WE MEET
@ DIGITAL DAYS

BETTER SAFE THAN SORRY; PRACTICAL EMC DESIGN CONSIDERATIONS

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Senior Field Application Engineer

WÜRTH ELEKTRONIK MORE THAN YOU EXPECT

AGENDA

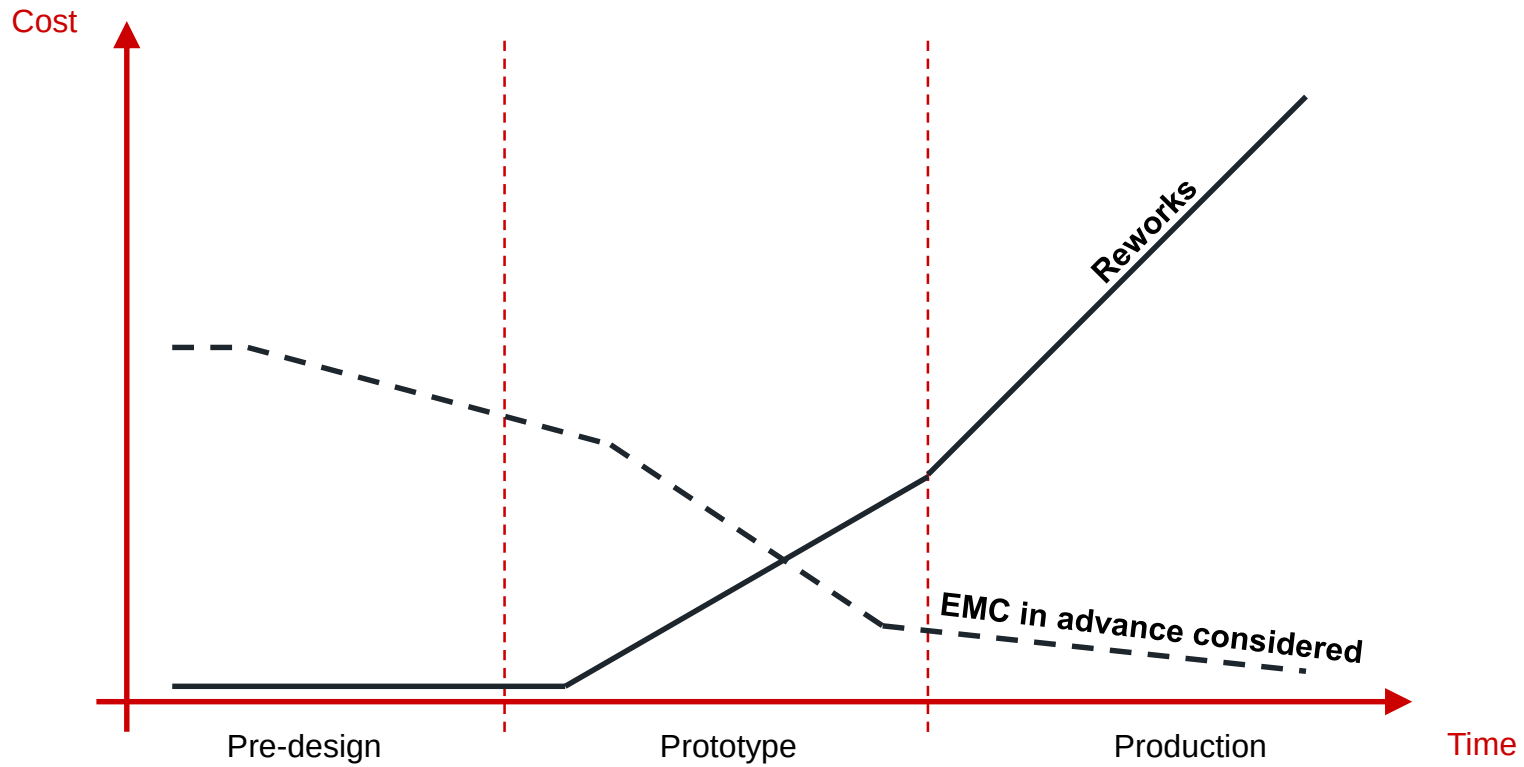
- Practical EMI Filter Design
  - Architecture
  - Selection (Redexpert)
  - Simulation (LT Spice)
- Layout and Tracking
  - Practical Example – PoE Type 2 Flyback
    - Filter design
    - Signal integrity
    - LT Spice Simulation vs RTA4004 Measurement
- General Interfaces (USB, RS485, Ethernet, CAN,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

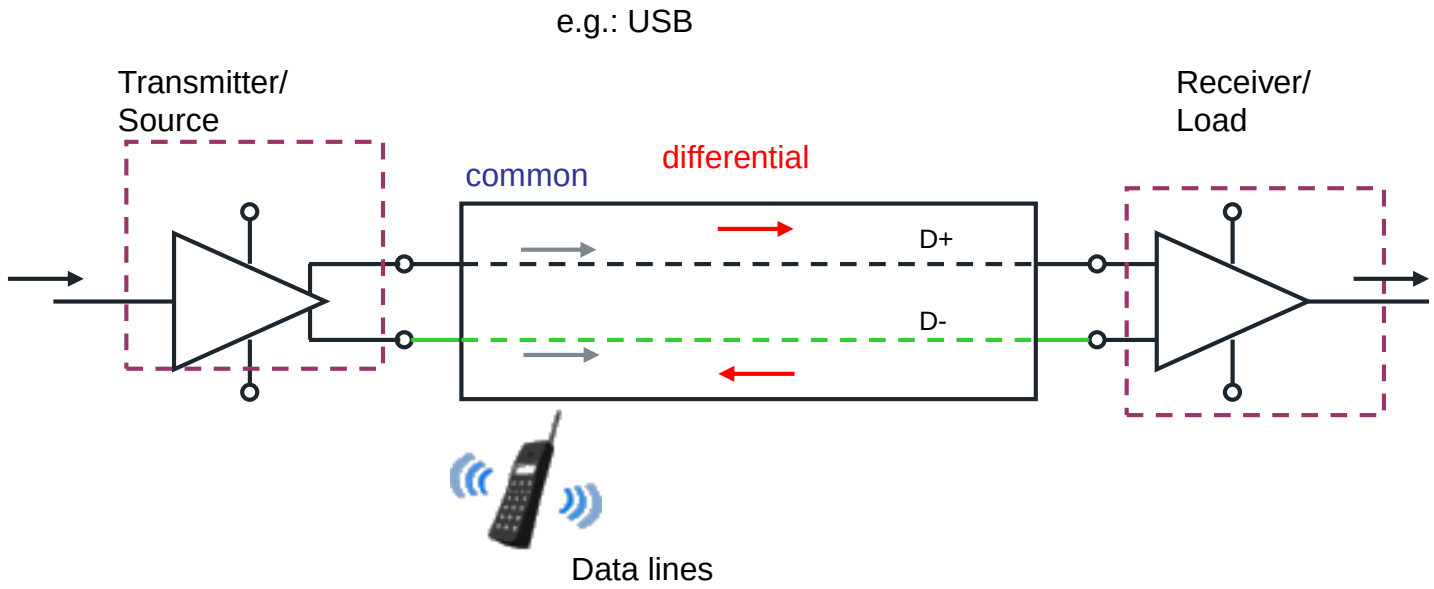
DESIGN CONSIDERATIONS

- 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

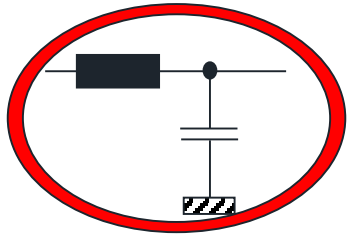
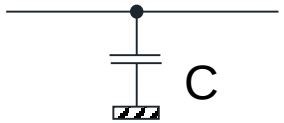
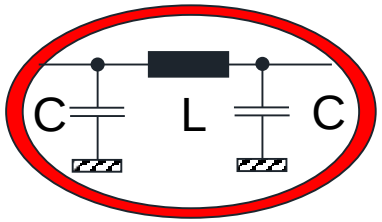
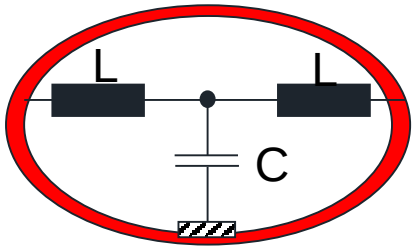
- Noise Mode



- Common Mode Noise
- Differential Mode Noise

ARCHITECTURE

DIFFERENTIAL FILTER TOPOLOGIES

Source Impedance		Load Impedance
low		high
high		high
high or unknown		high or unknown
low		low
low or unknown		low or unknown

→ small C = higher SRF

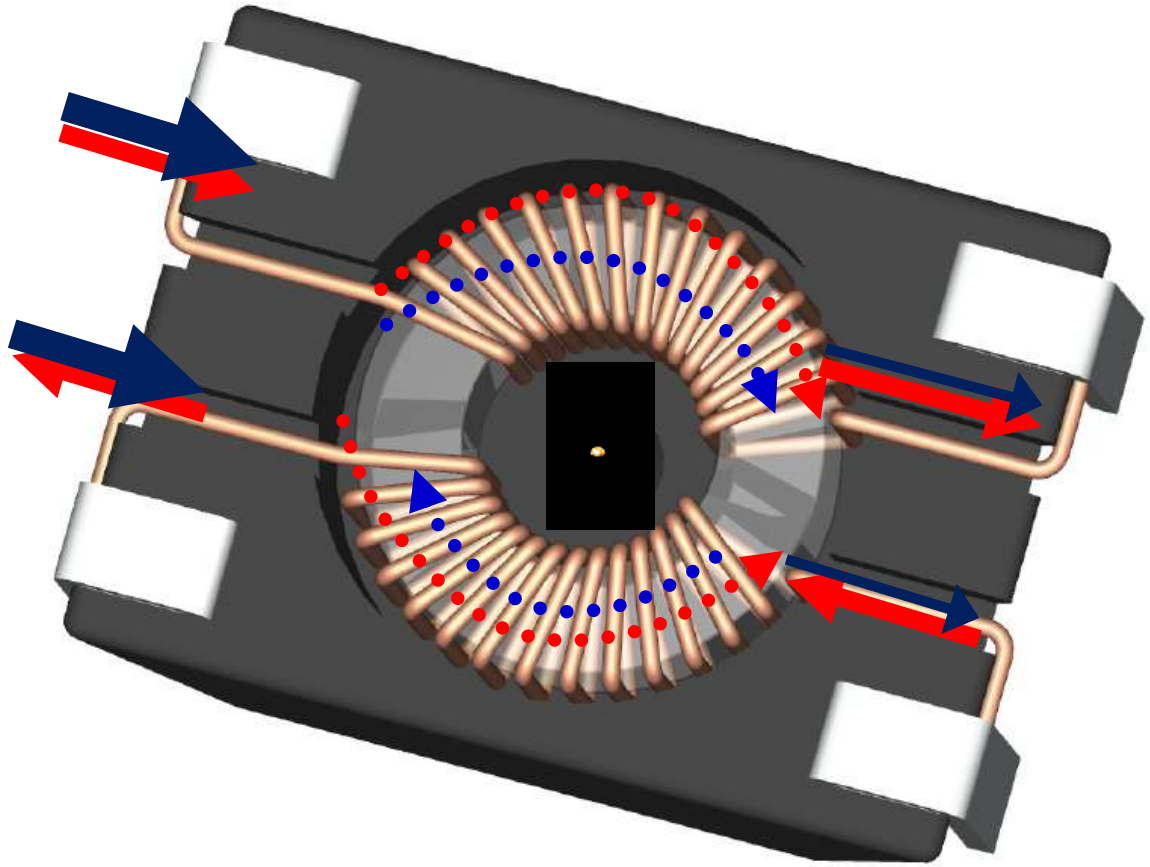
Choose ferrite bead
= build no resonance with C
= broadband filter

