Question & Answer Session:

Submit questions via Questions Window anytime. Questions will be addressed at the end of the presentation.

Important Notes

This webinar will be recorded and available on the PSMA web site shortly after the webinar. Participant Phone Lines will be muted throughout.
EMC Measures in general
Josefine Lametschwandtner, BSc
EMC-Online-Seminar, 31\textsuperscript{th} of May 2022
Agenda

- Measures for a first time pass
- First time fail
- Live Measurement Placement
Approach to a first time pass

- Concept of areas
- Classification of the signal types (aggressive, sensitive, equal)
- Connectors
- Interfaces: wires leaving the board
- Check the length of sensitive traces
- Filter
- Layer stack
- Parallel components used correctly
Separate different areas and order them
eg. Zone 1 – analog measurement,
  eg. Zone 1b – temperature measurement
eg. Zone 2 – interface of communication

Shielding and/or filtering of different Zones
Subzone – at least shielding
Zone-Zone - Shielding and Filtering, when entering from one zone to the other

When do I care about zones?
ASAP – latest at the first sketch of the block diagram
Signal Types

- Classify Signals
  - Aggressive
  - Sensitive
  - Indifferent

- Separate different signal types as well as possible

Fig.: Crosstalk between traces [2]
Connectors

- Placement of connectors

- Selection of connectors
  - Shielded
  - Type
  - Filtered

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Fig.: Placement of connectors [1]
Interfaces

- Wires & Traces leaving the board:
  - Filter
    - and / or
  - Shielding
    - and / or
  - Twisted pair

- Shielding
  - 360°
  - Direct
  - On both ends

- Filter
  - On both ends

Fig.: Handling of Interfaces [1]
Connectors & Shield – 360°

Fig.: Cable-Shield Connection [4]

Fig.: HF-Connectors [3]

Fig.: Shield connection [2]
Cable shield – 360°

Fig.: Cable Shield with bad connection
Cable shield – 360°

Fig.: Cable Shield improved

- Cable Sheath
- Cable Shield
- Insulated Wires
Low Pass – remove high frequencies

AC instability seen at the input

Acoustical noise (whining, whistling, …)

Middlebrook Criterion: $Z_{out,\text{filter}} \ll Z_{in,\text{converter}}$
Filter

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<th>$Z_G$</th>
<th>$Z_L$</th>
<th>Simple Filter</th>
<th>Advanced Filter</th>
<th>Amplification possible</th>
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<td>Yes</td>
</tr>
</tbody>
</table>

Fig.: Filter topologies [2]
Main Power Filter

Fig.: Generic Filter [4]
Type of Distortion: Differential Mode

a: Circuit without grounded connection
b: Circuit operated symmetrically
c: Circuit operated unsymmetrically

Fig.: Variations in differential mode interference [4]
Type of Distortion: Common Mode

a: Circuit operated symmetrically
b: Circuit operated unsymmetrically

Fig.: Variations of common mode interference [4]
Common Mode Interference in a Class II Power Supply

Coupling Capacitance: directly proportional to area and inversely proportional to gap distance

Fig.: Parasitic path to protective earth (PE) [5]
CM Capacitor

C3 is required in many cases to reduce the CM interference emissions.

Fig.: Filter Suggestion from RECOM datasheet
CM Capacitor

For example: Flyback

**Fig.:** Principle of a flyback converter [6]

**Fig.:** Current and voltage waveforms of a flyback [6]
Layerstack

- Power planes for low impedance path
- Power planes used as shielding
- Power planes used as HF-path – low impedance due to capacitance

Fig.: Layerstack [1]
Component placement of parallel devices

- HF-Path, as short as possible
- Place parallel components where needed, not far away
- Each length of trace has an inductive value

Fig.: Protective devices [7]
Capacitor on stubs

Fig.: Connection of capacitors [1]
Capacitor on Stubs - Correction

Fig.: Improved Connection of capacitors [1]
First time fail

- Action List to mitigate “First Time Fail”
- Allocation of frequency ranges
- Mitigation in system design
- Recommendations for troubleshooting
Action List for EMC Troubleshooting

- Detection
  - Locate
  - Isolate
  - Differentiate

- Countermeasures
  - Grounding
  - Wiring layout
  - Filter
  - Shielding

Fig.: Procedure when EMC limits are exceeded
Type of Interference and Mitigation Measures vs. Frequency

Fig.: Overview of the frequency range [8]
Shielding – Skin depth

\[ \delta_S = \sqrt{\frac{2}{\omega \mu \sigma}} = 2.09 \times 10^{-6} \text{m} \]

\[ \eta_c = \frac{1 + j}{\sigma \delta_S} = 8.2 \times 10^{-3} (1 + j) \Omega \]

\[ \delta_S = \text{Skin depth} \]

\[ \eta_c = \text{intrinsic impedance} \]

\[ \Gamma = \frac{\eta_c - \eta_0}{\eta_c + \eta_0} = 1 \angle 179.99^\circ \]

Fig.: Effect of shielding [9]
Grounding and Shielding

- Avoid slots in metal planes and surfaces
- Slots act like antennas; ideal antenna at $\lambda/4$, but effect starts at $\lambda/10$

![Fig.: Planes [1]](image1)

![Fig.: Slot antenna [10]](image2)
Filters

- Differential Mode
- Common Mode
- Combined CM/DM

Fig.: Ferrites [15][16]

Fig.: Combined filter [17]
Cable Shielding

- Use shielded cables
- Check the quality of the shield
- Connect the shield at both ends (GND)
- Connect the shield to ground/PE

Fig.: Shielded cable[18]
Use a Systematic Approach

- Make only one change per measurement
  - Top-Bottom or Bottom-Top approach

- Verify any action that appears to have an effect
  - Change it back to see if effect remains

- Work precisely!
  - Even a small inaccuracy can completely destroy the validity of the measurement.
EMC countermeasures start at the draft stage

The earlier EMC is considered in the design, the more time, cost and space efficient the countermeasures will be.

To meet the requirements, the remedial actions very often have to be combined.
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   Stefan Klein, Würth Elektronik;
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6. Schaltnetzteile und ihre Peripherie
   Schlienz, Ulrich; Vieweg Praxiswissen, 3. Auflage, 2007

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- Develops standard industry terminology
- Generates and publishes technology and market reports
- Provides regulatory agency interface
- Organizes technical workshops and seminars
- Coordinates with other power related organizations
- Facilitates benchmarking studies with member companies
- Promotes liaison with users, academia and government

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