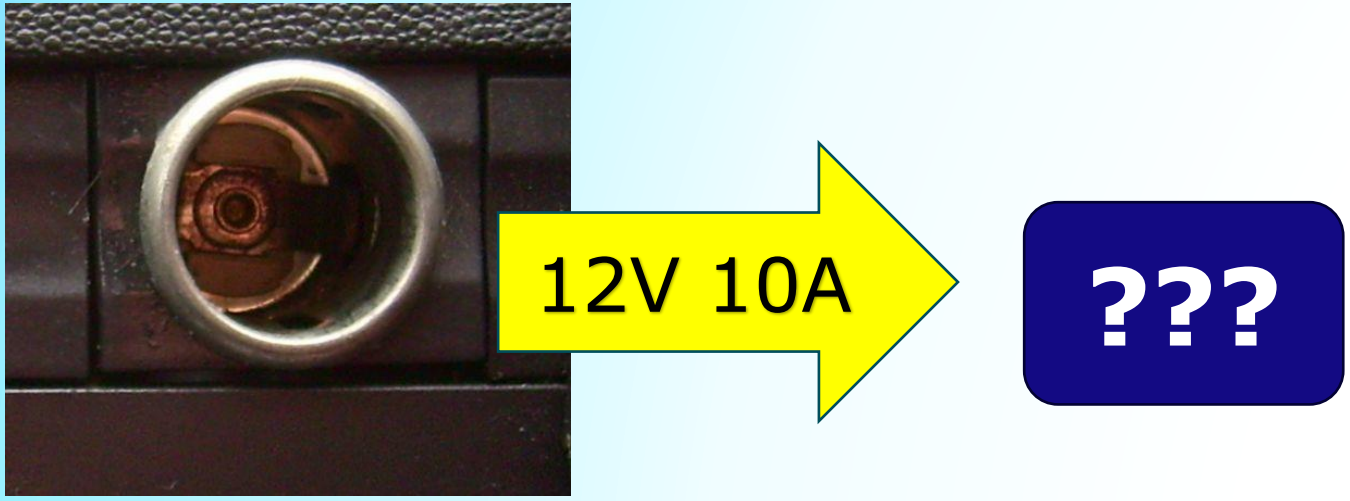
A Power Supply Filter for On-board Voltage Socket with 12V 10A

Omicron-Lab: 13th Power Analysis & Design Symposium

2024-04-17

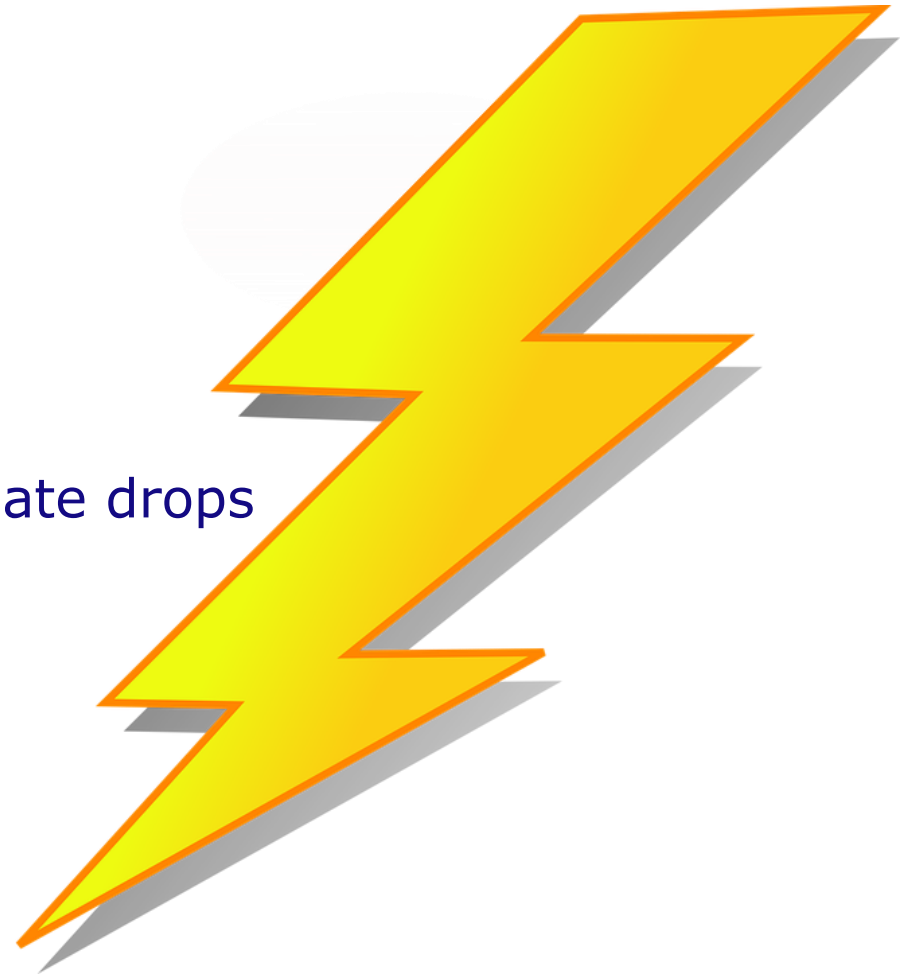


How did it start?

- My customer offers 12V battery powered systems for portable application.
- An opportunity raised to sell it for a vehicle application.
- He did it and told us: „I need a power supply cable for a On-board Voltage Socket.“

Now the trouble started!

- Supply track extended from 0.25m to 5m
  - 20 times longer
  - Supply impedance increased
- Input voltage varies
  - Battery had controlled 12V output
  - Car supply ranges from 10 … 14V with intermediate drops
- Additional interference sources
  - Other devices in the car may introduce noise on supply line
  - Our system may impact other devices via shared supply



We need a power supply filter!