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

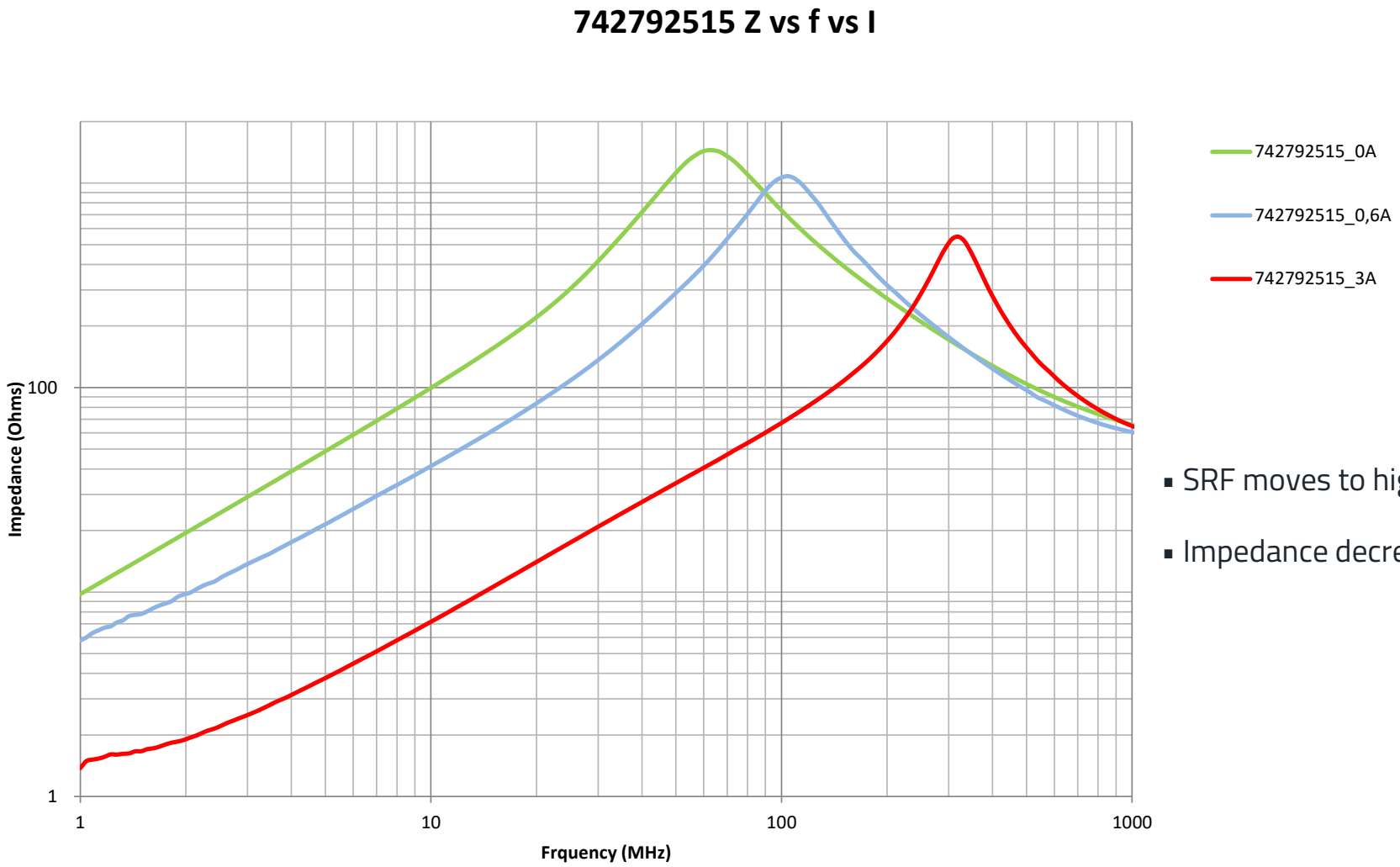
SELECTION

COMPONENT SELECTION CONSIDERATIONS

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

SELECTION

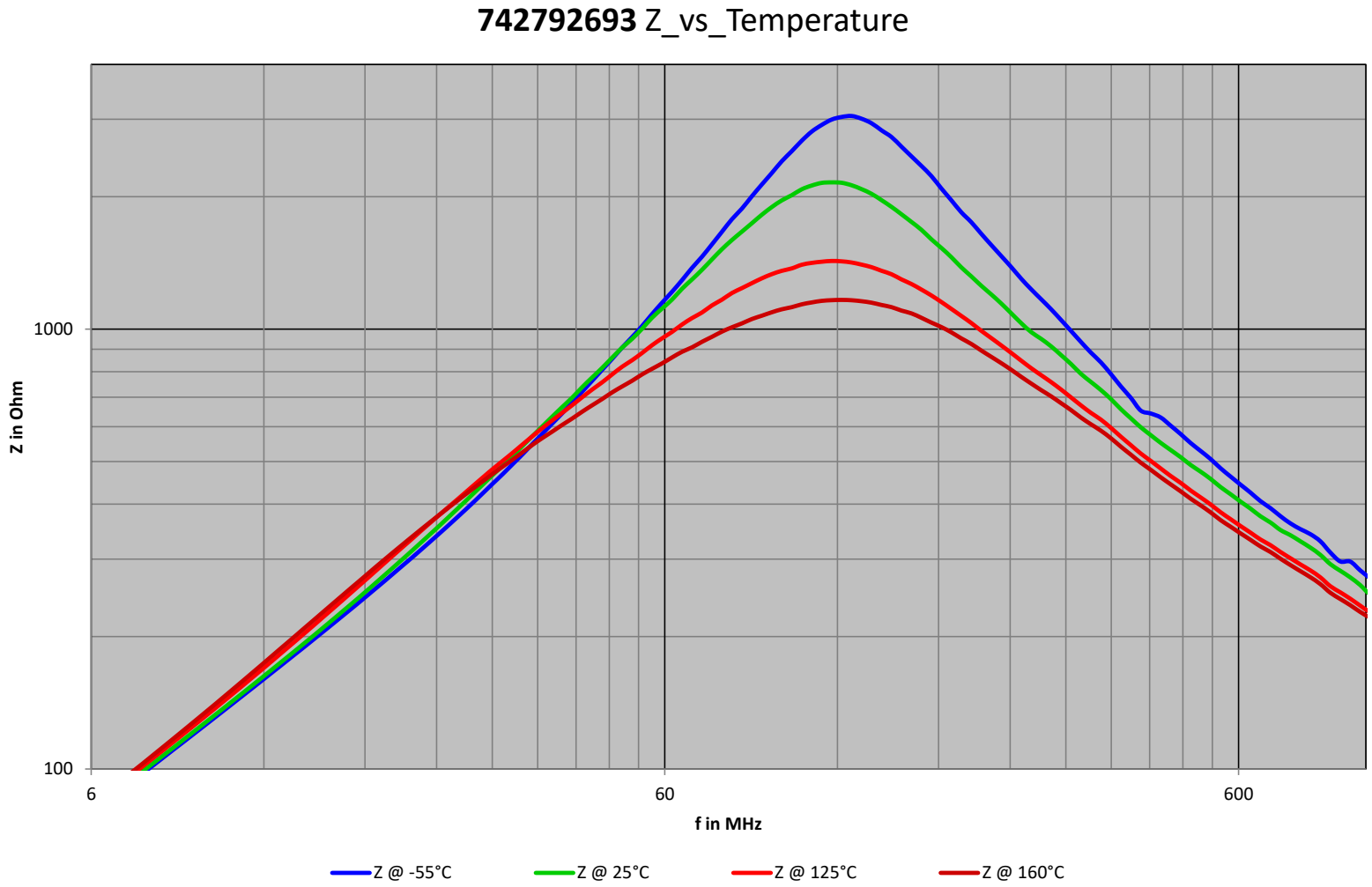
CHIP FERRITES DC BIAS



- SRF moves to higher frequency
- Impedance decrease

SELECTION

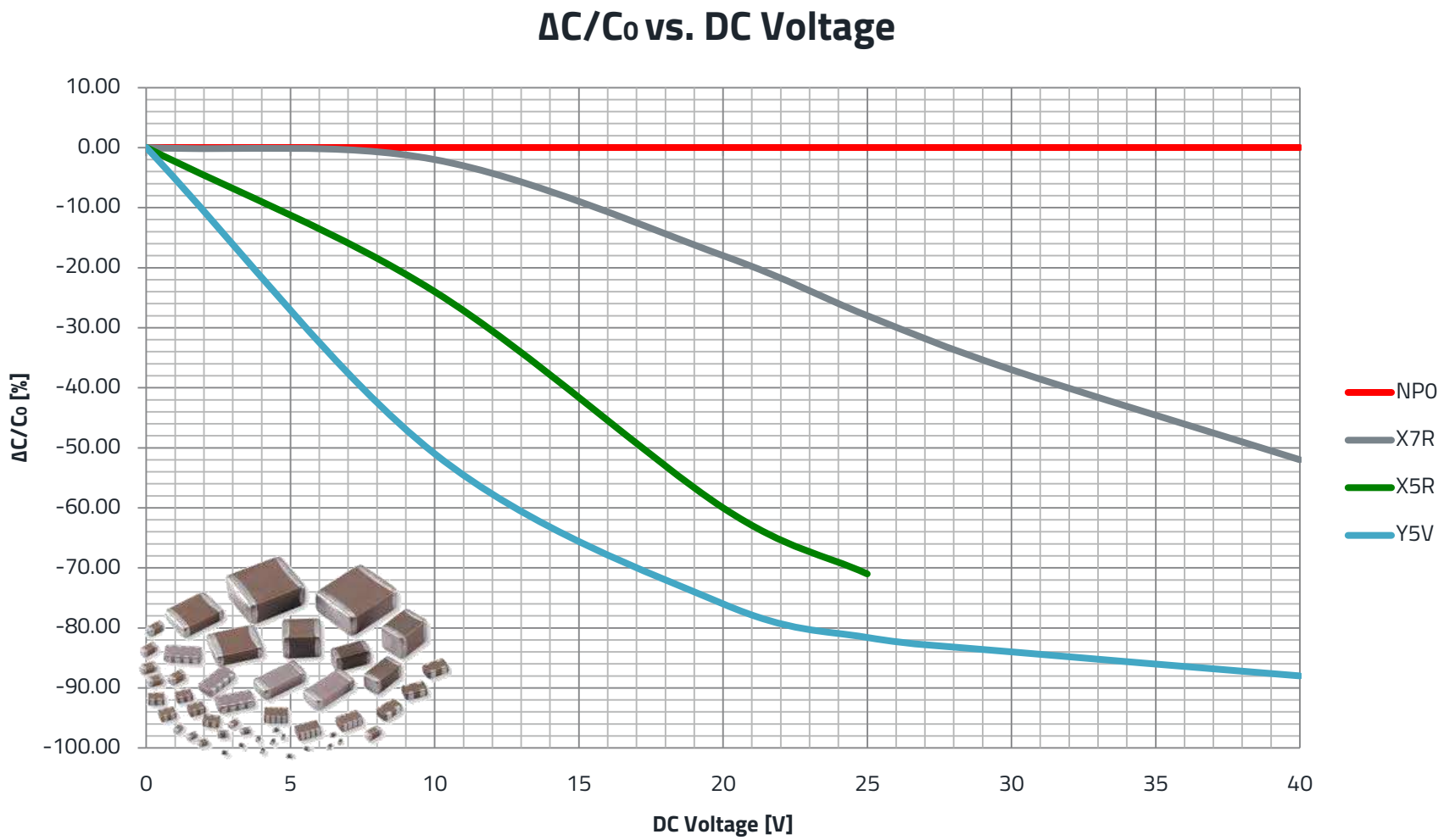
BEHAVIOR OF THE IMPEDANCE AT TEMPERATURE



With increasing temperature the impedance decrease

SELECTION

MLCC VOLTAGE DEPENDENCE

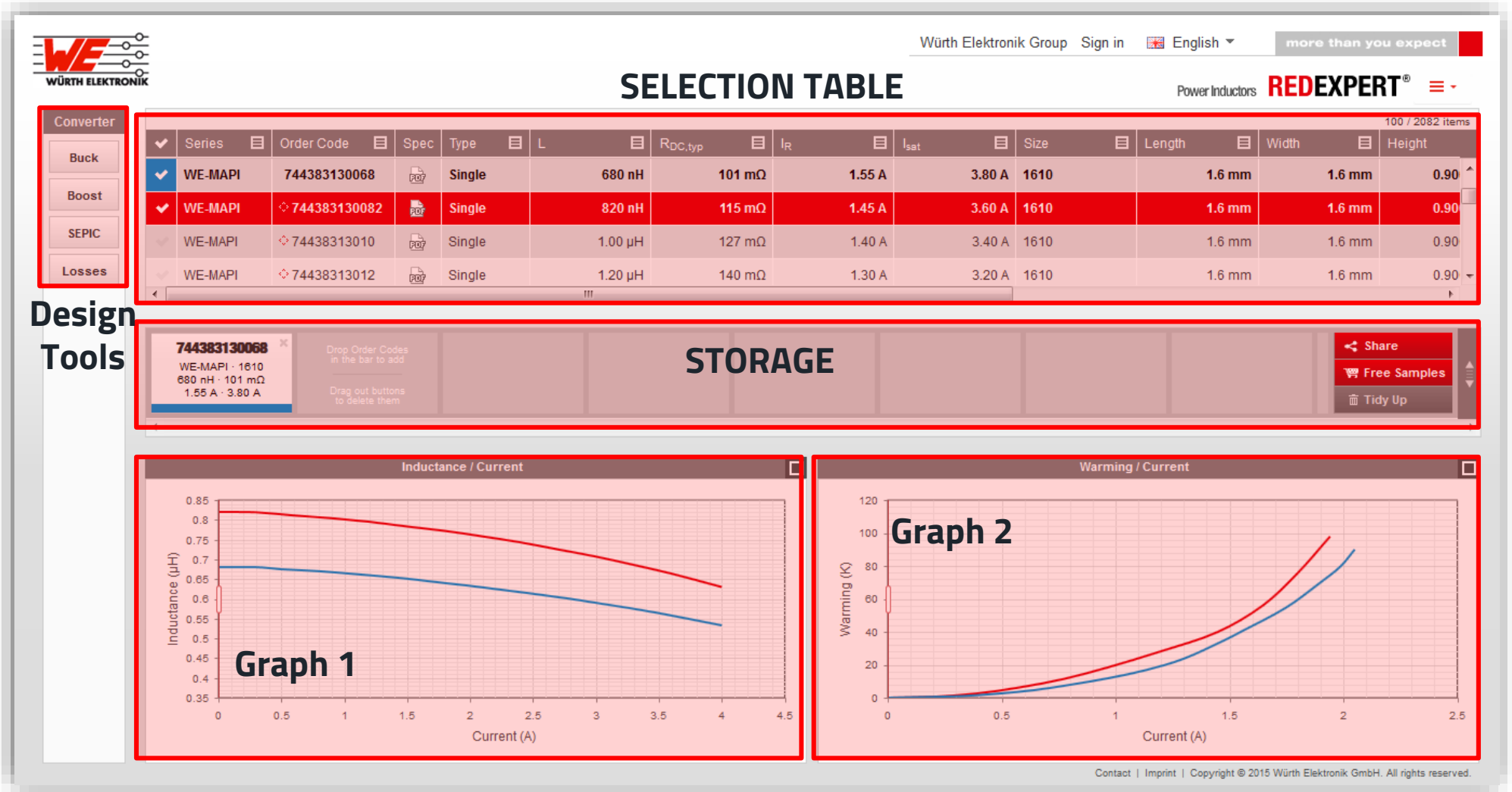


SELECTION

SELECTION TOOL - **RED**EXPERT

SELECTION

REDEXPERT – USER INTERFACE



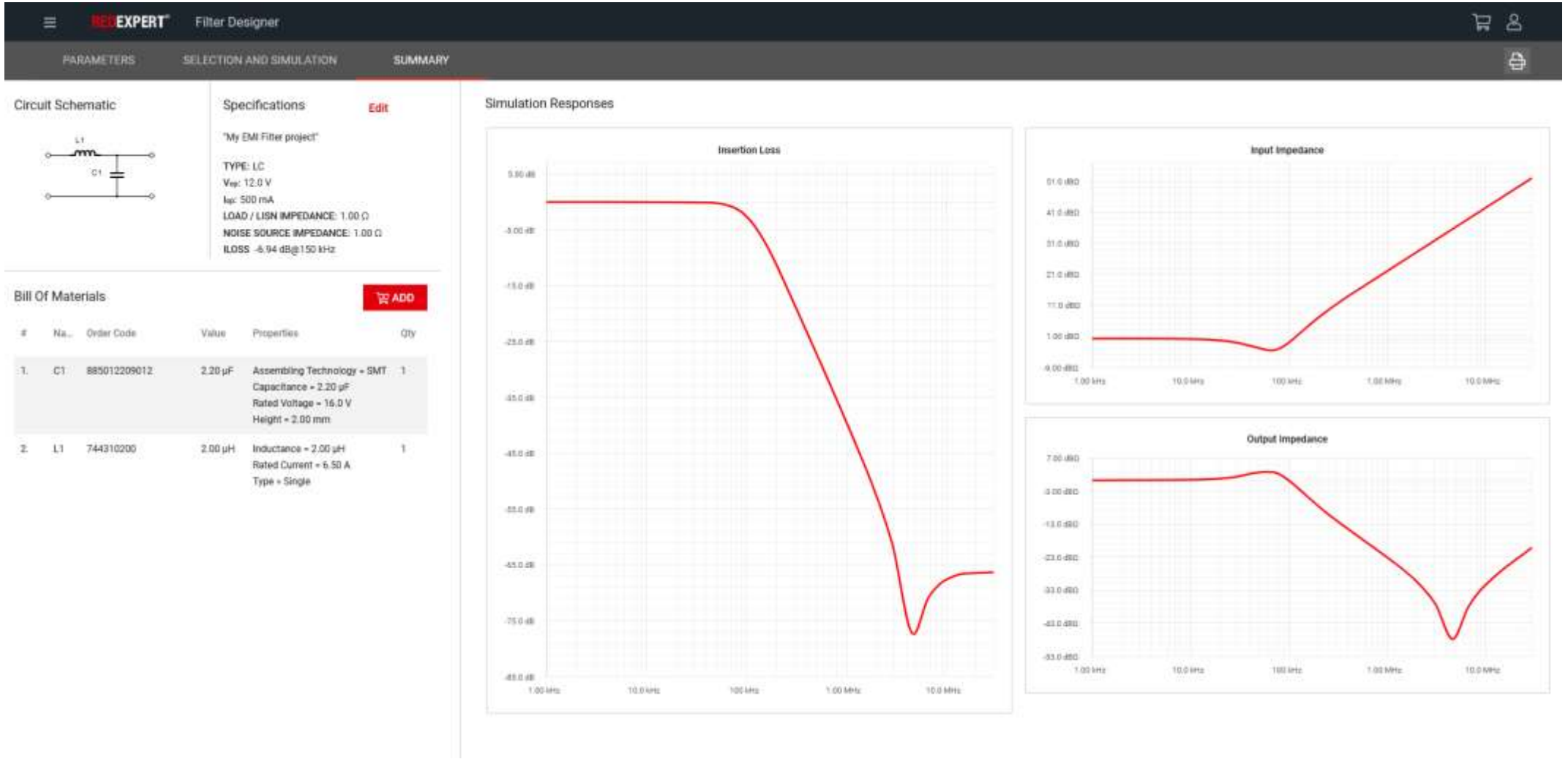
REDEXPERT

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

www.we-online.com/redexpert

SELECTION

FILTERING OF INPUT AND OUTPUT - EMI FILTER DESIGN

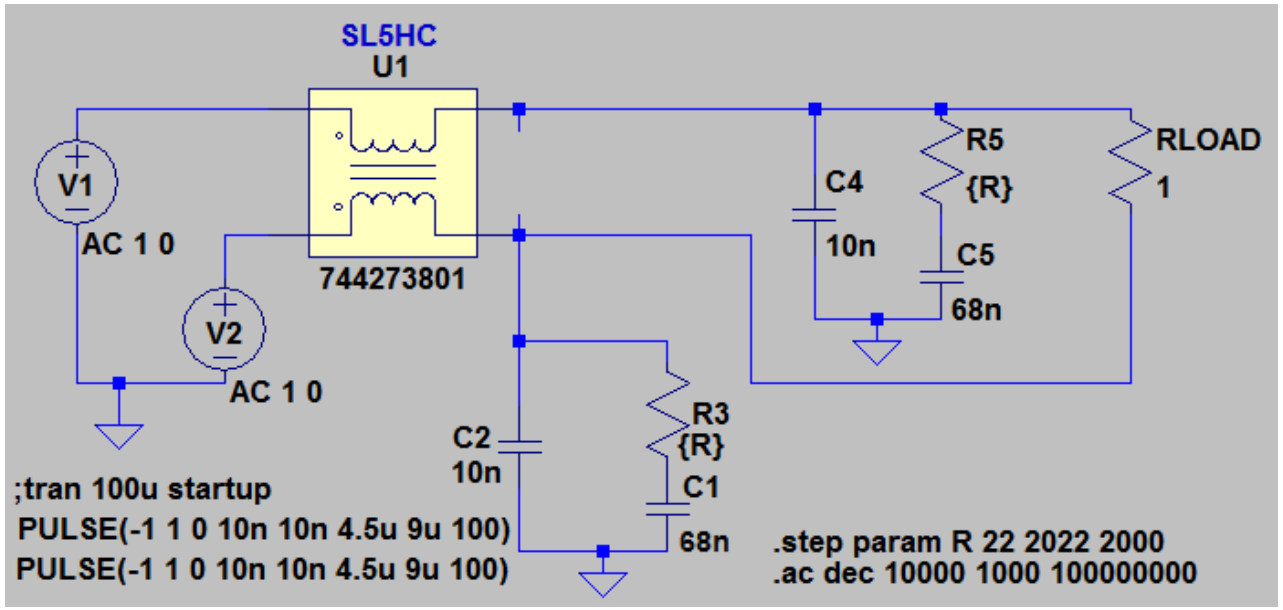


SIMULATIONS

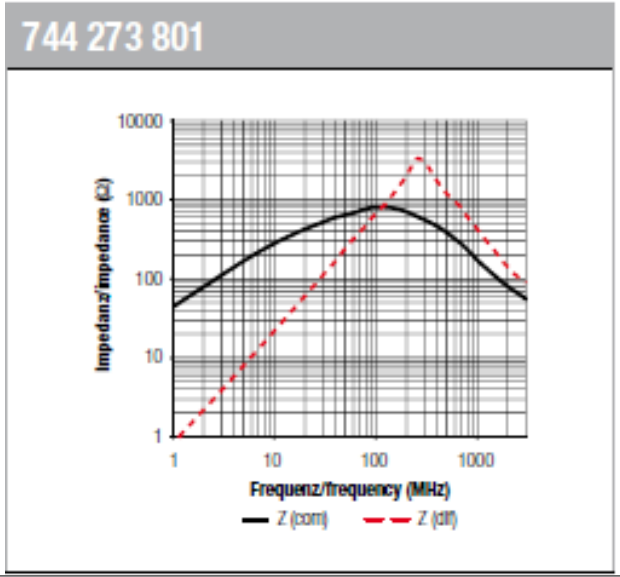
- Conducted Emissions (CE) and Radiated Emissions (RE)
- Damping
- Leakage Effect
- Oscillation (Instability)
- Time domain

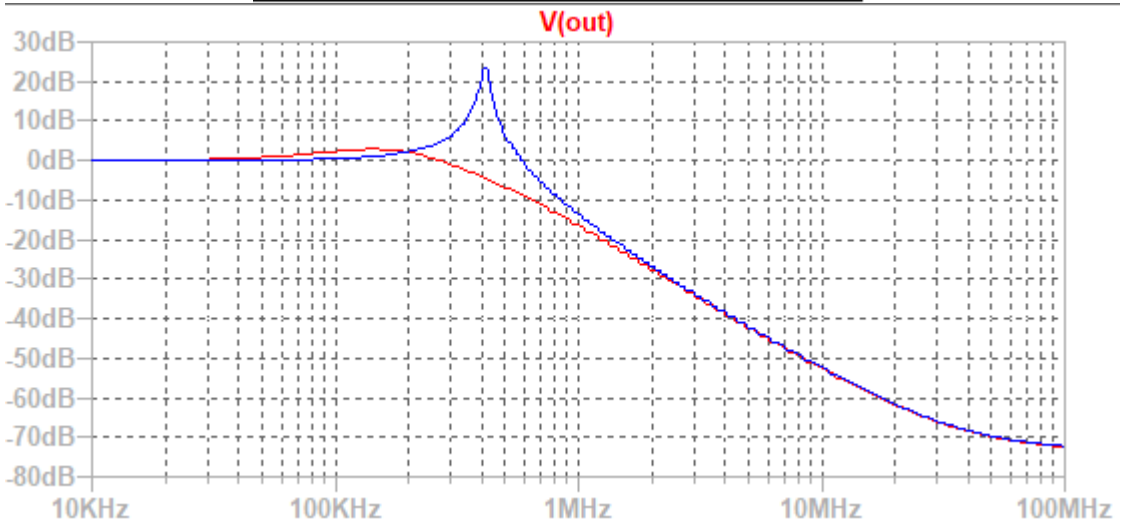
SIMULATIONS – COMMON MODE FILTER DESIGN

WITH CHASSIS / EMC GROUND



Take care

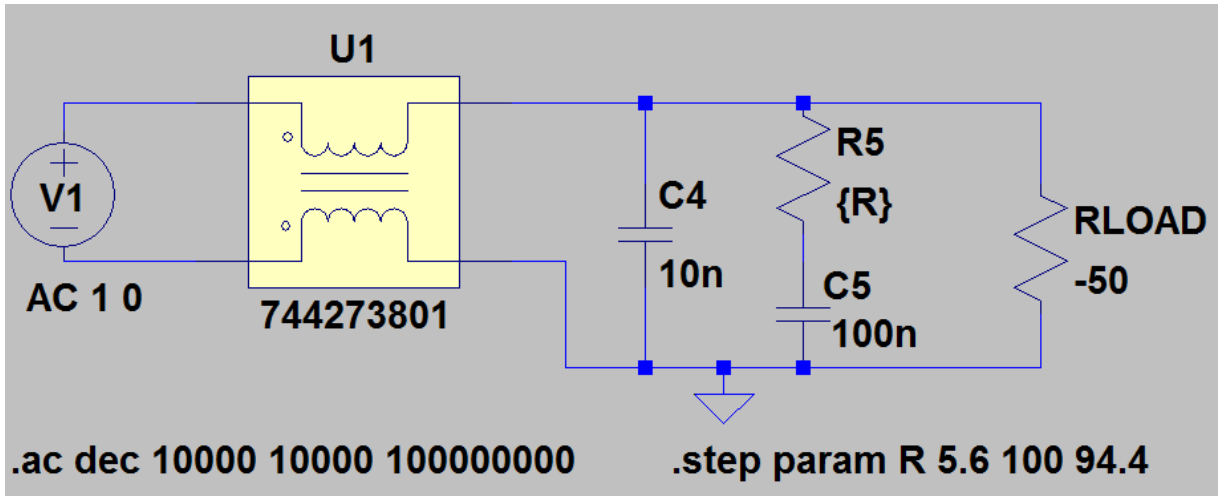




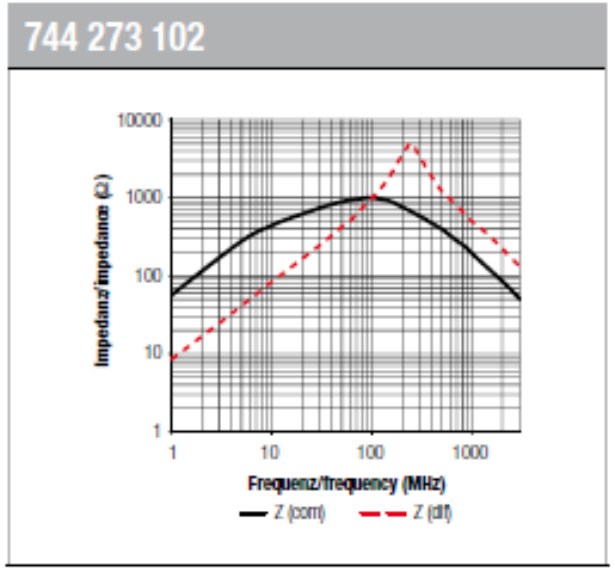
- Power Supply Switching Frequency Considerations (L)
- EMI Higher Frequency Considerations (Z)
- Layout and Tracking
- Capacitor with and without Damping

