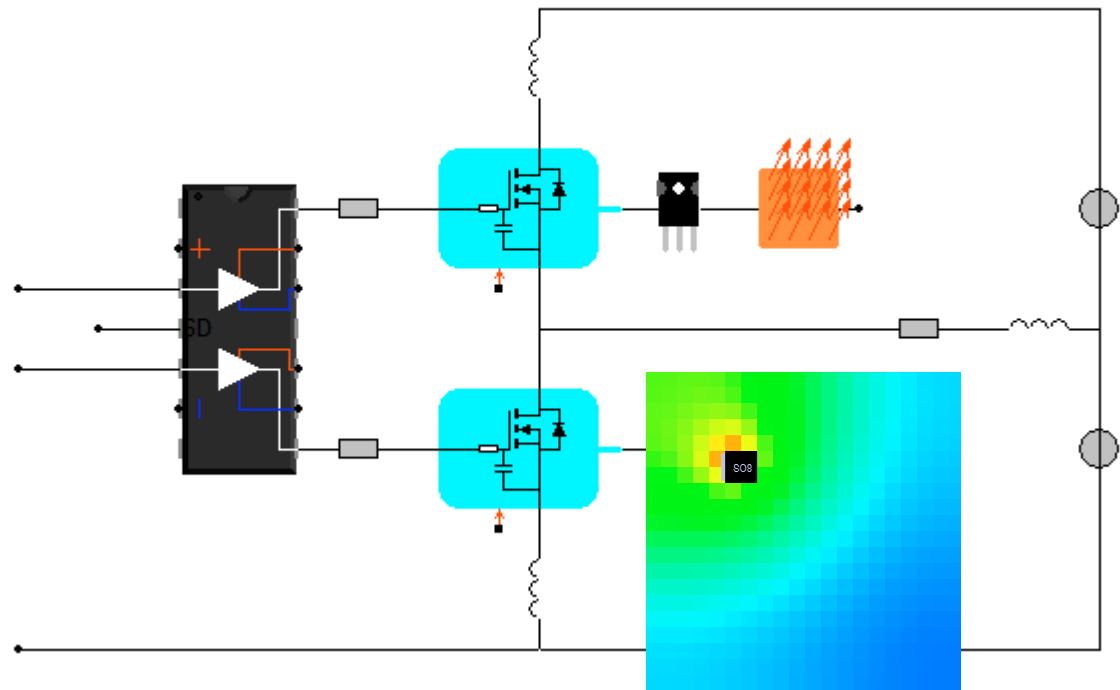


# Caspoc, A simulation Experience

## Help, het wordt te heet!

dr ir P.J.van Duijsen



Learning by Simulation

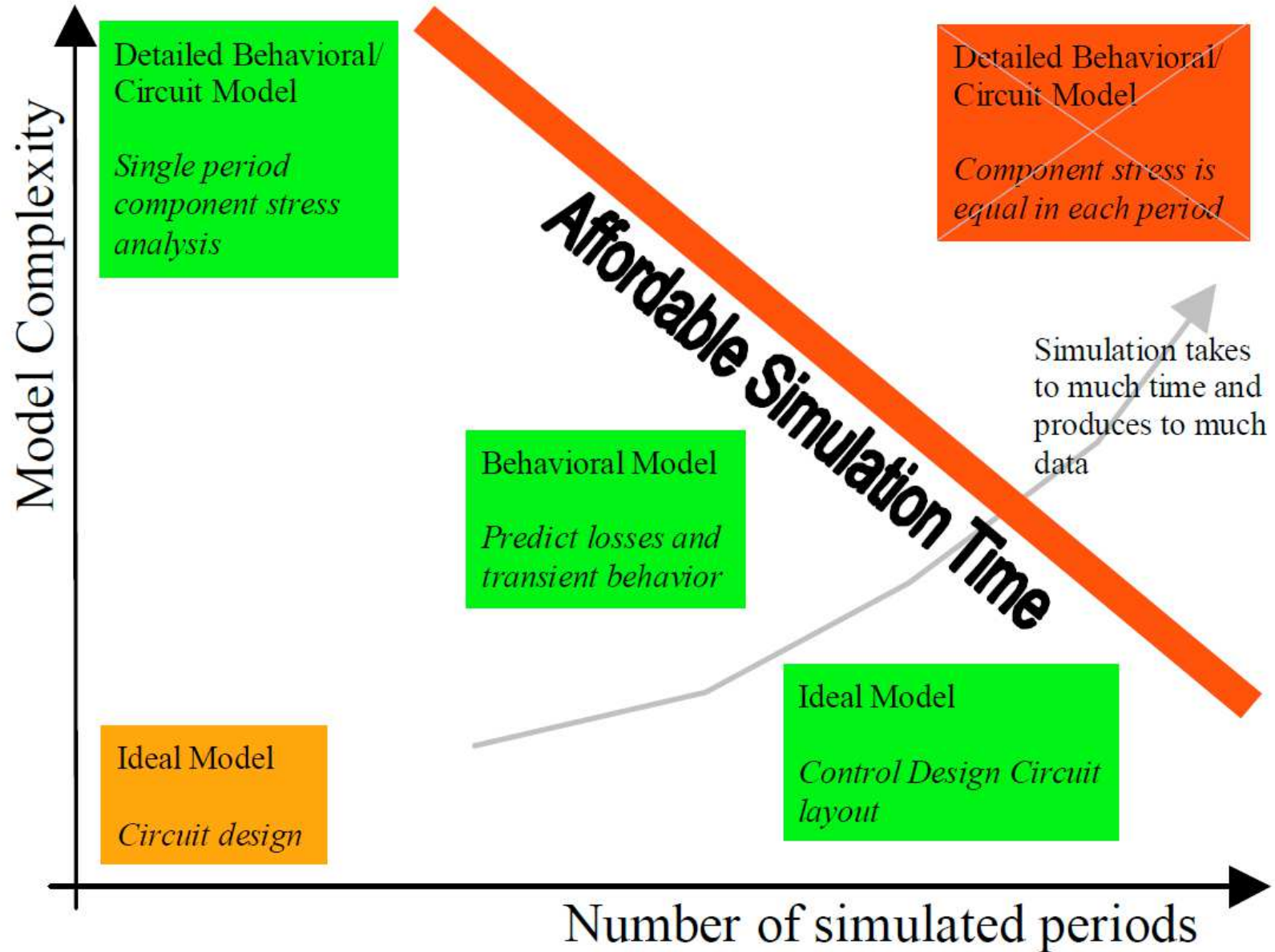
Simulation Research  
The Netherlands

- Multilevel Simulation
  - System level
  - Circuit level
  - Component level
  
- IGBT
  - Thermal modeling
  - Fatigue / Lifetime
  - PWM / SVM
  
- Mosfet
  - Thermal modeling
  - Component or circuit level
  - Cauer models

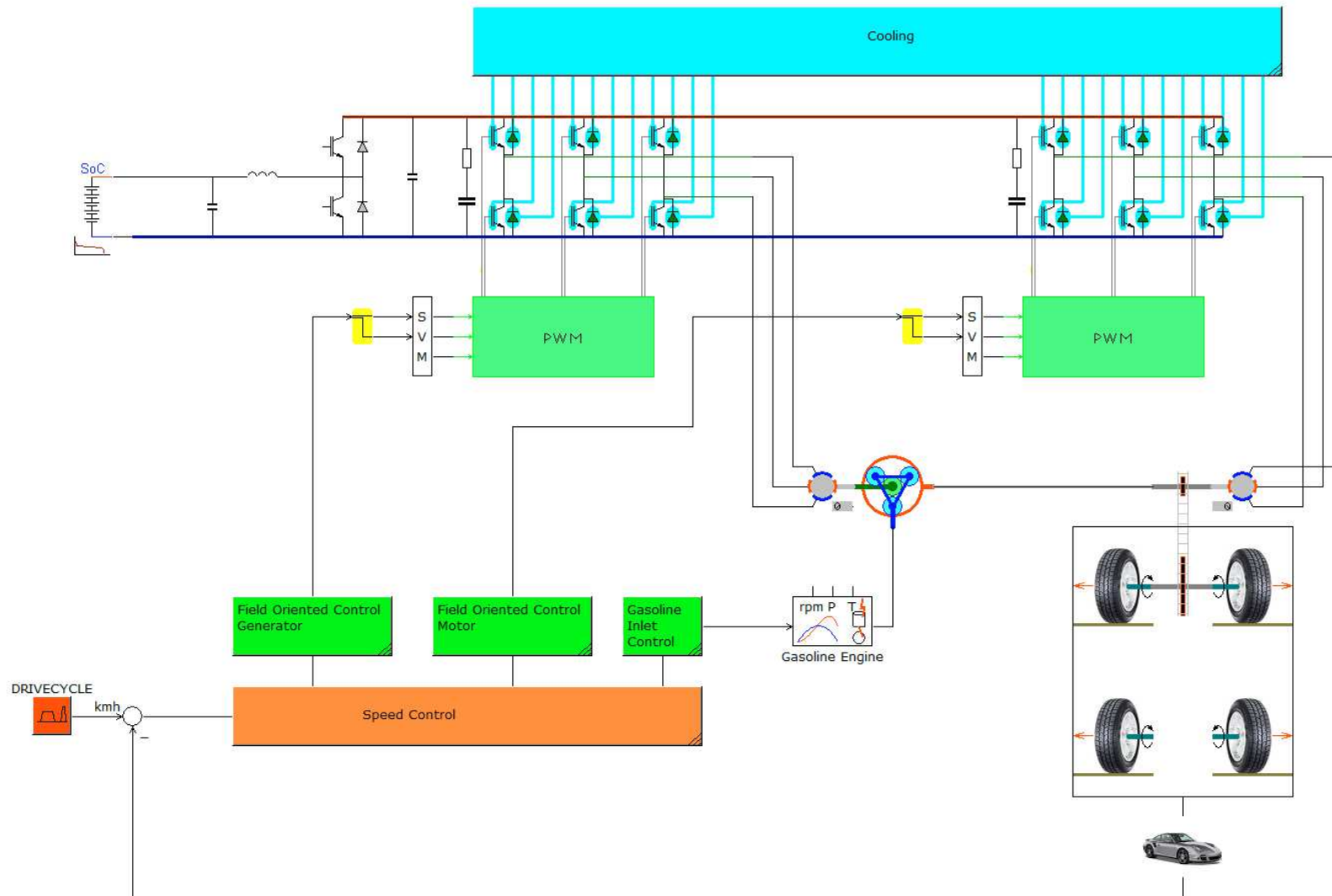
- What is simulation?
- What is your problem?
- What is your Goal?
- Do you have Models?
- Parameters?
- Where to start??????

Time constant	Model	Dynamics
1n	Parasitic components / Packaging	EMI
10n	Detailed Mosfet Model	Semiconductors
100n		
1u		
10u	Ideal Mosfet Model (Fs~20kHz)	Filter
100u	Circuit model Electrical Machine	
1m	Thermal model Junction	
10m	Block diagram model electrical machine	
100m		
1		Mechanical system
10	Thermal model heat sink	
100	Mechanical	

