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BETTER SAFE THAN SORRY; PRACTICAL EMC DESIGN CONSIDERATIONS



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Senior Field Application Engineer

WÜRTH ELEKTRONIK MORE THAN YOU EXPECT

AGENDA

- Practical EMI Filter Design
 - Architecture
 - Selection (Redexpert)
 - Simulation (LT Spice)
- Layout and Tracking
 - Practical Example – PoE Type 2 Flyback
 - Filter design
 - Signal integrity
 - LT Spice Simulation vs RTA4004 Measurement
- General Interfaces (USB, RS485, Ethernet, CAN, etc.)
 - EMI filtering and OVP

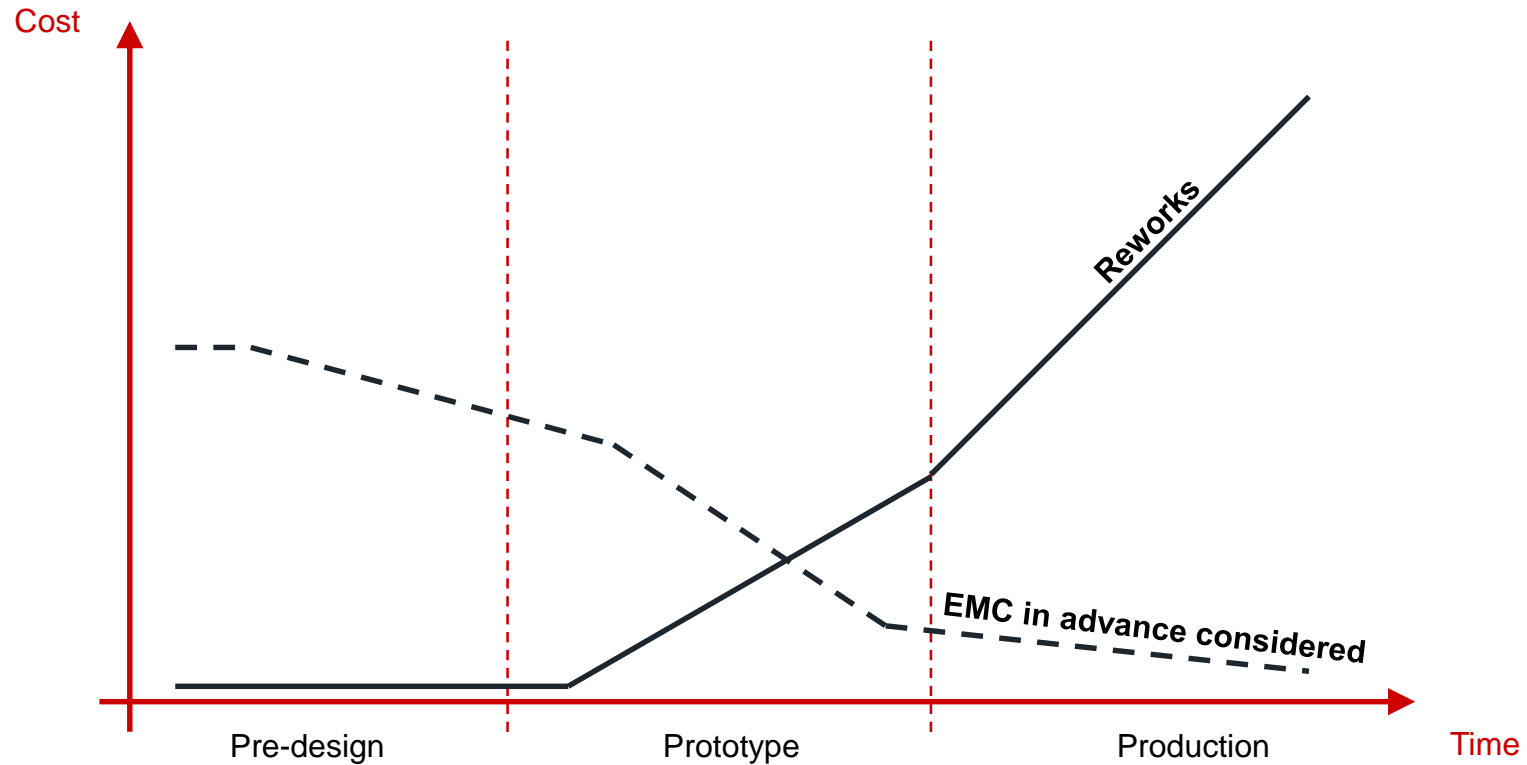


PRACTICAL EMI FILTER DESIGN

BETTER SAFE THAN SORRY

ECONOMICAL POINT OF VIEW:

- Dependent on when EMC conformity is considered in a design phase



ARCHITECTURE

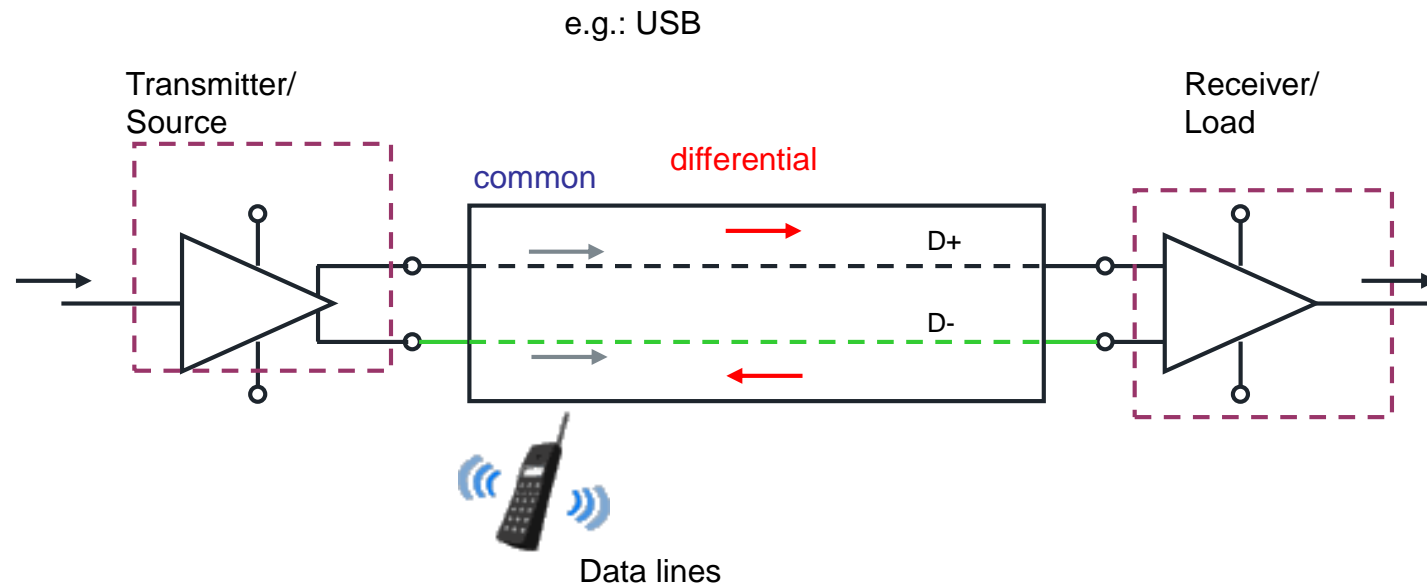
DESIGN CONSIDERATIONS

- Multiple stages
- Considers Conducted and Radiated Emissions/Immunity
- Accounts for Common mode and Differential mode transmission
- Includes OVP (ESD/EFT/Surge)
- Considers Layout and Tracking
- Considers practical component and functional shortfalls

ARCHITECTURE

SIGNAL PROPAGATION

- Noise Mode



- Common Mode Noise
- Differential Mode Noise

ARCHITECTURE

DIFFERENTIAL FILTER TOPOLOGIES

Source Impedance

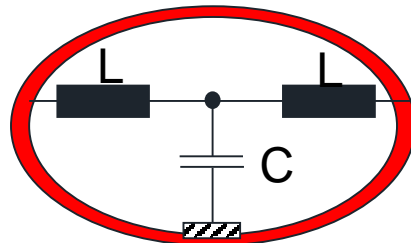
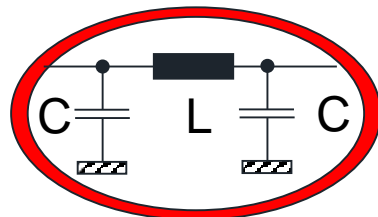
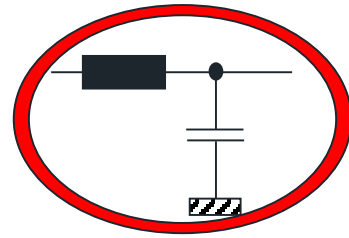
low

high

high or unknown

low

low or unknown



Load Impedance

high

high

high or unknown

low

low or unknown

→ small C = higher SRF

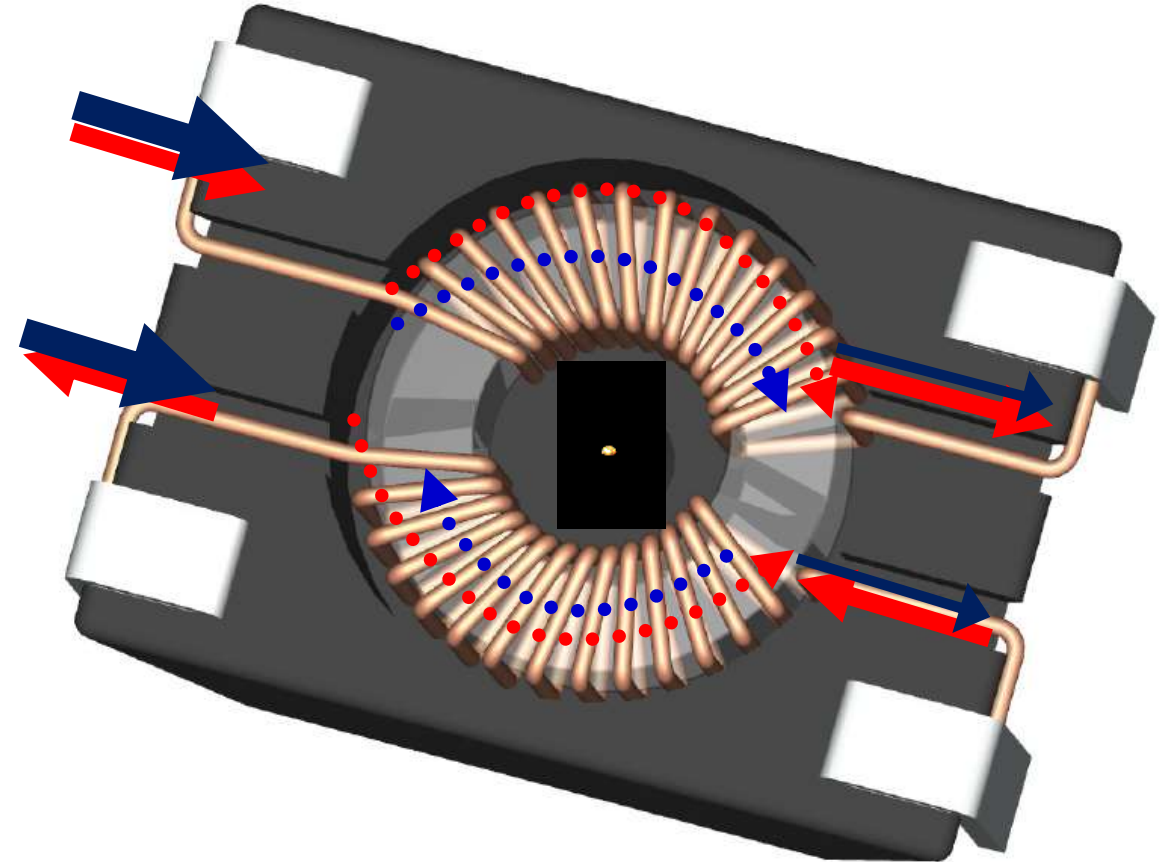
Choose ferrite bead
= build no resonance with C
= broadband filter

Pay attention to:
SRF of used components

ARCHITECTURE

COMMON MODE CHOKE – PRINCIPLE OF OPERATION

- It is a Bi-directional filter
 - From device to outside environment
 - From outside environment to inside device
- Intended Signal - **Differential mode**
- Interference Signal (noise) – **Common Mode**
- Conclusion:
 - “almost” no affect the signal - **Differential mode**
 - high attenuation to the interference signal (noise) – **Common Mode**



SELECTION

COMPONENT SELECTION CONSIDERATIONS

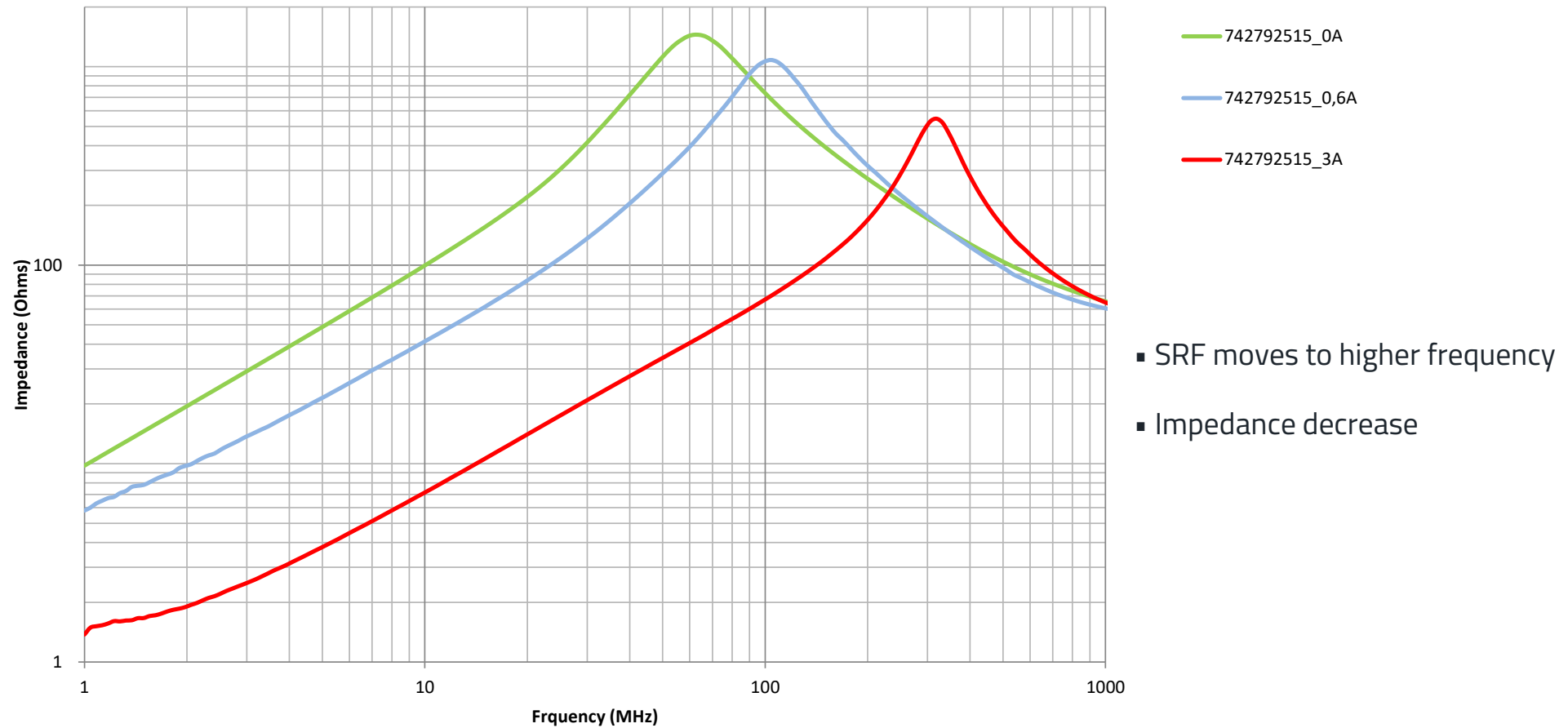
- DC Bias Effect
- Parasitic effects (e.g. Leakage Inductance)
- Temperature
- Impedance vs Frequency
- Most important

 - Availability !!!

