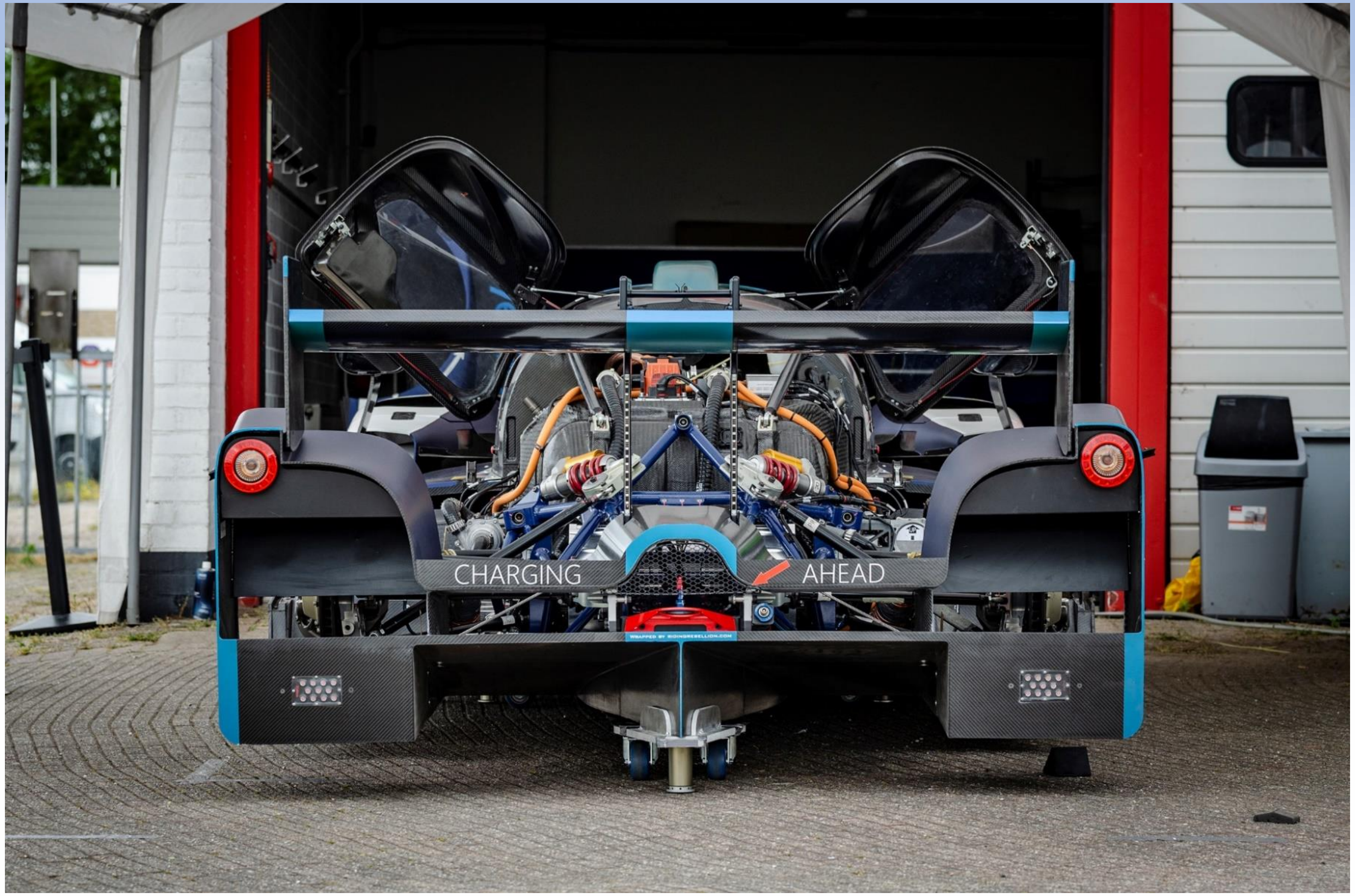
Systematic Approach temperature measurement in Power and battery/ accu applications

THAL TECHNOLOGIES

Overview

1. Introduction
2. Thermal design for optimal battery & power control cooling
    a. Thermal challenges of batttery cooling
    b. Thermal challenges cooling of Control electronics
3. Process to come to an optimal thermal design
4. Temperature measurements
5. Conclusion

1. Introduction



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2a. Thermal challenges batttery cooling

1. Battery performance heavily effected by internal temperature and temperature differences between cells and modules.
2. Heat generated by:
3. Reaction heat Qr
4. Polarisation heat Qp
5. Joule heat Qj
6. $Qt = Qr + Qp + Qj$
7. Joule heating in the busbar, interconnects and in the cells
8. Keep temperature uniform at 35-40°C max

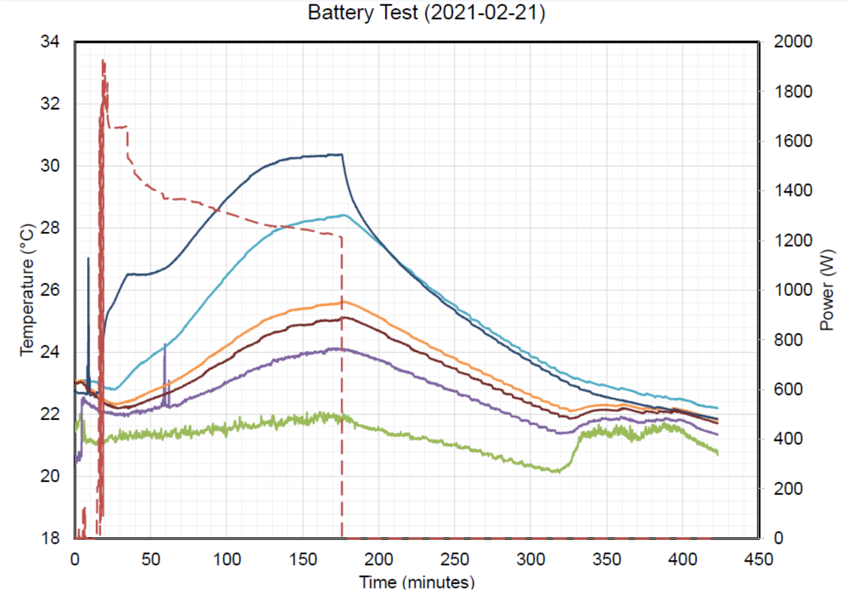
For more interesting data see paper:
Study on the thermal interaction and heat dissipation of cylindrical Lithium-Ion Battery cells
21-24 August 2017 ICAE2017, 21-24 August 2017 By Yuqi Huang and others

2a. Example

1. Assume battery electrical resistance is 1.5mOhm (3P4S spec sheet) fast-charge with 200A (50A/cell) versus 400A(100A/cell)
2. Pd=200^2$*$0.0015=60W / module, assume the full battery pack exist out of 48 modules, Pd=48$*$60=2880W
3. Pd=400^2$*$0.0015=240W assume the full battery pack has 48 modules, Pd=48$*$240=11520W
4. Fast charging and dis-charging has a large impact on dissipated power