SIMULATIONS - COMMON MODE FILTER DESIGN

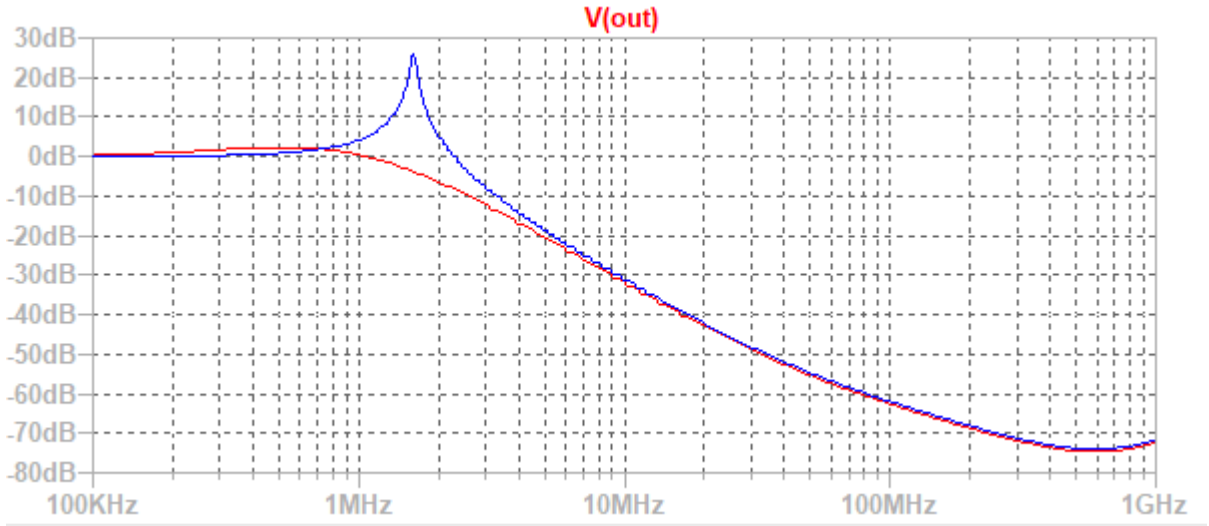
DM (LEAKAGE) EFFECT



Take care

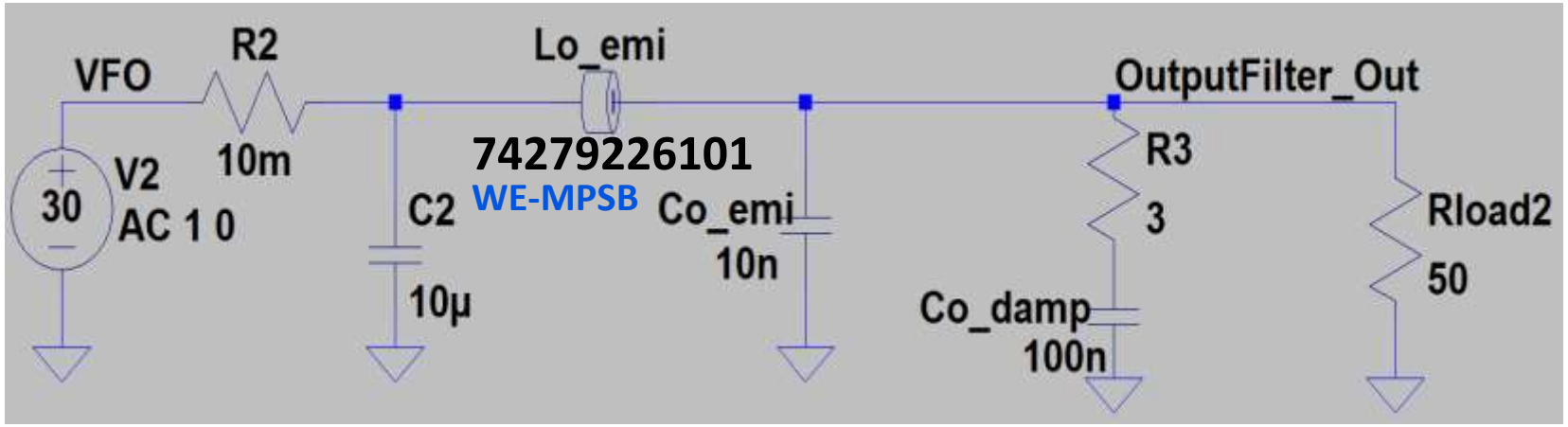


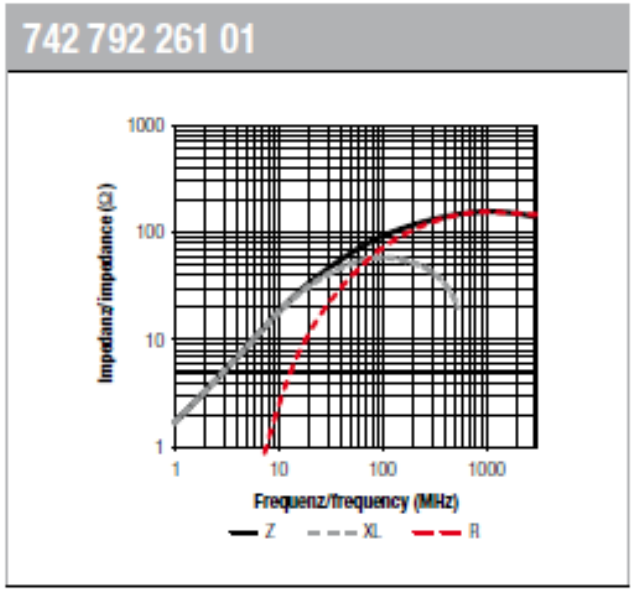
- Load Impact
- Capacitor Damping



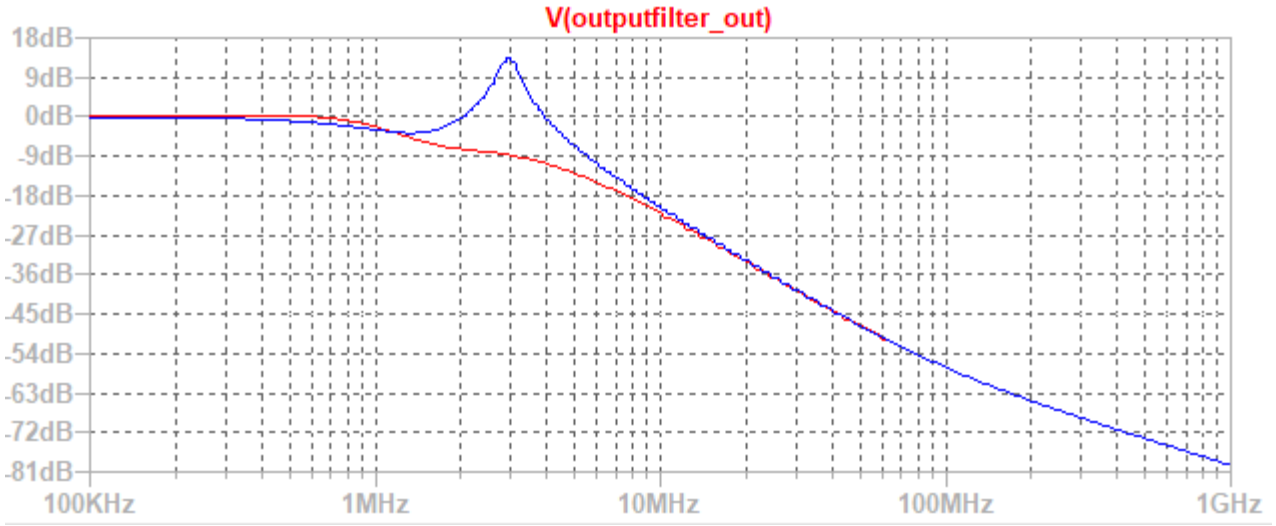
SIMULATIONS

RE DIFFERENTIAL MODE FILTER DESIGN



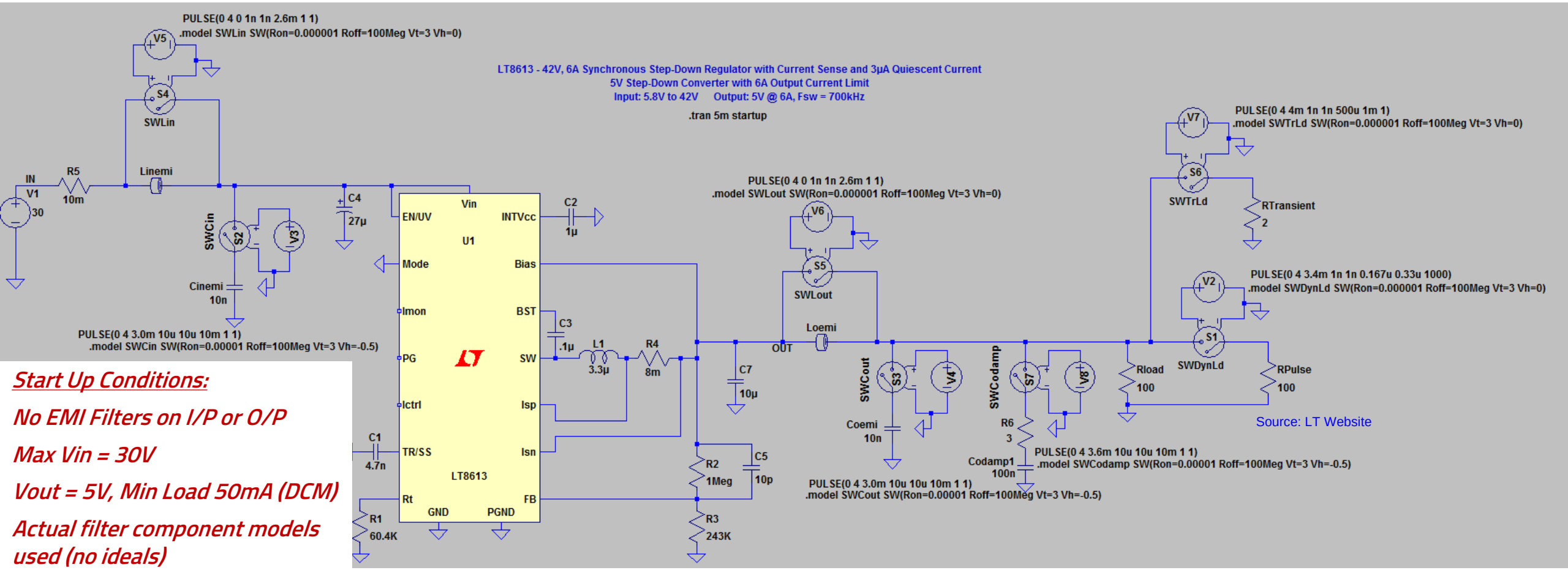


- Load Impact
- EMI Higher Frequency Considerations
- Pulse Rating (WE-MPSB)
- Layout and Tracking
- Capacitor Damping



SIMULATIONS

RE DIFFERENTIAL MODE FILTER DESIGN – BUCK EXAMPLE



Start Up Conditions:

No EMI Filters on I/P or O/P

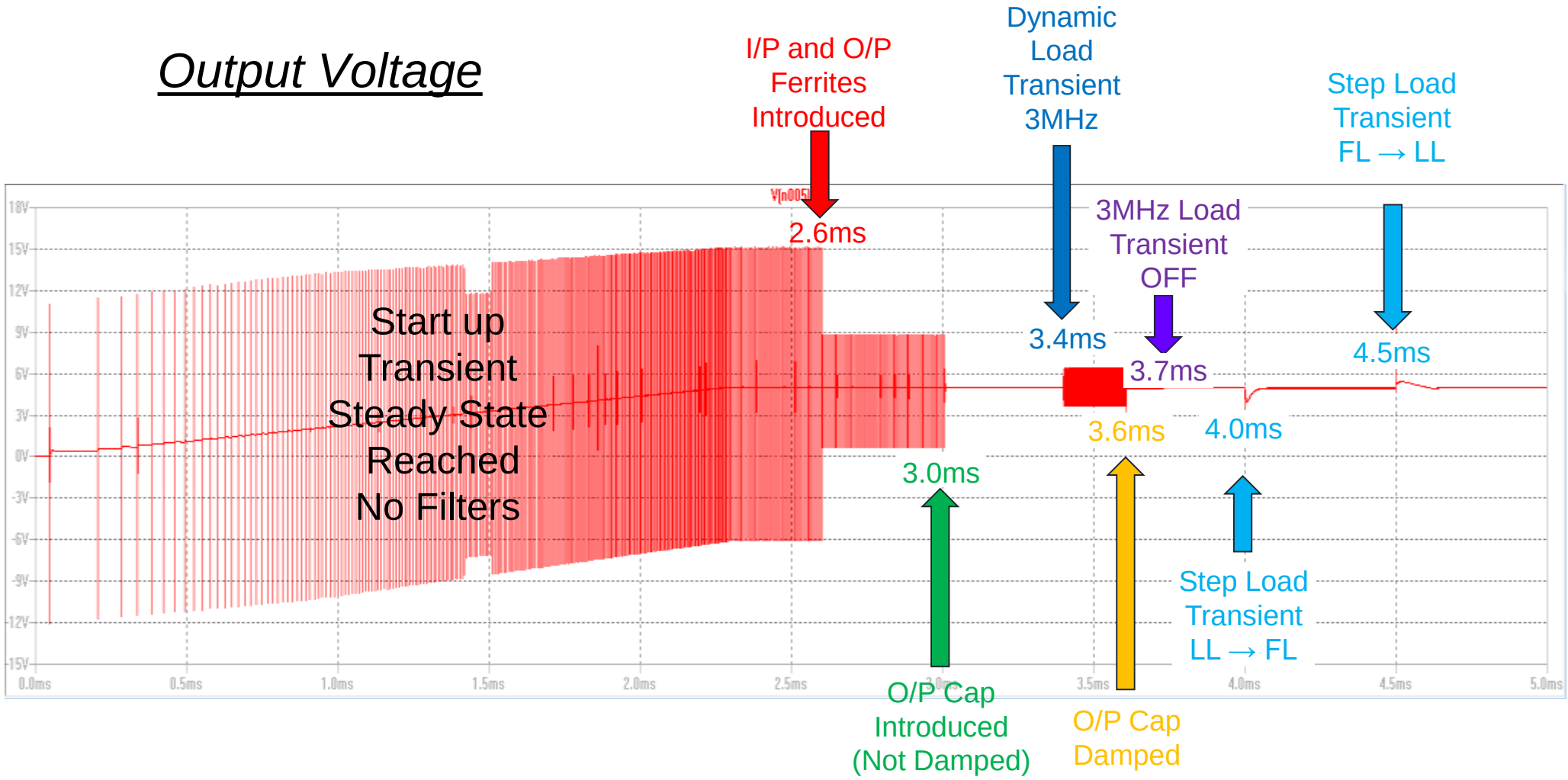
Max Vin = 30V

Vout = 5V, Min Load 50mA (DCM)

Actual filter component models used (no ideals)

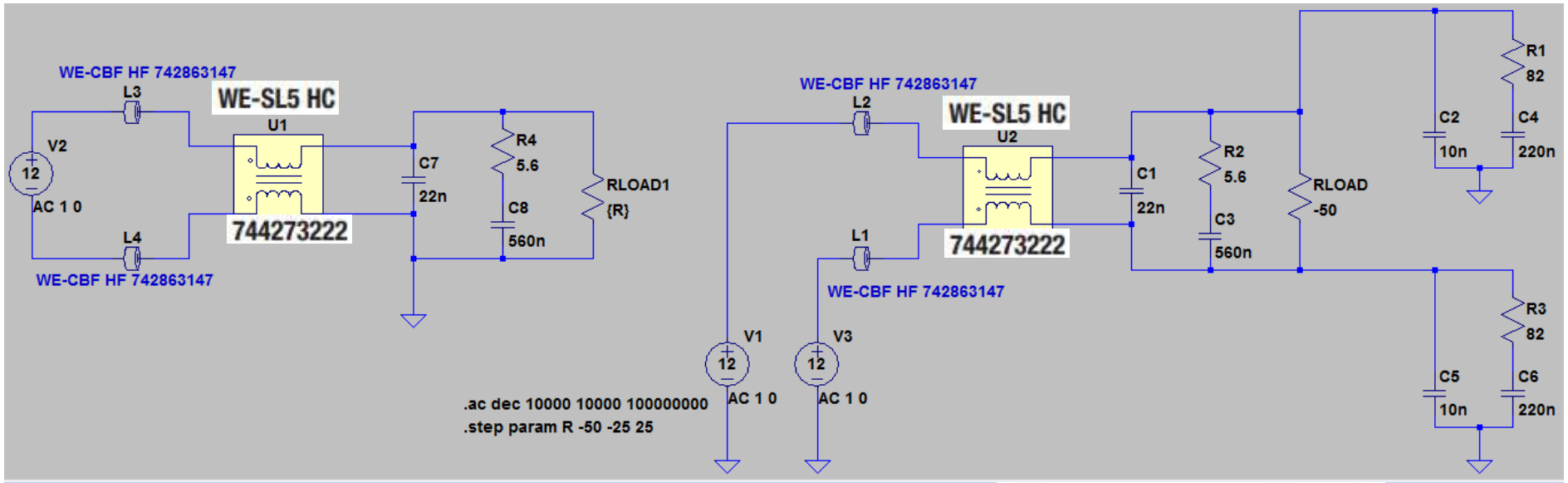
SIMULATIONS

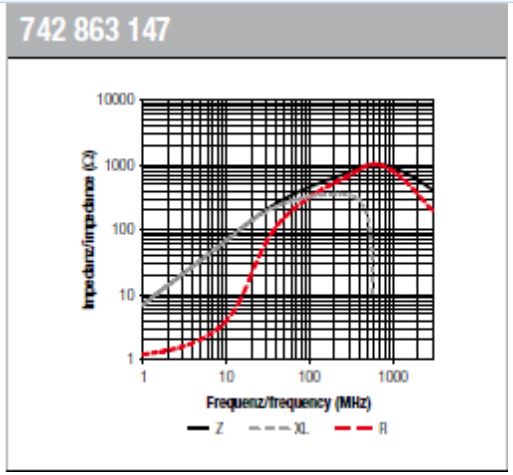
RE DIFFERENTIAL MODE FILTER DESIGN – BUCK EXAMPLE