SELECTION

CHIP FERRITES DC BIAS

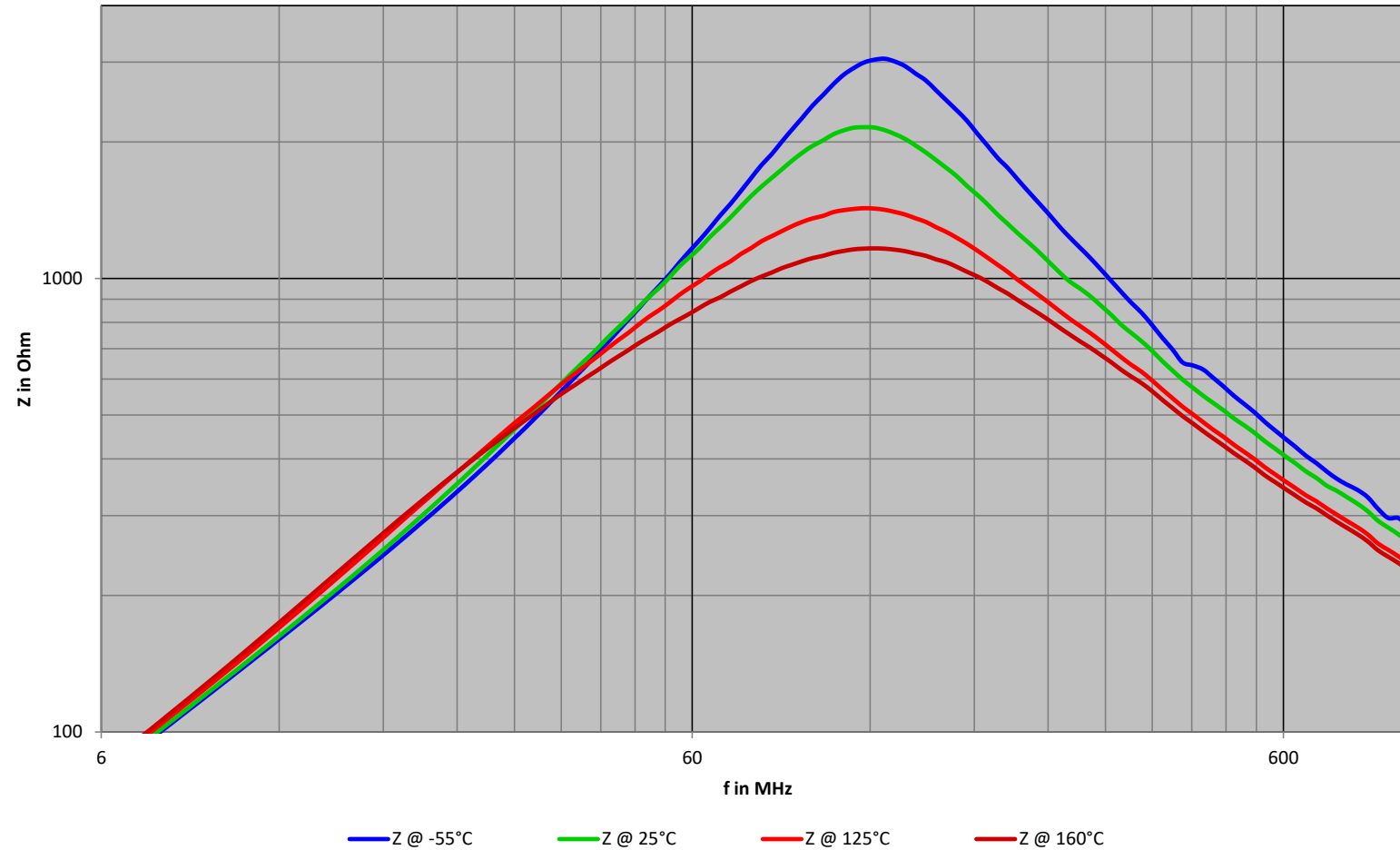
742792515 Z vs f vs I



SELECTION

BEHAVIOR OF THE IMPEDANCE AT TEMPERATURE

742792693 Z_vs_Temperature

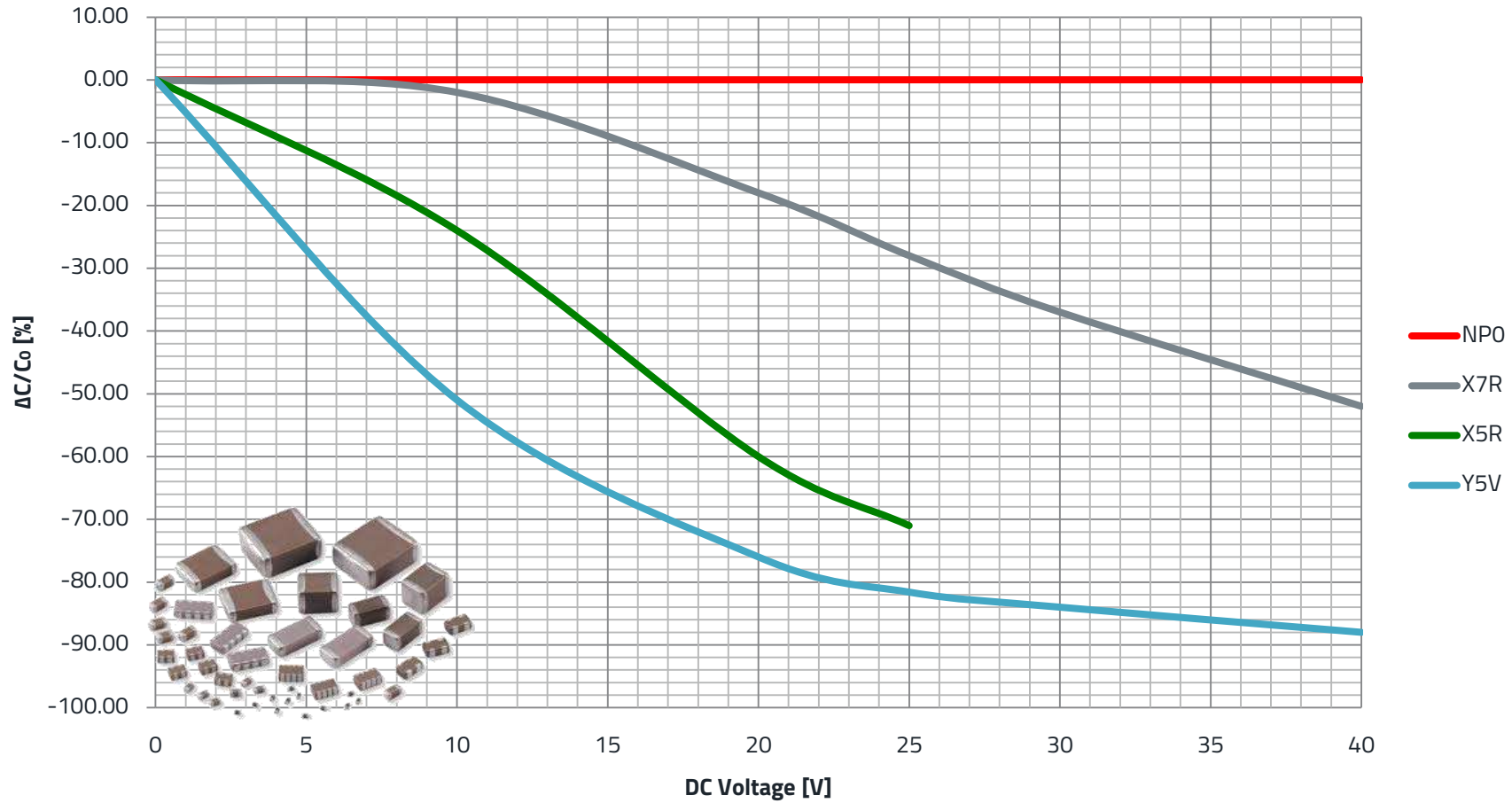


With increasing temperature the impedance decrease

SELECTION

MLCC VOLTAGE DEPENDENCE

$\Delta C/C_0$ vs. DC Voltage



SELECTION

SELECTION TOOL - **REDEXPERT**



World's most accurate AC loss model

The losses determined with REDEXPERT are based on real time DCDC measurements with its typical current and voltage waveforms. Besides all core and winding losses they do also consider losses in the air gap.

▶ Calculate the AC losses

Power Inductors
REDEXPERT

SELECTION

REDEXPERT - USER INTERFACE

The screenshot displays the REDEXPERT user interface for Power Inductors. At the top, the Würth Elektronik Group logo and navigation options (Sign in, English) are visible. The main heading is "SELECTION TABLE" with a sub-heading "Power Inductors REDEXPERT". A sidebar on the left lists converter types: Buck, Boost, SEPIC, and Losses. The selection table below shows a list of inductors with columns for Series, Order Code, Spec, Type, L, R_{DC,typ}, I_R, I_{sat}, Size, Length, Width, and Height. The second row is highlighted in red. Below the table is a "STORAGE" bar for the selected part (744383130068) with options to share, request free samples, or tidy up. At the bottom, two graphs are shown: "Graph 1" (Inductance / Current) and "Graph 2" (Warming / Current).

Series	Order Code	Spec	Type	L	R _{DC,typ}	I _R	I _{sat}	Size	Length	Width	Height
WE-MAPI	744383130068	PDF	Single	680 nH	101 mΩ	1.55 A	3.80 A	1610	1.6 mm	1.6 mm	0.90
WE-MAPI	744383130082	PDF	Single	820 nH	115 mΩ	1.45 A	3.60 A	1610	1.6 mm	1.6 mm	0.90
WE-MAPI	74438313010	PDF	Single	1.00 μH	127 mΩ	1.40 A	3.40 A	1610	1.6 mm	1.6 mm	0.90
WE-MAPI	74438313012	PDF	Single	1.20 μH	140 mΩ	1.30 A	3.20 A	1610	1.6 mm	1.6 mm	0.90

Graph 1: Inductance / Current

Current (A)	Inductance (μH) - Red Line	Inductance (μH) - Blue Line
0	0.85	0.70
0.5	0.82	0.68
1.0	0.78	0.65
1.5	0.75	0.62
2.0	0.70	0.58
2.5	0.65	0.55
3.0	0.60	0.52
3.5	0.55	0.48
4.0	0.50	0.45

Graph 2: Warming / Current

Current (A)	Warming (K) - Red Line	Warming (K) - Blue Line
0	0	0
0.5	5	5
1.0	15	15
1.5	35	30
2.0	75	60

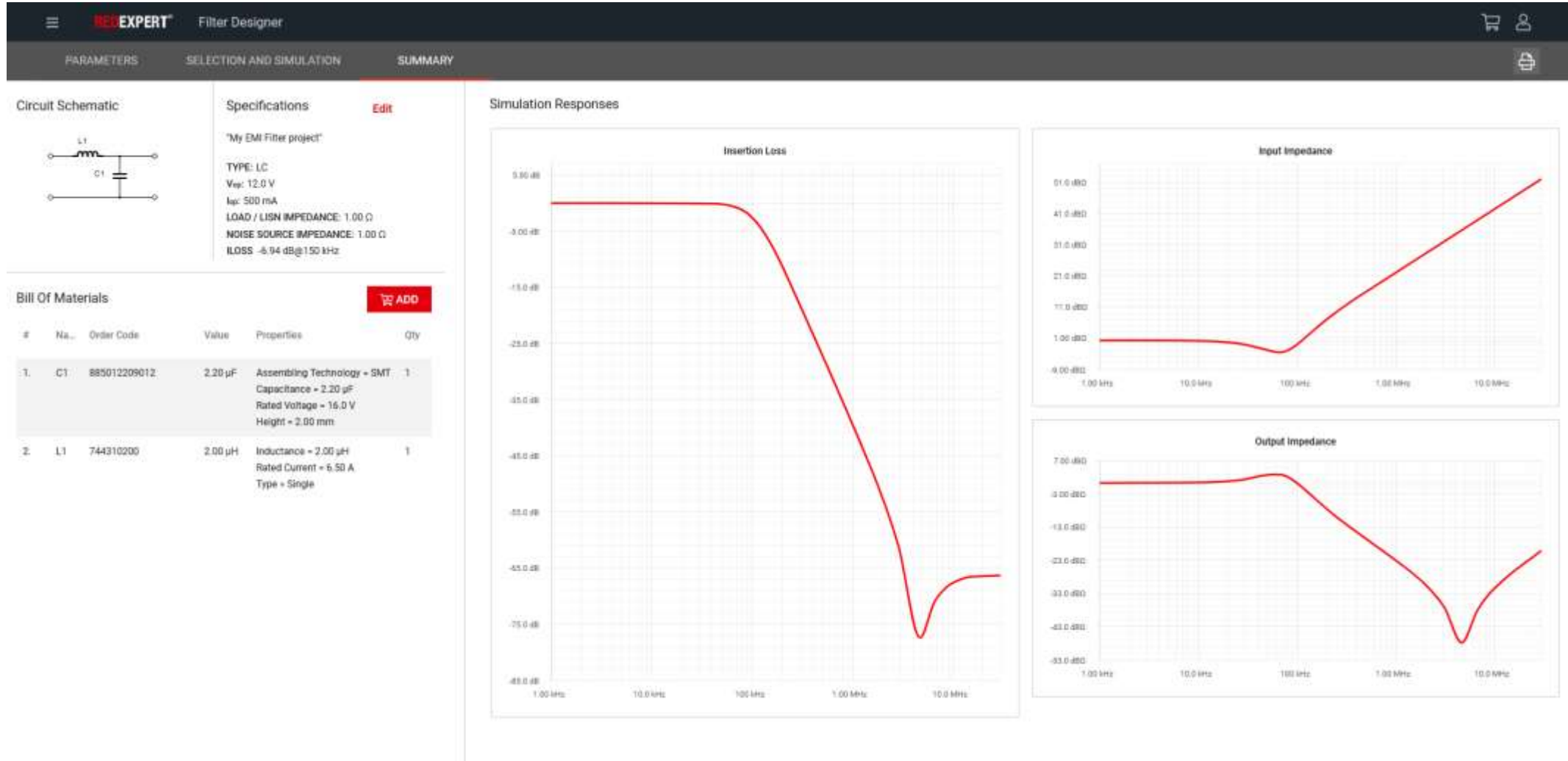
REDEXPERT

<https://www.we-online.com/redexpert/#/module/1>

www.we-online.com/redexpert

SELECTION

FILTERING OF INPUT AND OUTPUT - EMI FILTER DESIGN

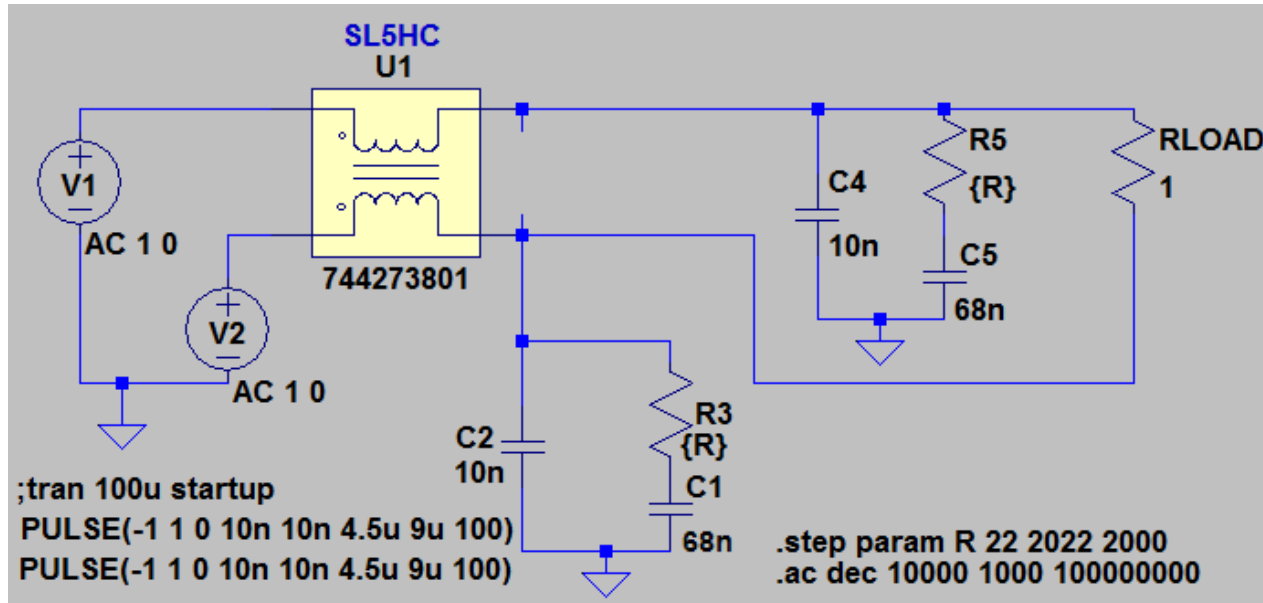


SIMULATIONS

- Conducted Emissions (CE) and Radiated Emissions (RE)
- Damping
- Leakage Effect
- Oscillation (Instability)
- Time domain

SIMULATIONS – COMMON MODE FILTER DESIGN

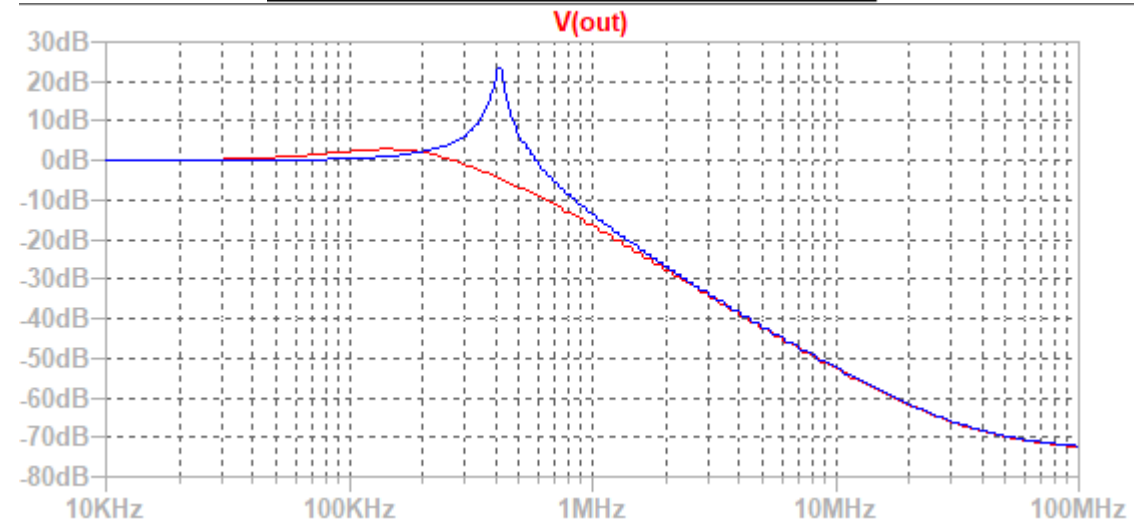
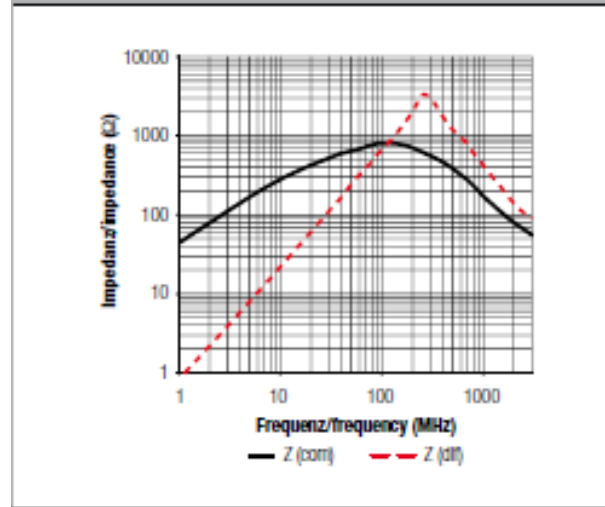
WITH CHASSIS / EMC GROUND



- Power Supply Switching Frequency Considerations (L)
- EMI Higher Frequency Considerations (Z)
- Layout and Tracking
- Capacitor with and without Damping

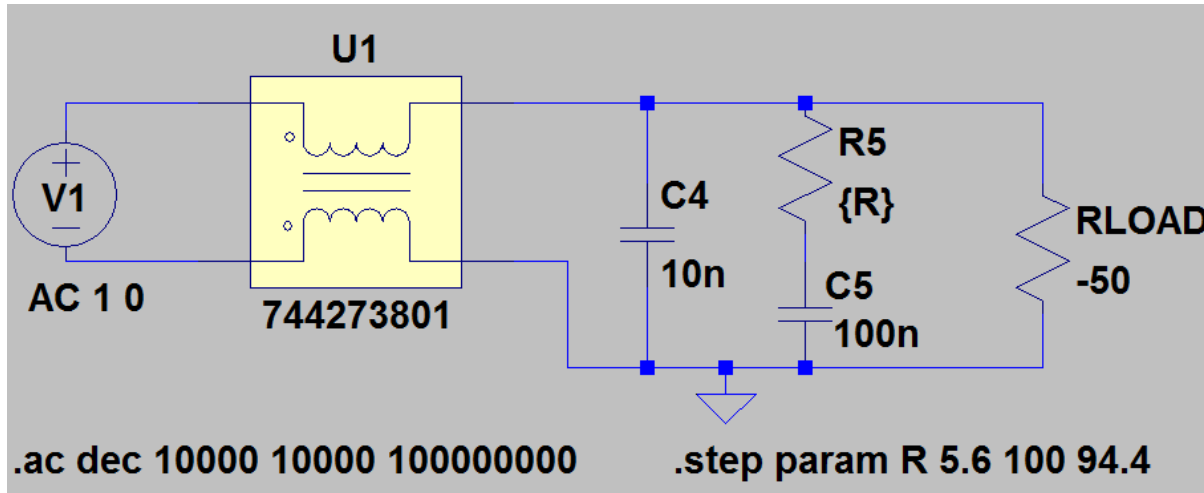
Take care

744 273 801



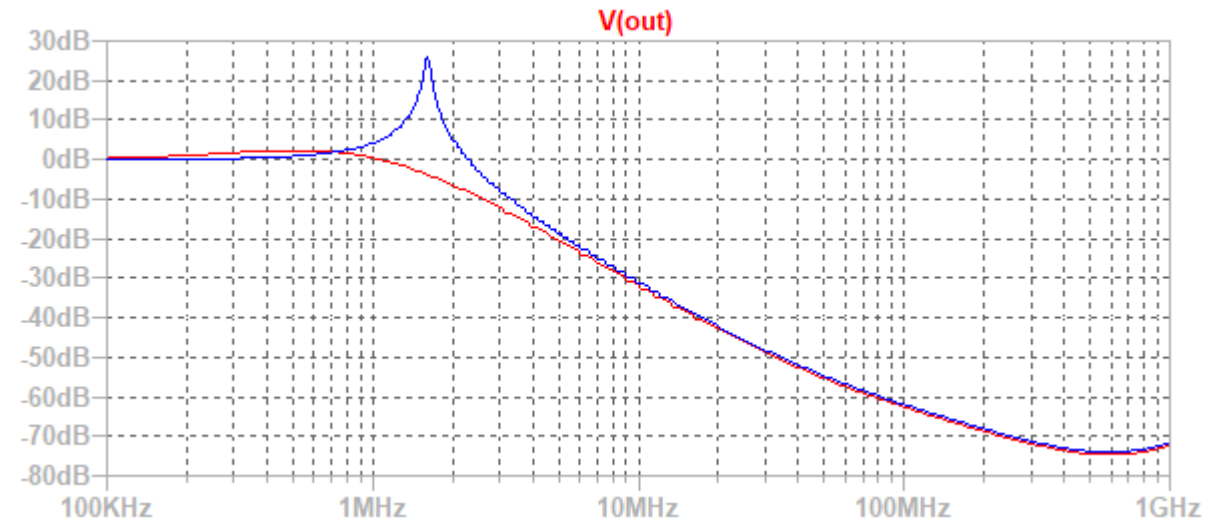
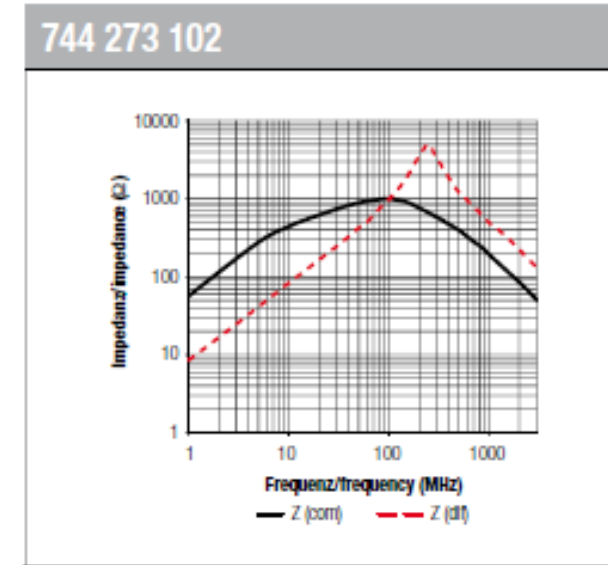
SIMULATIONS - COMMON MODE FILTER DESIGN

