



Integrating EMC Measurement, Power Consumption, and Sustainability into Electronics Engineering Education

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MSc (Electrical Engineering)

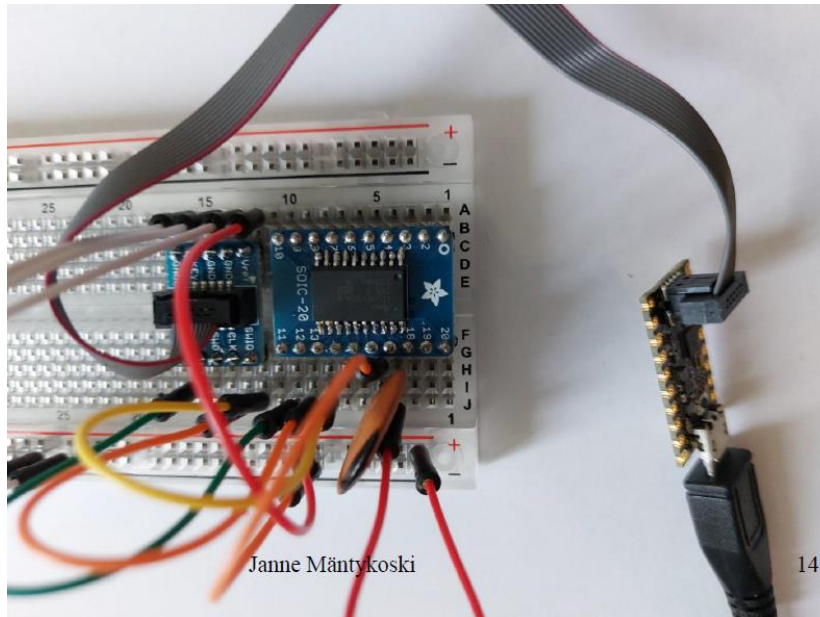
Teacher for over 20 years

Fields of interest include Programming and electronics (also FPGAs and Digital Asics)

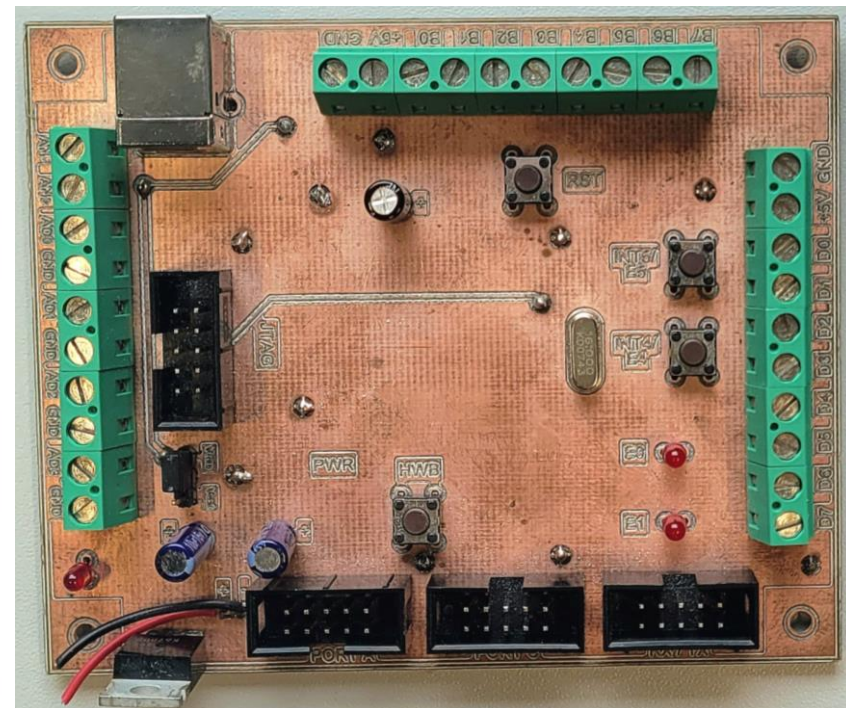
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Electromagnetic Compatibility (EMC) course, worth 15 ECTS

- EMC lectures and labs
- PCB design for embedded system: prototype to breadboard, milled PCB: Buck regulator with external inductor to create EMI
- RF lectures and labs



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EMC measurements

Currently

Precompliance EMC measurements:

