Safety and Compliance Committee

EMC Basics and Coupling Mechanism
April 6, 2021
Safety and Compliance Committee

- Meets once per month for 1 hour
- Safety and Compliance Database
  - Tracks changes in major industry compliance issues including materials, EMI-RFI, CISPR, etc.
  - E-mail alerts sent to anyone subscribed to the Safety and Compliance database, membership list is constantly growing
- Members share regular email blasts with articles of interest
- Monthly articles for How 2 Power, special section “Power Supply Safety and Compliance”
- Continued educational webinars
Bio – Josefine Lametschwandtner

- BS in Science with an emphasis on Electronics and Technology from FH Joanneum
- Lead EMC Engineer for RECOM Power
  - Joined in 2014
  - Previous experience with GE Medical Systems
- EMC filter development and testing
- Customer consulting around all EMC issues
- Organizes the RECOM EMC Seminar
- Tri-lingual (German, English, Spanish)
EMC Basics, Coupling Mechanism – Part 1/4
Josefine Lametschwandtner, BSc
EMC-Webinar, 6th April 2021
Topics

- Definition – EMC
- What do parasitics do?
  - Components
  - Coupling Mechanism
- Finding Coupling Mechanism in SMPS
- Discussion
Definitions

- EMC – Electromagnetic Compatibility
- EMI – Electromagnetic Interference
- EMS – Electromagnetic Susceptibility
General Principle

Fig. Principle of EMC


*Electromagnetic compatibility* according to the Directive 2014/30/EU means:

the ability of equipment to function satisfactory in its electromagnetic environment without introduction intolerable electromagnetic disturbances to other equipment in that environment.
Reality meets Electronics = EMC - Resistor

DC & low frequencies:

\[ Z = (R + L) \parallel C \]

High frequencies = Reality:

\[ Z = \frac{j\omega RC - \omega^2 LC}{R + j\omega (L + C)} \]

Fig. DC resistor [01]

Fig. Frequency response of resistors – black line is optimum [01]

Fig. real resistor [01]
Reality meets Electronics = EMC - Capacitor

DC & low frequencies:

\[ Z = R_{wire} + R_{Dielectric} || C + L \]

High frequencies = Reality:

\[ Z = \frac{R_{Dielectric}}{j\omega CR_{Dielectric} + 1} + j\omega L \]

Fig. DC capacitor [01]

Fig. Frequency response of real capacitor and its elements [01]
Reality meets Electronics = EMC - Capacitor

High frequencies = Reality:

![Diagram of a capacitor circuit](image)

**Fig. real capacitor [01]**

![Graph of frequency response](image)

**Fig. Frequency response of different capacitors [01]**

![Graph of frequency response with ESL](image)

**Fig. Frequency response of capacitor with different ESL [01]**

![Graph of frequency response of real capacitor and its elements](image)

**Fig. Frequency response of real capacitor and its elements [01]**
Reality meets Electronics = EMC - Inductance

DC & low frequencies:

\[ Z = R_{cu} + R_{Fe}||C||L \]

High frequencies = Reality:

\[ Z = R_{cu} + \frac{R_{Fe}j\omega L}{R_{Fe} - R_{Fe}\omega^2 LC + 1} \]

Fig. DC inductor = Rcu[01]

Fig. Real inductor [01]

Fig. Frequency response of inductor – normalized [01]
Types of Coupling

- Galvanic
- Capacitive
- Inductive
- Airborne

Fig. Overview of coupling mechanism including parasitics
Types of Coupling - Galvanic

Fig. Coupling mechanism – outlining galvanic coupling
Types of Coupling – Galvanic; Mechanism

\[ U(t) = Ri(t) + L \frac{di(t)}{dt} \]

Fig. Mechanism of galvanic coupling [02]
Types of Coupling – Galvanic; Mitigations

- Traces with very low impedance
- Reduction of disturbances
- Reduction of the frequency of the disturbing signal
- Star-grounding for critical paths

Fig. Remedial actions against galvanic coupling (green)
Types of Coupling - Capacitive

- Galvanic
- Capacitive
- Inductive
- Airborne

Fig. Coupling mechanism – outlining capacitive coupling
Types of Coupling – Capacitive; Mechanism

\[ I_{\text{noise}} = C \frac{dU_{\text{Noise}}(t)}{dt} \]