DM (LEAKAGE) EFFECT



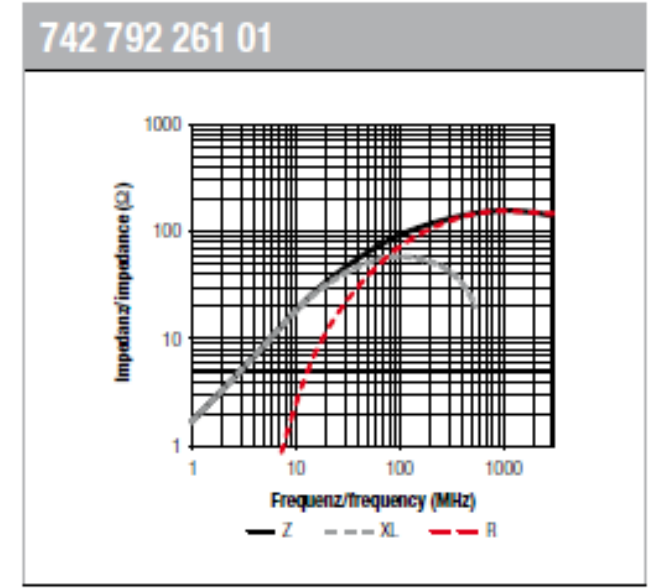
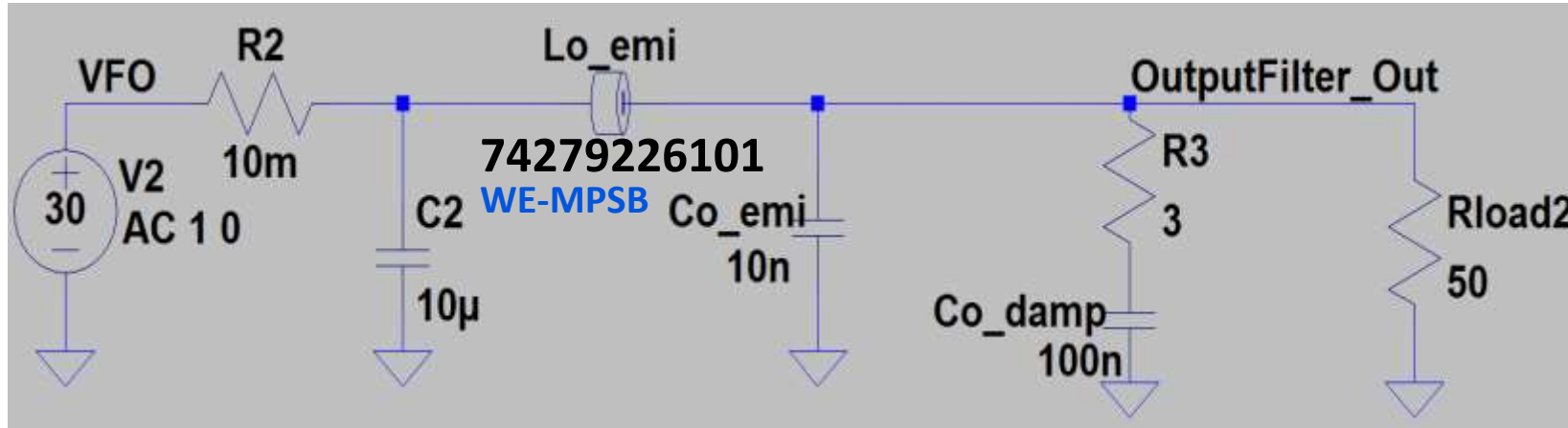
- Load Impact
- Capacitor Damping

Take care

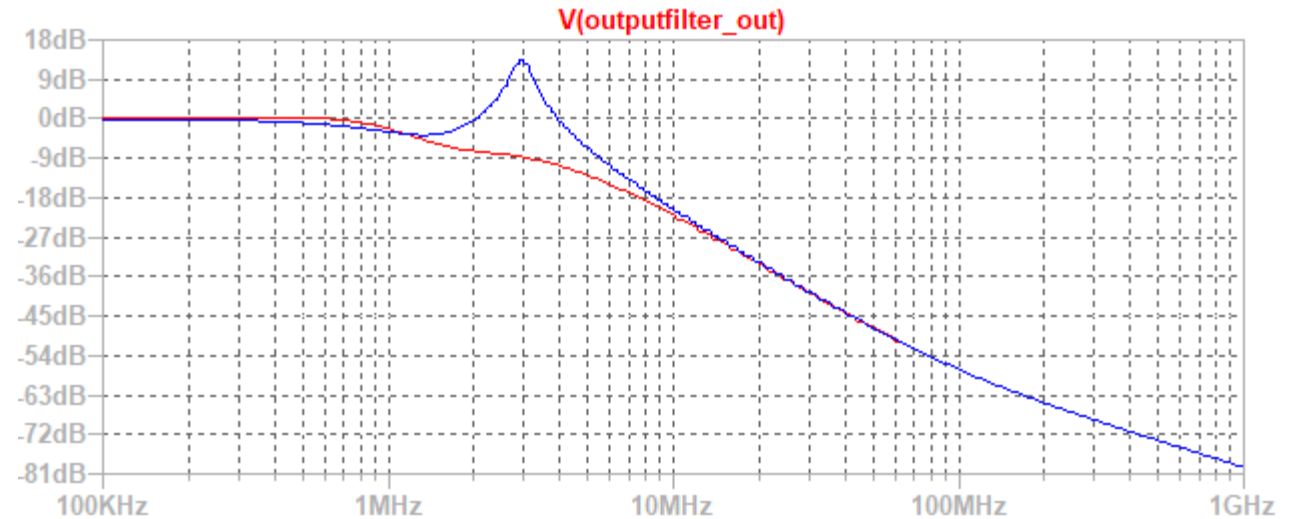


SIMULATIONS

RE DIFFERENTIAL MODE FILTER DESIGN

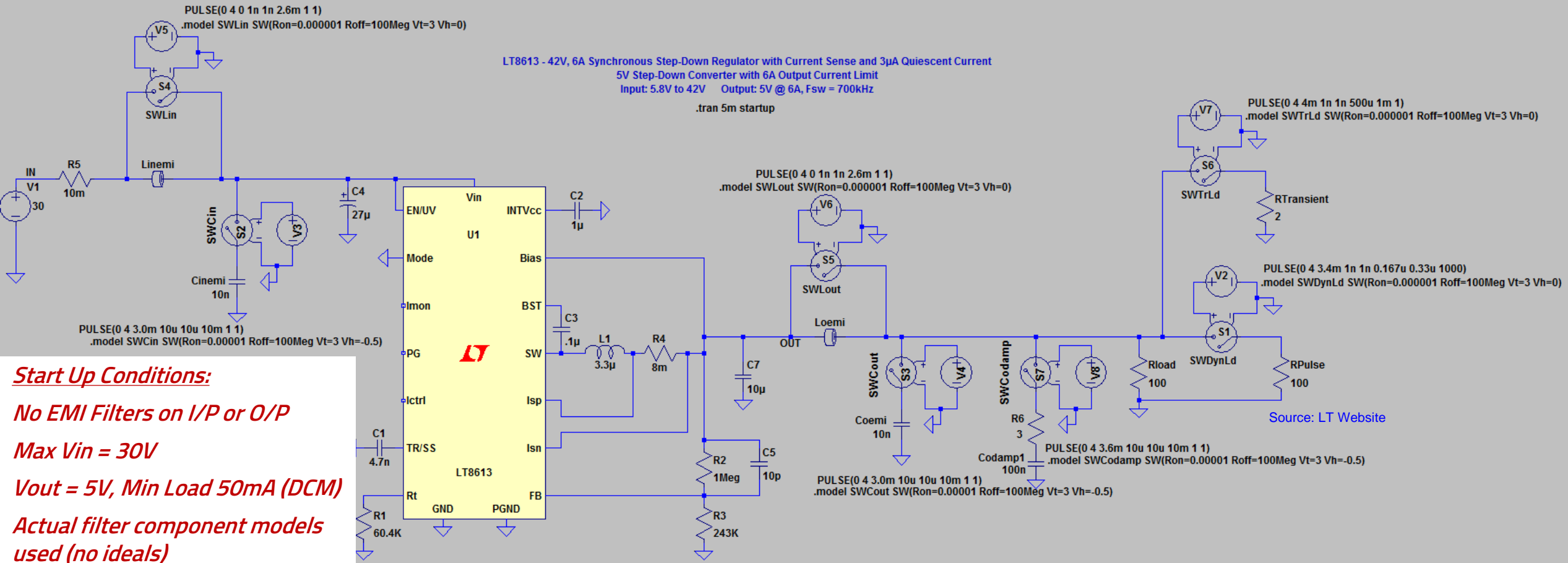


- Load Impact
- EMI Higher Frequency Considerations
- Pulse Rating (WE-MPSB)
- Layout and Tracking
- Capacitor Damping



SIMULATIONS

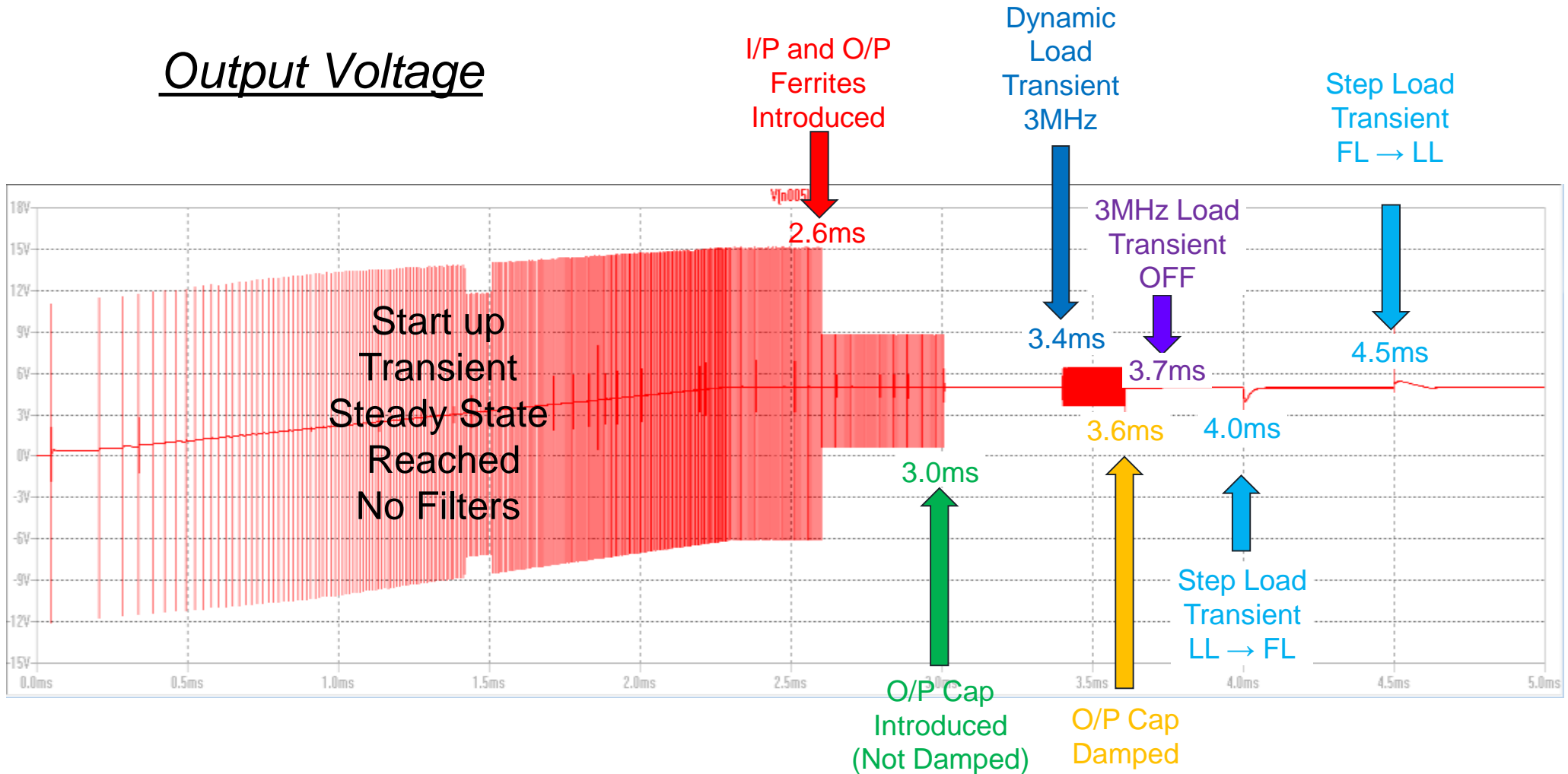
RE DIFFERENTIAL MODE FILTER DESIGN – BUCK EXAMPLE



SIMULATIONS

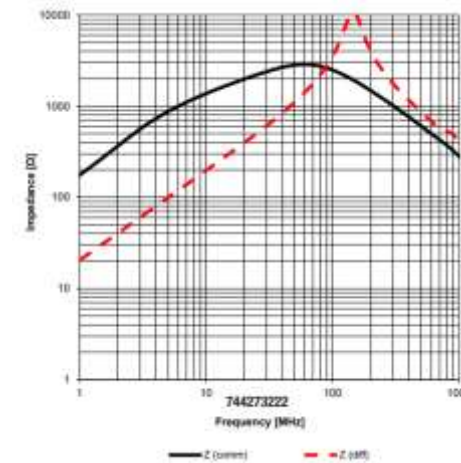
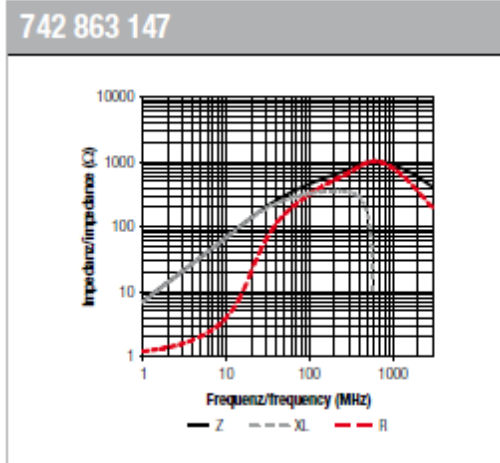
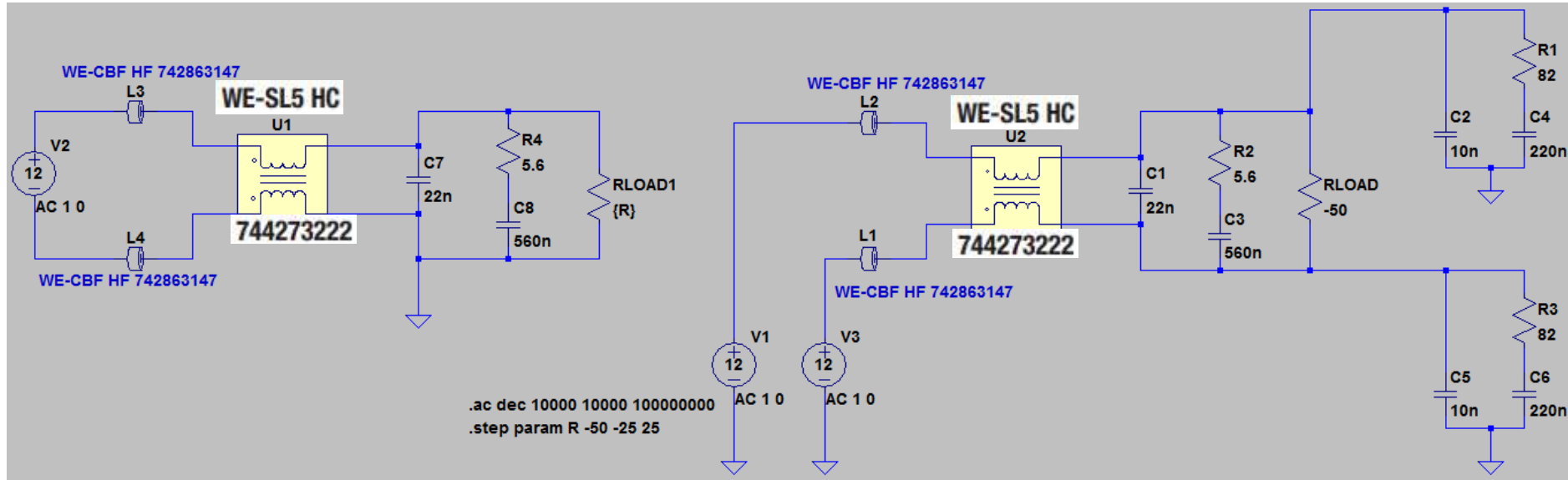
RE DIFFERENTIAL MODE FILTER DESIGN – BUCK EXAMPLE

Output Voltage



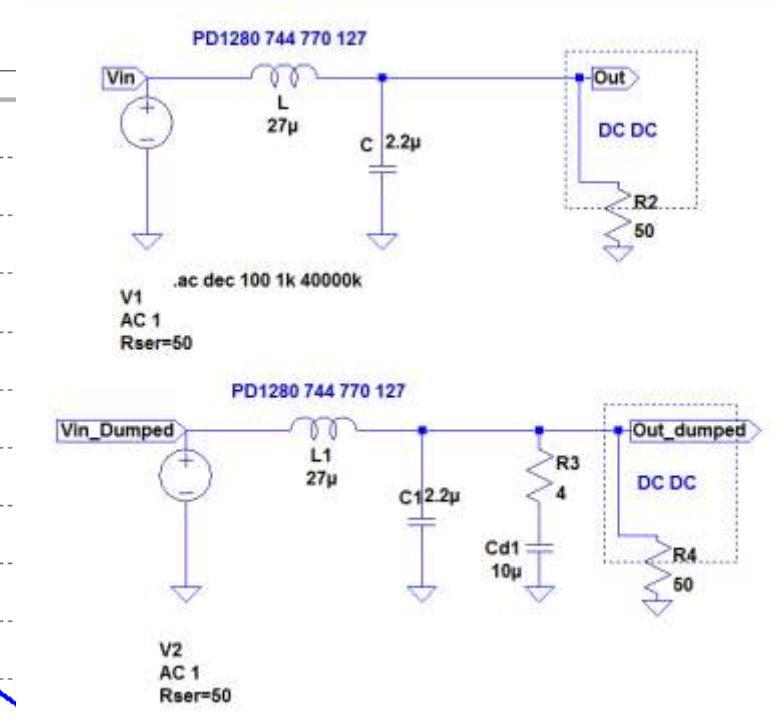
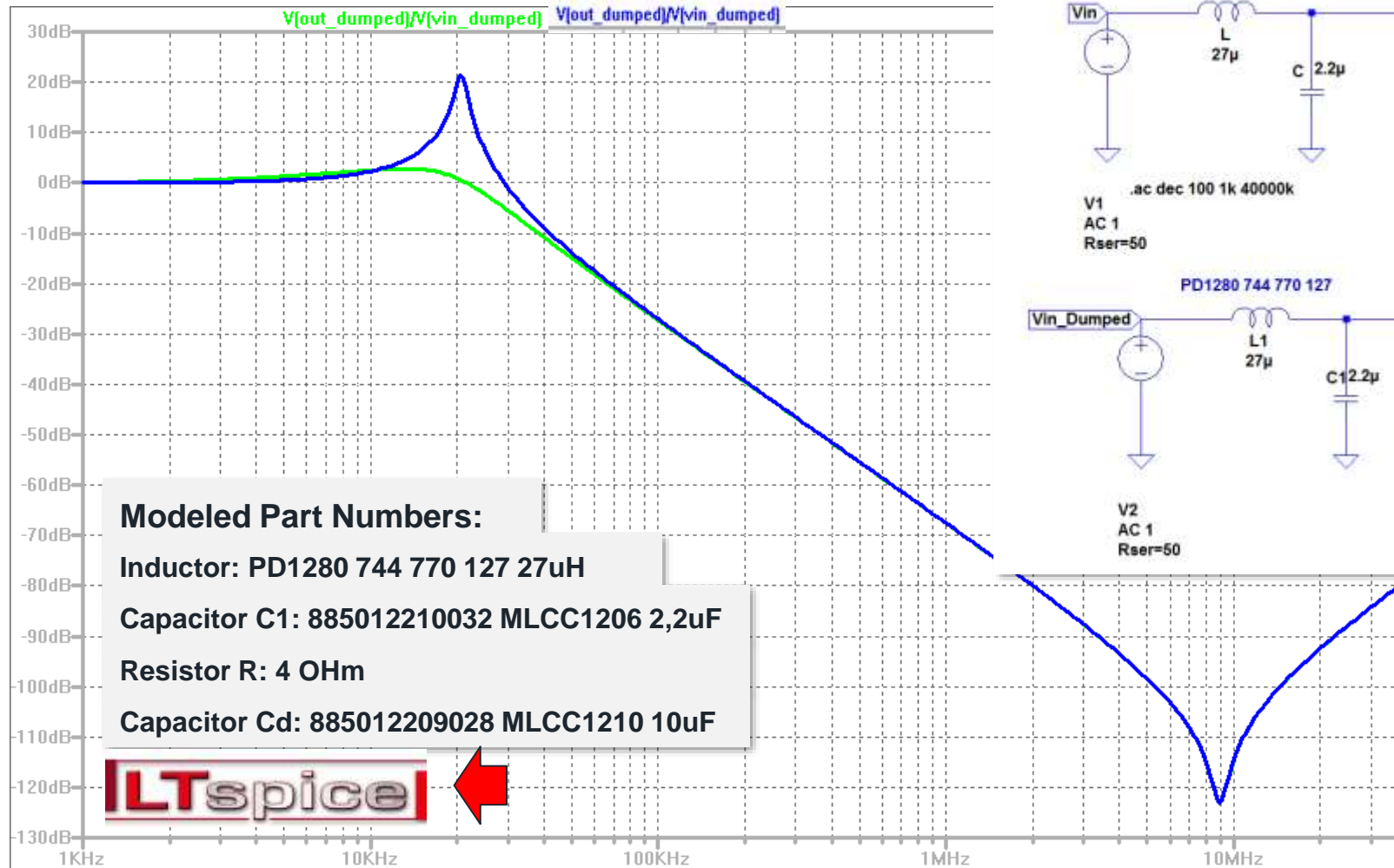
SIMULATIONS

