EMI FILTER DESIGNER
REDEXPERT

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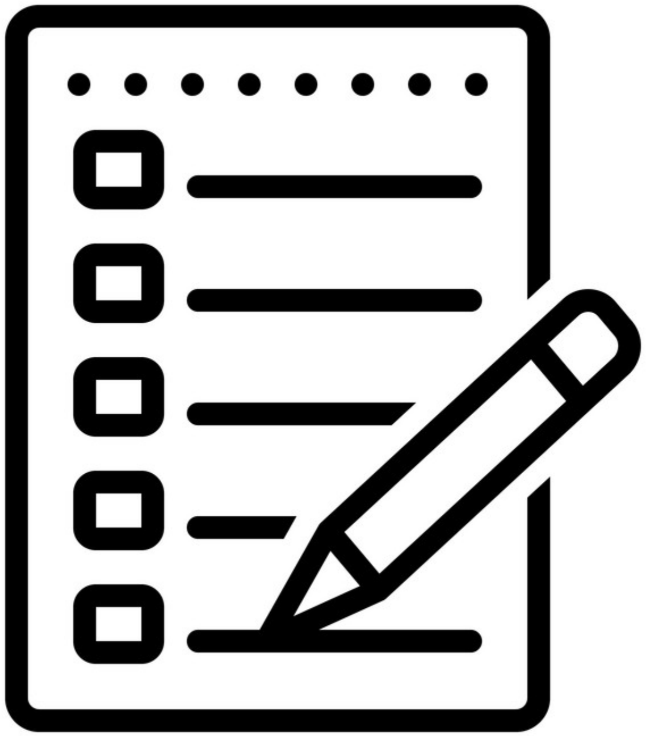
WÜRTH ELEKTRONIK MORE THAN YOU EXPECT

AGENDA

- Differential EMI Filter.
- Low Pass Filter topologies.
- Main parameters.
- Solution using **REDEXPERT.**
- Application examples.



INTRODUCTION TO DIFFERENTIAL EMI FILTER

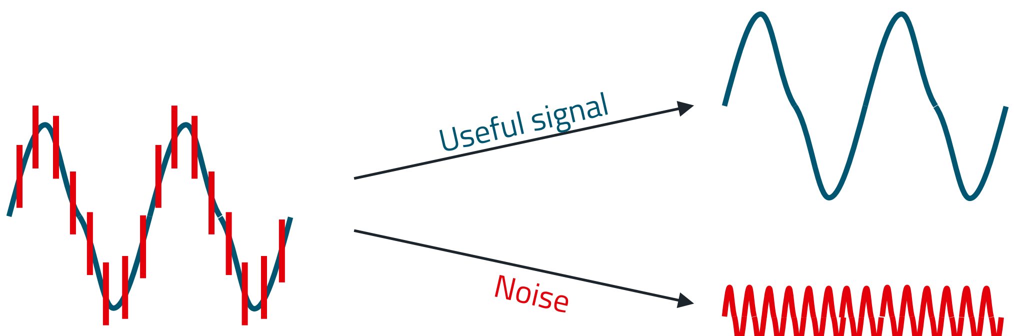
DIFFERENTIAL EMI FILTER

What is it?

- It's a filter designed to attenuate **differential** mode noise – **REDEXPERT** focuses on Power Supply Lines.
  - Transformer outputs.
  - Vcc lines.
  - DC-DC converters.

- Noise has a higher frequency than the useful signal.

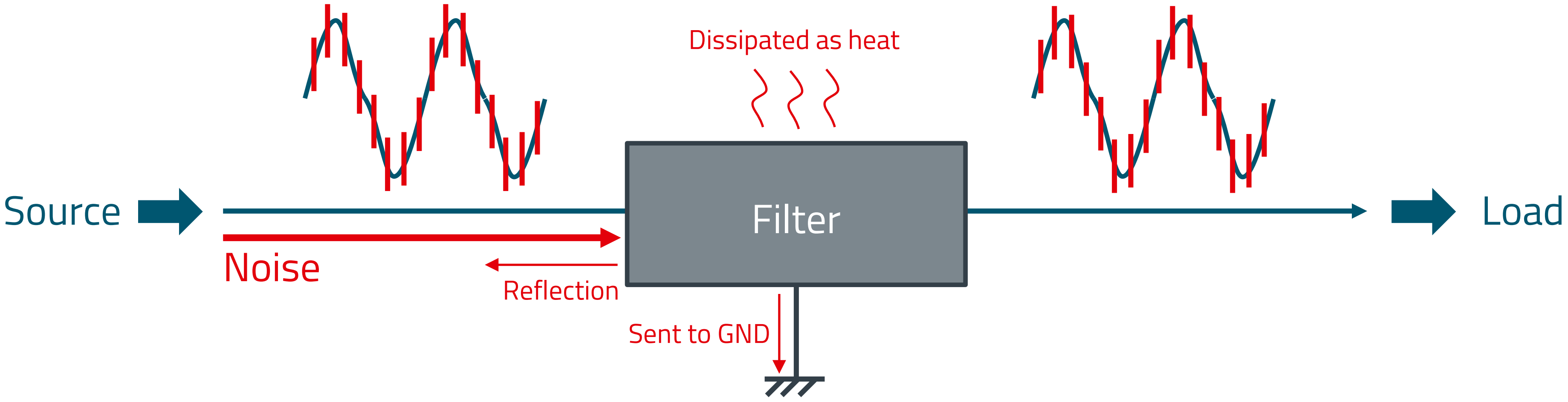
- A **low pass** filter is needed:
  - To pass the low-frequency (or CC) useful signal.
  - To attenuate the high-frequency noise.