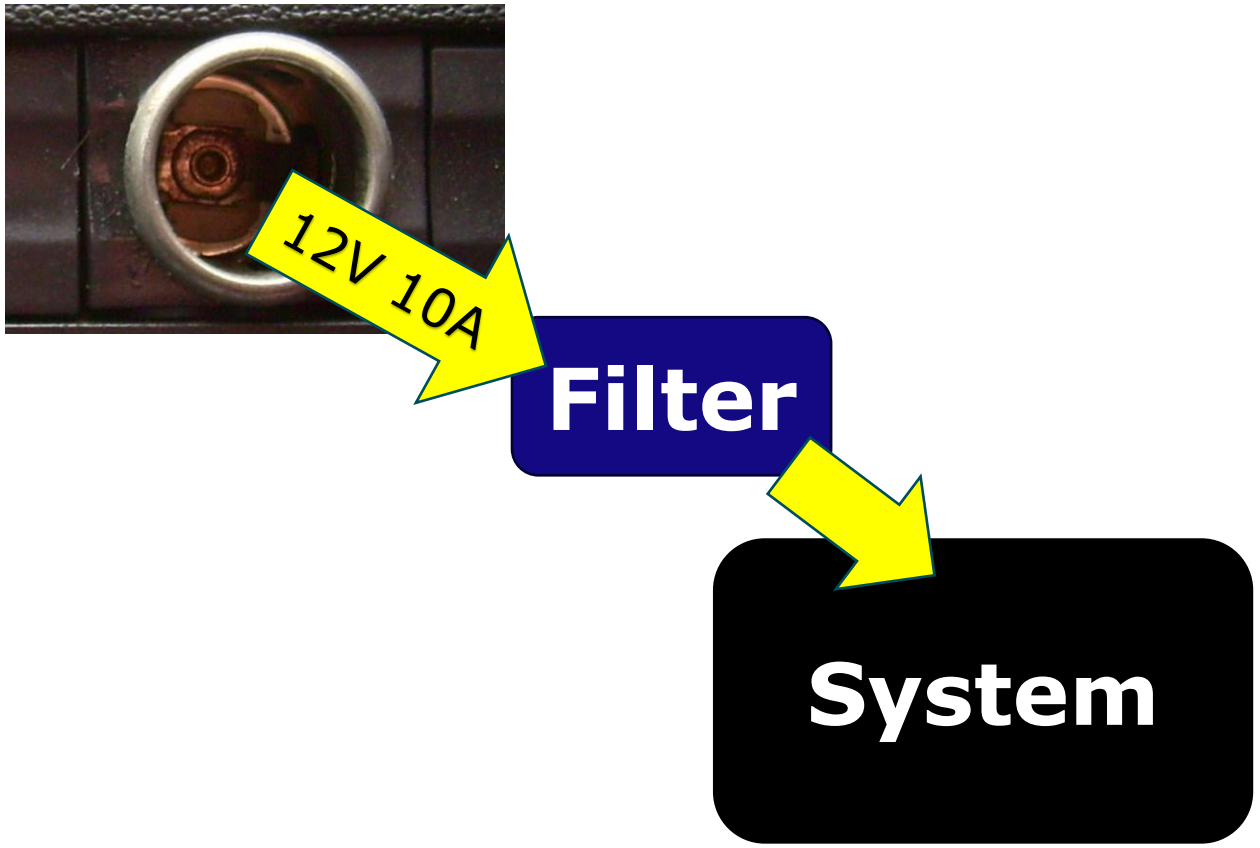
Requirements on power supply filter

From User:

- Allow an easy integration
- Do not delay system delivery!

From System:

- Block noise and interference
- Buffer fast voltage drops
- Lower supply impedance

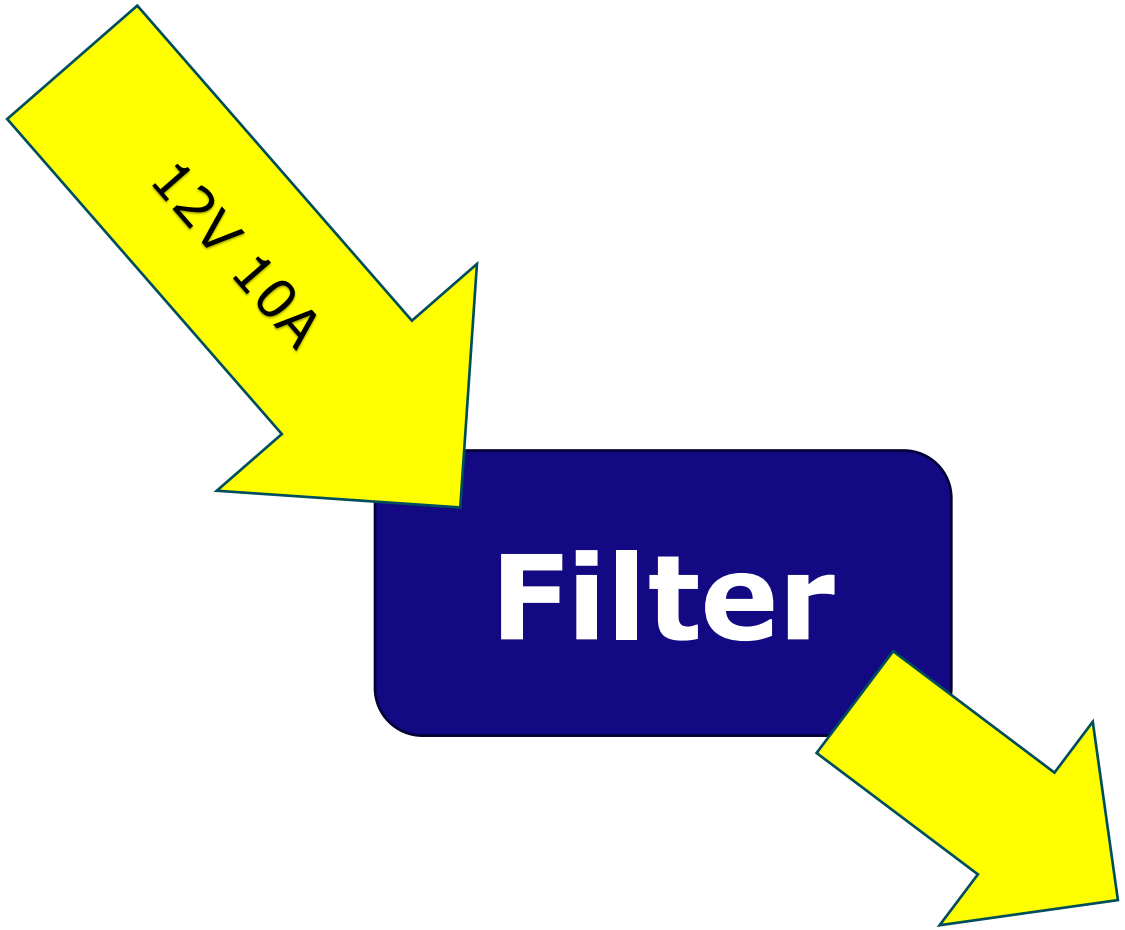


Let’s be more specific

Interference
- Isolation: > 40dB
- Frequency: 1kHz … 10MHz

Housing
- For dry environment (IP20)
- Easy mounting

Electric
- Voltage: 8 … 16V
- Current: 0 … 12A
- DC +/- runs through Filter

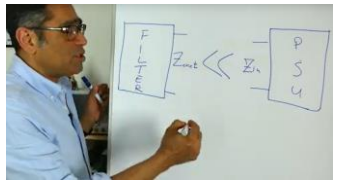


Low impedance requirement (1)

Inside our system there are many DC/DC converters.

- Known and unknown ones.
- All of them require a low source impedance.

