

DIGITAL WE DAYS

2023



EMC DEBUGGING ON FLYBACK  
CONVERTERS

WÜRTH ELEKTRONIK MORE THAN YOU EXPECT

## TODAY'S SPEAKERS



### **PRESENTATION**

Robert Schillinger  
Field Application Engineer



### **MODERATION**

Markus Eberle  
Marketing Department

# INFORMATION ABOUT THE WEBINAR

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However, you can ask us questions using the chat function.

**Duration of the presentation** 30 Min  
**Q&A:** 10 – 15 Min

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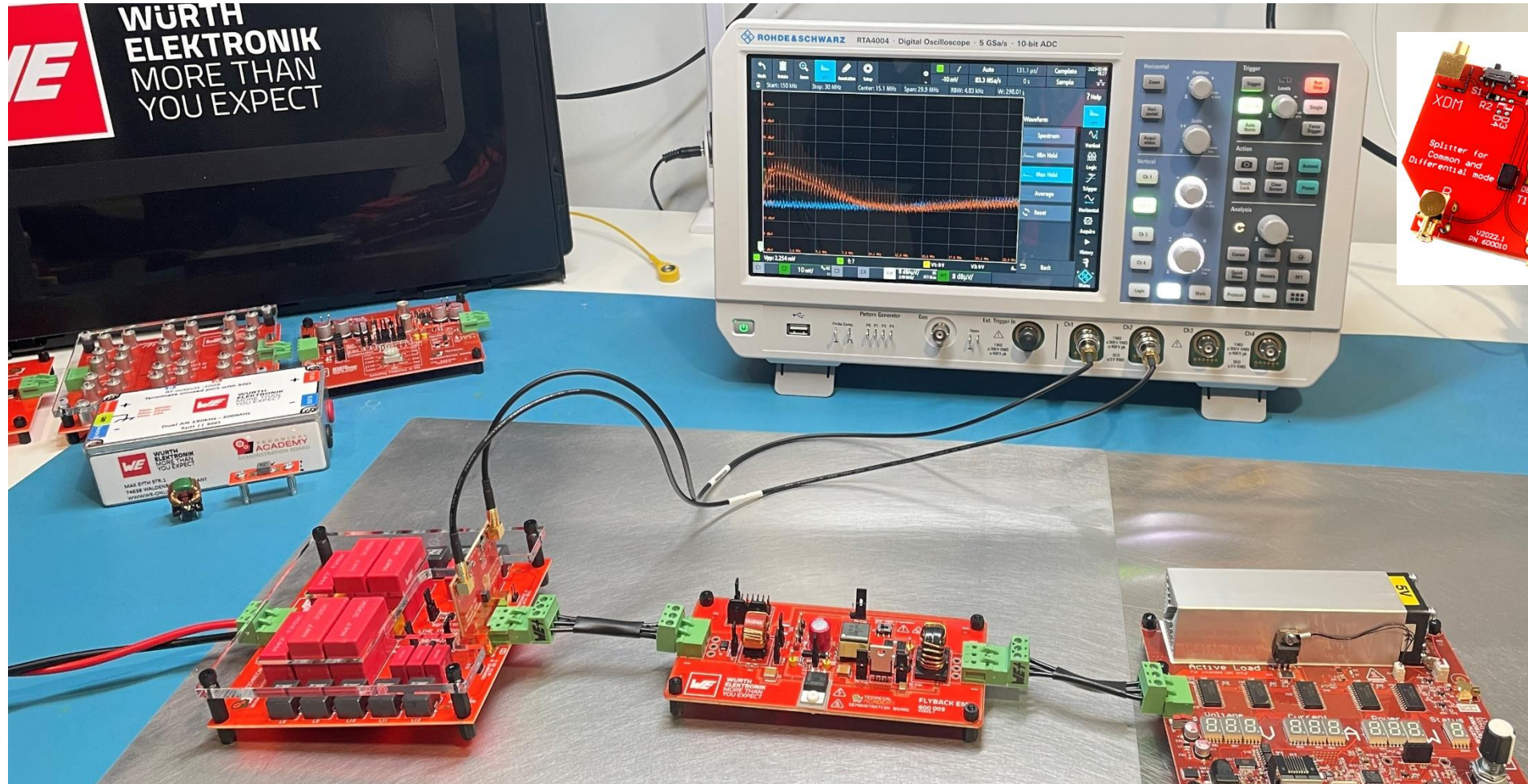
# AGENDA

- System Overview
  - Test Setup and Equipment
  - Test Specification
- Demo Objectives
- Test #1: Time Domain Impact of RC Snubber
- Test #2: Reference Measurement (No filtering)
- Test #3: Test #2 + RC Snubber
- Test #4: Test #3 + Pri->Sec Caps
- Test #5: Test #4 + {CMC + i/p Y-Caps}
- Test #6: Test #5 + X-Cap



# SYSTEM OVERVIEW

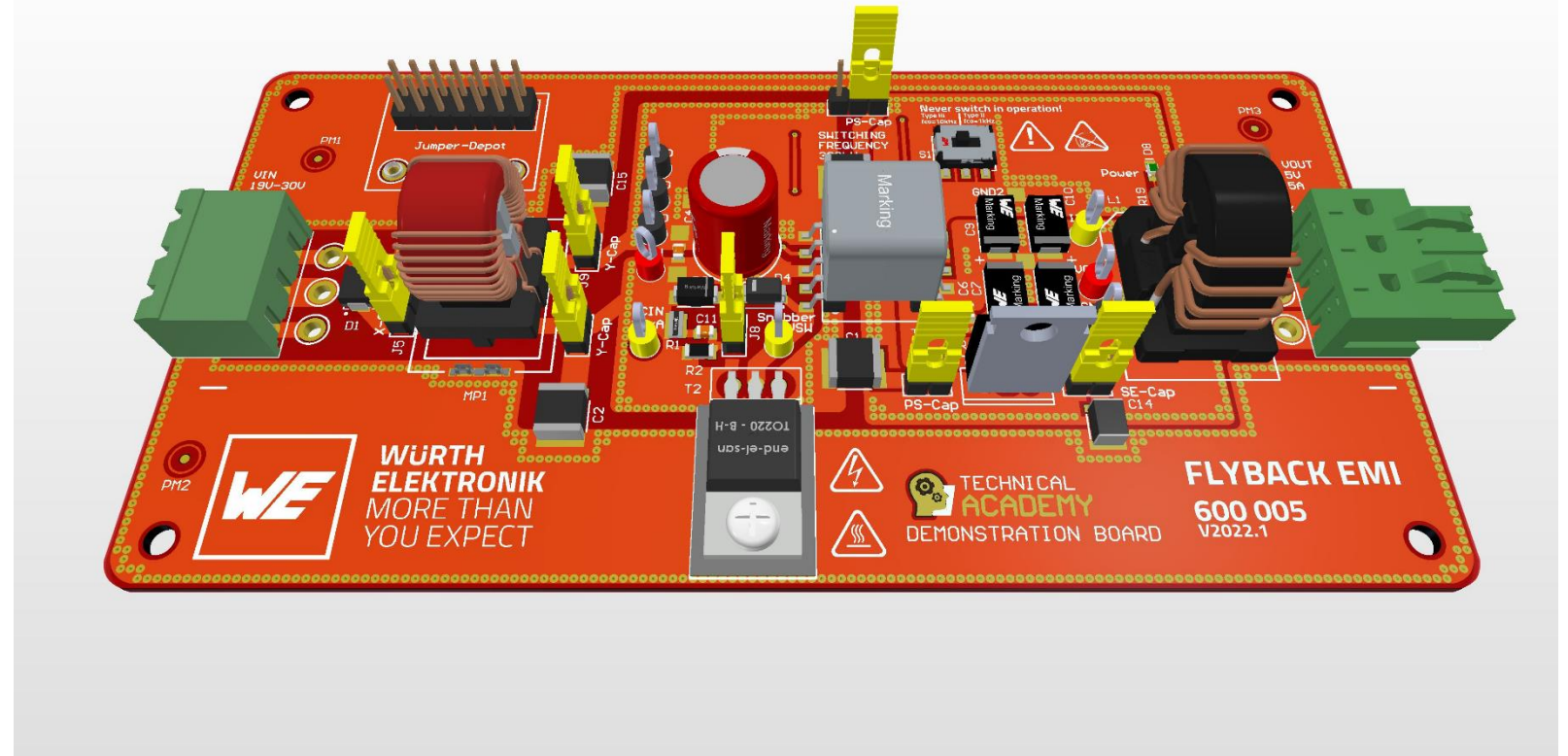
## Test Setup & Equipment



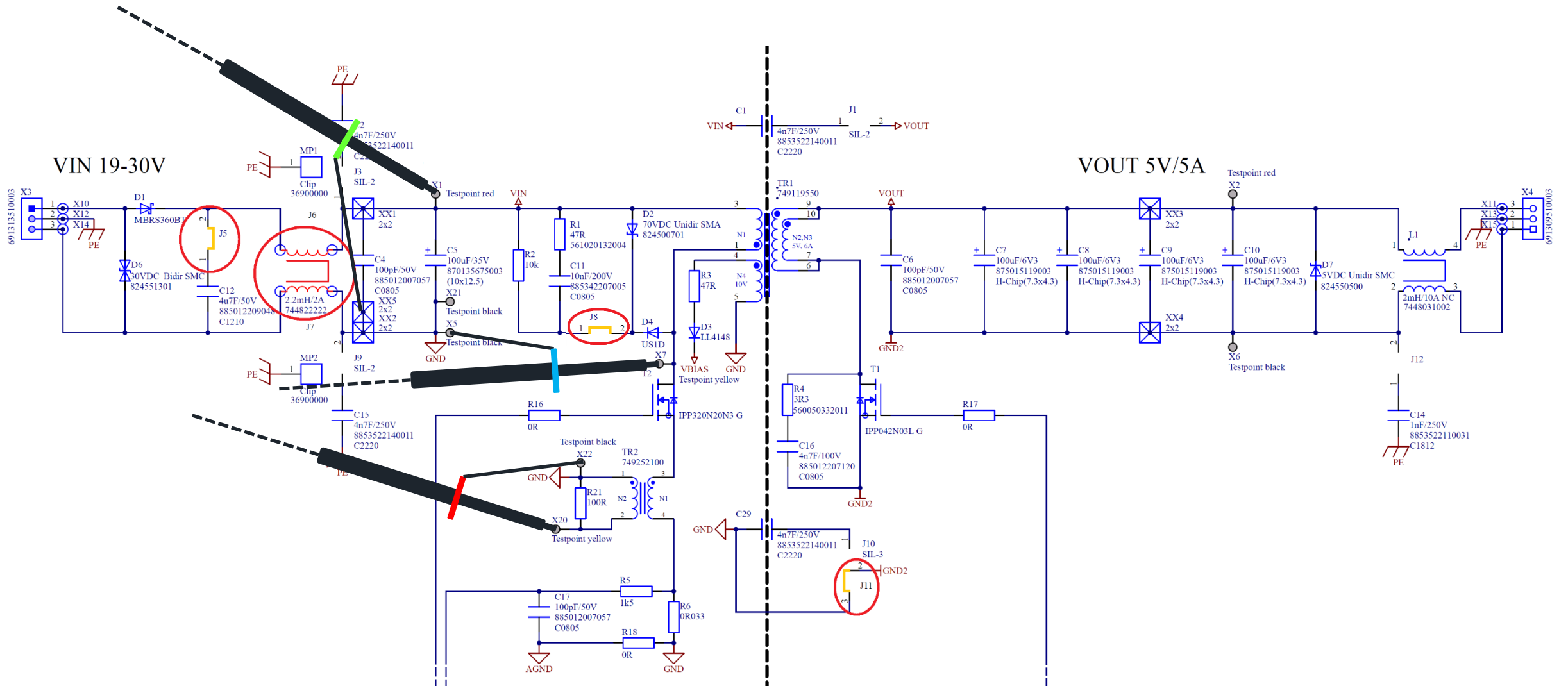
# SYSTEM OVERVIEW

## Test Specifications

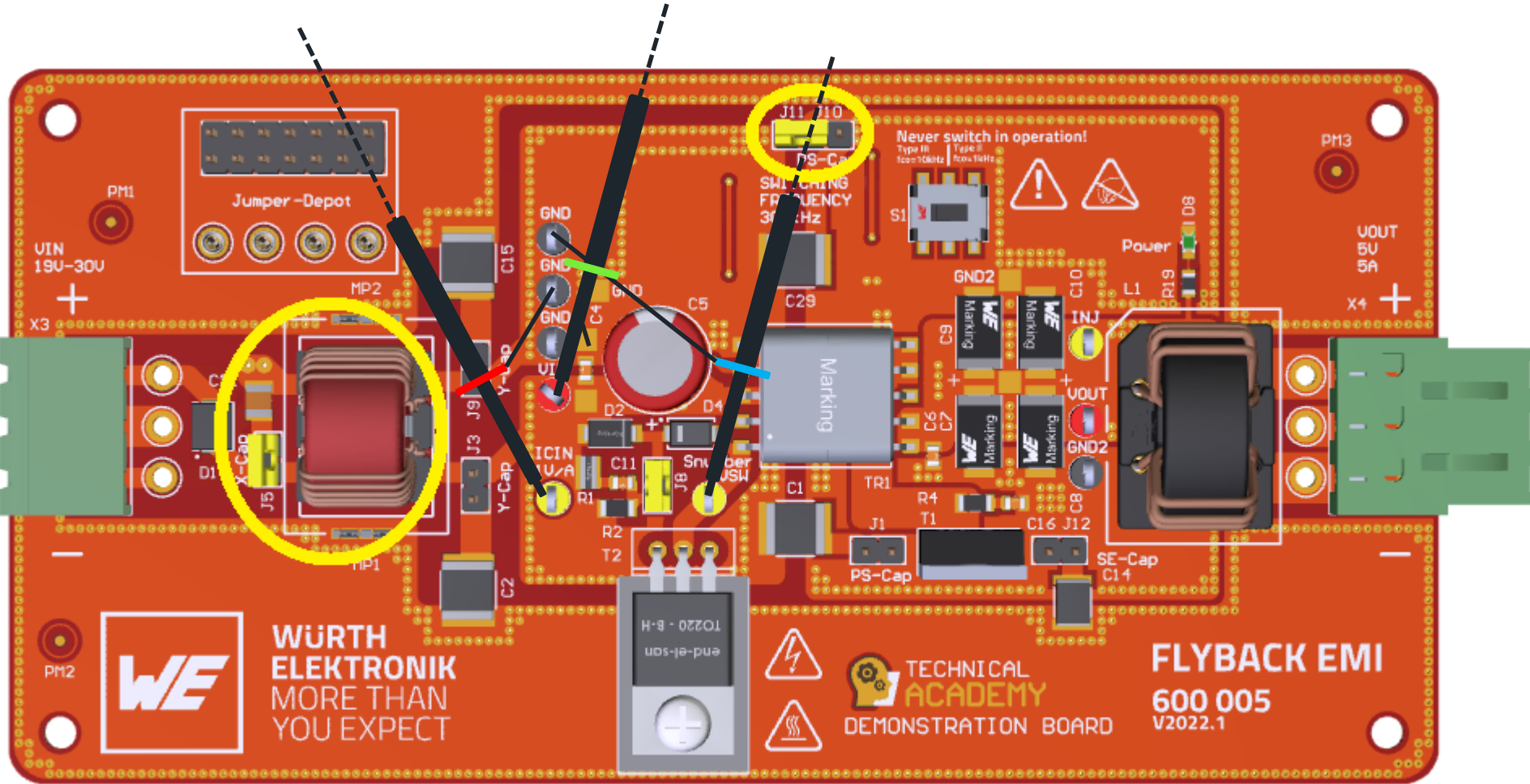
- DC/DC Flyback-Converter CCM (Continuous Conduction Mode)
  - $U_{in} = 24V$  (19-30V)
  - $U_{out} = 5V$
  - $I_{out,max} = 5A$  (25W)
  - $f_{sw} \approx 300kHz$
  - Efficiency  $\approx 90\%$
- IC: ADP1071-2 (Analog Devices)
  - with synchronous rectifier
- Transformer: 749119550
- MOSFETs in TO220-package