DIFFERENTIAL EMI FILTER

How does it work?

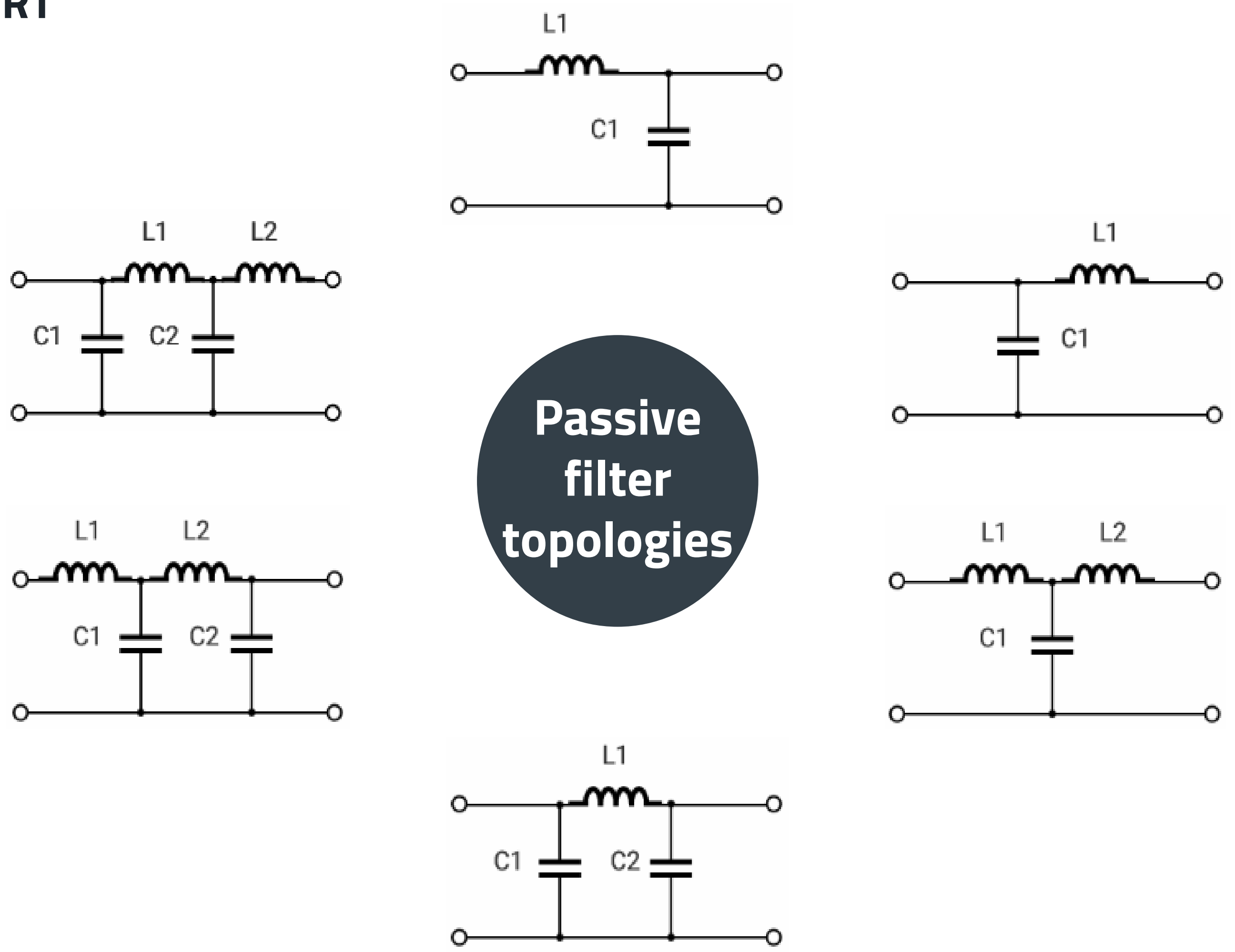
- The **useful signal** goes through the filter mostly unaffected.
- The **noise** is attenuated by the filter.