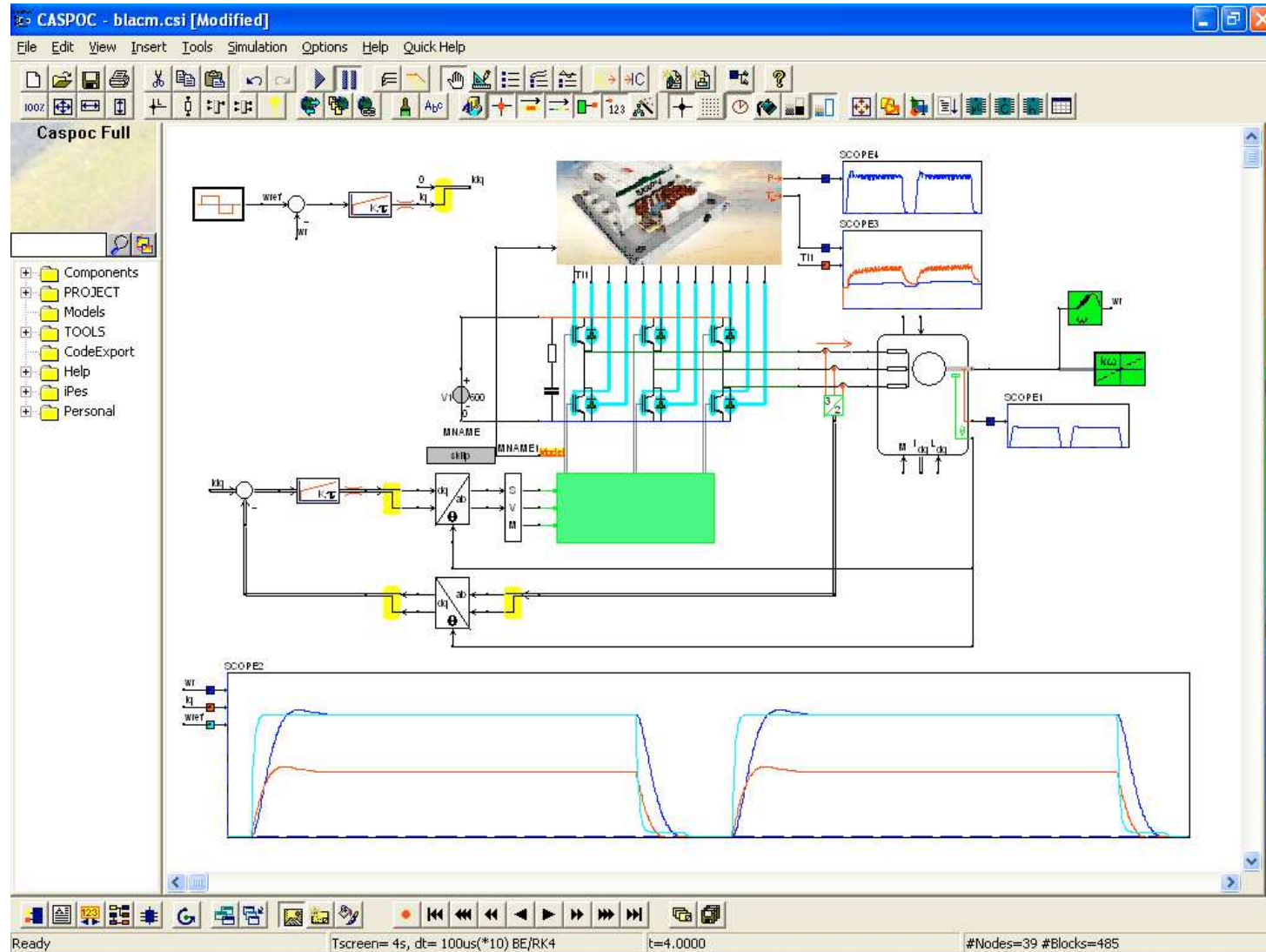
# Multilevel Simulation



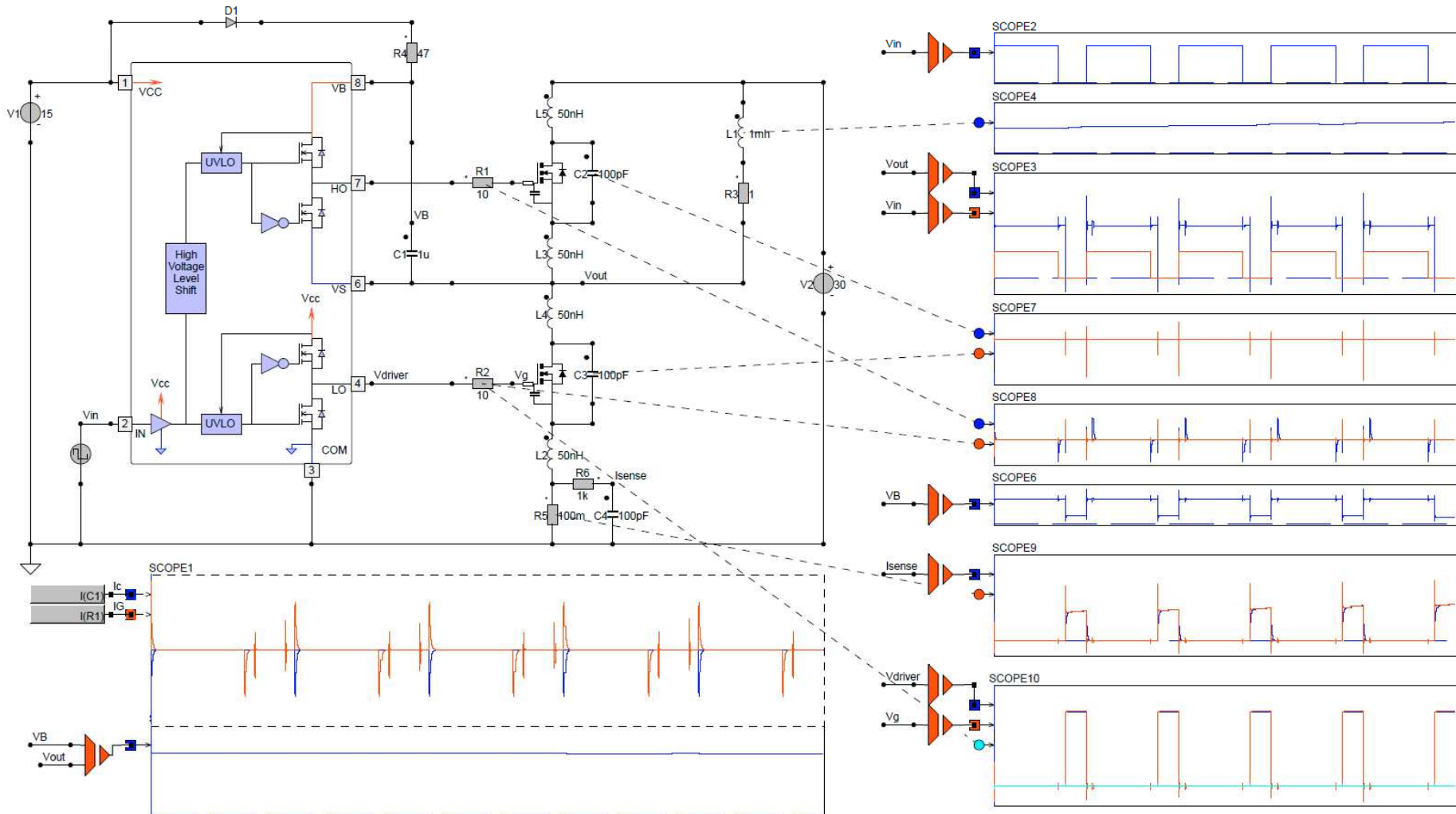
- System simulation of a Hybrid Electric Vehicle