EMI FILTER DESIGN – RE ARCHITECTURE



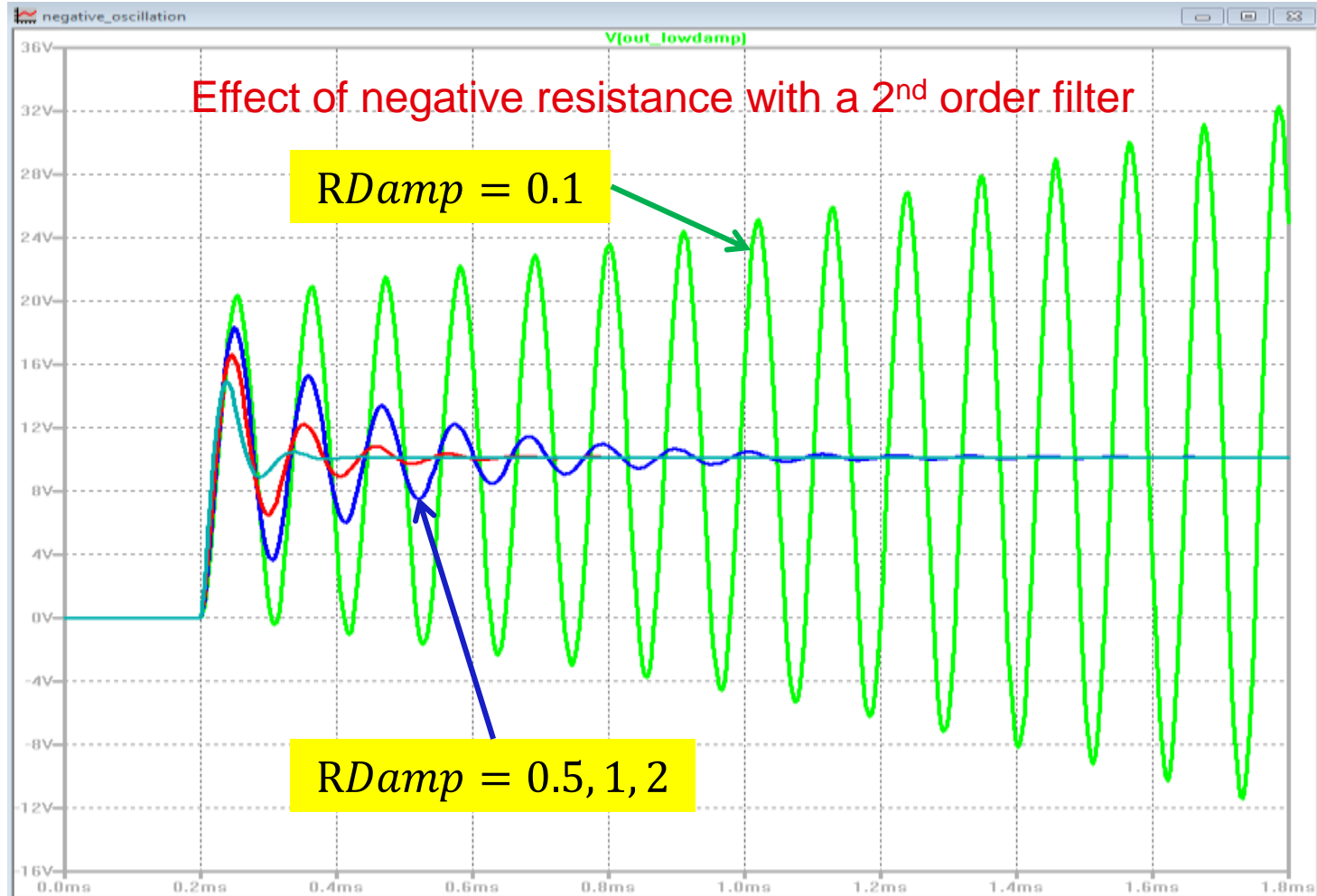
SIMULATIONS

CE DIFFERENTIAL MODE FILTER DESIGN

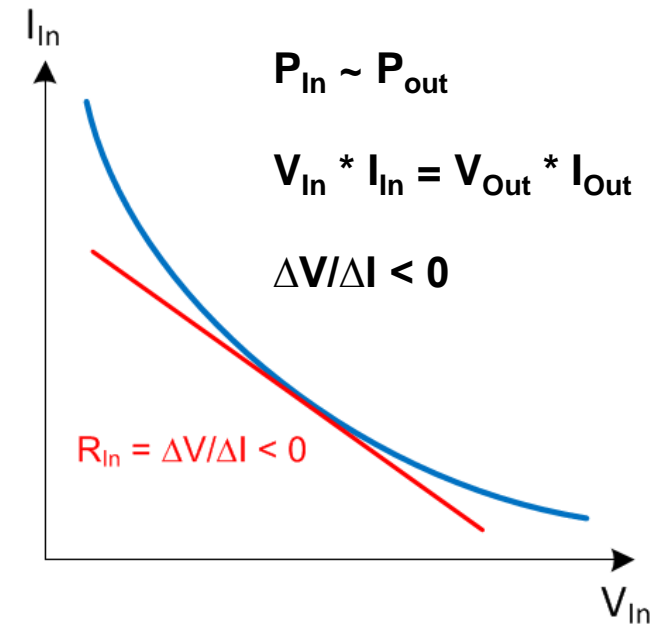
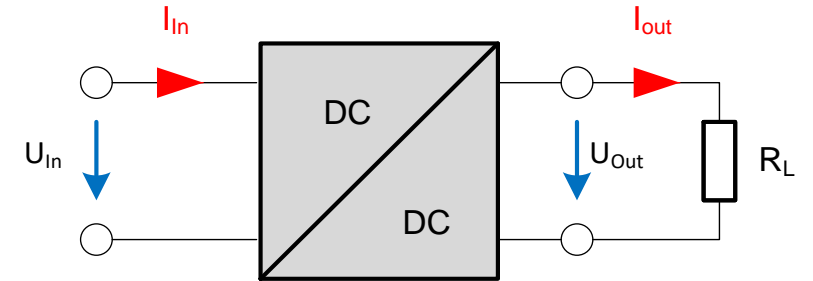


SIMULATIONS

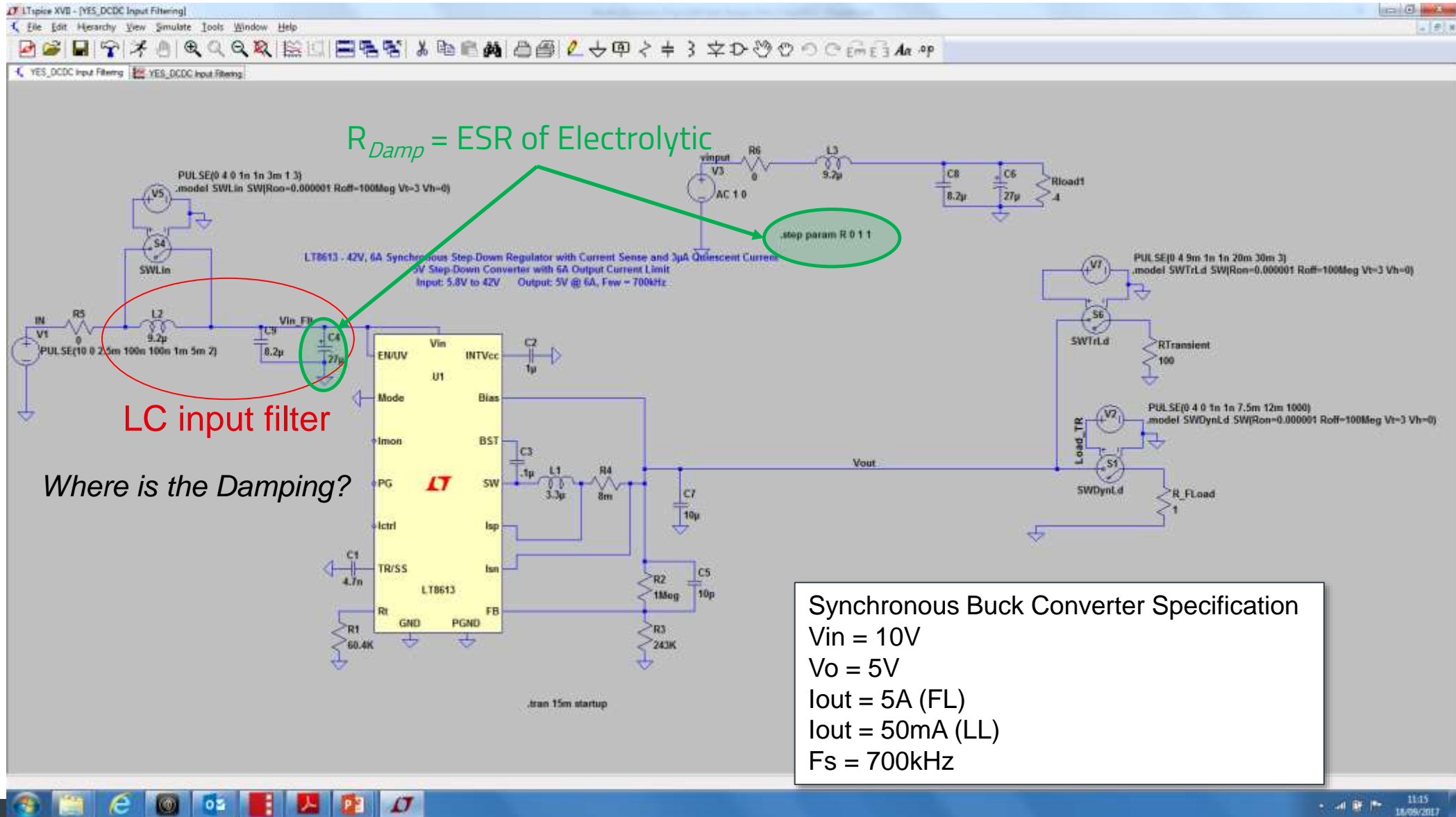
CE DIFFERENTIAL MODE FILTER DESIGN



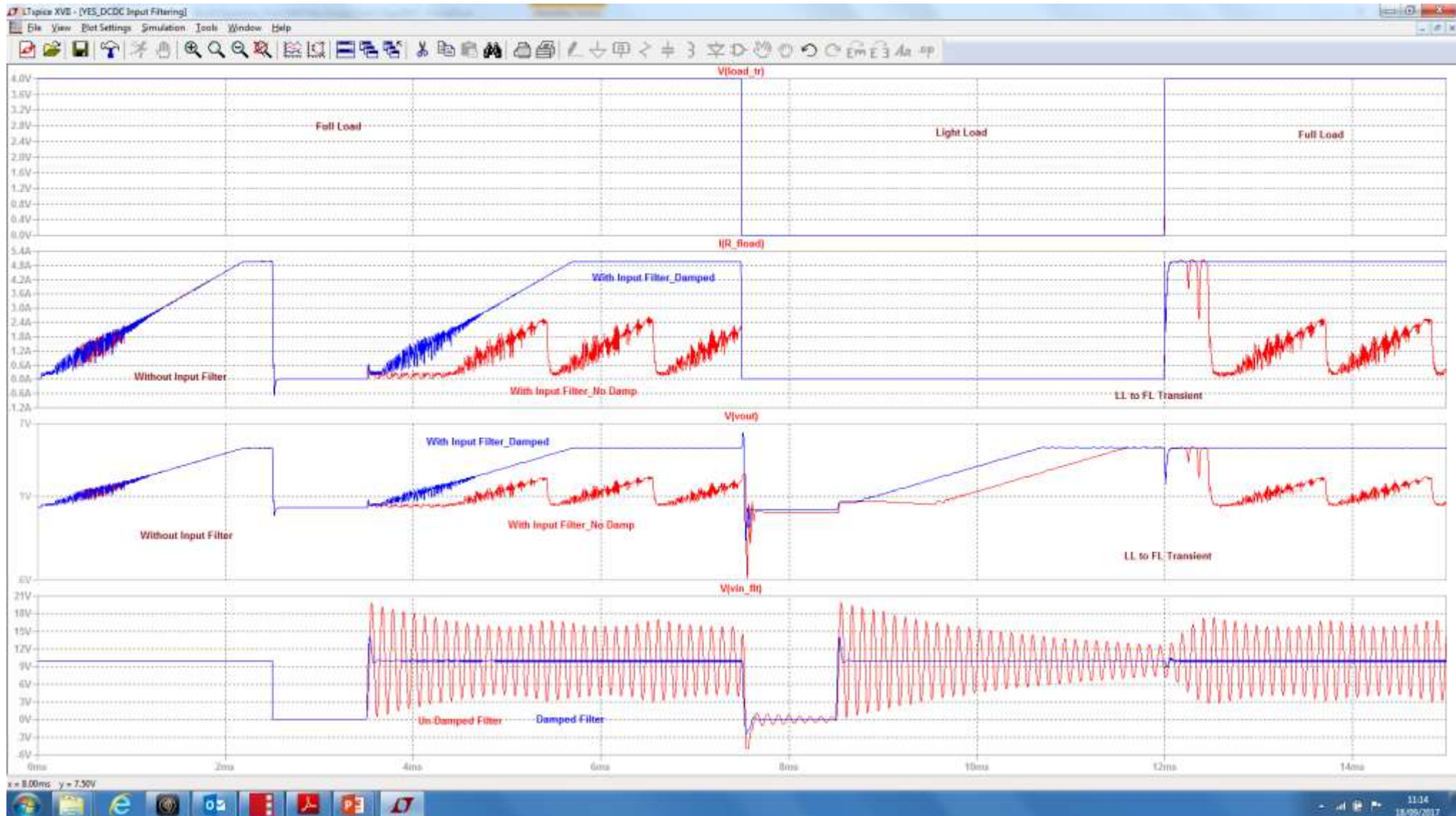
Take care



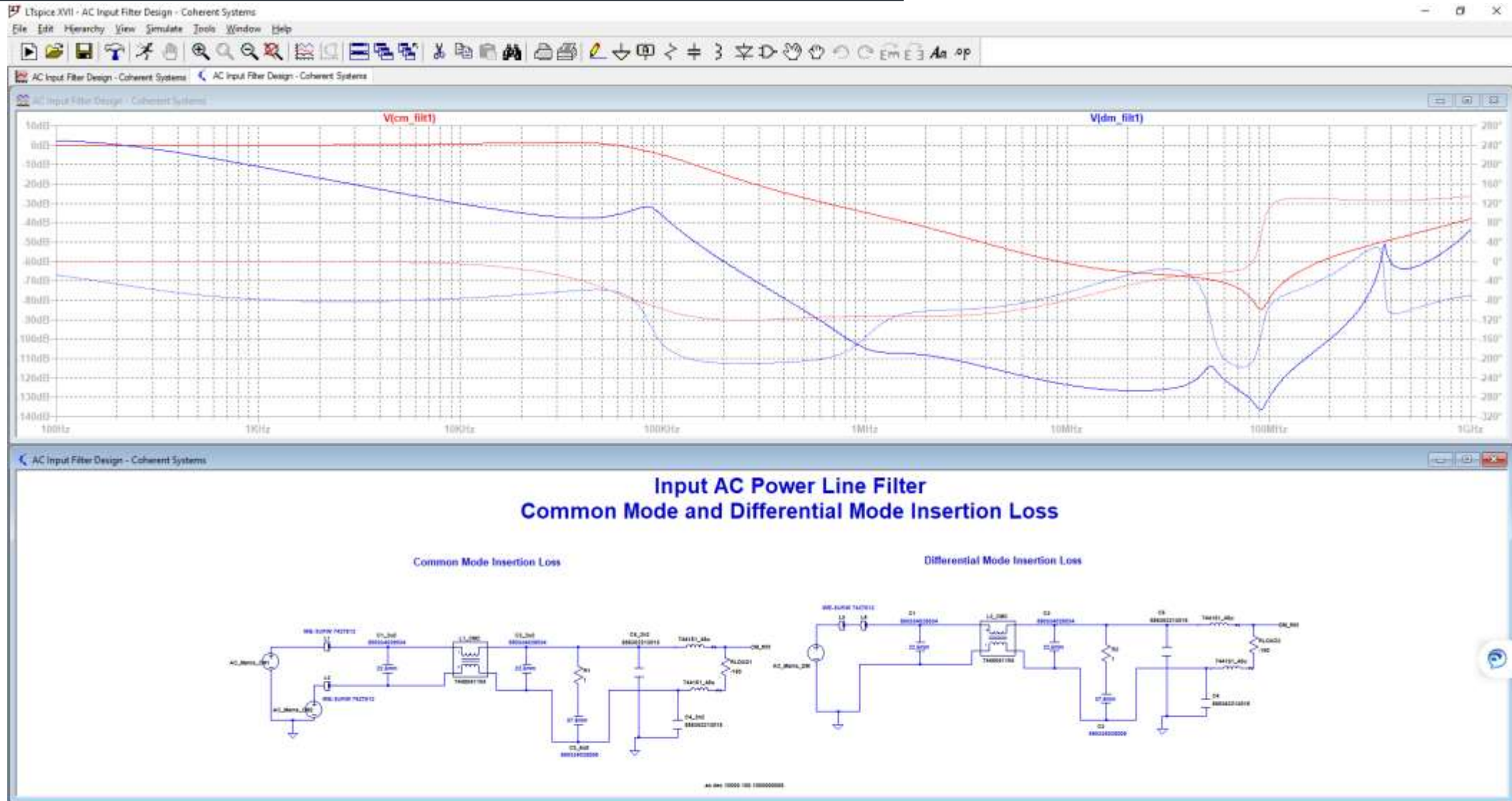
CE DIFFERENTIAL MODE FILTER DESIGN – BUCK EXAMPLE