LOW PASS FILTER TOPOLOGIES

LOW PASS FILTER TOPOLOGIES

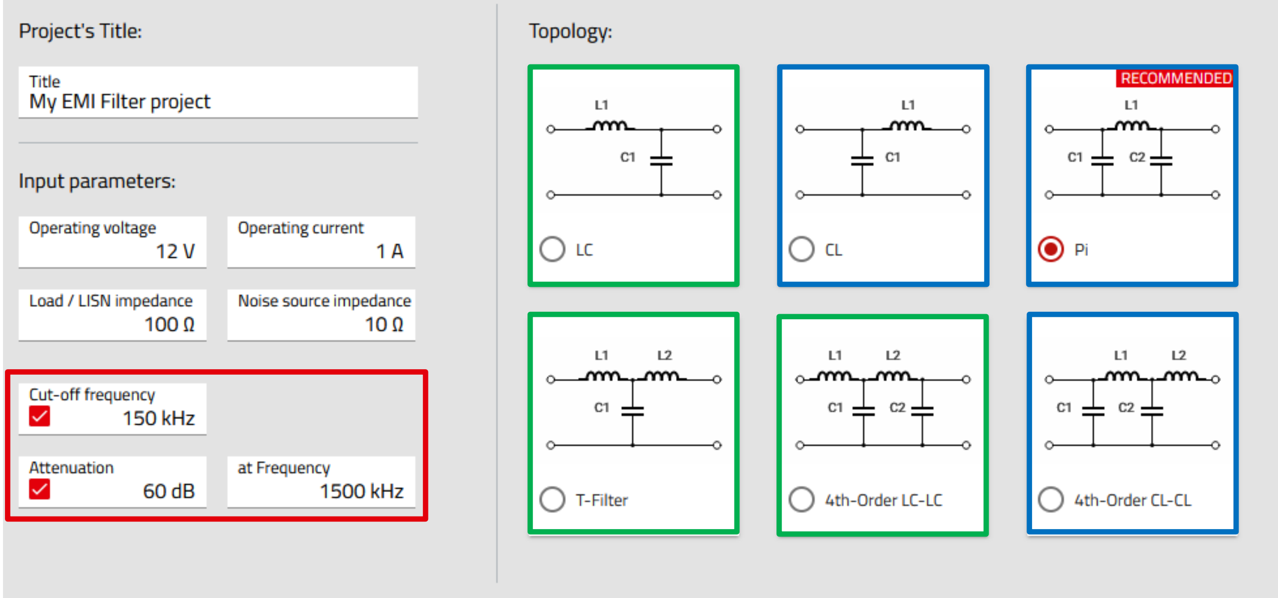
Topologies in REDEXPERT



LOW PASS FILTER TOPOLOGIES

Selection criteria

- Arrangement of capacitors and ferrites:
  - Z source > Z load → Ferrite first.
  - Z source = Z load → Ferrite or Capacitor first.
  - Z source < Z load → Capacitor first.
- Order of the filter – Number of passive components:
  - The more the dB per decade, the more passive components – 20 dB per decade per component.



60 dB from 150 kHz to 1.5 MHz (1 decade)
→ 3 passive components.

MAIN PARAMETERS

MAIN PARAMETERS

System Parameters

System Parameters

- Operating Voltage → From the power supply line (source).
- Operating Current → From the power supply line (source) – Add 40% to compensate for peaks.
- Source Impedance → If unknown, for power lines its typically 10 Ohms.
- Load Impedance → If unknown, for power lines its typically 10 Ohms.

MAIN PARAMETERS

Attenuation Requirements

Attenuation Requirements

- **Cut-off Frequency** → Frequency at which we want the filter to start the attenuation.
- **Attenuation at Frequency** → Enter the target of attenuation at a given frequency.

Considerations

- Cut-Off Frequency must be lower than the Attenuation at Frequency.
- At least one value must be filled out.
- Conducted emissions: 150 kHz – 30 MHz.

SOLUTION USING REDEXPERT

SOLUTION USING REDEXPERT

Parameters

- USB 3.1 60W – Low pass filter for the Vcc line.

- Operating voltage: 20V.
- Operating current: 3 A – 5 A to prevent peaks.
- Source impedance: 10 Ohms.
- Load impedance: 10 Ohms.

- Cut-Off frequency: 100 kHz.
- Special interest at 5MHz, attenuation of 100 dB.

