Alex Snijder | Field Application Engineer

VAN SIMULEREN KAN JE LEREN

WÜRTH ELEKTRONIK
MORE THAN YOU EXPECT

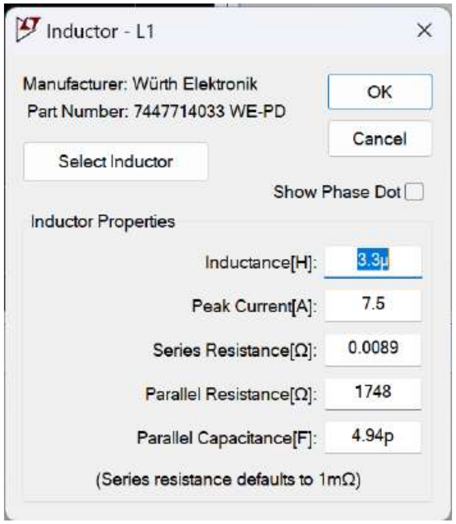
OBJECTIVE OF THIS PRESENTATION

- What does simulation mean?
- What are EDA (Electronic Design Automation) tools
- Short converter overview.
- Common EMI sources.
- Using simulation and selection tools to find the best passive components
- Summary.
- Q&A.

WHAT DOES SIMULATION MEAN

- Volgens Wikipedia (https://nl.wikipedia.org/wiki/Simulatie)
- "Een simulatie is een **nabootsing van de werkelijkheid**, in veel gevallen met behulp **van een model van die werkelijkheid**. Een simulatie is een dynamisch proces. Vanuit een **gegeven uitgangssituatie**, laat een simulatie zien hoe deze situatie verandert en zich ontwikkelt in de loop van de tijd. **Het model geeft daarbij als het ware de regels aan volgens welke deze verandering plaatsvindt."**

```
**************************************************
* Manufacturer:          Wurth Elektronik
* Kinds:                 SMT Power Inductor
* Matchcode:             WE-PD
* Library Type:          Pspice
* Version:               rev22a
* Created/modified by:   Ella
* Date and Time:         6/10/2022
* Team:                  eiSos EDA Service
* Contact:               libraries@we-online.com
**************************************************
* Copyright(C) 2022 Würth Elektronik eiSos GmbH & Co. KG
* All Rights Reserved.
**************************************************
* Disclaimer: While Würth Elektronik eiSos has made every reasonable effort to ensure the accuracy
* of the simulation models provided, Würth Elektronik eiSos does not guarantee the exemption of error on
* the simulation models, nor does Würth Elektronik eiSos guarantee that the simulation model is current.
* Würth Elektronik eiSos reserves the right to make any adjustments at any time without notice.
* Würth Elektronik eiSos expressly disclaims all implied warranties regarding this simulation model.
**************************************************
.subckt PD_1050_7447714033_3u3 1 2
Rp 1 2 1748
Cp 1 2 4.94p
Rs 1 N3 0.0089
L1 N3 2 2.946u
.ends PD_1050_7447714033_3u3
```



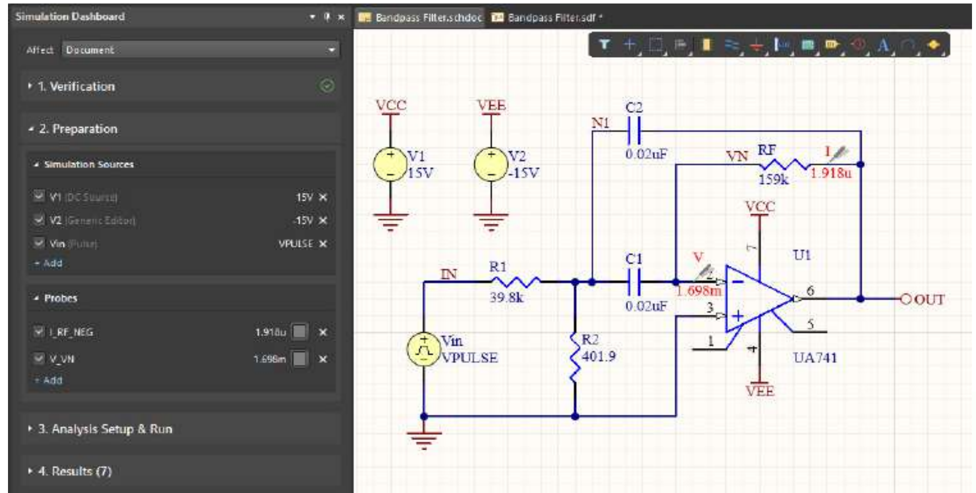
EXAMPLE OF SIMULATION TOOLS

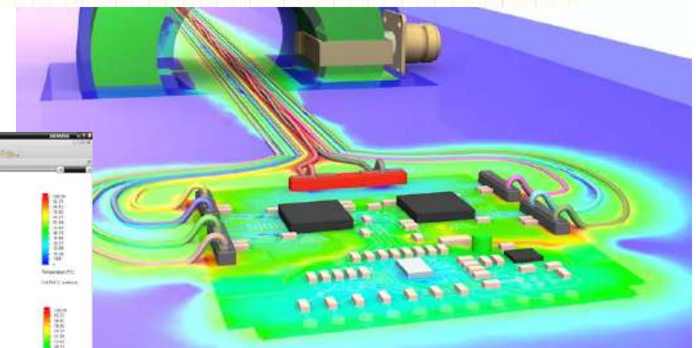
LTspice®

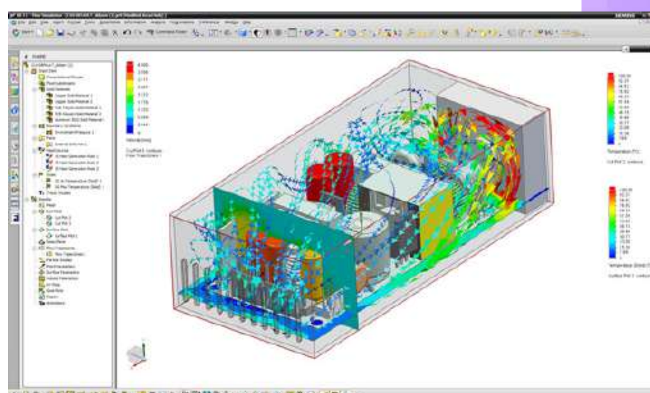
Ansys

ELECTRONIC DESIGN AUTOMATION
Siemens EDA

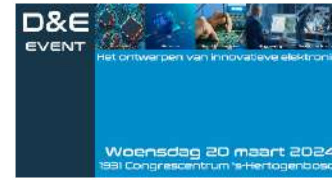
REDEXPERT®

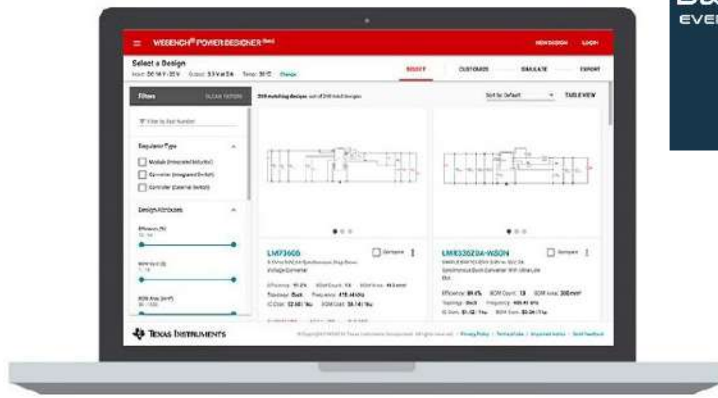




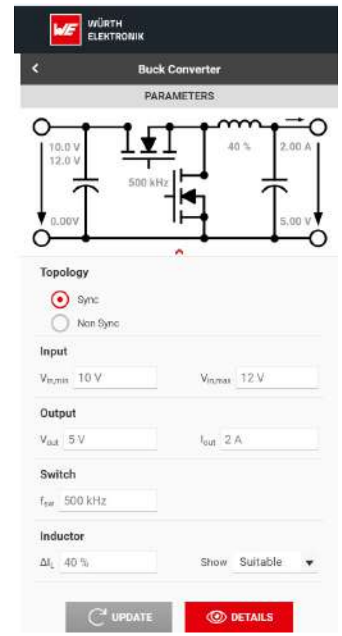


DESIGN TOOLS



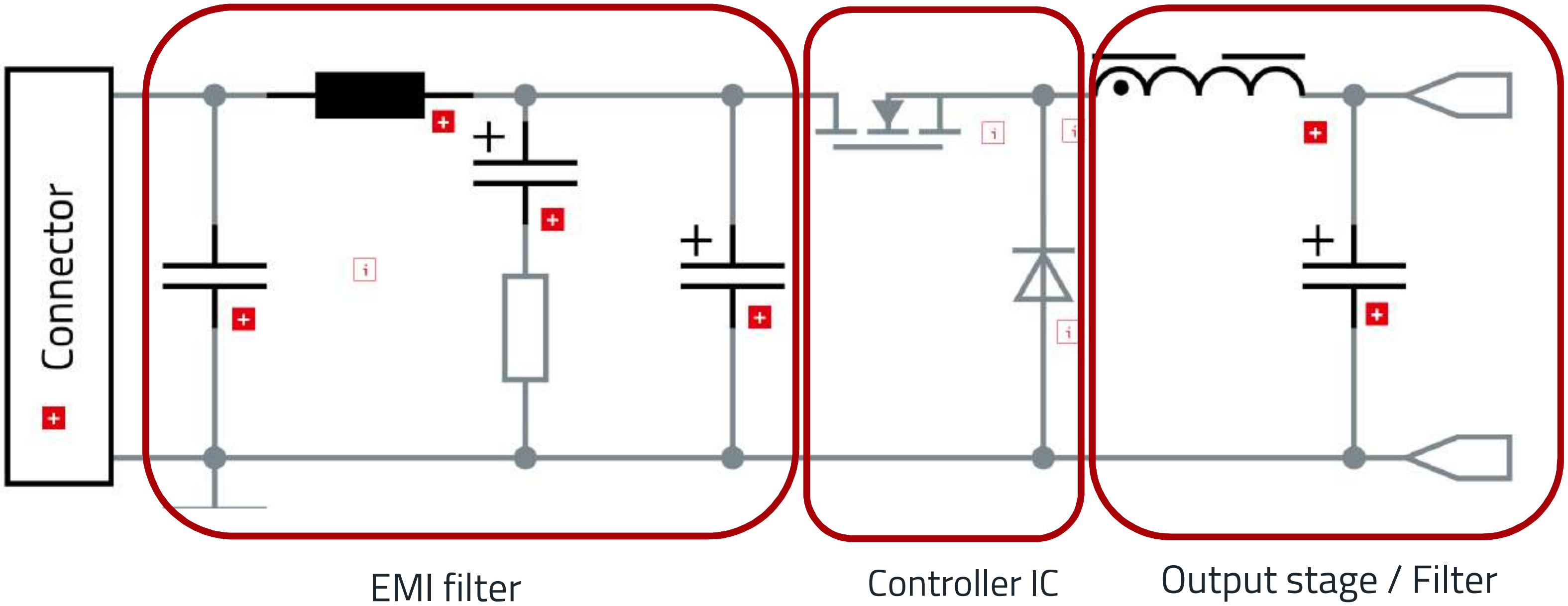


- Electronic design automation tools exist in many forms and
- Some examples
  - Altium design for PCB design
  - Siemens Capital harness designer for cable assemblies
  - Cadence Virtuoso Studio for analog and digital IC design
  - ……
- Other examples are IC and passive manufacture design tools
  - Usually free of charge
  - Focuses on a specific function or application
- Some examples
  - Texas Instruments WEBENCH®
  - Analog devices LTpowerCAD®
  - Infinion PowerEsim
  - Onsemi Webdesigner+
  - Würth Elektronik REDEXPERT
  - ……