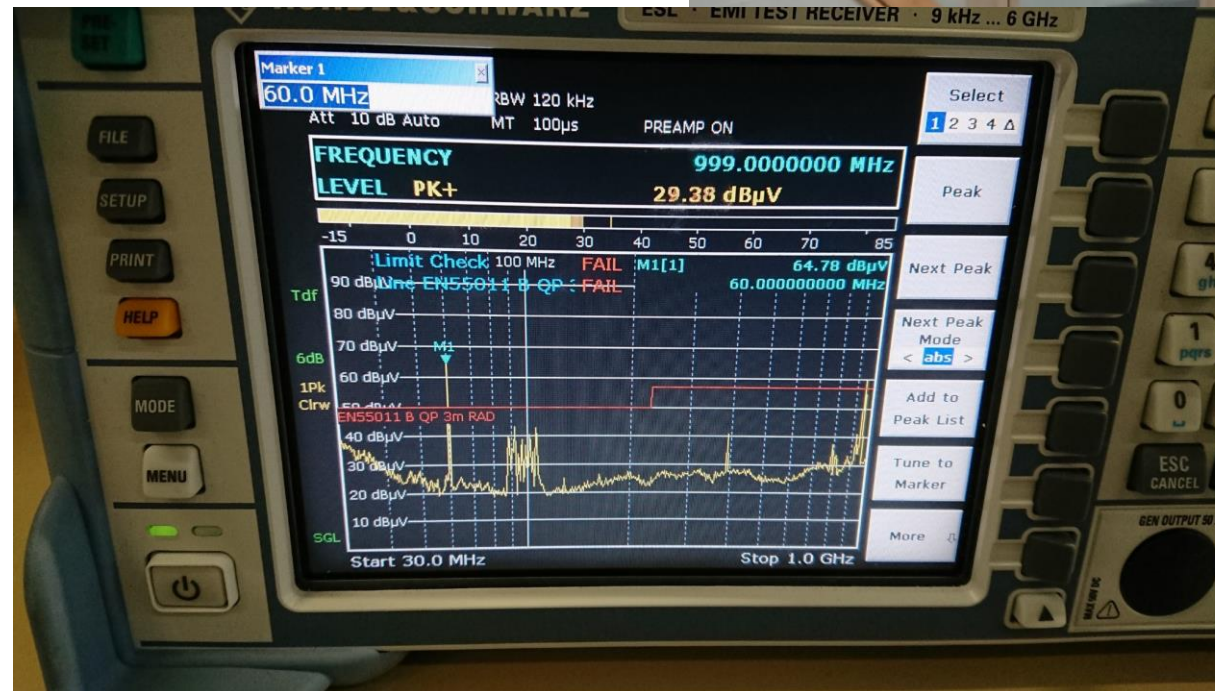
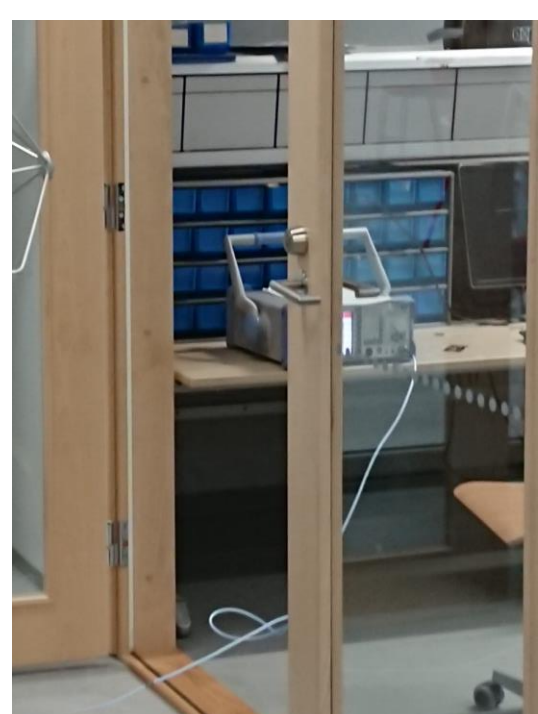
- RF radiated emissions and Conducted emissions
- ESD