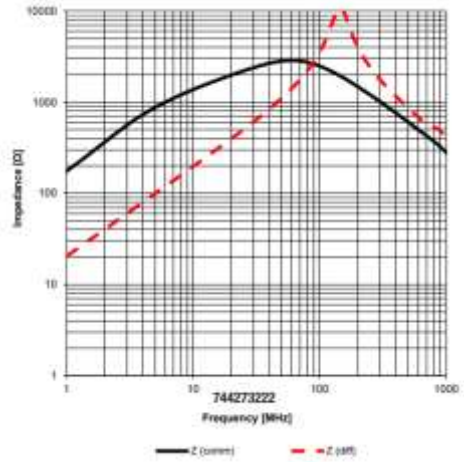


SIMULATIONS

EMI FILTER DESIGN – RE ARCHITECTURE

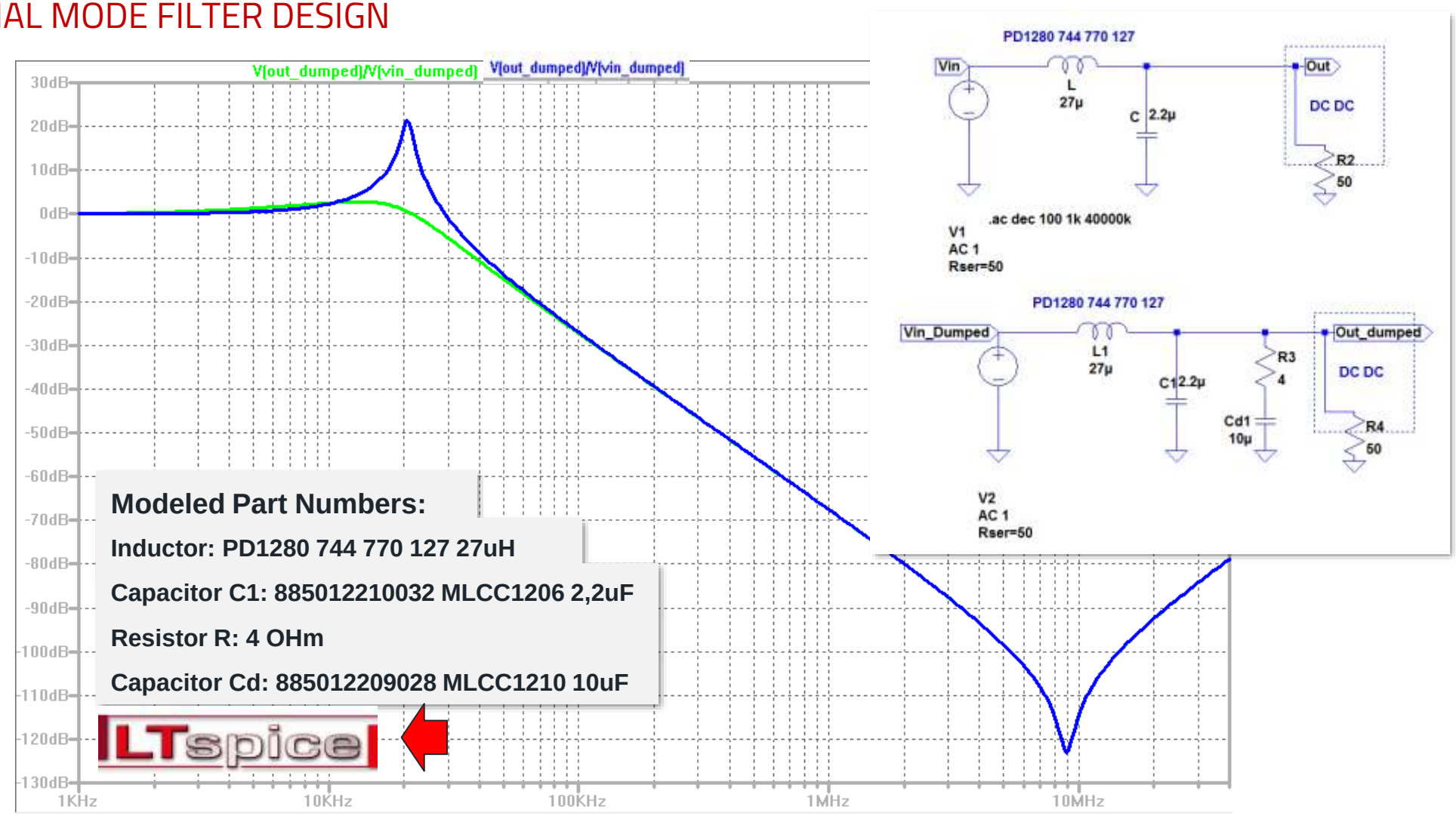






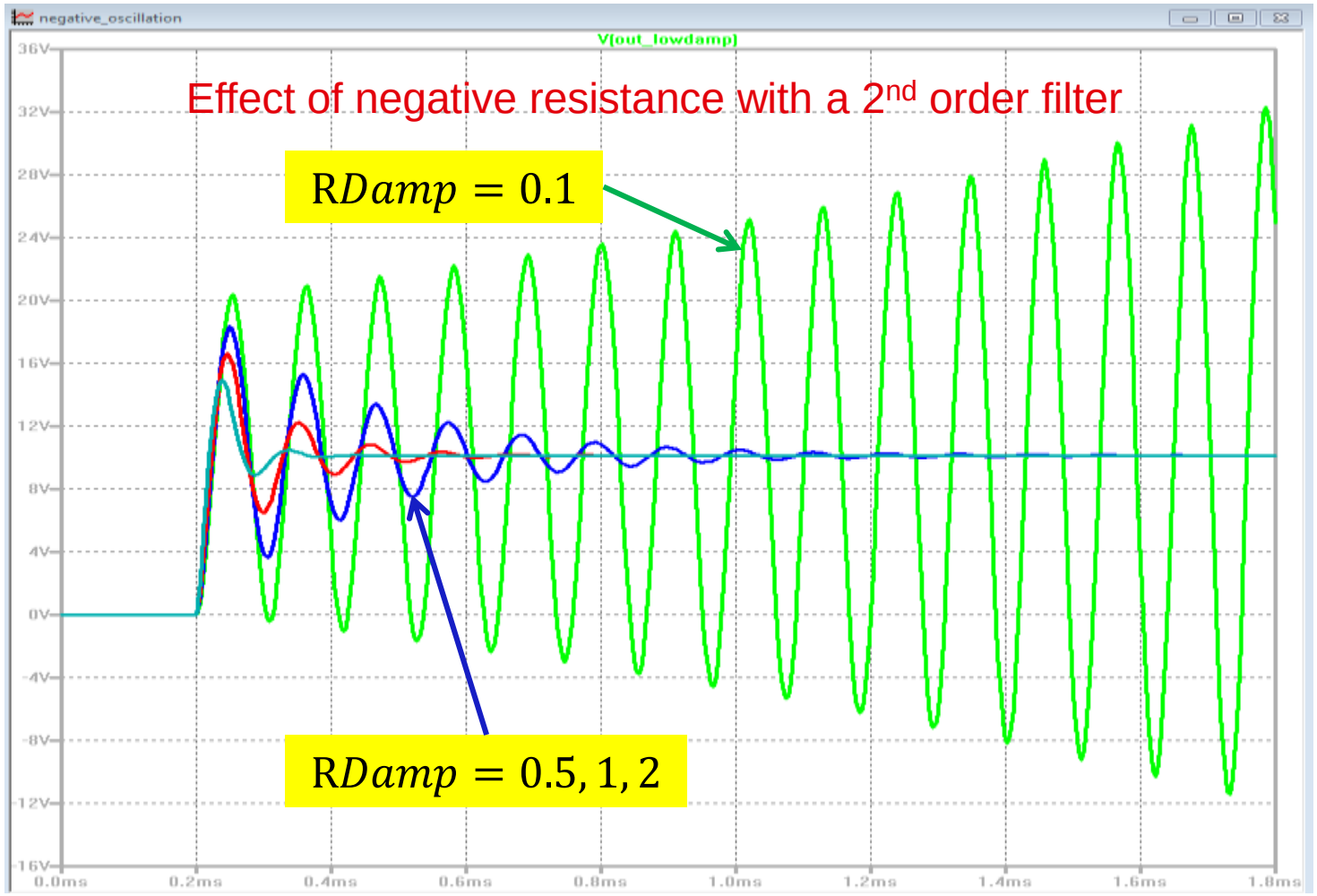
SIMULATIONS

CE DIFFERENTIAL MODE FILTER DESIGN

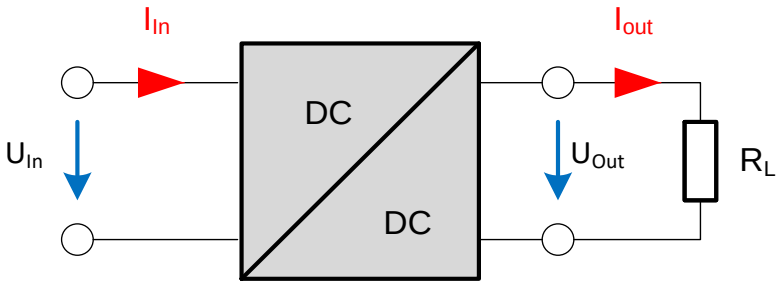


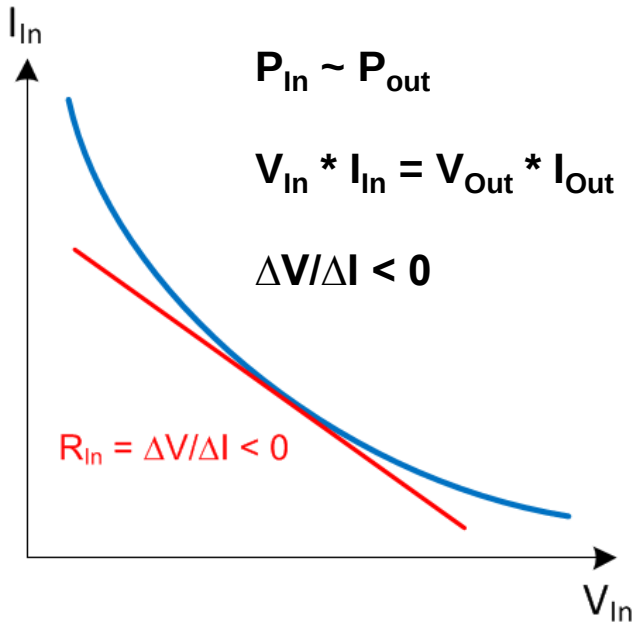
SIMULATIONS

CE DIFFERENTIAL MODE FILTER DESIGN



Take care



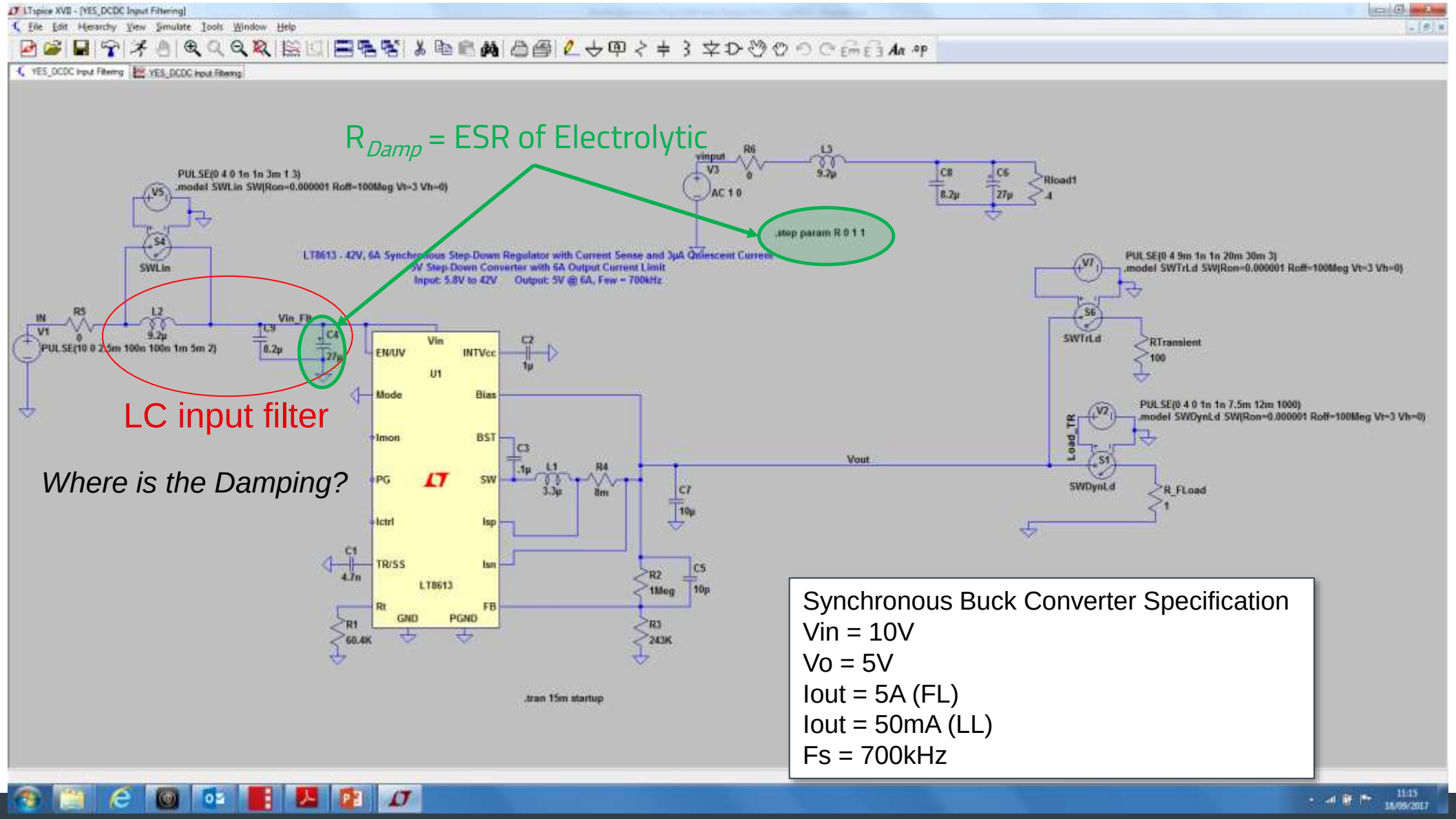


$P_{In} \sim P_{out}$

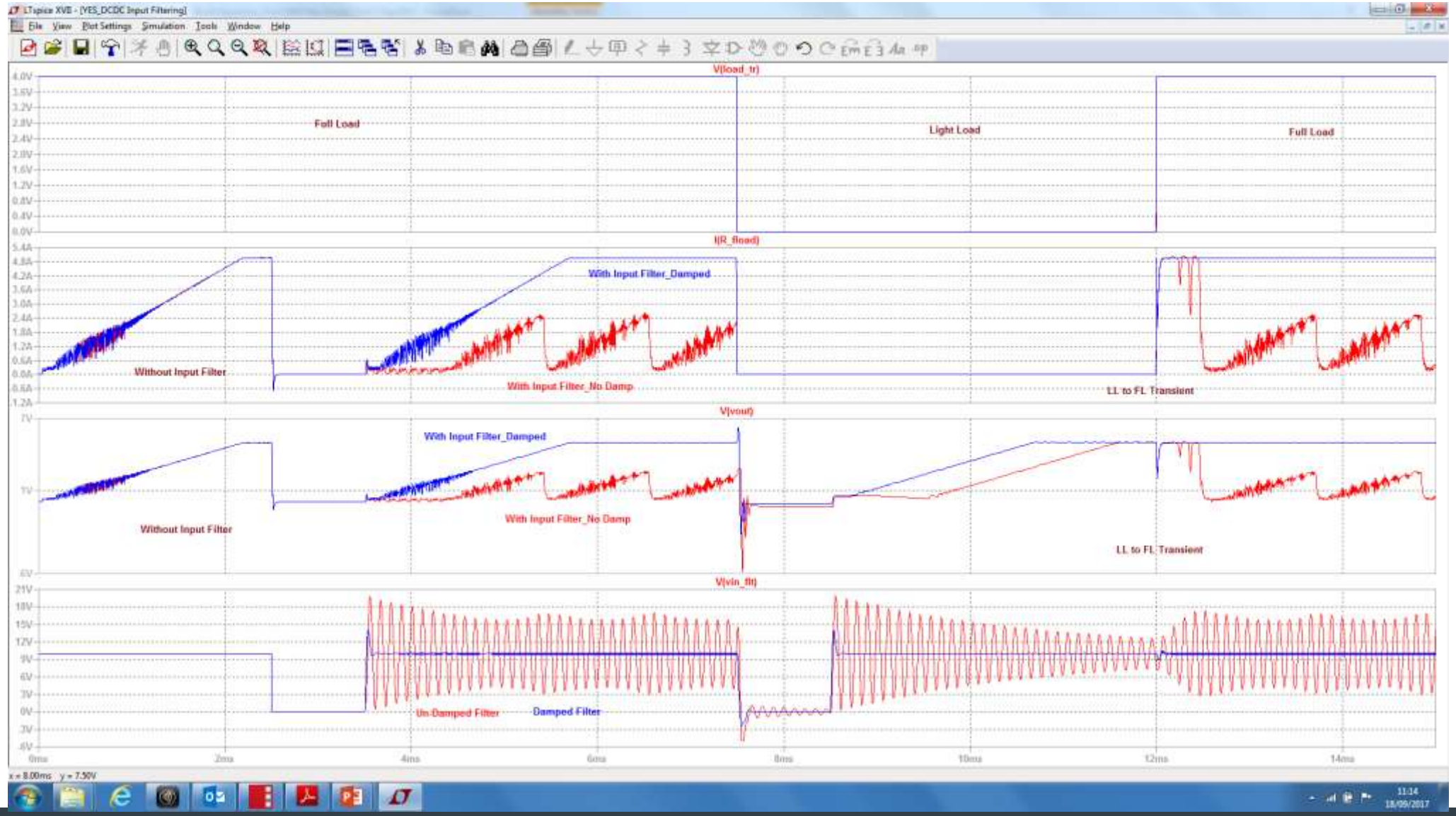
$V_{In} * I_{In} = V_{Out} * I_{Out}$

$\Delta V/\Delta I < 0$

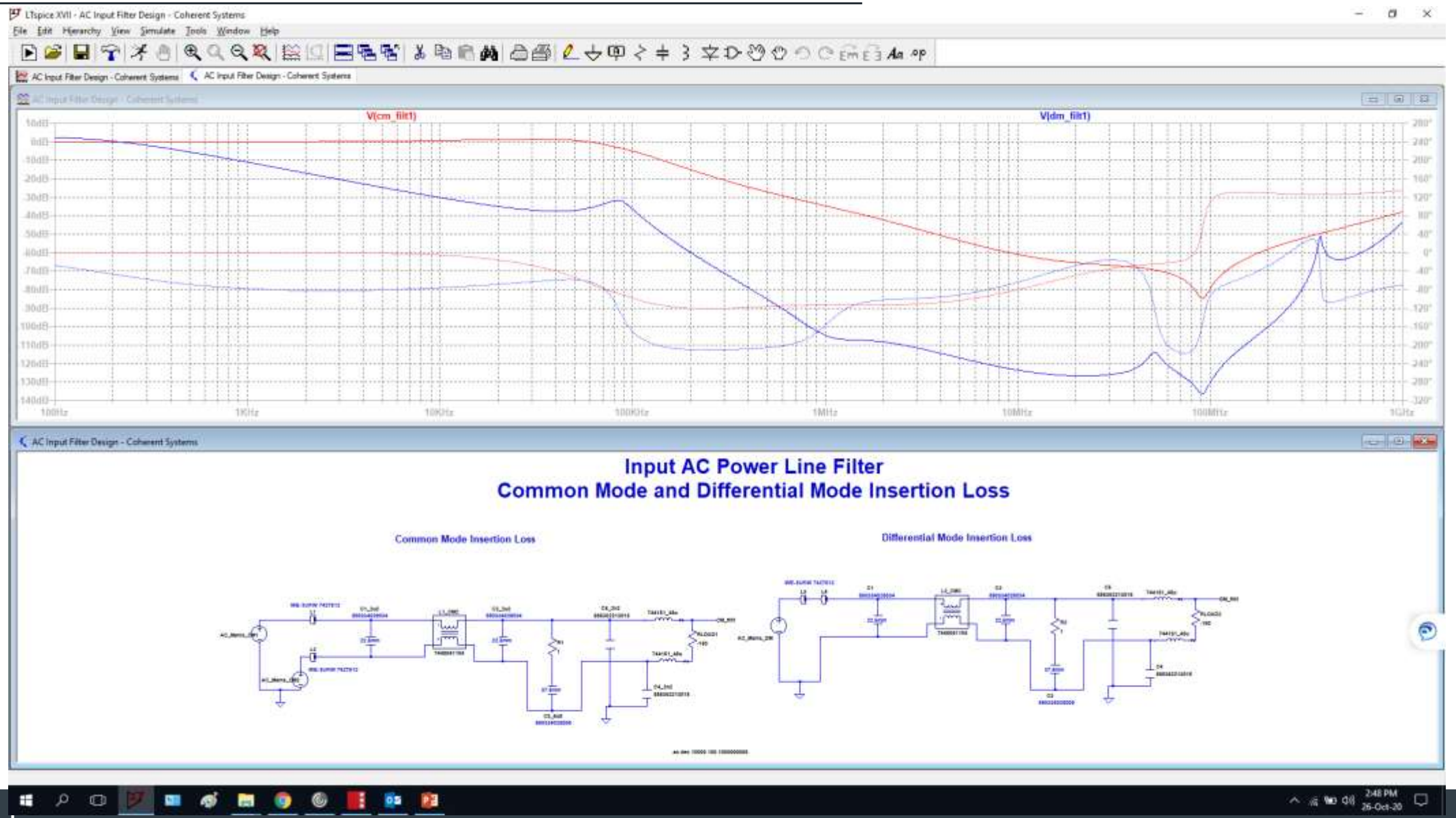
CE DIFFERENTIAL MODE FILTER DESIGN – BUCK EXAMPLE