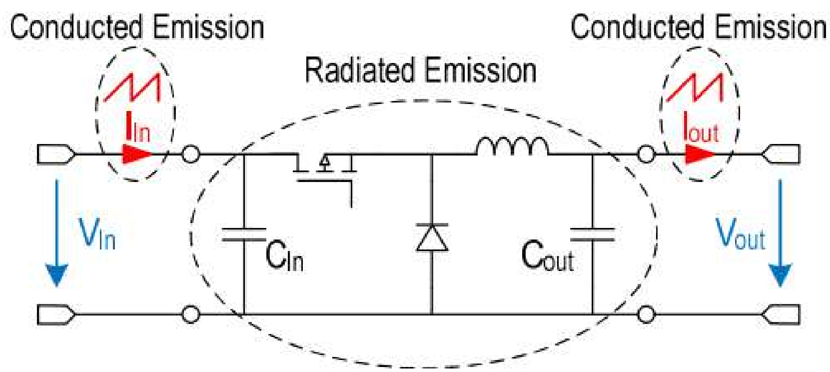
APPLICATION EXAMPLE

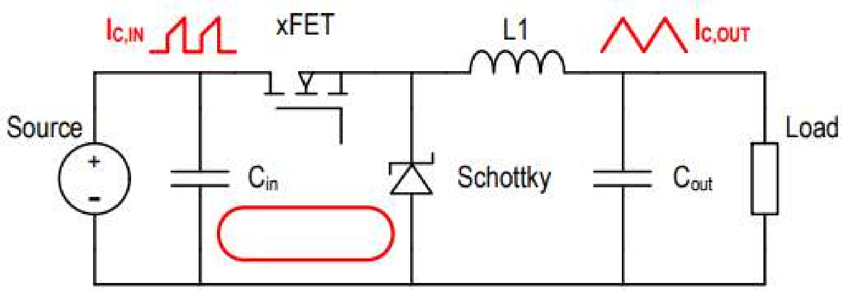
Buck converter



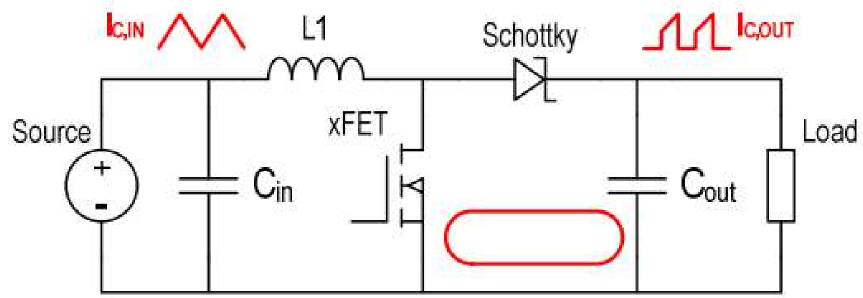
EMI SOURCE

Potential sources for conducted and radiated emission





critical current loop buck converter



critical current loop boost converter

SPECIFICATION TO DESIGN A SMPS

Electrical

- Input, output Voltage
  - Lo, nom, hi
- Output ripple voltage
  - Acceptable level to the load
- Input, output current
  - Lo, nom, hi, Short Circuit
- Line frequency
  - Holdup time (power Line disturbance)
- Dynamic load response time
- Line regulation
- Load regulation
- Overall efficiency
- …

Environment

- Operating Temp
- Ambient Temp
- Storage Temp
- Enclosure consideration
- Thermal management
- Safety regulatory
- EMI /RFI
- Surge
- Protection
- Fuses, OVP, ULVO,..
- …..

Other

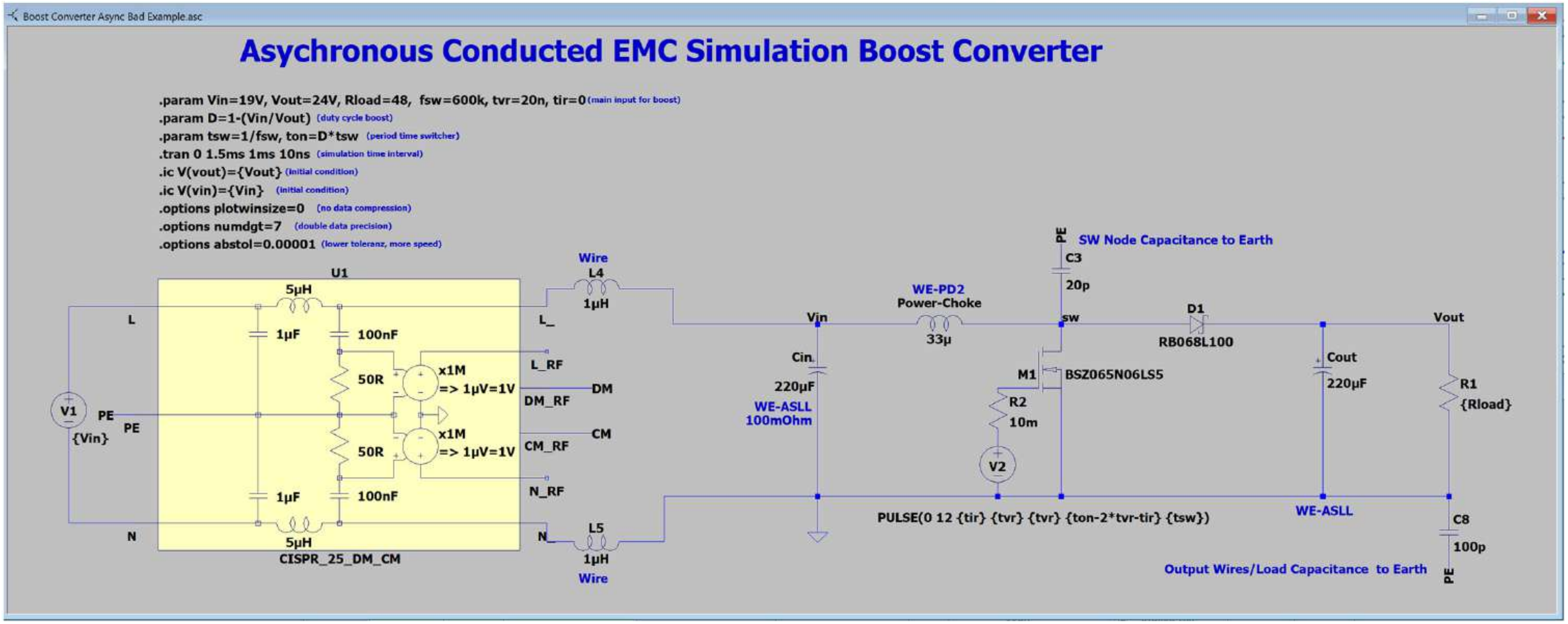
- Life time

e.g 5 years 8H/day=14600H

- MTBF
- Failure mode
- ….