Pin-point emissions: EMC scanner: Example PCB and PCB designed by students

Shielding

EMC measurements - RF radiated emissions in an open area test site

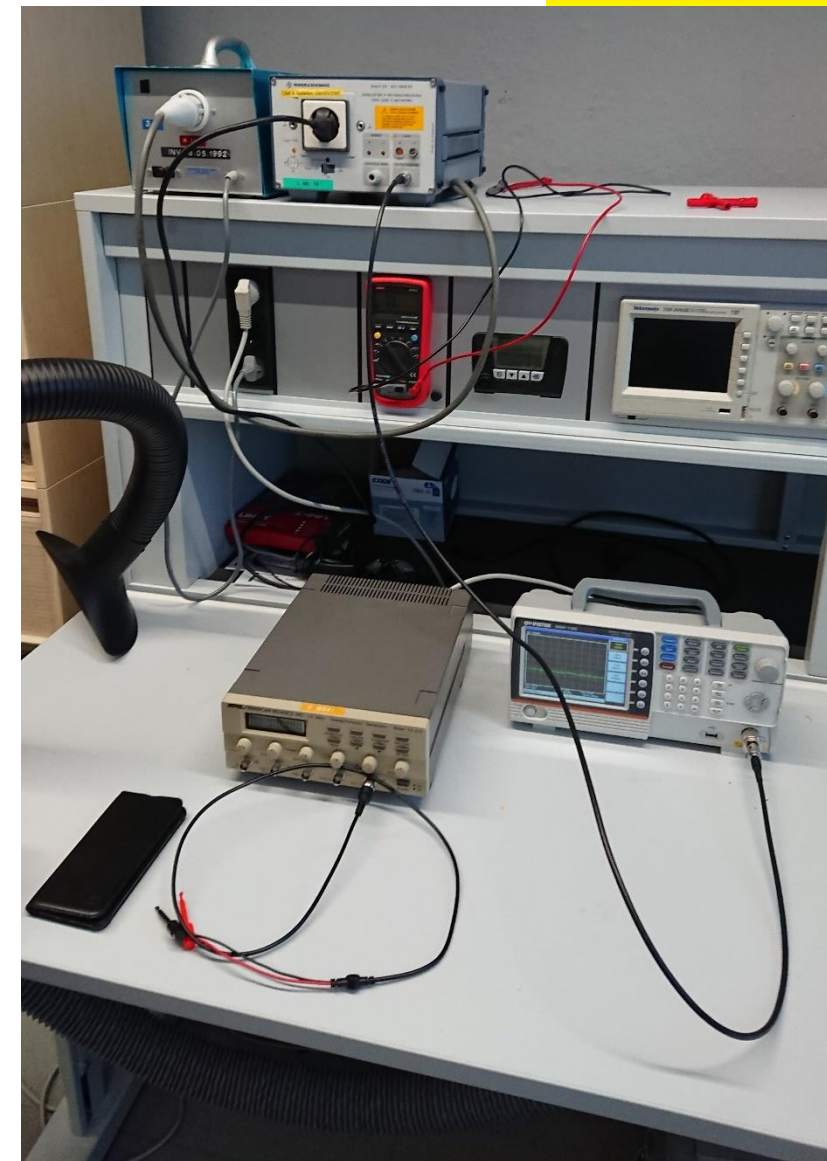
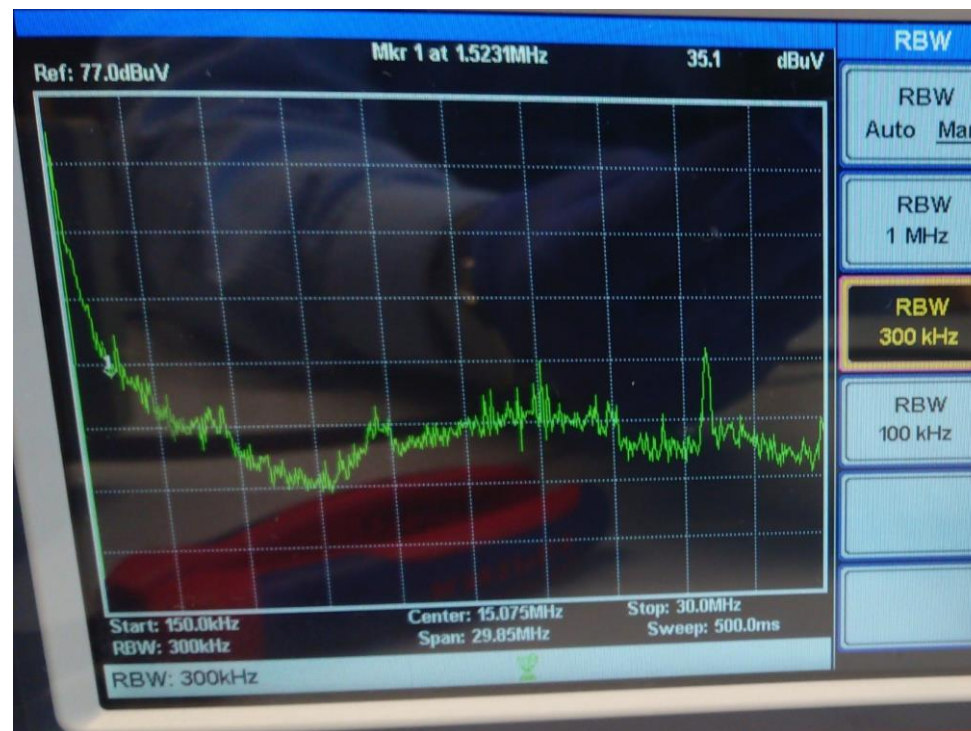
No ground plane
EMI test receiver