CE DIFFERENTIAL MODE FILTER DESIGN – BUCK EXAMPLE



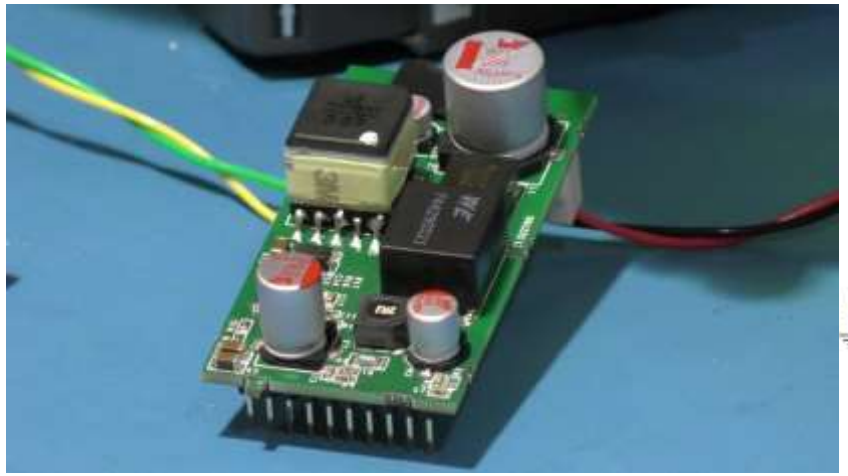
LT SPICE SIMULATION – MAINS FILTER EXAMPLE

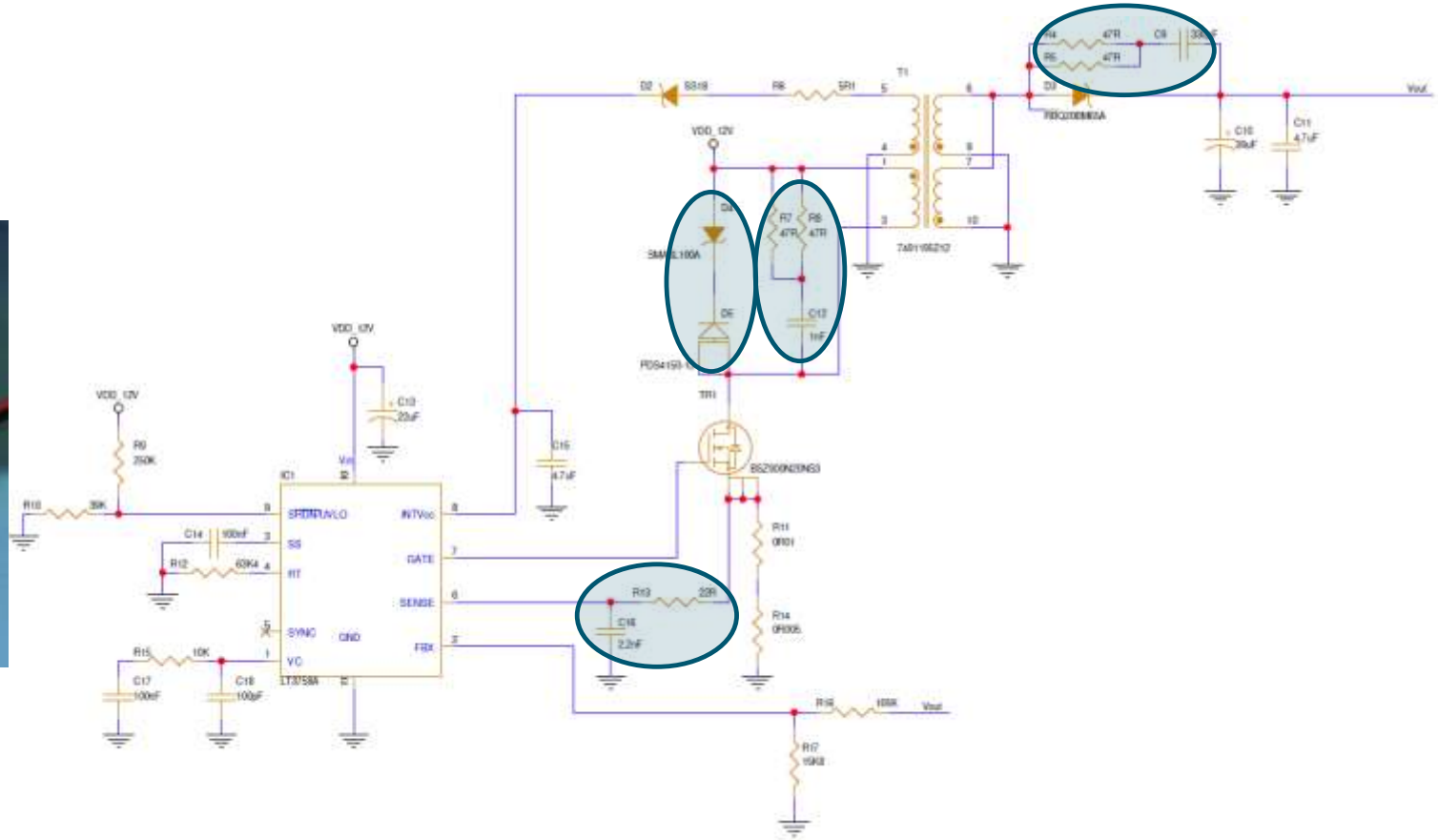


LAYOUT & TRACKING

TYPE 2 POE FLYBACK CONVERTER (LT3758A)

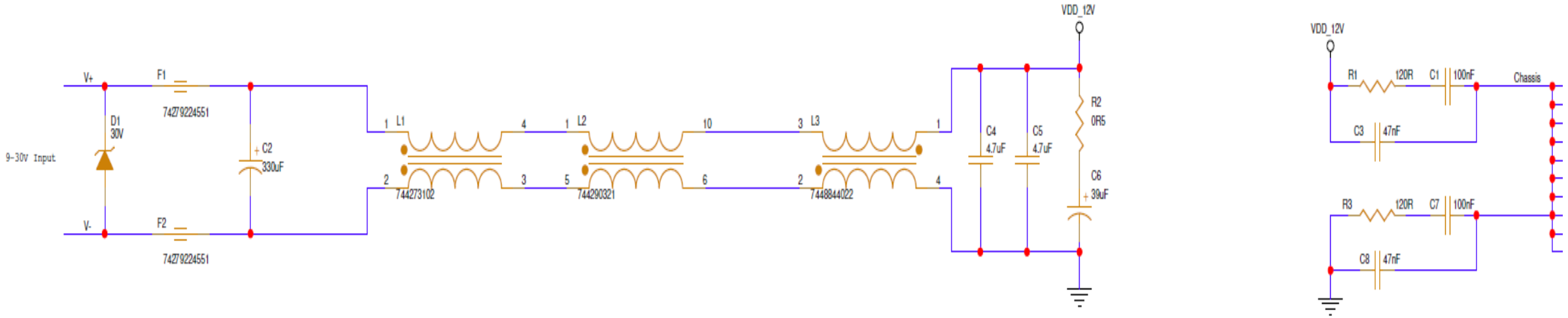
- **Design Requirements:**
  - Vin= 9V-30V
  - Vout = 12V
  - Iout = 1.5A (up to 2.5A)
  - Max Efficiency 90%





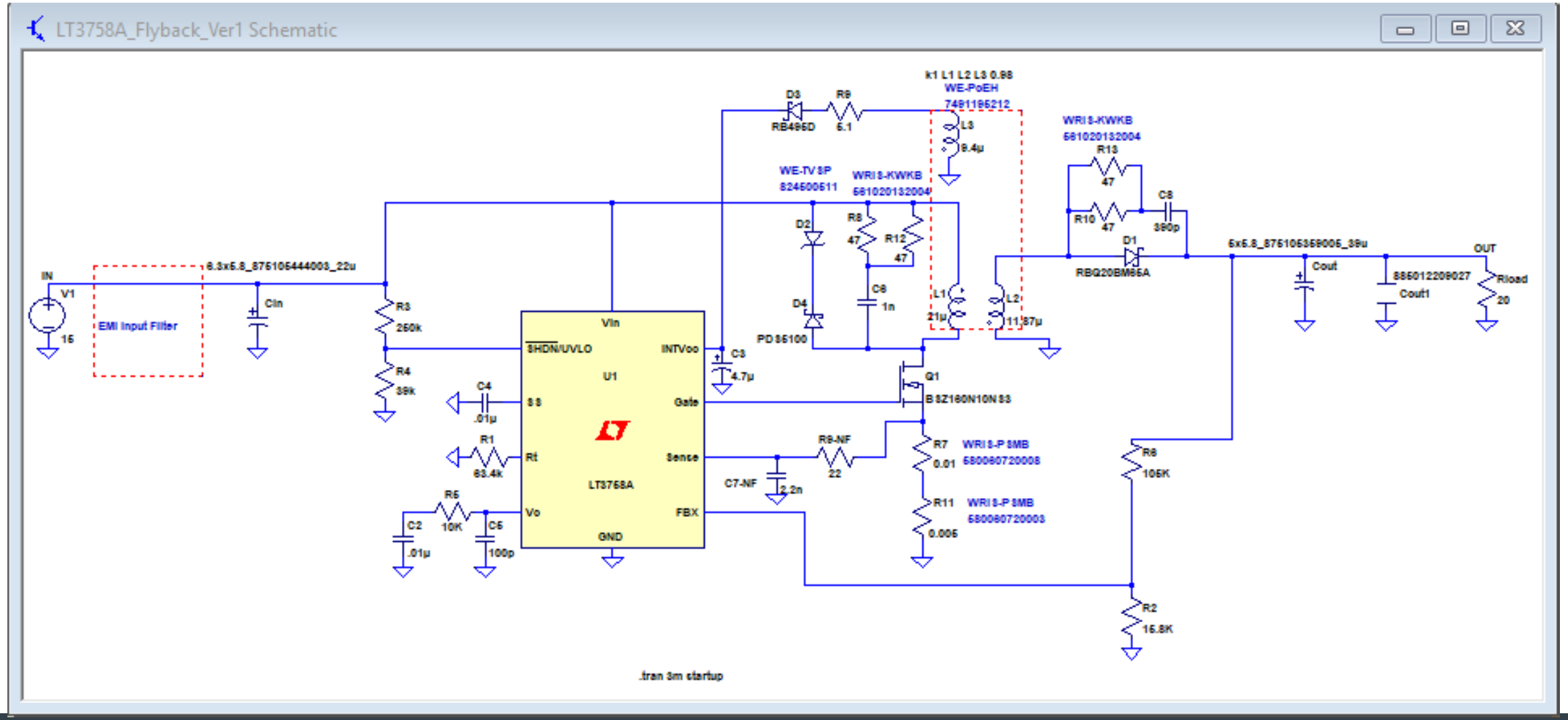
TYPE 2 POE FLYBACK CONVERTER (LT3758A)

EMI FILTER CIRCUIT



TYPE 2 POE FLYBACK CONVERTER (LT3758A)

DESIGN SIMULATION: POWER CIRCUIT



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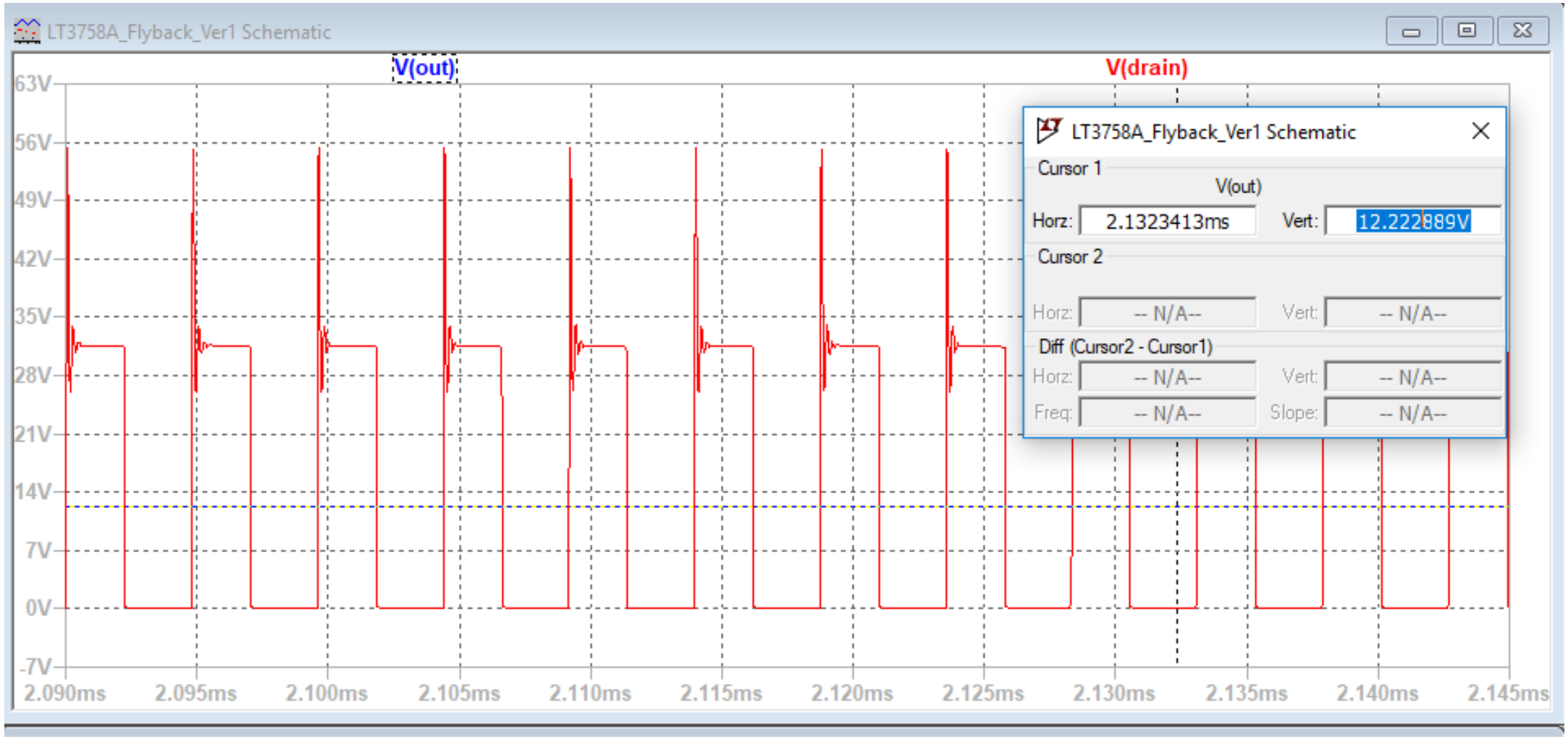
DESIGN SIMULATION: POWER CIRCUIT



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
885012209027
4.7uF / 25V
https://www.we-online.com/catalog/en/datasheet/885012209027.pdf

CY1 / CY2: WCAP-CSGP
885012006069
47nF / 25V
https://www.we-online.com/catalog/en/datasheet/885012206069.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

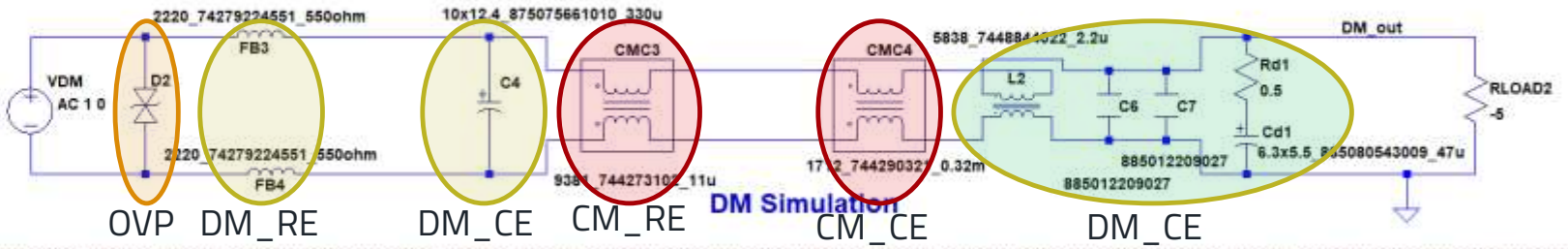
Cout: WCAP-PSHP
875115452003
100uF / 20V
https://www.we-online.com/catalog/en/datasheet/875115452003.pdf

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

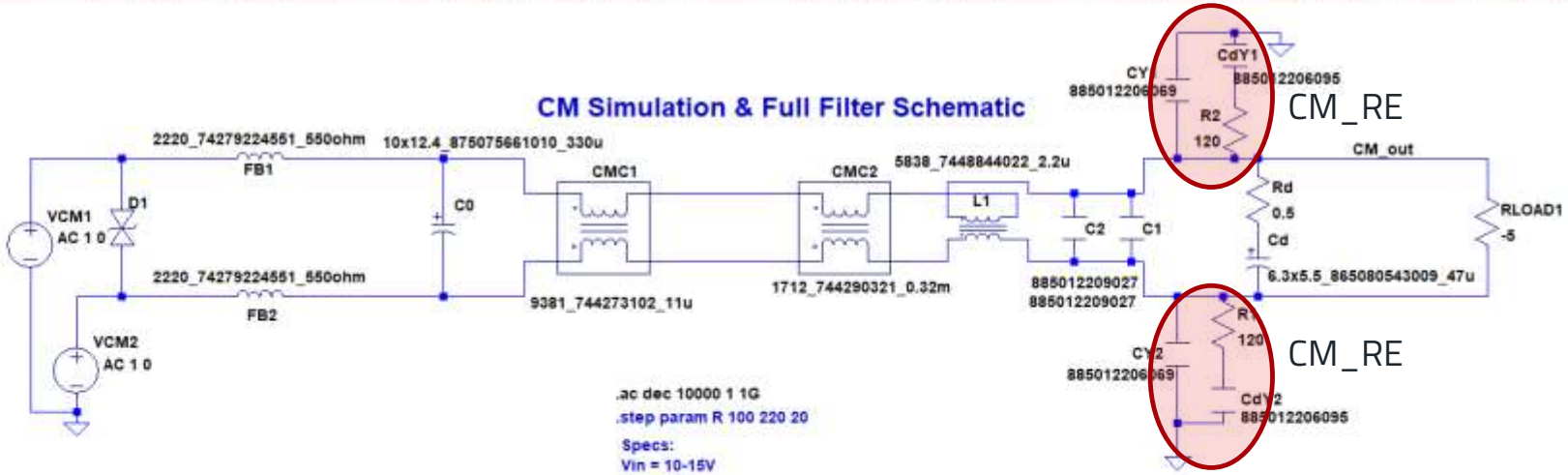
CMC2: WE-UCF
744290321
https://www.we-online.com/catalog/en/datasheet/744290321.pdf

