Safety and Compliance Committee

EMC Basics and Coupling Mechanism

April 6, 2021

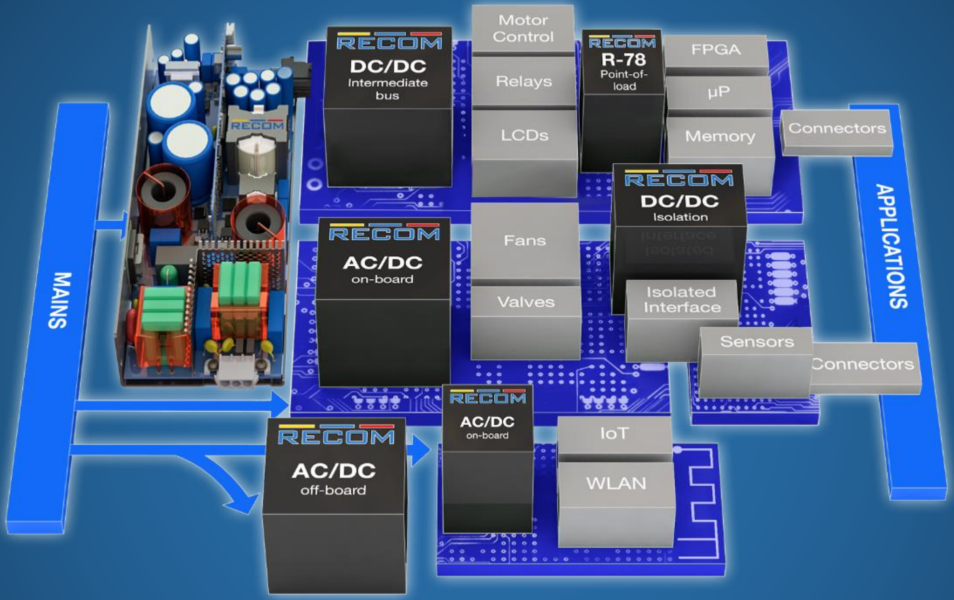
Safety and Compliance Committee

- 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)

MODULES FOR DISTRIBUTED POWER ARCHITECTURE



EMC Basics, Coupling Mechanism – Part 1/4

Josefine Lametschwandtner, BSc

EMC-Webinar, 6th April 2021

RECOM
WE POWER YOUR PRODUCTS

Topics

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

Definitions

- EMC – **E**lectro**M**agnetic **C**ompatibility
- EMI – **E**lectro**M**agnetic **I**nterference
- EMS – **E**lectro**M**agnetic **S**usceptibility

General Principle

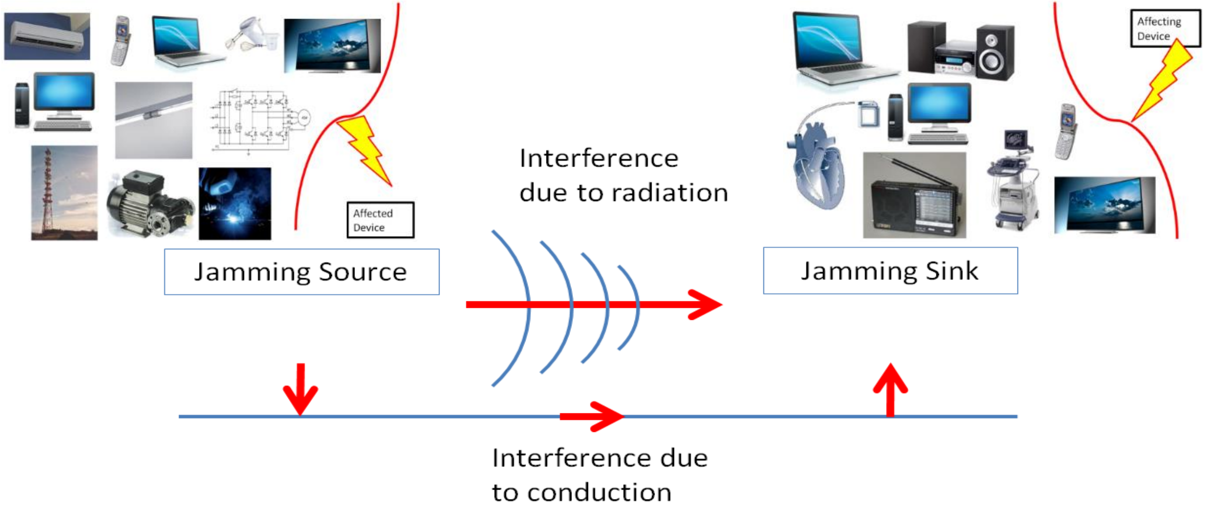


Fig. Principle of EMC

European Directive 2014/30/EU

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:

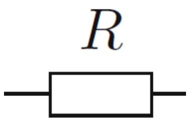


Fig. DC resistor [01]

High frequencies = Reality:

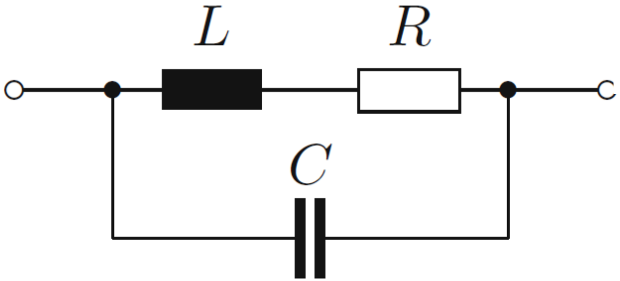


Fig. real resistor [01]

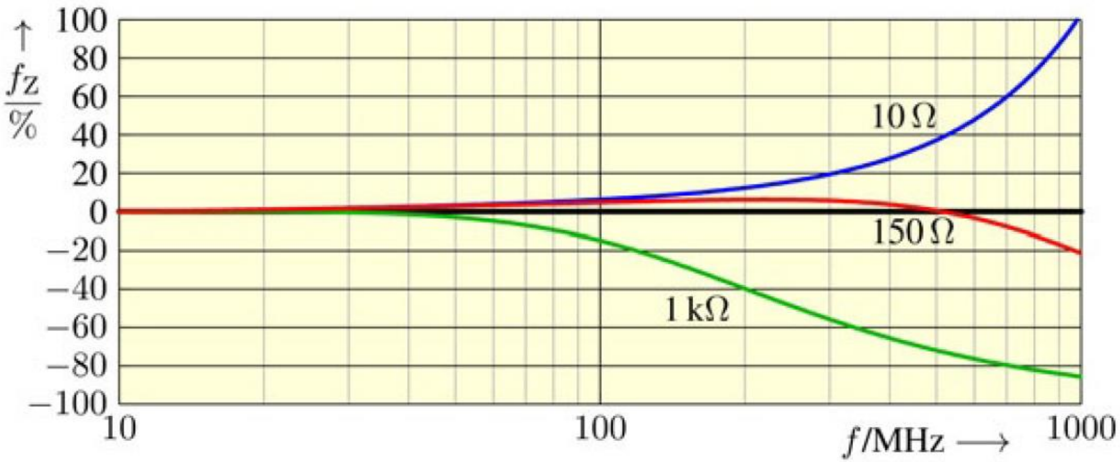


Fig. Frequency response of resistors – black line is optimum [01]

$$Z = (R + L)||C$$

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

Reality meets Electronics = EMC - Capacitor

DC & low frequencies:

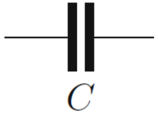


Fig. DC capacitor [01]

High frequencies = Reality:

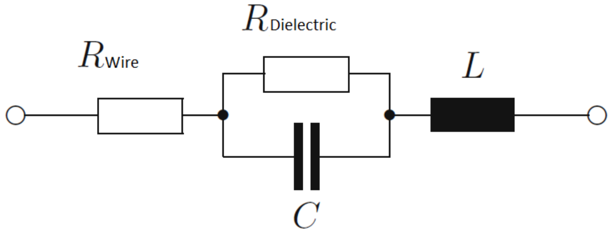


Fig. real capacitor [01]