EMC measurements – RF Conducted emissions

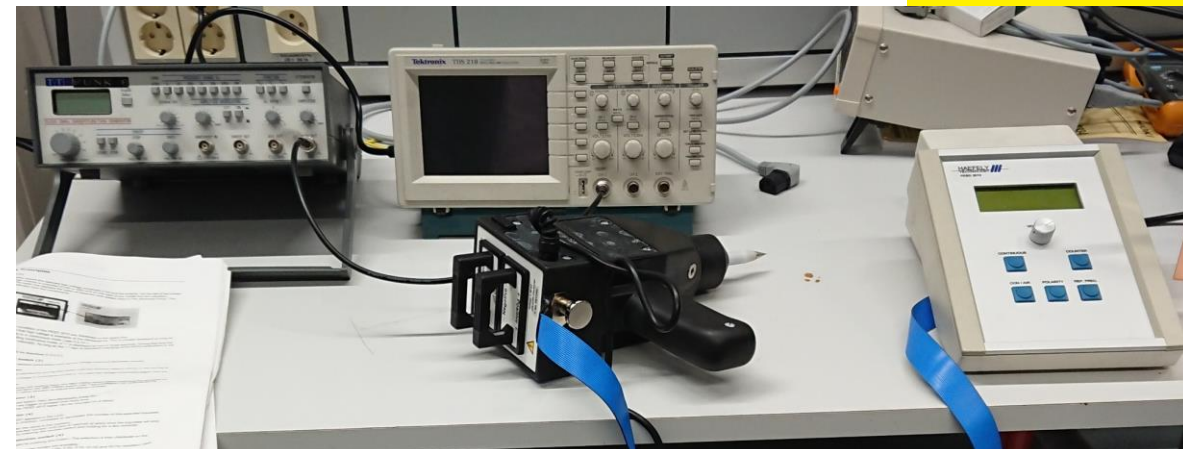
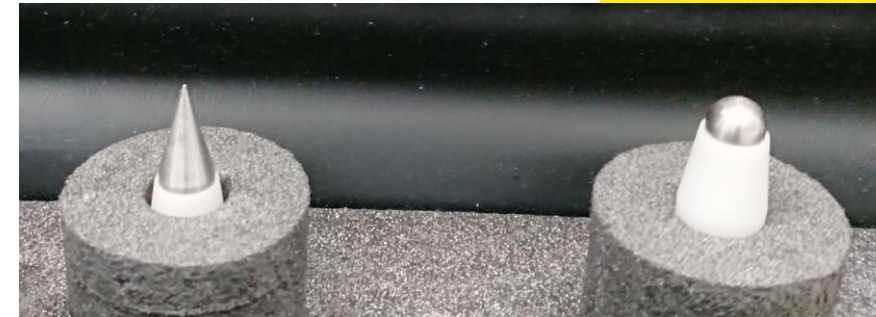
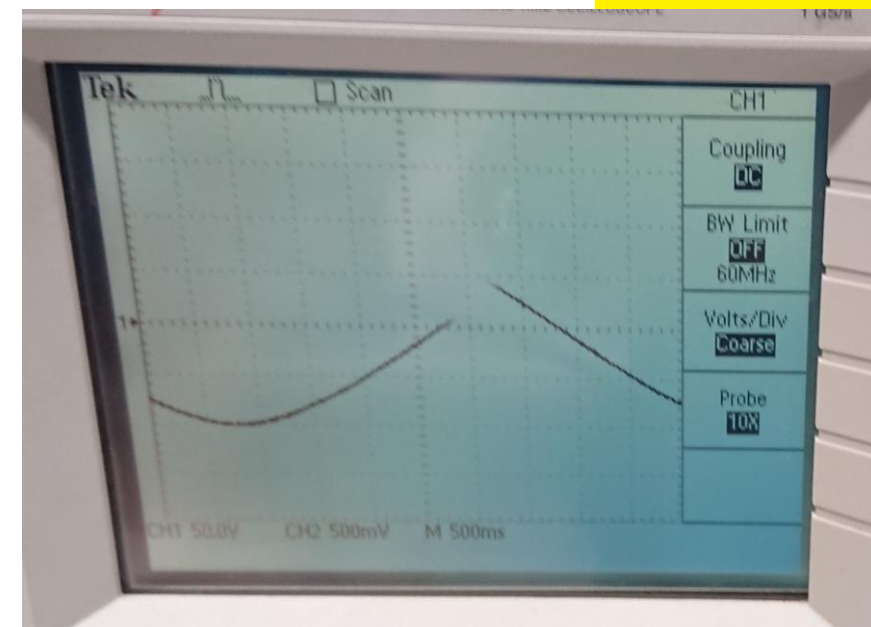
Line Impedance Stabilizing Network (LISN)