SOLUTION USING REDEXPERT

Parameters

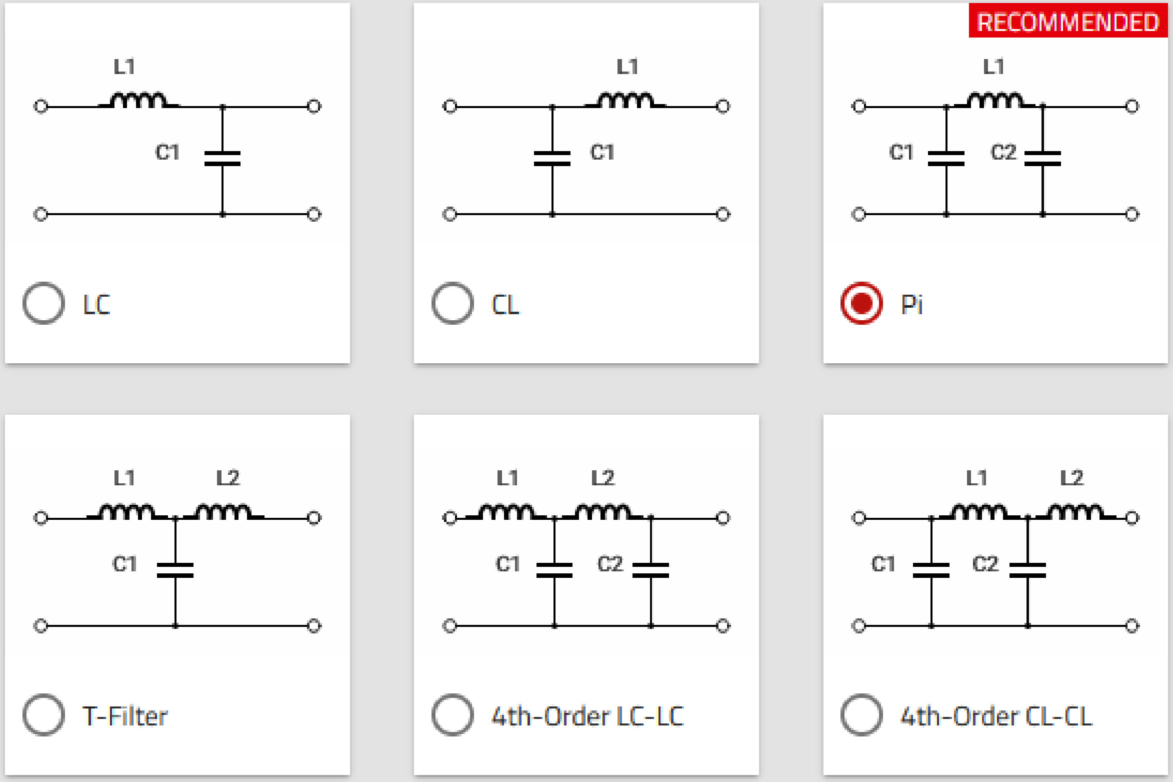
Project's Title:

Title
Power Line USB 3.1 60W

Input parameters:

Operating voltage	20 V
Operating current	5 A
Load / LISN impedance	10 Ω
Noise source impedance	10 Ω
Cut-off frequency (checked)	100 kHz
Attenuation (checked)	100 dB
at Frequency	5000 kHz

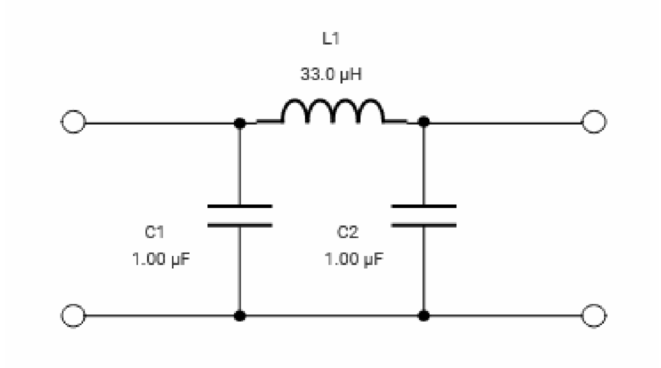
Topology:



SOLUTION USING REDEXPERT

Selection and simulation - Capacitors

Power Line USB 3.1 60W



C1	1.00 µF	25.0 V	8.58 mΩ	⇄
L1	33.0 µH	5.20 A	35.0 mΩ	⇄
C2	1.00 µF	25.0 V	8.58 mΩ	⇄

Details

Calculated C1 Capacitance

159 nF

Calculated C2 Capacitance

159 nF

Calculated L1 Inductance

31.8 µH

Insertion Loss

-108 dB@5.00 MHz

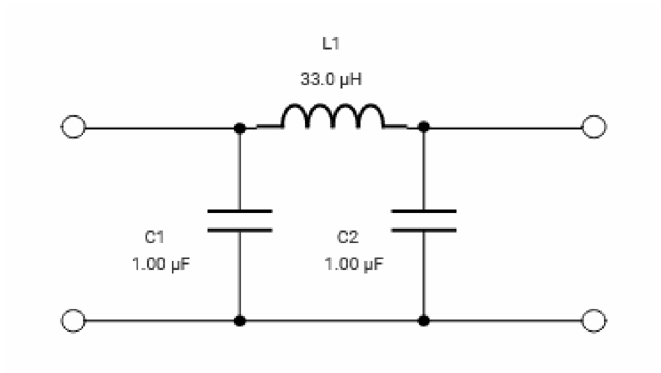
	C	C@20.0 V
✓	1.00 µF	163 nF

The voltage across a capacitor decreases its capacitance – **REDEXPERT** considers the capacitance drop to pick the right part.