2a.Process to come to optimal cooling design

- Experimental testing of battery
- Build detailed computational model of battery/ cooling of power electronics
- Cold-plate design - Analytical modelling in combination with computational and experimental modelling
- Design of cooling assembly
- Experimental test full system



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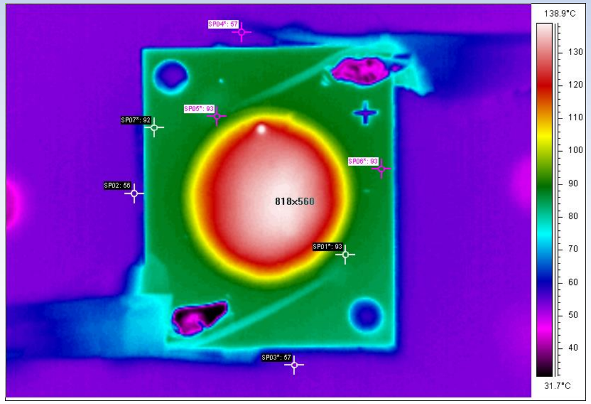
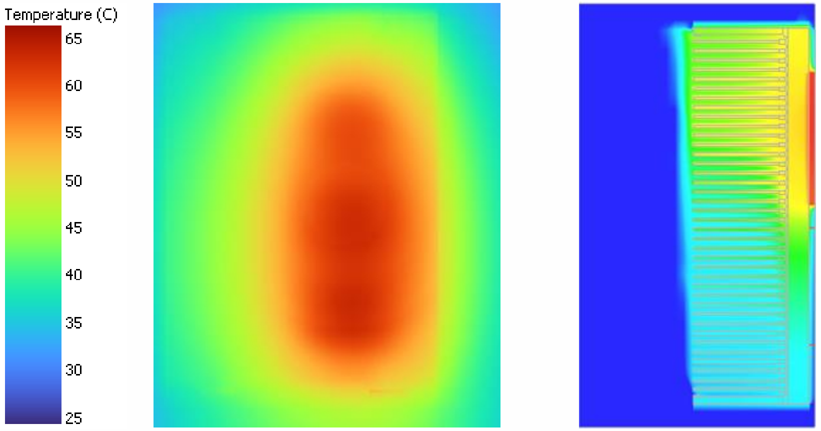
2b. Thermal challenges cooling of Control electronics

1. High concentration of power e.g. FETs, IGBTS, coils, transformers, capacitors
2. Other: cables, tracks, interconnects.
3. (Thermal) Interface resistances
4. (Thermal) Spreading resistance

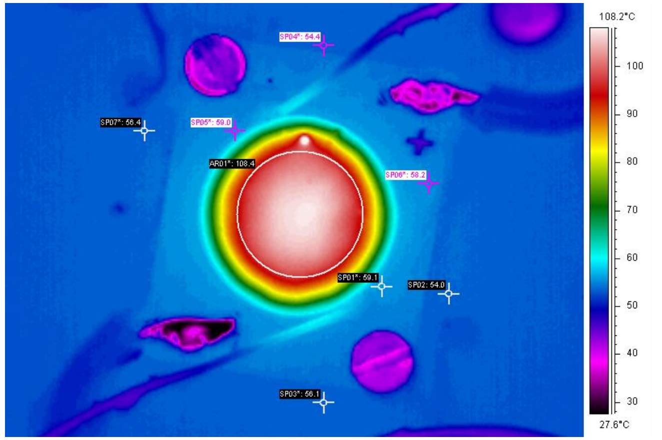
Bad interface



Spreading resistance base Heat Sink



Good interface



IXYS

Infineon

2b.Process to come to optimal cooling design

- Analytical calculation in combination with detailed computational modelling cooling of power electronics
- Optimization of flow and heat paths, design of cooling mechanics, heat sink, cold plate
- Design of final cooling assembly
- Experimental test full system

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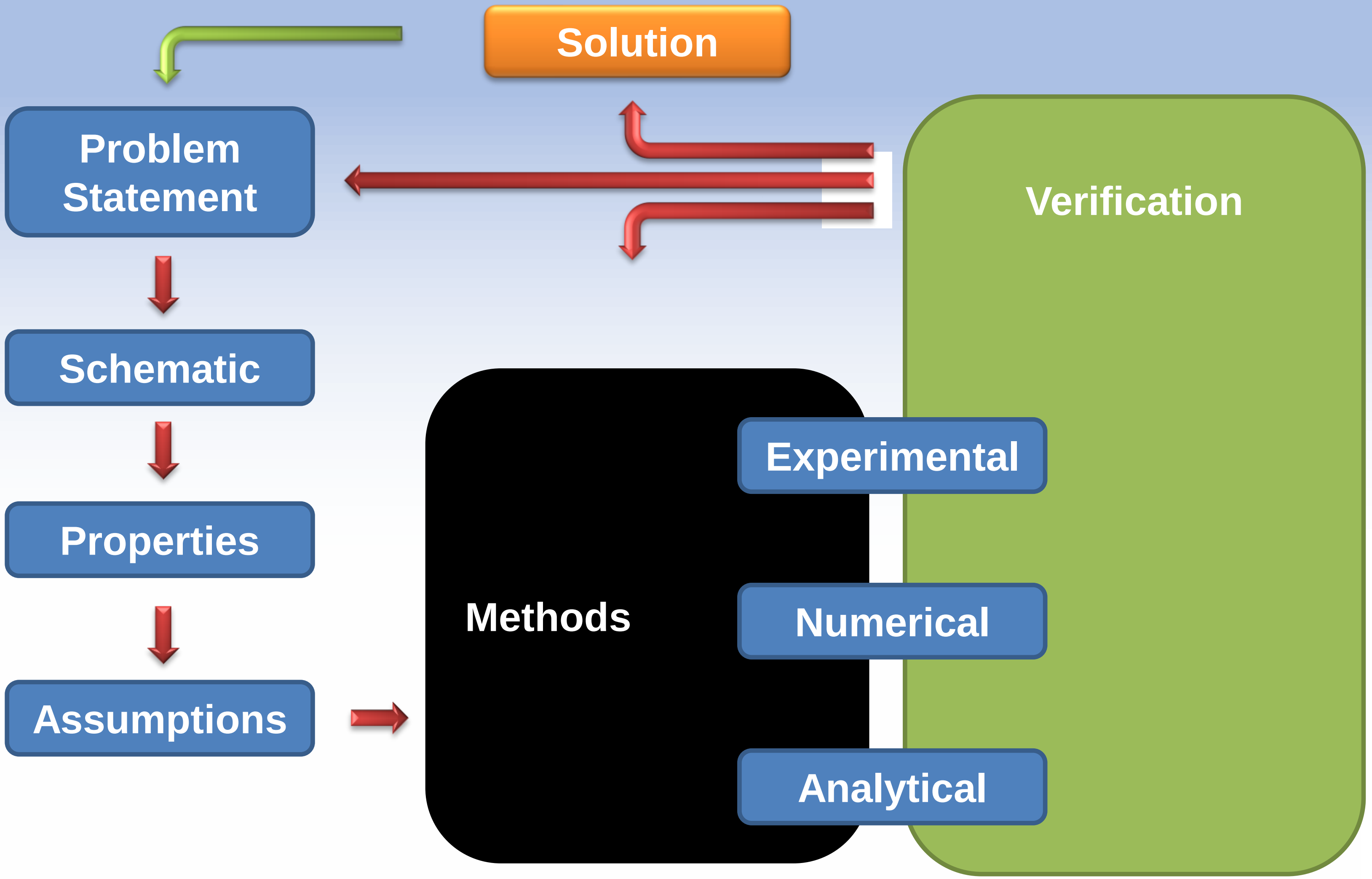
3. Process schematic review



