EMV in der Leistungselektronik am Beispiel eines SEPIC Wandlers

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Agenda

• Sources of EMI
• Conducted emissions
• Emissions of a 12V SEPIC converter
• EMI Filters
DC-DC Converters and EMI in the Board Net

Larger Electrical Power Consumption

Difficult with 12V Board Net

Introduce 48V Board Net

Need/Challenge to ensure EMC!

Source of EMI with large Power Throughput

Need DC-DC Converter between Nets

Source: emo-berlin.de
Sources of EMI – DC-DC Converters

• Example: SEPIC converter

• Switching frequency 0.5MHz → Fast switching device!

• Up- and Down-Conversion

• Two modes of operation depending on load and duty cycle
  • Two-phase or Three-phase
Sources of EMI – DC-DC Converters

• Periodic Signal
  • Contributions in the spectral domain at multiples of 0.5MHz
  • Largest Contribution at 0.5MHz (typically)

• Switching and Resonant Circuits
  • Resonant circuits due to parasitic inductances and capacities
    • Board
    • Components
  • Frequency much higher than switching period
  • Steep switching edges excite those circuits
  • Contribution largely independent of switching period
Quantifying EMI

- Disturbances in form of
  - Conducted emissions (CE)
  - Radiated emissions (RE)

- CISPR standard:
  - Artificial network (LISN)
  - Conducted emissions measured over a 50Ω termination
  - Two LISNS for power and GND
Quantifying EMI

• Important
  • Shielding from external signals
  • Proper ground
  • Wiring harnesses
  • Distance from proper ground
Modeling EMI

- Parasitic behavior of capacitors and inductors
  - Measured
  - Equivalent circuit fitted

- Behavioral models of active components from manufacturer
  - SPICE models
Modeling EMI

- Parasitics of the board and cables from field simulation
- State space models
- Important to take care of ground!
Modeling EMI

- Wiring Harness as a 2D model
Modeling EMI

- With ideal components and no parasitics from the layout
  - No resonant circuits
  - No spikes due to switching
- The lower part of the emissions spectrum is modeled by an ideal circuit.
- For the higher part of the spectrum parasitics are important!
Conducted Emissions of the SEPIC Converter

- Transient signal measured at the LISNs
  - Periodic
  - Three phases of SEPIC

- Lower part of spectrum: Differential mode
- Higher part of spectrum: Common mode
Conducted Emissions of the SEPIC Converter
• Conducted (guided) waves on the wiring harness can form standing waves.

• Those resonances influence the emissions of the converter.
Influence of a Wiring Harness

- Standing waves in the wiring harness lead to resonances!

<table>
<thead>
<tr>
<th>Mode</th>
<th>$l[\mu\text{H/m}]$</th>
<th>$c[\text{pF/m}]$</th>
<th>$v_0[10^8\text{m/s}]$</th>
<th>$Z_0[\Omega]$</th>
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</thead>
<tbody>
<tr>
<td>Differential</td>
<td>0.50</td>
<td>72</td>
<td>1.7</td>
<td>83</td>
</tr>
<tr>
<td>Common</td>
<td>0.99</td>
<td>12</td>
<td>2.9</td>
<td>287</td>
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</tbody>
</table>

$$\Delta f_{\text{diff}} = \frac{v_0}{2L} \approx 39\text{MHz} \quad \text{or} \quad \Delta f_{\text{comm}} = \frac{v_0}{2L} \approx 66\text{MHz}.$$
• The wiring harness forms a resonant circuit
Influence of a Wiring Harness

Common Mode Of wiring harness

Emissions_PWR

Emissions_Diff

Emissions_Comm
Filters

• Reduce emissions with the help of EMI filters

Acts against AC currents

Divert AC currents

• Performance of a filter measured using S-Parameters

AC source

Filter

Voltage measured
• Parasitic Effects reduce the performance of a filter

Board
Effect of Filter

- No Harness
- With Harness
Radiated Emissions

- Wiring Harness acts as Antenna
- Push Excitations from Simploer to HFSS
Summary:
With appropriate modeling many EMI effects can be captured and even quantified!
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