- Circuit level simulation IGBT inverter with Field Oriented Control / Skiip

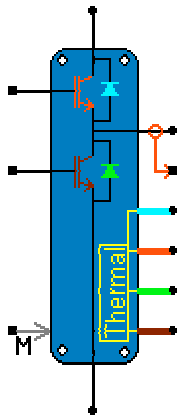


- Component level simulation 2 IGBTs with parasitic L

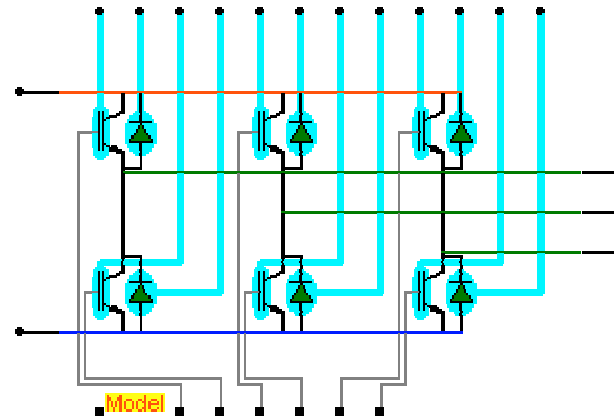


- Simulation Level

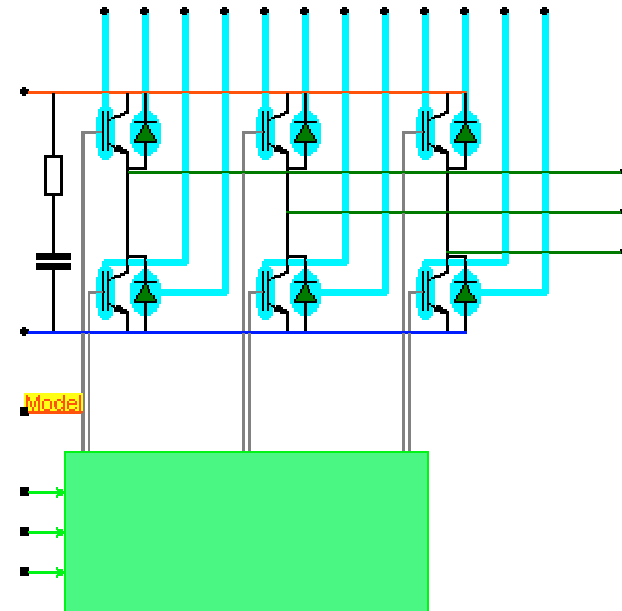
- Component



- Circuit

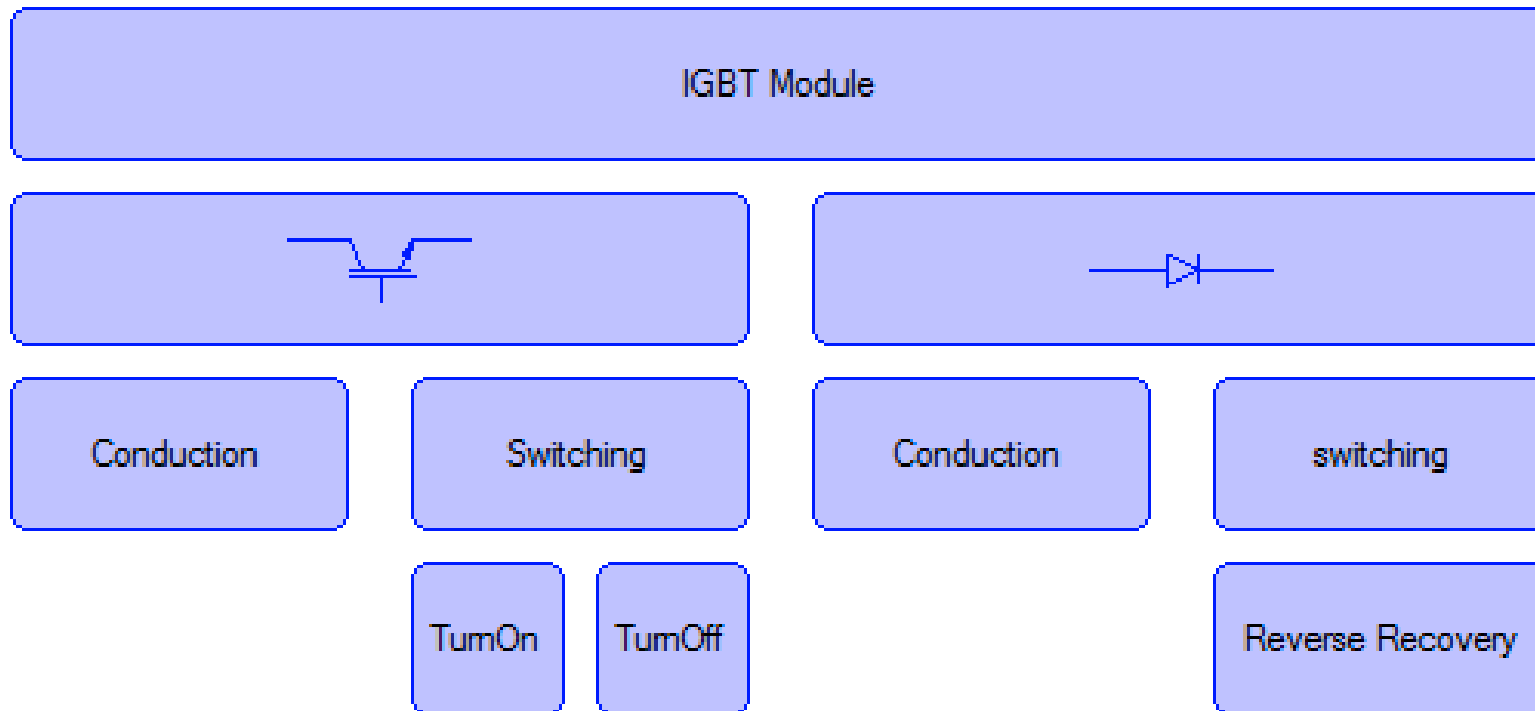


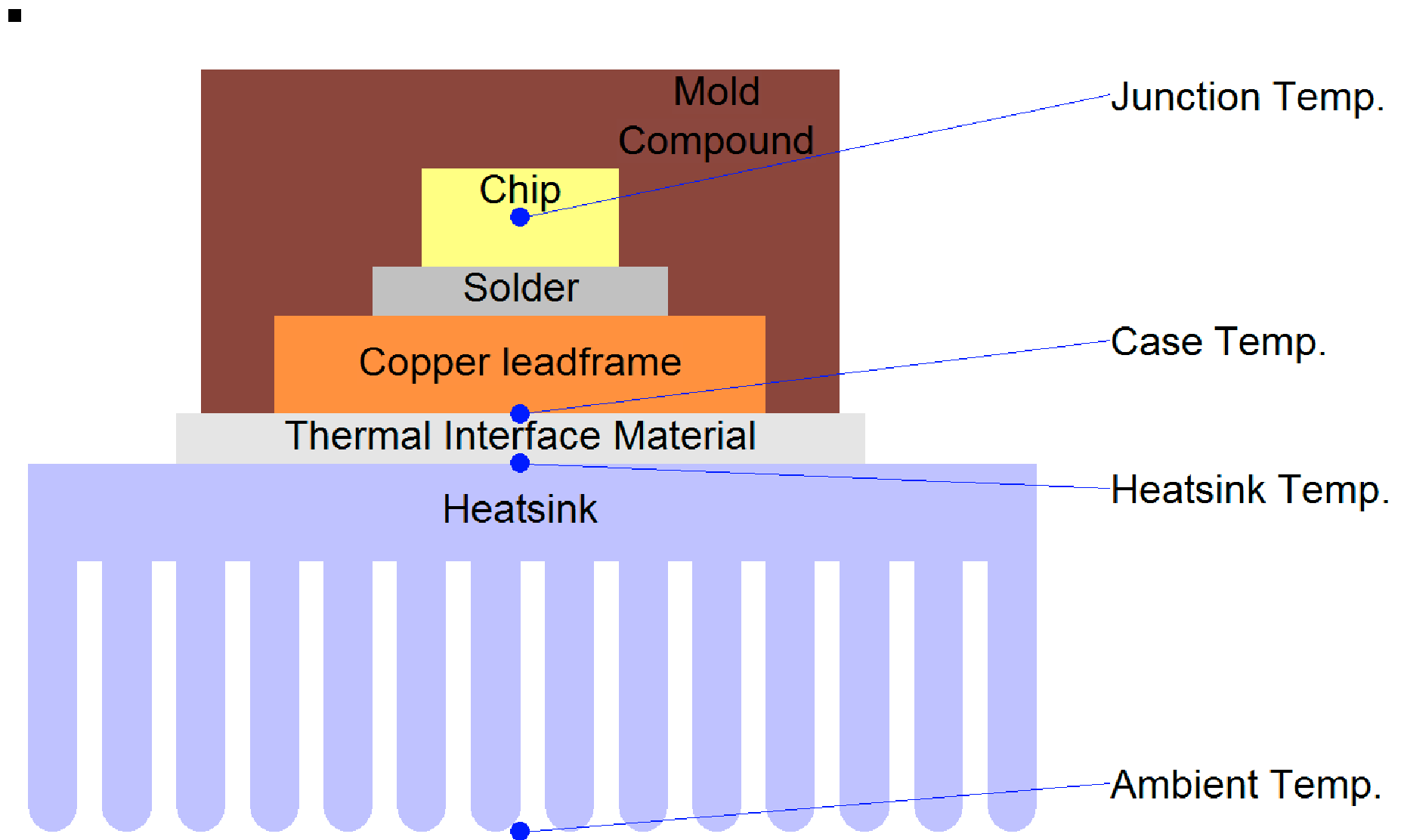
- System



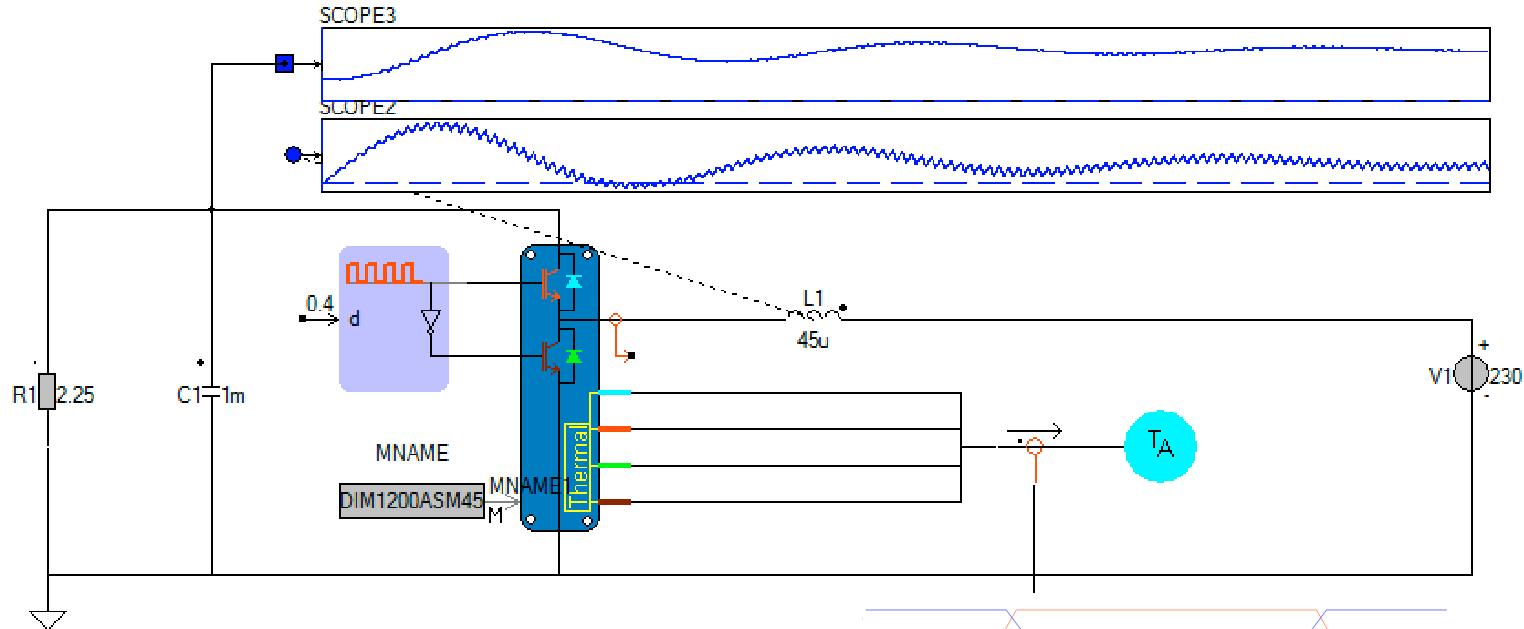
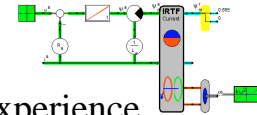


- Losses from an IGBT





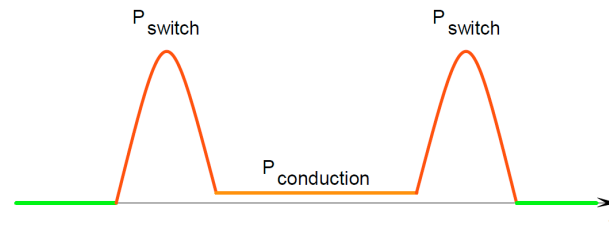
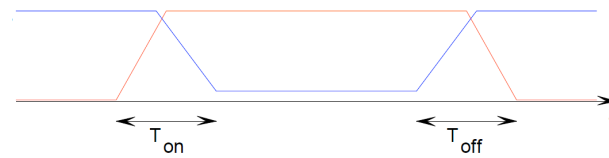
# IGBT Losses



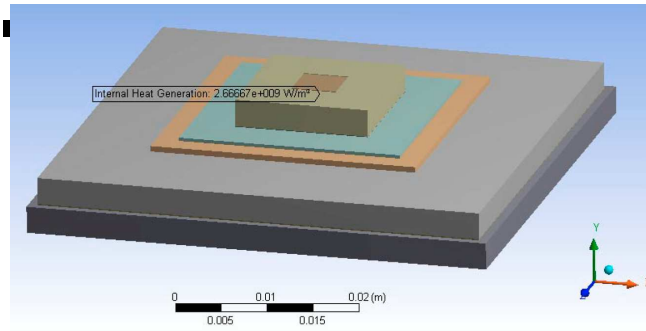
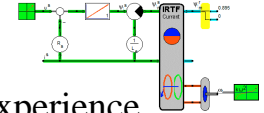
NETLIST1

```

Inom=100
Vnom=600
Err125=50m
Eon125=50m
Rd125=10m
Vd125=0.5
Rce125=25m
Vce125=1
Eoff125=50m
Eoff25=50m
Vce25=1
Rce25=25m
Vd25=0.5
Rd25=10m
Eon25=50m
Err25=50m
    
```

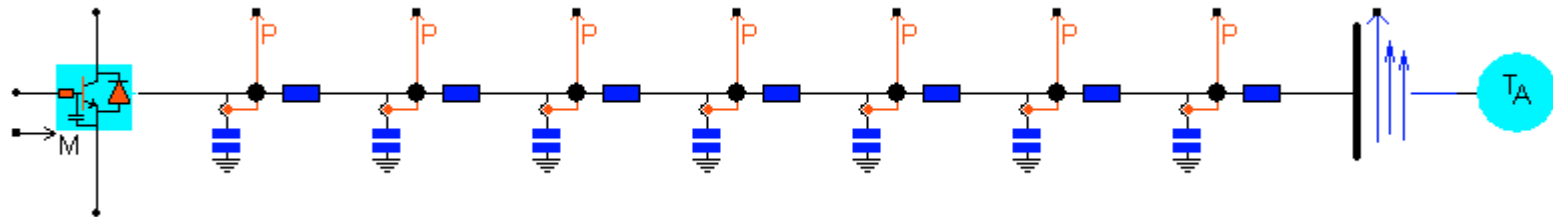
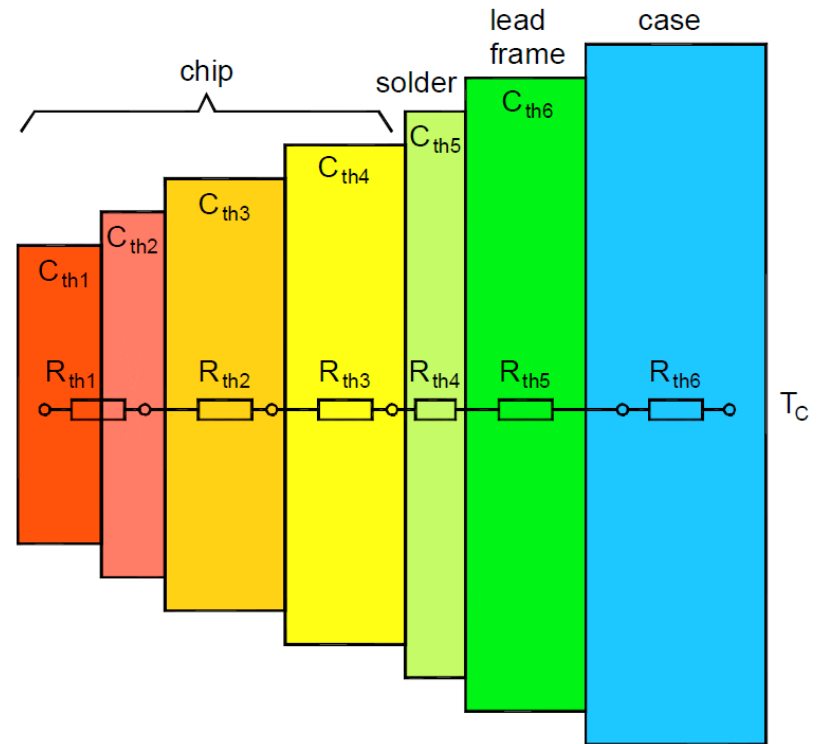
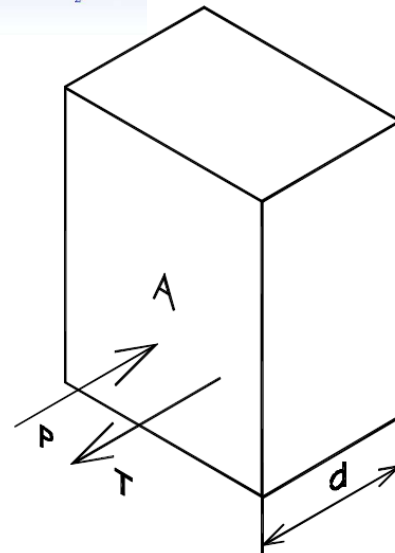