**Fig.** Mechanism of capacitive coupling [01]

**Fig.** Mechanism of capacitive coupling [02]

**Fig.** Mechanism of capacitive coupling [03]

**Fig.** Mechanism of capacitive coupling [03]
Types of Coupling – Capacitive; Mitigations

- Short traces
- Avoid parallel traces with different signals
- Separation of traces with different signals
- Symmetry
- Shielding
- Reduction of switching frequencies
- Twisted cabling

**Fig.** Remedial actions against capacitive coupling (green)
Types of Coupling - Inductive

Fig. Coupling mechanism – outlining inductive coupling
Types of Coupling – Inductive; Mechanism

\[
u_{L2}(t) = \frac{di_1(t)}{dt} M_{12} = \frac{d\phi_{12}}{dt}
\]

\[
\phi_{12} = \int_{A2} B_1 \cdot dA
\]

Fig. Mechanism of inductive coupling [02]

Fig. Mechanism of inductive coupling [04]
Types of Coupling – Inductive; Mitigations

- Very small loops (low impedance)
- Twisted cabling
- Avoid parallel traces with different signals
- Shorten parallel traces length
- Reduction of switching frequencies
- Shielding (μ-Metal or Permalloy)

Fig. Remedial actions against inductive coupling (green)
Types of Coupling - Airbourne

- Galvanic
- Capacitive
- Inductive
- Airborne

Fig. Mechanism of airborne coupling
Types of Coupling – Airborne; Mechanism

Fig. Mechanism of airborne coupling [02]

Field model

Net model

Fig. Mechanism of airborne coupling [05]
Equivalent Circuit for PCB Tracks

\[ Z = \frac{R + j\omega L}{G + j\omega C} \]

\[ \lambda = \frac{c}{f} \]

**Fig.:** Impedance per unit length [04]
DC-Converters Topologies

Galvanic non isolated
- Boost
- Buck
- Buck-Boost
- SEPIC
- ...

Galvanic isolated
- Flyback
- Forward Converter
- Push-Pull
- Bridges
- ...

...
Boost-Converter: Analysis – Coupling mechanism

Fig.: Schematic of Boost converter [01]
Boost-Converter: Analysis – Coupling mechanism

Fig.: Schematic of Boost converter [01]
Boost-Converter: Analysis – Coupling mechanism

Fig.: Schematic of Boost converter [01]
Capacitive coupling
Inductive coupling
Galvanic coupling

Fig.: Schematic of Boost converter [01]
Boost-Converter: Analysis

- Critical Loop – as small as possible
- Split output capacitors in functional- and HF-Cap
- Starpoint for GND to reduce galvanic coupling
- Short traces about switching node
Flyback Converter

Fig.: Typical schematic of Flyback [01]
Flyback Converter

![Typical schematic of Flyback](fig01)

**Fig.**: Typical schematic of Flyback [01]

Galvanic coupling
Flyback Converter

Fig.: Typical schematic of Flyback [01]

Capacitive coupling

Galvanic coupling
Flyback Converter

Fig.: Typical schematic of Flyback [01]

- Capacitive coupling
- Inductive coupling
- Galvanic coupling
Flyback-Converter – EMC Analysis

- Critical loops
- Multiple output capacitors
- Input side filtering
- CM capacitor
- Star grounding

Fig.: EMC-improved schematic [01]
Buck Converter – Resonant circuit

Fig.: Basic Buck-Converter-Schematic [06]

Fig.: Basic Buck-Converter-Schematic including resonant capacitor [06]

Fig.: Current & Voltage – Basic [06]

Fig.: Current & Voltage – improved [06]
EMC Tests simulate “real“ EM-Phenomena and should lead to reproducible results

- High frequency “converts” passive elements

- Coupling mechanism are everywhere
Outlook – Part 2 (Emission)

- Sources (Noise)
- Mitigations in general
- Influence of component placement (practical example)
Sources

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Q & A
Thank You

Please take the survey
We appreciate any ideas or suggestions for improvement.
Upcoming PSMA Events of Interest

• April 27 – Safety And Compliance Committee meeting (virtual)
• June – Magnetics and Capacitor Virtual Workshops before and after APEC 2021
• Visit the PSMA website for more information
Thank You and hope you have enjoyed the webinar

“Wisdom is not a product of schooling but of the lifelong attempt to acquire it.” – Albert Einstein

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