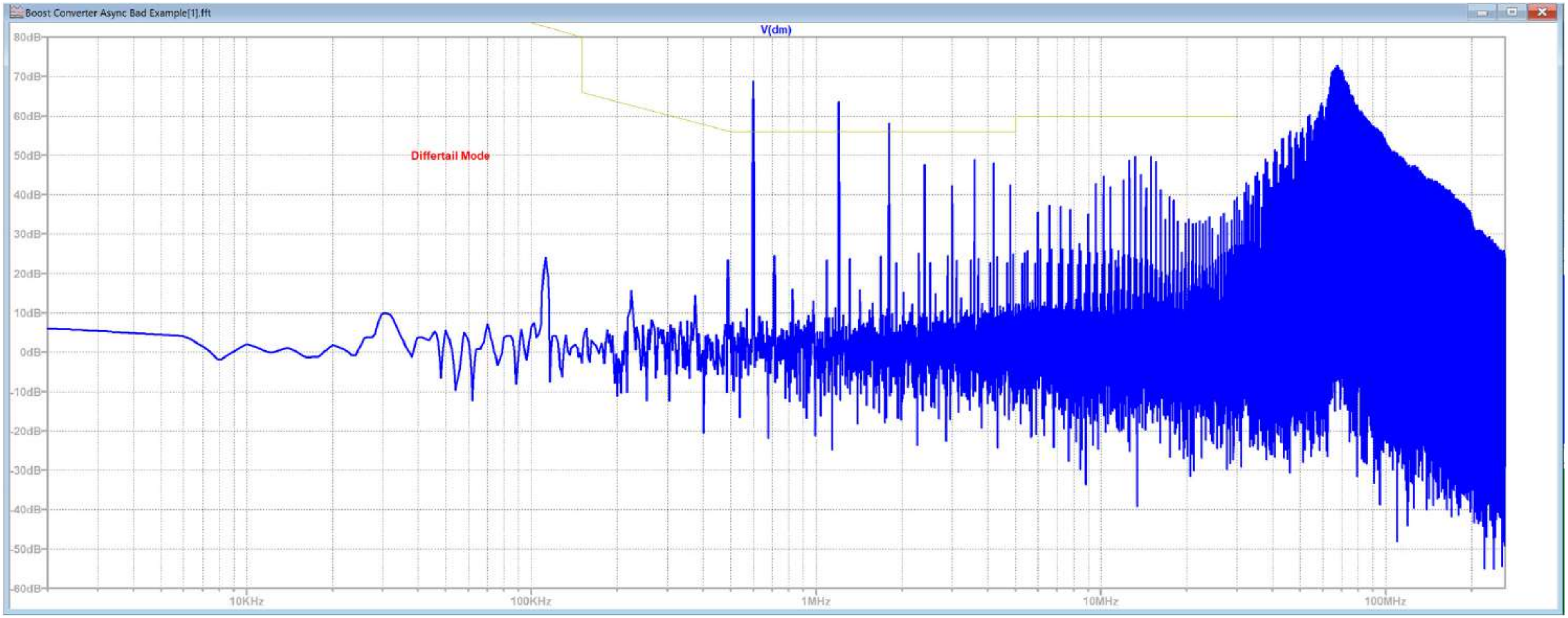
EXAMPLE OF SIMULATION

Boost converter



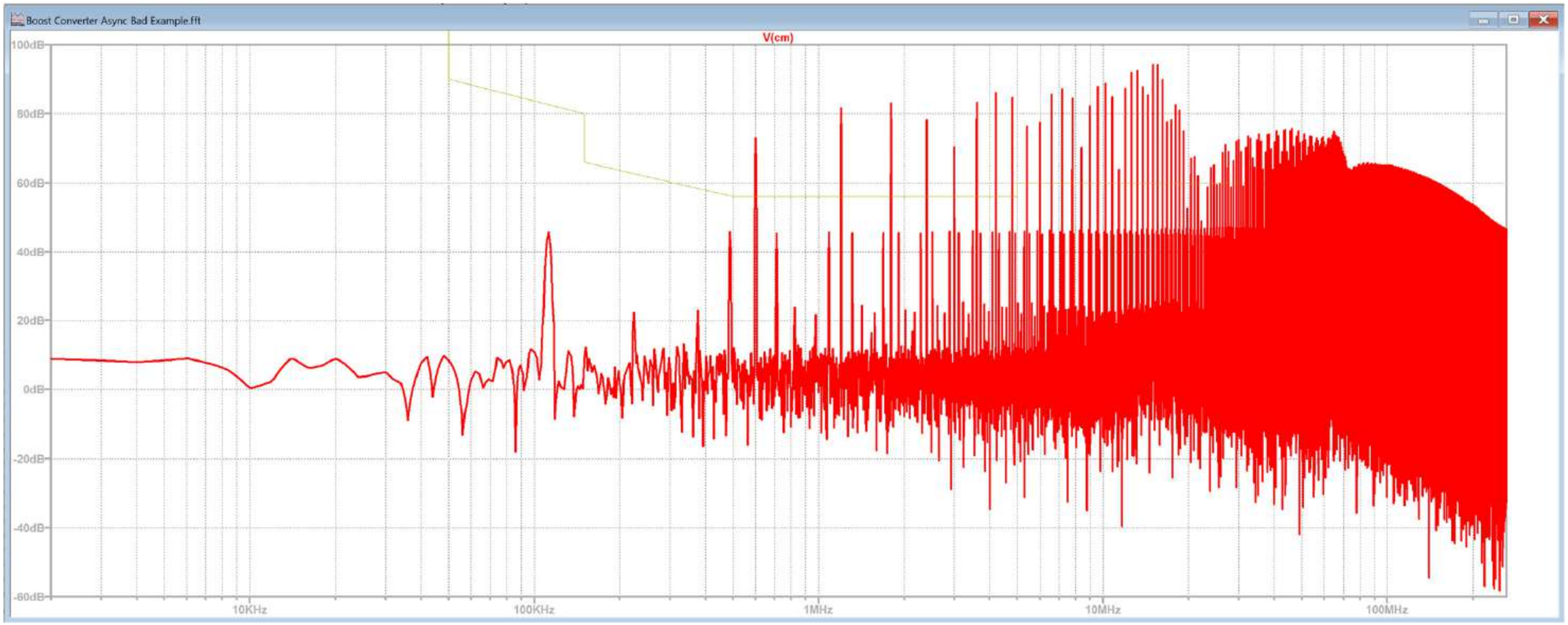
FFT ANALIST

Differential mode noises

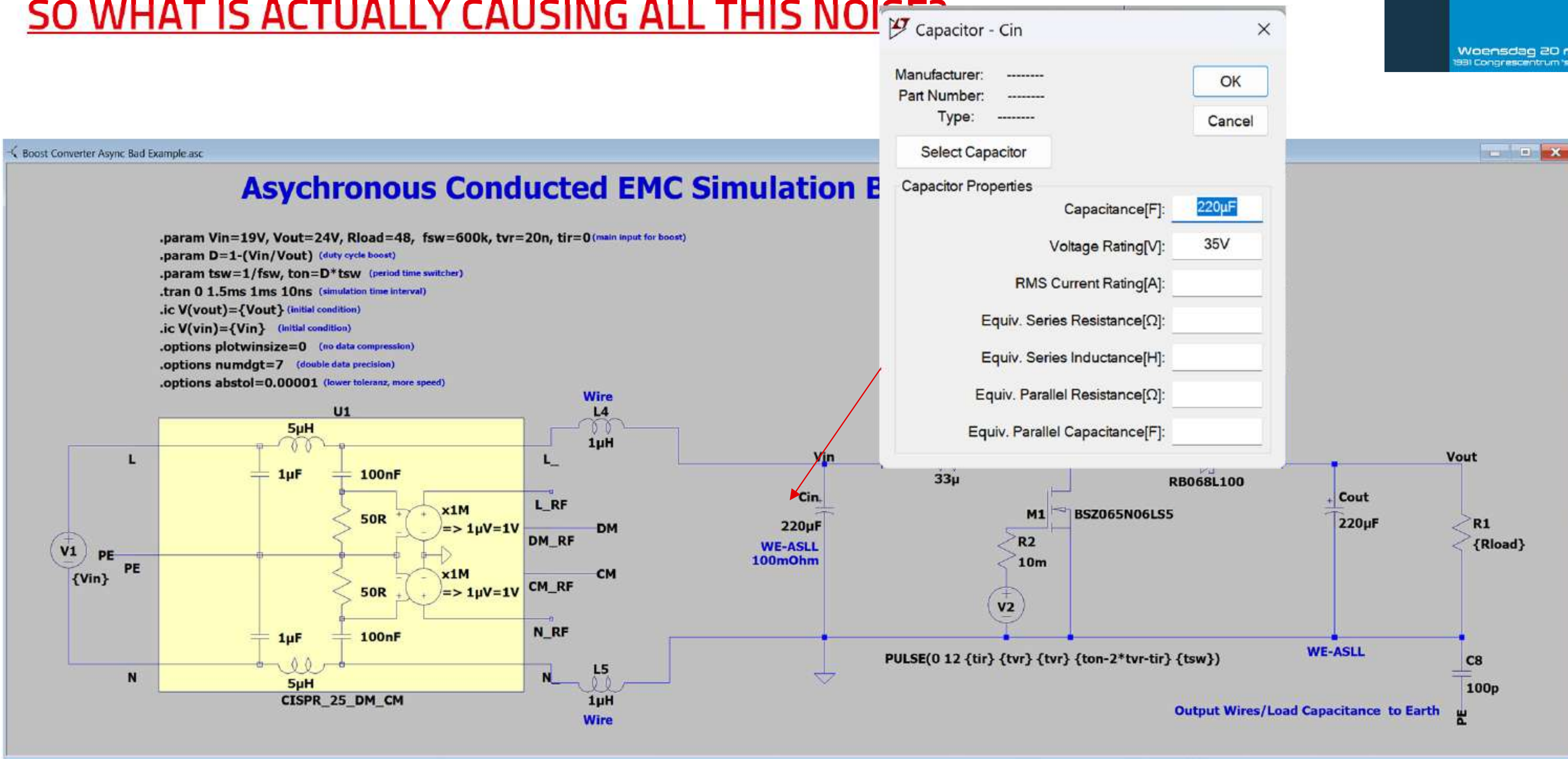


FFT ANALIST

Common mode noise



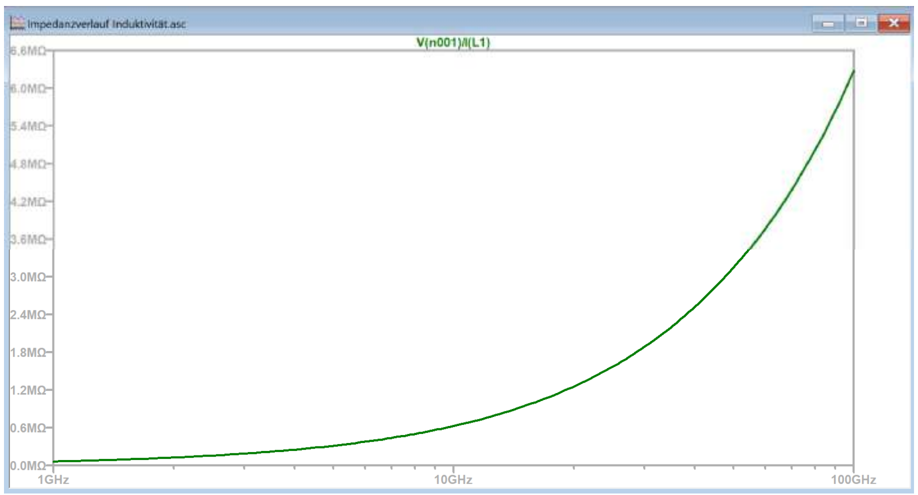
SO WHAT IS ACTUALLY CAUSING ALL THIS NOI



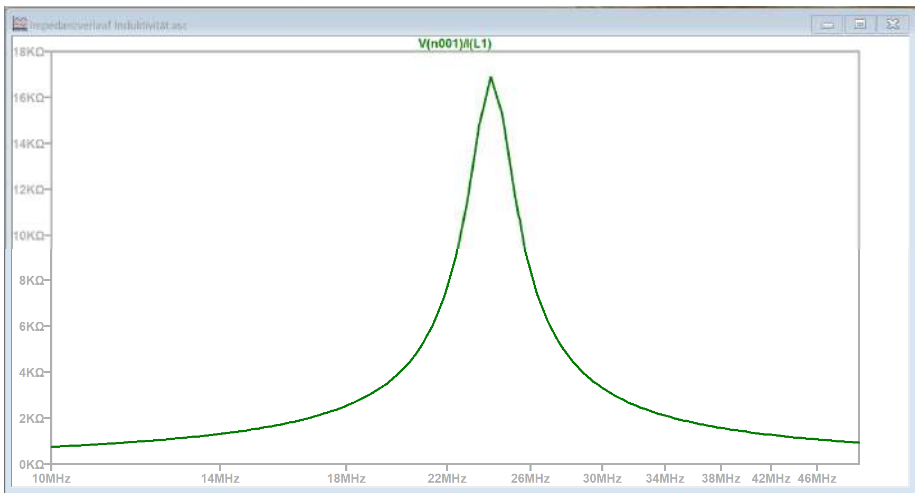
IDEAL COMPONENT VS. REAL COMPONENT

Impedance of an inductor (Z over frequency)