# Thermal model

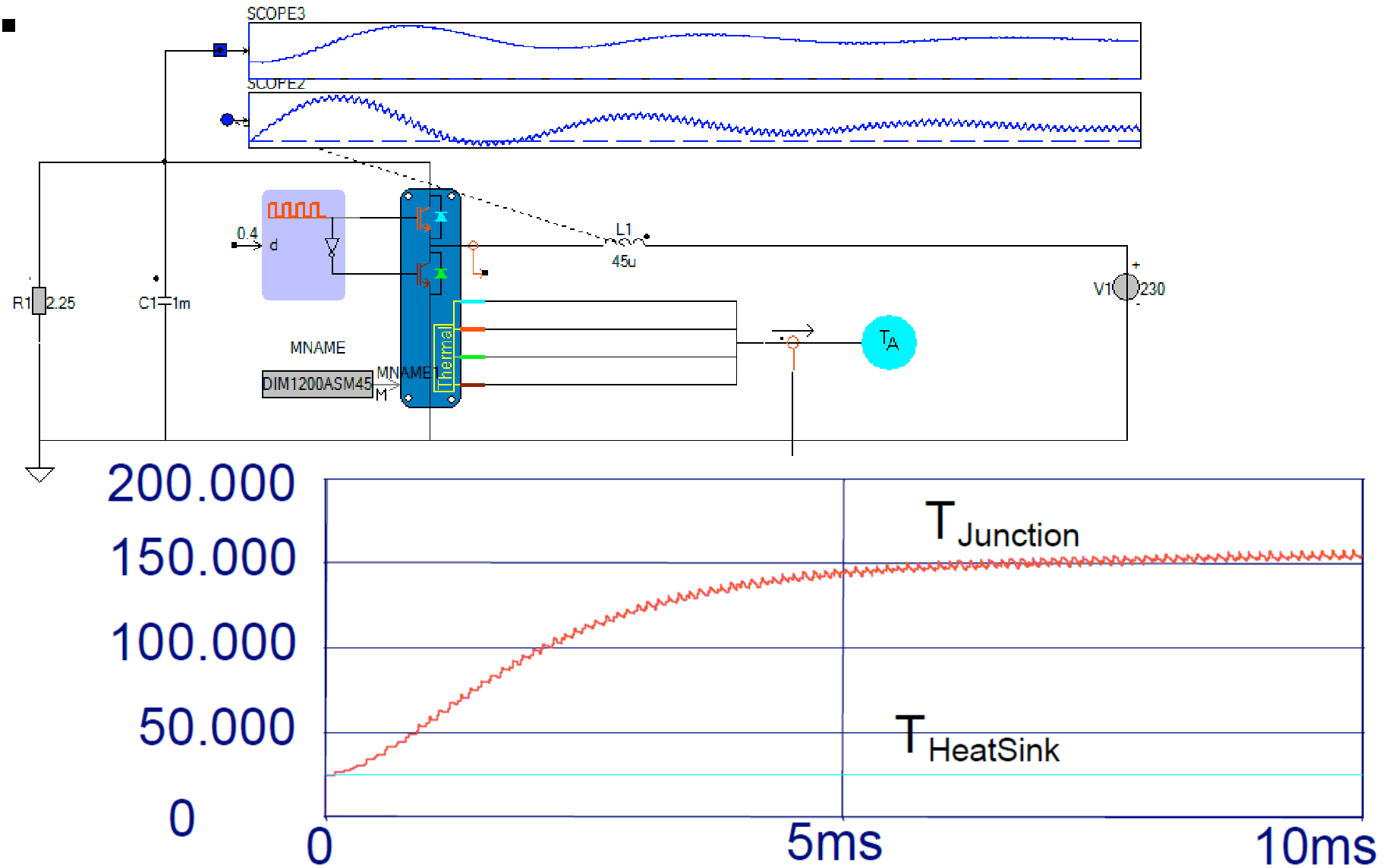


$$R_{tn} = \frac{d}{\lambda_{tn} A}$$

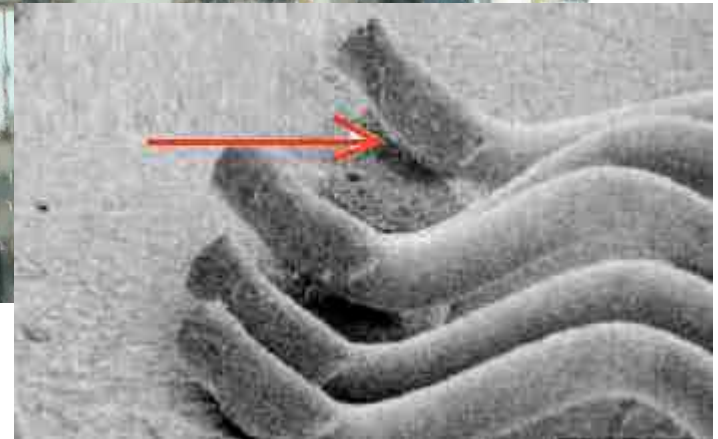
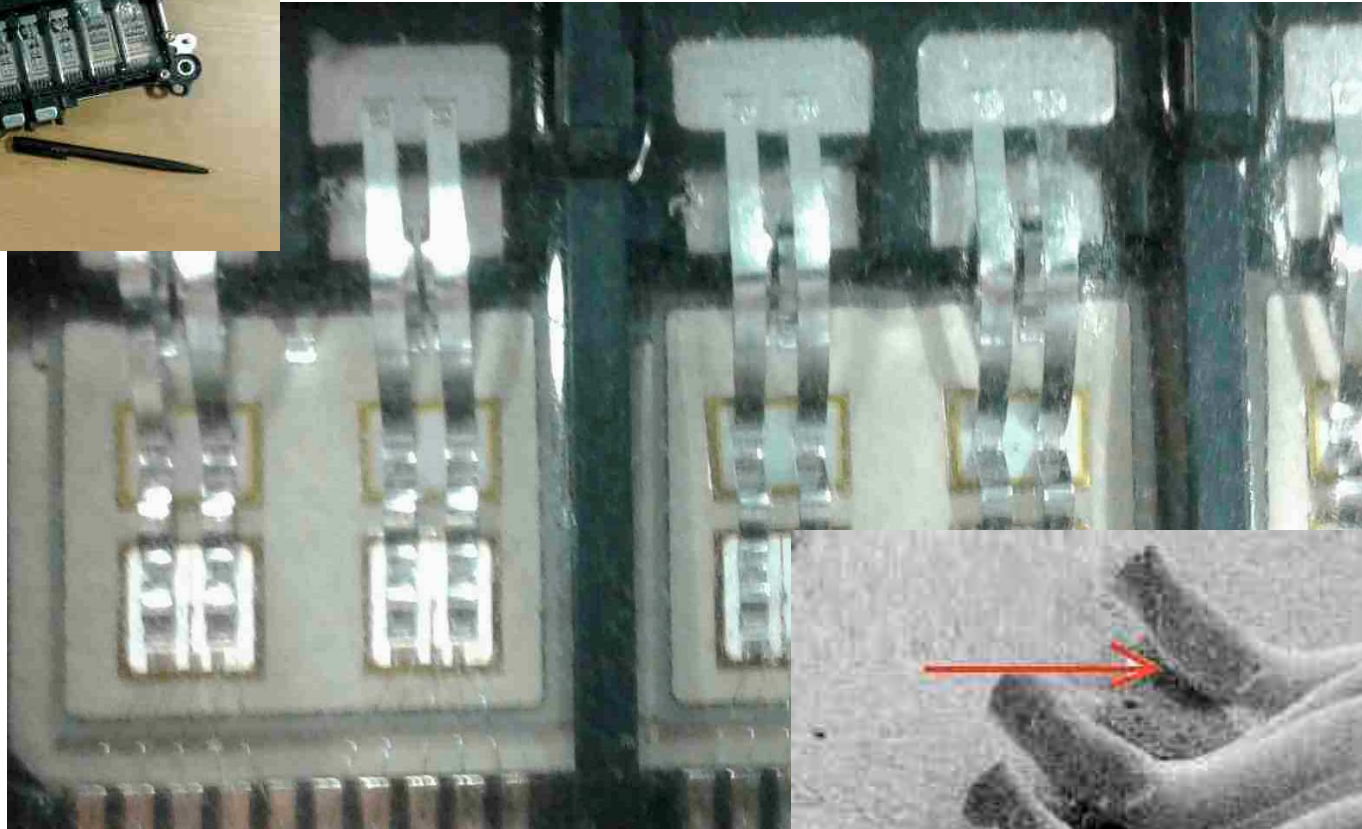
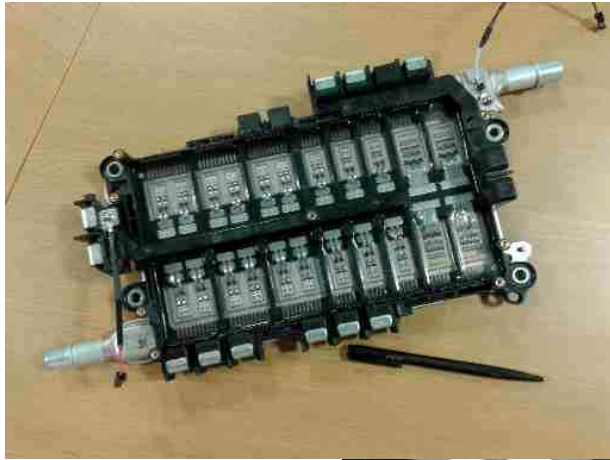
$$C_{tn} = C_p d A$$