SOLUTION USING REDEXPERT

Selection and simulation – Ferrite / Inductor

Power Line USB 3.1 60W



C1		1.00 µF	25.0 V	8.58 mΩ	⇄
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Details

Calculated C1 Capacitance

159 nF

Calculated C2 Capacitance

159 nF

Calculated L1 Inductance

31.8 µH

Insertion Loss

-108 dB@5.00 MHz

	L	L@5.00 A	I_R
✓	33.0 µH	31.7 µH	5.20 A

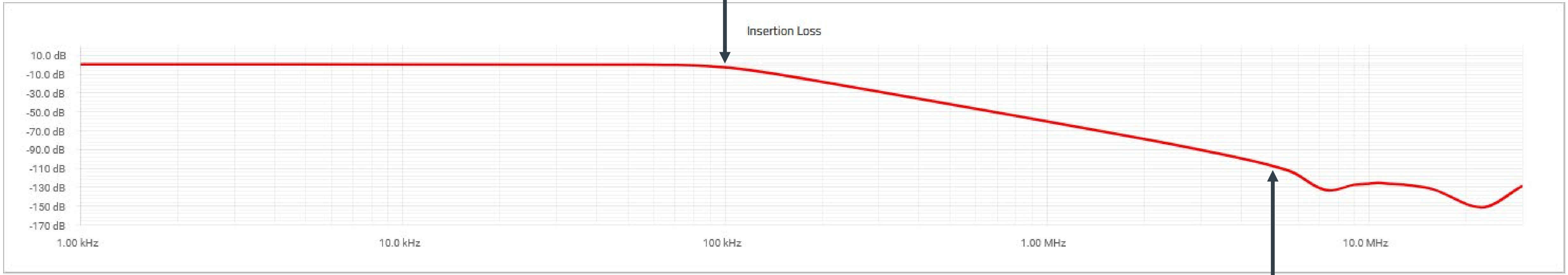
The current driven in a ferrite decreases its inductance – **REDEXPERT** considers the inductance drop to pick the right part.

SOLUTION USING REDEXPERT

Selection and Simulation - Insertion Loss

Cut Off at 100 kHz

-3dB of attenuation

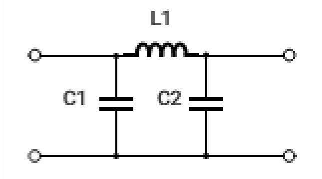


-108 dB at 5 MHz

SOLUTION USING REDEXPERT

Summary

Circuit Schematic



Specifications

Edit

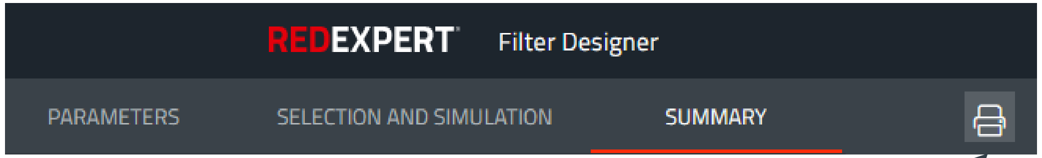
"Power Line USB 3.1 60W"

TYPE: Pi
V_{op}: 20.0 V
I_{op}: 5.00 A
LOAD / LISN IMPEDANCE: 10.0 Ω
NOISE SOURCE IMPEDANCE: 10.0 Ω
ILOSS -108 dB@5.00 MHz

Bill Of Materials

ADD

#	N...	Order Code	Value	Properties	Qty
1.	C1...	885012106022	1.00 µF	Assembling Technology = SMT Capacitance = 1.00 µF Rated Voltage = 25.0 V Height = 800 µm	2
2.	L1	7447704330	33.0 µH	Inductance = 33.0 µH Rated Current = 5.20 A	1