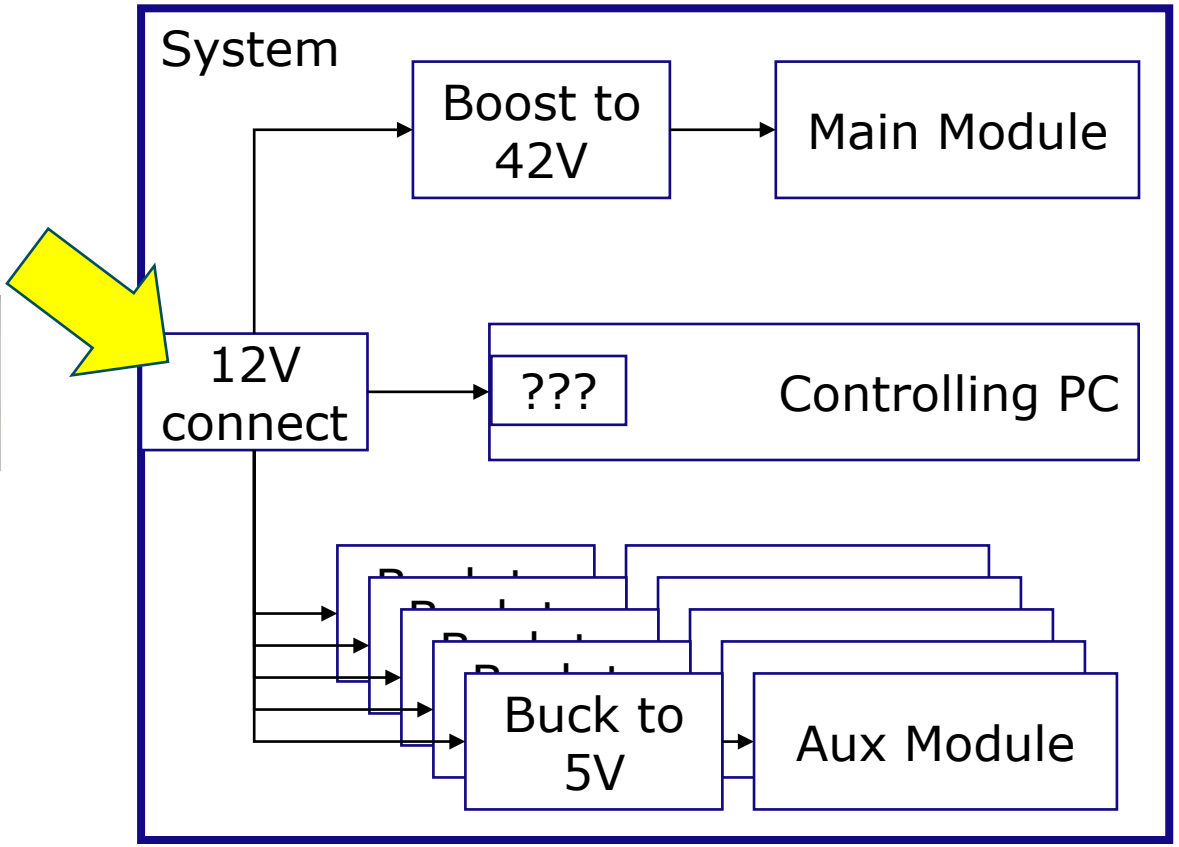
Middlebrook Criteria:



- $Z_{source} << Z_{in}$
- Valid for loop frequency range

Assumption:

- Max. switching: 2MHz
- Max. loop: 200kHz (=2MHz/10)



Low impedance requirement (2)

Peak load is 120W

= 12V * 10A (R_{in} =1.2Ω)
= 10V * 12A (R_{in} =0.82Ω)
= 14.4V * 8.3A (R_{in} =1.73Ω)

Dynamic input resistance (est.)

R_{Dyn} = 0.82Ω - 1.73Ω = -0.91Ω

Supply wire inductance

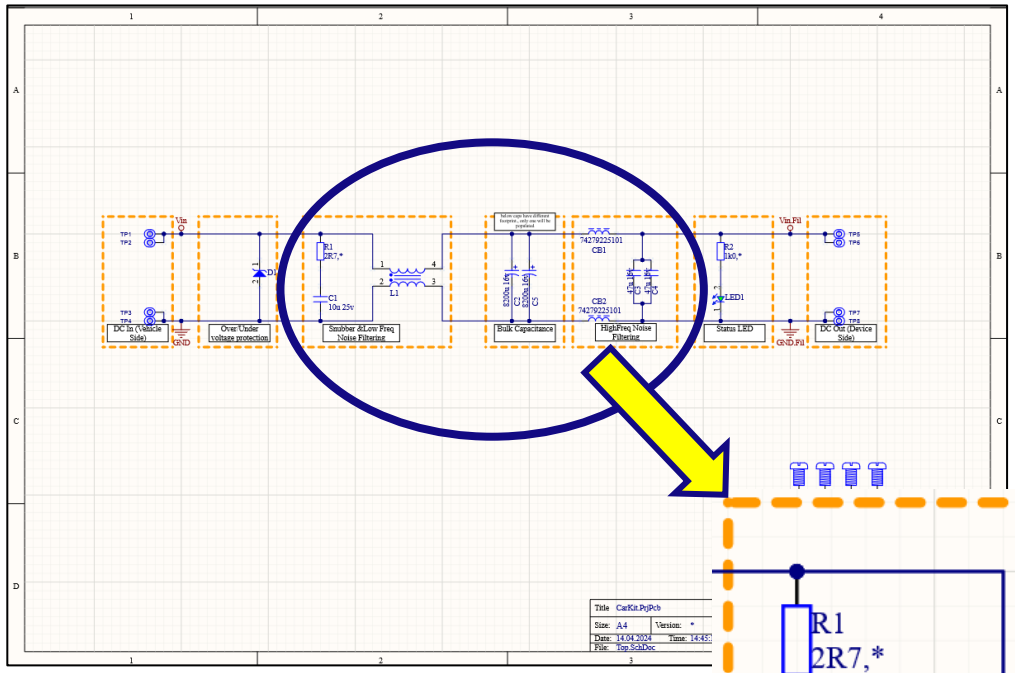
length = 10m (2x5m)
Ø = 4mm
L = 215µH (https://chemandy.com)

Supply impedance with wire

- 500Ω @ 400kHz ×
- 50Ω @ 40kHz ×
- 5Ω @ 4kHz ×
- 0.5Ω @ 400Hz ×
- 0.15Ω @ 100Hz ✓

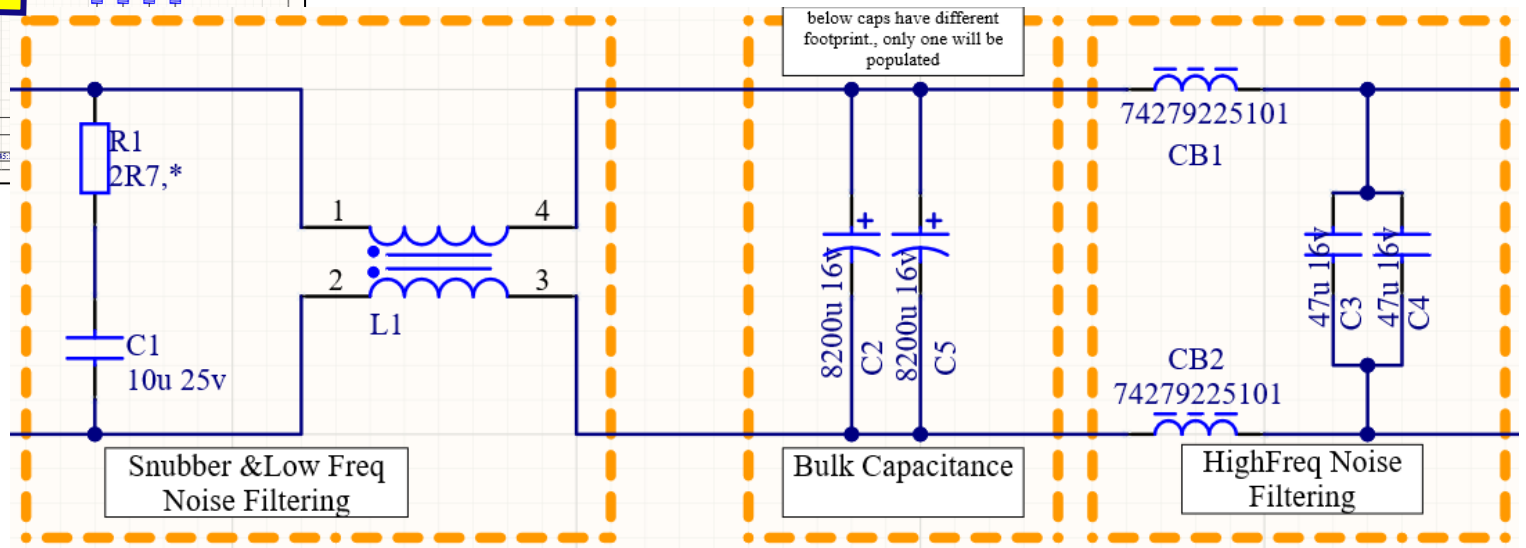
Only at frequencies **below 100Hz** supply impedance is low enough to fulfill Middlebrook criteria!

