DEMO STATION: HOW CAPACITORS INFLUENCE THE PERFORMANCE OF A FLYBACK CONVERTER

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Capacitors and Resistors - Würth Elektronik eiSos GmbH & Co. KG

2023 PSMA MAGNETICS WORKSHOP

WURTH ELEKTRONIK MORE THAN YOU EXPECT
TEST SETUP

Taking advantage of the FFT capabilities of Rohde & Schwarz Oscilloscopes for EMI Testing
TECHNICAL SPECIFICATION

DC/DC Flyback-Converter CCM (Forced Continuous Conduction Mode)

- Specification
  - $U_{\text{in}} = 24\, \text{V} \ (19-30\, \text{V})$
  - $U_{\text{out}} = 5\, \text{V}$
  - $I_{\text{out,max}} = 5\, \text{A} \ (25\, \text{W})$
  - $f_{\text{SW}} \approx 300\, \text{kHz}$
  - Efficiency $\approx 90\%$

- IC: ADP1071-2 (Analog Devices)
  - with synchronous rectifier

- Transformer: 749119550

- MOSFETs in TO220-package
TEST#3: BACKGROUND - NOISE CATEGORIES

Theory: Noise categories

Differential Mode

Common Mode
TEST#3: BACKGROUND - NOISE CATEGORIES

Theory: DM and CM noise path in a flyback converter

\[
U_{L,RF} = U_{CM} + U_{DM}
\]

\[
U_{N,RF} = U_{CM} - U_{DM}
\]

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

\[
U_{CM} = \frac{U_{L,RF} + U_{N,RF}}{2}
\]
TEST#1: WAVEFORMS - SWITCH NODE VOLTAGE

Switch node ringing $f \approx 10\text{MHz}$
TEST#1: WAVEFORMS - INPUT CAPACITOR CURRENT

Current ringing f≈10MHz
TEST#1: WAVEFORMS - INPUT CAPACITOR VOLTAGE RIPPLE

Input capacitor voltage ringing $f \approx 10\text{MHz}$
TEST#2: BOARD CONFIGURATION

Input capacitor current
TEST#3: BOARD CONFIGURATION
TEST#4: BOARD CONFIGURATION
TEST#4: BOARD CONFIGURATION
TEST#5: BACKGROUND - SWITCH NODE CAPACITANCE
TEST#6: BOARD CONFIGURATION
TEST#7: BOARD CONFIGURATION
TEST#7: TOTAL CONDUCTED EMISSIONS - LINE

**Name** | **Description**
--- | ---
Test#3 | Reference (no improvement)
Test#4 | Test#3 + RCD-snubber
Test#5 | Test#4 + primary to secondary y-capacitors
Test#6 | Test#5 + CMC and y-capacitors (CM filter)
Test#7 | Test#6 + x-capacitor (DM filter)
CMC COMPARISON - CONDUCTED EMISSIONS - COMMON MODE – 100 KHz - 1 MHz

**CMC Core material:**
- MnZn/MnZn
- NiZn
- Nanocrystalline

**Note:**
Different color choice!
Test#7: *green before → red (for 2,2mH MnZn)*
Test#7 h): *green (for NiZn)*

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<td>Test#7 - CMC: 2,2mH/2A MnZn - 744822222</td>
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<td>Test#7 - CMC: 1mH/3A MnZn - 744822301</td>
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<td>Test#7 h)</td>
<td>Test#7 - CMC: 110µH/3A NiZn - 744842311</td>
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<tr>
<td>Test#7 k)</td>
<td>Test#7 - CMC: 5mH/3A Nc - 7448023005</td>
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### CMC COMPARISON - CONDUCTED EMISSIONS - COMMON MODE – 10 MHz – 30 MHz

#### Test Results:

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#### CMC Core material:
- MnZn/MnZn
- NiZn
- Nanocrystalline

**Note:**
- different color choice!
  - Test#7: green before → red (for 2,2mH MnZn)
  - Test#7 h): green (for NiZn)
CMC COMPARISON: CONDUCTED EMISSIONS - DIFFERENTIAL MODE - 10 MHz – 30 MHz

### Name | Description
--- | ---
Test#5 a) | Test#5 + y-capacitors + x-capacitor
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Test#7 e) | Test#7 - CMC: 1mH/3A MnZn - 744822301
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CMC Core material:
- MnZn/MnZn
- NiZn
- Nanocrystalline

Note: different color choice!
Test#7: green before → red (for 2,2mH MnZn)
Test# 7 h): green (for NiZn)
CMC COMPARISON: BACKGROUND - DIFFERENTIAL MODE - 100 kHz – 1 MHz

REDEXPERT: Differential Mode Impedance

- CMC Core material:
  - MnZn/MnZn
  - NiZn
  - Nanocrystalline

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<tr>
<th>Component Details</th>
<th>Impedance (Ω)</th>
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<tr>
<td>744822222 WE-CMB S</td>
<td>2.20 mH 2.00 A</td>
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<td>744822301 WE-CMB S</td>
<td>1.00 mH 3.00 A</td>
</tr>
<tr>
<td>7448023005 WE-CMBNC S</td>
<td>5 mH 3.00 A</td>
</tr>
<tr>
<td>744842311 WE-CMB NiZn S</td>
<td>110 µH 3.00 A</td>
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Frequency range: 1 kHz to 100 MHz
TEST#3-7: CONDUCTED EMISSIONS - EMI LABRATORY

Test setup
EMI LABORATORY VS. PRECOMPLIANCE - CONDUCTED EMISSIONS - LINE

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TEST#3-7: CONDUCTED EMISSIONS - LTSPICE

Link to simulation folder

Simulation settings

Filter

Common-Mode Noise Model

Supply + LISN + Line

Note

1. Run simulation
2. View FFT
3. Select V(cm,rf), V(dm,rf) and V(l,rf) by holding the ctrl-key - OK
4. Plot Settings - Reload Plot Settings

LPE = Line inductance PE
LL = Line inductance L +/-
LN = Line Inductance N -/+ 
LLX = Primary-side leakage inductance
CDE = Drain to Earth (PE) capacitor
CPS = Primary to secondary winding capacitor (Interwinding capacitor)
RPS = Primary to secondary resistor (find the DC operating point)
Line inductance measured with LCR45 (1mm=1nH)
K2 = V(1-LSC/LFC) = V(1-0.48μH/0.8μH) = 0.6325

Link to simulation folder
LTSPICE VS. MEASUREMENT - TOTAL CONDUCTED EMISSIONS - LINE

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