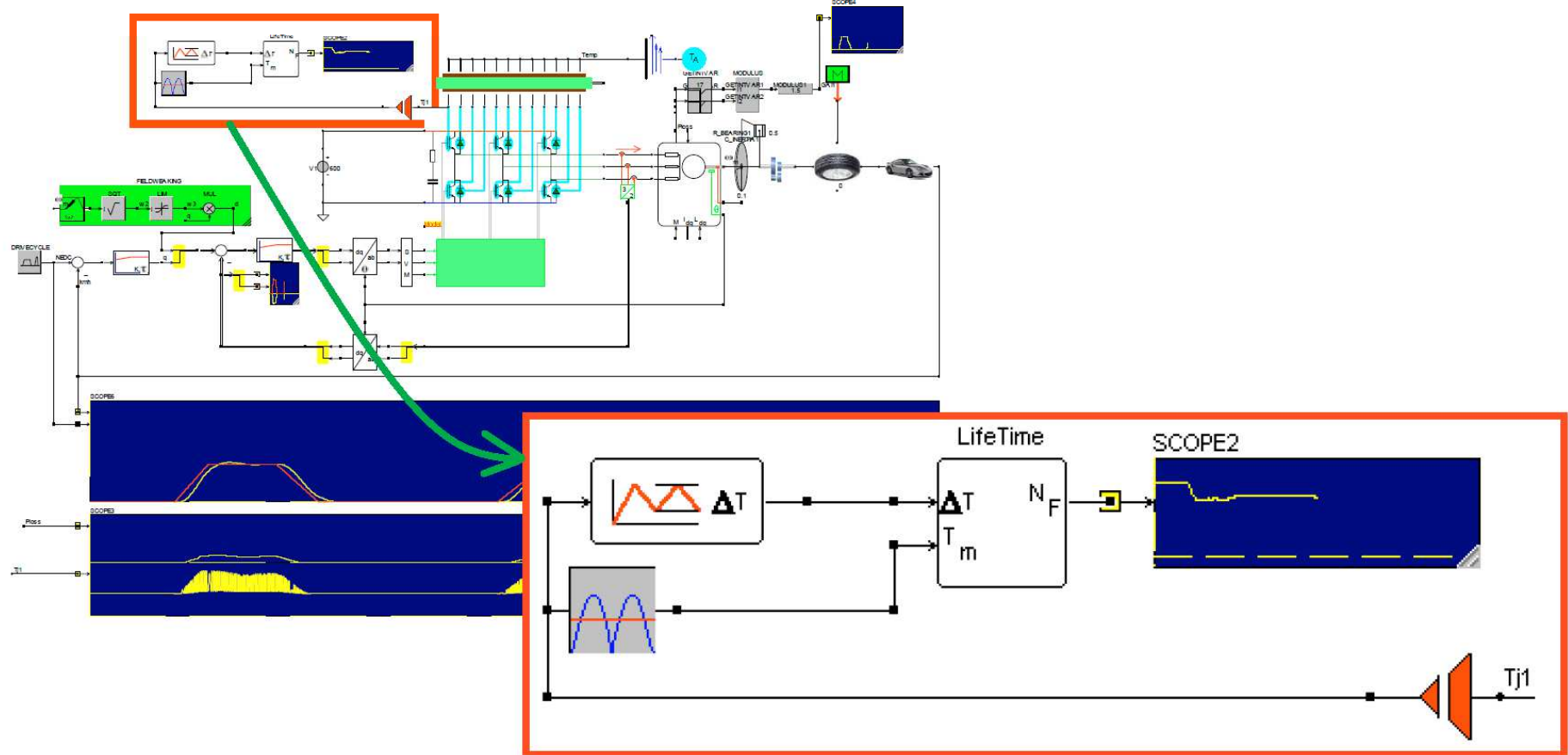


# Thermal and electric model

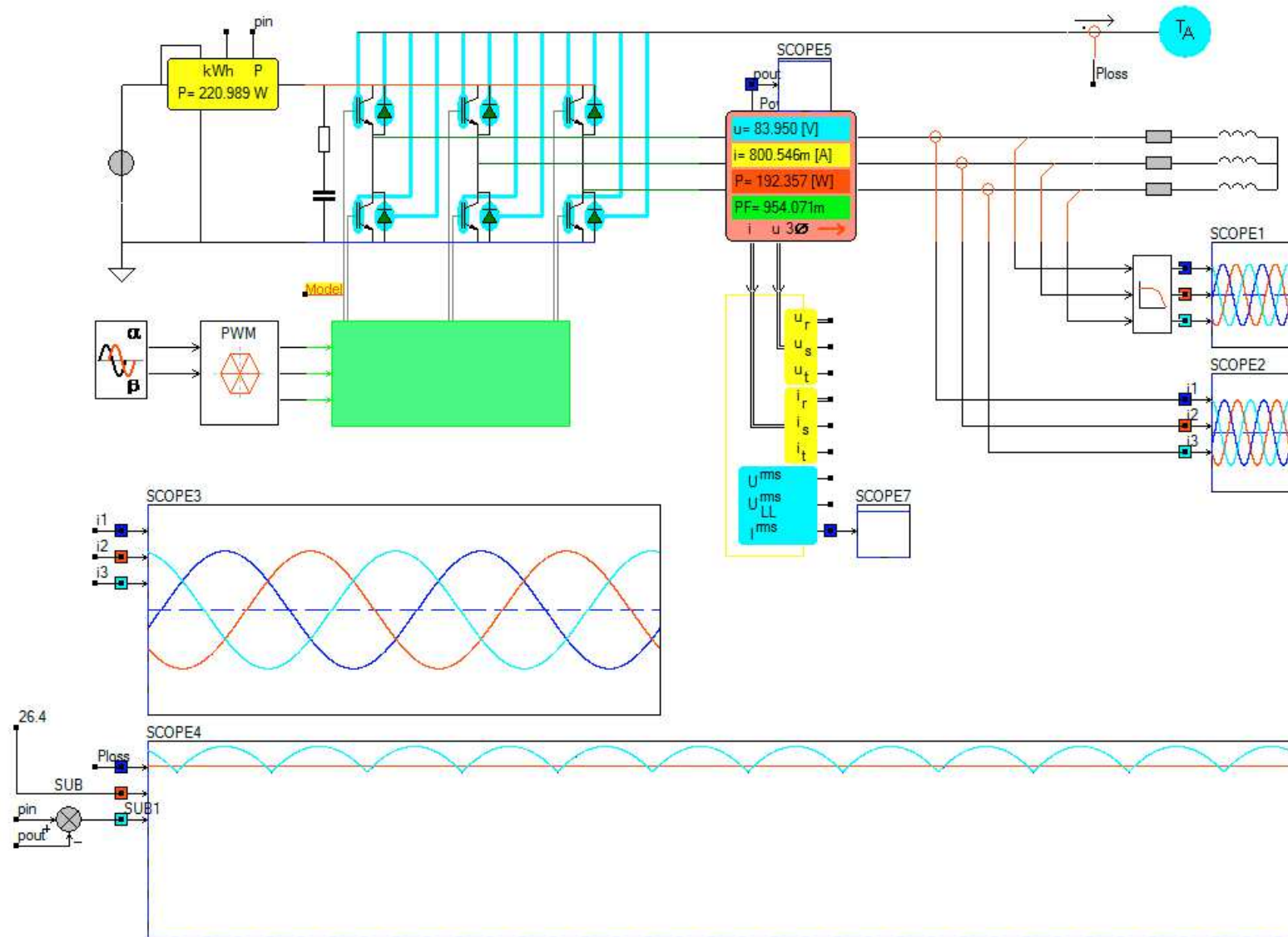


# Fatigue



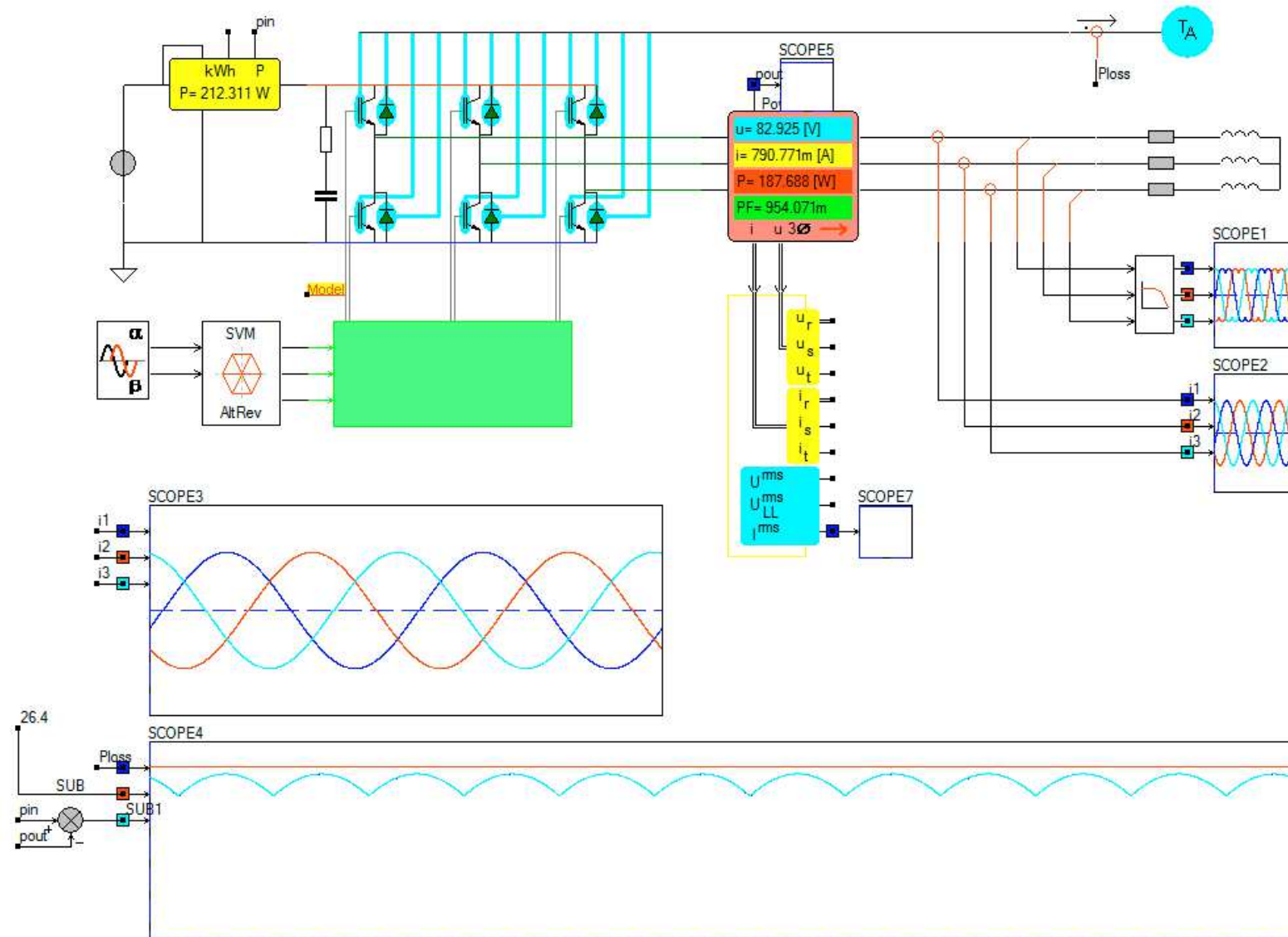


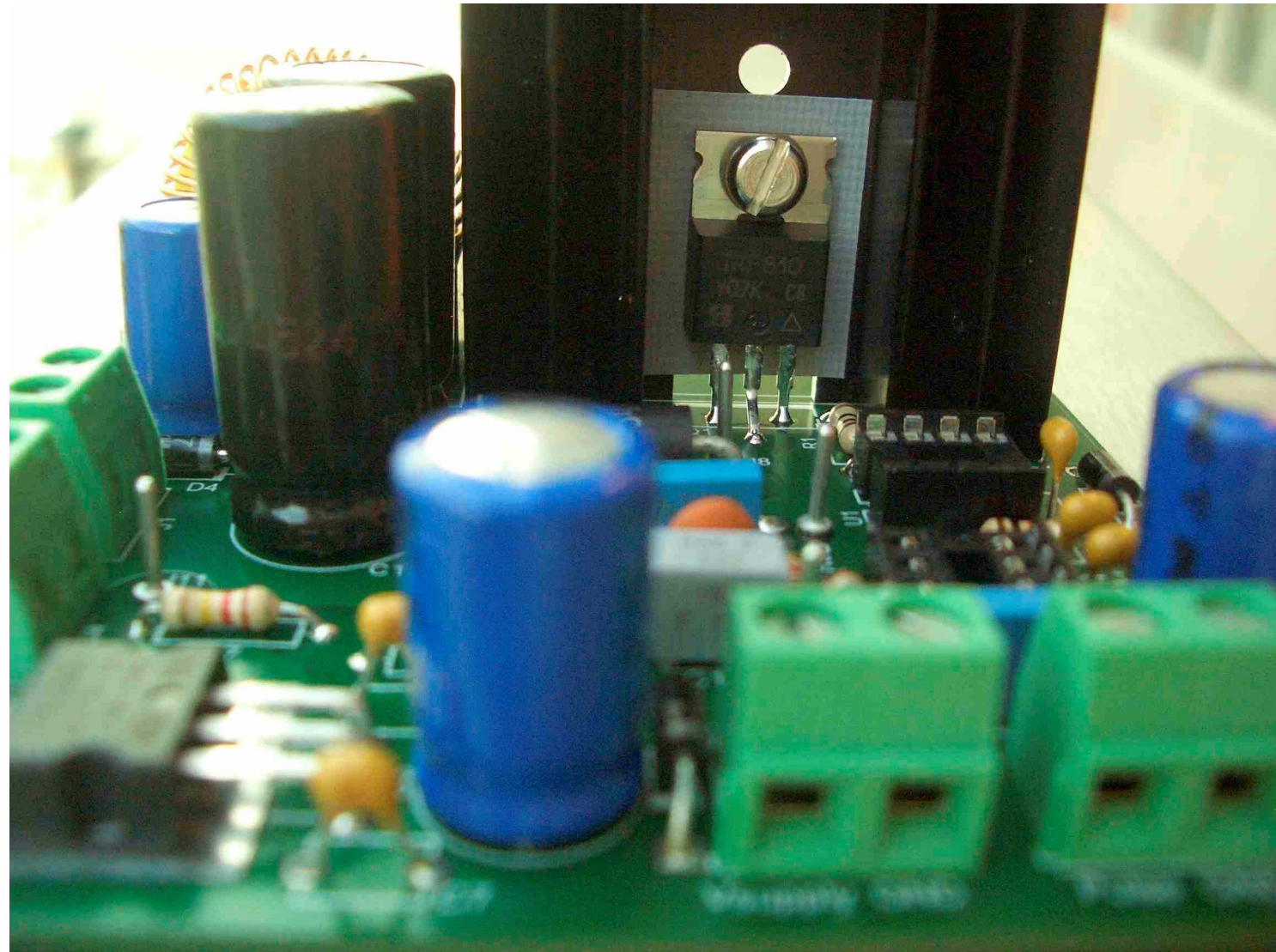
# Influence control PWM



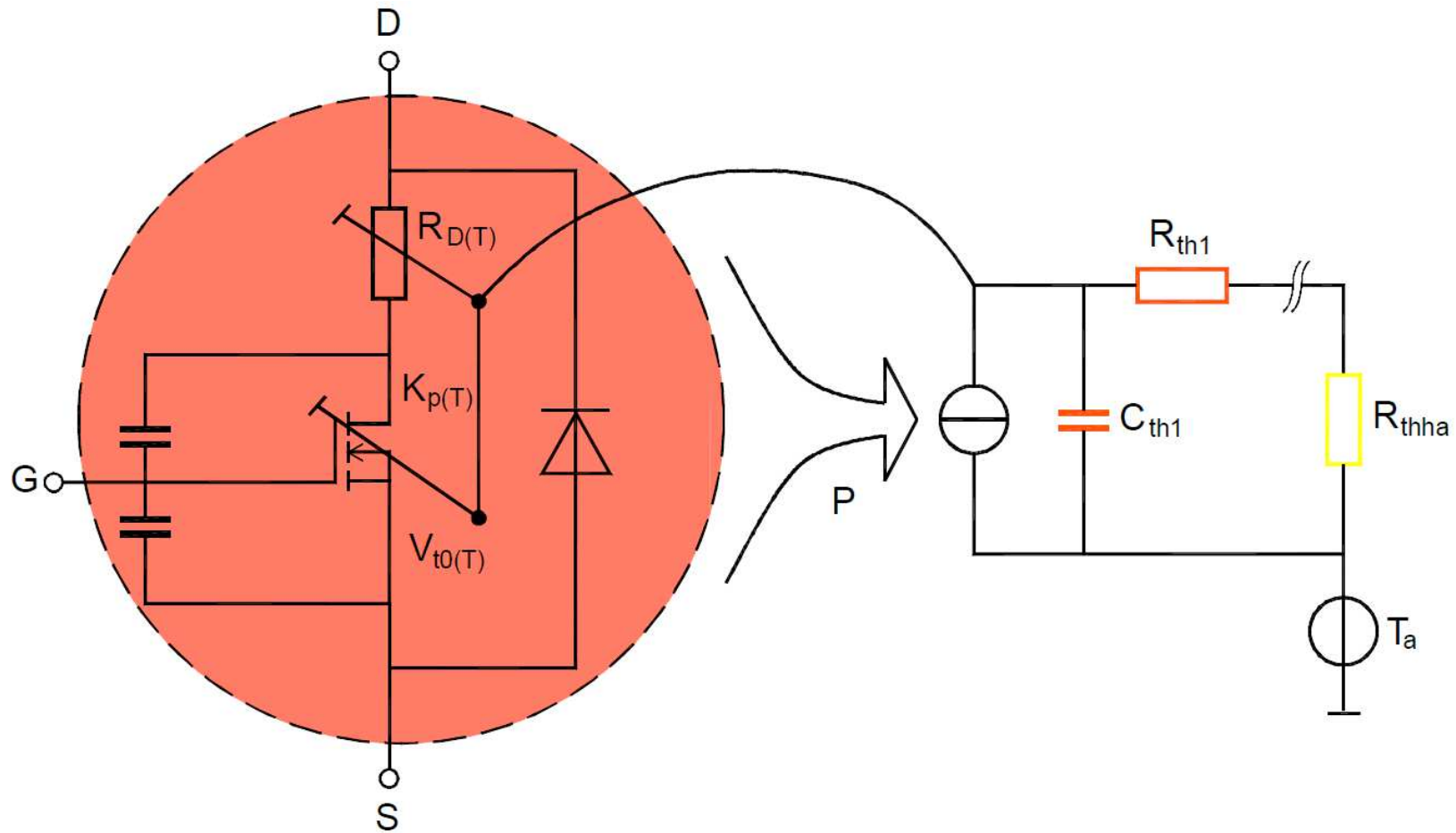


# Influence control SVM





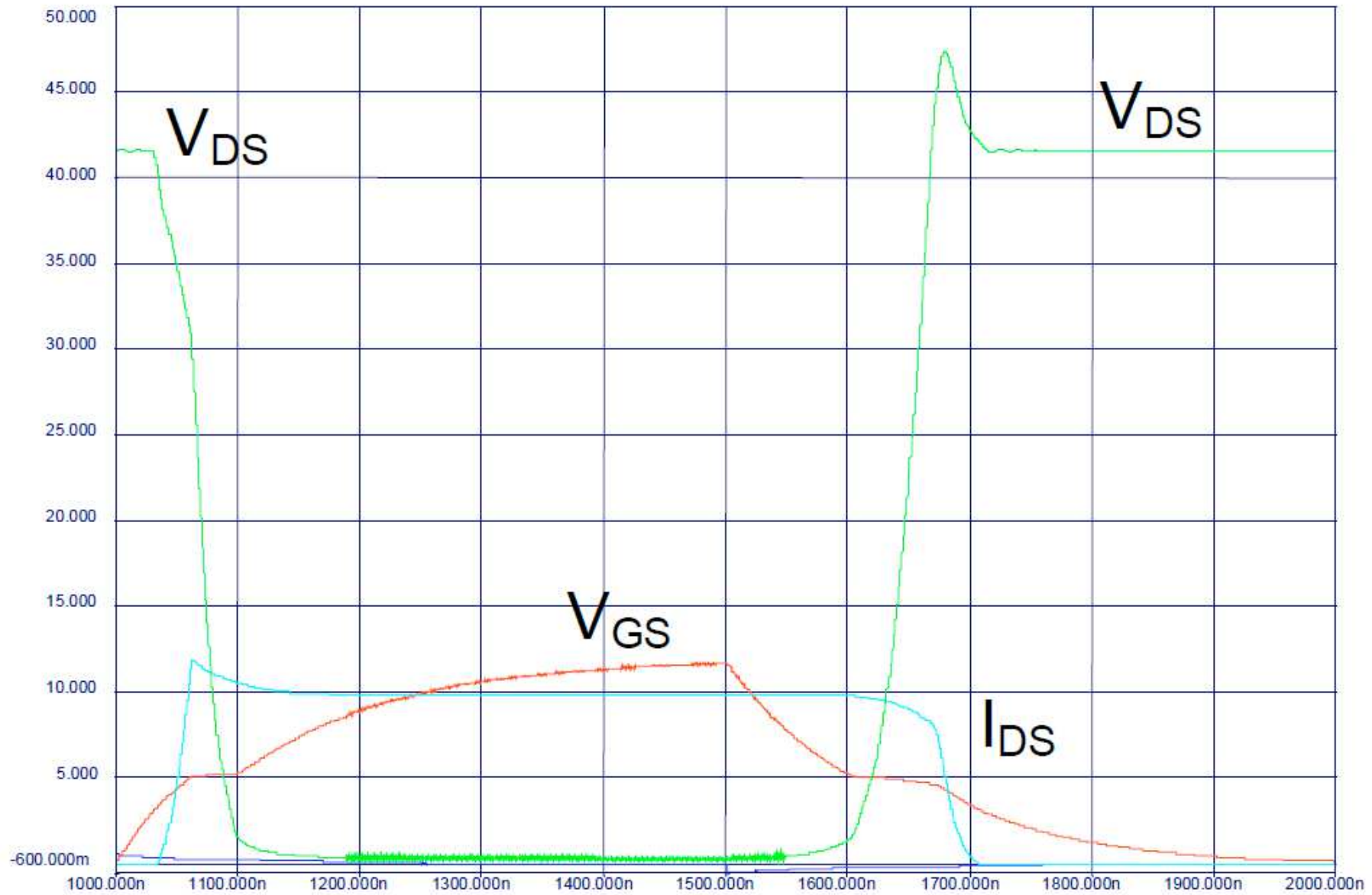
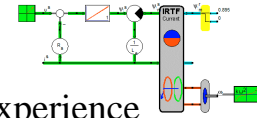