# TEST#1: TIME DOMAIN IMPACT OF RC SNUBBER - SCHEMATIC

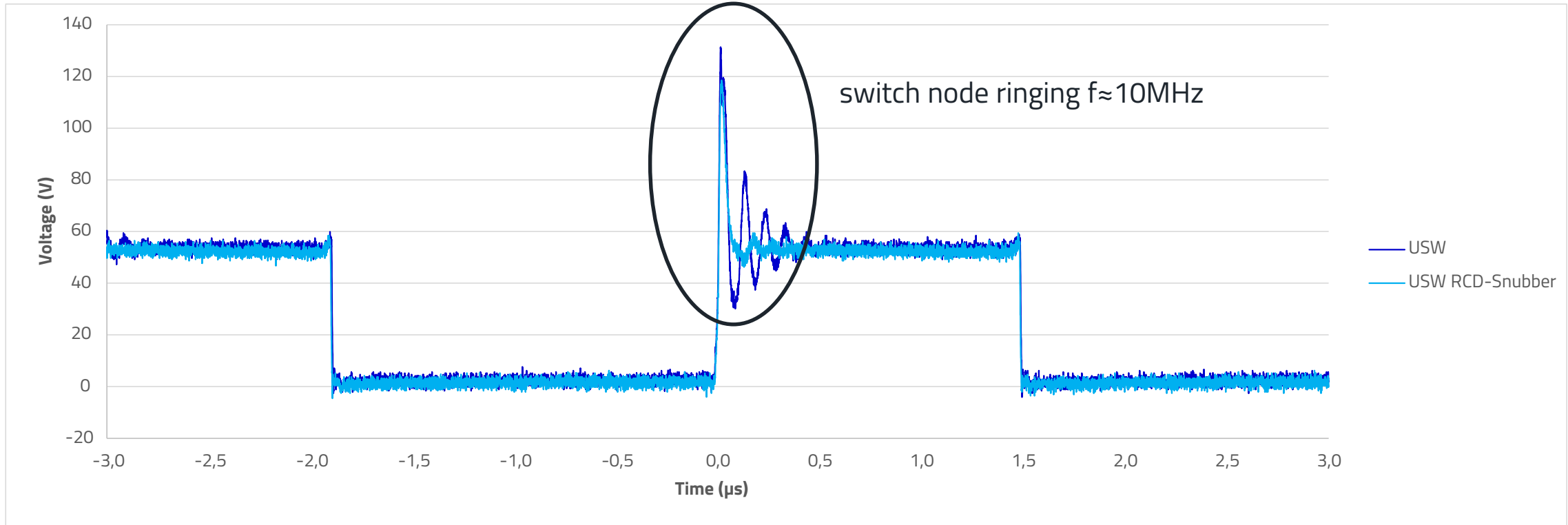


# TEST#1: BOARD CONFIGURATION

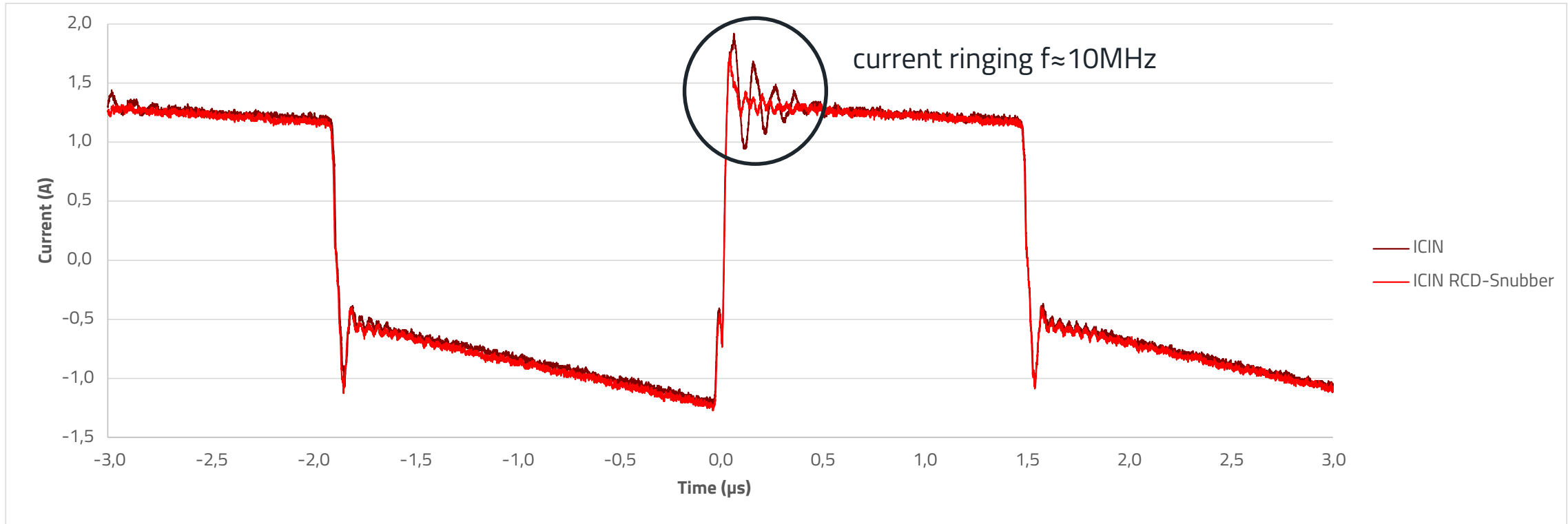




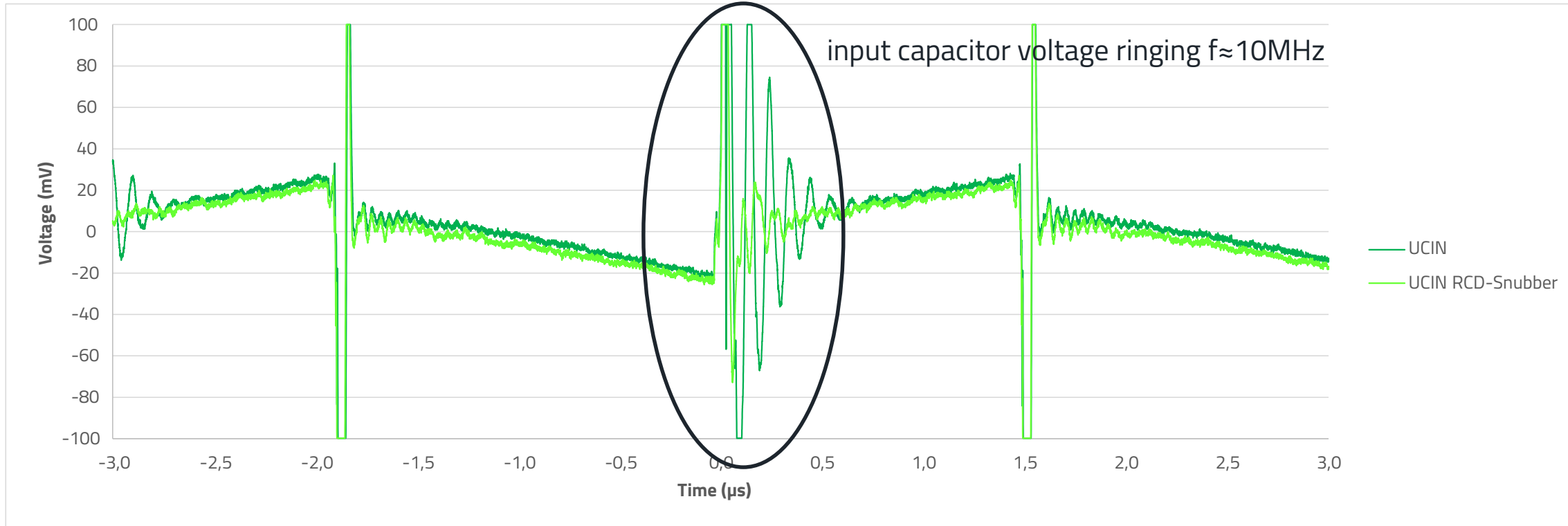
# TEST#1: WAVEFORMS - SWITCH NODE VOLTAGE



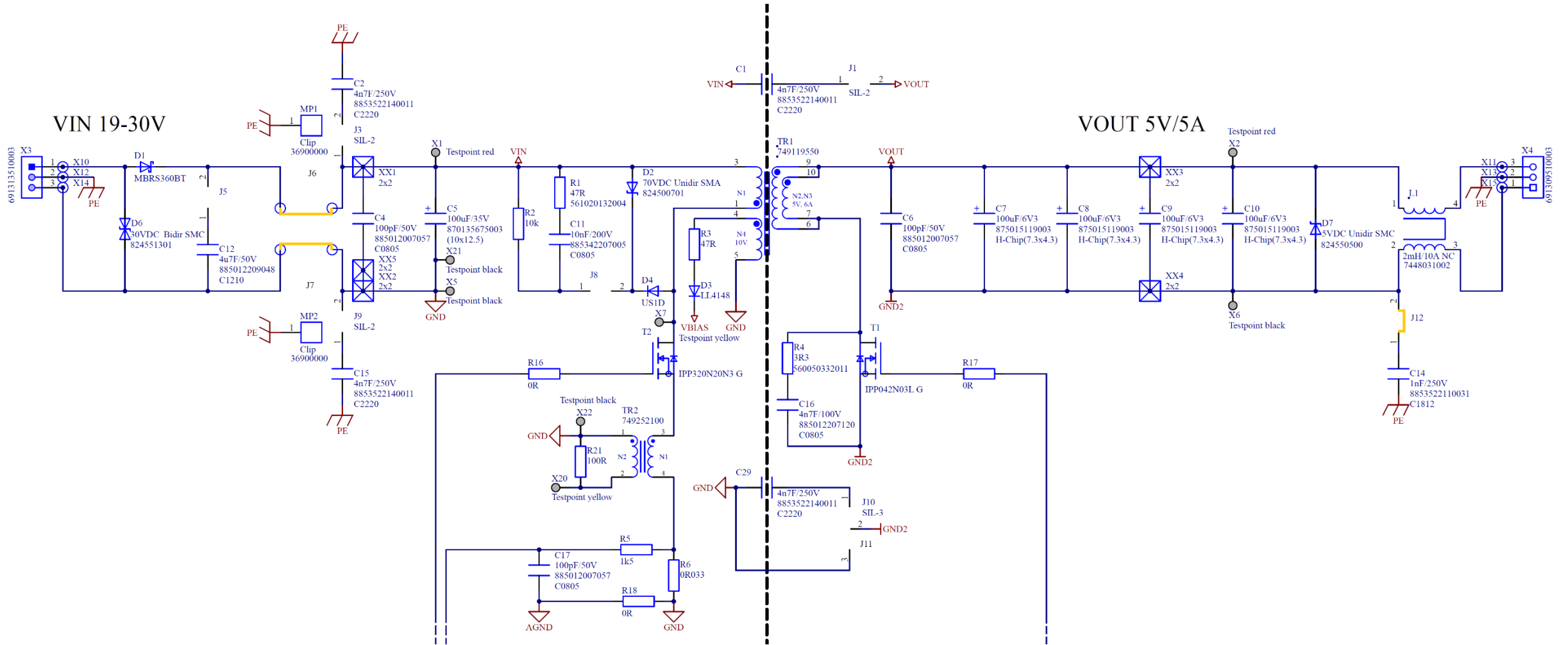
# TEST#1: WAVEFORMS - INPUT CAPACITOR CURRENT