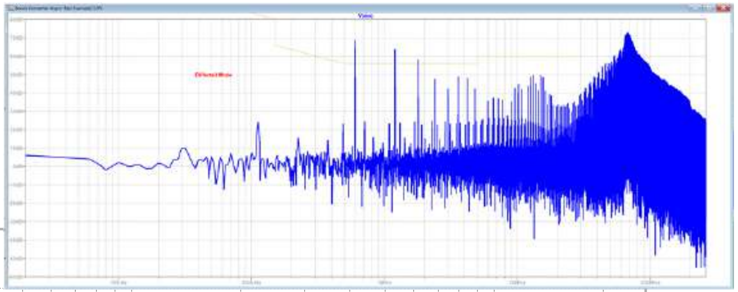
Ideal behavior of an inductor

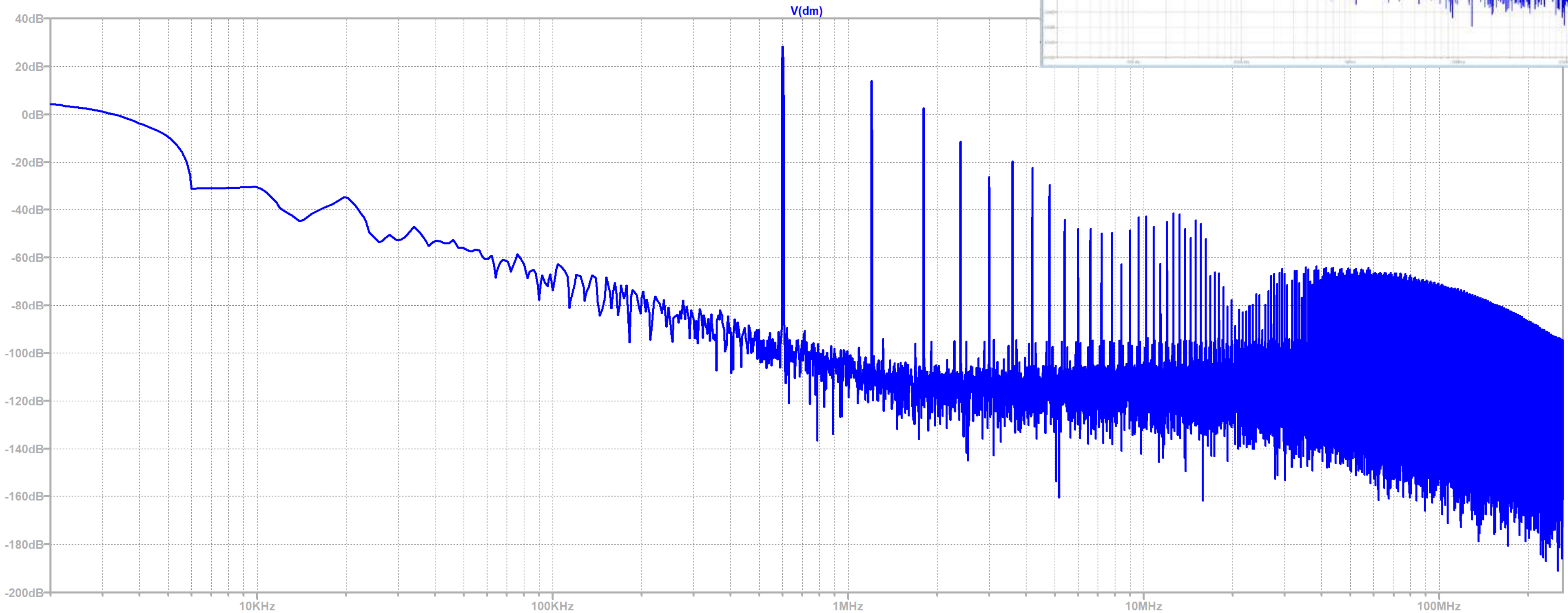


Real behavior of an inductor

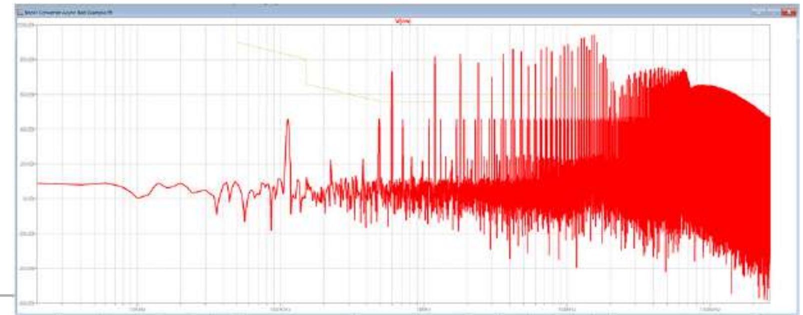


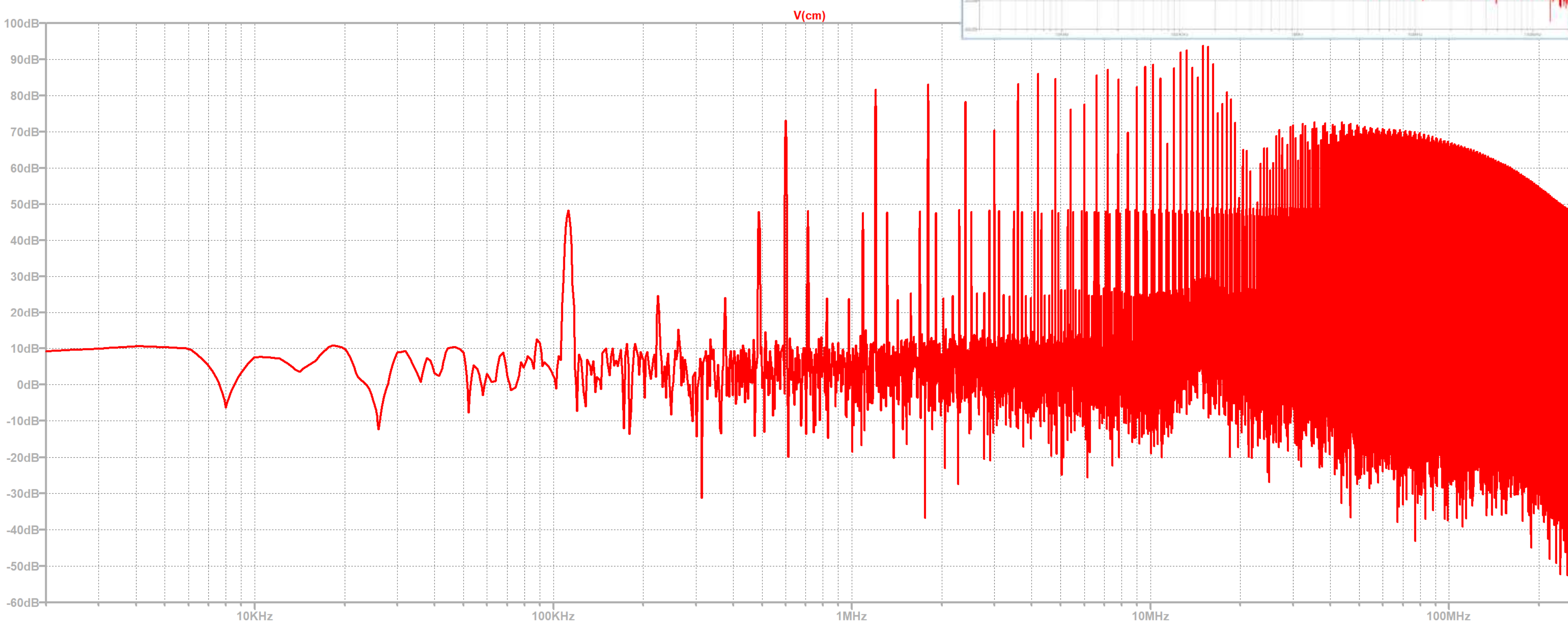
DIFFERENTIAL MODE NOISE





EFFECTS ON COMMON MODE NOISES





INPUT CAPACITOR

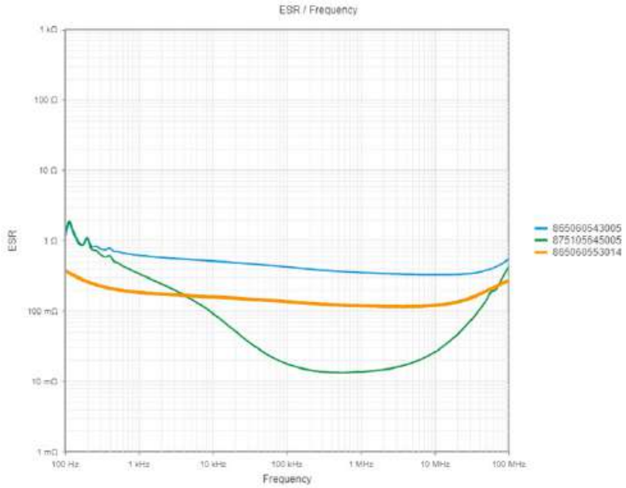
Using REDEXPERT

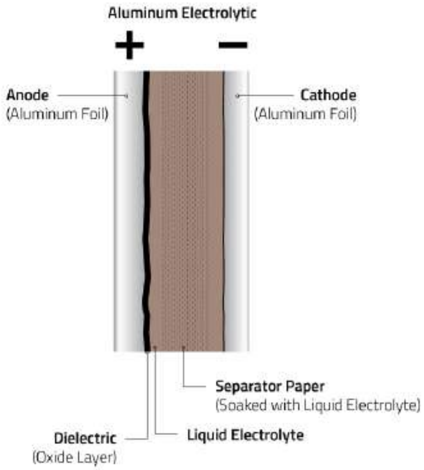
WÜRTH ELEKTRONIK — REDEXPERT Aluminum Electrolytic / Aluminum Polymer Capacitors

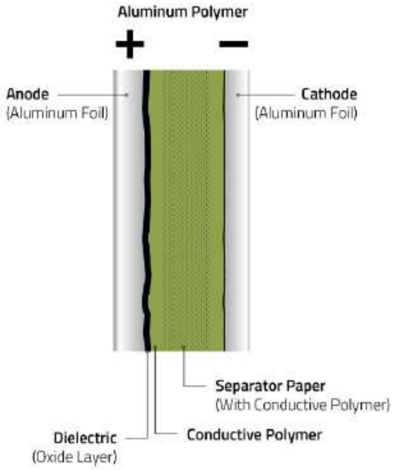
Filters: 47.0 µF ≤ C ≤ 220 µF | 35.0 V ≤ V_R ≤ 35.0 V | Not Internal | Assembling Technology = SMT | Series = WCAP-ASLL, WCAP-PSLP | Is selected

Lifetime Calculator

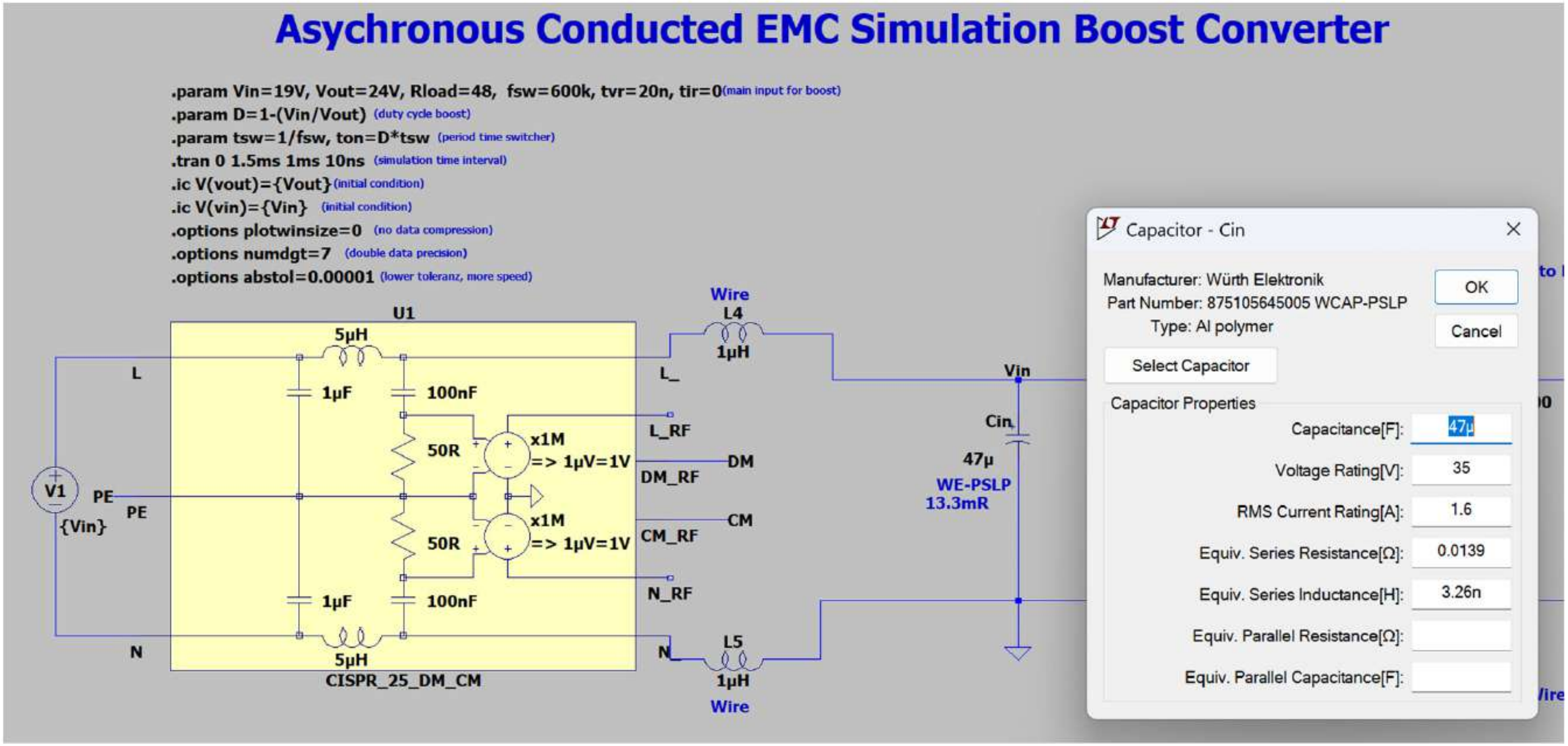
	Order Code	Series	Spec		Technology	ESR @600 ...	C	I@20°C @600 ...	V_R	L_s	R_s	DF	Lifetime	To...	I_{leak}	T_{min}	T_{max}
✔	865060543005	WCAP-ASLL			Alum. Electrolytic	360 mΩ	47.0 µF	240 mA	35.0 V	2.75 nH	320 mΩ	< 14 %	2000.0 h	±20%	16.4 µA	-55°C	105°C
✔	875105645005	WCAP-PSLP			Alum. Polymer	13.3 mΩ	47.0 µF	1.60 A	35.0 V	3.26 nH	13.9 mΩ	< 12 %	2000.0 h	±20%	600 µA	-55°C	105°C
✔	865060553014	WCAP-ASLL			Alum. Electrolytic	120 mΩ	220 µF	590 mA	35.0 V	550 pH	120 mΩ	< 14 %	5000.0 h	±20%	77.0 µA	-40°C	105°C