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



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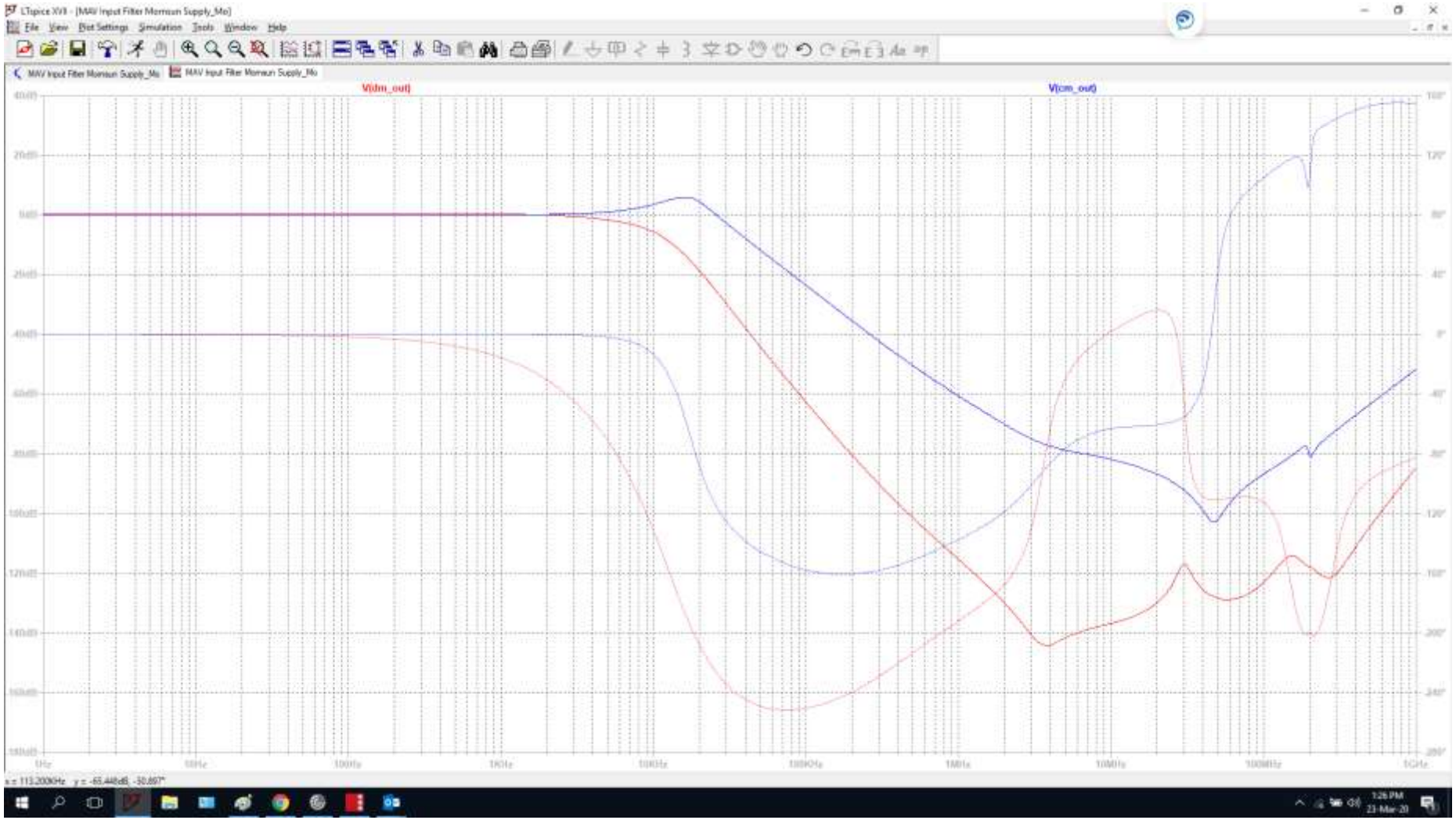
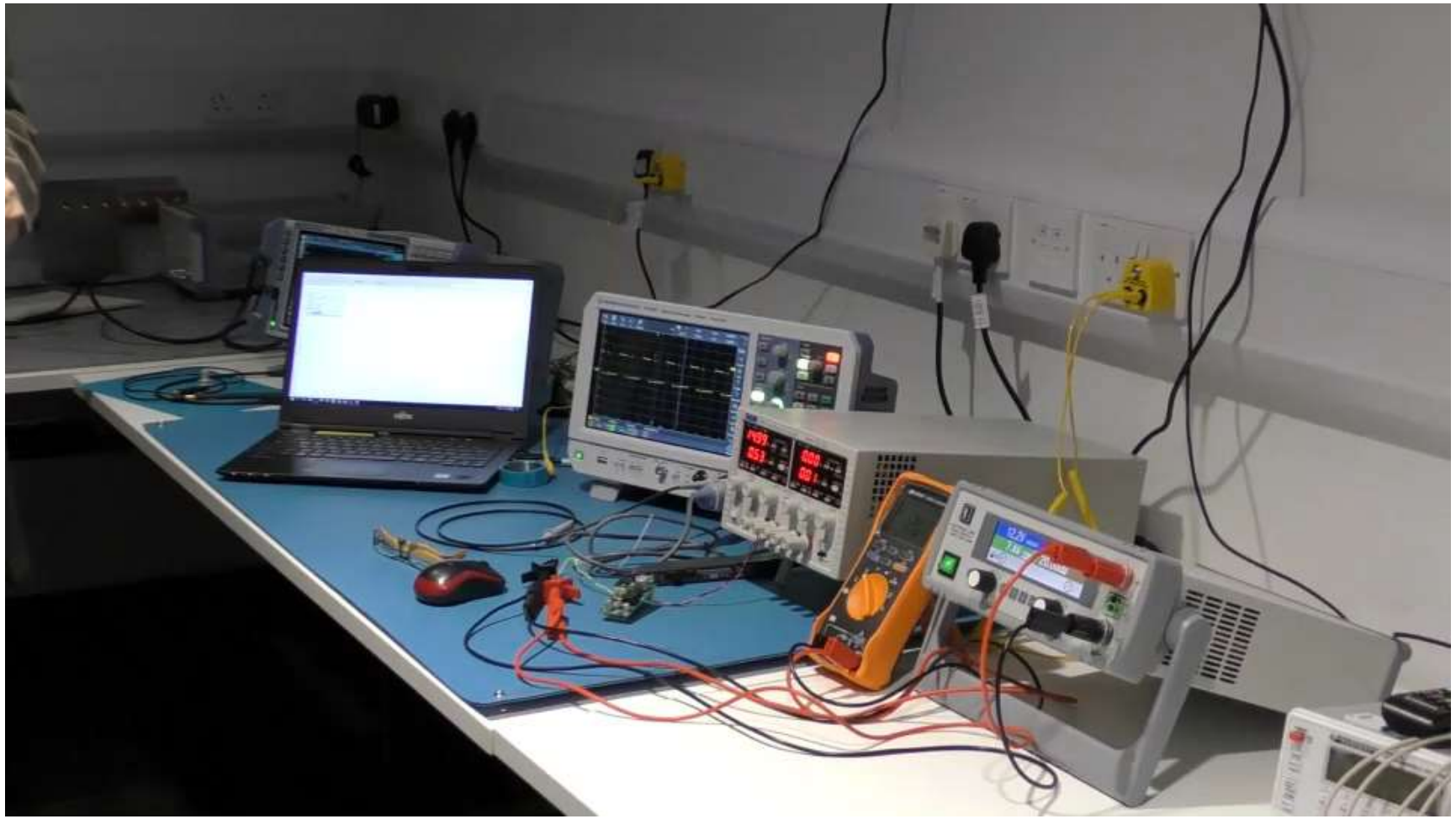
DESIGN SIMULATION: FILTER CIRCUIT



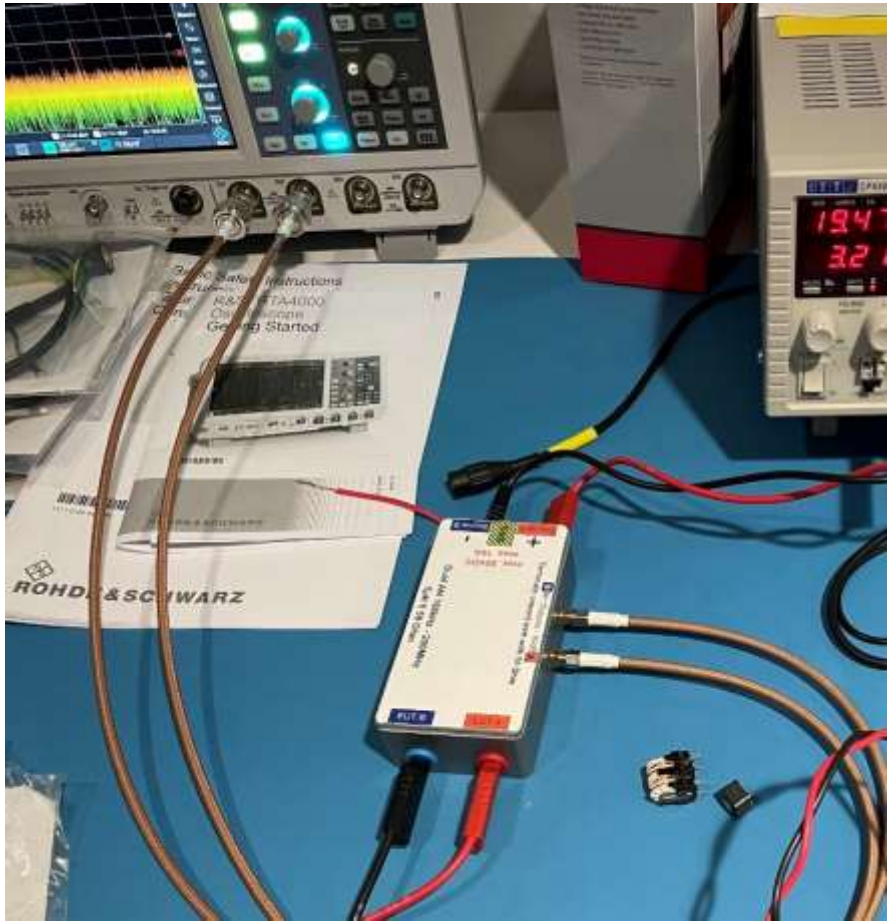
TYPE 2 POE FLYBACK CONVERTER (LT3758A)

TEST AND MEASUREMENT: OVERVIEW



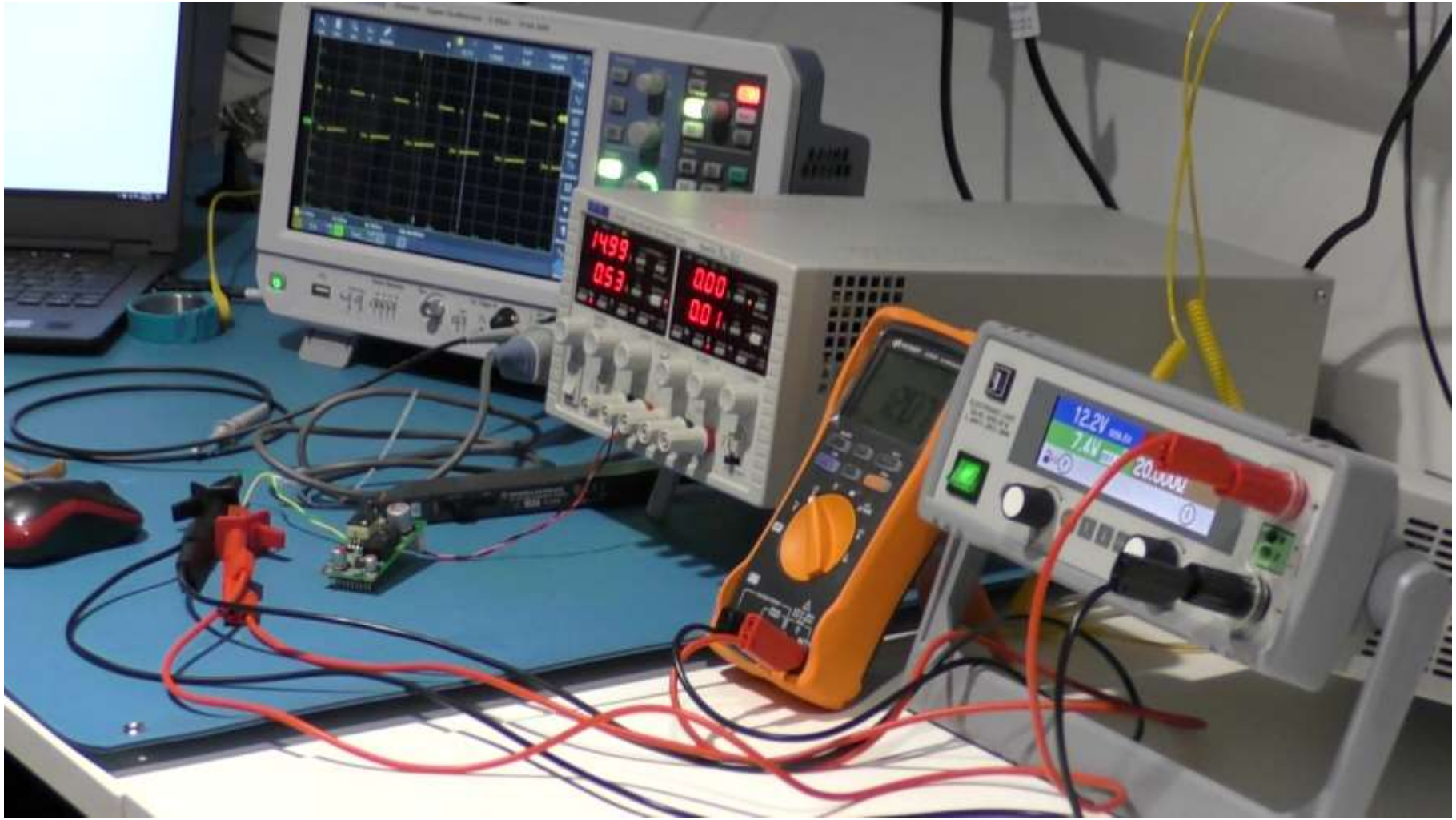
TYPE 2 POE FLYBACK CONVERTER (LT3758A)

TEST AND MEASUREMENT: CONDUCTED EMISSIONS



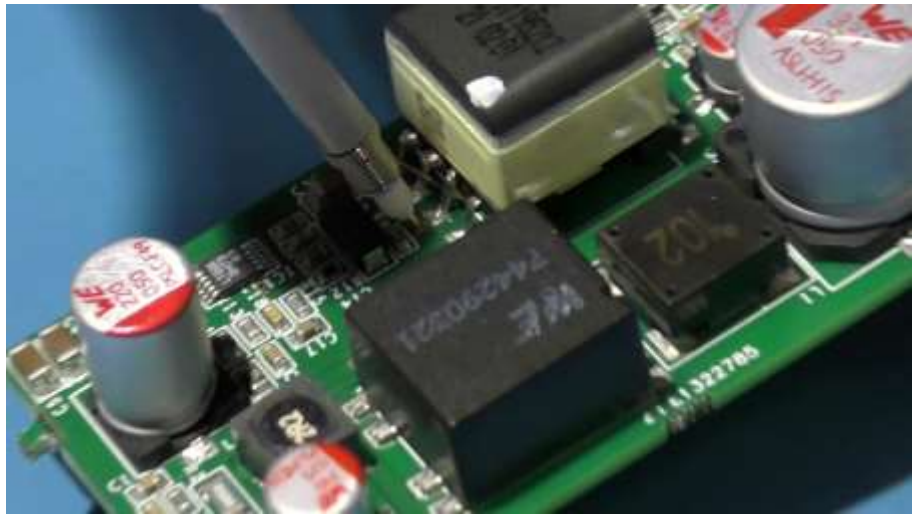
TYPE 2 POE FLYBACK CONVERTER (LT3758A)

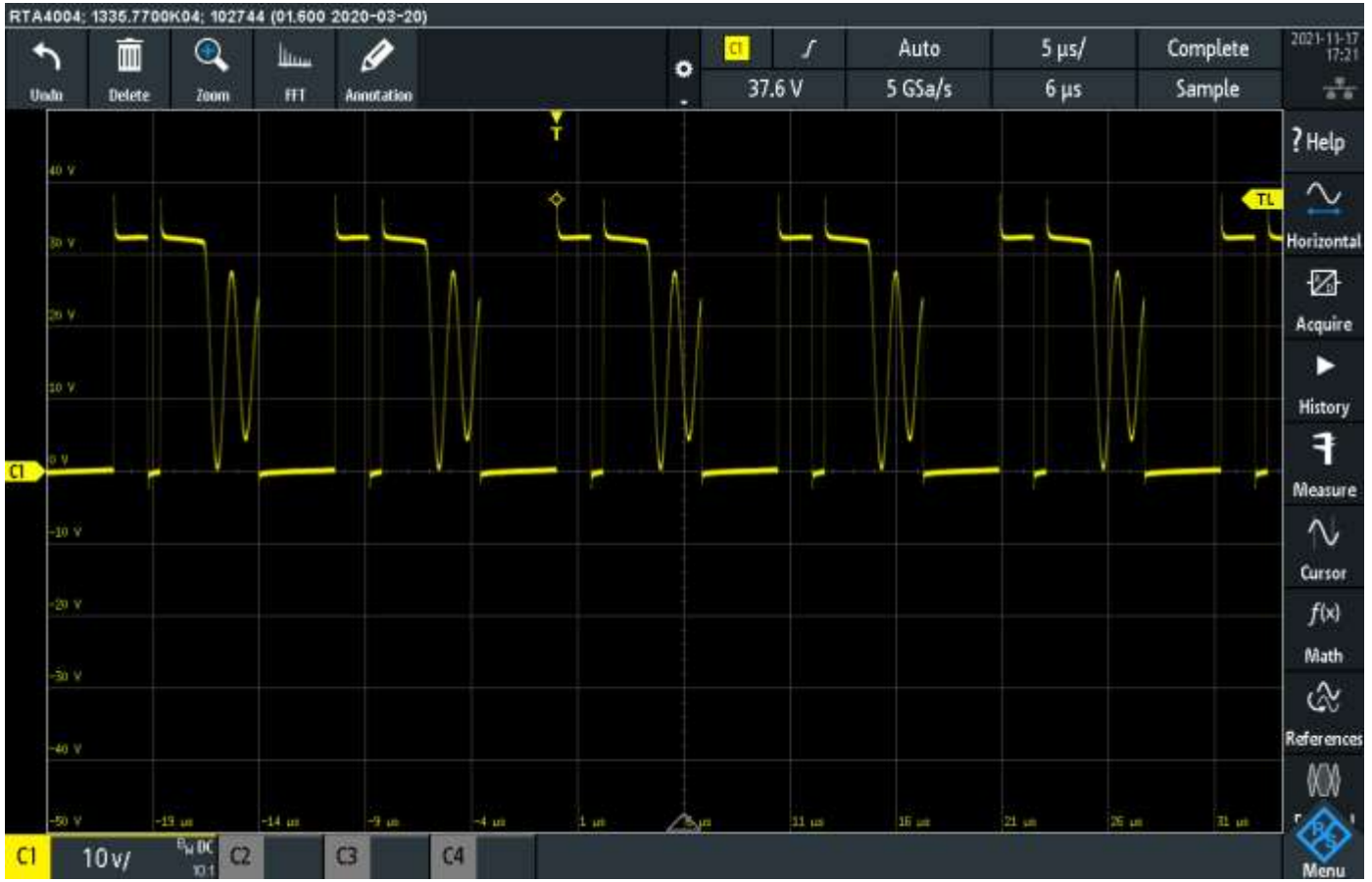
TEST AND MEASUREMENT: SIGNAL INTEGRITY



TYPE 2 POE FLYBACK CONVERTER (LT3758A)

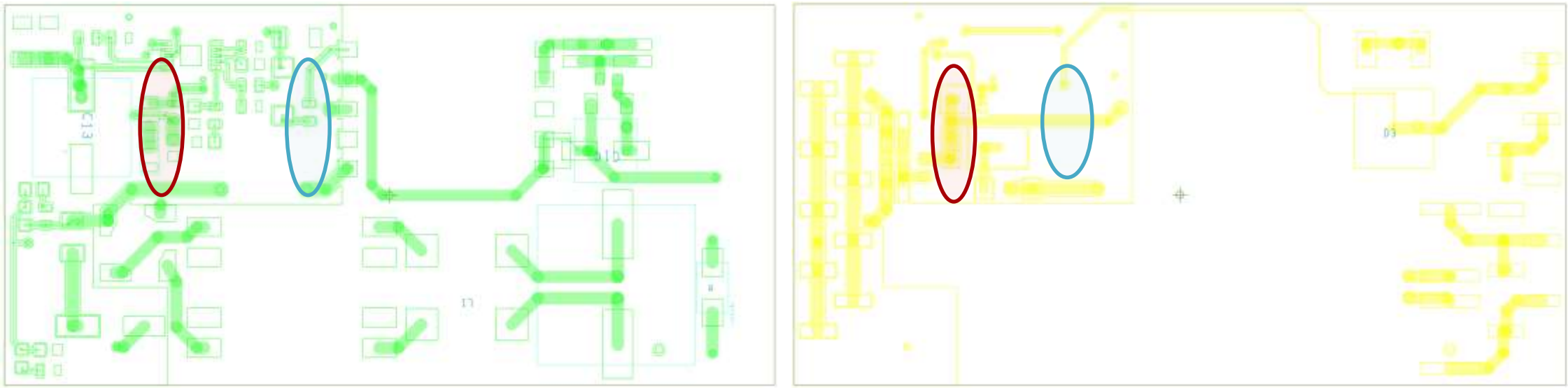
TEST AND MEASUREMENT: SIGNAL INTEGRITY





TYPE 2 POE FLYBACK CONVERTER (LT3758A)