CE DIFFERENTIAL MODE FILTER DESIGN – BUCK EXAMPLE



LT SPICE SIMULATION – MAINS FILTER EXAMPLE

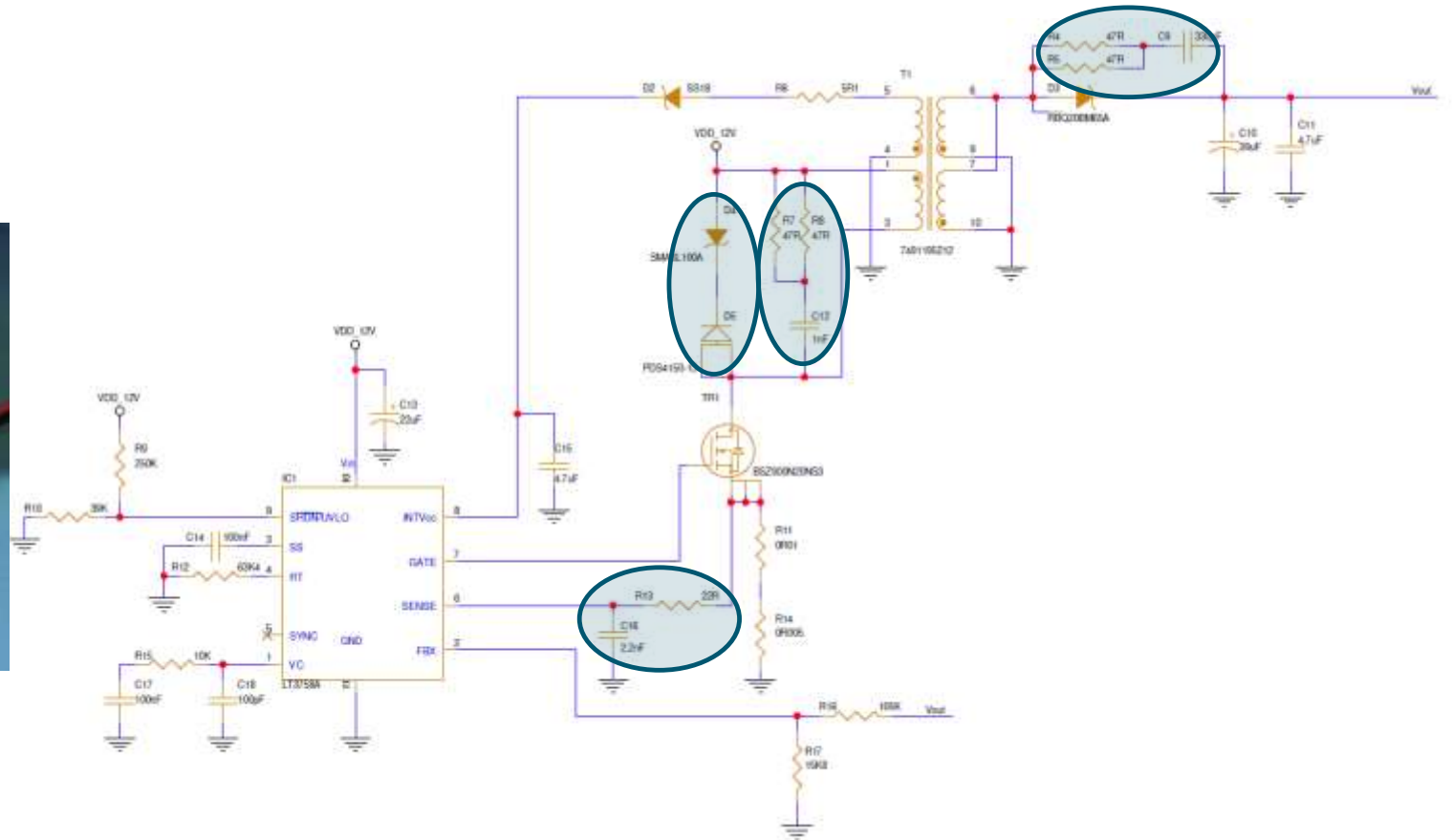
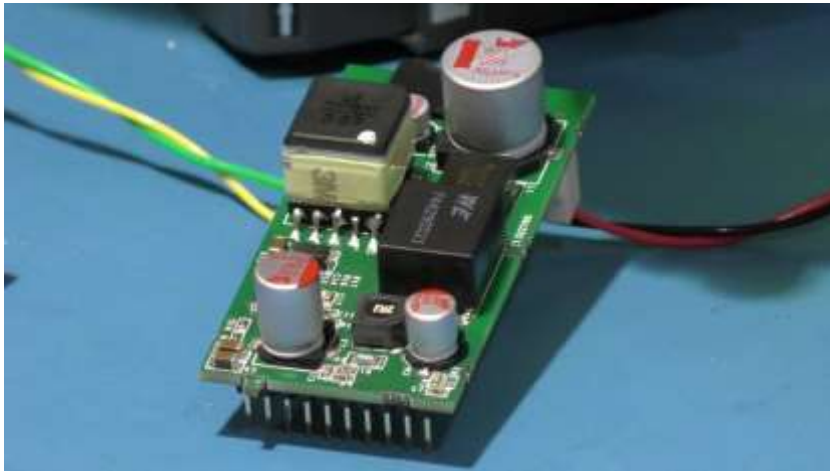


LAYOUT & TRACKING

TYPE 2 POE FLYBACK CONVERTER (LT3758A)

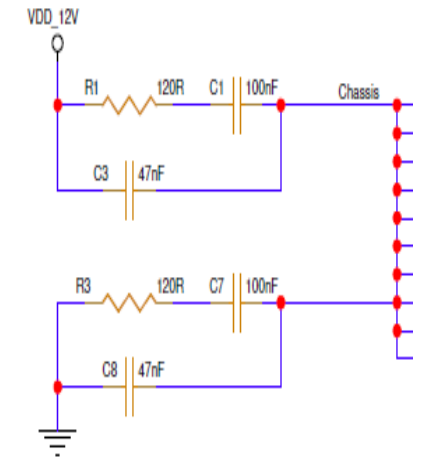
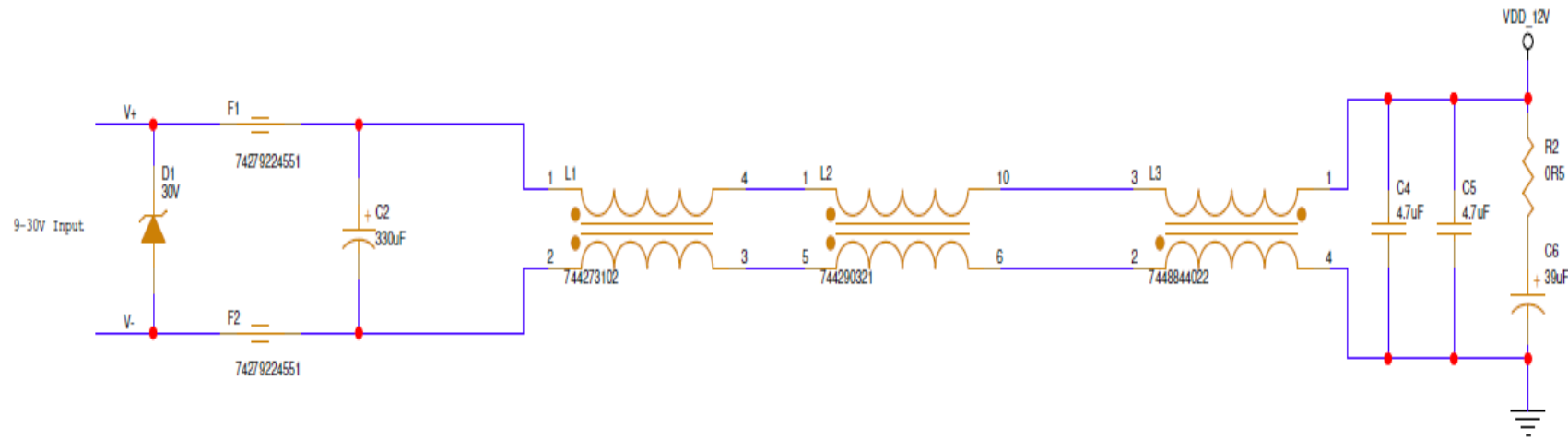
■ Design Requirements:

- $V_{in} = 9V-30V$
- $V_{out} = 12V$
- $I_{out} = 1.5A$ (up to 2.5A)
- Max Efficiency 90%



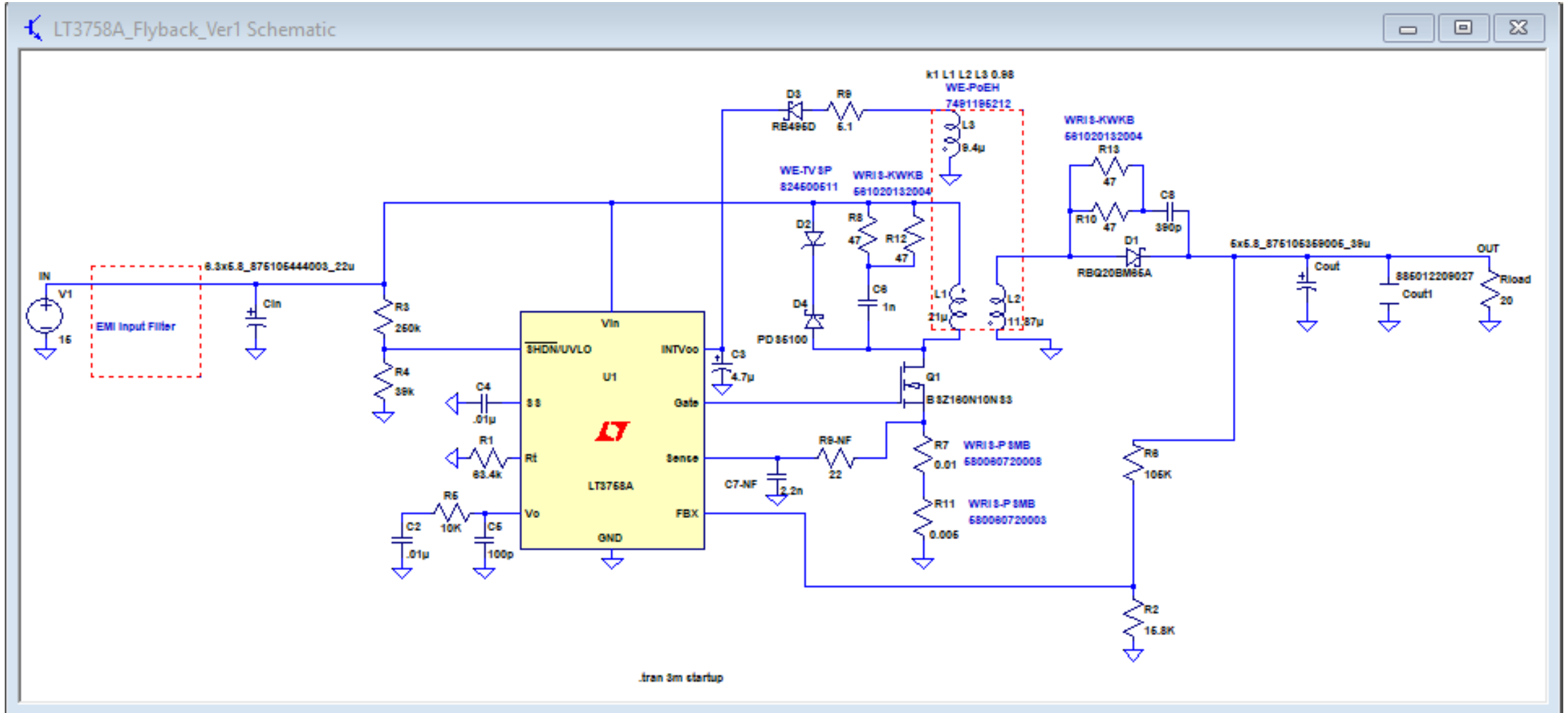
TYPE 2 POE FLYBACK CONVERTER (LT3758A)

EMI FILTER CIRCUIT



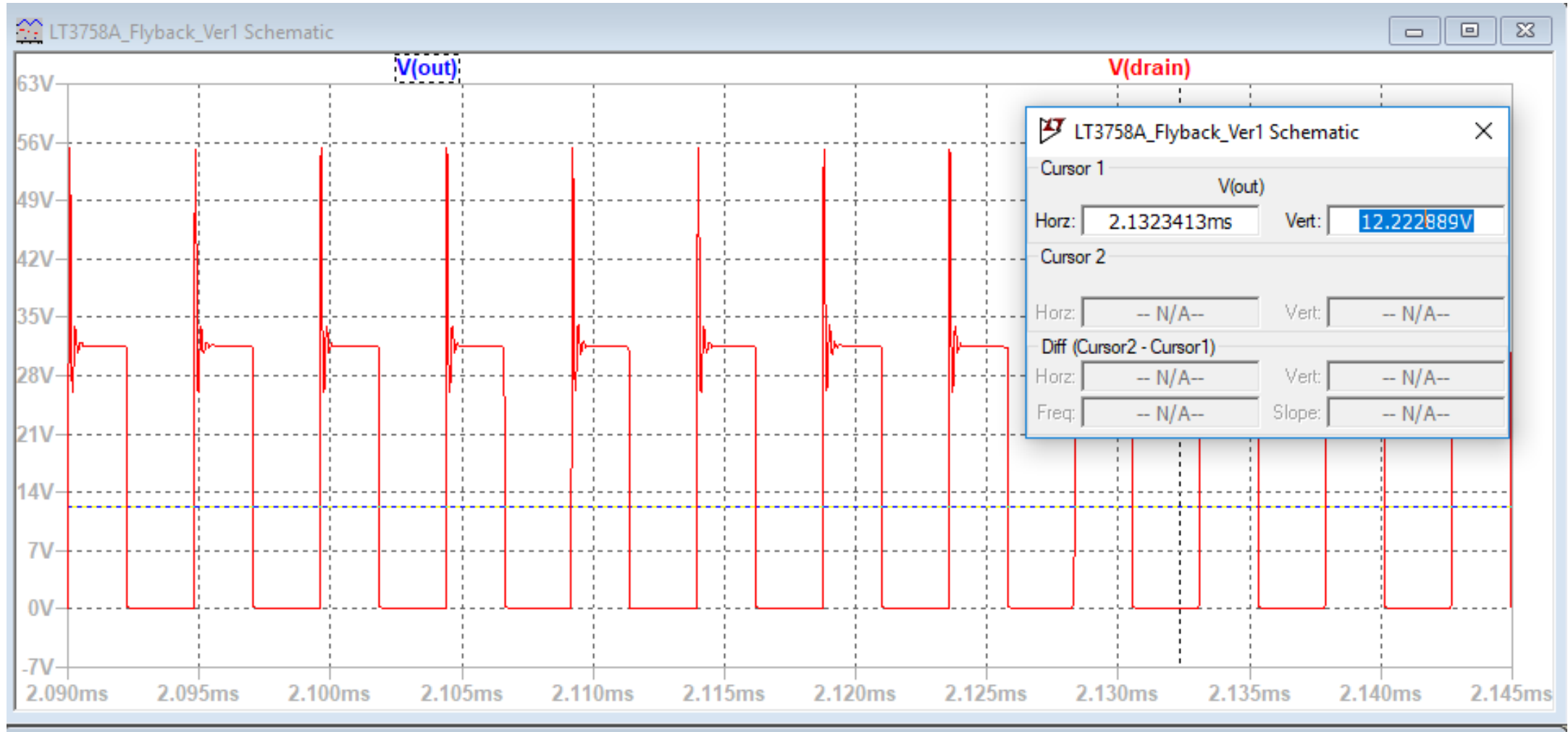
TYPE 2 POE FLYBACK CONVERTER (LT3758A)

DESIGN SIMULATION: POWER CIRCUIT



TYPE 2 POE FLYBACK CONVERTER (LT3758A)

DESIGN SIMULATION: POWER CIRCUIT



TYPE 2 POE FLYBACK CONVERTER (LT3758A)

DESIGN SIMULATION: FILTER CIRCUIT

List of Parts

D1: WE-TVSP
824501141
<https://www.we-online.com/catalog/datasheet/824501141.pdf>

FB1/FB2: WE-MPSB
74279224551
<https://www.we-online.com/catalog/datasheet/74279224551.pdf>

C0: WCAP-PSLC
875075661010
330uF / 35V
<https://www.we-online.com/catalog/en/datasheet/875075661010.pdf>

C1 / C2: WCAP-CSGP
88501220907
4.7uF / 25V
<https://www.we-online.com/catalog/en/datasheet/88501220907.pdf>

CY1 / CY2: WCAP-CSGP
885012006069
47nF / 25V
<https://www.we-online.com/catalog/en/datasheet/885012006069.pdf>

CdY1/CdY2: WCAP-CSGP
100nF/50V
<https://www.we-online.com/catalog/en/datasheet/885012206095.pdf>

Cd: WCAP-ASLI
47uF/35V
<https://www.we-online.com/catalog/en/datasheet/865080543009.pdf>

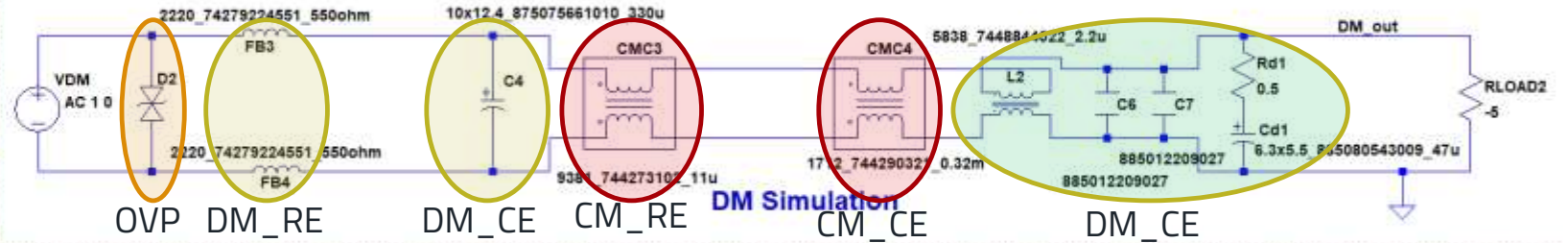
Cout: WCAP-PSHP
875115452003
100uF / 20V
<https://www.we-online.com/catalog/en/datasheet/875115452003.pdf>

CMC1: WE-SL5 HC
744273102
<https://www.we-online.com/catalog/en/datasheet/744273102.pdf>

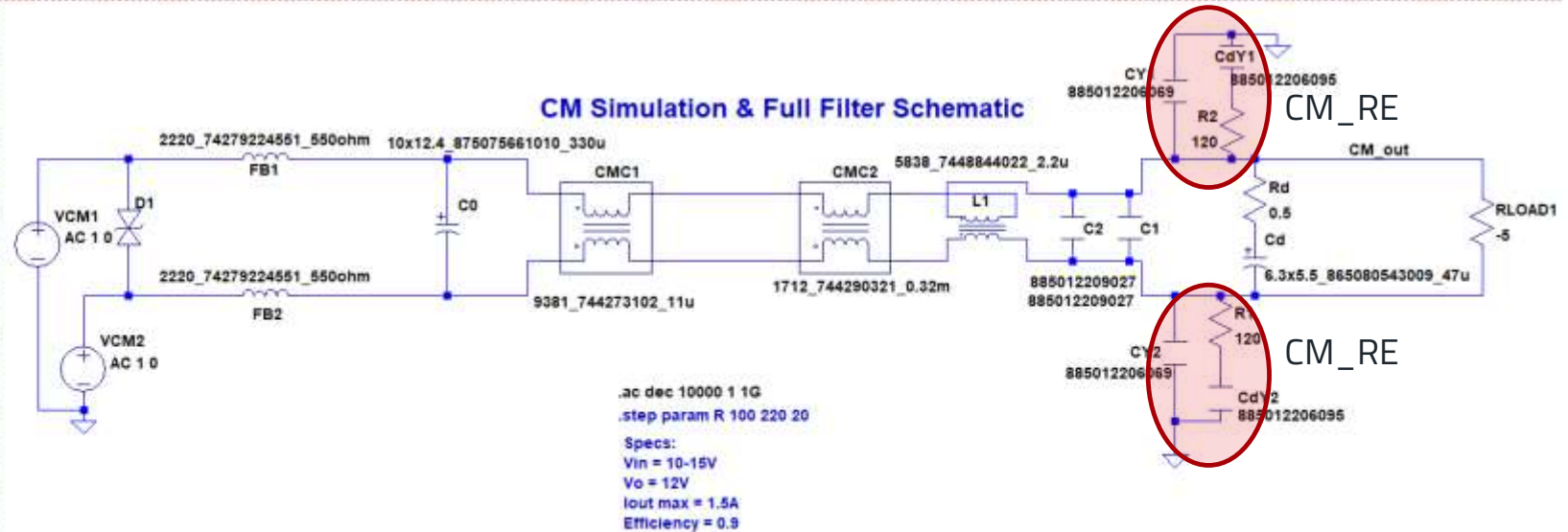
CMC2: WE-UCF
744290321
<https://www.we-online.com/catalog/en/datasheet/744290321.pdf>

L1: WE-DPV
7448844022
<https://www.we-online.com/catalog/en/datasheet/7448844022.pdf>