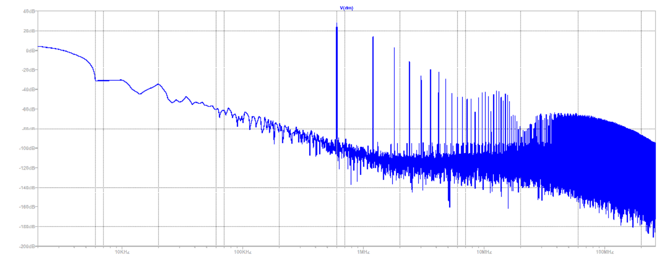


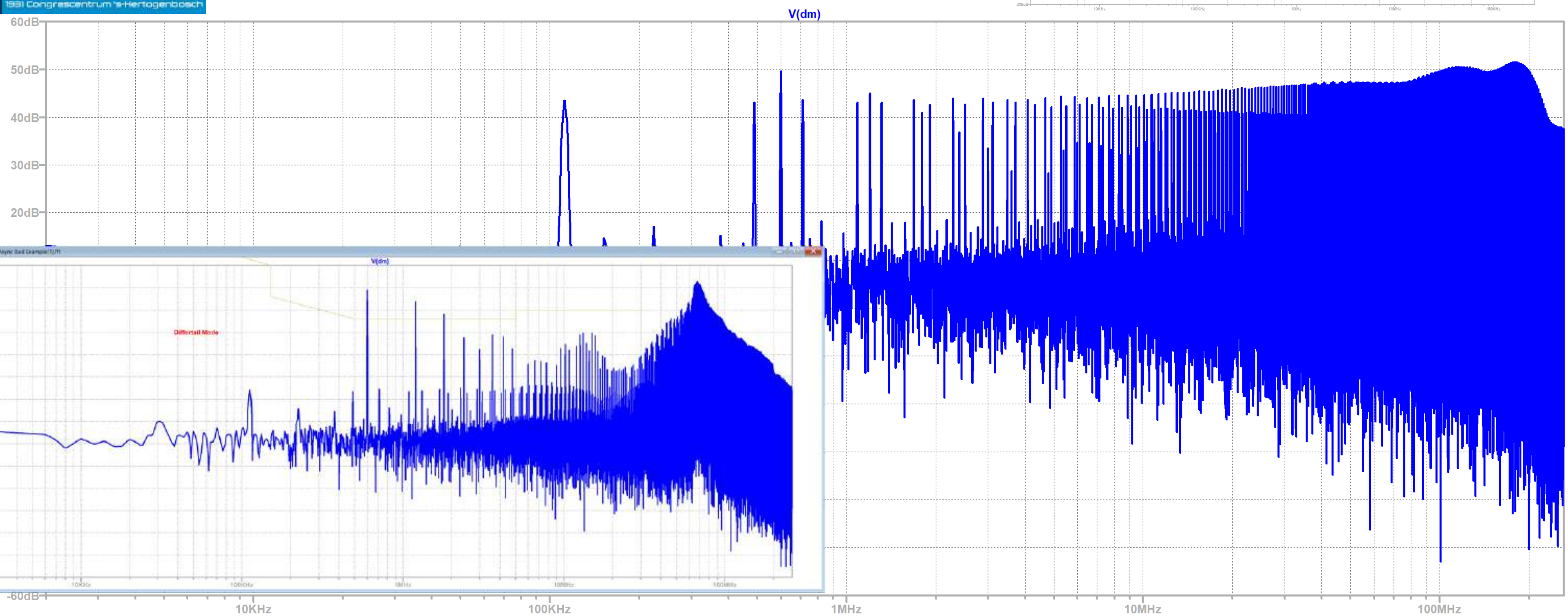


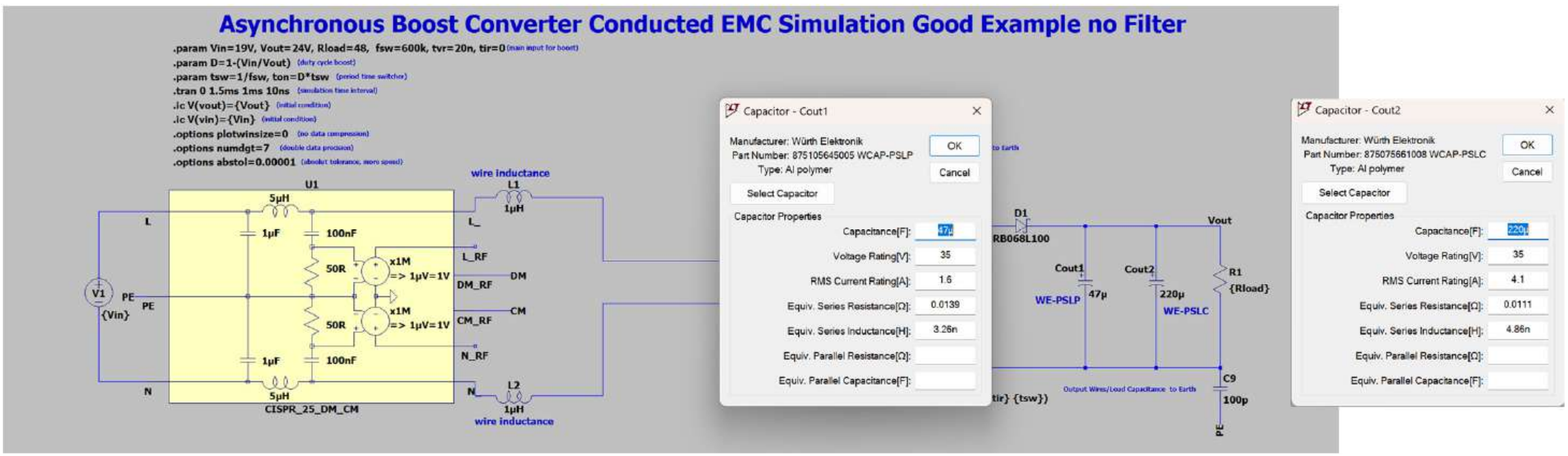
UPDATE OUR SIMULATION



DIFFERENTIAL MODE SIMUALTION

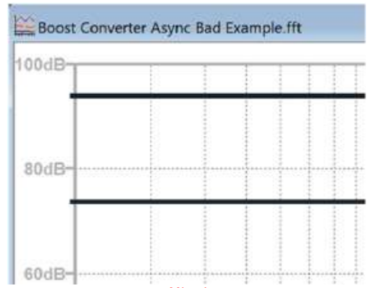


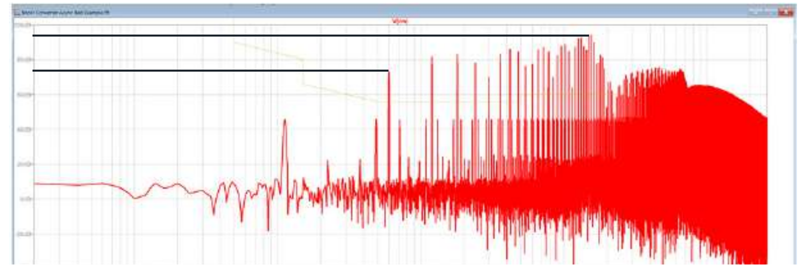


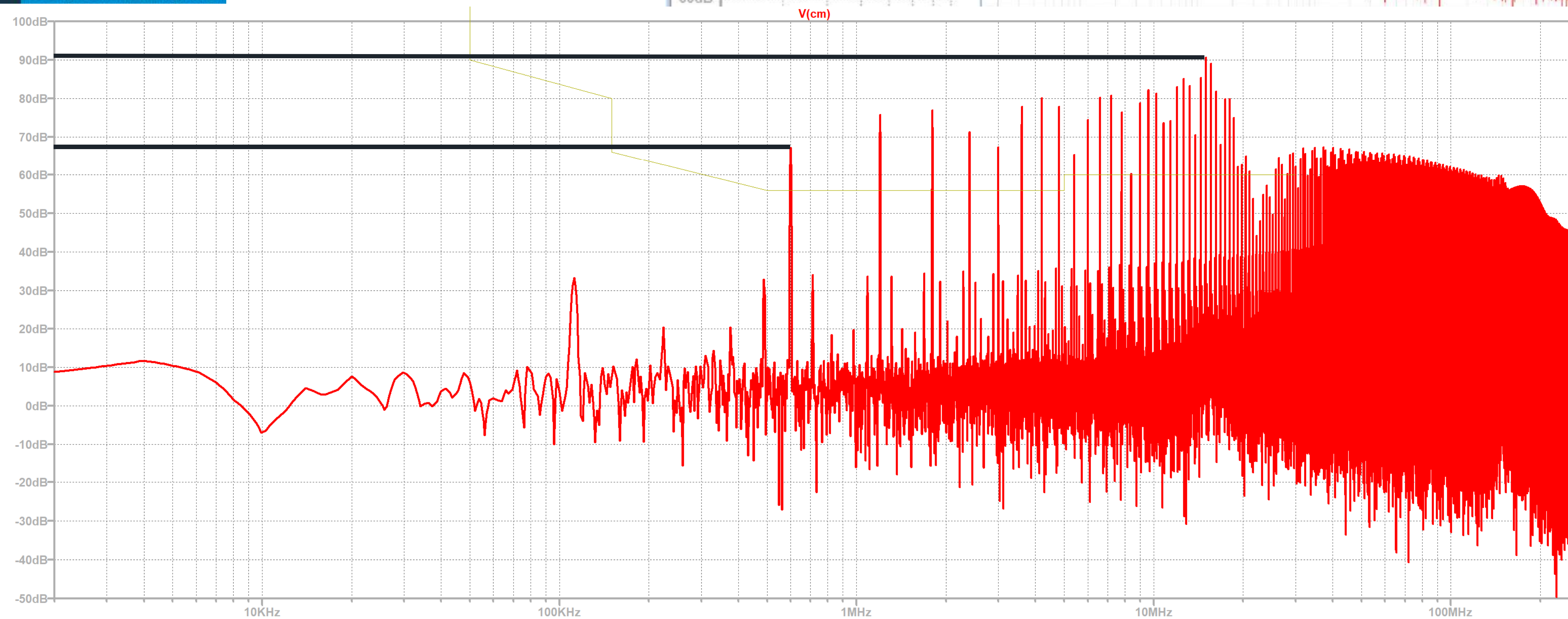


Asynchronous Boost Converter Conducted EMC Simulation Good Example no Filter
.param Vin=19V, Vout=24V, Rload=48, fsw=600k, tvr=20n, tir=0 (main input for boost)
.param D=1-(Vin/Vout) (duty cycle boost)
.param tsw=1/fsw, ton=D*tsw (period time switcher)
.tran 0 1.5ms 1ms 10ns (simulation time interval)
.ic V(vout)={Vout} (initial condition)
.ic V(vin)={Vin} (initial condition)
.options plotwinsize=0 (no data compression)
.options numdgt=7 (double data precision)
.options abstol=0.00001 (absolut tolerance, more speed)
wire inductance
L1
1µH
L2
1µH
wire inductance
U1
5µH
1µF
100nF
50R
x1M
=> 1µV=1V
50R
x1M
=> 1µV=1V
1µF
100nF
5µH
CISPR_25_DM_CM
L
PE
N
V1
{Vin}
L_
L_RF
DM_RF
DM
CM_RF
CM
N_RF
N
D1
RB068L100
Vout
Cout1
47µ
WE-PSLP
Cout2
220µ
WE-PSLC
R1
{Rload}
C9
100p
PE
tir} {tsw})
Output Wires/Load Capacitance to Earth
Capacitor - Cout1
Manufacturer: Würth Elektronik
Part Number: 875105645005 WCAP-PSLP
Type: Al polymer
OK
Cancel
Select Capacitor
Capacitor Properties
Capacitance[F]: 47µ
Voltage Rating[V]: 35
RMS Current Rating[A]: 1.6
Equiv. Series Resistance[Ω]: 0.0139
Equiv. Series Inductance[H]: 3.26n
Equiv. Parallel Resistance[Ω]:
Equiv. Parallel Capacitance[F]:
Capacitor - Cout2
Manufacturer: Würth Elektronik
Part Number: 875075661008 WCAP-PSLC
Type: Al polymer
OK
Cancel
Select Capacitor
Capacitor Properties
Capacitance[F]: 220µ
Voltage Rating[V]: 35
RMS Current Rating[A]: 4.1
Equiv. Series Resistance[Ω]: 0.0111
Equiv. Series Inductance[H]: 4.86n
Equiv. Parallel Resistance[Ω]:
Equiv. Parallel Capacitance[F]:

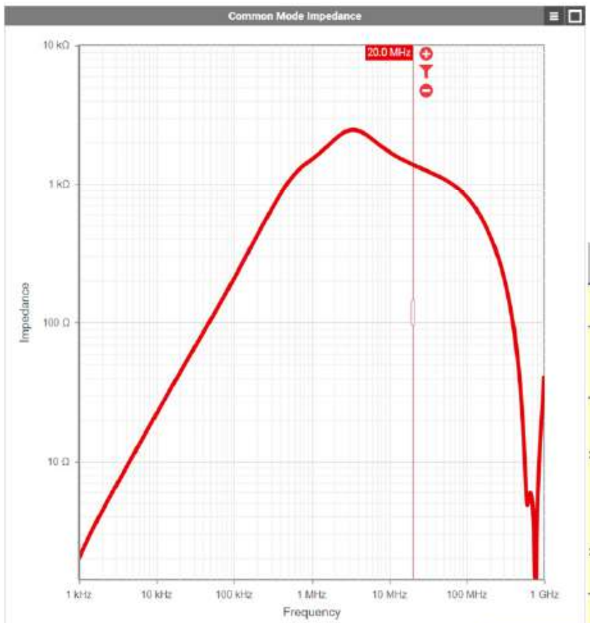
COMMON MODE EFFECTS

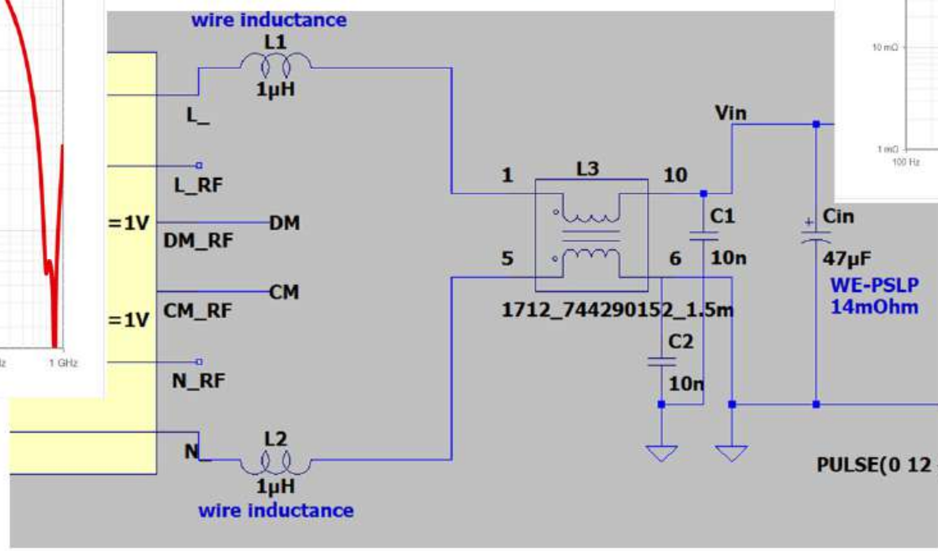


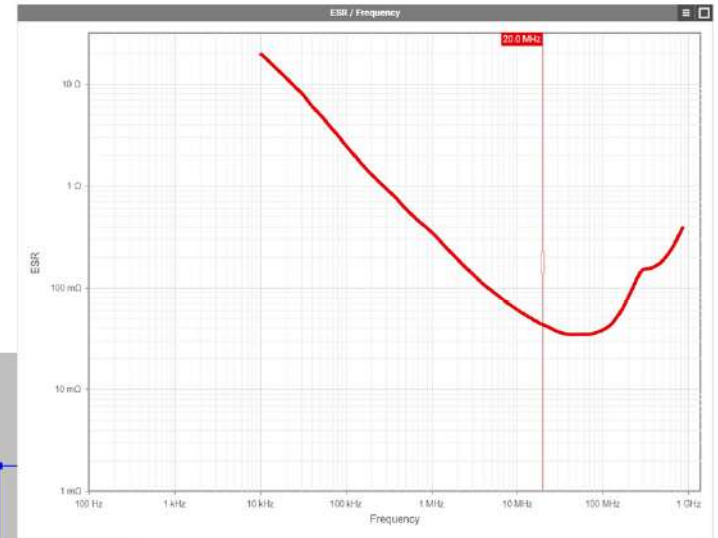




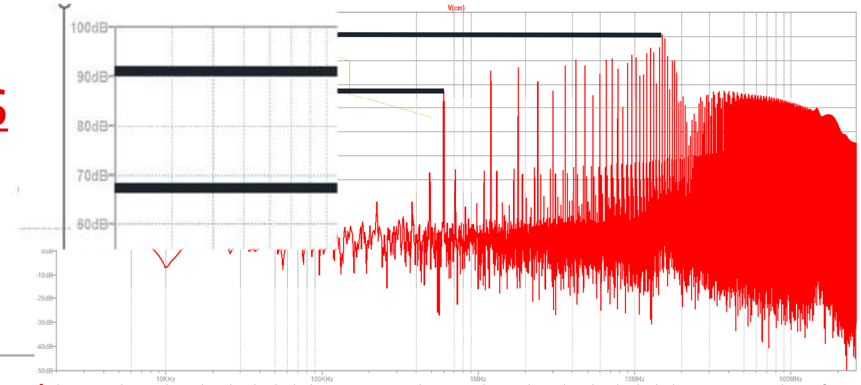
ADDING AN COMMON MODE CHOKE AND CAPS

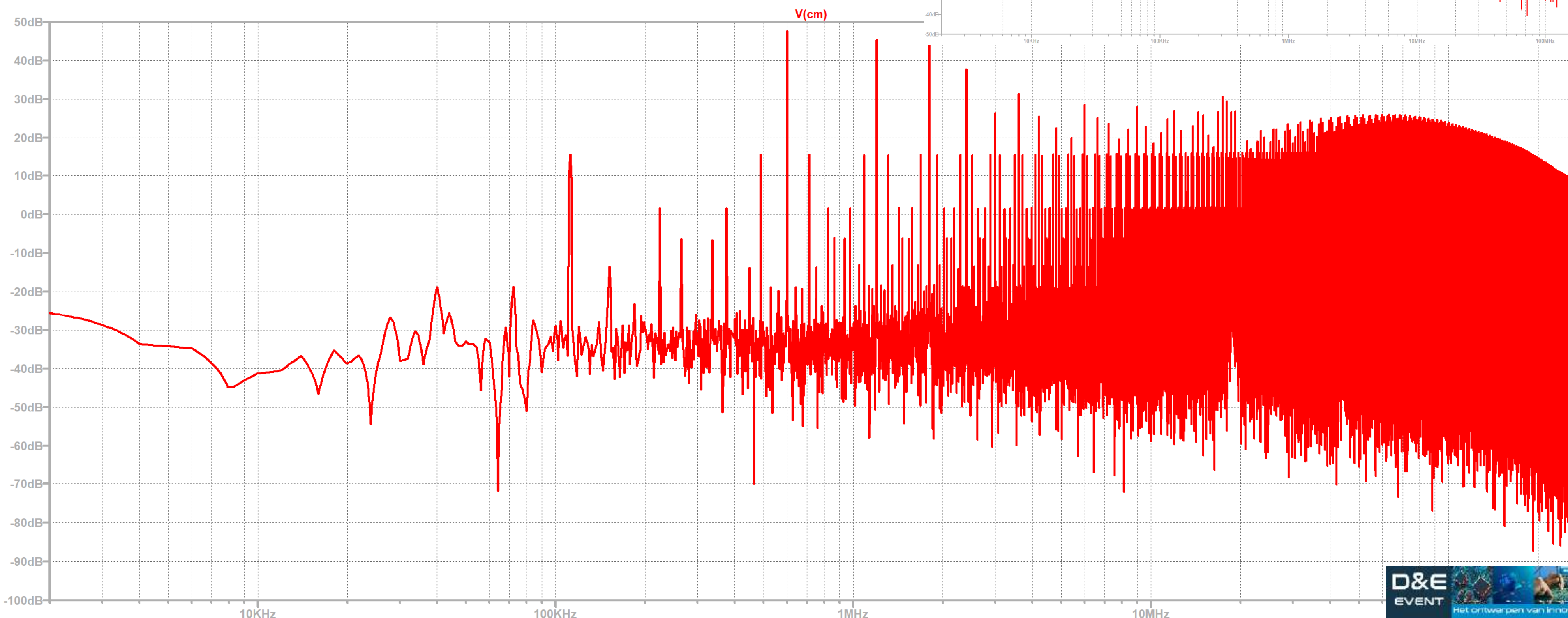


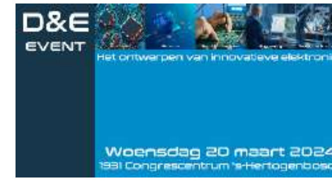




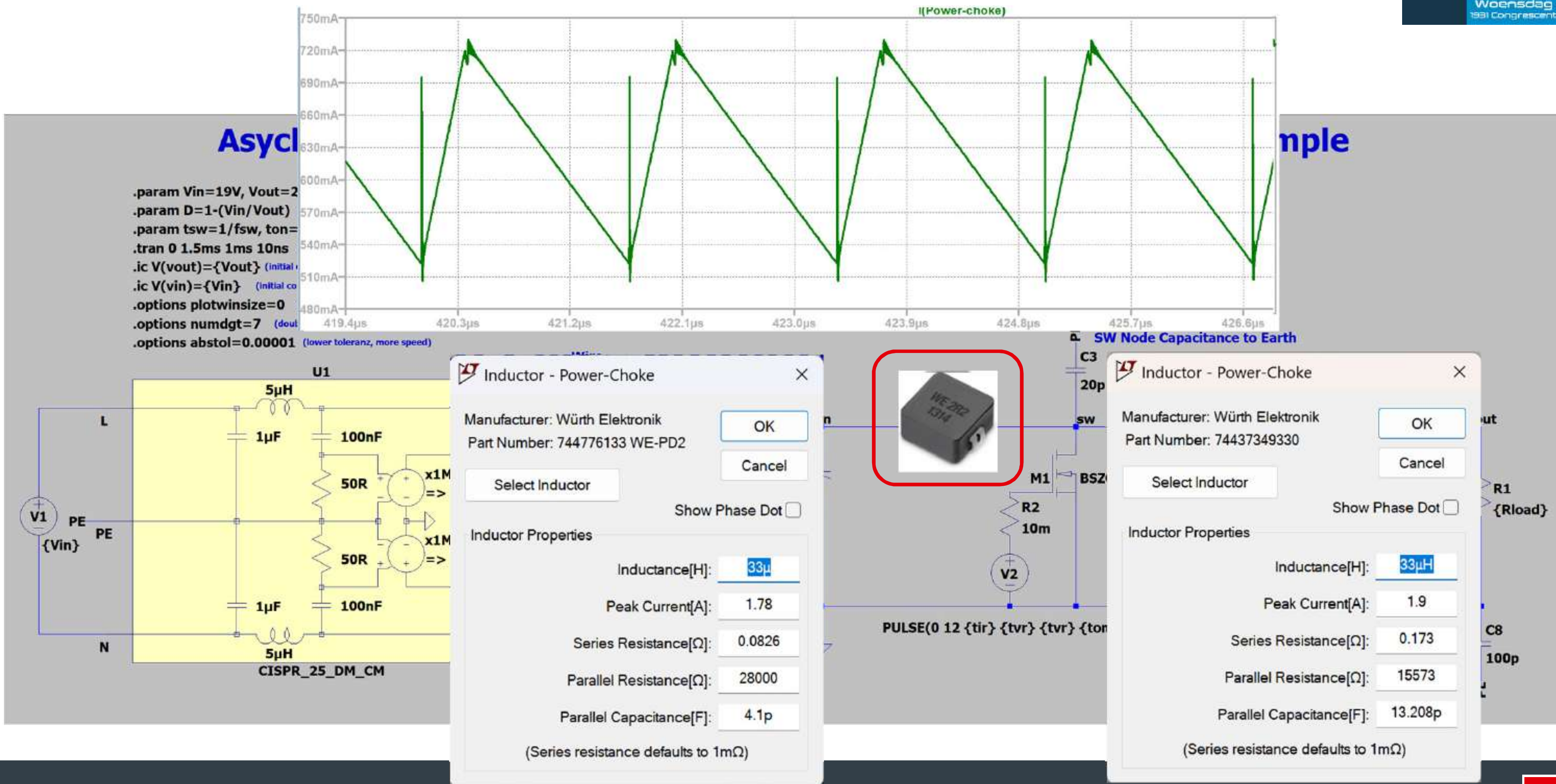
ADDING AN COMMON MODE CHOKE AND CAPS





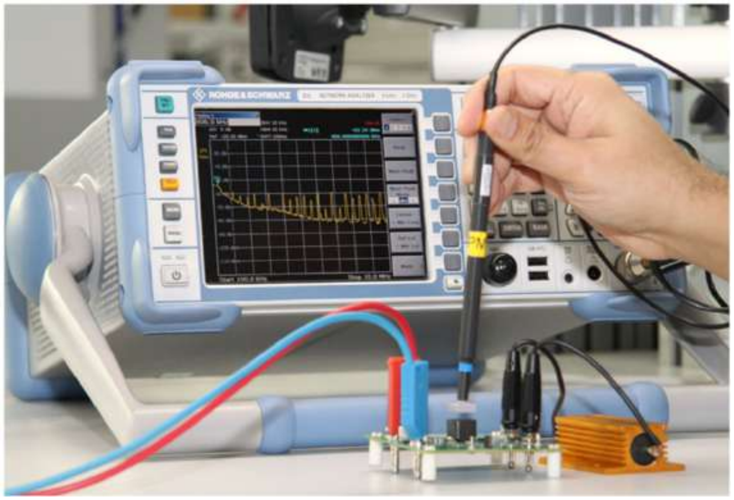


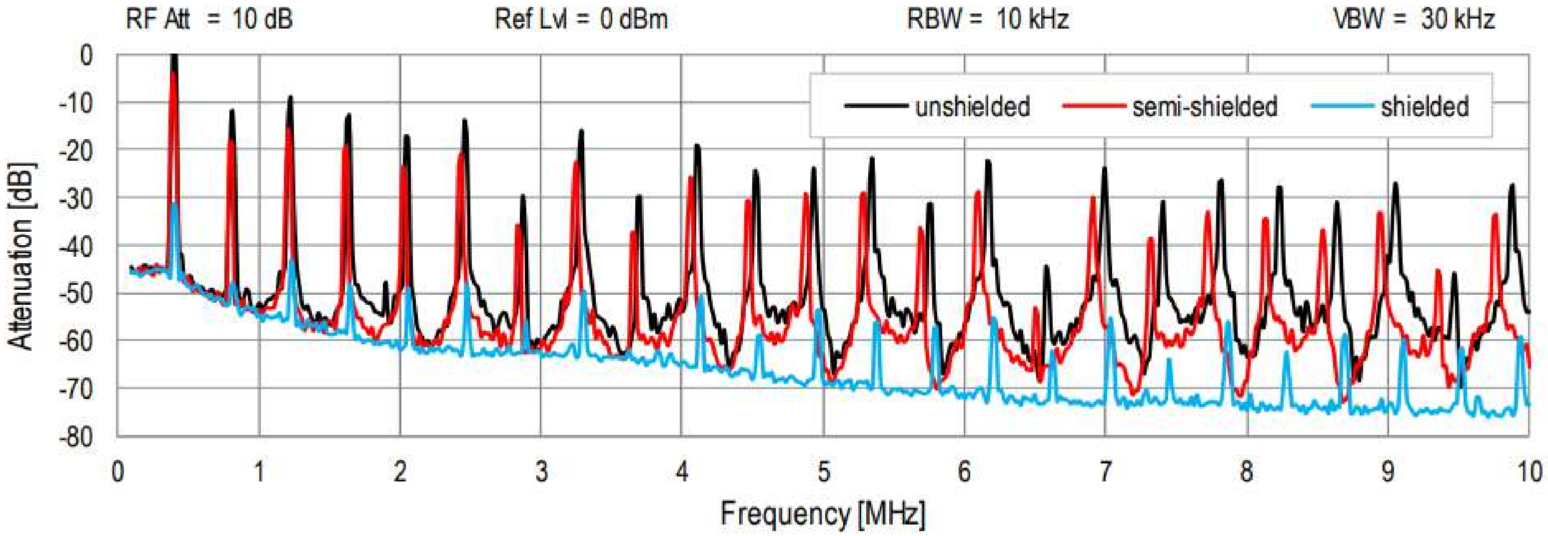
NOW LETS LOOK AT THE INDUCTOR



RADIATED H-FIELD

Different shielding types