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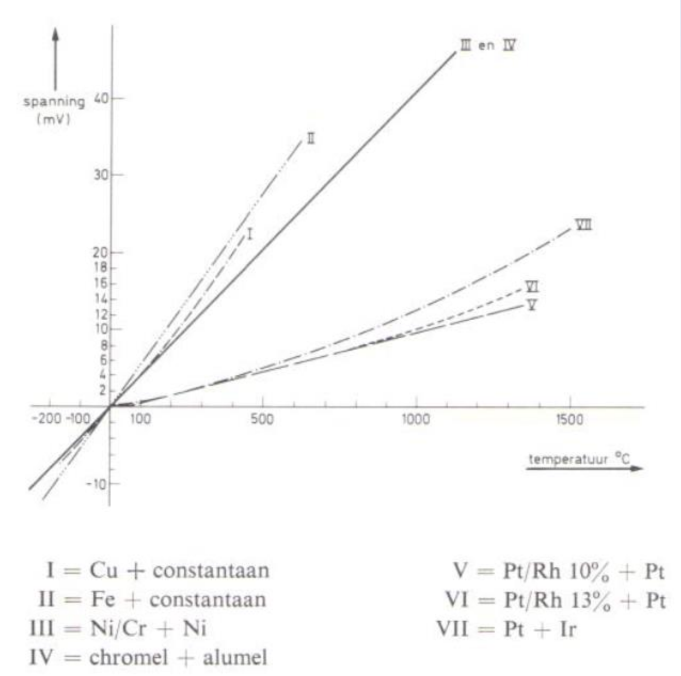
Temperature measurement

- Measuring is knowing, but what are you measuring?
  - By using the three methods, analytical, computational, experimental you get insight in what need to be measured, where and how.
  - Methods:
    - Temperature sensor, thermocouple, NTC, PT100
    - Infrared imaging
    - Diode (junction) measurement

Thermocouple

- Every temperature sensor measures its own temperature
- Thermocouple is a line sensor not a spot sensor



$$EMF = \int_0^L \varepsilon_1 \frac{dT}{dx} dx + \int_L^0 \varepsilon_2 \frac{dT}{dx} dx$$

ε = total thermoelectric power of material mv/C

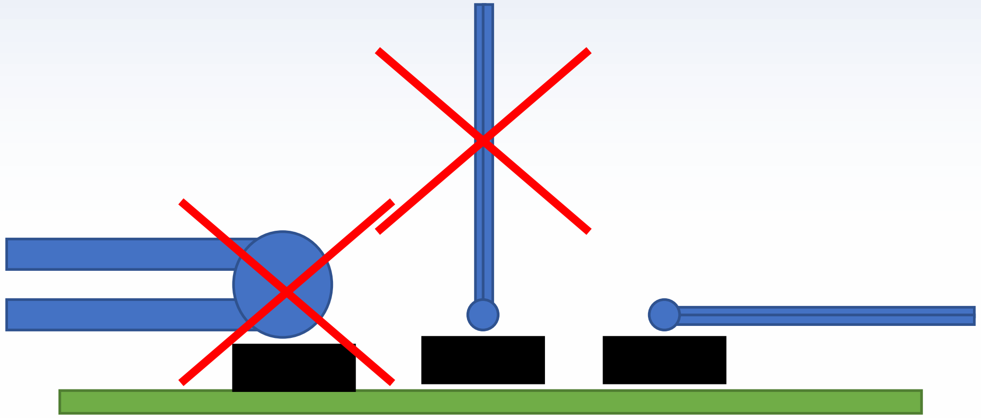
T = Temperature

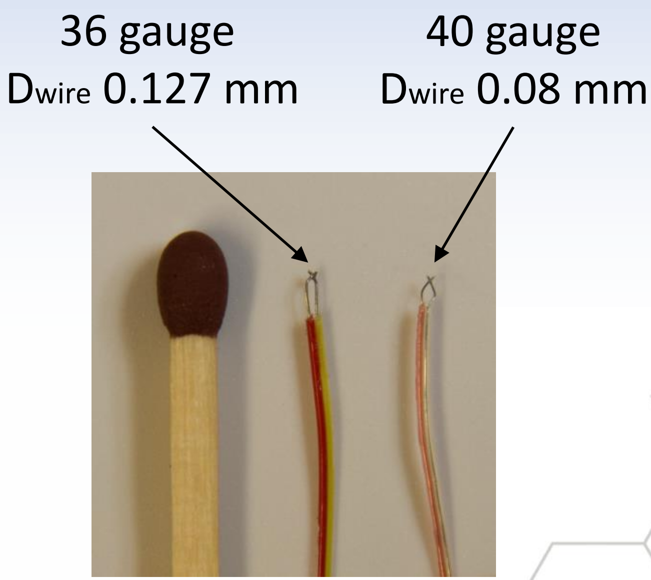
x = distance along the wire, m

L = length of the wire, m

Thermocouple

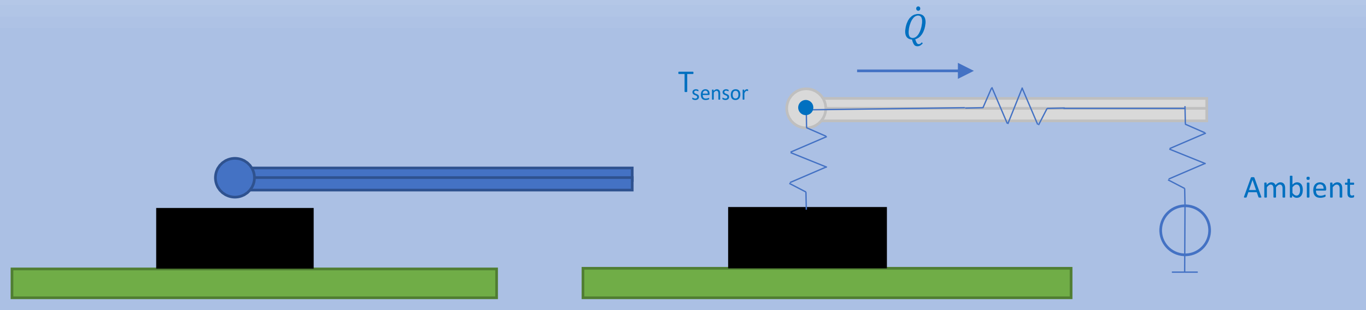
- Contact surface > 10x diameter, using glue best
- Flat joint, don't connect by twisting => many junctions
- Diameter wires small in line with object to be measured
- No copper constantan