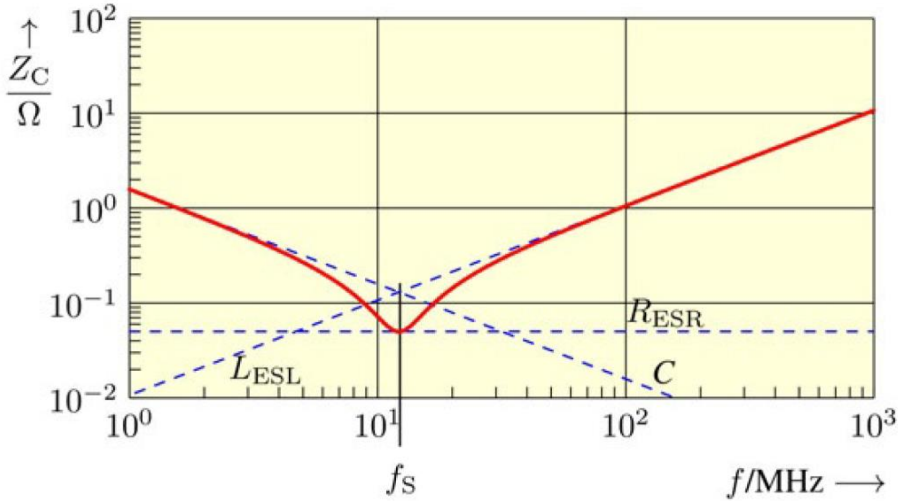


Fig. Frequency response of real capacitor and its elements [01]

$$Z = R_{wire} + R_{Dielectric} || C + L$$

$$Z = R_{wire} + \frac{R_{Dielectric}}{j\omega C R_{Dielectric} + 1} + j\omega L$$

Reality meets Electronics = EMC - Capacitor

High frequencies = Reality:

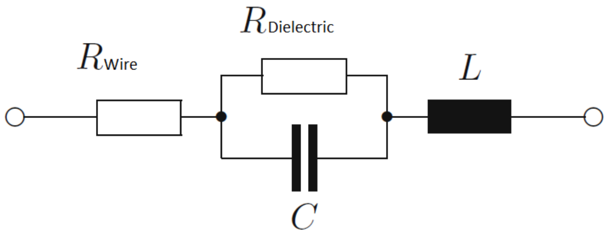


Fig. real capacitor [01]

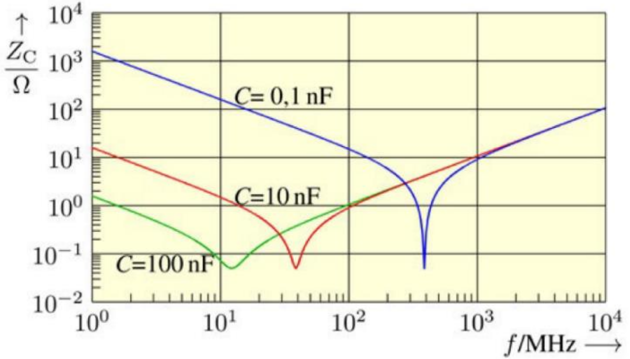


Fig. Frequency response of different capacitors [01]

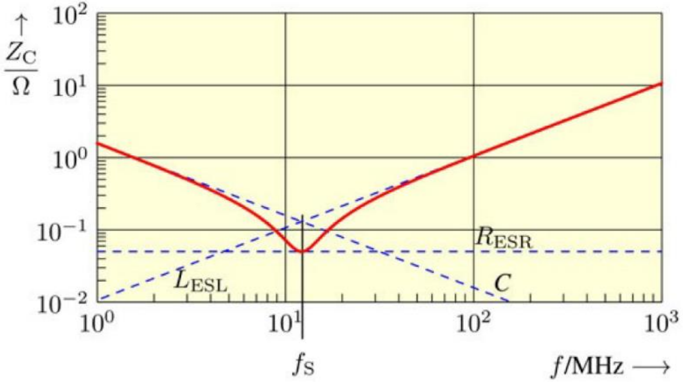


Fig. Frequency response of real capacitor and its elements [01]

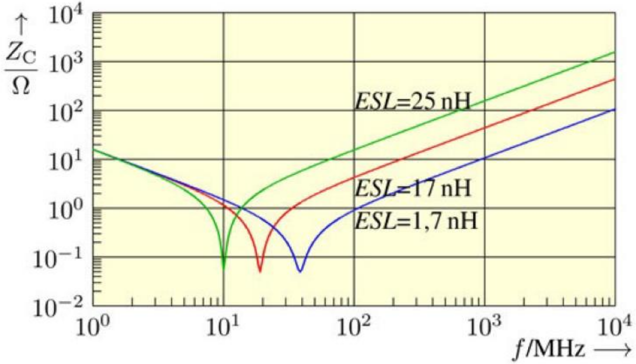


Fig. Frequency response of capacitor with different ESL [01]