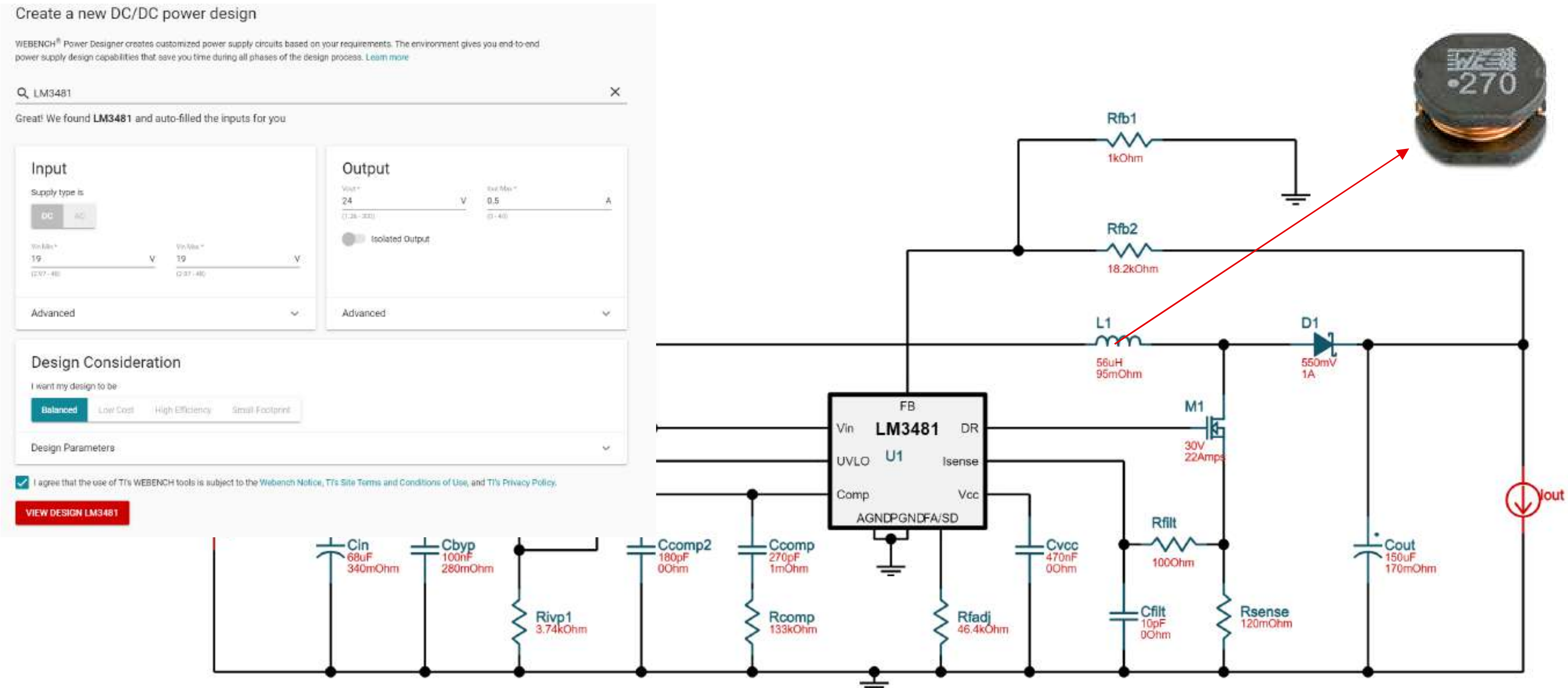




ANP047

TEXAS INSTRUMENTS DESIGN TOOL

WEBENCH® POWER DESIGNER results

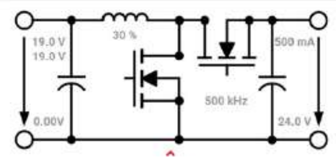


INDUCTOR SELECTION

WÜRTH ELEKTRONIK — REDEXPERT Power Inductors

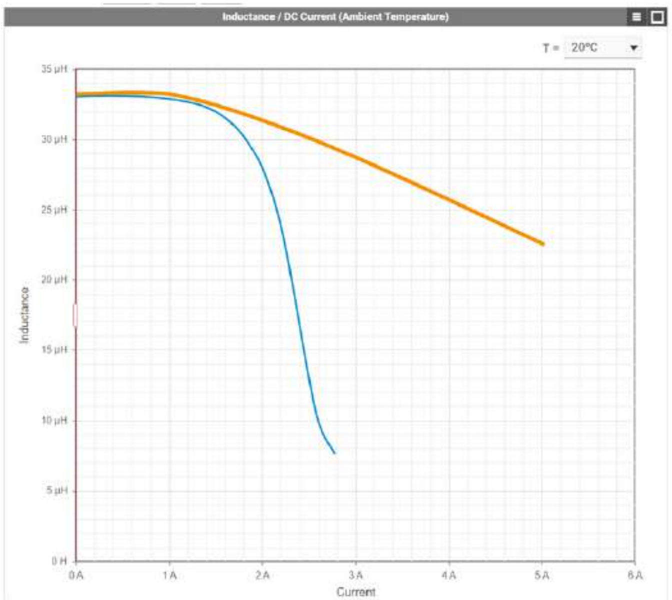
Boost Converter

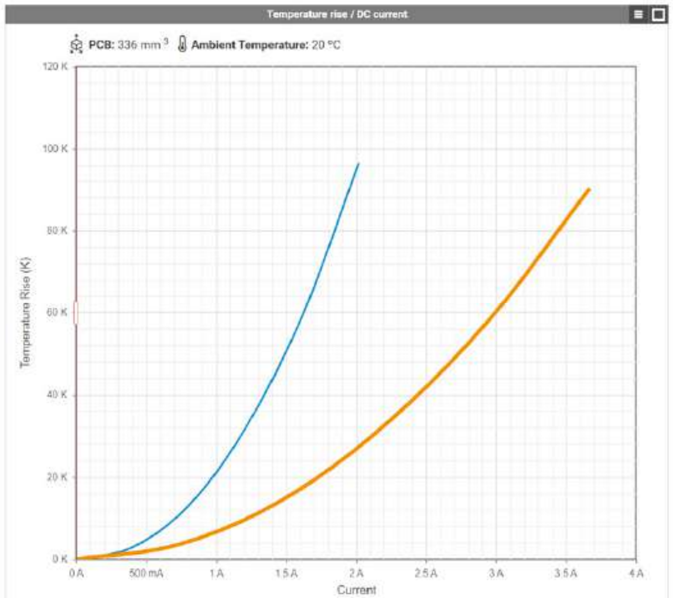
PARAMETERS

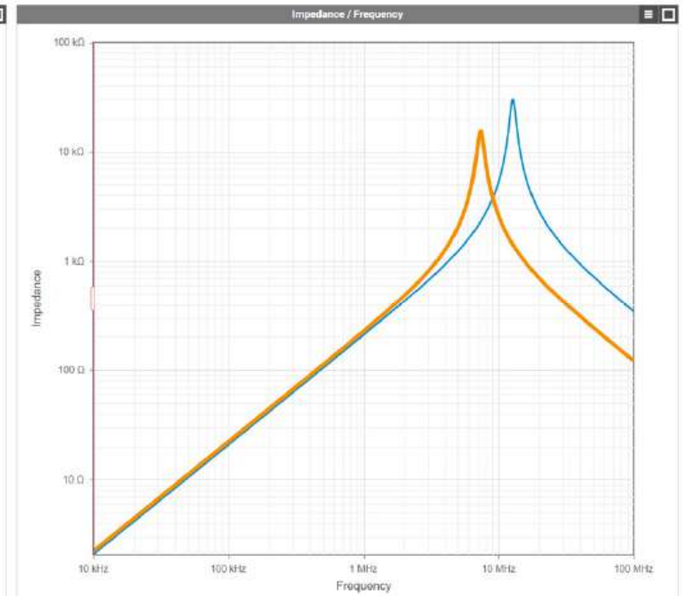


Filters: Type = Single, Single HV | 29.2 µH ≤ L20.0°C@632 mA ≤ 54.3 µH | Isat ≥ 726 mA | IR ≥ 632 mA | Vp ≥ 24.0 V | ΔTTOT,L ≤ 80.0 K | Series = WE-PD2, WE-LHMI | Is selected