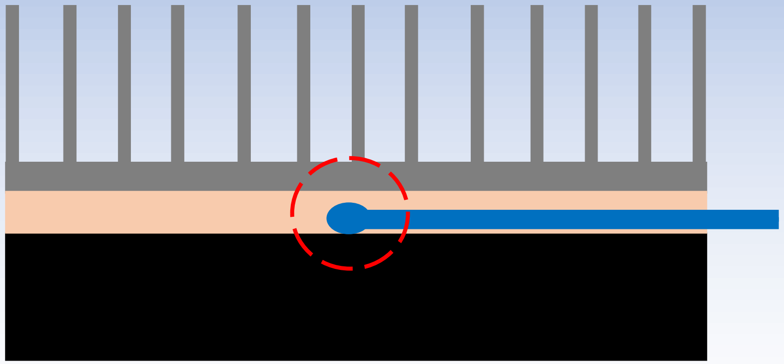




Measurement errors

- Size of sensor
- Location of sensor

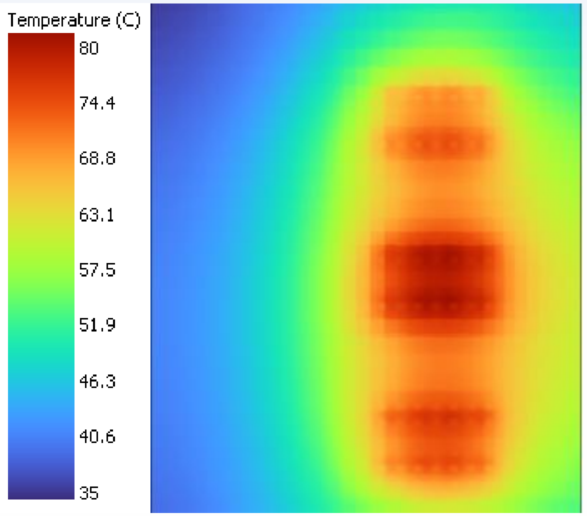




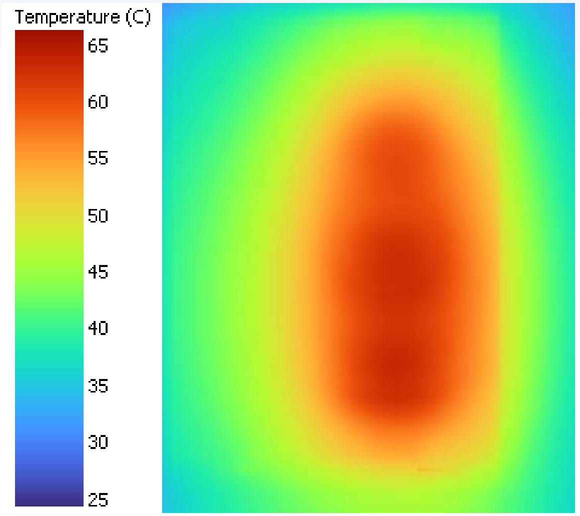
What do I want to measure?
What do I measure?

- Component case
- Heatsink
- TIM

Base of power module

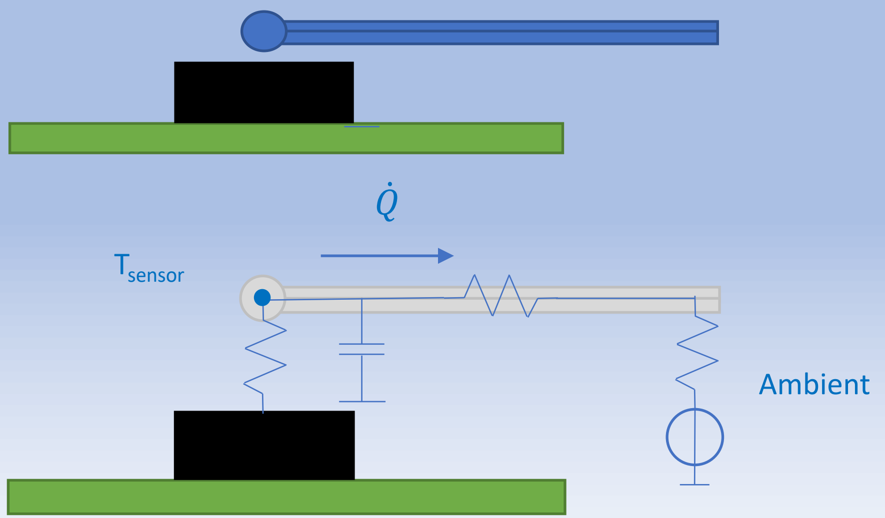


Base of HS – below module (temp scale different)