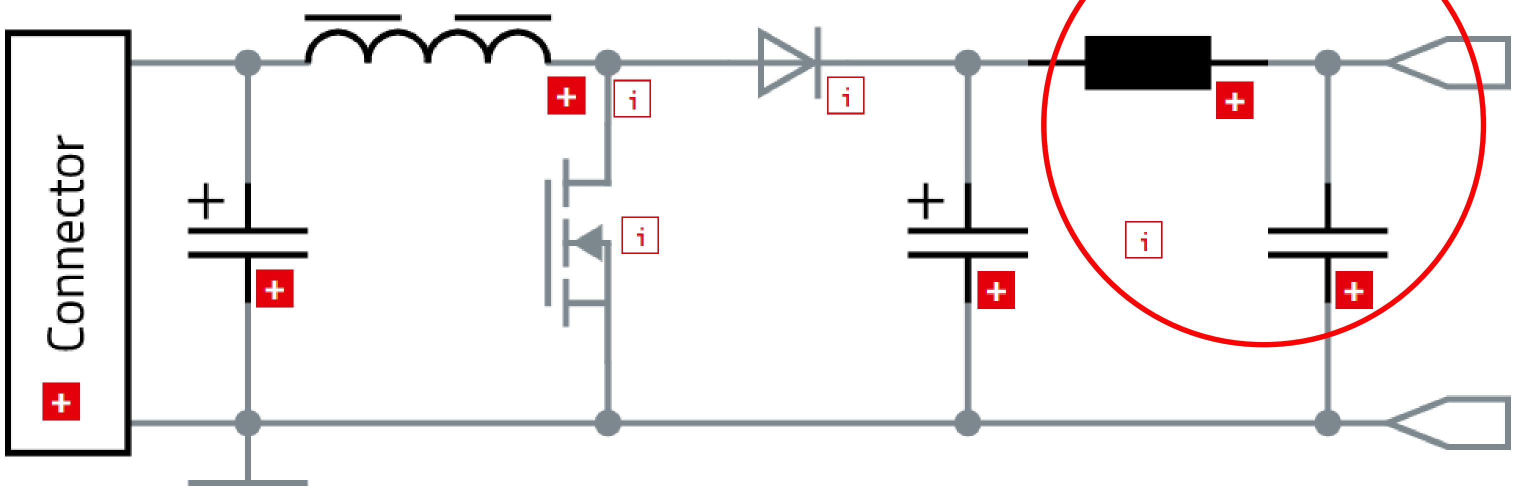
Print the summary

APPLICATION EXAMPLES

APPLICATION EXAMPLES

Example 1

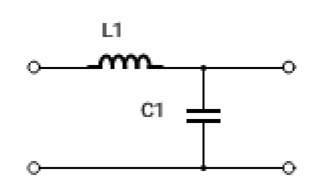
- Offer a filter for an output of a Boost Converter:
  - The output power is 24W (48 V @ 0.5 A) – Add more current for peaks, 0.7 A.
  - Cut-Off frequency required at 25 kHz
  - Power line – Consider 10 Ohms impedance



APPLICATION EXAMPLES

Example 1 - Summary

Circuit Schematic



Specifications

Edit

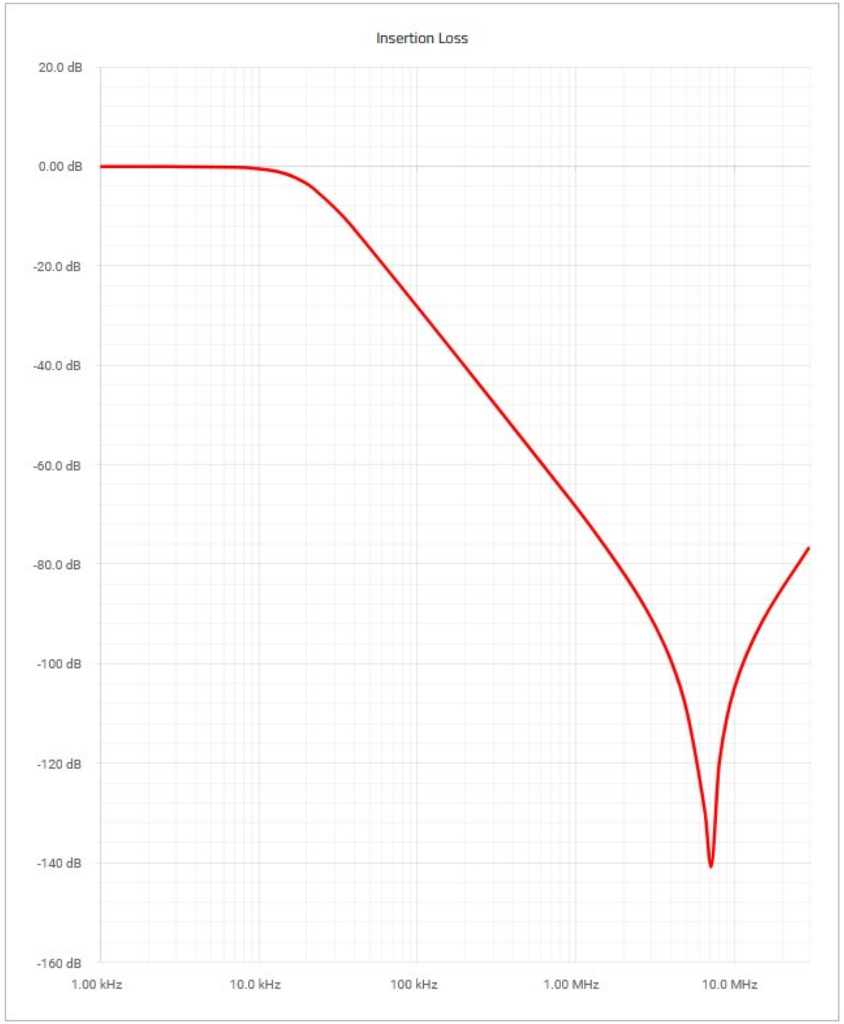
"Boost Converter 24W"

TYPE: LC
V_{op}: 48.0 V
I_{op}: 800 mA
LOAD / LISN IMPEDANCE: 10.0 Ω
NOISE SOURCE IMPEDANCE: 10.0 Ω
ILOSS -5.92 dB@25.0 kHz