Developing schematic

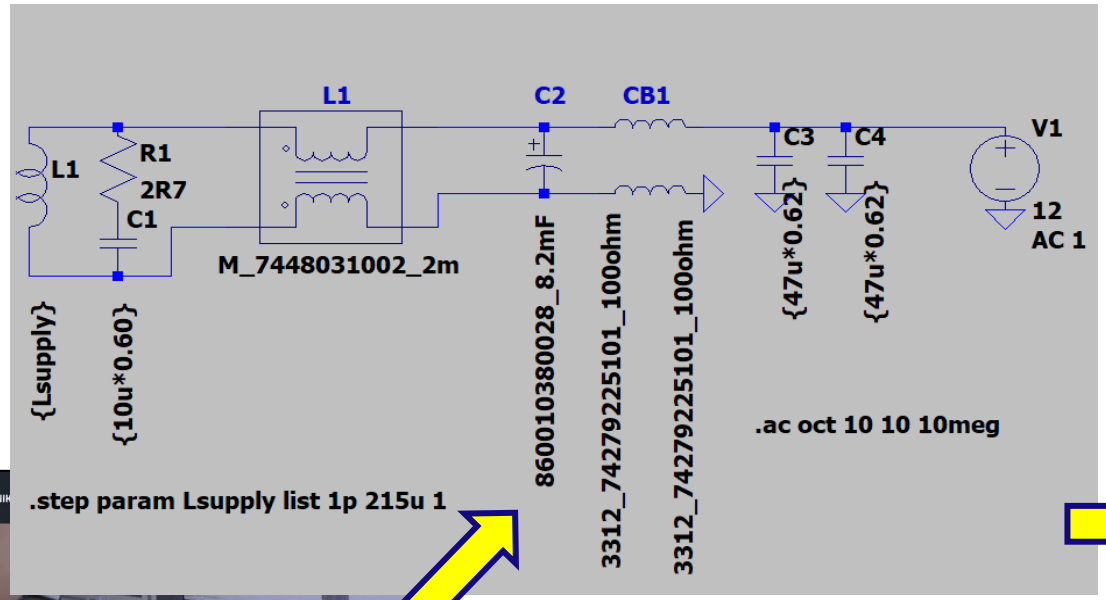


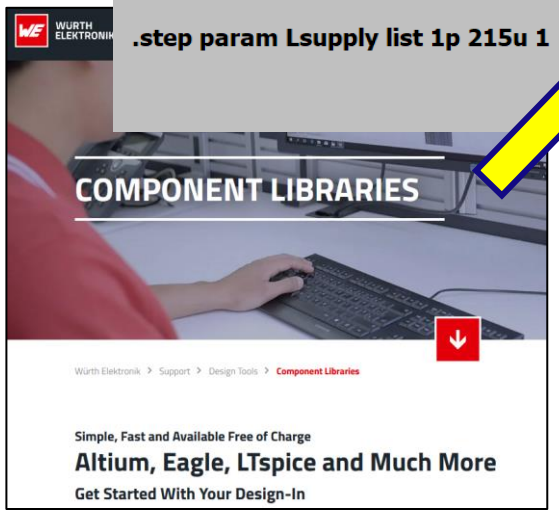
Develop a filter circuitry:

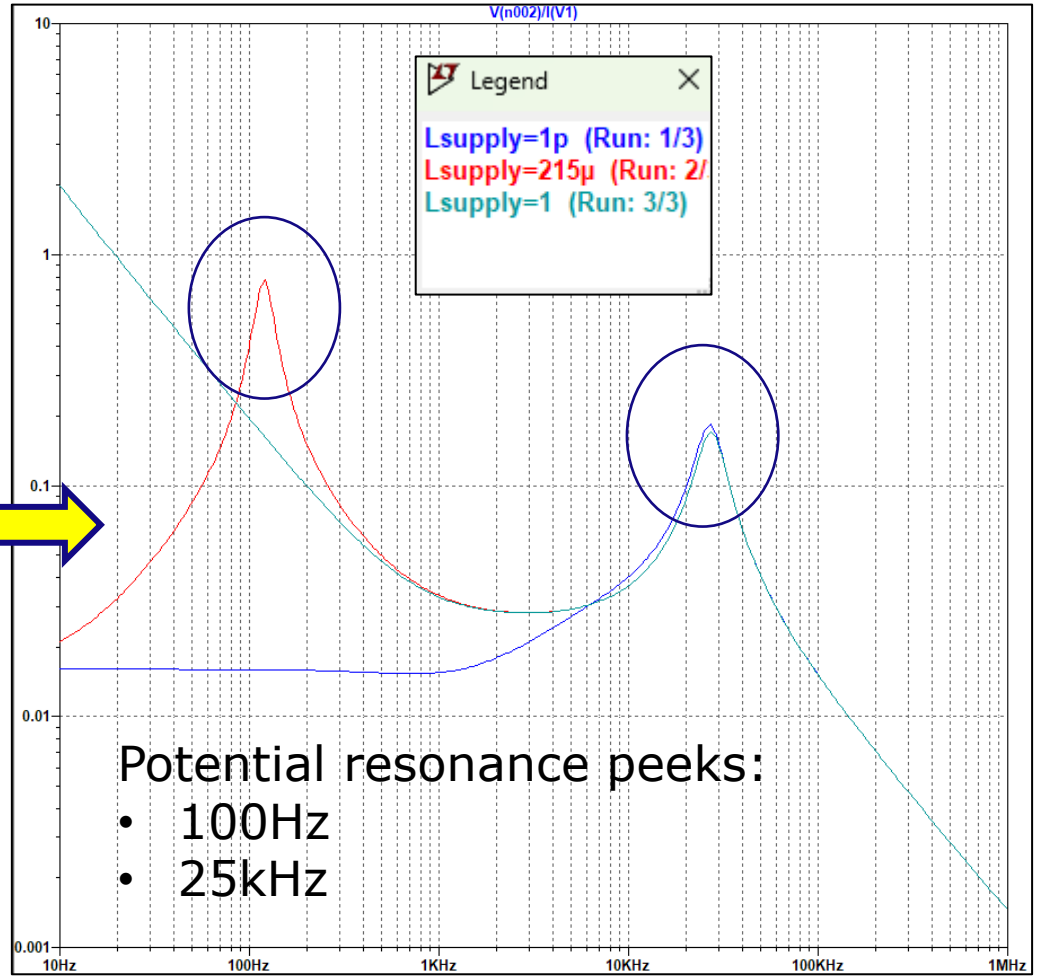
- high isolation
- low output impedance
- low cut-off frequency