Reality meets Electronics = EMC - Inductance

DC & low frequencies:

Fig. DC inductor = Rcu[01]

High frequencies = Reality:

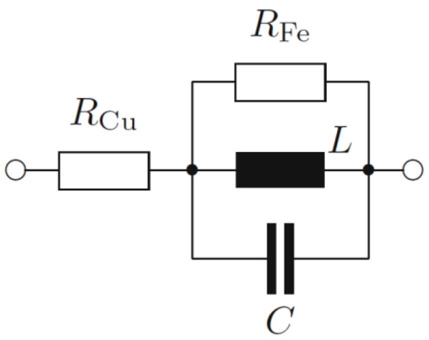


Fig. Real inductor [01]

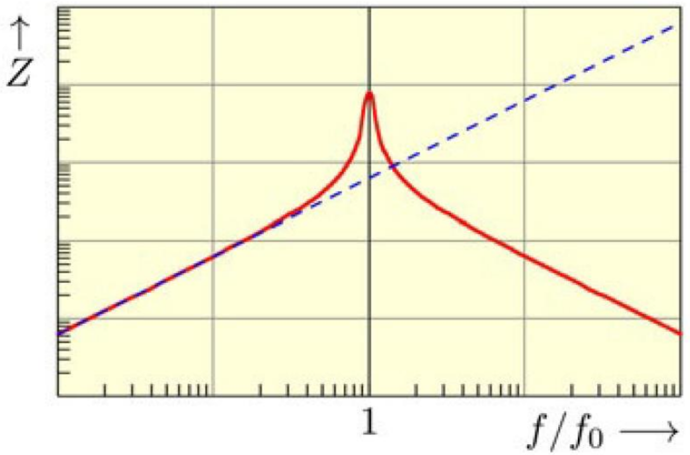


Fig. Frequency response of inductor – normalized [01]