LAYOUT AND TRACKING REVIEW

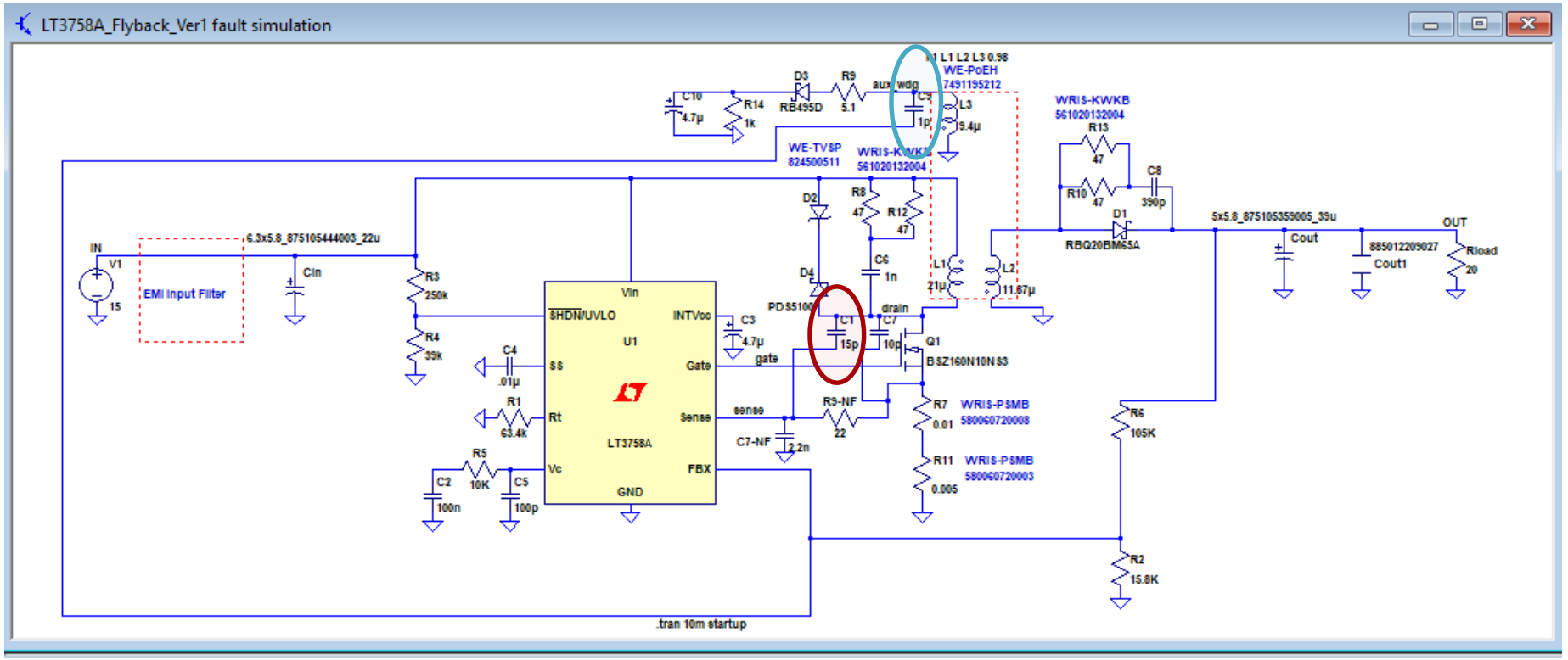


- **Several issues identified:**
  - Ground connection far from the input/output capacitors, Mosfet Source / Rsens and IC Power GND
  - AGND and PGND not separated
  - Track to gate of mosfet to small
  - Critical: Feedback signal shadows the auxiliary winding switching signal.
  - Critical: Current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

TYPE 2 POE FLYBACK CONVERTER (LT3758A)

SIGNAL INTEGRITY SIMULATION: POWER CIRCUIT

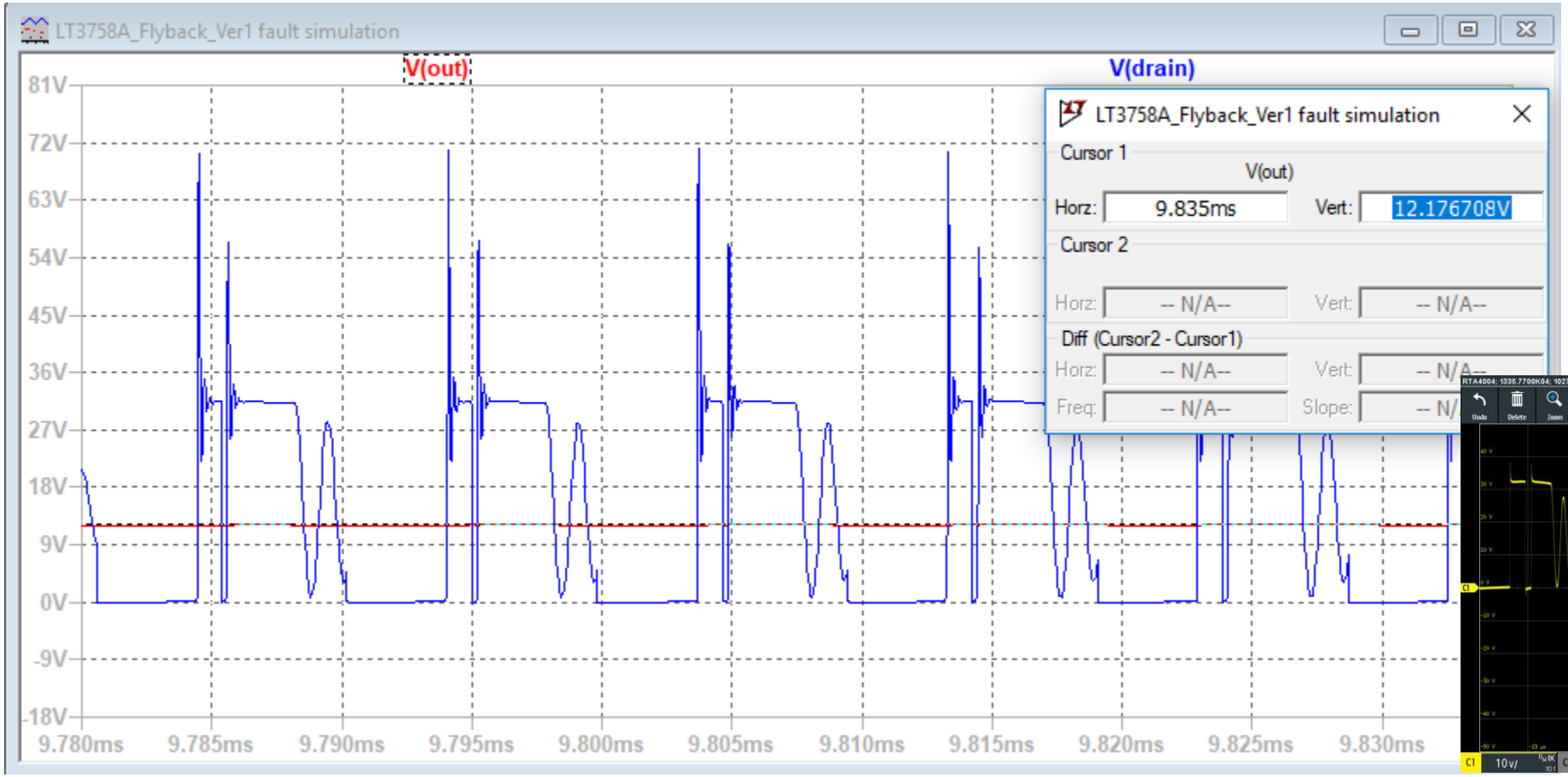
- **Parasitic coupling capacitance estimated based on pcb and track parameters**
  - **https://www.emisoftware.com/calculator/biplanar-capacitance/**
- **Modelled in LT Spice and simulated**

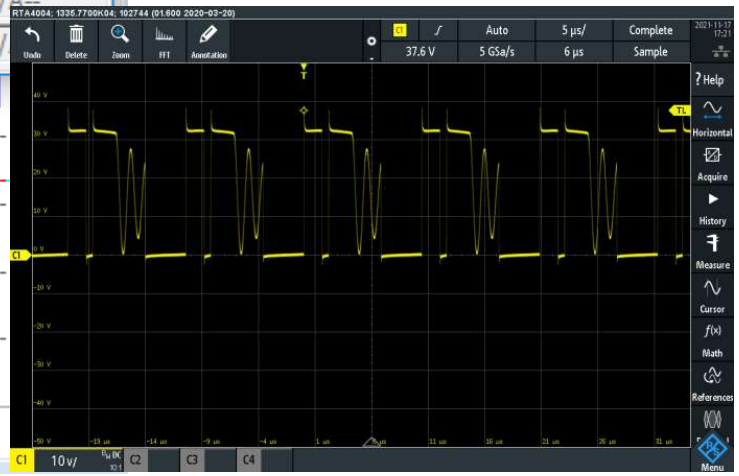


TYPE 2 POE FLYBACK CONVERTER (LT3758A)

SIGNAL INTEGRITY SIMULATION: POWER CIRCUIT

- **Results consistent with the measurements**





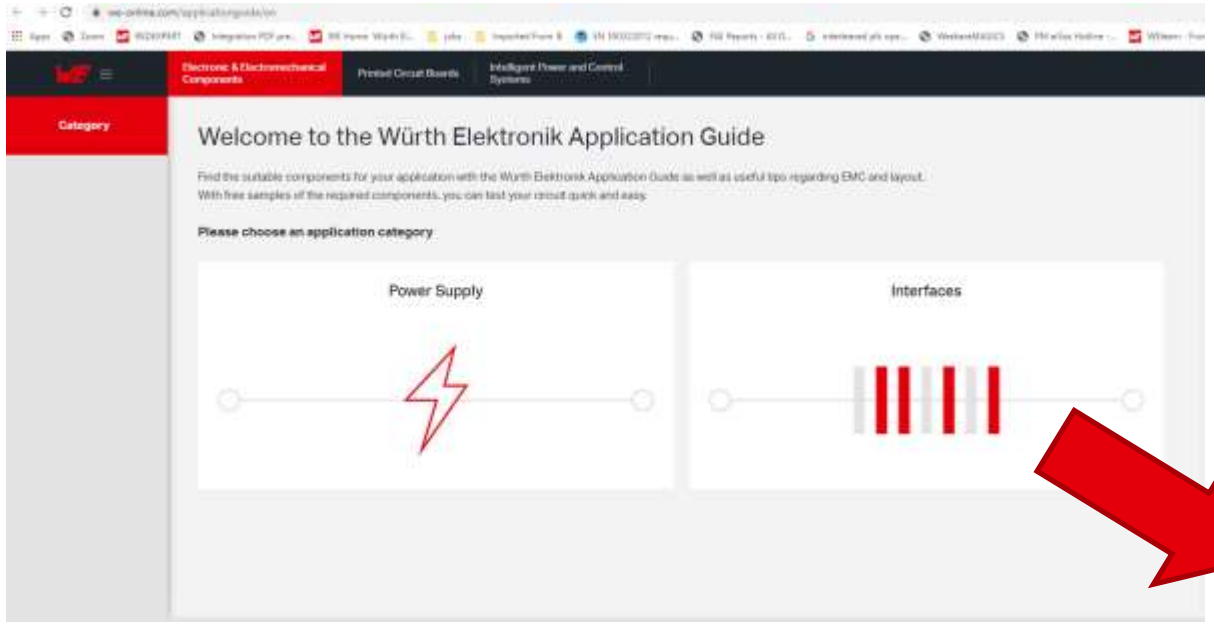
TYPE 2 POE FLYBACK CONVERTER (LT3758A)

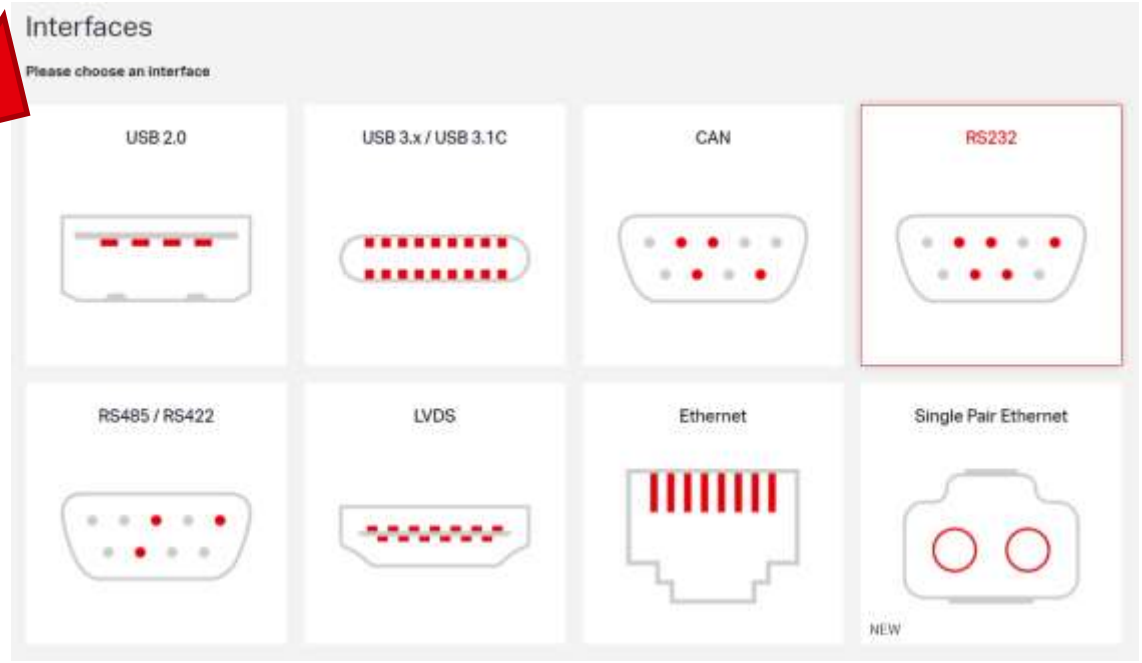
SUMMARY AND CONCLUSIONS

- 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

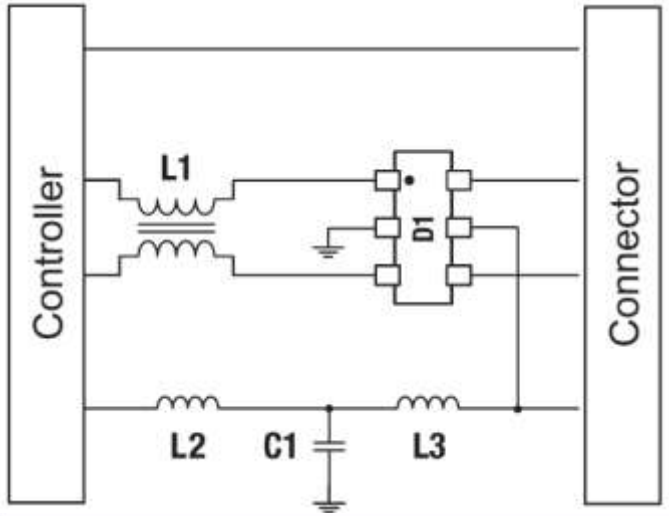




USB 2.0 FILTER

P/N 829999 STICK

P/N 829999 BAG



Order Code: 829 999 BAG

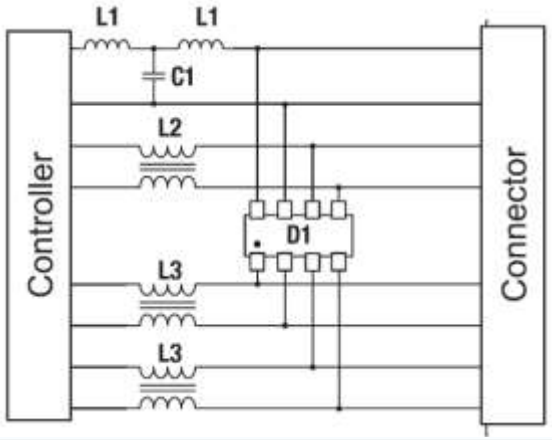
With this kit you can rebuild the design of the USB 2.0 EMC stick.
829 999 BAG contains schematic and the required components:

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



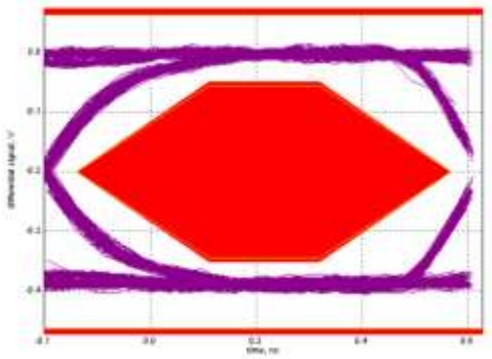
Order Code: 829 993 BAG

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

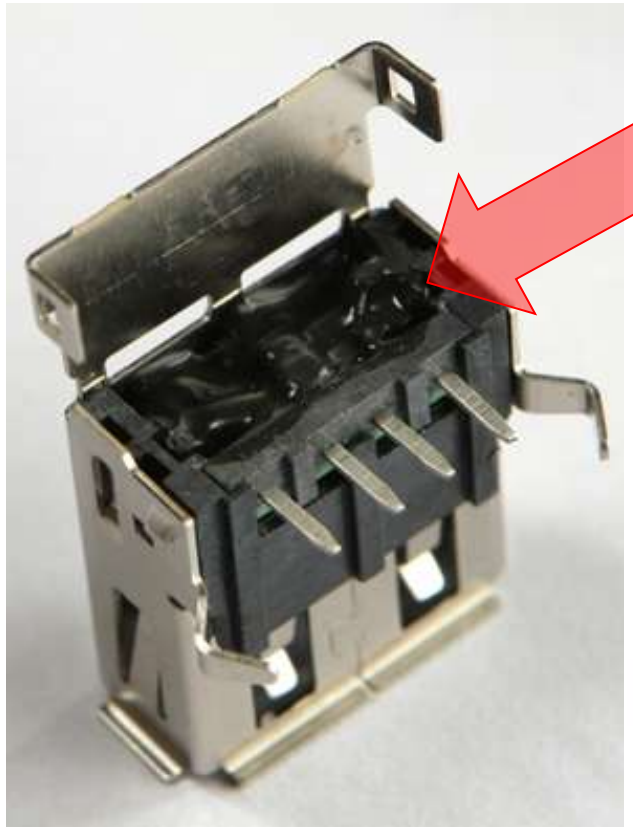
- ESD Protection of data channels and VDD
- Common Mode Noise Rejection
- VDD Differential Mode Noise Rejection
- Provides ESD protection for each channel to
  IEC 61000-4-2 (ESD) ±15kV (air), ±8kV (contact)
  IEC 61000-4-4 (EFT) (5/50ns) 20A (I/O), 40A VDD
  IEC 61000-4-5 (Lightning) 6A (8/20µs)
- Ultra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