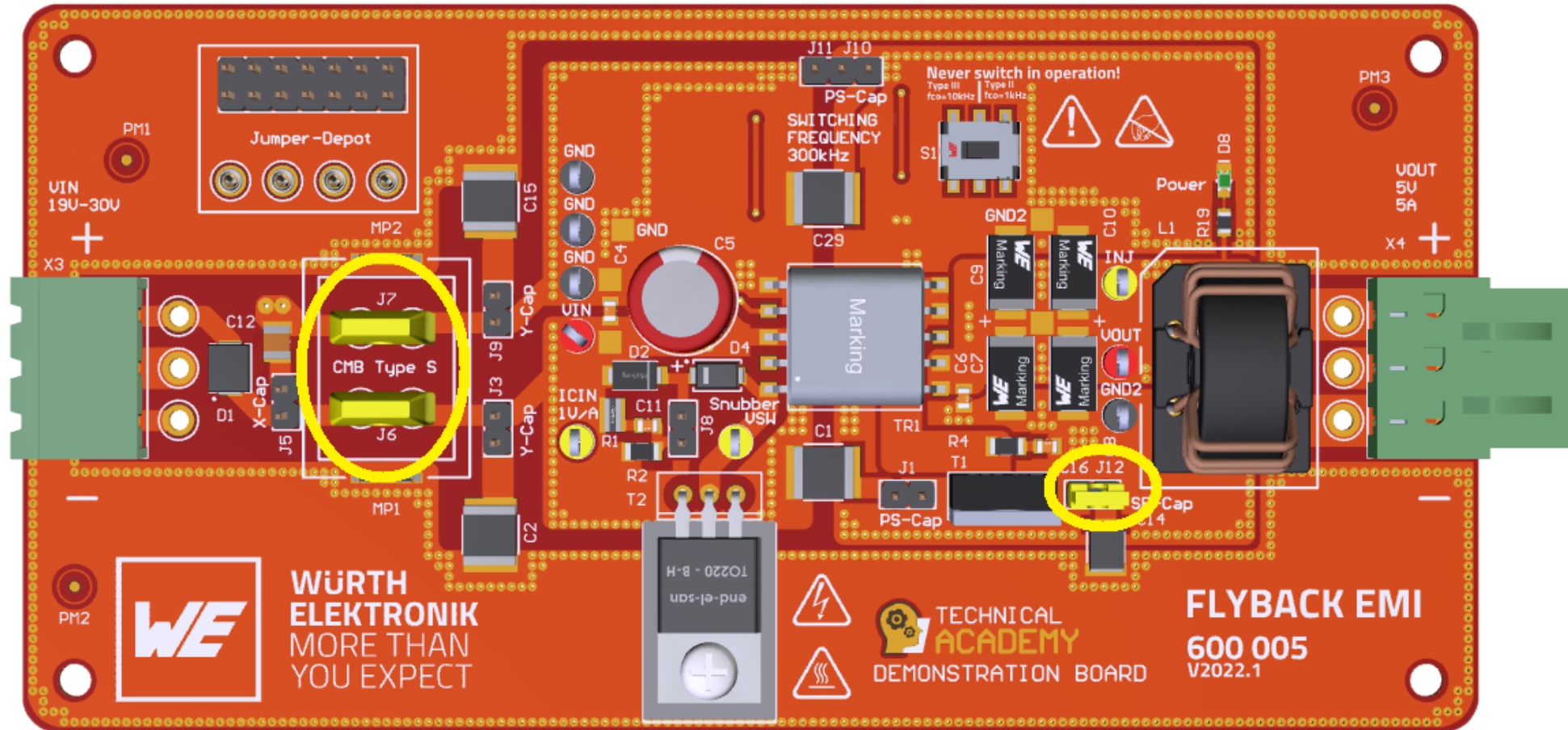
# TEST#1: WAVEFORMS – INPUT CAPACITOR VOLTAGE AC



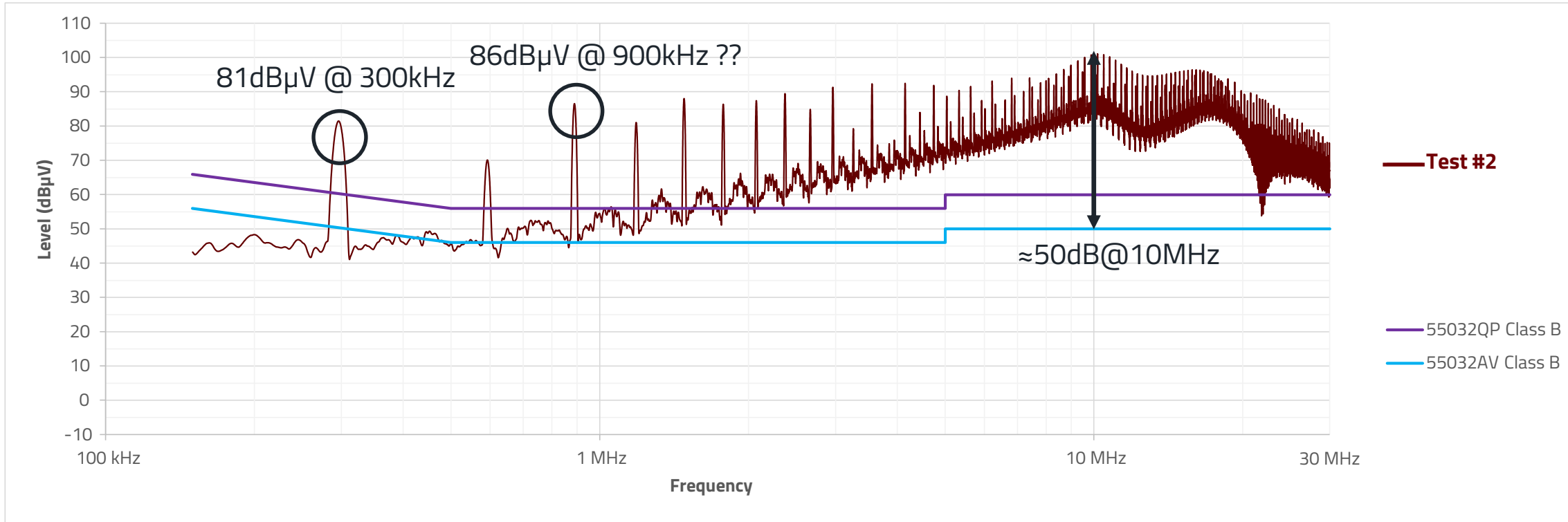
# TEST#2: REFERENCE MEASUREMENT - SCHEMATIC



# TEST#2: BOARD CONFIGURATION



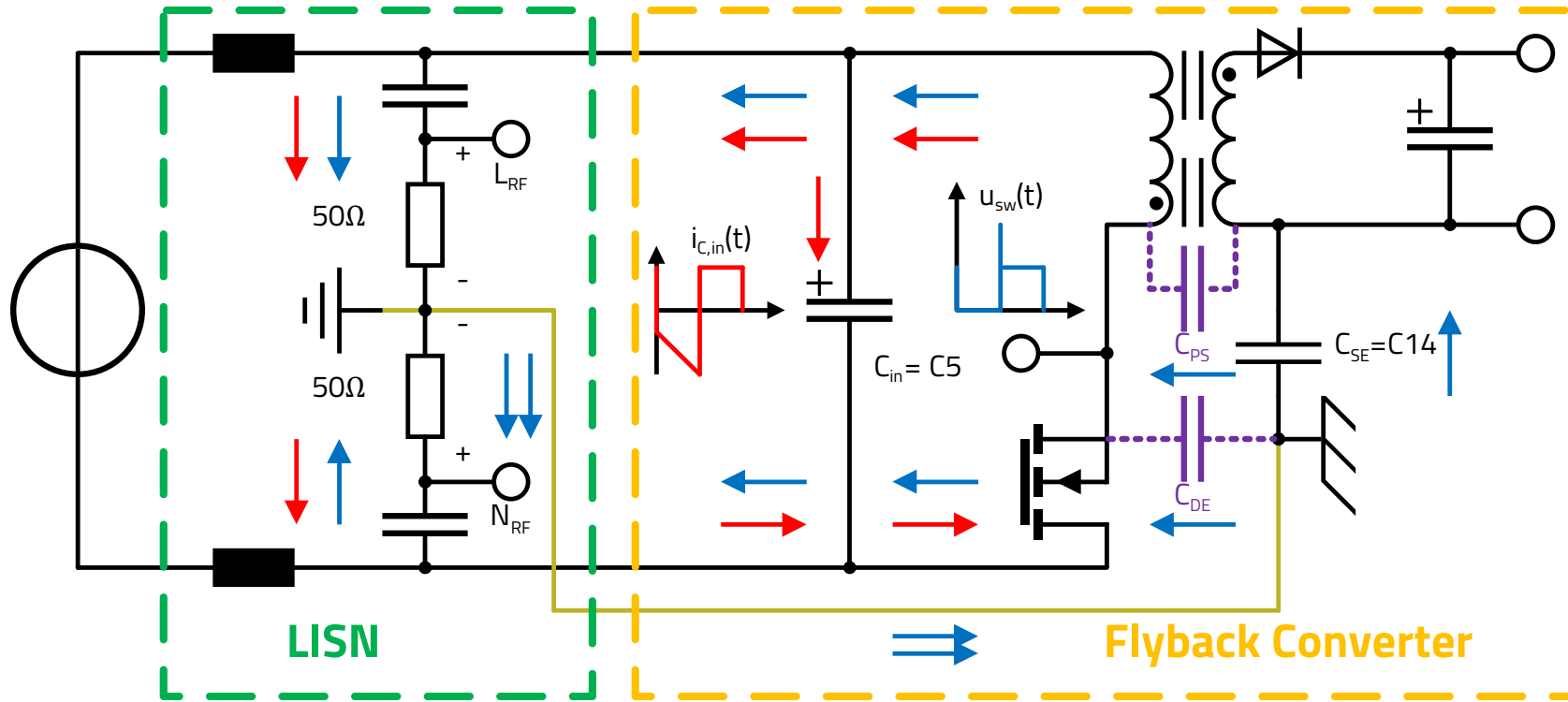
# TEST#2: TOTAL CONDUCTED EMISSIONS – LINE



Name	Description
<b>Test #2</b>	<b>Reference (no improvement)</b>

# TEST#2: BACKGROUND

Theory: DM and CM noise path in a flyback converter



$$U_{L,RF} = U_{CM} + U_{DM}$$

$$U_{N,RF} = U_{CM} - U_{DM}$$



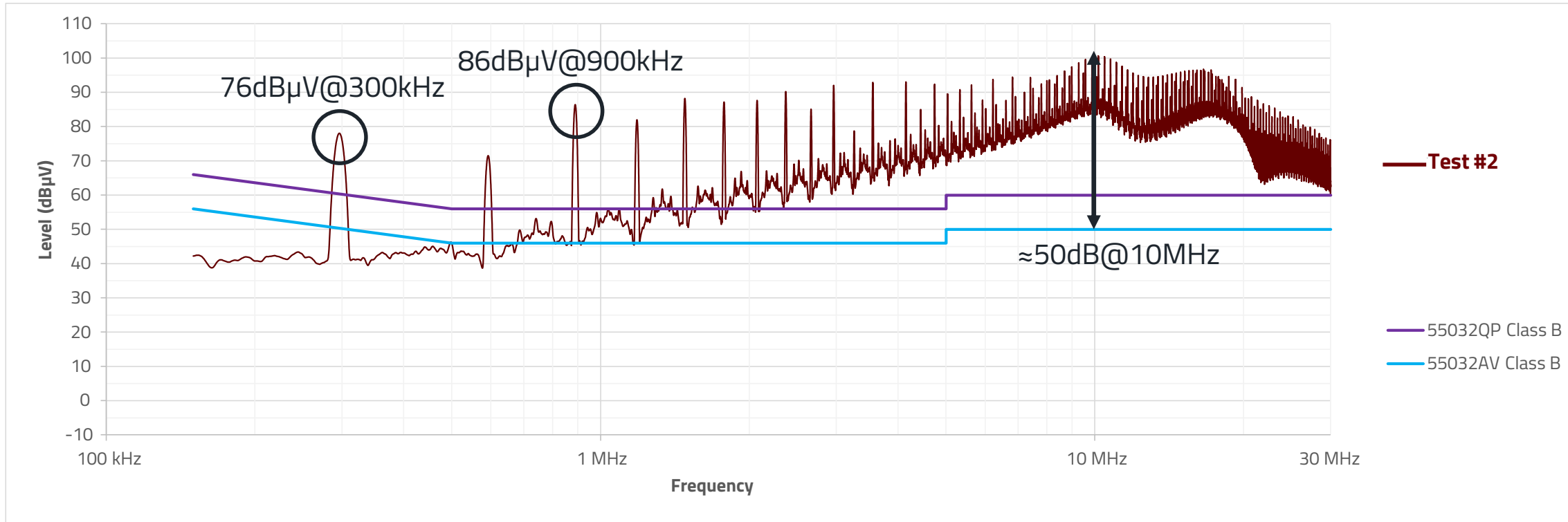
$$U_{DM} = \frac{U_{L,RF} - U_{N,RF}}{2}$$

$$U_{CM} = \frac{U_{L,RF} + U_{N,RF}}{2}$$

→ DM Current      PE-Frame      PE = Reference Ground  
→ CM Current

MaT/eiSos

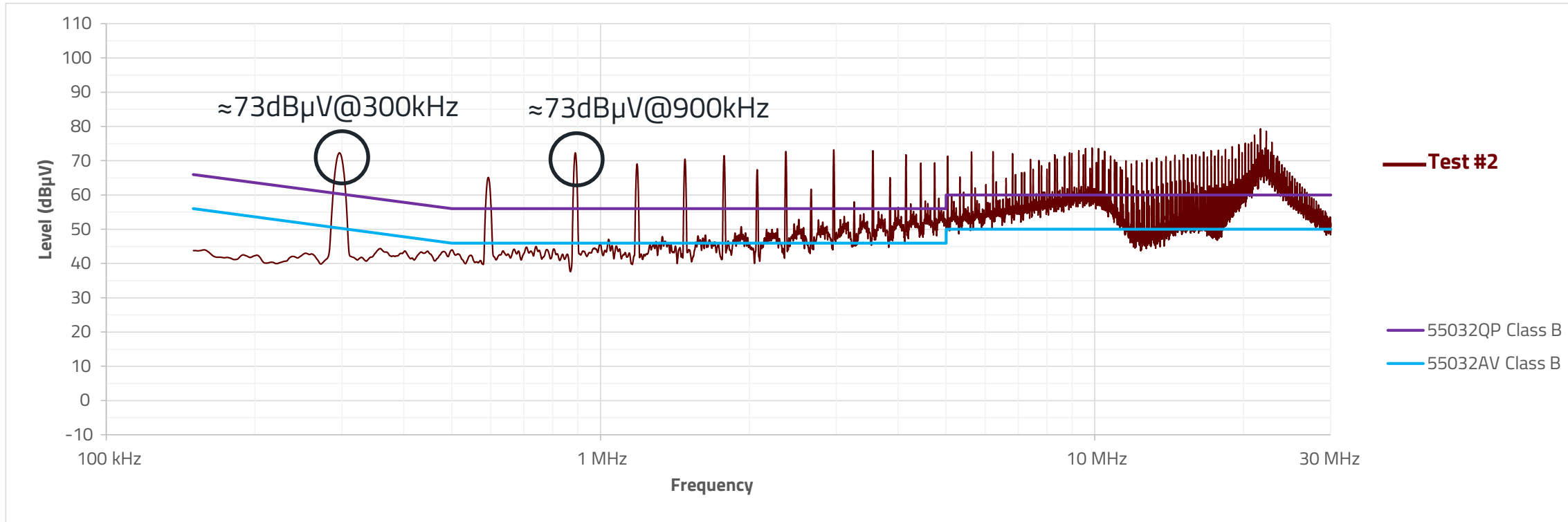
# TEST#2: CONDUCTED EMISSIONS - COMMON MODE