12V DC Supply Input Optimised Filter

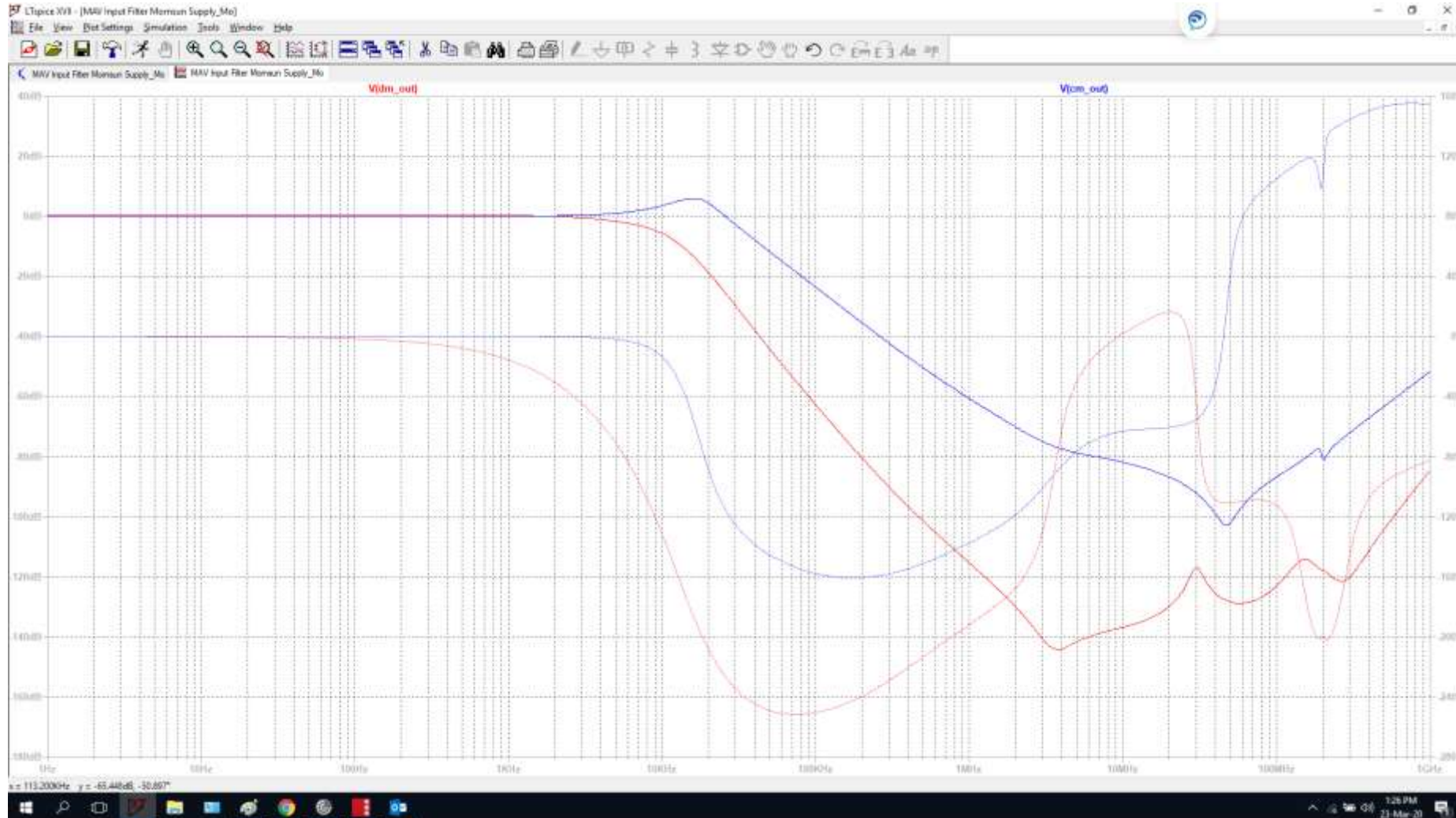


CM Simulation & Full Filter Schematic



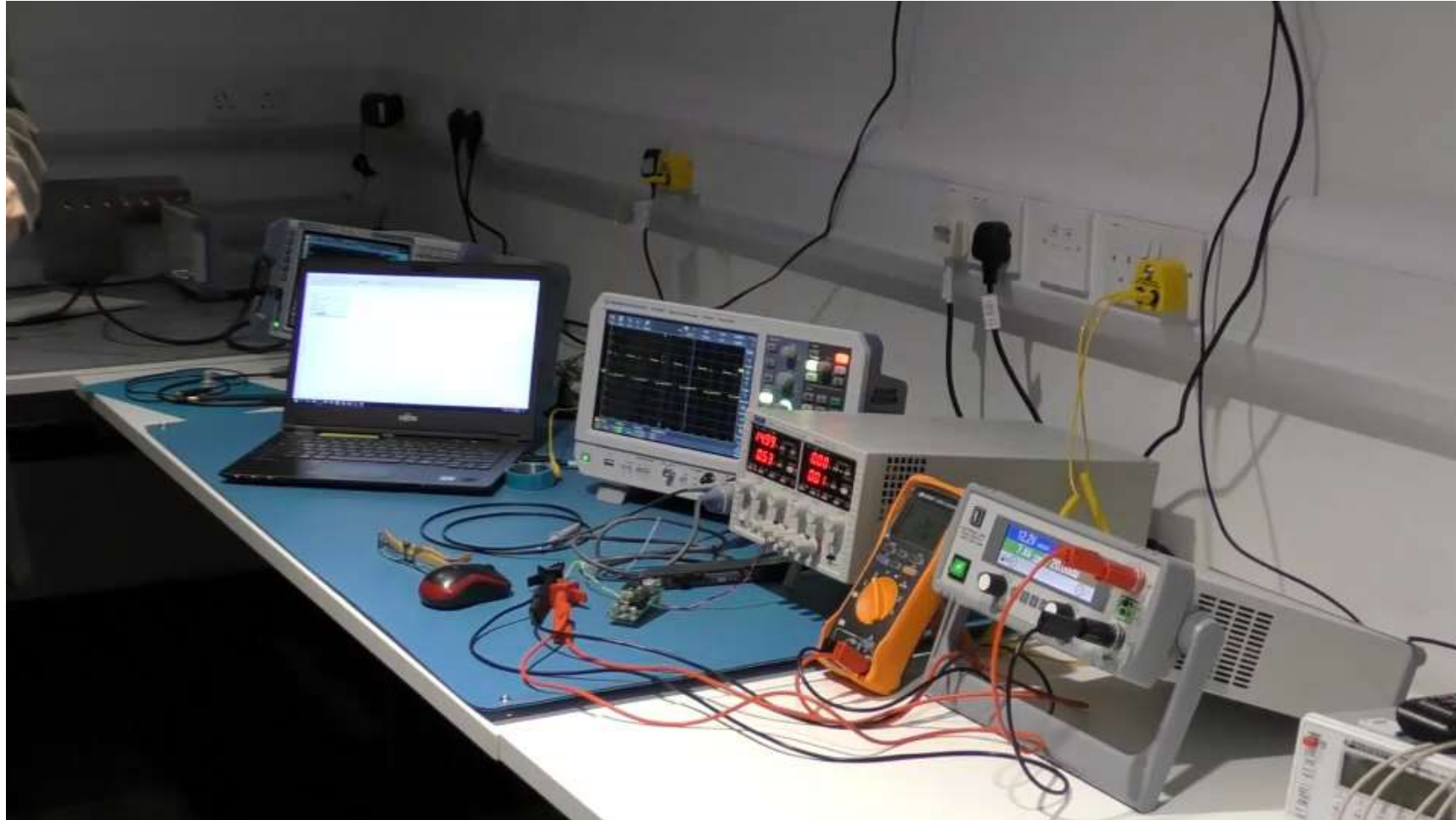
TYPE 2 POE FLYBACK CONVERTER (LT3758A)

DESIGN SIMULATION: FILTER CIRCUIT



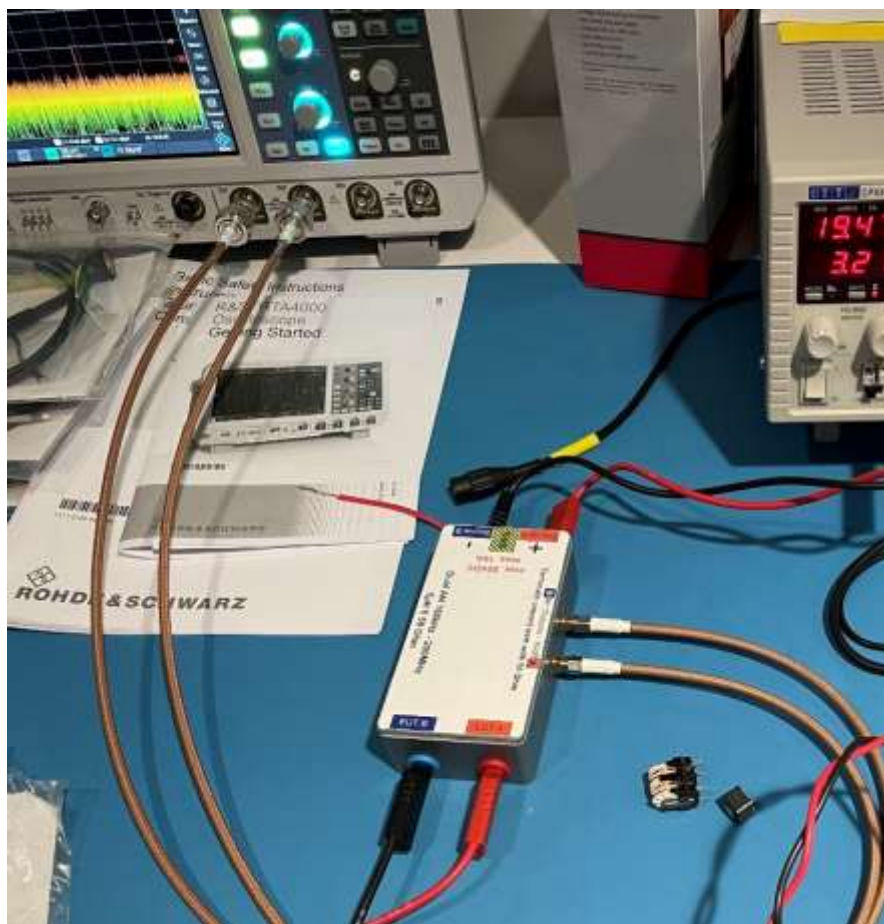
TYPE 2 POE FLYBACK CONVERTER (LT3758A)

TEST AND MEASUREMENT: OVERVIEW



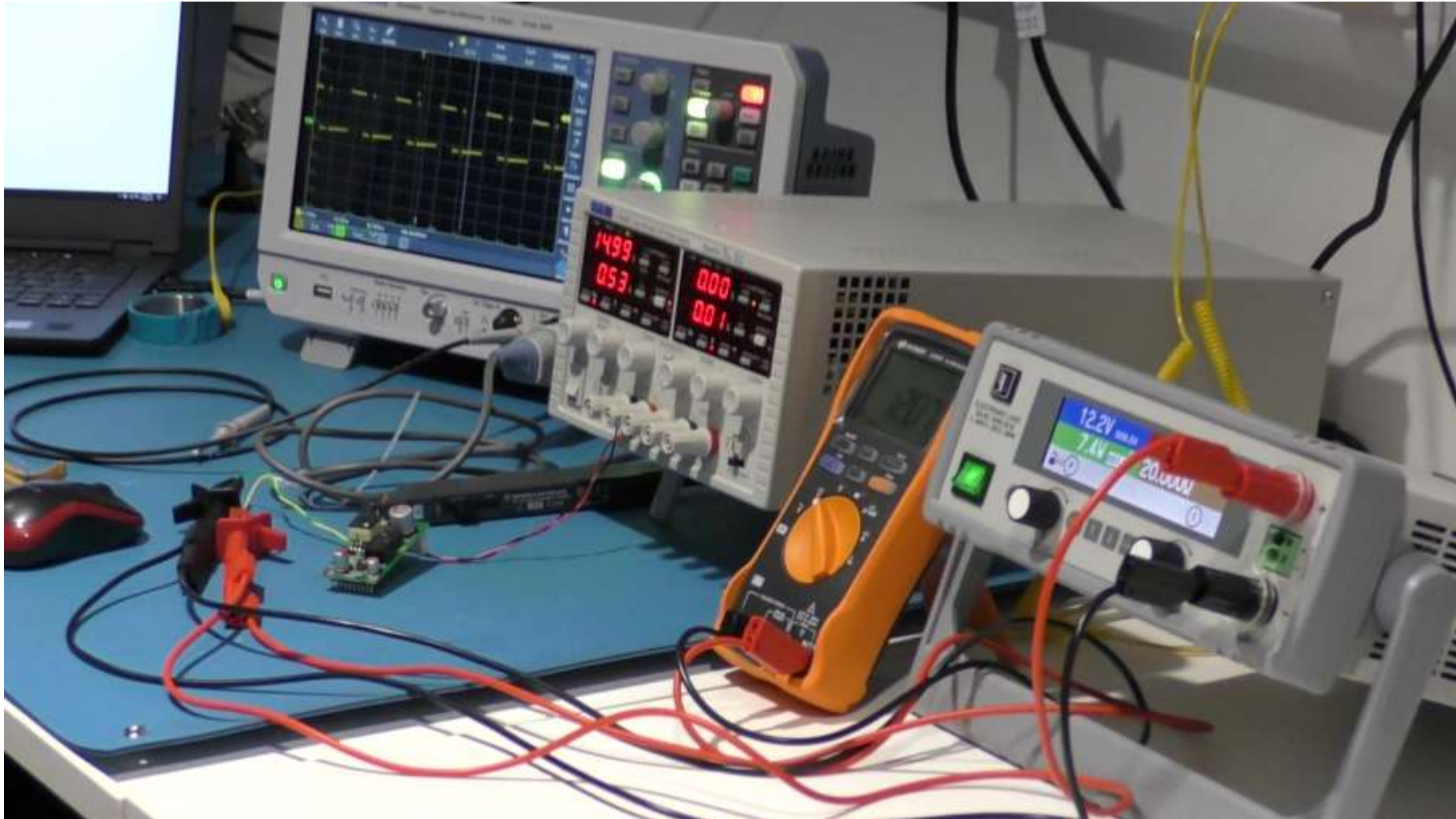
TYPE 2 POE FLYBACK CONVERTER (LT3758A)

TEST AND MEASUREMENT: CONDUCTED EMISSIONS



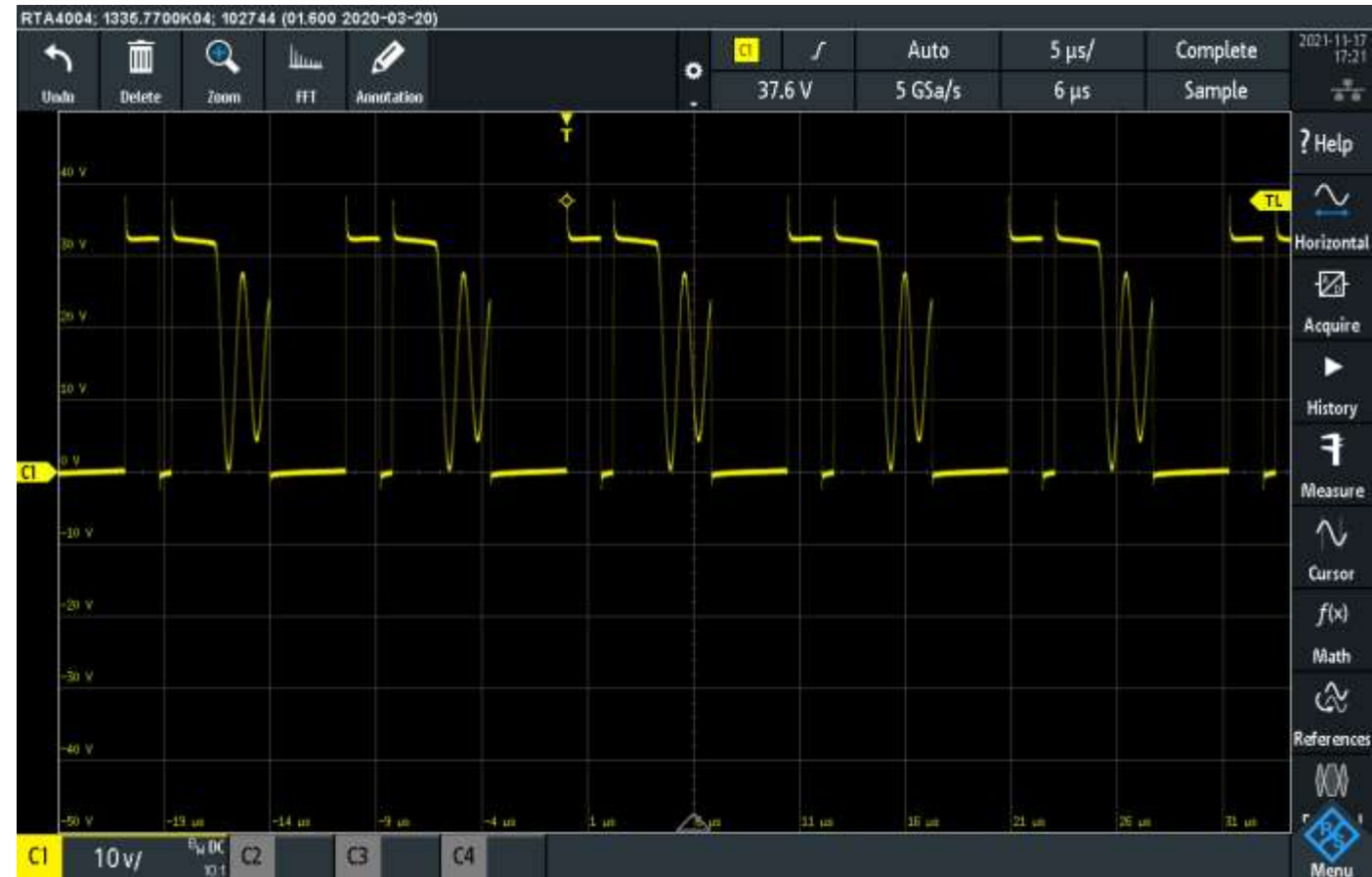
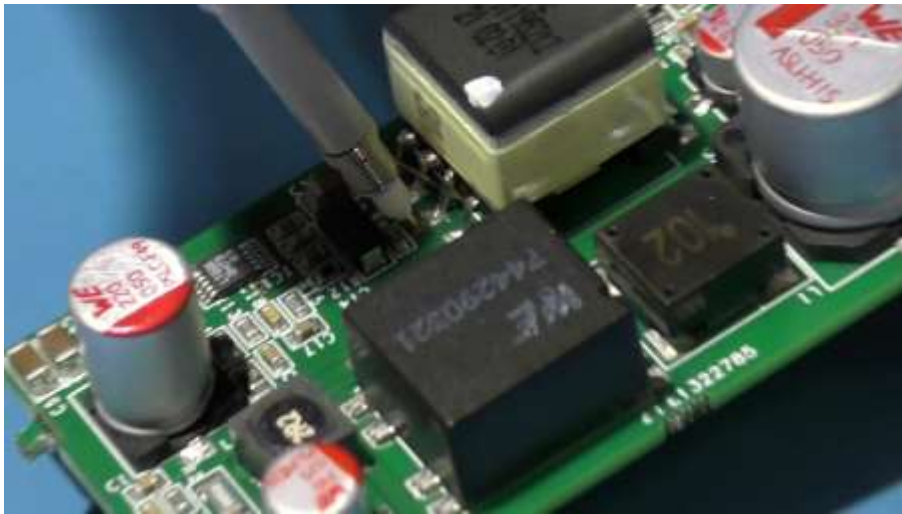
TYPE 2 POE FLYBACK CONVERTER (LT3758A)

TEST AND MEASUREMENT: SIGNAL INTEGRITY



TYPE 2 POE FLYBACK CONVERTER (LT3758A)

TEST AND MEASUREMENT: SIGNAL INTEGRITY



TYPE 2 POE FLYBACK CONVERTER (LT3758A)

LAYOUT AND TRACKING REVIEW



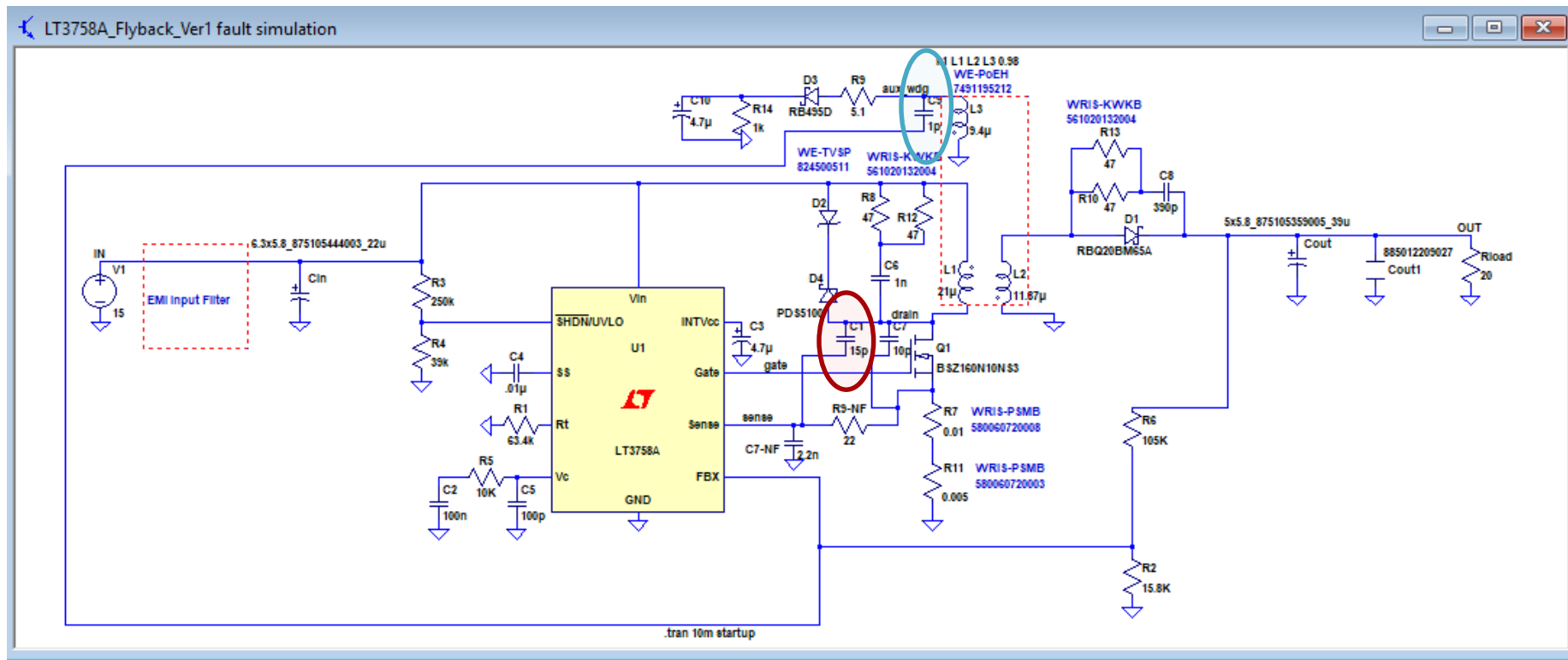
■ Several issues identified:

- Ground connection far from the input/output capacitors, Mosfet Source / Rsens and IC Power GND
- AGND and PGND not separated
- Track to gate of mosfet too small
- Critical: Feedback signal shadows the auxiliary winding switching signal.
- Critical: Current sense signal overlaps the FET Drain signal.