Verify with simulation



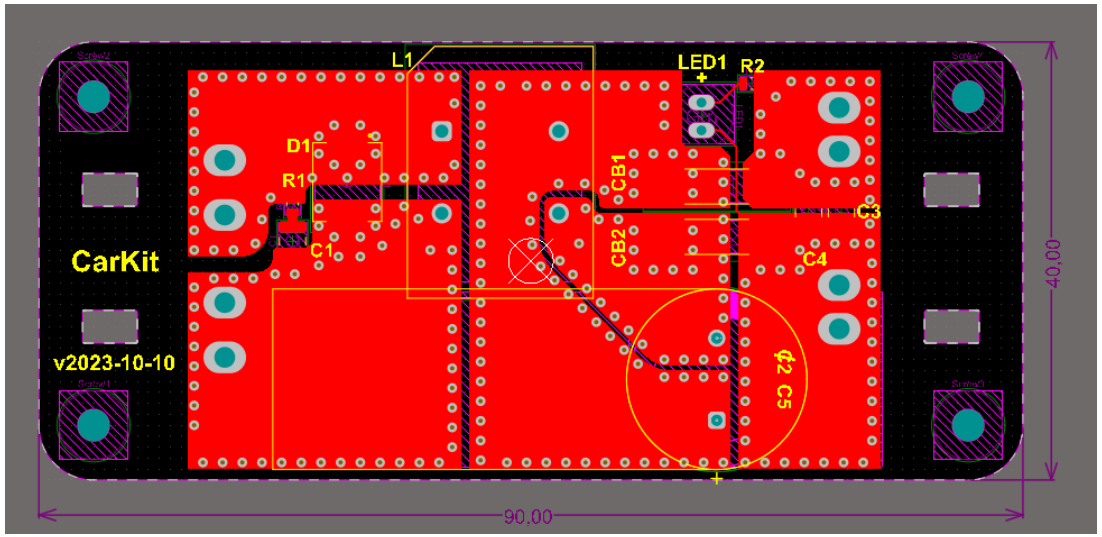


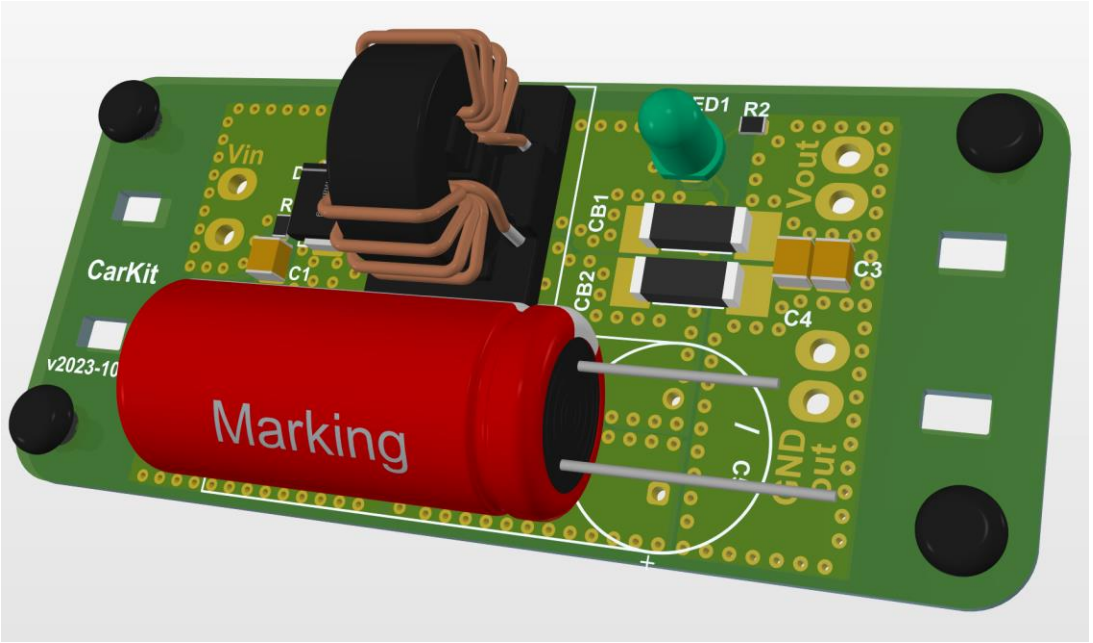


Potential resonance peeks:

- 100Hz
- 25kHz

Layout





PCB: FR4, 2 layer, 1.6mm

Population: one side, SMT&THT

Compact!

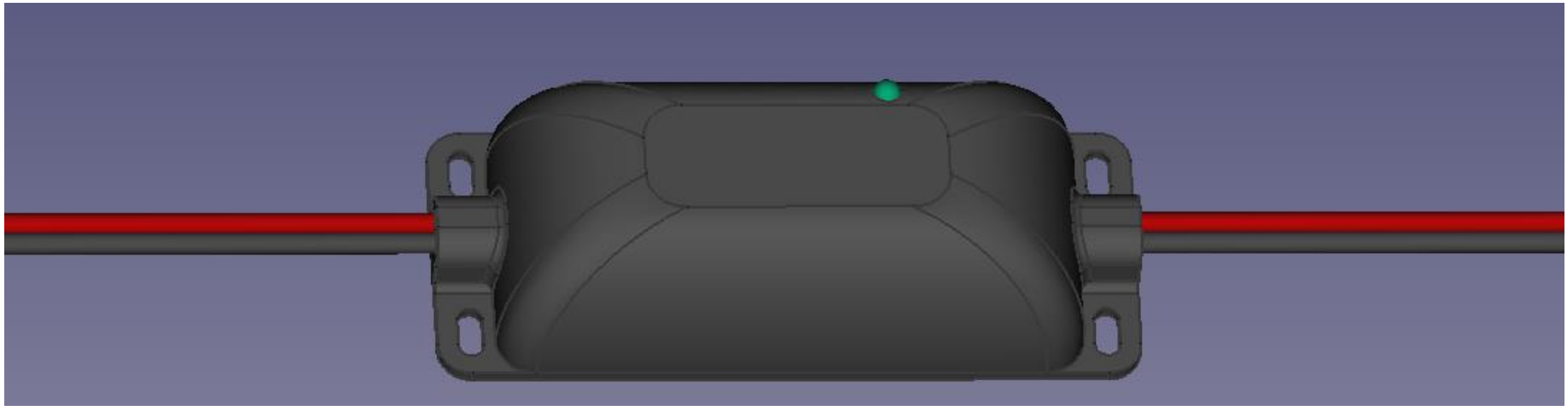
Housing (1)

