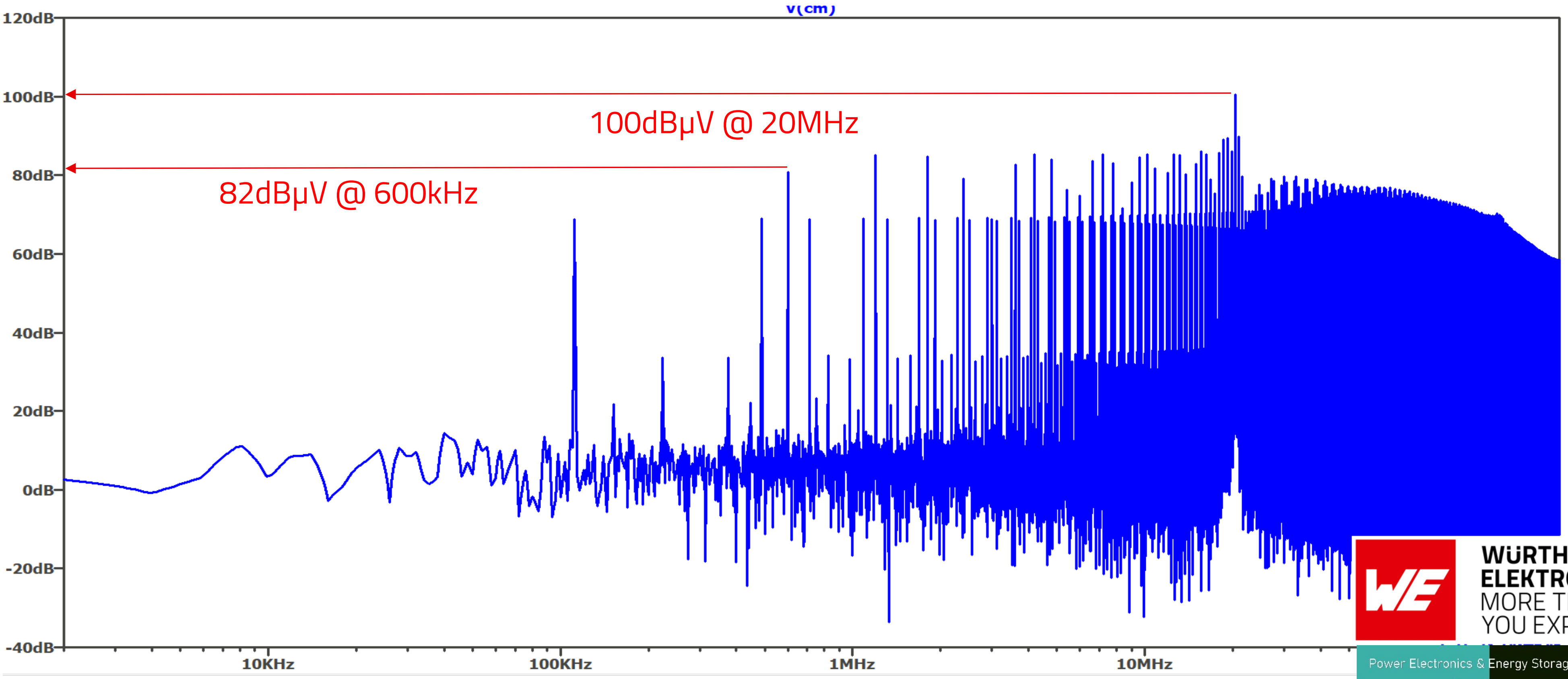
```

PULSE(0 12 {tir} {tvr} {tvr} {ton-2*tvr-tir} {tsw})

dV/dt = 1,2V/1ns

EMC Aspects

LTspice Model for Common-mode Noise Level Prediction



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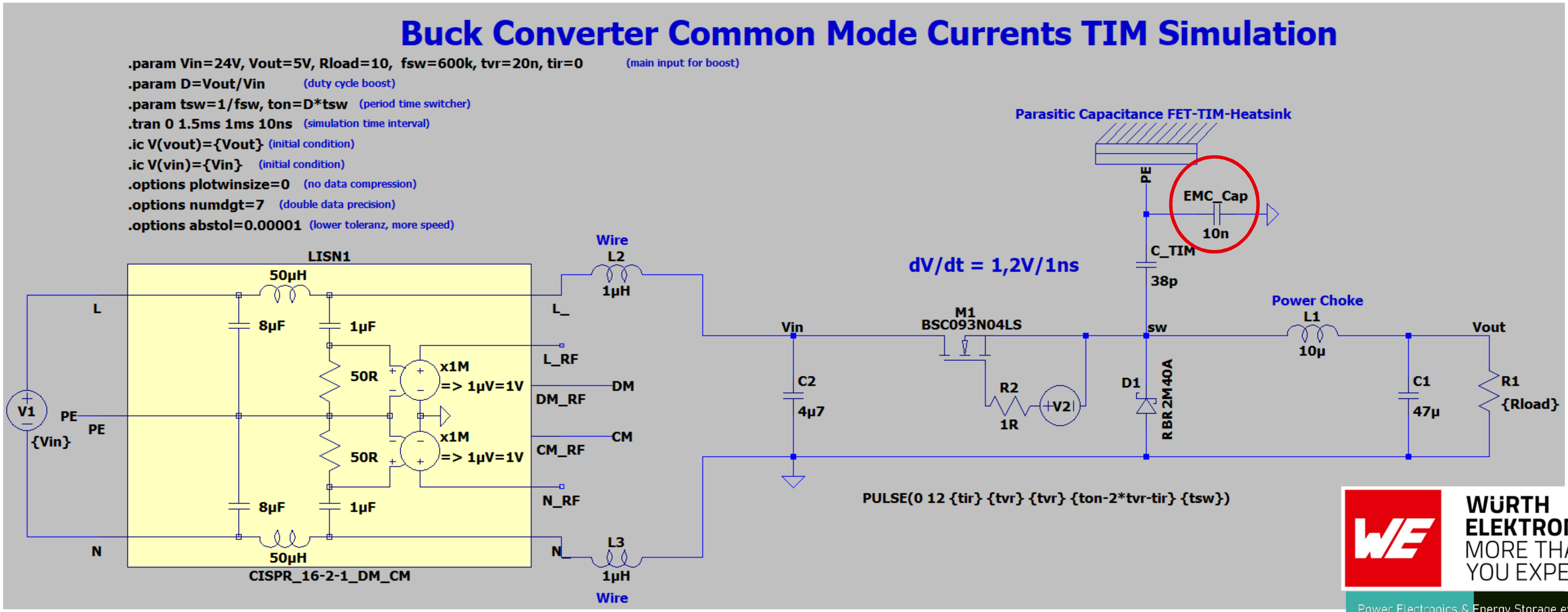

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EMC Aspects

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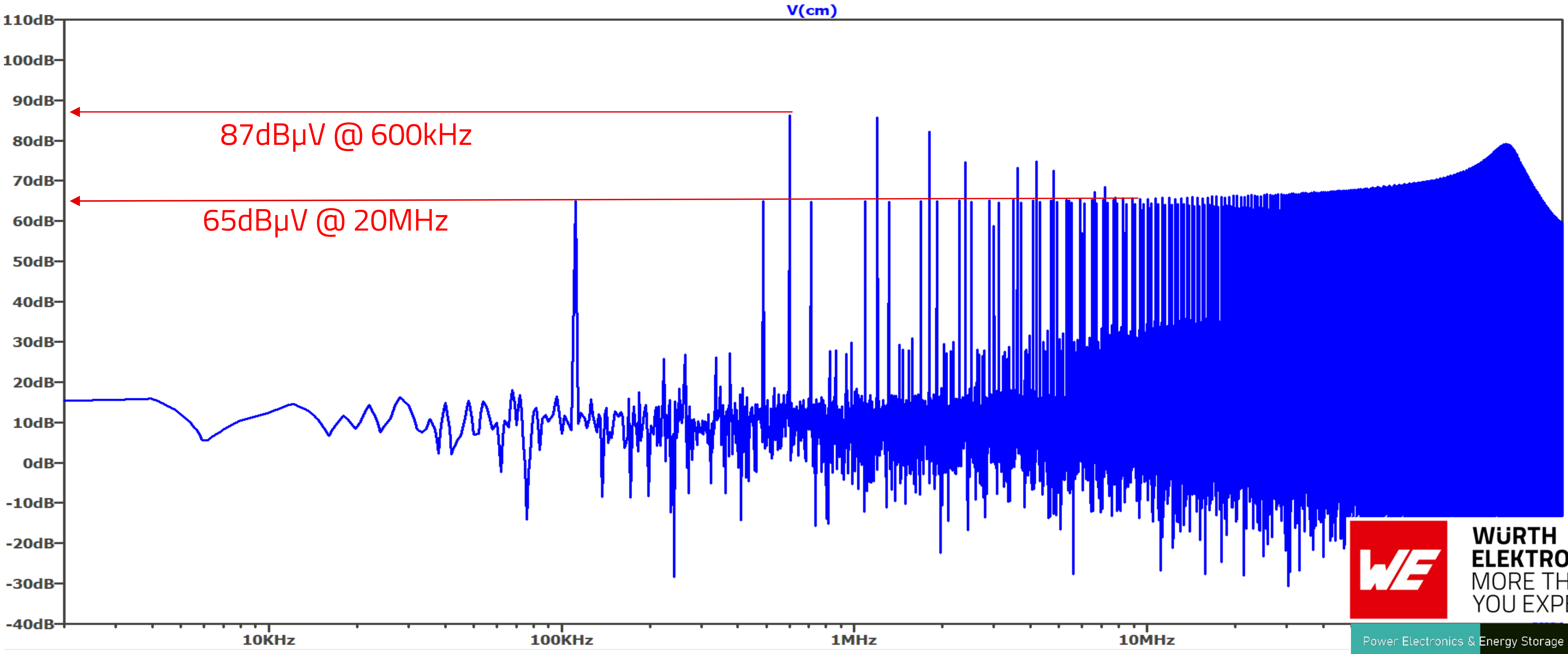


87dBµV @ 600kHz

65dBµV @ 20MHz

WÜRTH ELEKTRONIK
MORE THAN YOU EXPECT