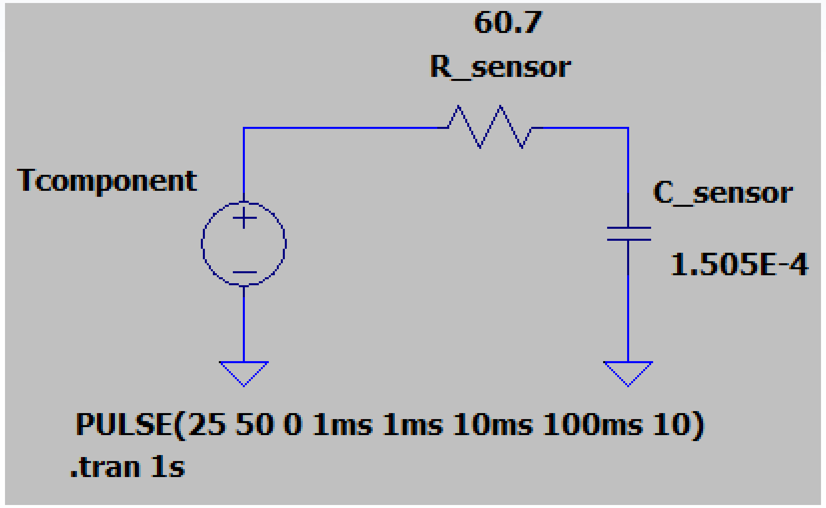


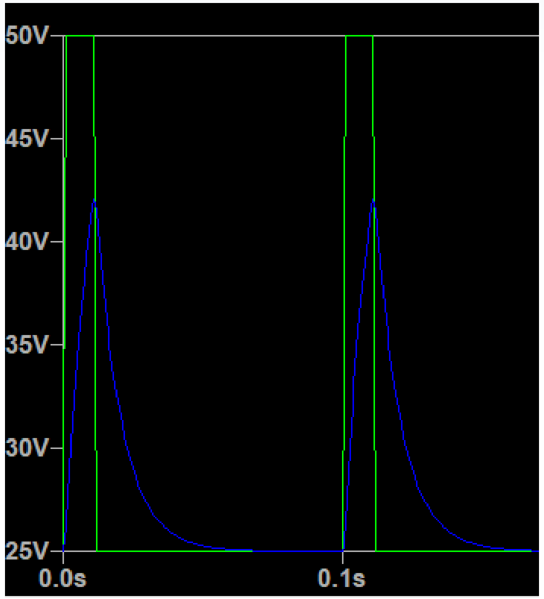
Measurement errors cont'd

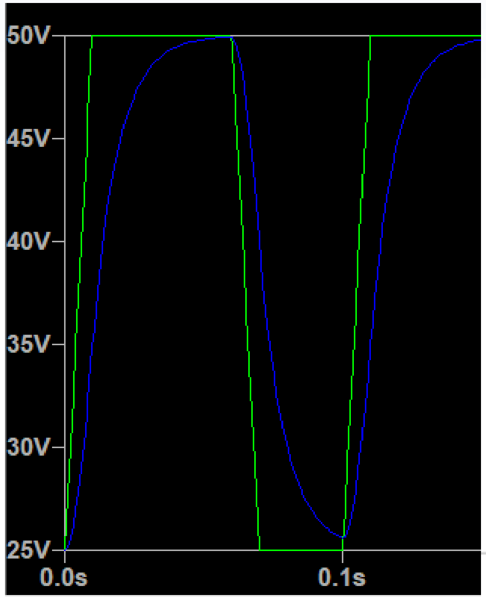
- Time constant of sensor
  - Is the time constant in line with the phenomena



Glass bead sensor, Ø0.37mm tau 17.2+/-0.8ms (measured)







Measurement errors cont’d

Measurement speed datalogger

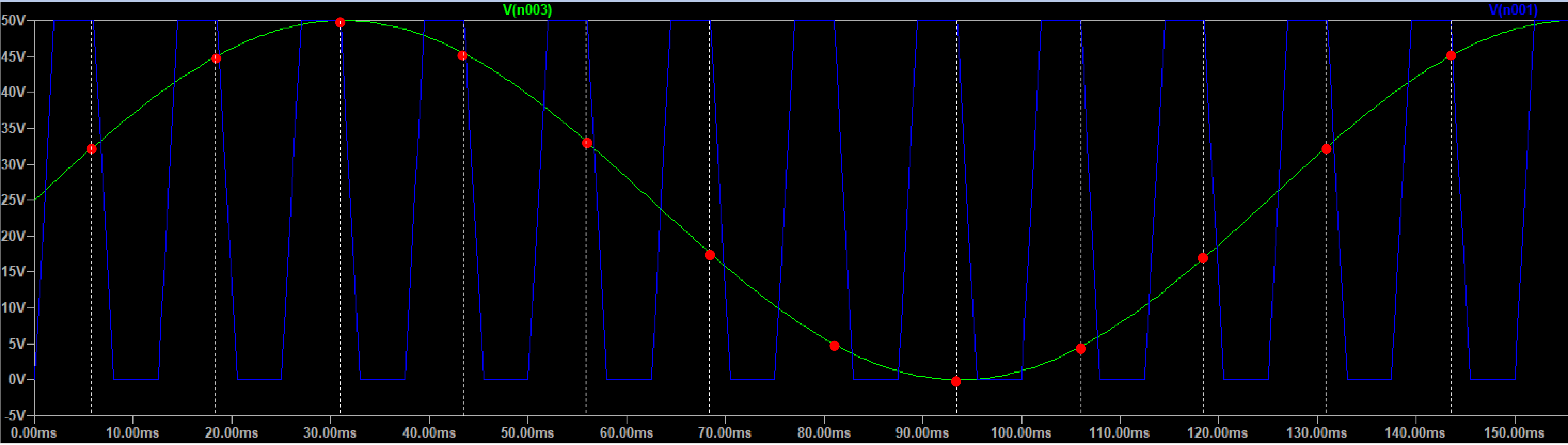
- Example Keysight DAQ970A with DAQM901A module
- Scanning speed
  - 1 channel used max 80 samples per second (80Hz)
  - 20 channels used 4 samples per second/ channel (4Hz)
  - Check if the signal (temperature) profile can be represented
    use as rule of thumb measurement speed 10x signal speed

➢ 80Hz measurement speed for signals of 8Hz

	Multiplexer				Actuator	Matrix	RF multiplexer	Multifunction
	DAQM900A	DAQM901A	DAQM902A[1]	DAQM908A	DAQM903A	DAQM904A	DAQM905A	DAQM907A
General								
Number of channels	20 + 2 2/4 wire	20 + 2 2/4 wire	16 2/4 wire	40 1 wire	20 SPDT	4 x 8 2 wire	Dual 1 x 4 50 Ω	See page 25 for module specifications
Connects to internal DMM		●	●	●				
Scanning speed	450 ch/s	80 ch/s	250 ch/s[1]	100 ch/s				
Open/close speed	120/s	120/s	120/s	70/s	120/s	120/s	60/s	

Measurement errors cont'd

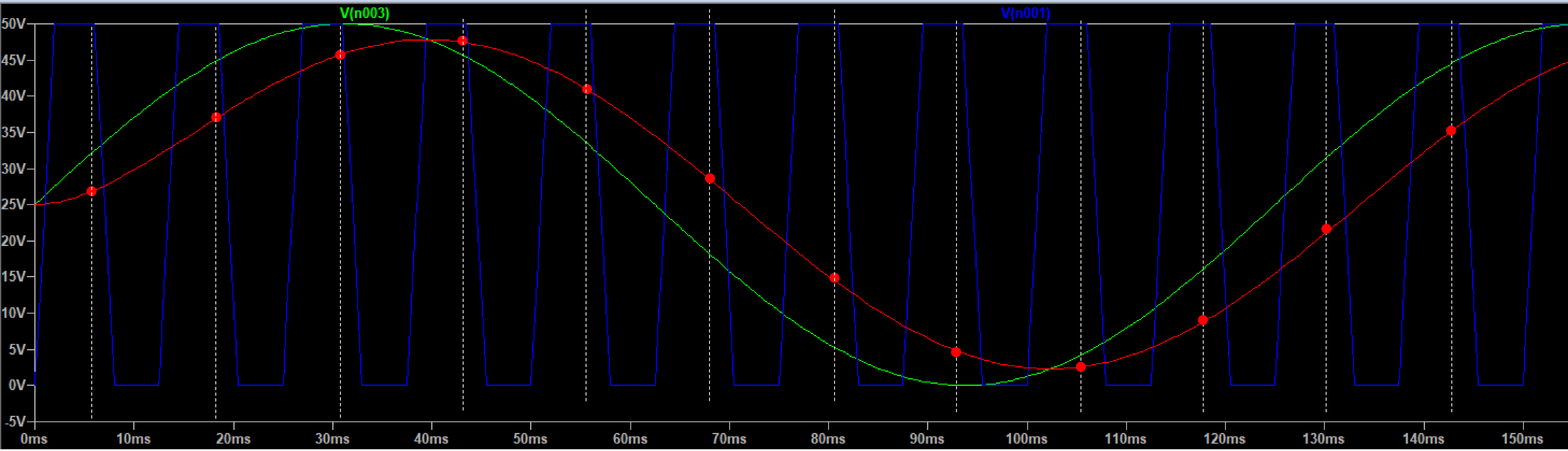
Signal 8Hz (green), measurement speed 80Hz (blue)