Specification

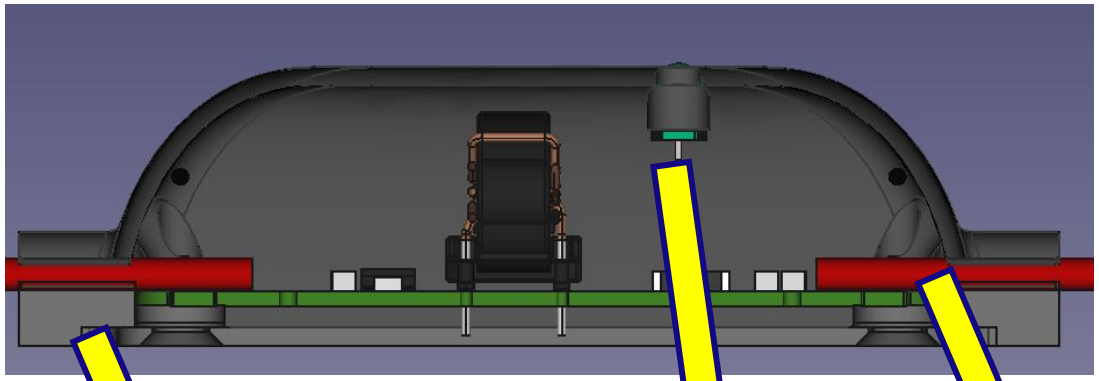
- Easy to mount
- IP20

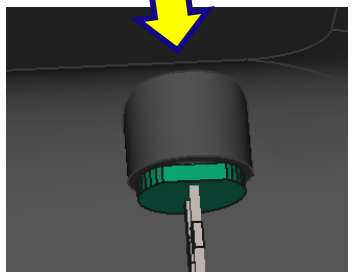
Implementation

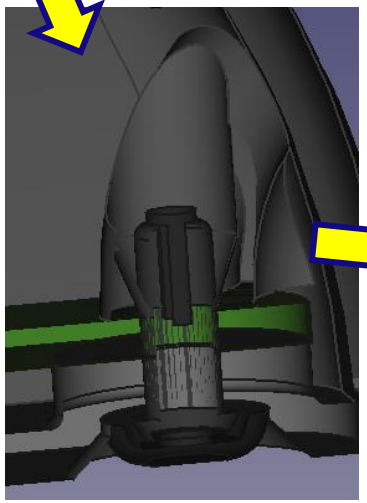
- 3D-Print
- Snap Rivets, no screws

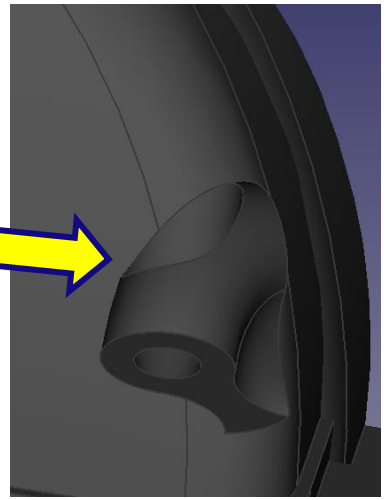


Housing (2)