TYPE 2 POE FLYBACK CONVERTER (LT3758A)

SIGNAL INTEGRITY SIMULATION: POWER CIRCUIT

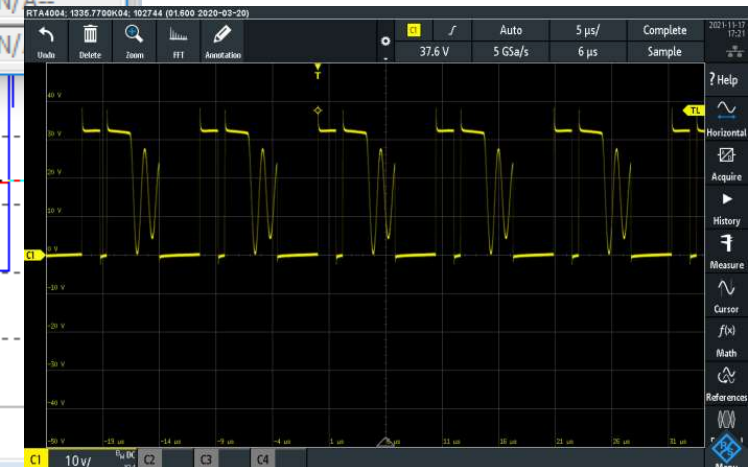
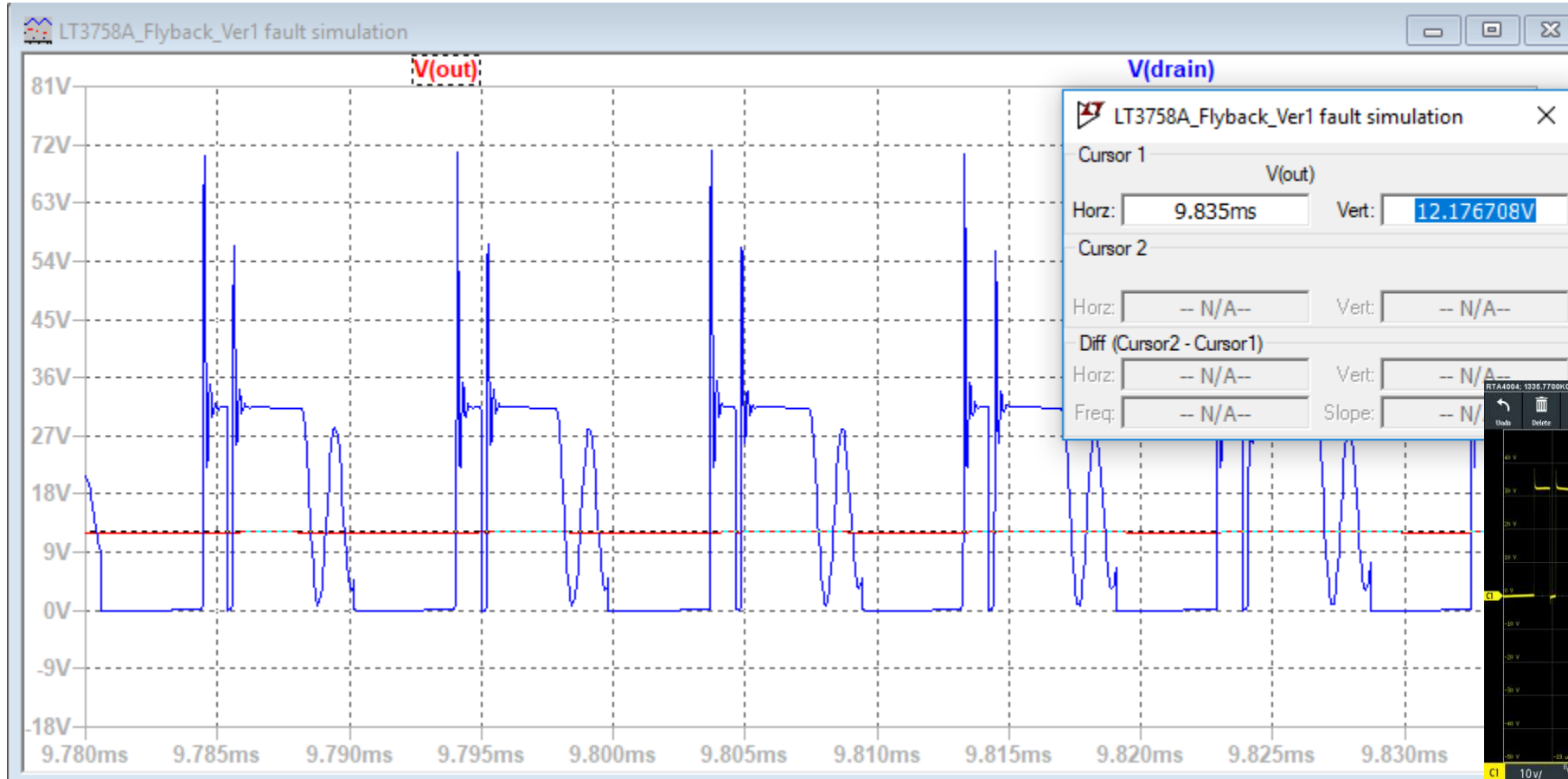
- Parasitic capacitance estimated based on pcb and track parameters
 - <https://www.emisoftware.com/calculator/biplanar-capacitance/>
- Modelled in LT Spice and simulated



TYPE 2 POE FLYBACK CONVERTER (LT3758A)

SIGNAL INTEGRITY SIMULATION: POWER CIRCUIT

- Results consistent with the measurements



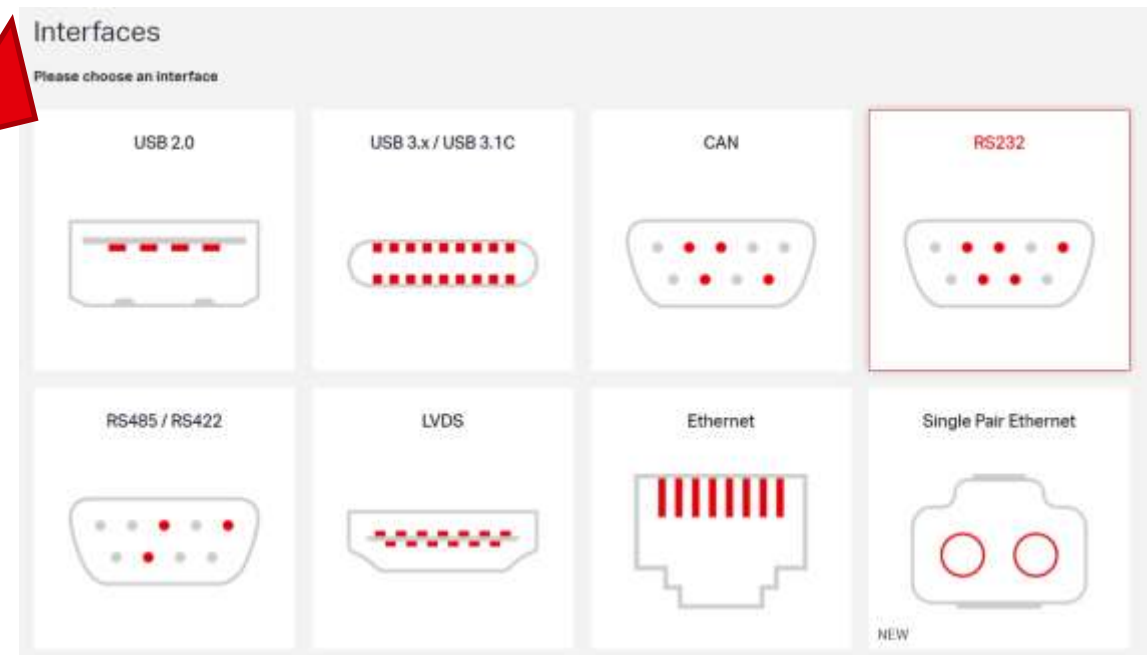
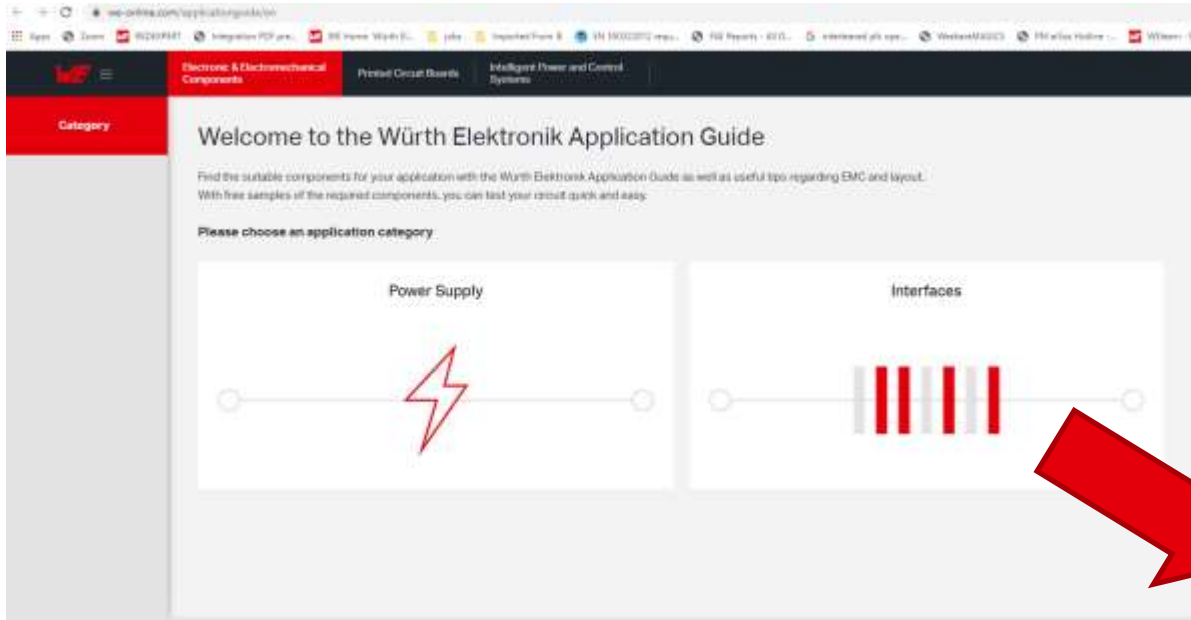
TYPE 2 POE FLYBACK CONVERTER (LT3758A)

SUMMARY AND CONCLUSIONS

- Regulation is fine across the load and line spec conditions
- Efficiency is good at around 87%
- Thermal performance is very good (max board temperature 42.4DegC).
- EMC Conducted emissions performance is also very good.
- However, layout and tracking has resulted in an issue with signal integrity.
- In General, Layout and Tracking issues:
 - Can be difficult to identify
 - May not result in an immediate failure
 - Or may result in a complete failure of the converter
- A good layout and tracking is essential along with filtering to achieve EMC and good functional performance.

GENERAL INTERFACES

APPLICATION GUIDE

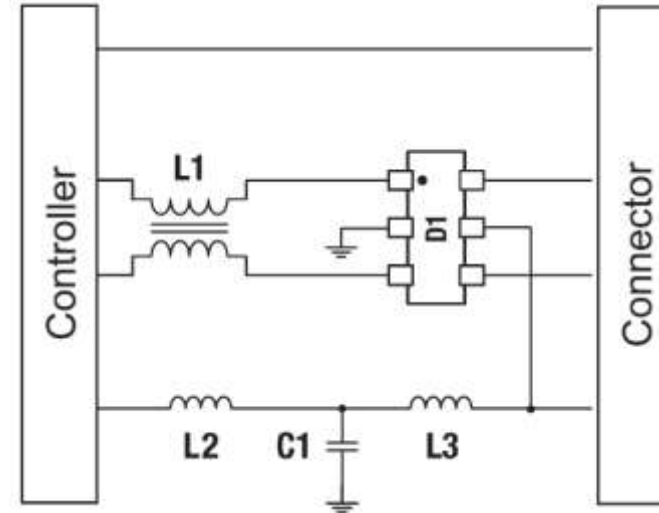


USB 2.0 FILTER

P/N 829999 STICK



P/N 829999 BAG



Order Code: 829 999 BAG

With this kit you can rebuild the design of the USB 2.0 EMC stick.

829 999 BAG contains schematic and the required components:

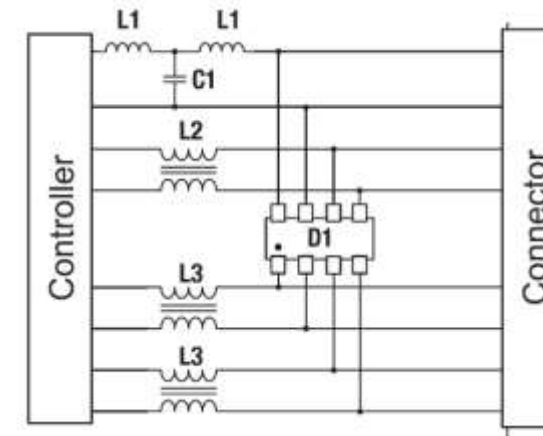
10x	WE-CBF	742 792 651
5x	WE-CNSW	744 232 090
5x	WE-TVS	824 001 02
10x	WCAP-CSGP	885 012 206 051
1x	USB Plug WR-COM	629 004 113 921
1x	USB Socket WR-COM	629 004 160 21

USB 3.0 FILTER

P/N 829993 STICK



P/N 829993 BAG



Order Code: 829 993 BAG

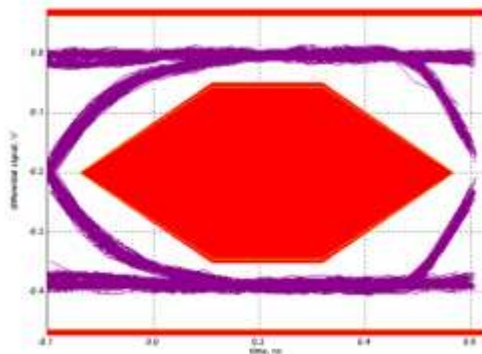
With this kit you can rebuild the design of the USB 3.0 EMC stick.

829 993 BAG contains schematic and the required components:

2x	WE-CBF	742 792 040
1x	WE-CNSW	744 232 090
2x	WE-CNSW HF	744 233 670
1x	WE-TVS	824 016 46
1x	WCAP-CSGP	885 012 206 051
1x	WR-COM USB Plug	692 112 030 100
1x	WR-COM USB Socket	692 122 030 100

WE- EPLE CONNECTOR WITH INTEGRATED EMI & ESD FUNCTION

- ESD Protection of data channels and VDD
- Common Mode Noise Rejection
- VDD Differential Mode Noise Rejection
- Provides ESD protection for each channel to
 - IEC 61000-4-2 (ESD) $\pm 15\text{kV}$ (air), $\pm 8\text{kV}$ (contact)
 - IEC 61000-4-4 (EFT) (5/50ns) 20A (I/O), 40A VDD
 - IEC 61000-4-5 (Lightning) 6A (8/20 μs)
- Ultra Low capacitance: 2pF typical
- Fast turn on and low clamping voltage

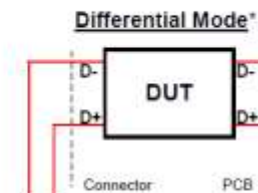
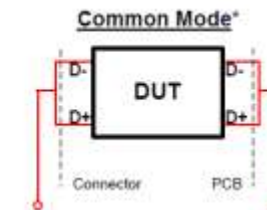
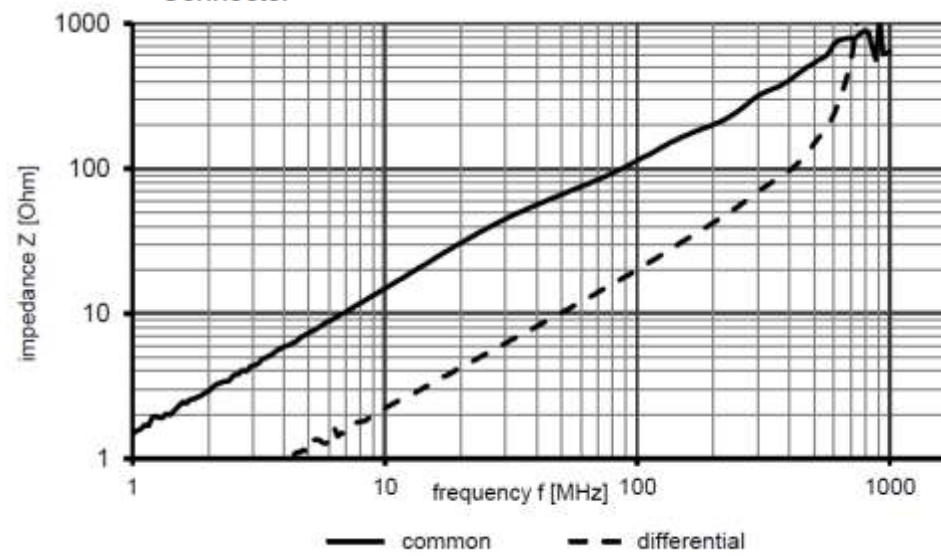
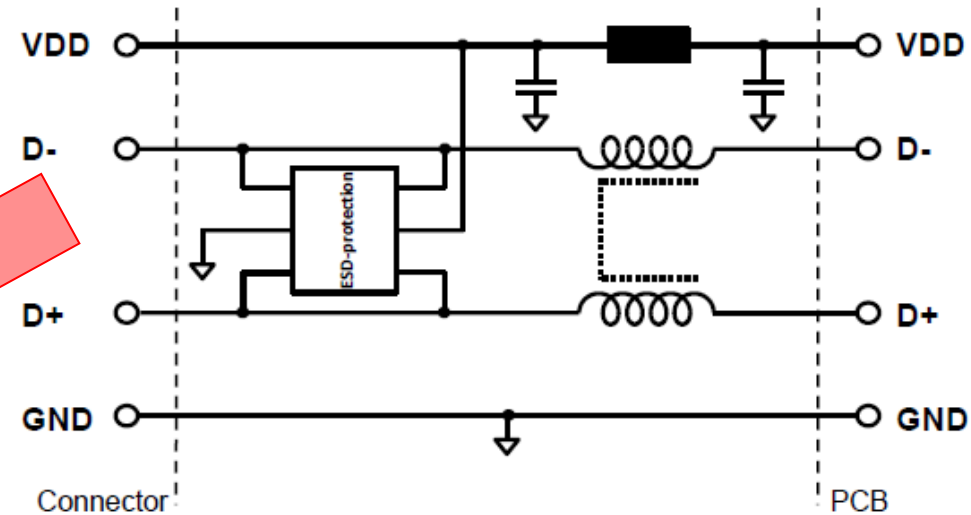
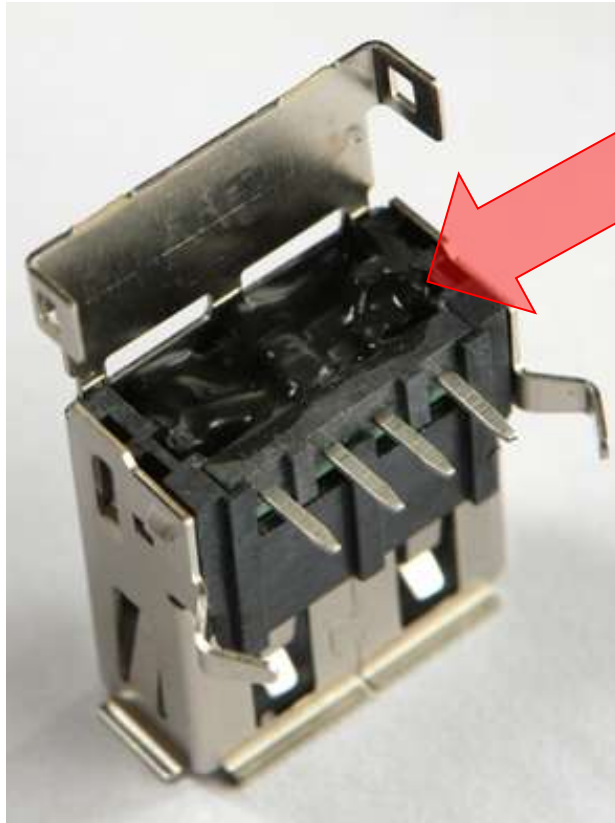