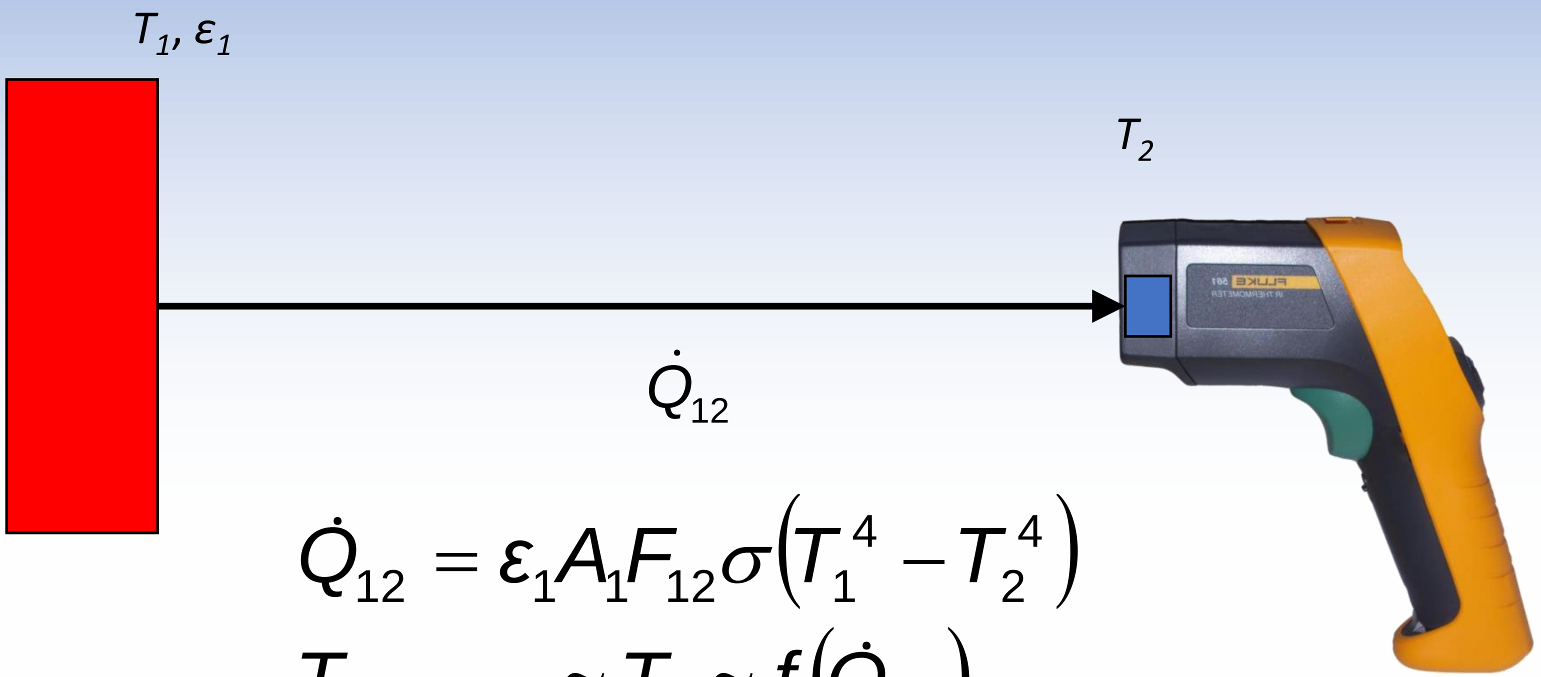
Measurement errors cont'd

Signal 8Hz (green), measurement speed 80Hz (blue)

Red sensor (including time constant sensor)