Bill Of Materials

ADD

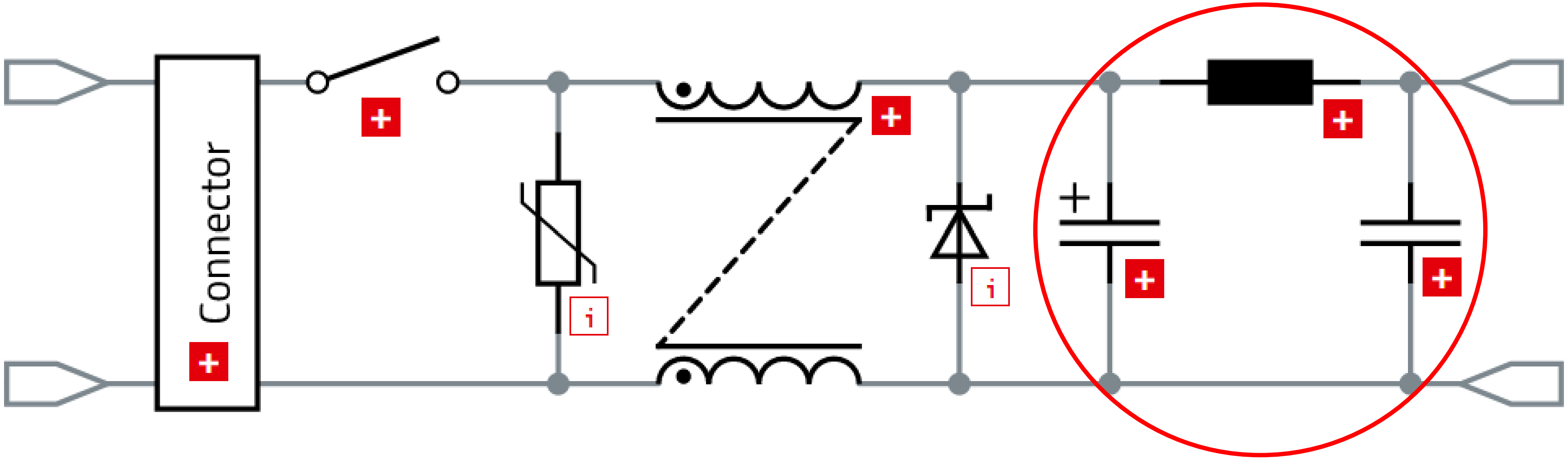
#	N...	Order Code	Value	Properties	Qty
1.	C1	885012210032	2.20 µF	Assembling Technology = SMT Capacitance = 2.20 µF Rated Voltage = 50.0 V Height = 2.50 mm	1
2.	L1	7447462101	100 µH	Inductance = 100 µH Rated Current = 800 mA	1



APPLICATION EXAMPLES

Example 2

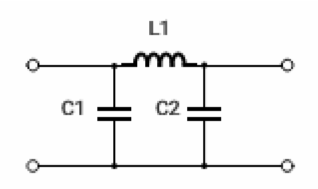
- Offer a filter for an output of a battery:
  - The battery provides 18 A up to 50 VDC (nominal 36 VDC) – Let's set the current to 25 A for peaks.
  - Cut off frequency at 150 kHz – 120 dB needed at 30 MHz



APPLICATION EXAMPLES

Example 2 - Summary

Circuit Schematic



Specifications

Edit

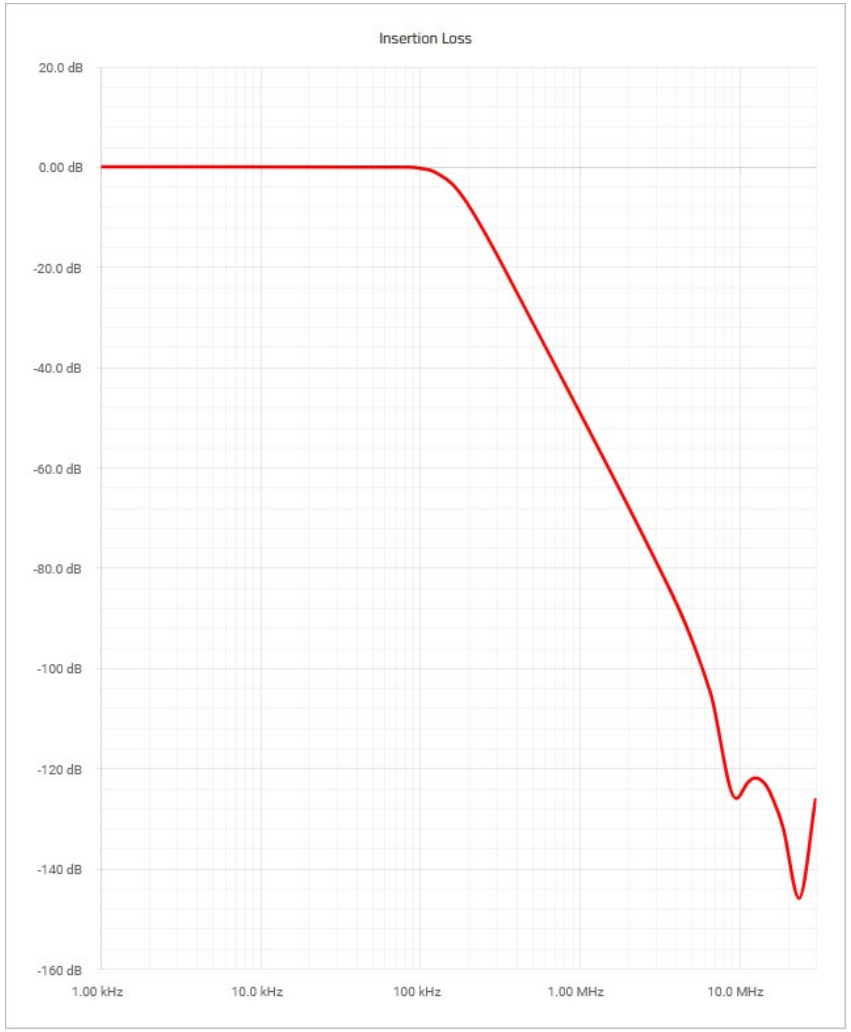
"Battery"