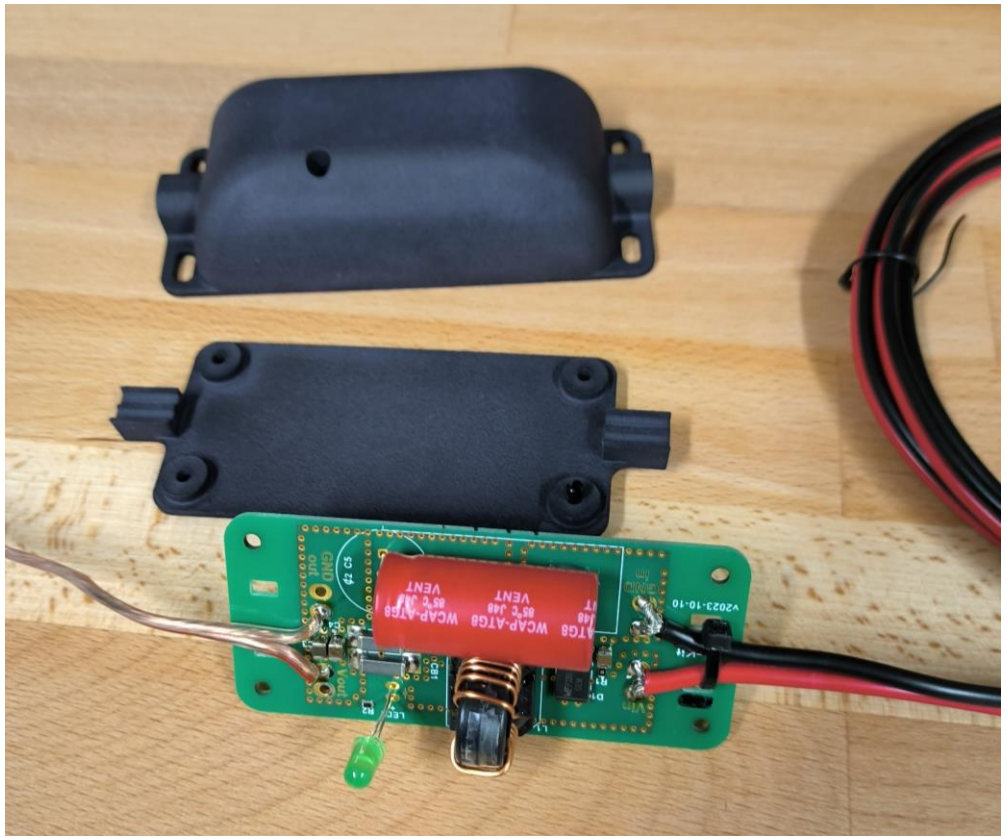


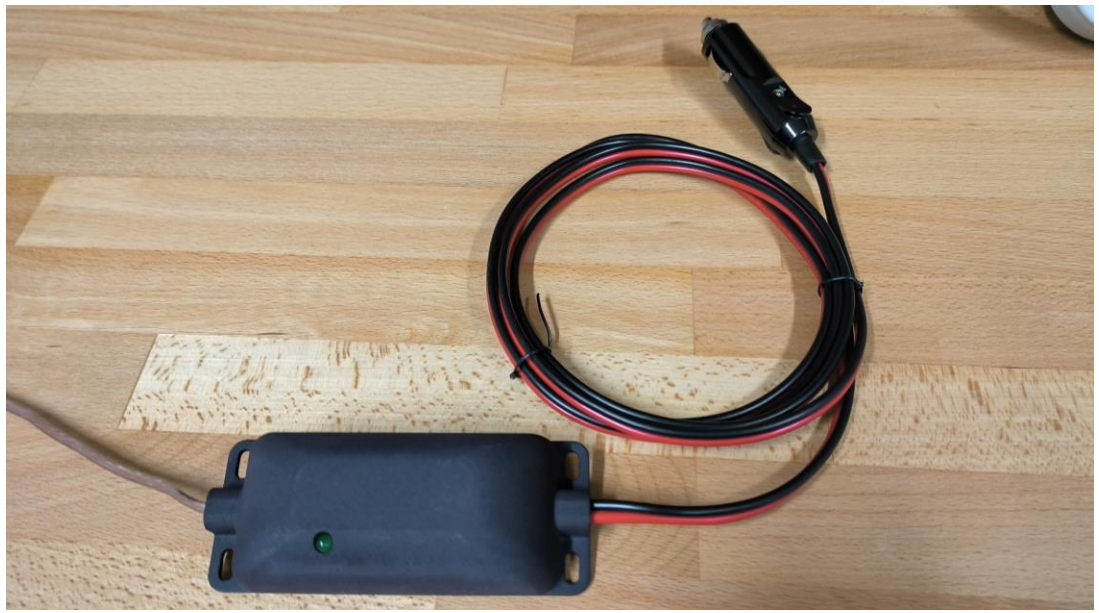


3D-Print housing

- Cable clamp
- LED protection
- Snap rivet holder

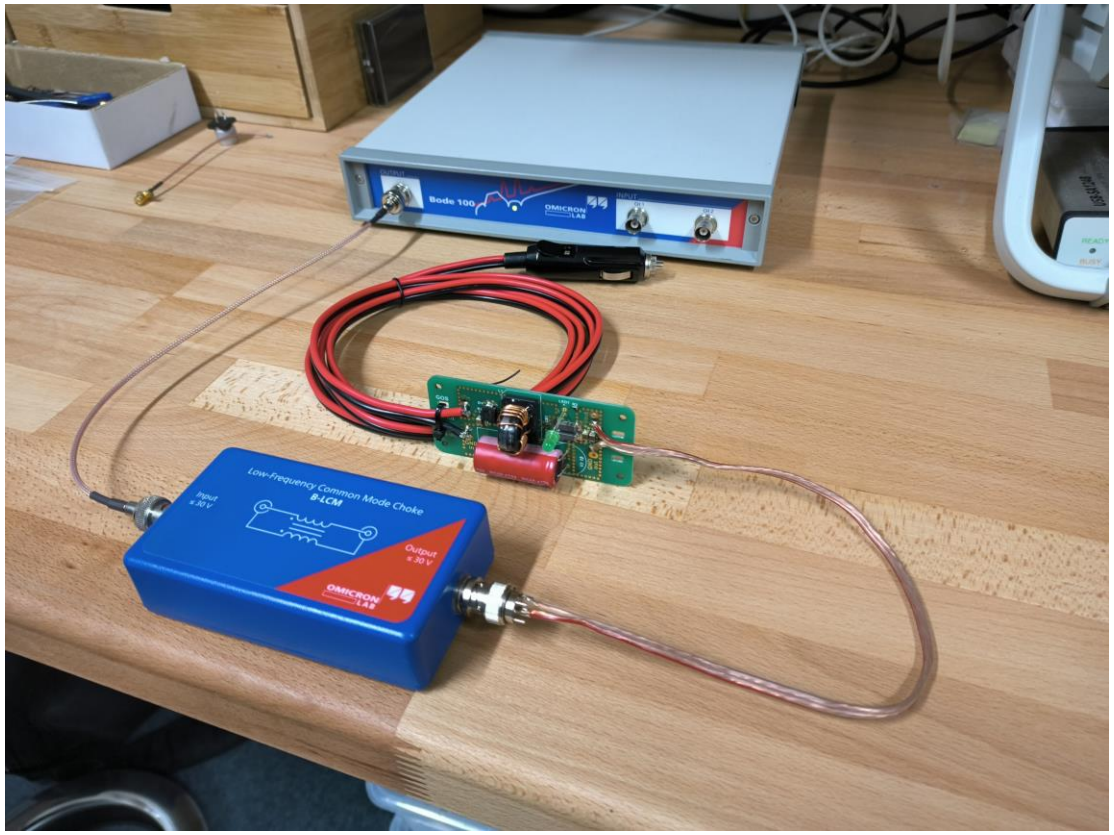
Final Product





We made it in time. How good is it?

Put it under test!



Use Bode 100!

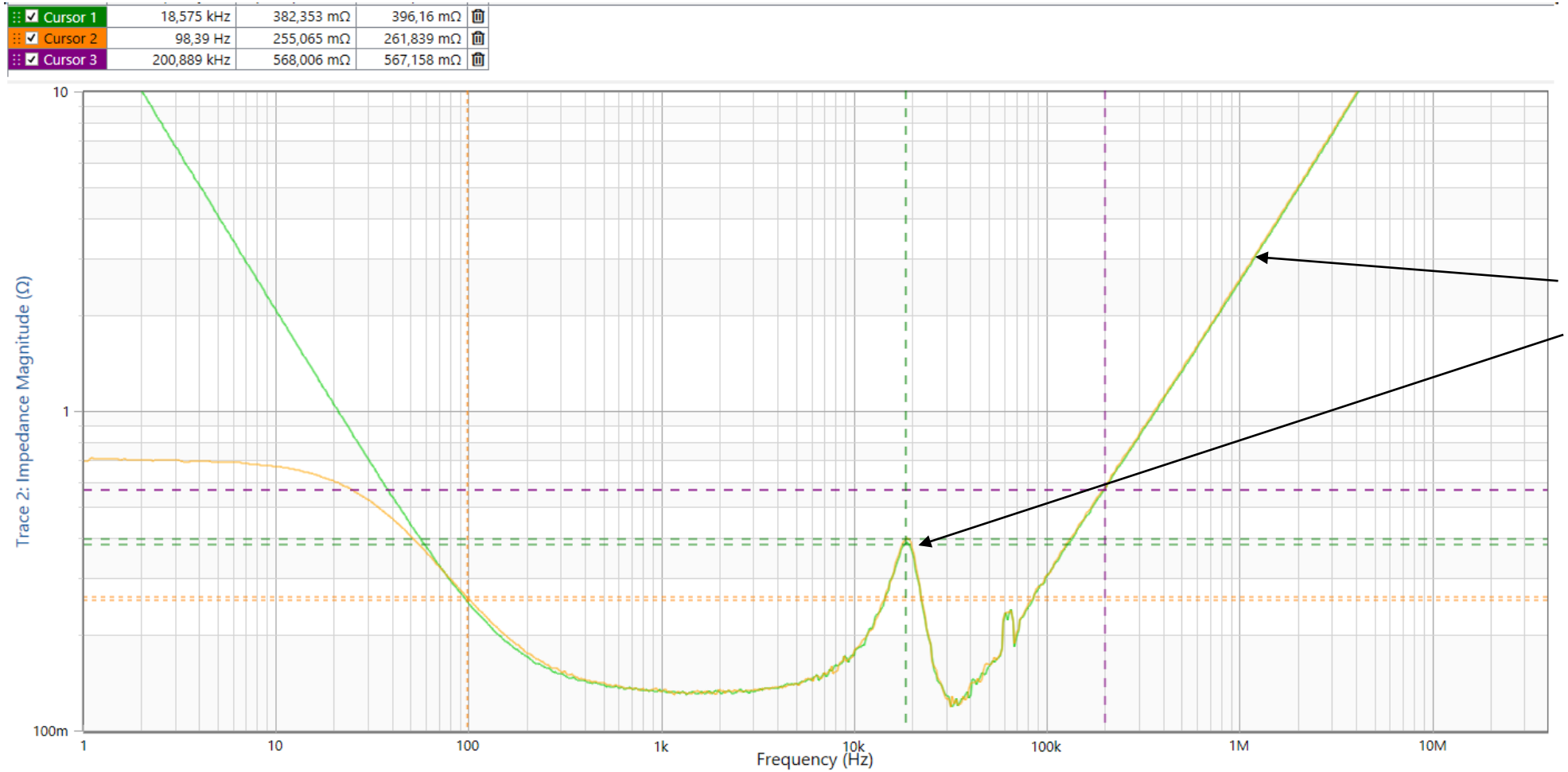
Add B-LCM:

- Low-frequency common mode choke
- Differential measurement
- No common ground
- 100 Hz to 10 MHz

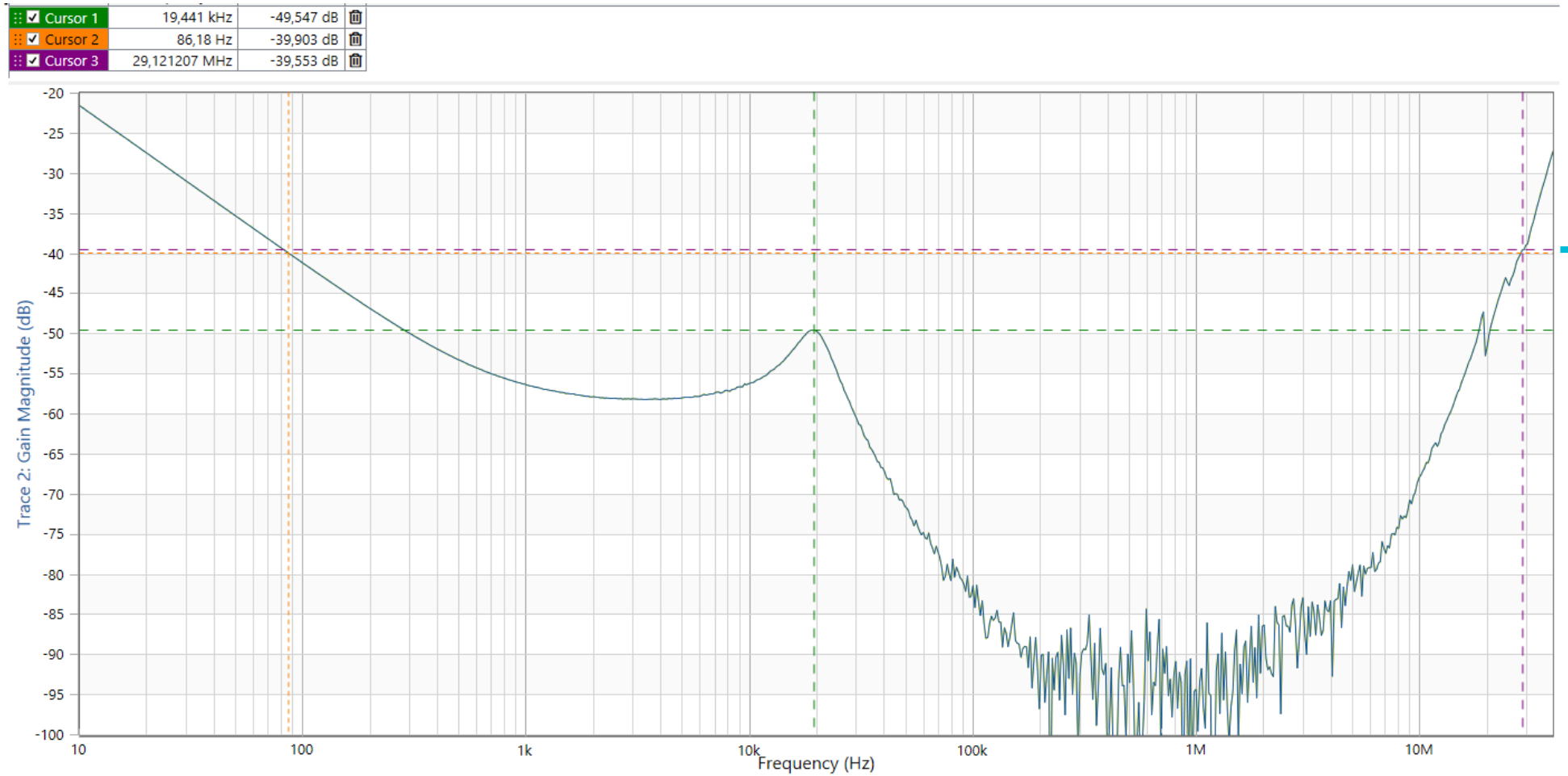
Start measure:

- Impedance (S11)
- Blocking (S21)

Results (1), Output Impedance



Results (2), Blocking

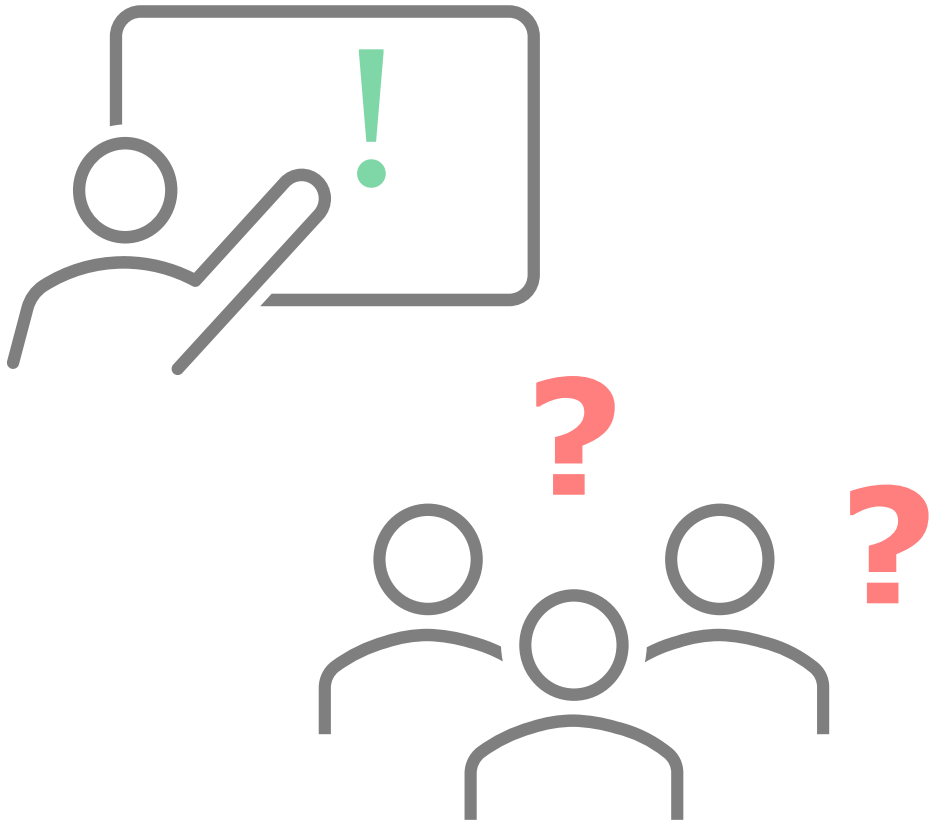


Better 40dB

Results (3)

It worked!

Customer is happy!



Contact:

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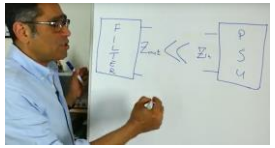
Picture reference

https://de.wikipedia.org/wiki/Bordspannungssteckdose#/media/Datei:12volt-socket_21mm.jpg

https://www.mscdirect.com/product/details/70461538

https://www.pngall.com/suv-png/download/67907



https://www.youtube.com/watch?v=zPcMNpyavMw

https://www.we-online.com/en/support/design-tools/libraries

On all other pictures contact g.klenner@kk-prime.com