Name	Description
<b>Test #2</b>	<b>Reference (no improvement)</b>

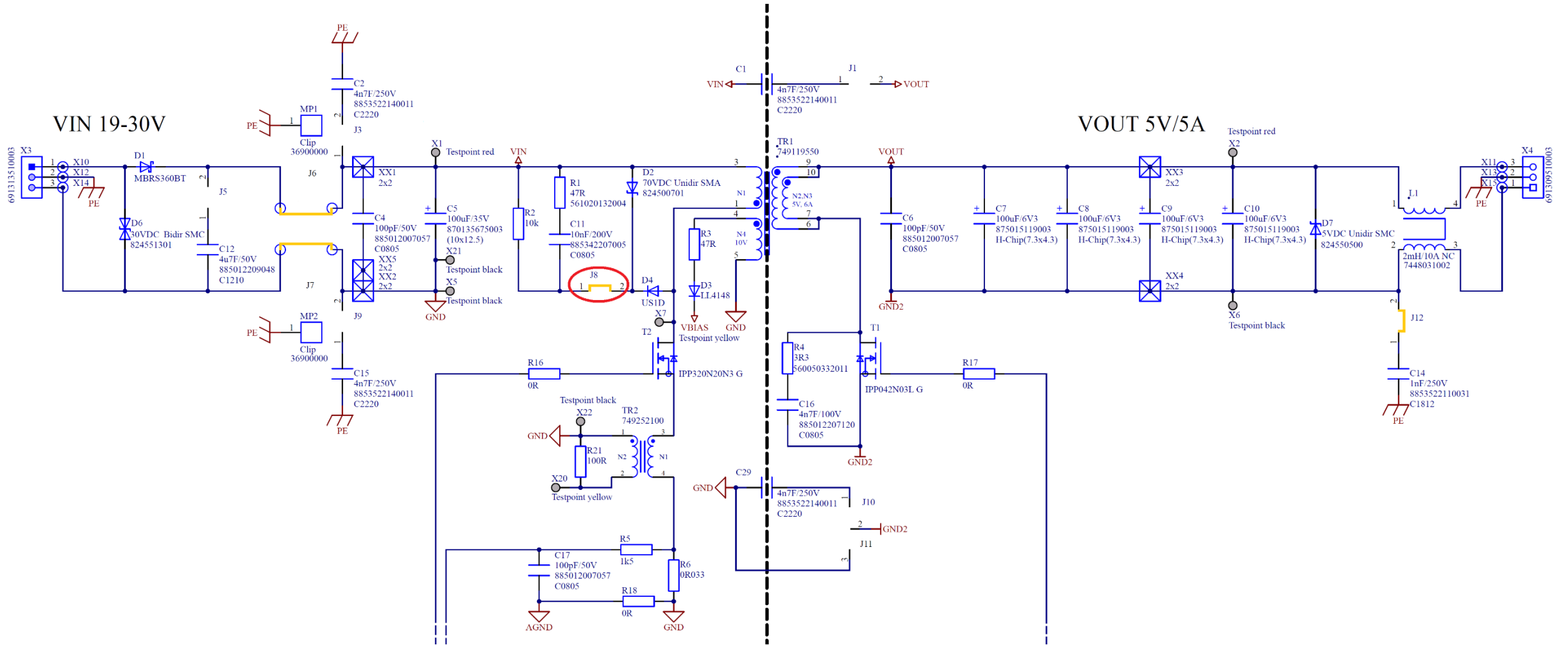


# TEST#2: CONDUCTED EMISSIONS - DIFFERENTIAL MODE

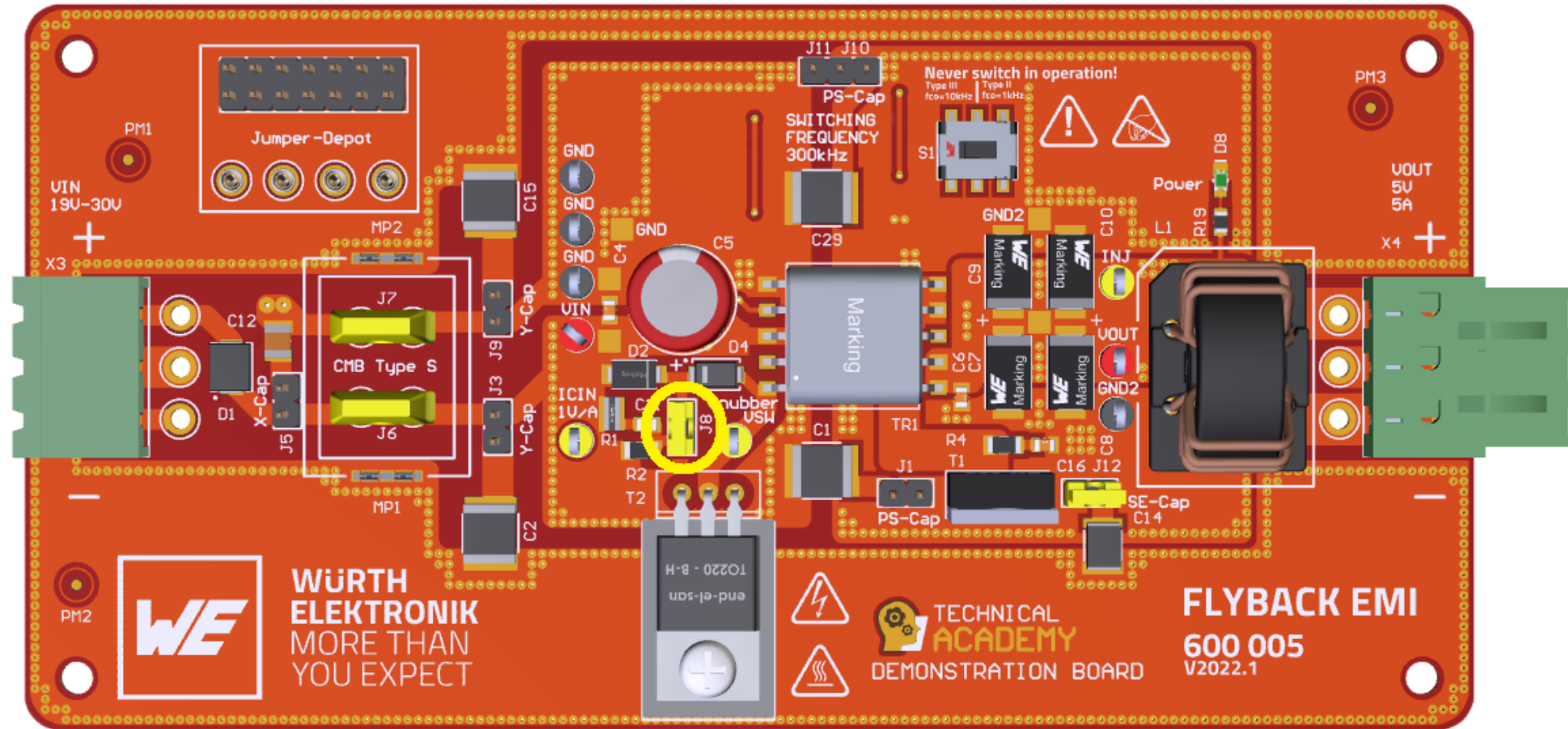


Name	Description
<b>Test #2</b>	<b>Reference (no improvement)</b>

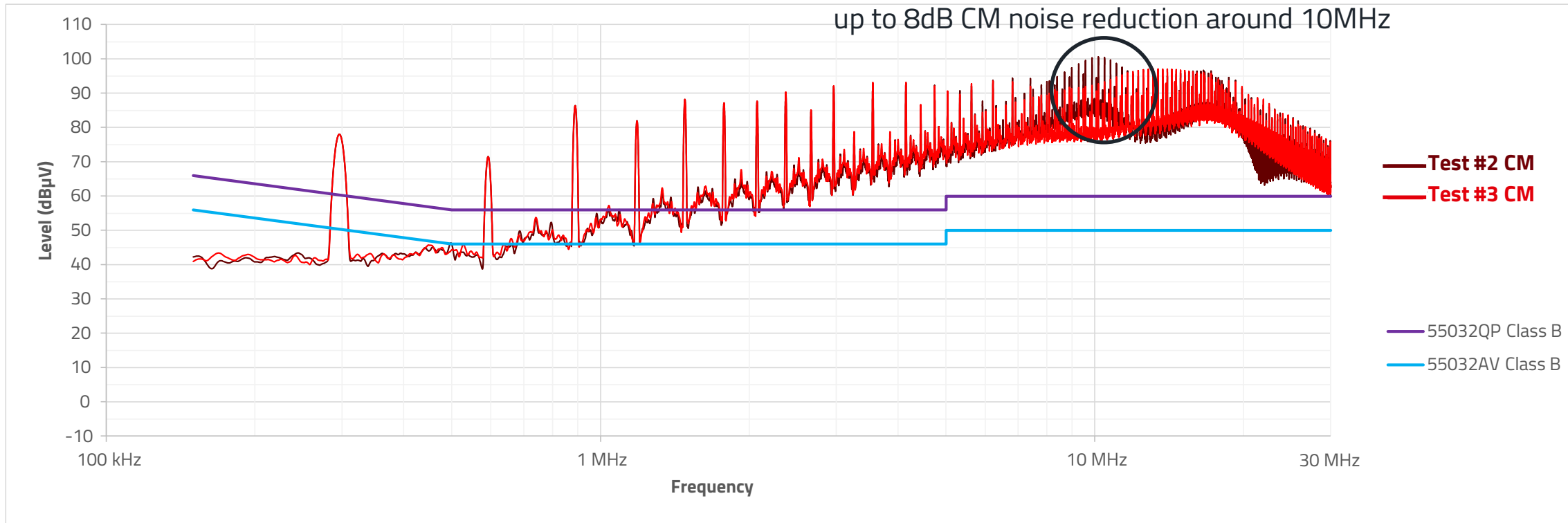
# TEST#3: RC SNUBBER - SCHEMATIC



# TEST#3: BOARD CONFIGURATION

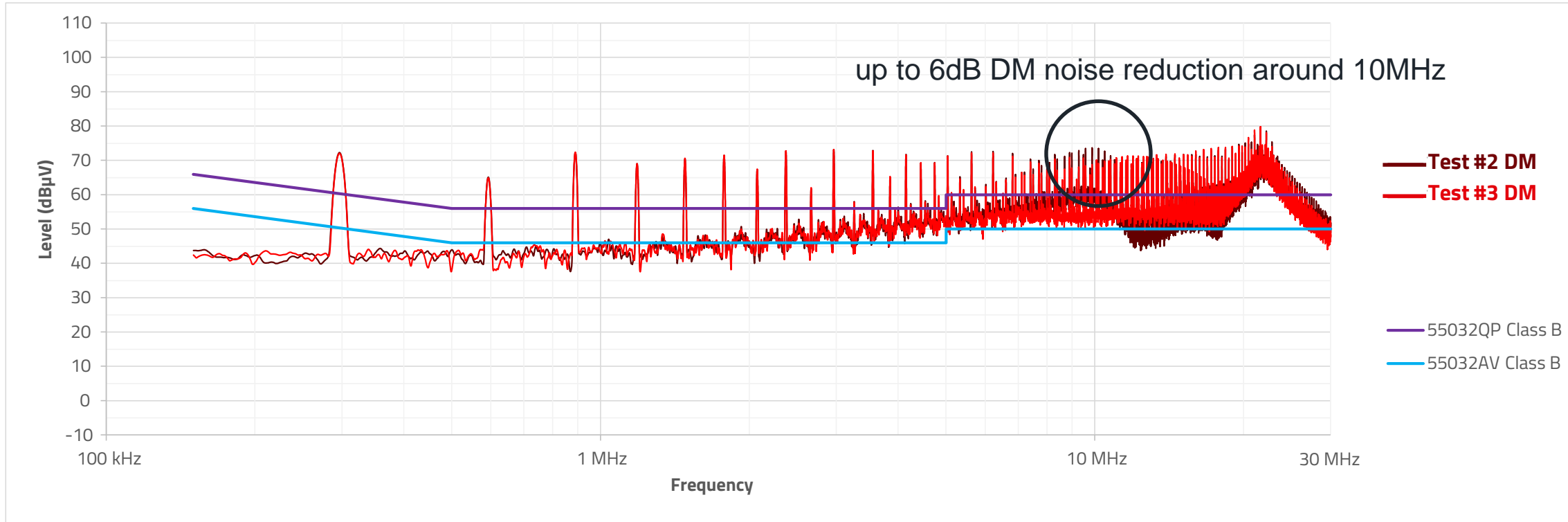


# TEST#3: CONDUCTED EMISSIONS - COMMON MODE



Name	Description
Test #2	Reference (no improvement)
Test #3	Test#2 + RCD-snubber

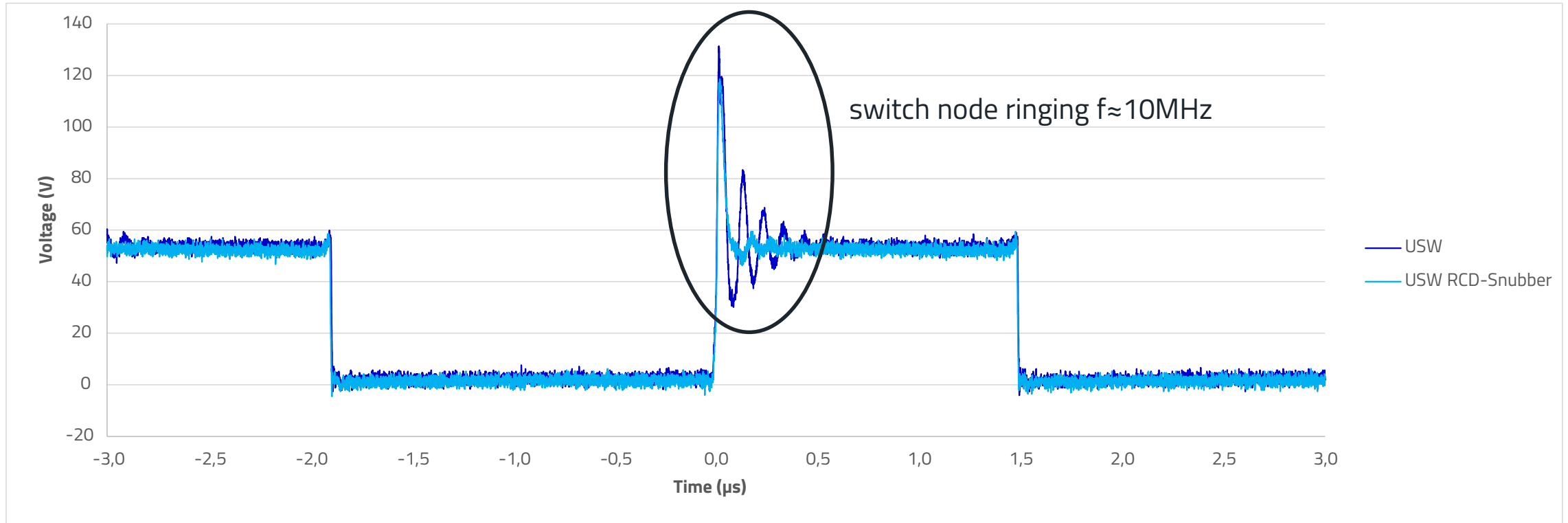
# TEST#3: CONDUCTED EMISSIONS - DIFFERENTIAL MODE