Inexpensive spectrum analyzer – no Quasi-Peak



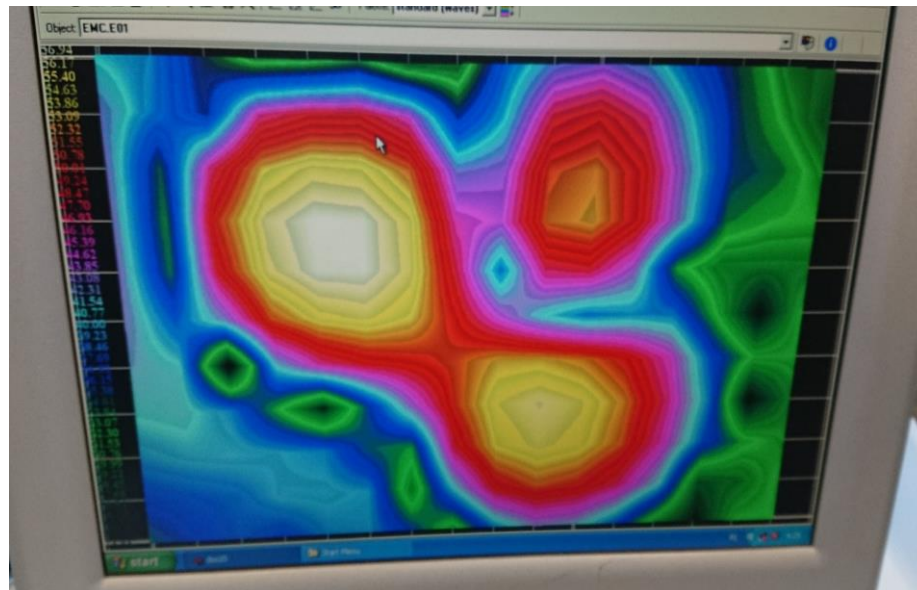
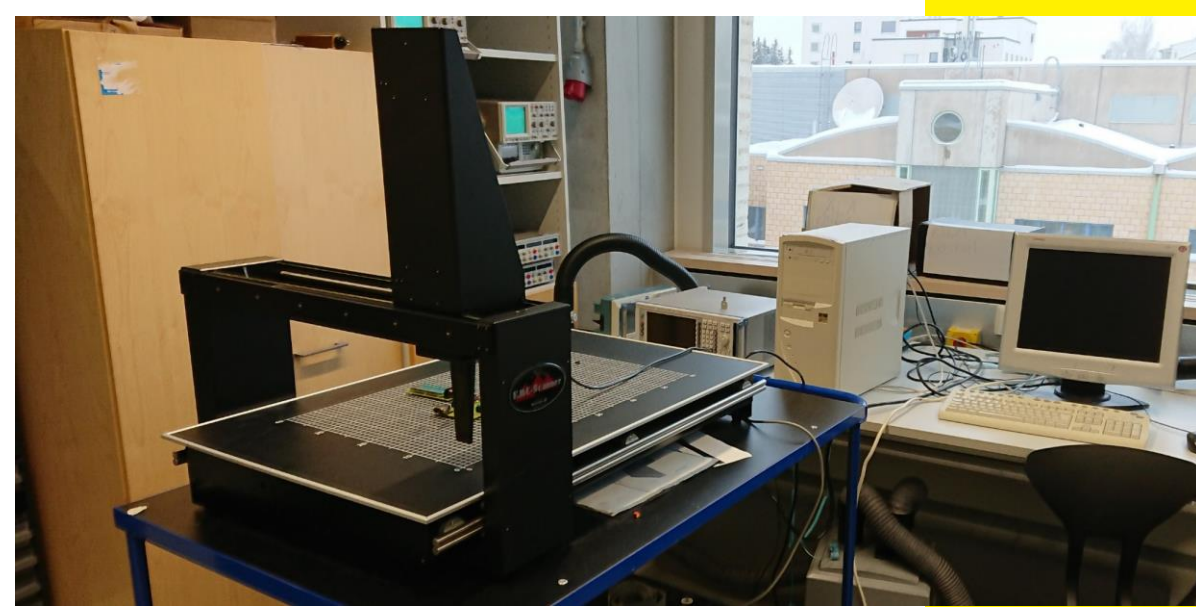
EMC measurements – ESD immunity