Full Speed – 480MHz



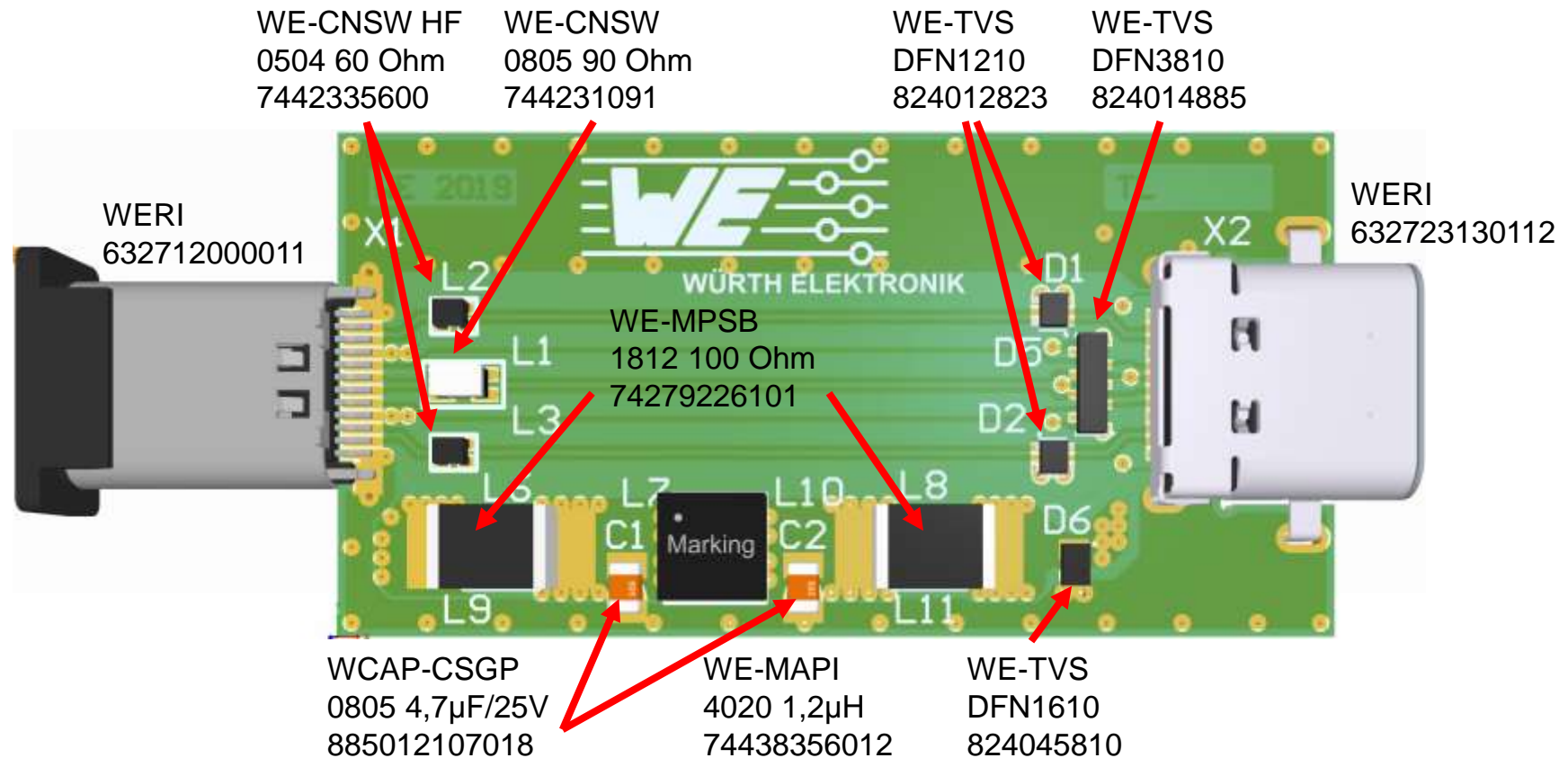
P/N 8492121

WE- EPLE CONNECTOR WITH INTEGRATED EMI & ESD



* 50Ω system impedance measured on PCB level

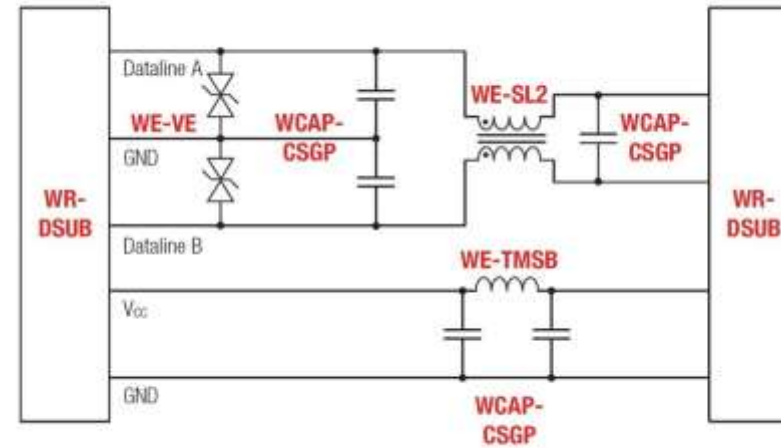
TYPE-C FILTER BOARD – OVERVIEW



APP NOTE 007

RS-485 FILTERING

Demo Board



Design Bag BOM

Function	Index	Description	Product Series	Order Code
Data Line	L1	Common Mode Line Filter ZMAX = 6000 Ω, VR(AC) = 50 V	WE-SL2	744 222
Data Line	RV1, RV2	ESD Suppressor VDC = 5 V, ILEAK = 1 μA, VCLAMP, typ = 55 V	WE-VE	023 570 505 60
Data Line	C1, C2, C3	Multilayer Ceramic Chip Capacitor C = 100 pF, VR(DC) = 10 V, NP0	WCAP- CSGF	885 012 005 013
Power Line	C4, C5	Multilayer Ceramic Chip Capacitor C = 1 μF pF, VR(DC) = 6.3 V, XSR	WCAP- CSGF	885 012 105 006
Power Line	L2	SMD-Ferrit Z @ 100 MHz = 1500 Ω; IR = 500 mA	WE-TMSB	742 692 41152
Connector	CON1	D-SUB Female PCB Connector - 8.08 mm	WR-DSUB	610 009 231 121
Connector	CON2	D-SUB Male PCB Connector - 8.08 mm	WR-DSUB	618 009 231 221

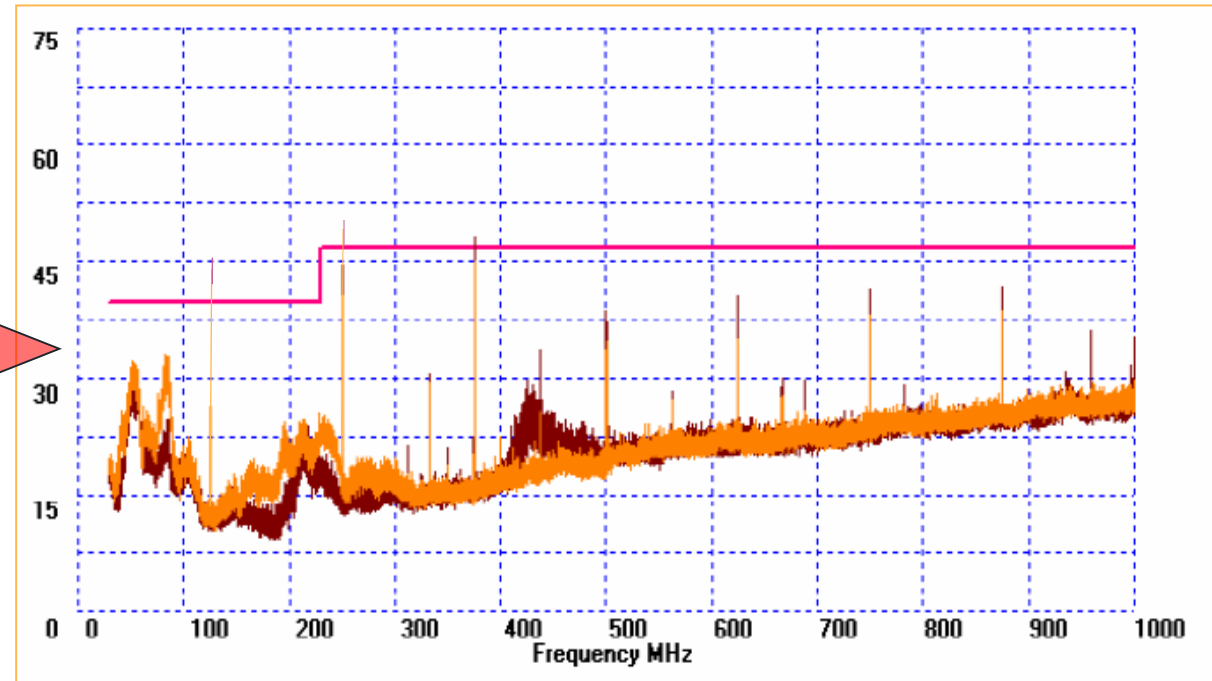
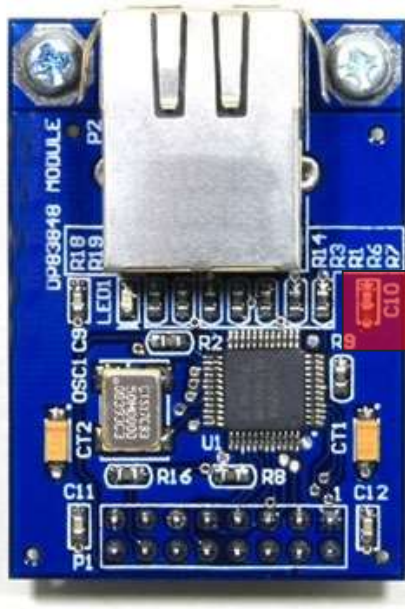
EMI filtering adapter for RS-485 interfaces



App Note 083

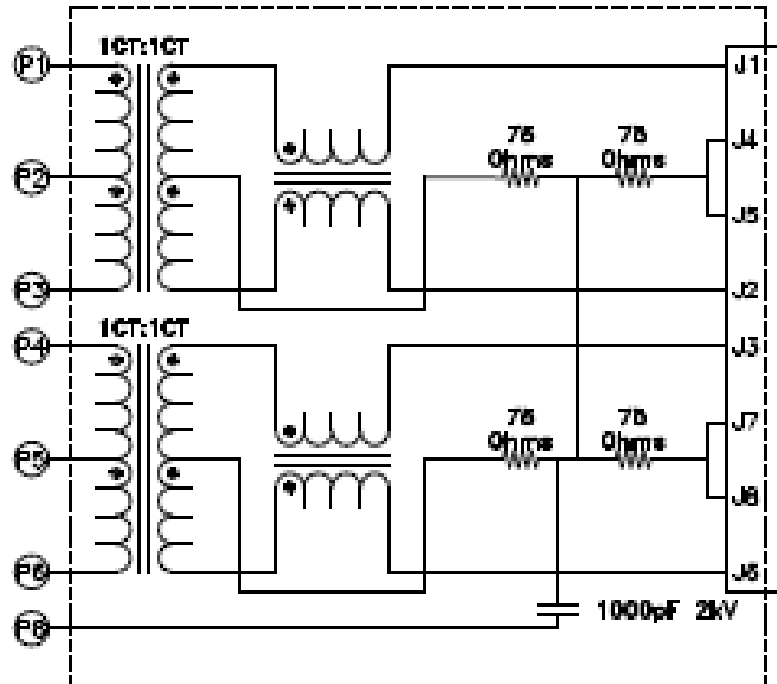
HPLE WHAT IS THIS?

- Why do I need this?
- HPLE = High Performance Low EMI

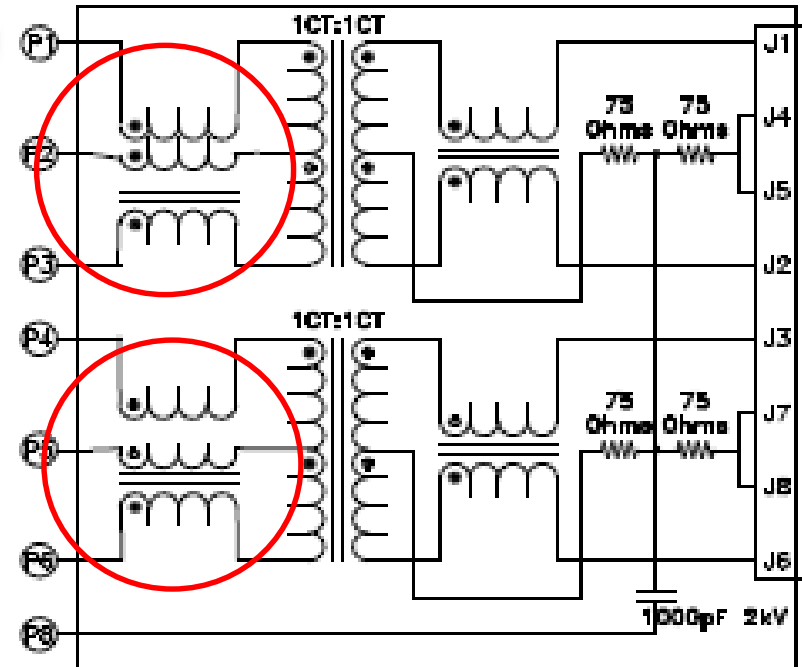


DIFFERENCE BETWEEN STANDARD AND HPLE?

Standard Integrated LAN Xfmr

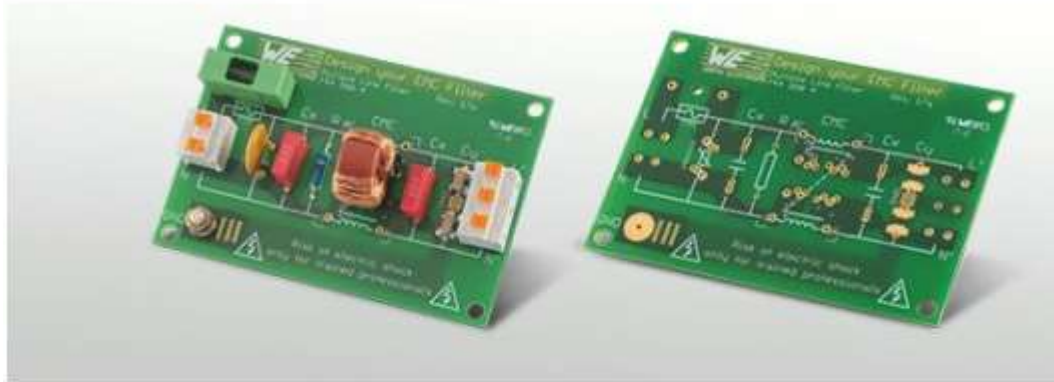


HPLC Integrated LAN Xfmr



NEW DEMONSTRATORS – DESIGN YOUR EMC FILTER

Evaluation Boards

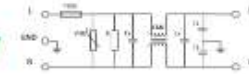


Part Number	Rated Voltage	Overtoltage Protection	Multi Pad Layout	Common Mode Attenuation	Differential Mode Attenuation
7449981	250 V (AC)	-	-	+	+
7449982	250 V (AC)	-	-	+	++
7449983	80 V (DC)	-	-	++	++
7449984	250 V (AC)	+	+	+	+

Multiple Line Filter

This Evaluation Board (744 998 4) is especially capable of handling unknown source and sink impedances and covers the following characteristics:

- Different common mode choke sizes adjustable
- Overtoltage protection through fuse and varistor
- Pi-Filter for differential mode noise
- LC-Filter for common mode noise



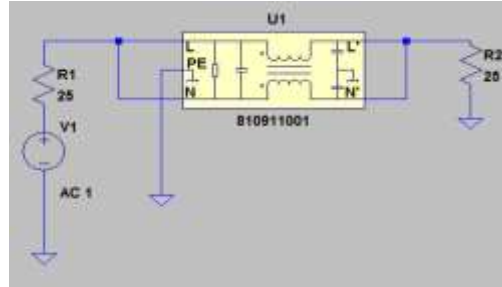
An inquiry can be made [here](#).

Designator on PCB	Article
Cx X-Capacitor	WCAP-RTX2 Pitch 12.5 WCAP-RTX2 Pitch 15 WCAP-RTX2 Pitch 22.5 WCAP-RTXX Pitch 12.5 WCAP-RTXX Pitch 15 WCAP-RTXX Pitch 22.5
Cy Y-Capacitor	WCAP-CB5A Size 2211 WCAP-CB5A Size 1513
CMC Common mode choke	WE-CMB WE-TFCH WE-SIB WE-CMBNC
L / N Input connector	WR-TBL 521411910002
L / N Output connector	WR-TBL 521411910002
FUSE Fuse holder	WR-GSH 556105003002
FUSE Fuse	Recommended: 5 ± 20 mm to 10 A
VDR Disk Varistor	WE-VDR 10 mm WE-VDR 14 mm WE-VDR 20 mm
GNL Ground connector	WE-SHSH 102 WE-SHSH 104
Spacer	WA-SHNR 102926000
R Resistor	Recommended: 1 Megaohm

INTEGRATED MAINS FILTER: WE-CLFS

THREE TYPES

- UR: 250 V (AC/DC)
- 1-Phase Filter
- Climatic Category 25/100/21 →
(-25 to +100°C / 21 days moisture test)
- Fast-On Terminals
- Chassis Mounting (M4)



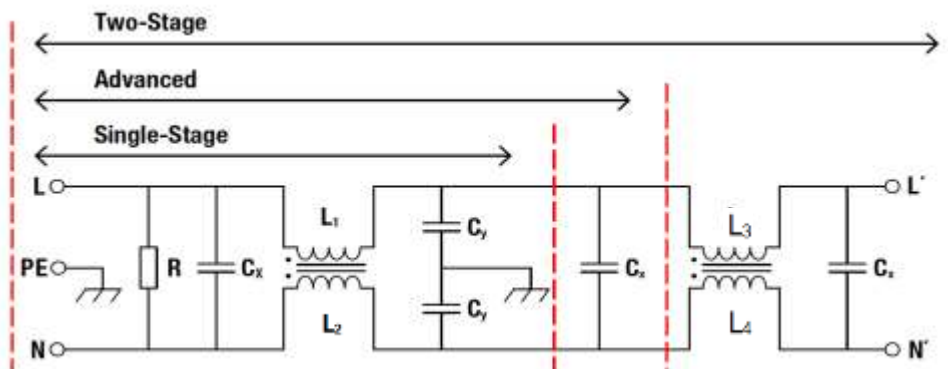
Single-Stage



Single-Stage Advanced



Two-Stage



NEXT BIG EVENT

- F2F Event
- Birmingham, UK
- Large Venue
- [Registration link](#)



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Any Questions