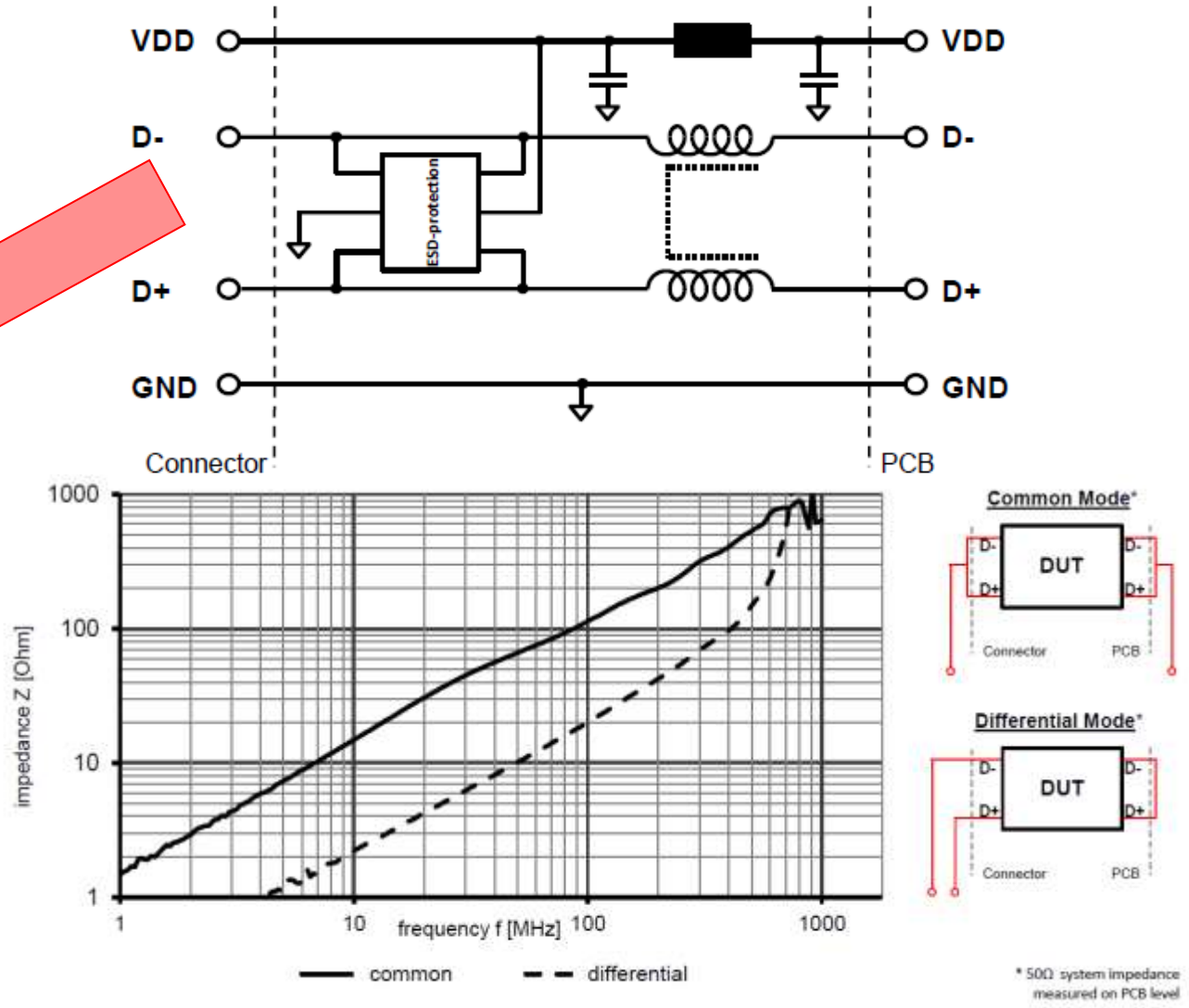


Full Speed – 480MHz

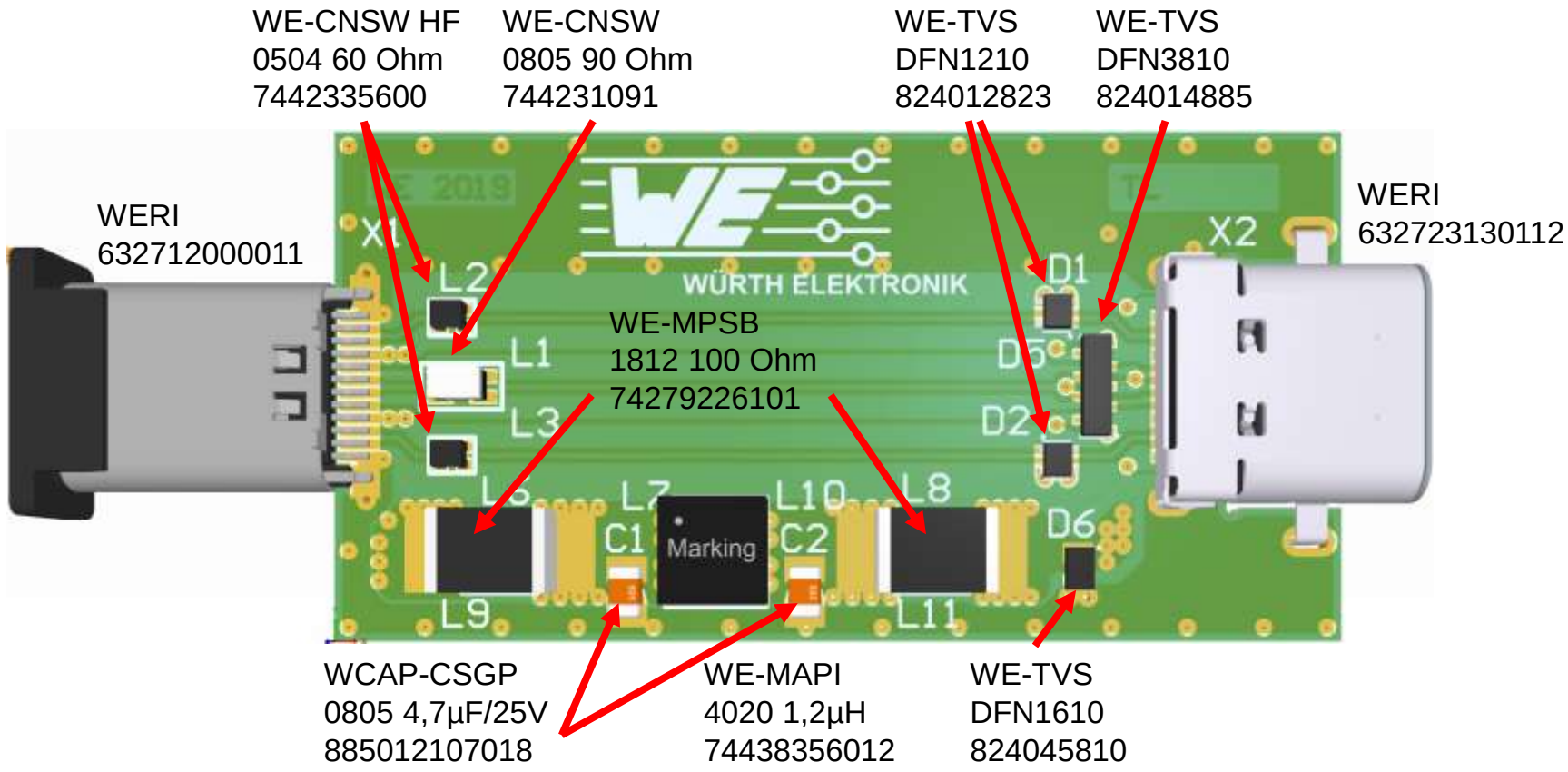
P/N 8492121

WE- EPLE CONNECTOR WITH INTEGRATED EMI & ESD





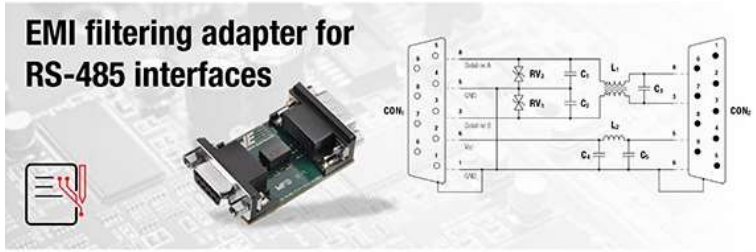
TYPE-C FILTER BOARD – OVERVIEW



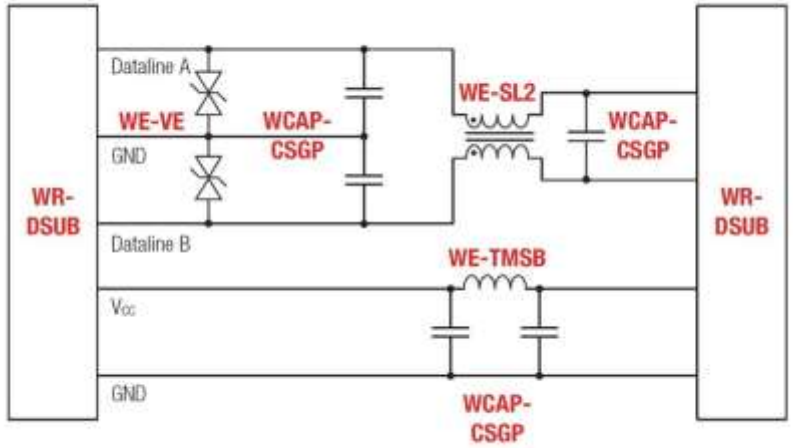
APP NOTE 007

RS-485 FILTERING

Demo Board



App Note 083

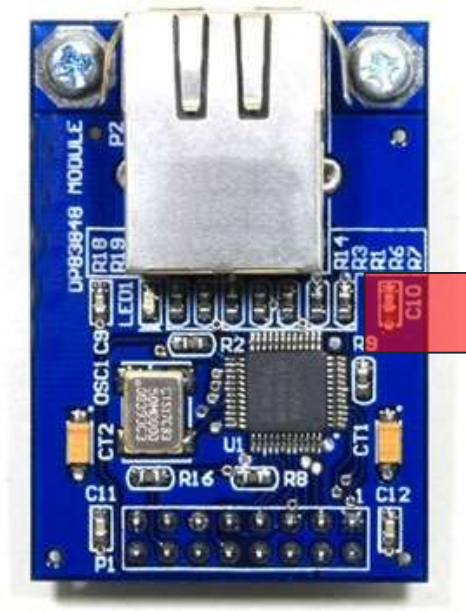


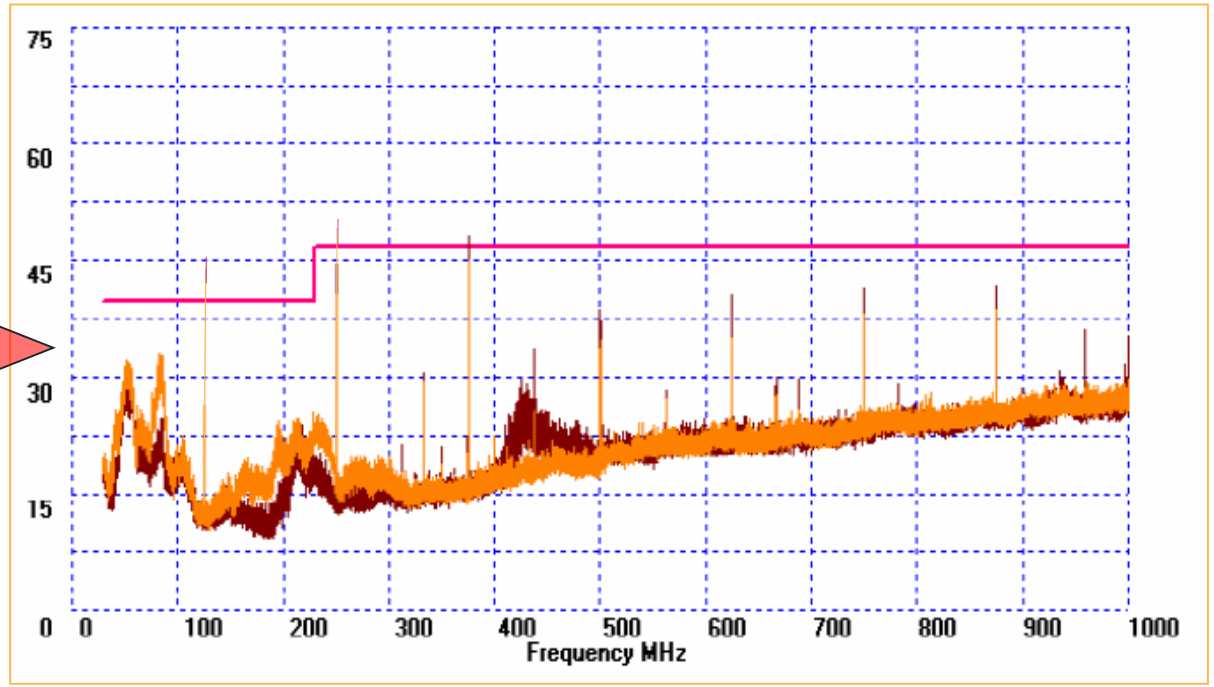
Design Bag BOM

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	823 570 505 60
Data Line	C1; C2; C3	Multilayer Ceramic Chip Capacitor C = 100 pF; VR(DC) = 10 V; NP0	WCAP-CSGP	885 012 005 013
Power Line	C4; C5	Multilayer Ceramic Chip Capacitor C = 1µF pF; VR(DC) = 6.3 V; X5R	WCAP-CSGP	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	618 009 231 121
Connector	CON2	D-SUB Male PCB Connector - 8.08 mm	WR-DSUB	618 009 231 221

HPLE WHAT IS THIS?

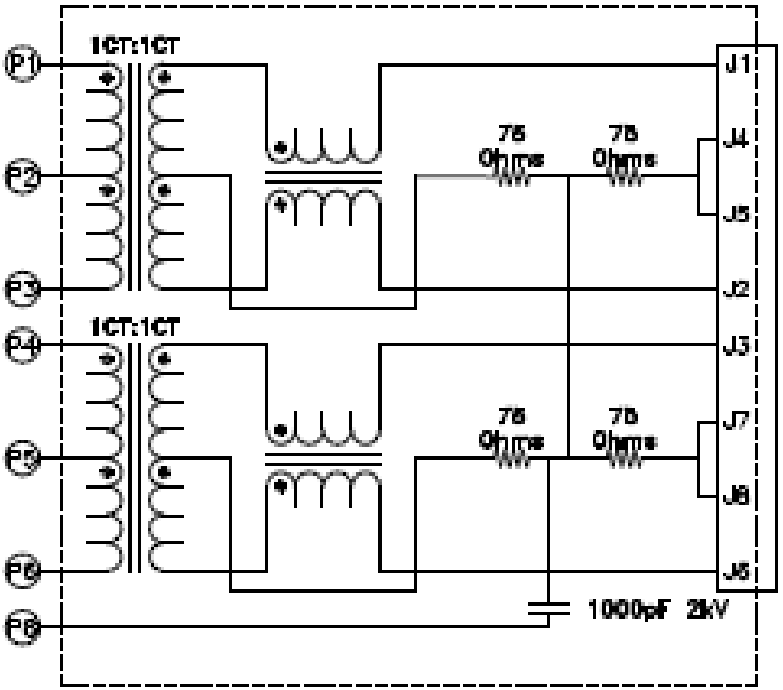
- Why do I need this?
- HPLE = High Performance Low EMI



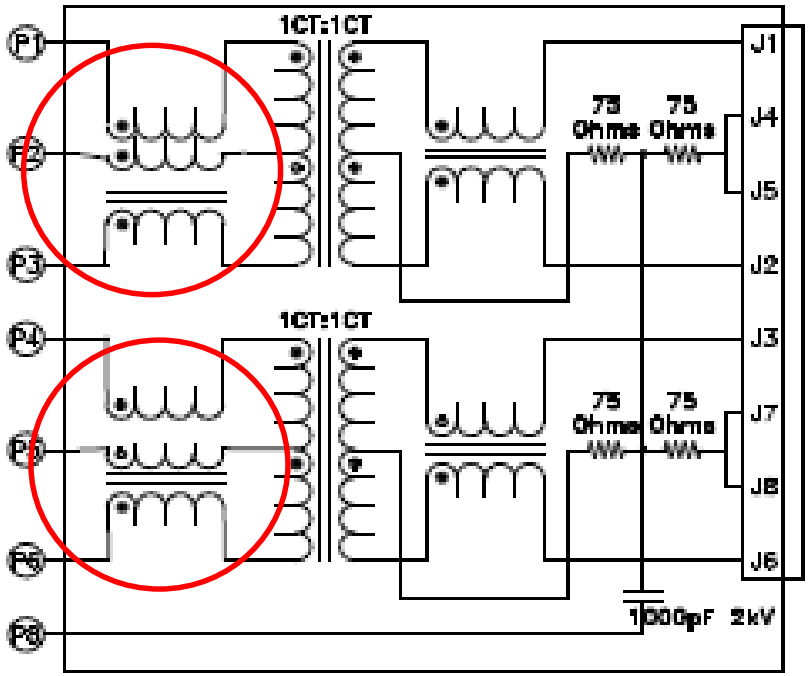


DIFFERENCE BETWEEN STANDARD AND HPLE?

Standard Integrated LAN Xfmr

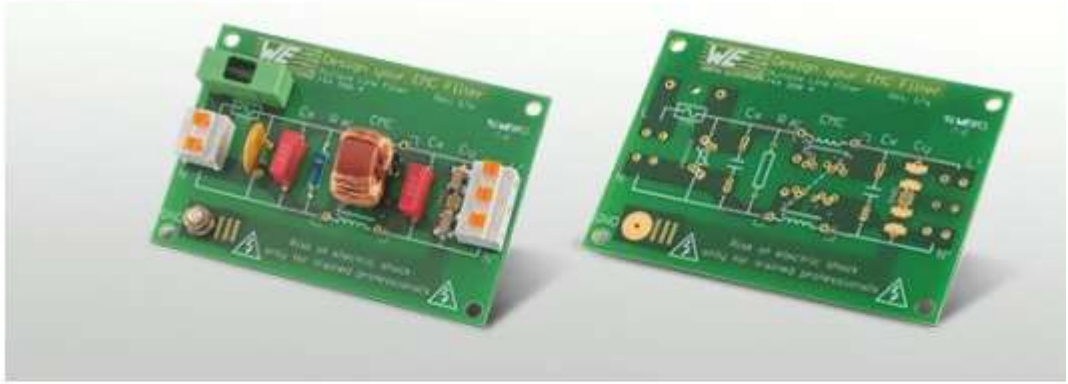


HPLE Integrated LAN Xfmr



NEW DEMONSTRATORS – DESIGN YOUR EMC FILTER

Evaluation Boards

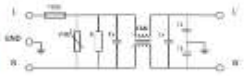


Part Number	Rated Voltage	Overvoltage Protection	Multi Pad Layout	Common Mode Attenuation	Differential Mode Attenuation
7449981	250 V (AC)	-	-	+	+
7449982	250 V (AC)	-	-	+	++
7449983	80 V (DC)	-	-	++	++
7449984	250 V (AC)	+	+	+	+

Multiple Line Filter

This Evaluation Board (744 995 4) is especially capable of handling unknown source and sink impedances and covers the following characteristics:

- Different common mode choke sizes adjustable
- Overvoltage 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-FTXI Pitch 12.5 WCAP-FTXI Pitch 15 WCAP-FTXI Pitch 22.5 WCAP-FTXX Pitch 12.5 WCAP-FTXX Pitch 15 WCAP-FTXX Pitch 22.5
Cy Y-Capacitor	WCAP-CSSA Size 2211 WCAP-CSSA Size 1812
CMC Common mode choke	WE-CMB WE-TFCH WE-SMI WE-CMBNC
L / N Input connector	WR-TBL 691411910003
L' / N' Output connector	WR-TBL 691411910003
FUSE Fuse holder	WR-FSH 696106003002
FUSE Fuse	Recommended: 5 x 20 mm to 10 A
VDR Disk Varistor	WE-VD 10 mm WE-VD 14 mm WE-VD 20 mm
GND Ground connector	WE-SMSH M3 WE-SMSH M4
Spacer	WA-SNSR 702926000
R Resistor	Recommended: 1 Megaohm

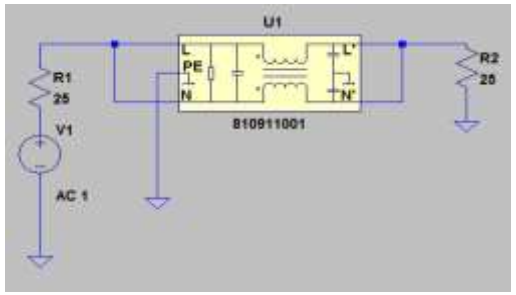
INTEGRATED MAINS FILTER: WE-CLFS

THREE TYPES

- UR: 250 V (AC/DC)
- 1-Phase Filter
- Climatic Category 25/100/21 →

(-25 to +100°C / 21 days moisture test)

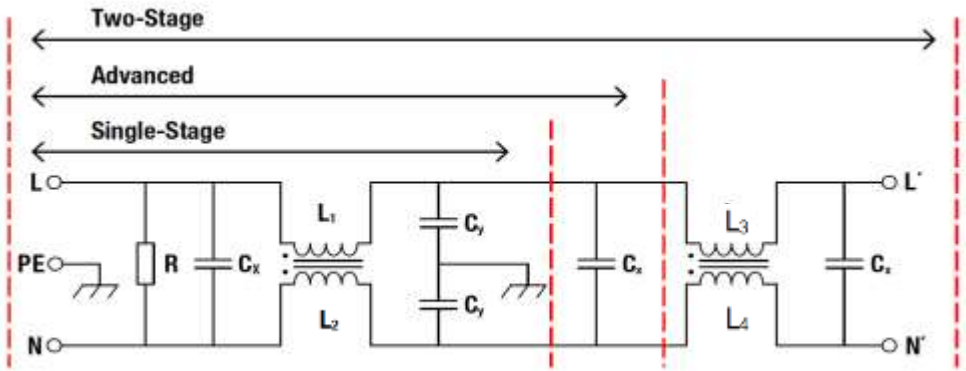
- Fast-On Terminals
- Chassis Mounting (M4)



Single-Stage

Single-Stage Advanced

Two-Stage



NEXT BIG EVENT

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

Any Questions