# Mosfet electric model



# Mosfet Losses Component Level

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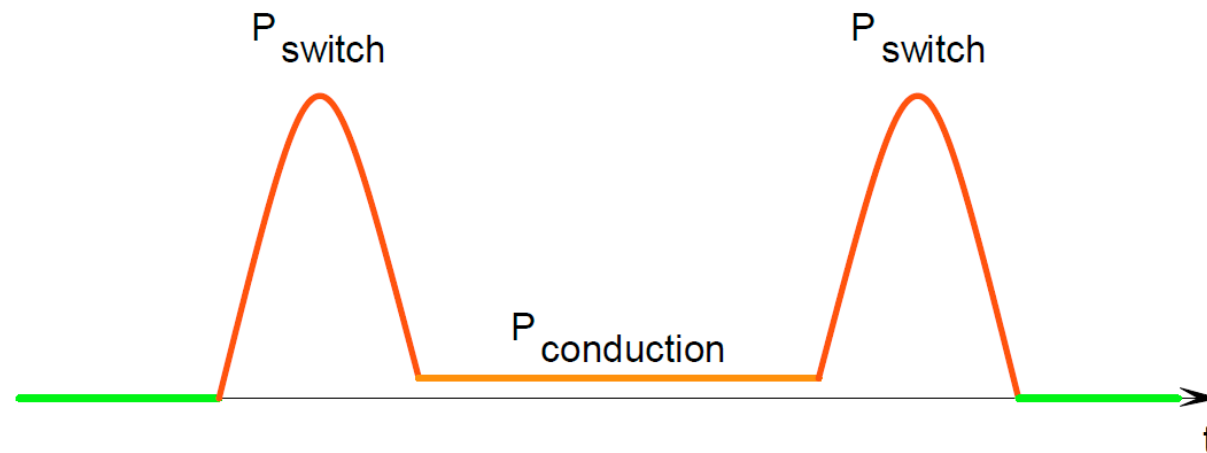
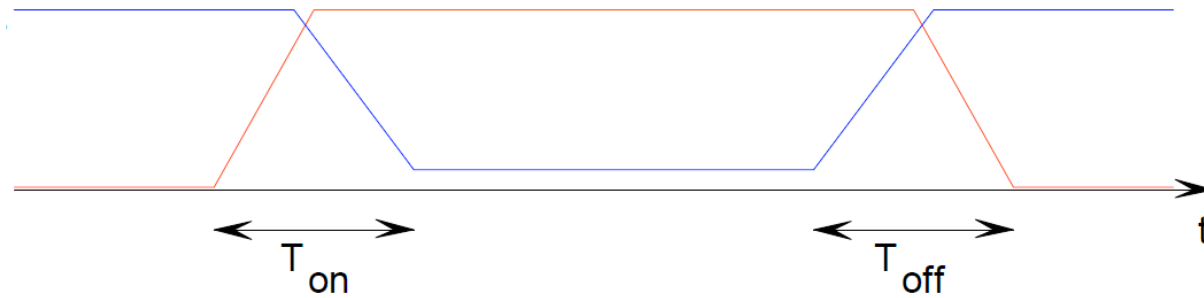
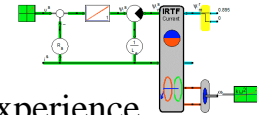
A simulation Experience



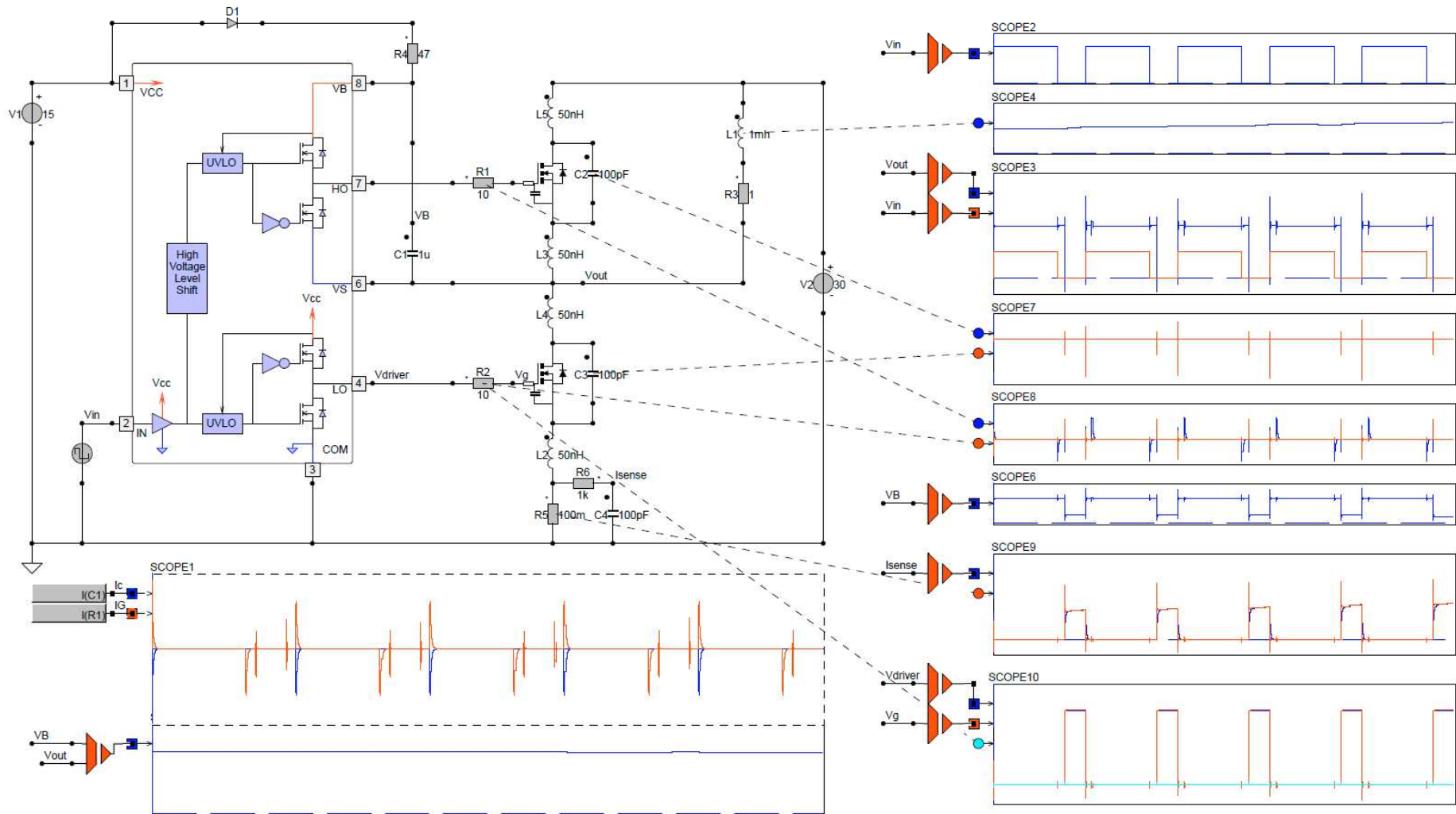
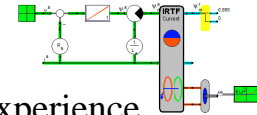
# Mosfet Losses Circuit / System Level