Spec	Series	Size	L_0	$L_{20.0°C}$@632 ...	$P_{AC,L}$	$P_{DC,L}$	$R_{DC,typ}$	$P_{TOT,L}$	$\Delta T_{TOT,L}$	ΔI_L	Shielded	Materia...	R_p	C_p	I_R	I_{sat}	Footprint	Volume
	WE-LHMI	7050	33.0 µH	33.3 µH	21.8 mW	69.0 mW	173 mΩ	90.8 mW	3.46 K	37.6 %	Shielded	Iron Powder	15.6 kΩ	13.2 pF	2.45 A	4.75 A	48.18 mm²	231.26 mm³
	WE-PD2	7850	33.0 µH	33.0 µH	30.1 mW	35.0 mW	87.8 mΩ	65.1 mW	15.1 K	38.0 %	Unshielded	NiZn	30.0 kΩ	4.70 pF	1.35 A	1.47 A	54.60 mm²	273.00 mm³



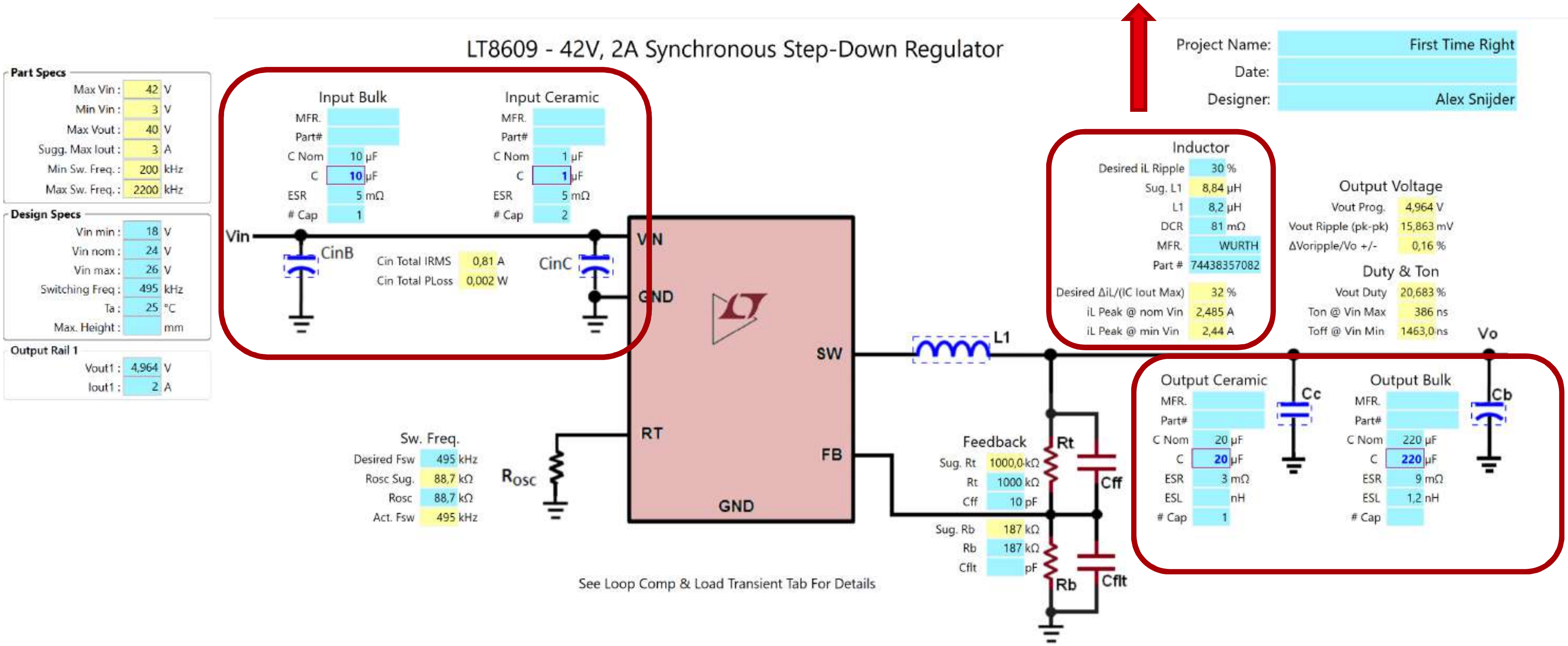


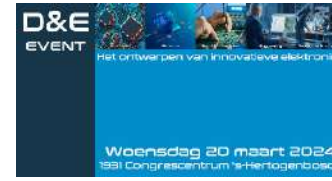


EXAMPLE USING ANALOGDEVICES POWERCAD

LT8609 Design

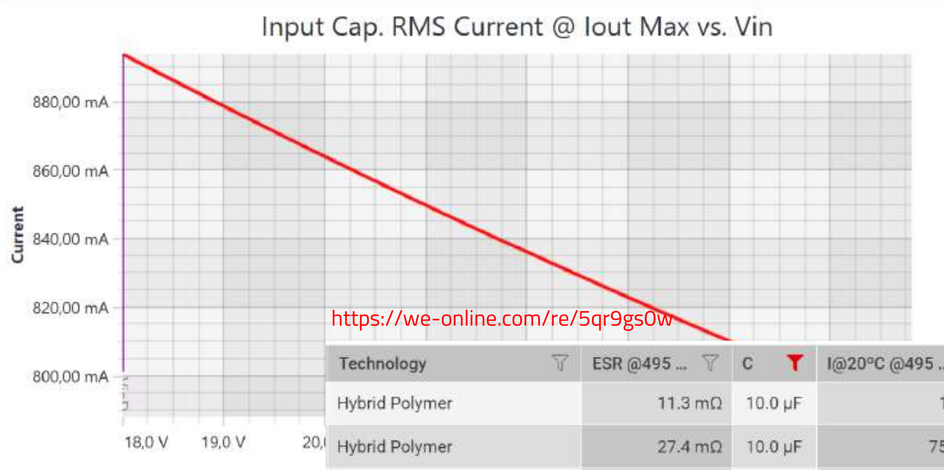
$$L = \frac{V_{OUT} + V_{SW(BOT)}}{f_{SW}}$$

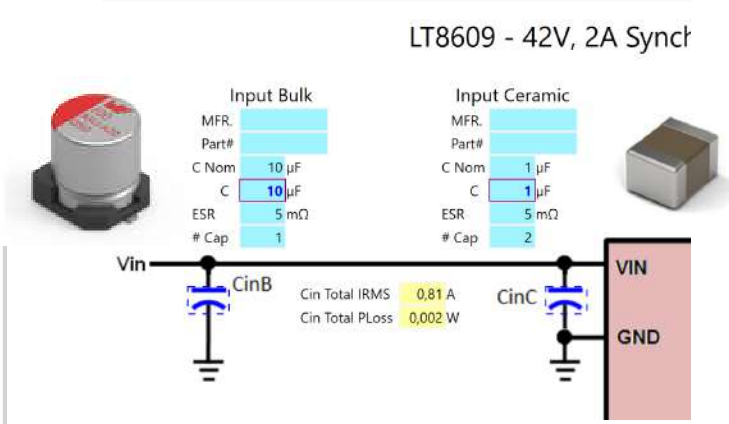




INPUT CAPACITOR SELECTION

PowerCAD generated curves





https://we-online.com/re/5qr9gs0w

Technology	ESR @495 ...	C	I@20°C @495 ...
Hybrid Polymer	11.3 mΩ	10.0 µF	1.00 A
Hybrid Polymer	27.4 mΩ	10.0 µF	750 mA
Hybrid Polymer	12.5 mΩ	10.0 µF	700 mA
Alum. Electrolytic	1.01 Ω	10.0 µF	165 mA
Alum. Electrolytic	1.58 Ω	10.0 µF	95.0 mA
Alum. Electrolytic	1.02 Ω	10.0 µF	80.0 mA
Alum. Electrolytic	2.82 Ω	10.0 µF	65.0 mA
Alum. Electrolytic	1.49 Ω	10.0 µF	60.0 mA
Alum. Electrolytic	2.37 Ω	10.0 µF	52.5 mA
Alum. Electrolytic	2.17 Ω	10.0 µF	52.5 mA

https://we-online.com/re/5qraQcmV

C	Size	ESR @495 kHz	$C(V_{DC-Bias})$ @5.00 V	$V_{R...}$
1.00 µF	1210	27.0 mΩ	1.00 µF	50.0 V
1.00 µF	0805	5.13 mΩ	982 nF	50.0 V
1.00 µF	1812	6.87 mΩ	1.00 µF	50.0 V
1.00 µF	1210	27.0 mΩ	1.00 µF	50.0 V
1.00 µF	1206	7.92 mΩ	1.00 µF	50.0 V
1.00 µF	0805	5.13 mΩ	982 nF	50.0 V
1.00 µF	**0603**	**16.5 mΩ**	**726 nF**	**50.0 V**
1.00 µF	1210	7.31 mΩ	1.01 µF	100 V

ANALOG POWERCAD

Inductor selection losses includes

○ Show All ◉ Show Suggested ○ Show Suggested w/ AC Loss Info **Key:** *Built-in Parts:* *User Parts:* ☐ Show On

* Loss values calculated at Vin nom. and Iout max.

All Parts | **User Parts**

Vendor	Name	Area(mm2)	DC Loss(W)	Total Loss(W)	L(µH)	L Tol(%)	DCR(mΩ)	DCR Tol(%)	I Sat(A)	L Dec(%)	I Heat(A)	T Rise(C)	Core	L(mm)	W(mm)	H(mm)	V Max (V)
WURTH	74438357082	16,8	0,33	0,436	8,2	20	81	6	5,2	20	2,8	40	Iron Alloy	4,1	4,1	3,1	80
WURTH	78438357082	16,8	0,33	0,435	8,2	20	81	6	5,2	20	2,8	40	Metal Alloy	4,1	4,1	3,1	30
WURTH	74438357100	16,8	0,409	0,491	10	20	100,8	9	4,6	20	2,7	40	Iron Alloy	4,1	4,1	3,1	80
WURTH	78438357100	16,8	0,409	0,49	10	20	100,8	9	4,6	20	2,7	40	Metal Alloy	4,1	4,1	3,1	30
WURTH	78438367082	29,2	0,204	0,31	8,2	20	50	15	5	20	4,4	40	Metal Alloy	5,4	5,4	3,1	30
WURTH	78438367100	29,2	0,247	0,307	10	20	61	15	4,8	20	3,3	40	Metal Alloy	5,4	5,4	3,1	30
WURTH	74438367082	31,4	0,204	0,315	8,2	20	50	15	5	20	4,4	40	Metal Alloy	5,6	5,6	3,1	80
WURTH	74404064082	36	0,175	0,29	8,2	20	43	30	4,3	30	3	40	NiZn	6	6	4,3	120
WURTH	78439346082	42,9	0,094	0,164	8,2	20	23	10	9,3	30	6,95	40	Hyperflux	6,65	6,45	5,8	40
WURTH	74439346082	42,9	0,094	0,162	8,2	20	23	10	8,4	30	5,3	40	Hyperflux	6,65	6,45	5,8	120
WURTH	78439346100	42,9	0,107	0,165	10	20	26,5	10	9,7	30	6,4	40	Hyperflux	6,65	6,45	5,8	40
WURTH	74439346100	42,9	0,107	0,162	10	20	26,5	9	7,6	30	5	40	Hyperflux	6,65	6,45	5,8	120
WURTH	74437349082	48,2	0,228	0,296	8,2	20	56	12	9	20	3,3	40	Iron Powder	7,3	6,6	4,8	40
WURTH	74437346082	48,2	0,261	0,369	8,2	20	64	6	7,5	20	3,25	40	Iron Powder	7,3	6,6	2,8	40

REDEXPERT

SUMMERY

- Simulation is a powerful tool that can help evaluate a design upfront or during EMI debugging.
  - All simulation tools have limitations
  - Good models need to be used for reliable results
- Design tools can help select component values
  - But do not just copy paste the suggested parts
  - Not all parameters are always taken in to account
- Use these tools to help you, but keep thinking for yourself and understand component choices.

THANK YOU FOR YOUR ATTENTION

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WÜRTH ELEKTRONIK MORE THAN YOU EXPECT