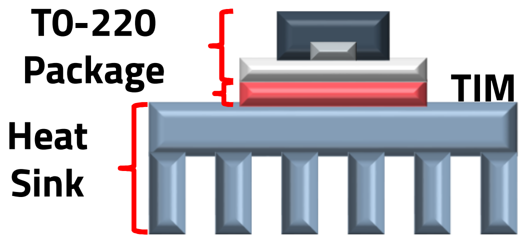
EMI Aspects

Thermal Performance versus EMI

Thermal

- Thinner TIM = Better thermal performance
  - Please make sure TIM is thick enough to fill the gap

$$R_{th} = \frac{l}{\lambda \cdot A} = \left[\frac{K}{W}\right]$$



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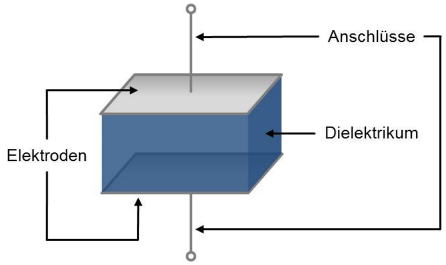

$l = Material\ thickness[m]$

$A = Cooling\ overall\ surface[m^2]$

Summary

- Thermal performance can be improved by:
  - Thermal interface materials as gap filler
  - Heat spreaders
  - Combination of both

- Common mode noise can flow through the thermal interface material

- Thickness of the TIM is important for both common mode noise and thermal performance
  - Trade-off needs to be made

- LTSpice can help you with predicting and improving EMC

Thanks for your attention!

- Würth Elektronik Nederland - België
- Raf Vleugels – FAE – raf.vleugels@we-online.com
- Alex Snijder – FAE – alex.snijder@we-online.com

- Looking forward meeting you at booth 27