Caspoc

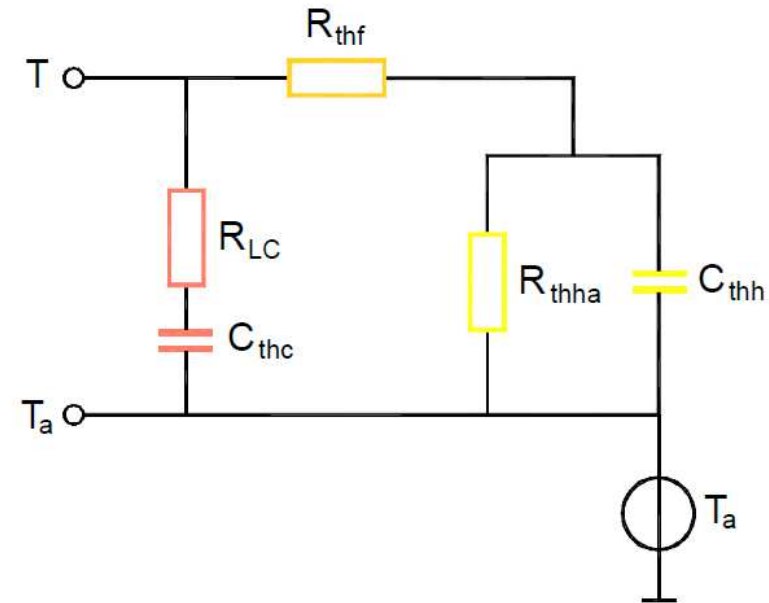
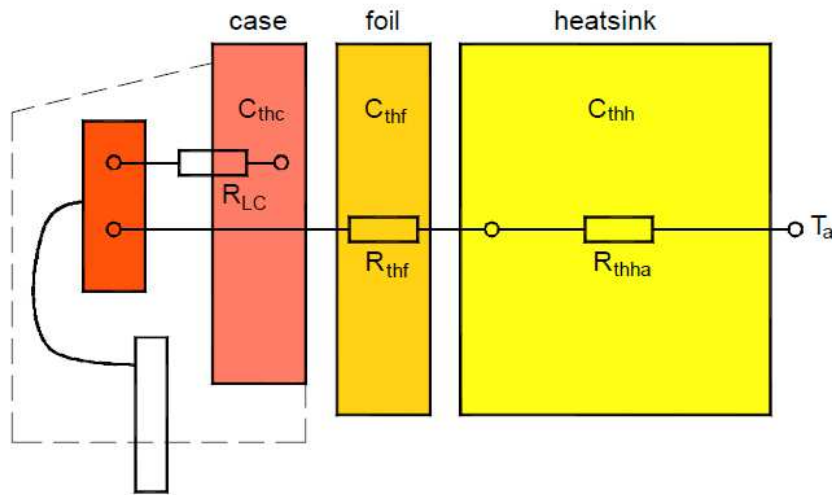
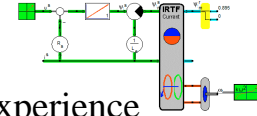
A simulation Experience



# Gate driver



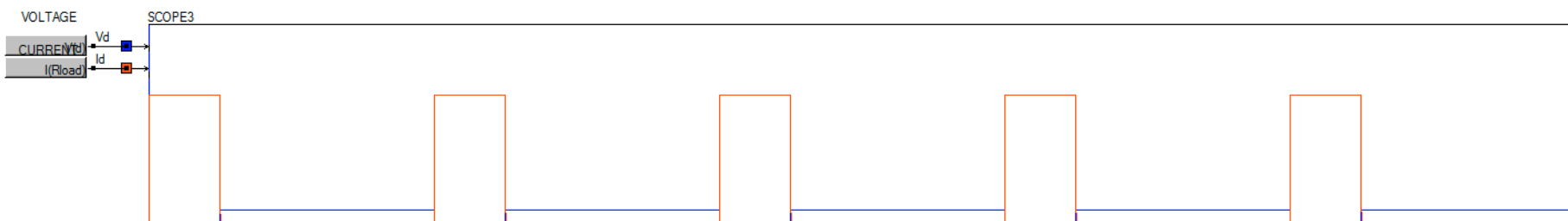
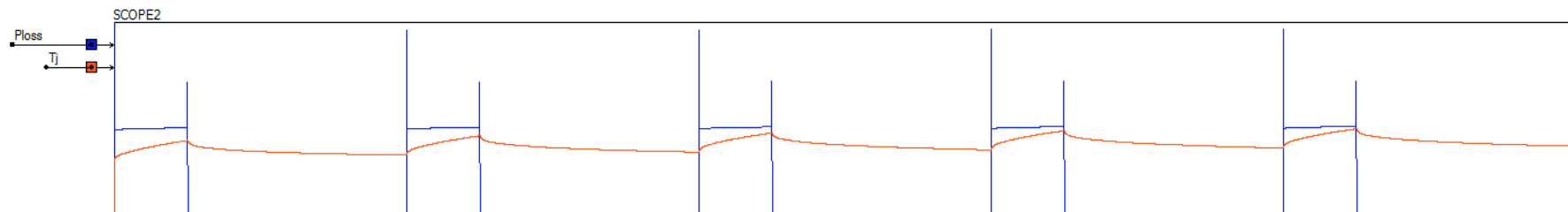
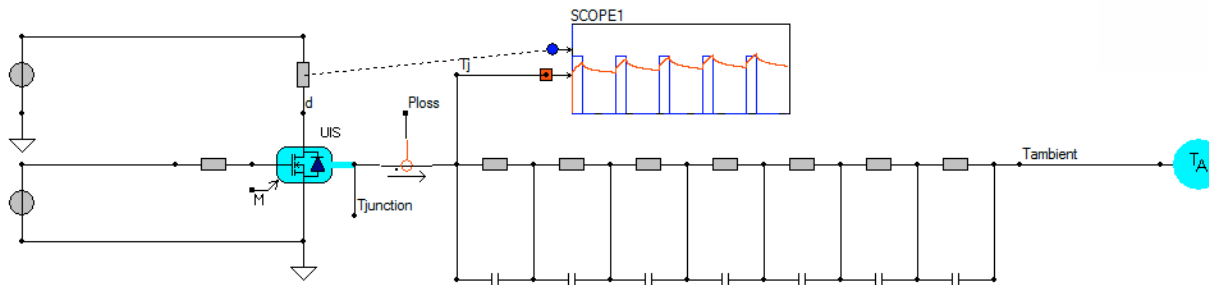
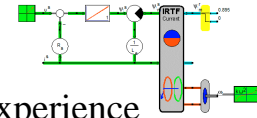
# Mosfet thermal model