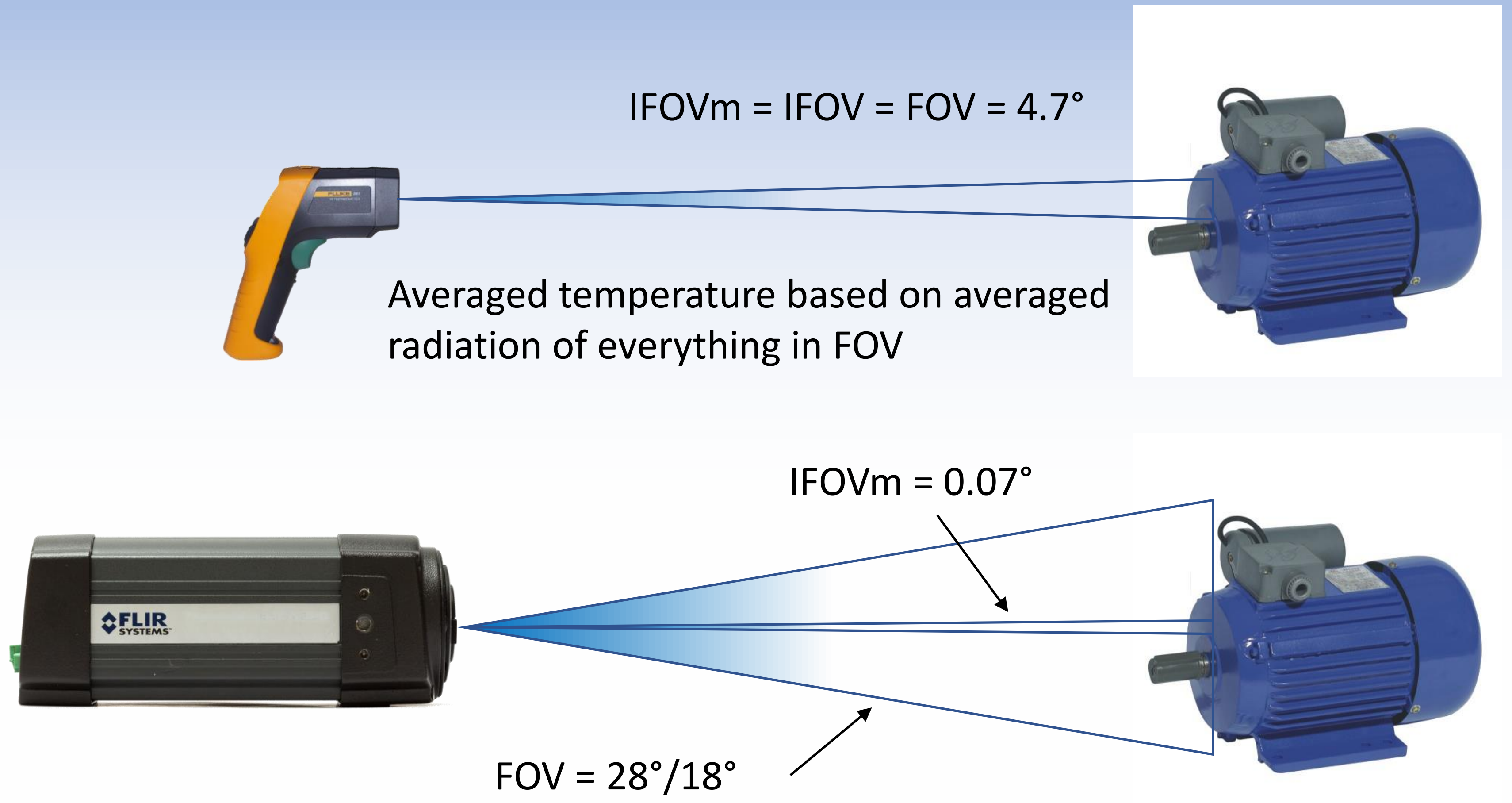
Infrared imaging



$$\dot{Q}_{12} = \varepsilon_1 A_1 F_{12} \sigma \left(T_1^{\,4} - T_2^{\,4} \right)$$

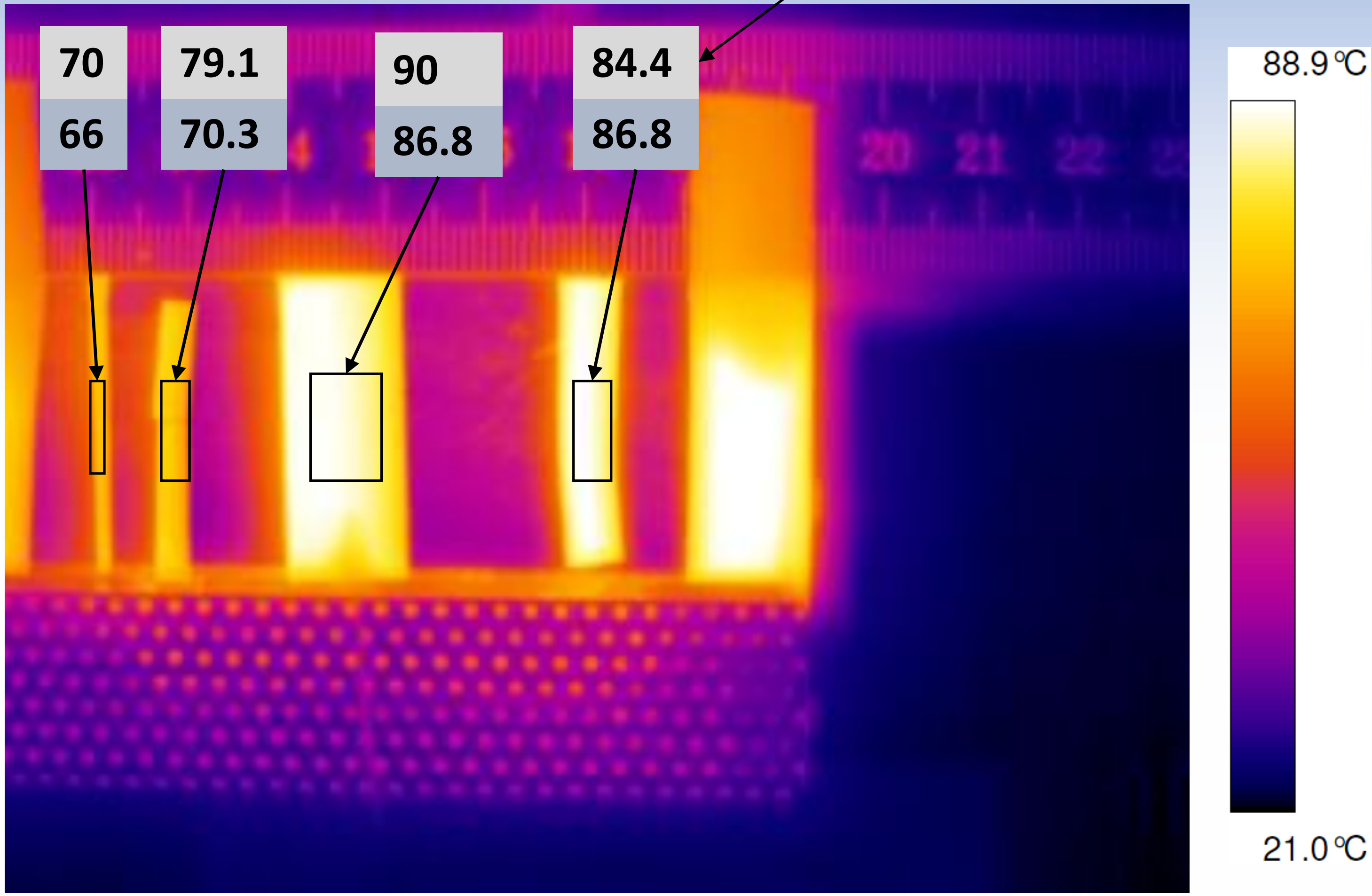
$$T_{indicated} \approx T_1 \approx f\left(\dot{Q}_{12} \right)$$