Name	Description
Test #2	Reference (no improvement)
Test #3	Test#2 + RCD-snubber

## TEST#3: BACKGROUND

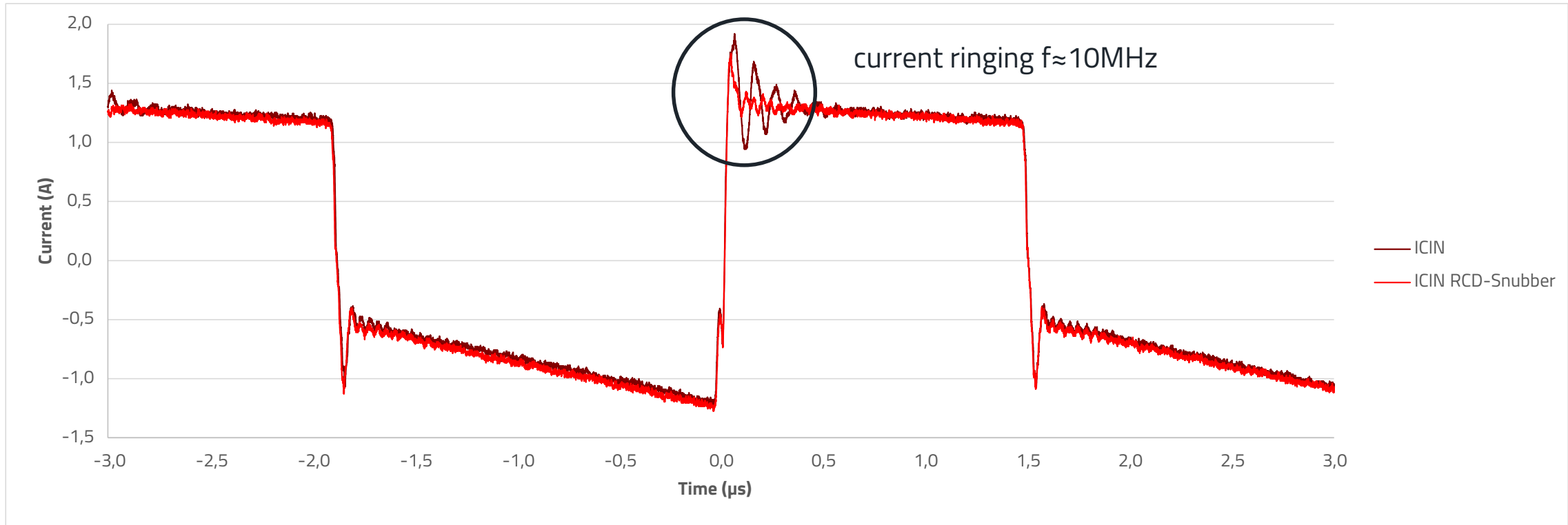
### Common mode



- The voltage change at the switch node is the cause of the CM noise
- The 10MHz switch node ringing is damped by the snubber

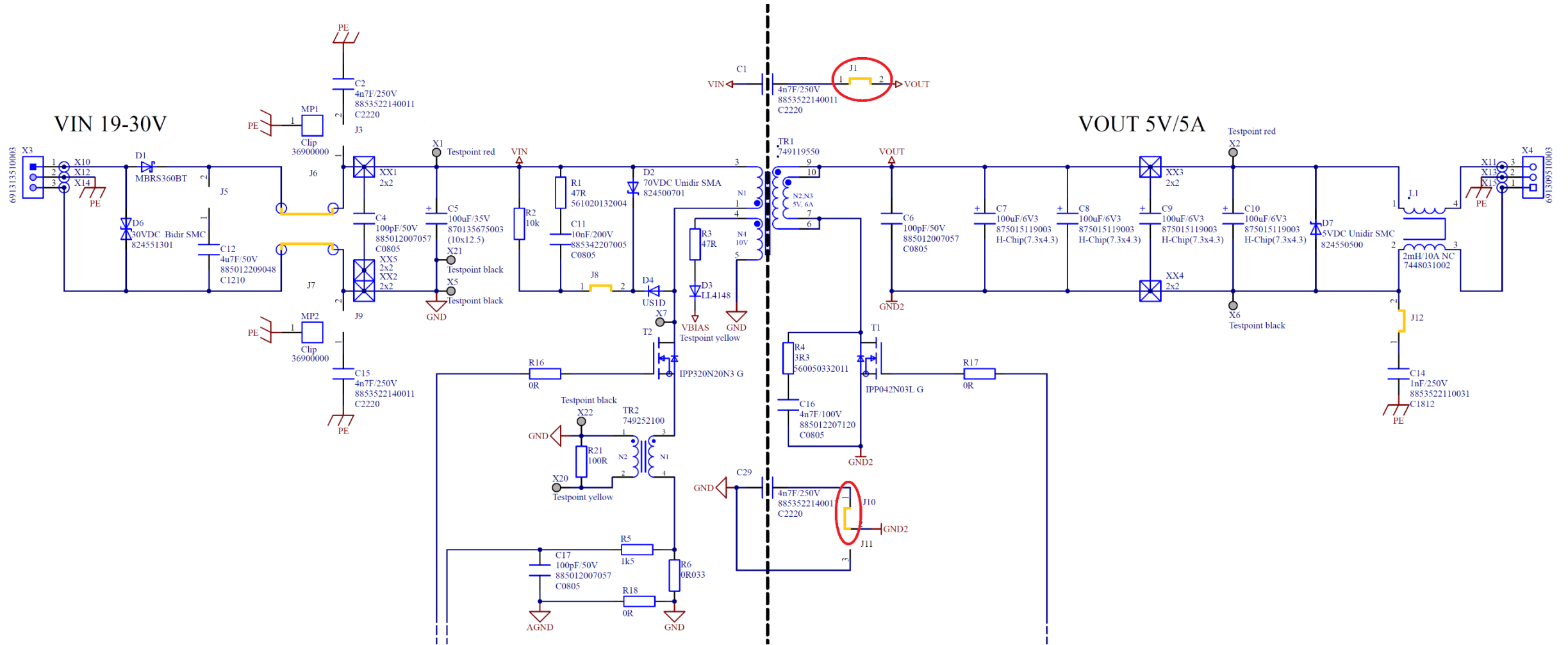
## TEST#3: BACKGROUND

Differential mode



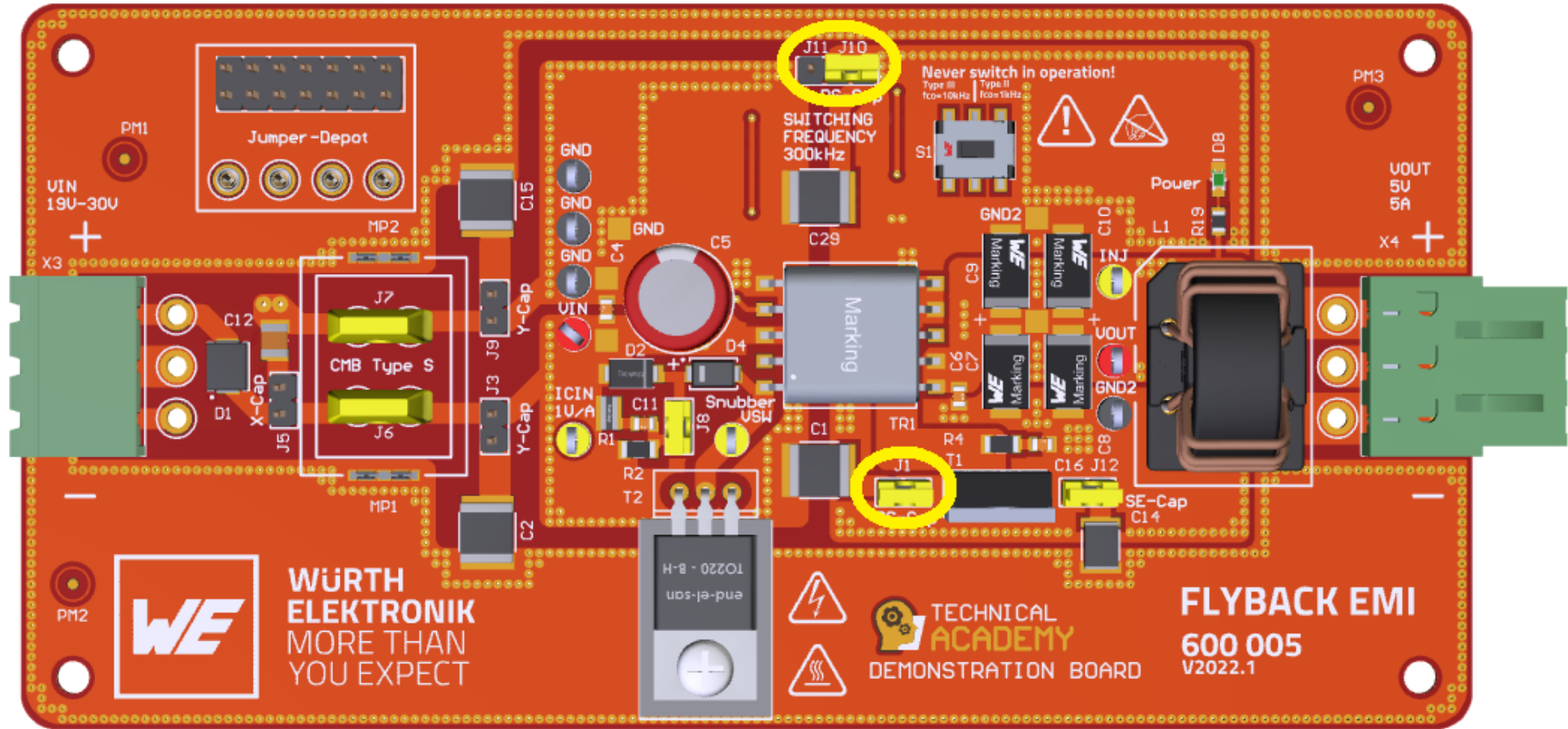
- The input capacitor current waveform causes a voltage drop across the impedance of the input capacitor
- The 10MHz current ringing is damped by the snubber