TYPE: Pi
V_{op}: 50.0 V
I_{op}: 25.0 A
LOAD / LISN IMPEDANCE: 10.0 Ω
NOISE SOURCE IMPEDANCE: 10.0 Ω
ILOSS -126 dB@30.0 MHz

Bill Of Materials

ADD

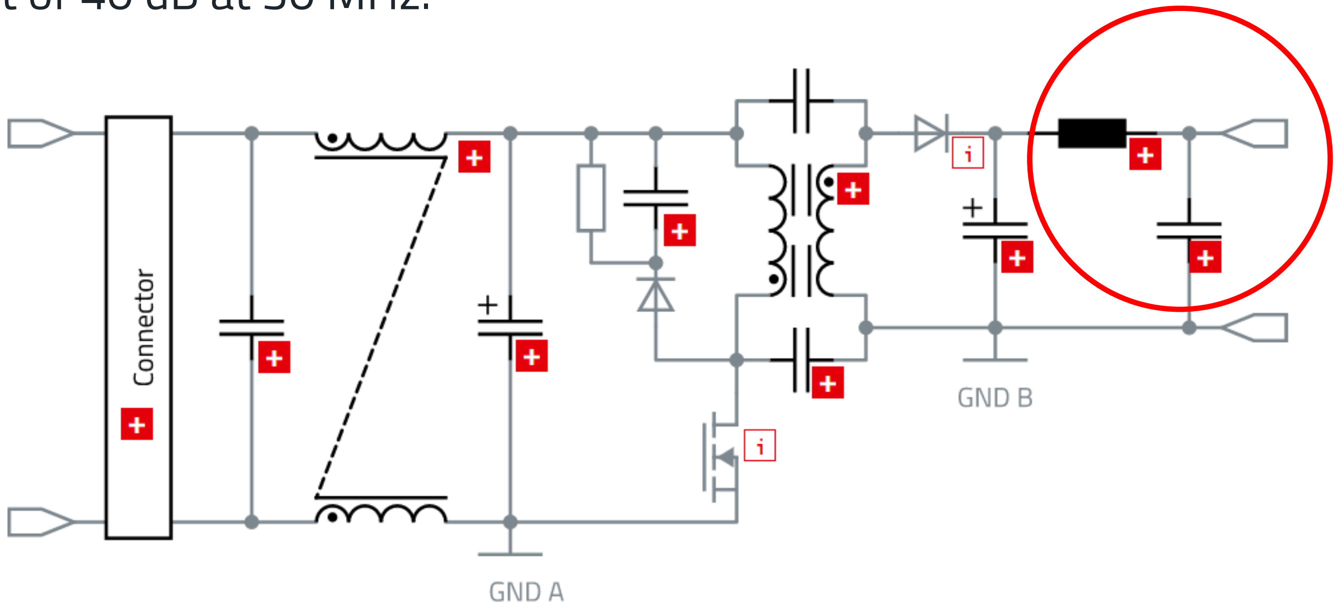
#	N...	Order Code	Value	Properties	Qty
1.	C1...	885012207100	220 nF	Assembling Technology = SMT Capacitance = 220 nF Rated Voltage = 50.0 V Height = 1.25 mm	2
2.	L1	7443763540220	22.0 µH	Inductance = 22.0 µH Rated Current = 40.6 A	1



APPLICATION EXAMPLES

Example 3

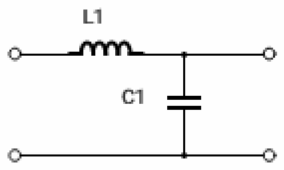
- Offer a filter for the output of the transformer 750370041:
  - Output of 5 V at 1 A (let's do 1.5 A to compensate for peaks).
  - Switching at 1 MHz – Cut off at the frequency of operation, interest of 40 dB at 30 MHz.



APPLICATION EXAMPLES

Example 3 - Summary

Circuit Schematic



Specifications

Edit

"Transformer"

TYPE: LC
V_{op}: 5.00 V
I_{op}: 1.50 A
LOAD / LISN IMPEDANCE: 10.0 Ω
NOISE SOURCE IMPEDANCE: 10.0 Ω
ILOSS -65.8 dB@30.0 MHz

Bill Of Materials

ADD

#	N...	Order Code	Value	Properties	Qty
1.	C1	885012205015	33.0 nF	Assembling Technology = SMT Capacitance = 33.0 nF Rated Voltage = 10.0 V Height = 500 µm	1
2.	L1	74438343022	2.20 µH	Inductance = 2.20 µH Rated Current = 1.65 A	1

QUESTIONS?

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