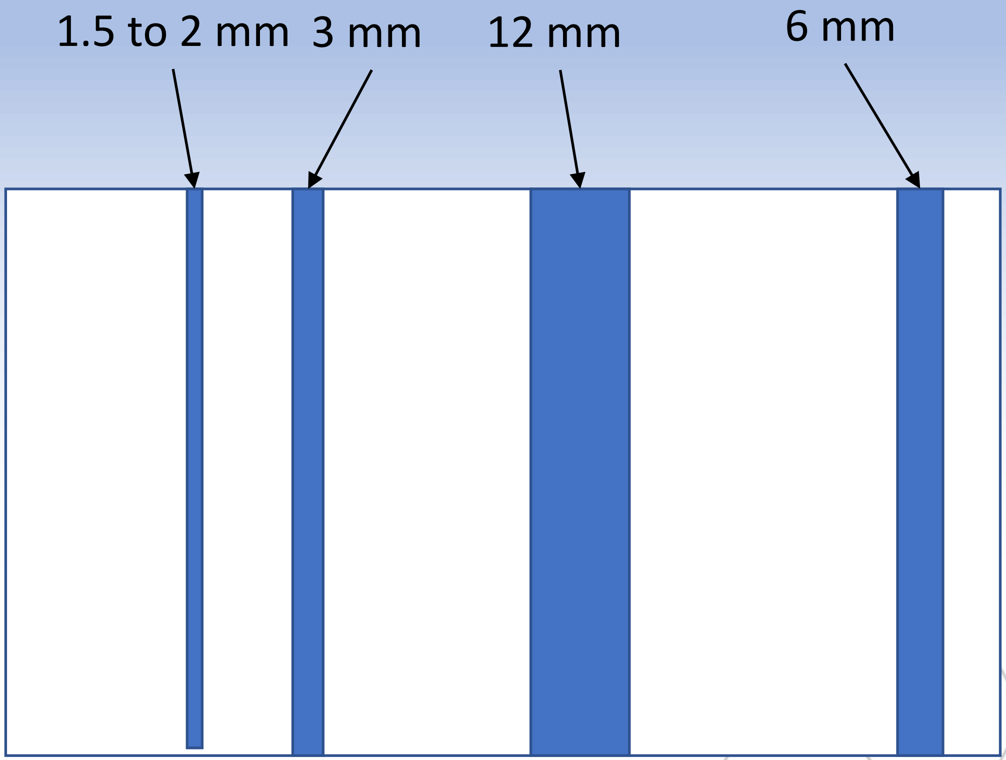
Infrared imaging
Field of View – comparison of IVOF



Infrared imaging
Field of View - exceptions

IR Image centred results





Low & high
emissivity areas

Infrared imaging

FLIR i series

FLIR E Series

FLIR T420

FLIR SC325

FLIR t640

FLIR X8000

Infrared imaging

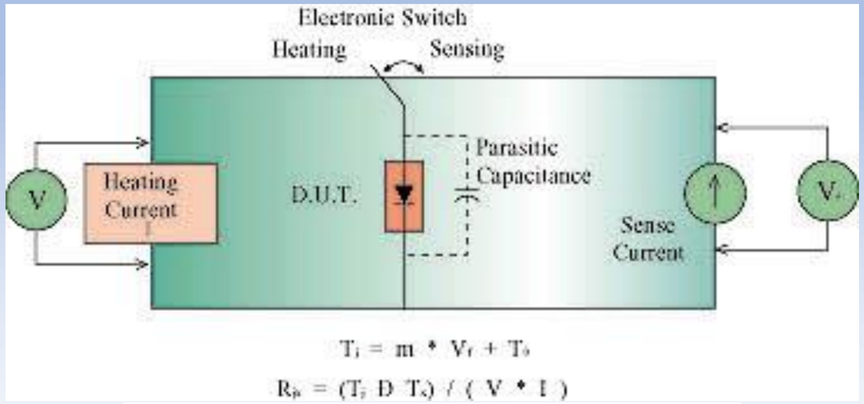
- What are the differences – where do you pay for?

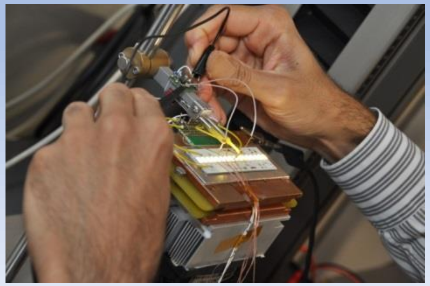
Parameter	FLIR A40	FLIR i3	FLIR i5	FLIR i7	FLIR E30bx	FLIR E50bx	FLIR T420	FLIR SC325	FLIR T640	X8000 **
θ_H [°]	28	12.5	21	29	25	25	25	28	15	22
θ_V [°]	18	12.5	21	29	19	19	19	19	11	17
Hres. [pixel]	320	60	100	140	160	240	320	320	640	1280
Vres. [pixel]	240	60	100	140	120	180	240	240	480	1024
Focal Distance [mm]	300	600	600	600	400	400	400	400	500	400
IFOVm,MAX [mm]	1.4	6.6	6.7	6.7	3.3	2.2	1.7	1.9	0.6	0.4
Price indication (excl VAT) ***	€ 15 000	€ 1 000	€ 1 500	€ 2 100	€ 2 864	€ 5 254	€ 8 532	€ 14 000	€ 24 000	?

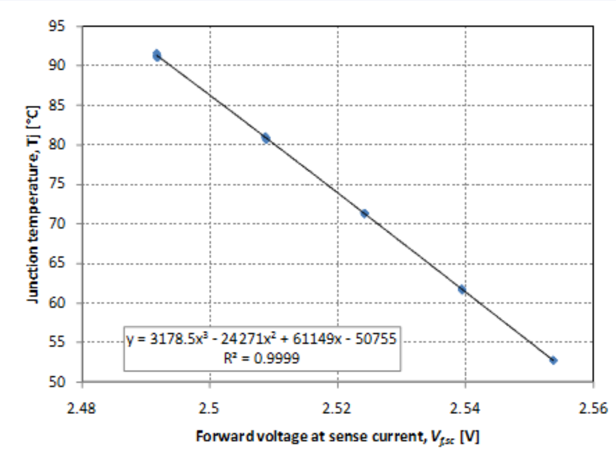
** X8000: Avaliable optics - 38° x 31°, 22° x 17°, 11° x 9°, 5.5° x 4.4° and close up x3 (6.4 x 5.1 mm, IFOV ~= 5 µm)

*** Price indication purely as reference. Macro lens for SC325: ~€2000.-

Junction measurement

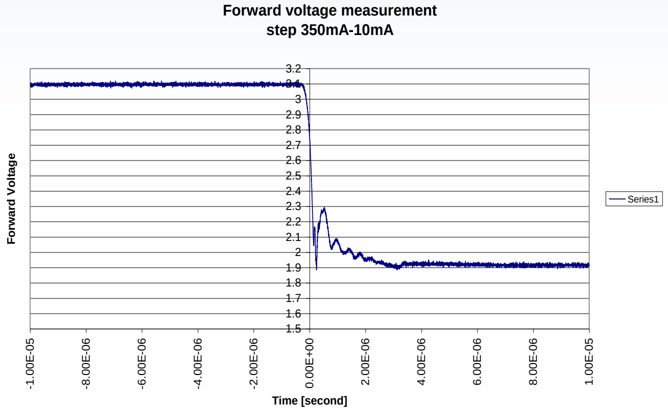






calibration curve

Response of forward voltage, shown in μseconds



Conclusion

- Measuring is knowing, but what are you measuring?
  - By using the three methods, analytical, computational, experimental you get insight in what need to be measured, where and how.
- Important is:
  - Selection of sensor type
  - Size of sensor
  - Location and mounting method
- For transient behaviour check you sensor time constant and datalogger sample rate
- For infrared imaging check if the camera/lens you use is capable to capture the size of the object. Calibrate for emissivity and check reflections

Q&A

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