# TEST#4: PRI -> SEC CAPS - SCHEMATIC

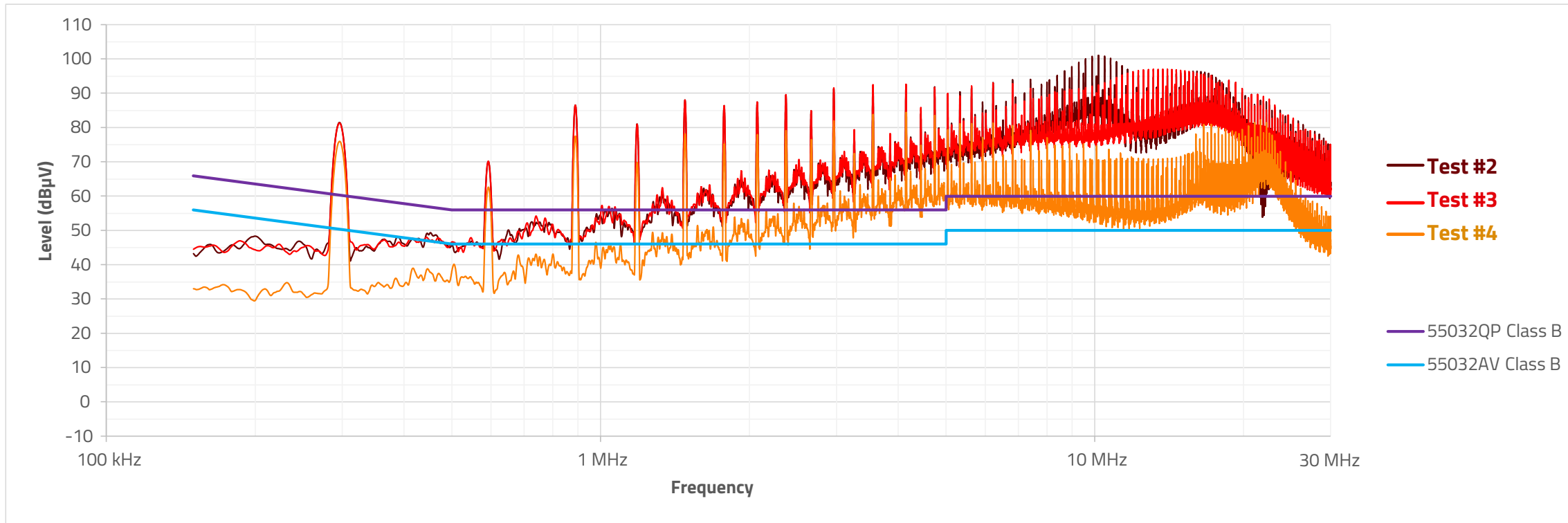




## TEST#4: BOARD CONFIGURATION

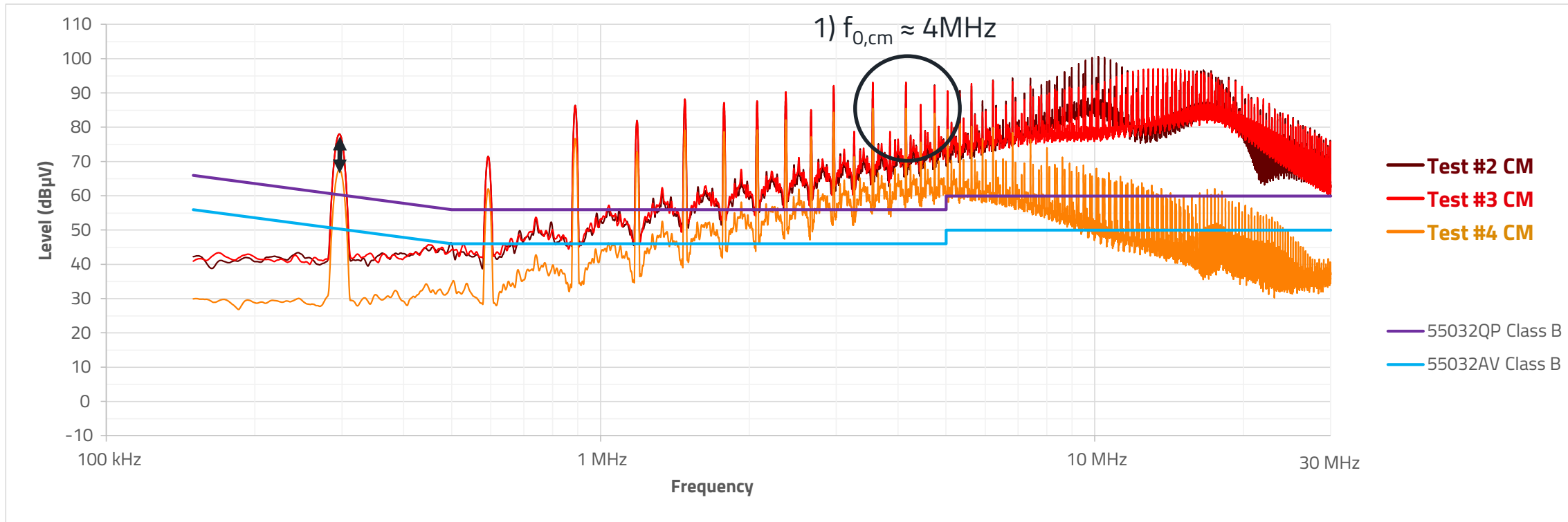


# TEST#4: TOTAL CONDUCTED EMISSIONS - LINE



Name	Description
Test#2	Reference (no improvement)
Test#3	Test#2 + RCD-snubber
Test#4	Test#3 + primary to secondary y-capacitors

# TEST#4: CONDUCTED EMISSIONS - COMMON MODE



Name	Description
Test#2	Reference (no improvement)
Test#3	Test#2 + RCD-snubber
Test#4	Test#3 + primary to secondary y-capacitors

## TEST#4: BACKGROUND

Measurement: 1) CM line inductance L/N & PE



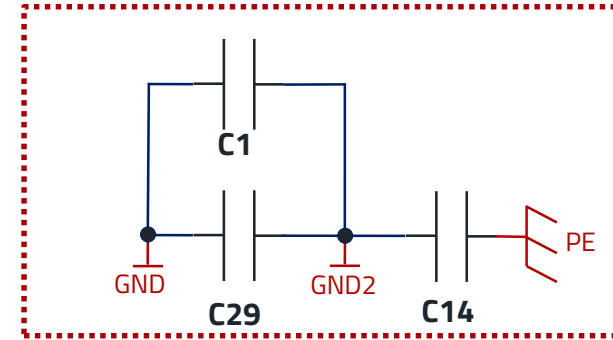
$$L_{cm,L/N} \approx 0,8\mu H$$



$$L_{PE} \approx 0,8\mu H$$

$$\rightarrow L_{line} = L_{PE} + L_{cm,L+N} \approx 0,8\mu H + 0,8\mu H = 1,6\mu H$$

Effective ground capacitance in common mode

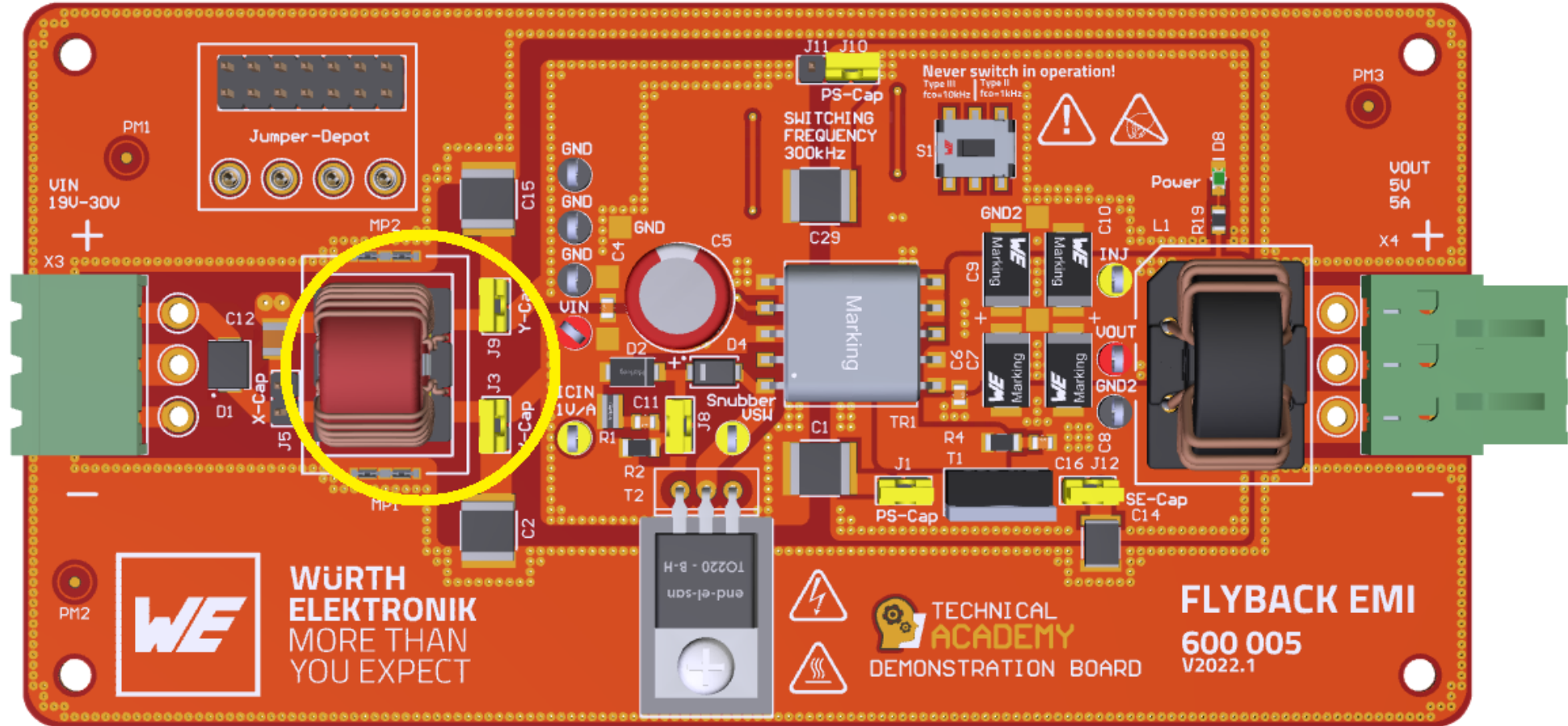


$$\rightarrow C_E \approx \frac{(C_1 + C_{29}) \cdot C_{14}}{C_1 + C_{29} + C_{14}} = \frac{(4,7nF + 4,7nF) \cdot 1nF}{4,7nF + 4,7nF + 1nF} \approx 0,904nF$$

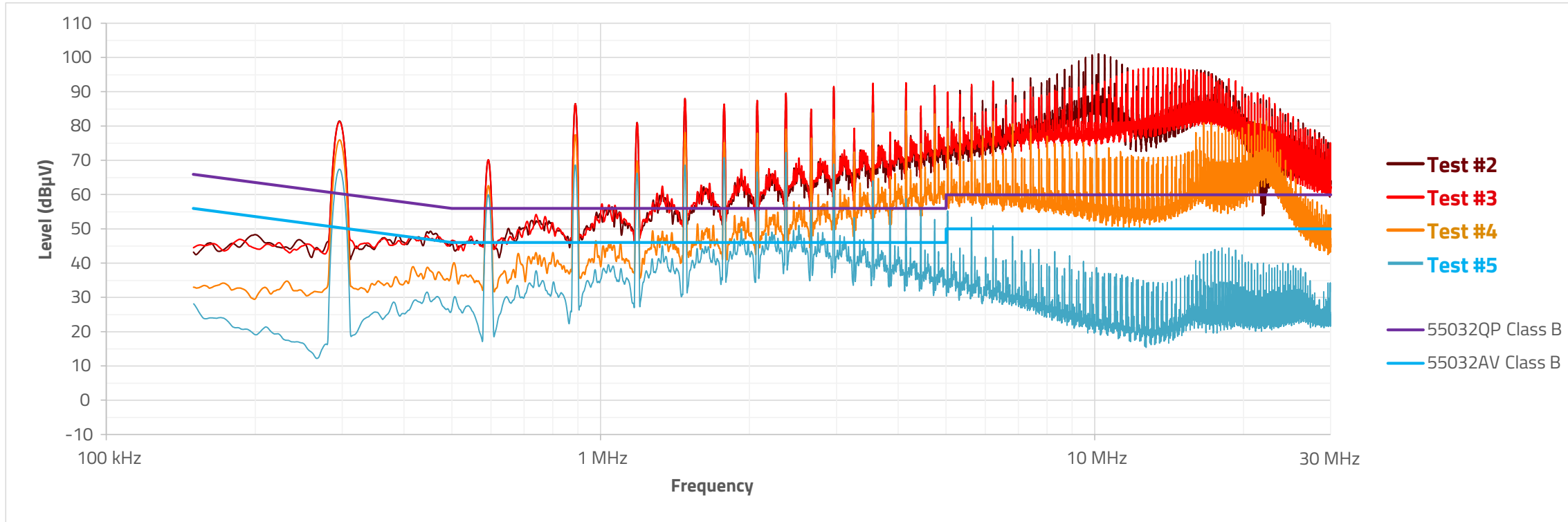
$$f_{0,cm} = \frac{1}{2\pi \cdot \sqrt{L_{line} \cdot C_E}} = \frac{1}{2\pi \cdot \sqrt{1,6\mu H \cdot 0,904nF}} \approx 4,2MHz$$



# TEST#5: BOARD CONFIGURATION

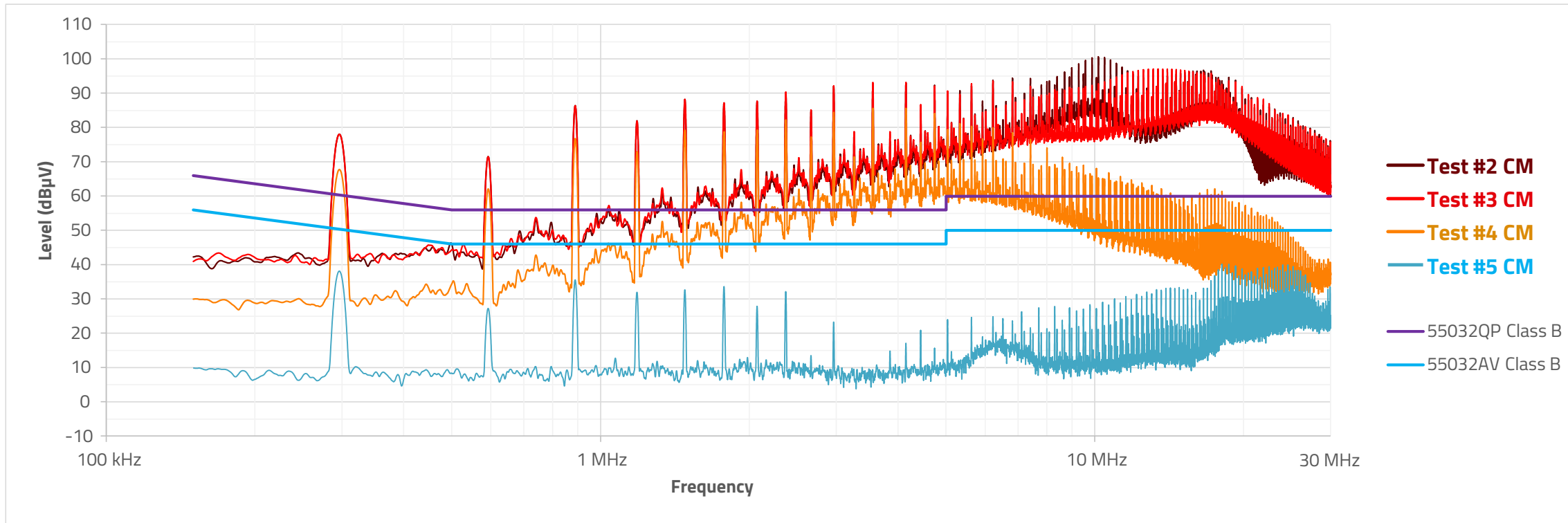


# TEST#5: TOTAL CONDUCTED EMISSIONS – LINE



Name	Description
Test#2	Reference (no improvement)
Test#3	Test#2 + RCD-snubber
Test#4	Test#3 + primary to secondary y-capacitors
Test#5	Test#4 + CMC and y-capacitors (CM filter)