Vertical plane
Human model



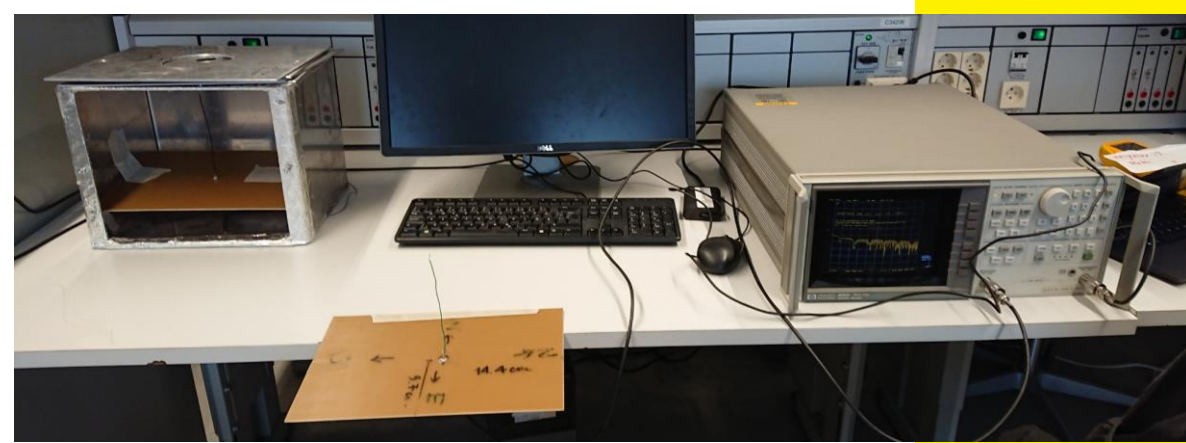
EMC measurements –EMC scanner

- Near-field probe moved in X and Y directions
- Heat camera



EMC measurements - The effect of a conductive wall/enclosure

Reflection and transmission test
Shielding effectiveness calculation



EMC measurements Not currently used

Immunity measurements in GTEM cell

EM Eye Electromagnetic field and RF signal meter

Measurements of EMC antennas in an RF ~~anechoic chamber~~

Differential and common mode interferences and ferrite components

...

EMC measurements in near future and Should have

- New measurements: RF immunity
- Improve test environment: ESD
- New or replacement equipment: EMC scanner, AC LISN device, Near-field probes

A more demanding PCB design for students – high frequencies
CE marking

Power consumption – Current measurement

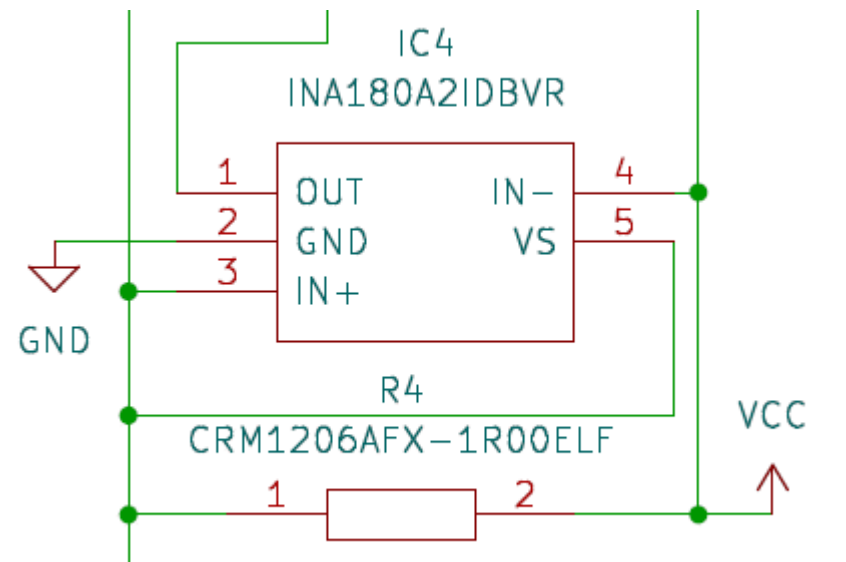
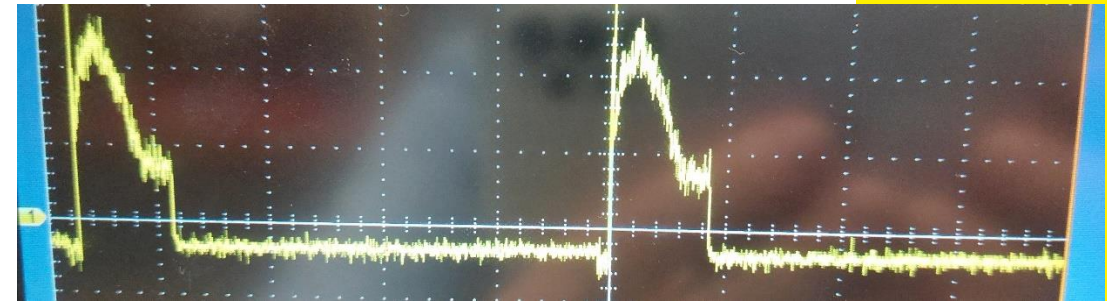
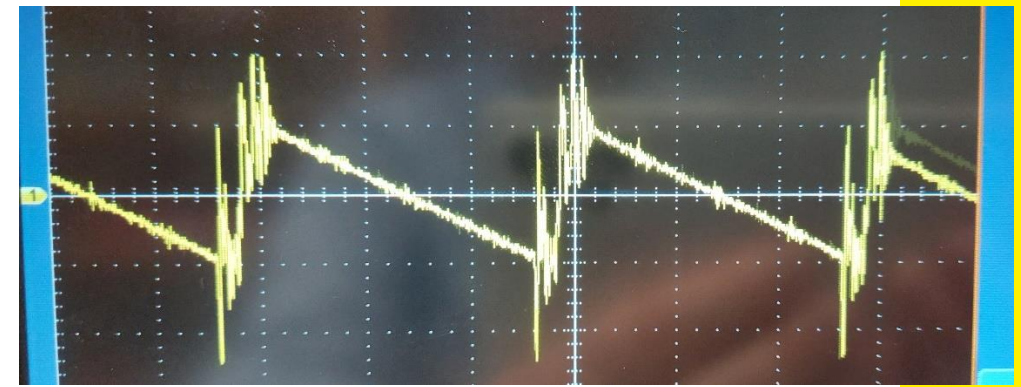
Shunt resistor