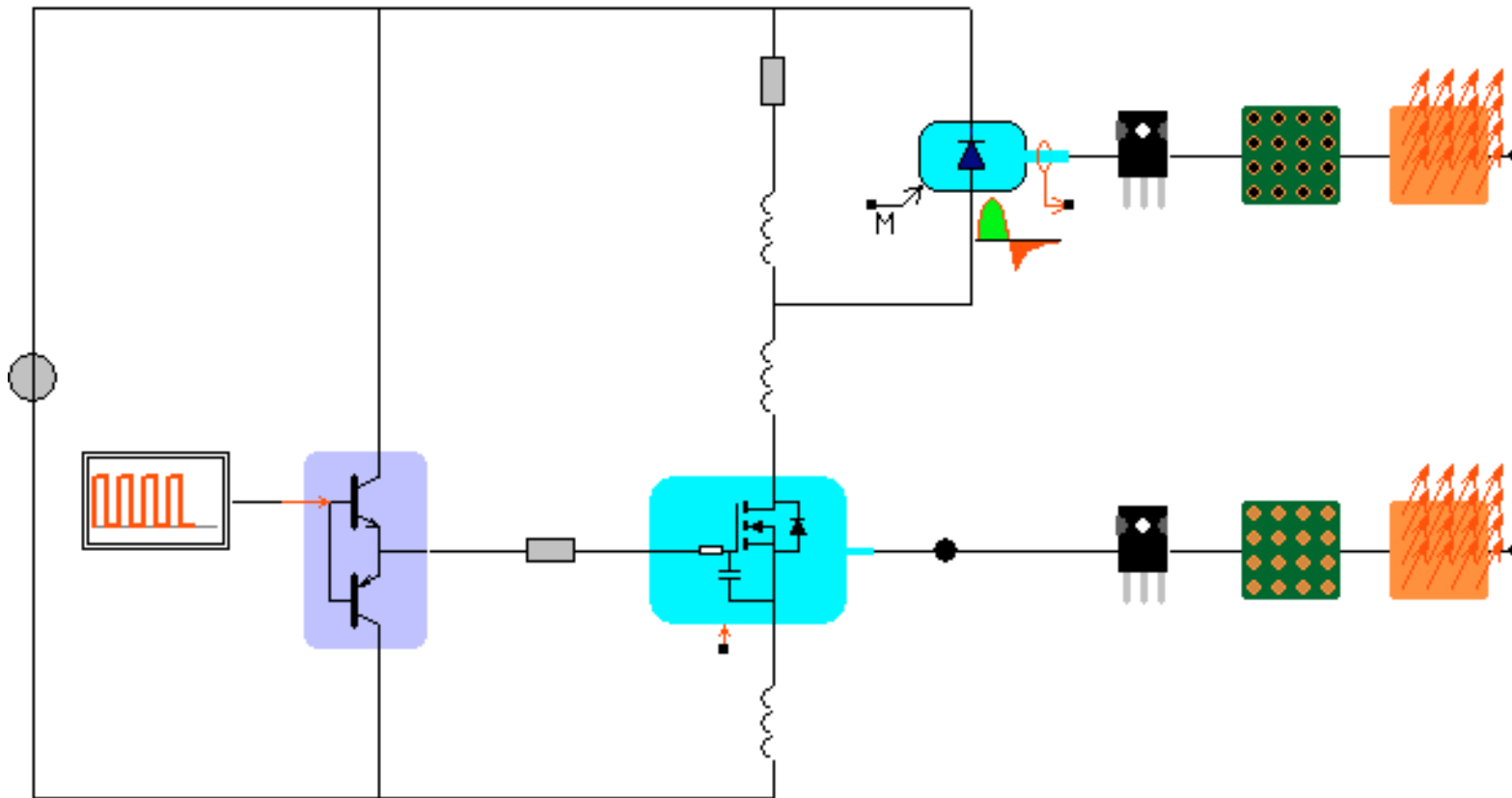


# Thermal model BUK7Y7R6-40E



# Thermal cooling via PCB

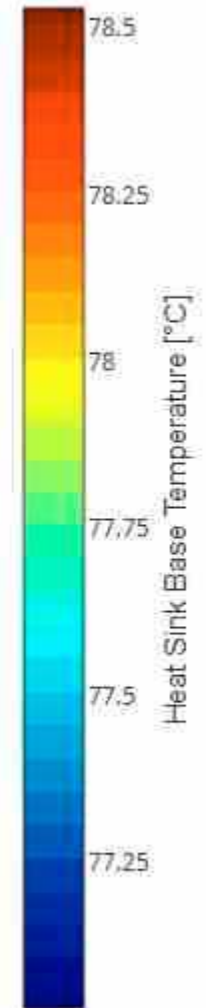
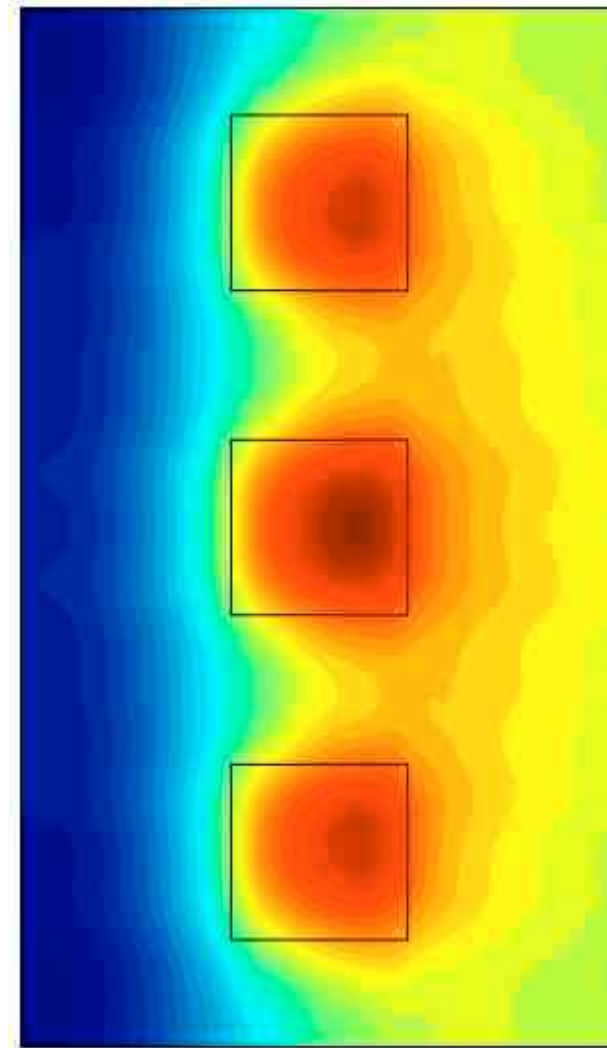
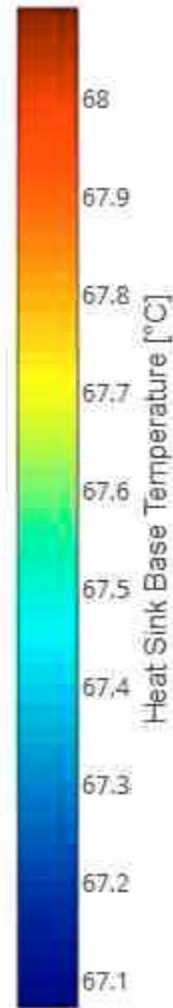
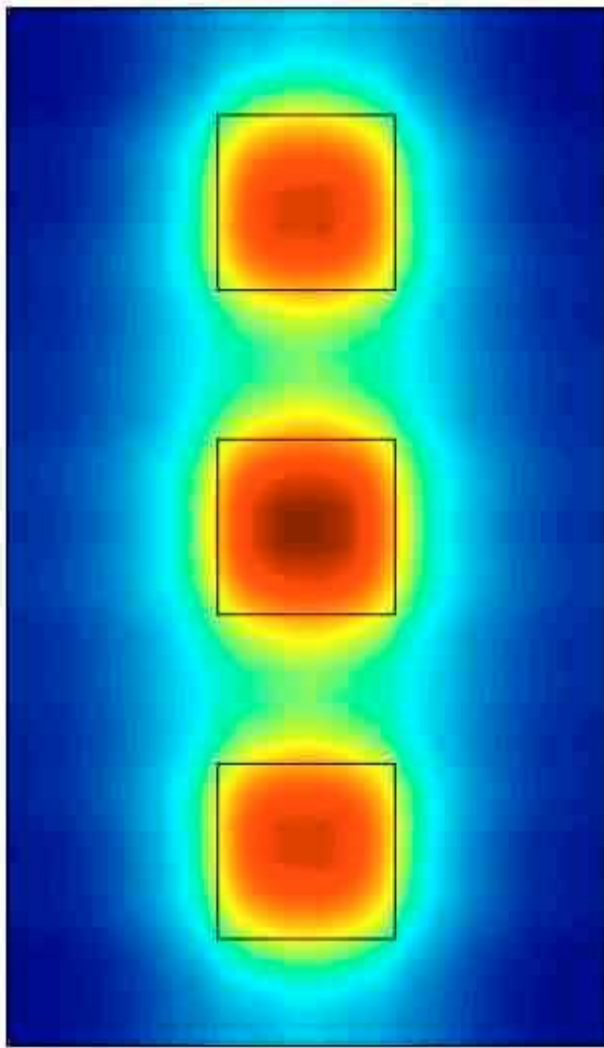
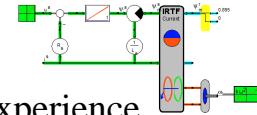
- Rule of thumb: 1mW --> 1cm<sup>2</sup> --> 1 Degr. Celsius
- Convection & Radiation



# Convection (Vertical or Horizontal)

Caspoc

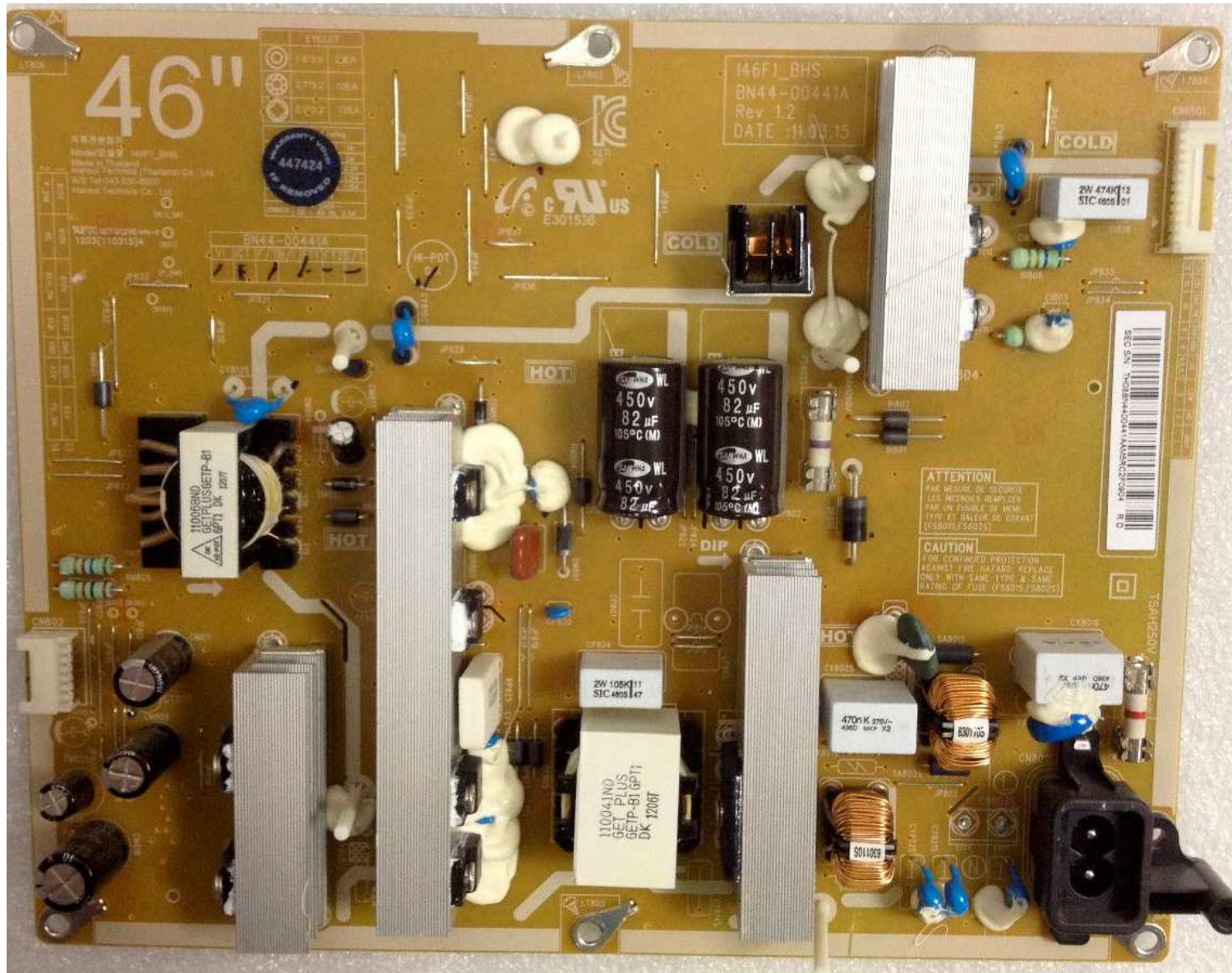
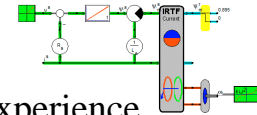
A simulation Experience



# Is PCB cooling the future?

Caspoc

A simulation Experience



# Conclusion

- Multilevel Simulation

- Component level
- Circuit level
- System level

- IGBT

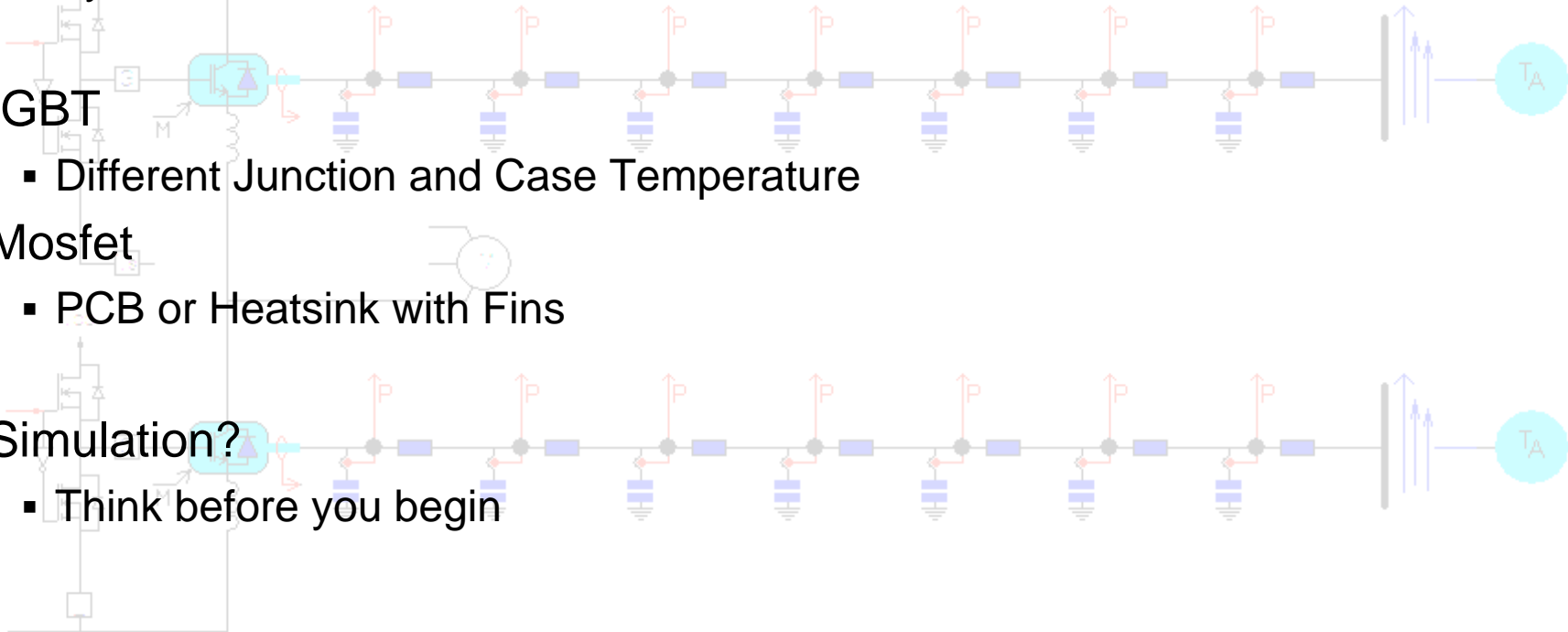
- Different Junction and Case Temperature

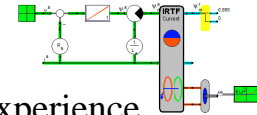
- Mosfet

- PCB or Heatsink with Fins

- Simulation?

- Think before you begin





▪ Questions?