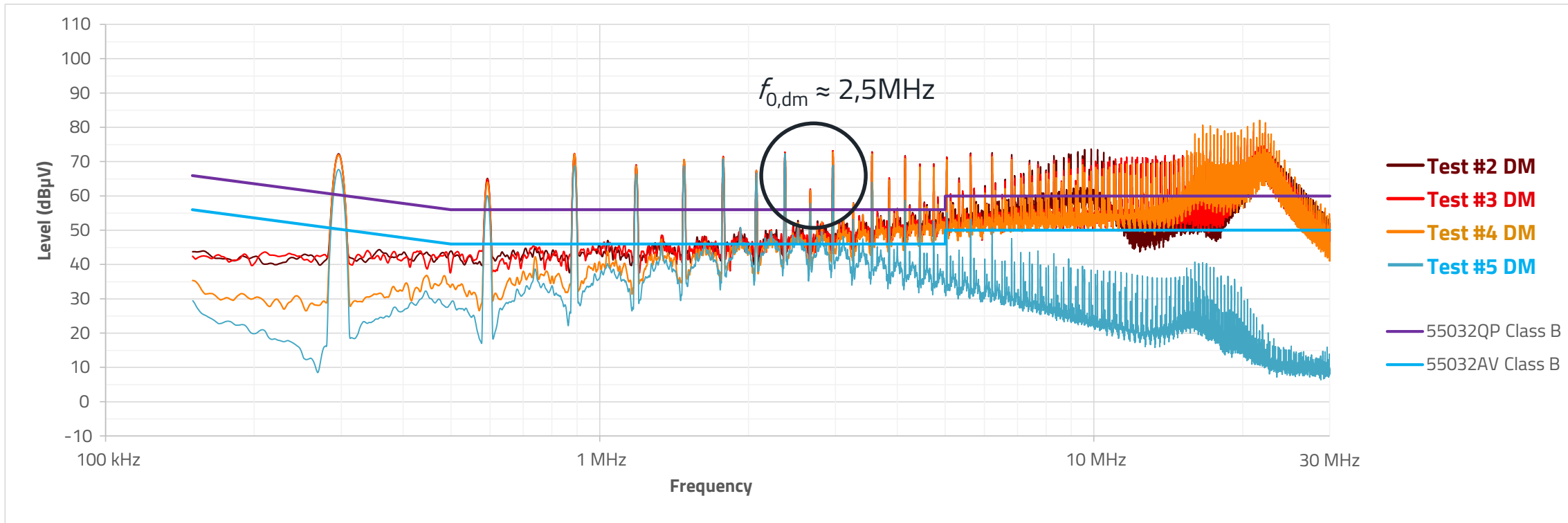
# TEST#5: CONDUCTED EMISSIONS - COMMON MODE



Name	Description
Test#2	Reference (no improvement)
Test#3	Test#2 + RCD-snubber
Test#4	Test#3 + primary to secondary y-capacitors
Test#5	Test#4 + CMC and y-capacitors (CM filter)



# TEST#5: CONDUCTED EMISSIONS - DIFFERENTIAL MODE



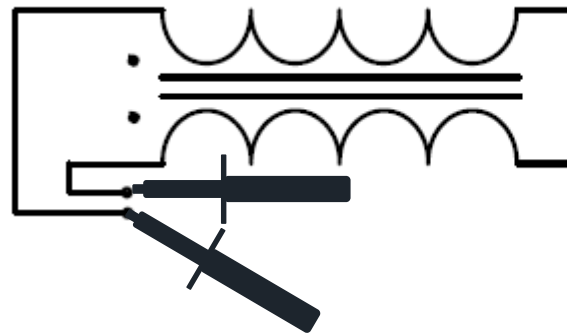
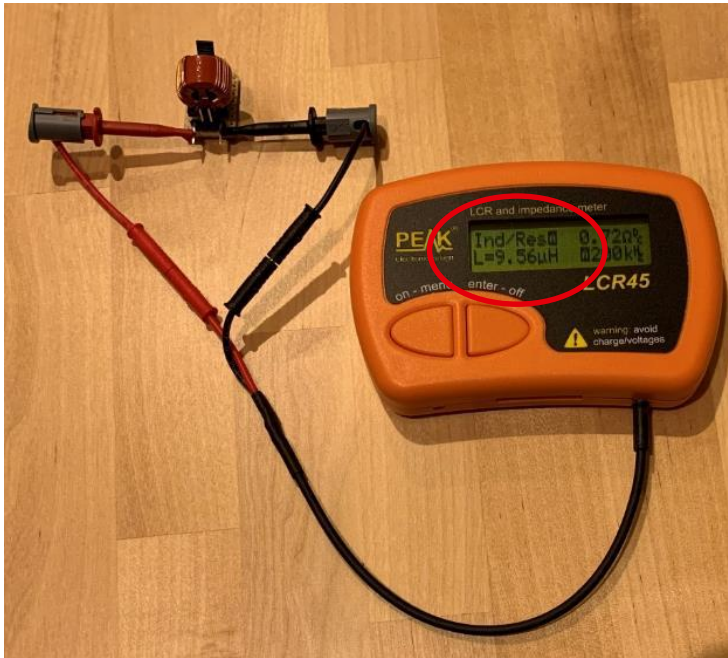
Name	Description
Test#2	Reference (no improvement)
Test#3	Test#2 + RCD-snubber
Test#4	Test#3 + primary to secondary y-capacitors
Test#5	Test#4 + CMC and y-capacitors (CM filter)

Where does this cut off frequency come from?  
How do we attenuate this DM noise?

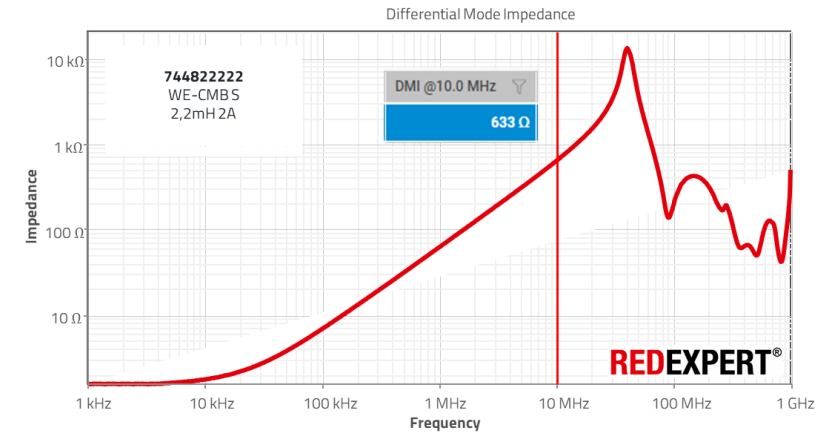
## TEST#5: BACKGROUND

Measurement: Stray inductance

- The stray inductance of the CMC and the junction capacitance ( $C_{J,D6} \approx 400pF$ ) of D6 (WE-TVSP) act as differential mode filter (LC-filter) for free
  - Stray inductance of the CMC (744822222 – 2.2mH/2A CMB Type S):



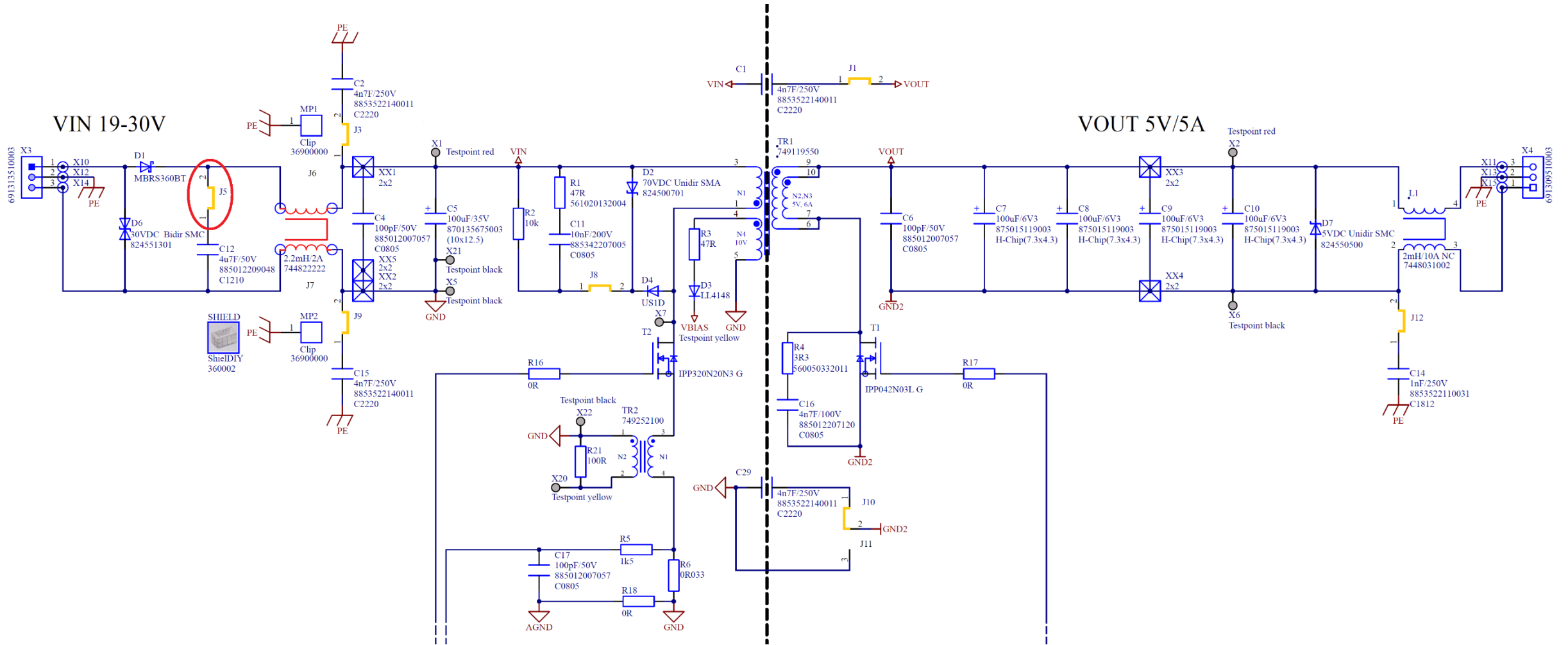
$$L_{S,cmc} \approx 10\mu H$$



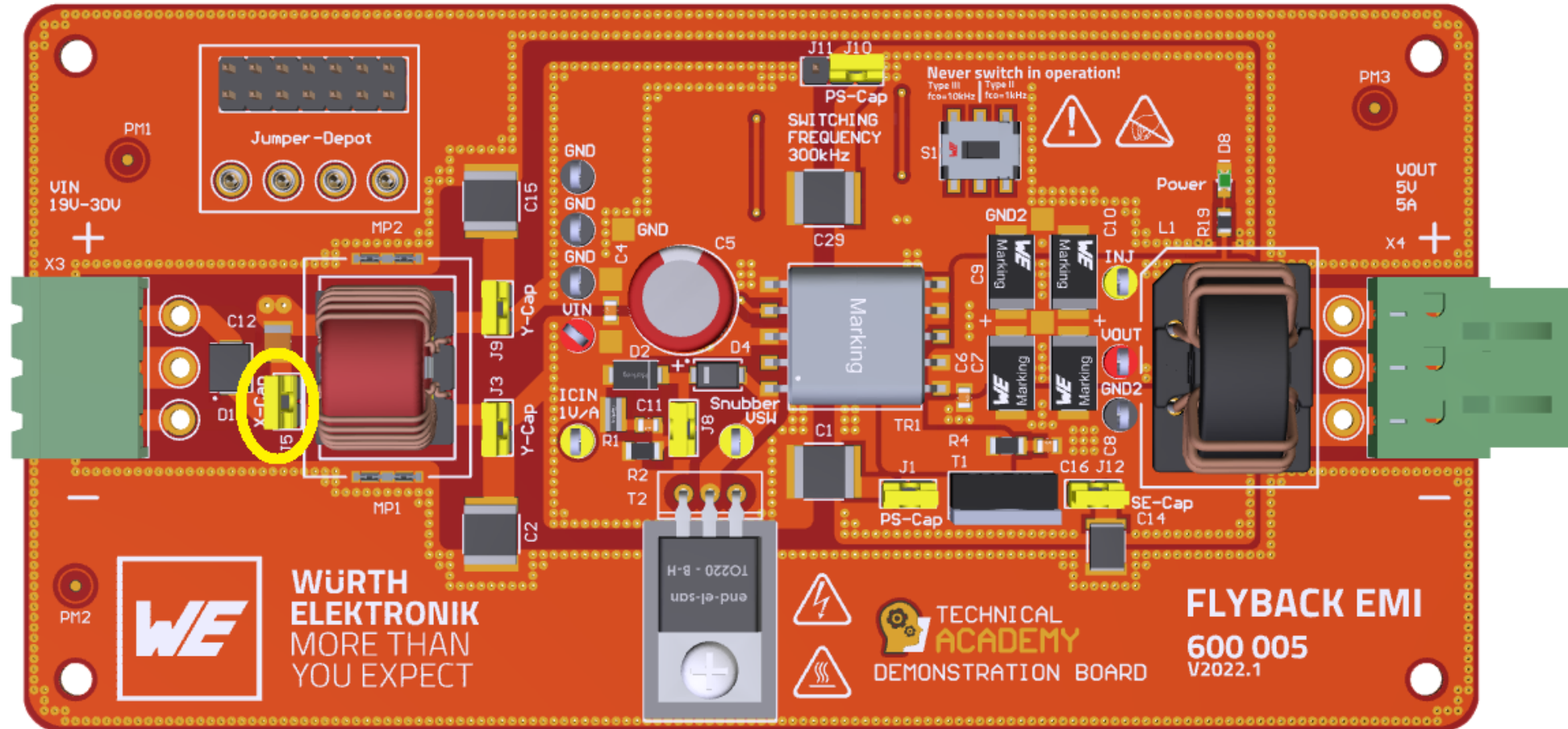
$$L_{S,cmc} = L_{dm} = \frac{|Z_{dm}|}{2\pi \cdot f} = \frac{633\Omega}{2\pi \cdot 10MHz} \approx 10\mu H$$

$$f_{0,dm} = \frac{1}{2\pi \cdot \sqrt{L_{S,cmc} \cdot C_{J,D6}}} = \frac{1}{2\pi \cdot \sqrt{10\mu H \cdot 400pF}} \approx 2,5MHz$$