Instrumentation amplifier

Current sense amplifier

Good enough

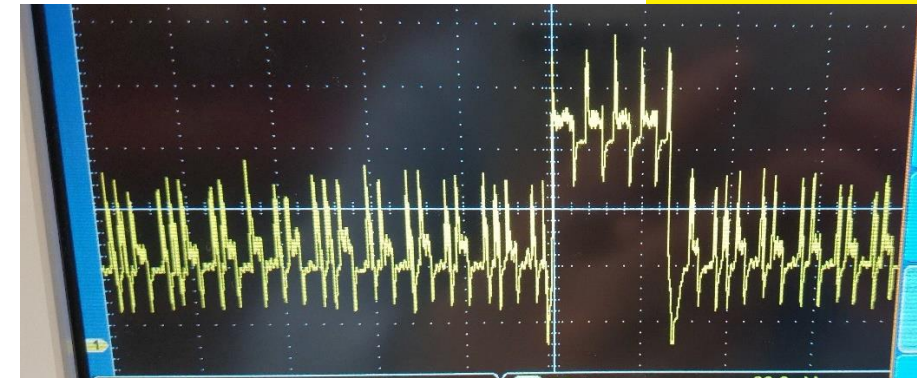
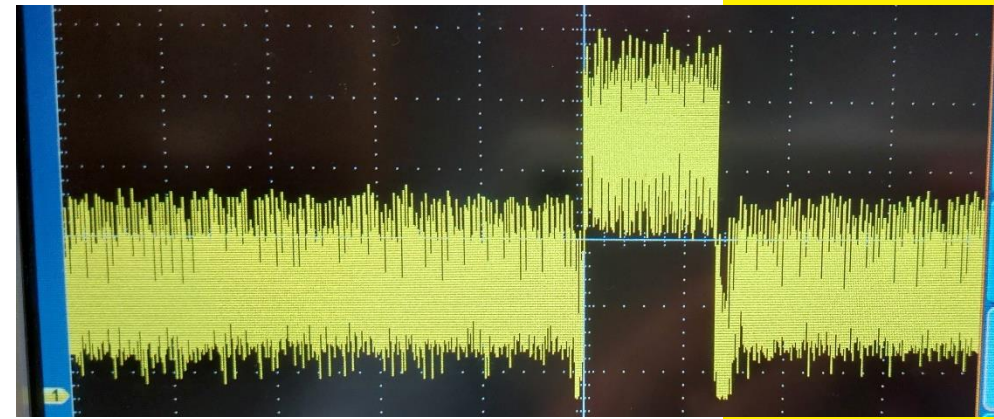
Improvement: Add filtering



Power consumption – Current measurement

12V, USB or battery powered
energy-efficient

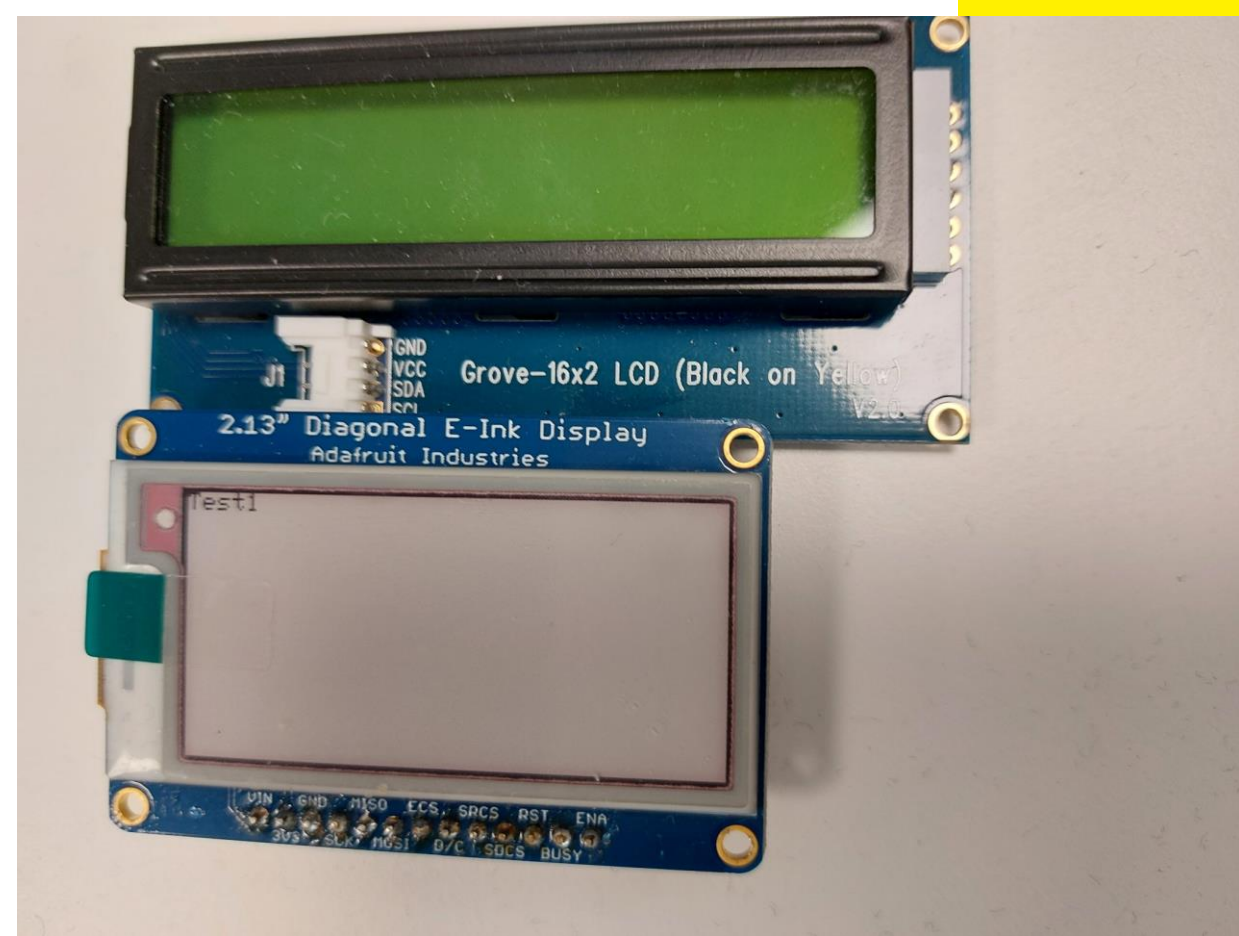
- Multisim used to simulate some circuits: No simulation support for microcontroller
- Falstad circuit simulator