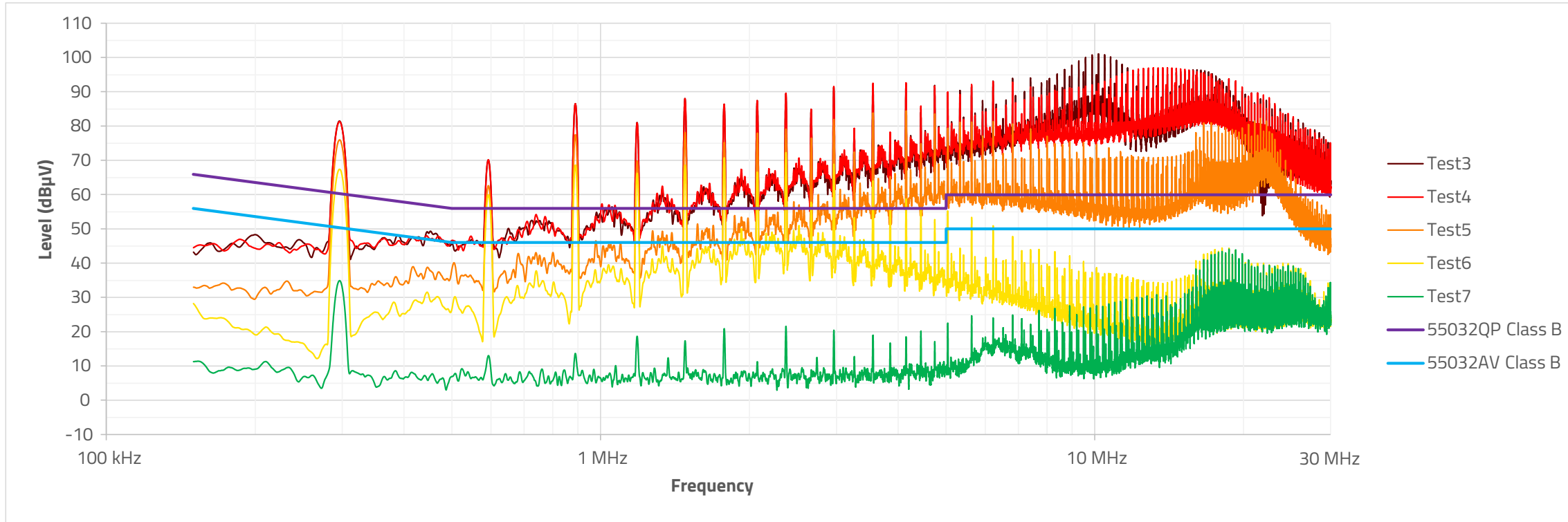
# TEST#6: SCHEMATIC



# TEST#6: BOARD CONFIGURATION

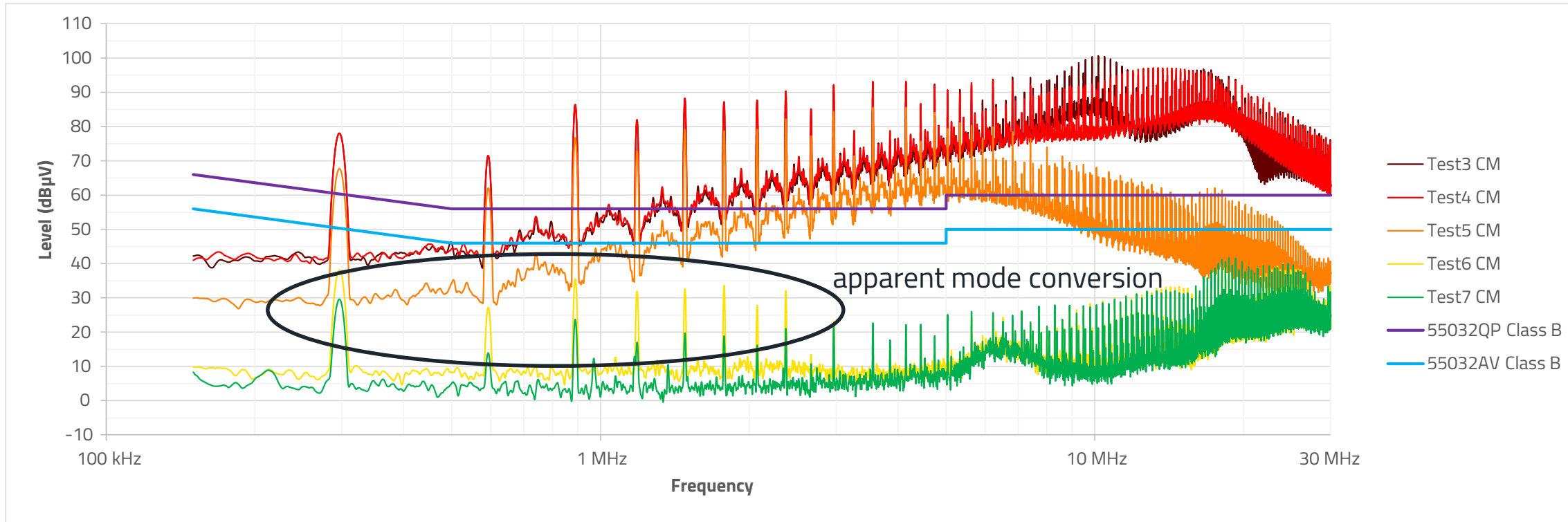


# TEST#6: TOTAL CONDUCTED EMISSIONS - LINE



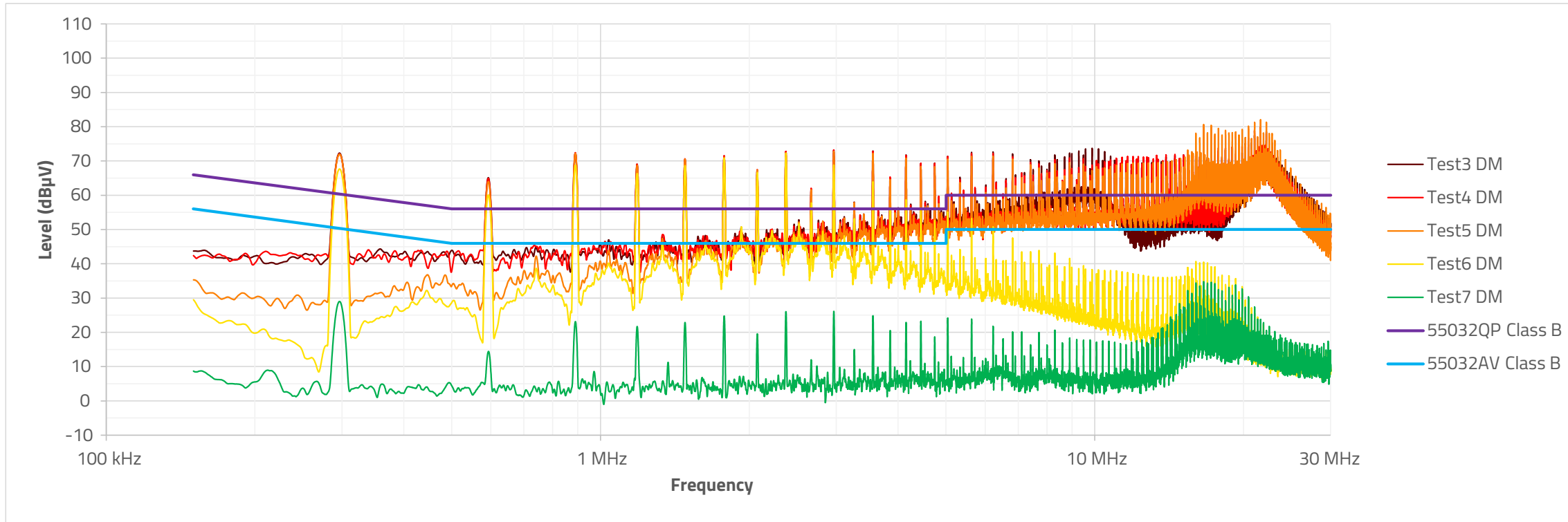
Name	Description
<b>Test#3</b>	<b>Reference (no improvement)</b>
<b>Test#4</b>	<b>Test#3 + RCD-snubber</b>
<b>Test#5</b>	<b>Test#4 + primary to secondary y-capacitors</b>
<b>Test#6</b>	<b>Test#5 + CMC and y-capacitors (CM filter)</b>
<b>Test#7</b>	<b>Test#6 + x-capacitor (DM filter)</b>

# TEST#6: CONDUCTED EMISSIONS - COMMON MODE



Name	Description
<b>Test#3</b>	<b>Reference (no improvement)</b>
<b>Test#4</b>	<b>Test#3 + RCD-snubber</b>
<b>Test#5</b>	<b>Test#4 + primary to secondary y-capacitors</b>
<b>Test#6</b>	<b>Test#5 + CMC and y-capacitors (CM filter)</b>
<b>Test#7</b>	<b>Test#6 + x-capacitor (DM filter)</b>

# TEST#6: CONDUCTED EMISSIONS - DIFFERENTIAL MODE

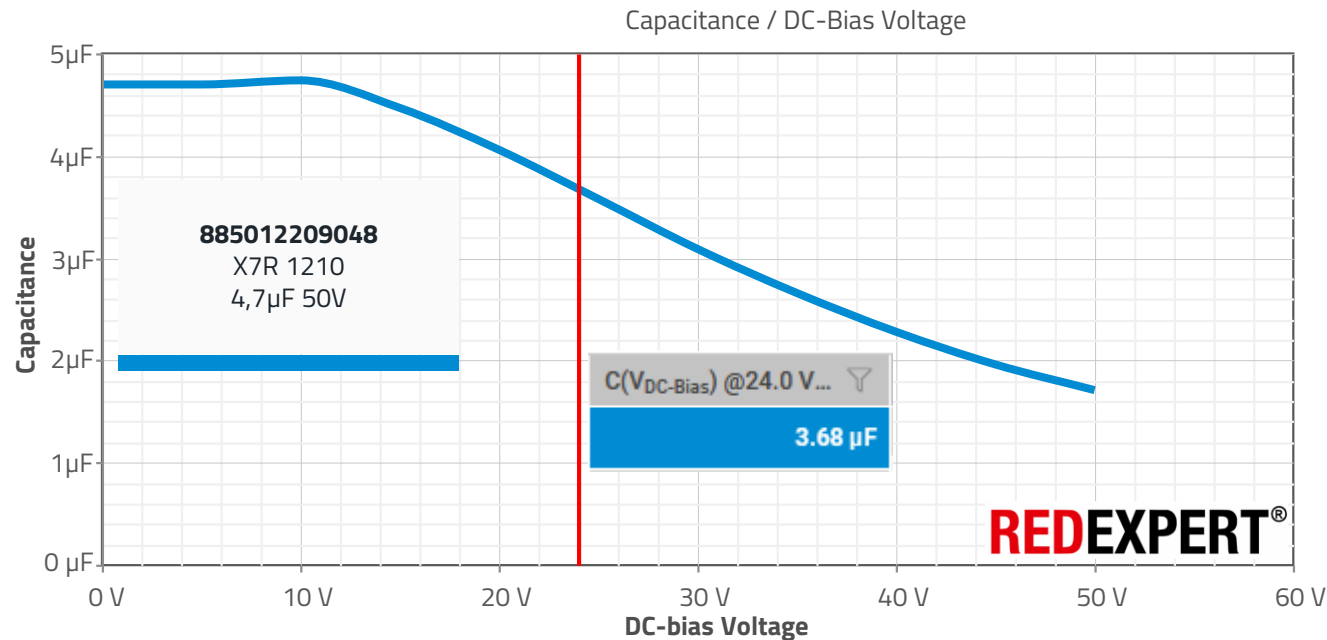


Name	Description
<b>Test#3</b>	<b>Reference (no improvement)</b>
<b>Test#4</b>	<b>Test#3 + RCD-snubber</b>
<b>Test#5</b>	<b>Test#4 + primary to secondary y-capacitors</b>
<b>Test#6</b>	<b>Test#5 + CMC and y-capacitors (CM filter)</b>
<b>Test#7</b>	<b>Test#6 + x-capacitor (DM filter)</b>

## TEST#6: BACKGROUND

REDEXPERT: Capacitance / DC-Bias

- The DM filter results from the stray inductance of the CMC and the x-capacitor
  - stray inductance of the CMC  $\approx 10\mu\text{H}$
  - x-capacitors C12/C<sub>x</sub>: 4,7 $\mu\text{F}$ /50V-1210-MLCC



$$C_x \approx 3,68\mu\text{F}@24\text{VDC}$$



## TEST#6: BACKGROUND

### Theorie

- The DM filter results from the stray inductance of the CMC and the x-capacitor:
  - stray inductance of the CMC  $\approx 10\mu\text{H}$
  - x-capacitors C12/C<sub>x</sub>: 4,7 $\mu\text{F}$ /50V-1210-MLCC

$$f_{0,\text{dm}} = \frac{1}{2\pi \cdot \sqrt{L_{S,\text{cm}} \cdot C_x}} = \frac{1}{2\pi \cdot \sqrt{10\mu\text{H} \cdot 3,68\mu\text{F}}} \approx 26,2\text{kHz}$$

$$A_{\text{dm},f,\text{sw}} = \log\left(\frac{f_{\text{sw}}}{f_{0,\text{dm}}}\right) \cdot 40\text{dB} = \log\left(\frac{300\text{kHz}}{26,2\text{kHz}}\right) \cdot 40\text{dB} \approx 42,3\text{dB}$$

# Questions

& Answers



We are here for you now!  
Ask us directly via our chat or via E-Mail.

[digital-we-days@we-online.com](mailto:digital-we-days@we-online.com)  
[Robert.Schillinger@we-online.de](mailto:Robert.Schillinger@we-online.de)