Power optimization

Sleep modes – Sensor nodes

Replace components – LCD vs e-ink



Sustainability

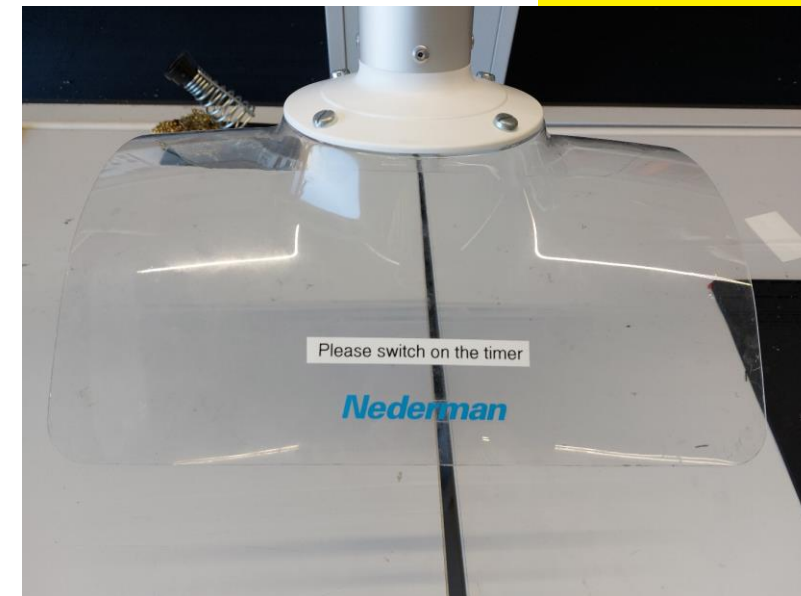
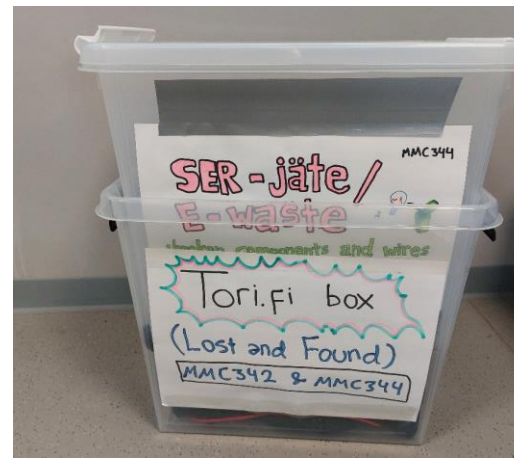
Environmental sustainability – Small measures

Don't throw components to the bin after a laboratory exercise

Use unleaded solder instead of leaded solder – Flux?

Use soldering fume extractor – Poor funnel nozzles?

Economic sustainability – Good enough



Teaching trends

Integration: PCB assembly, mechanical design, EMC

Course evaluation: Peer and group evaluation in PCB projects

Artificial Intelligence (AI) in embedded programming

Balanced student groups



Thank you