$$Z = R_{cu} + R_{Fe}||C||L$$

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

Types of Coupling

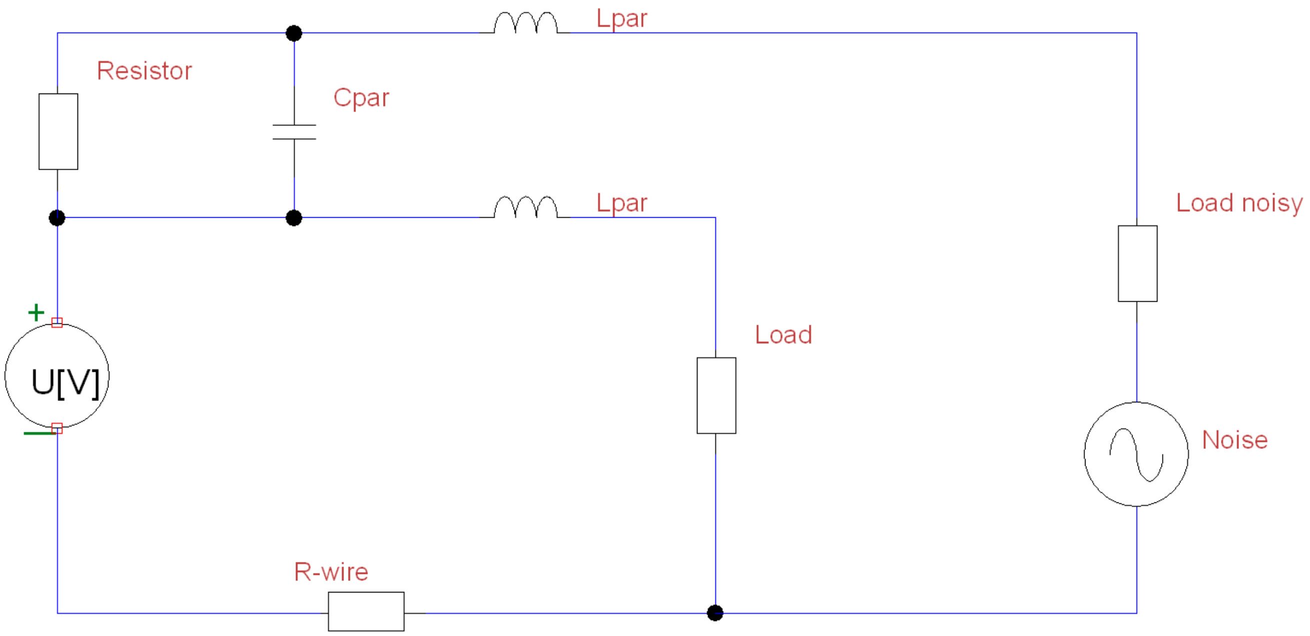


Fig. Overview of coupling mechanism including parasitics

- Galvanic
- Capacitive
- Inductive
- Airborne

Types of Coupling - Galvanic

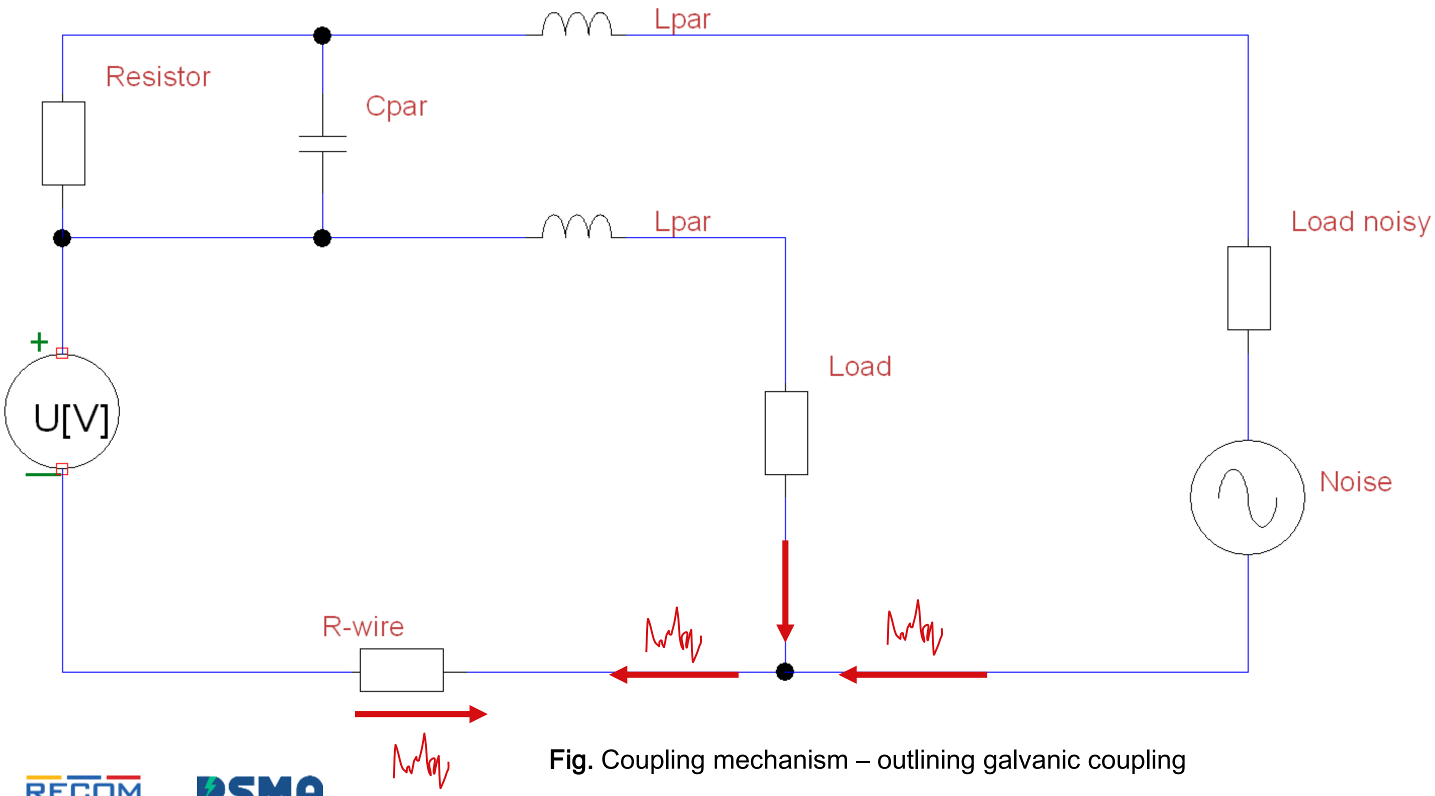
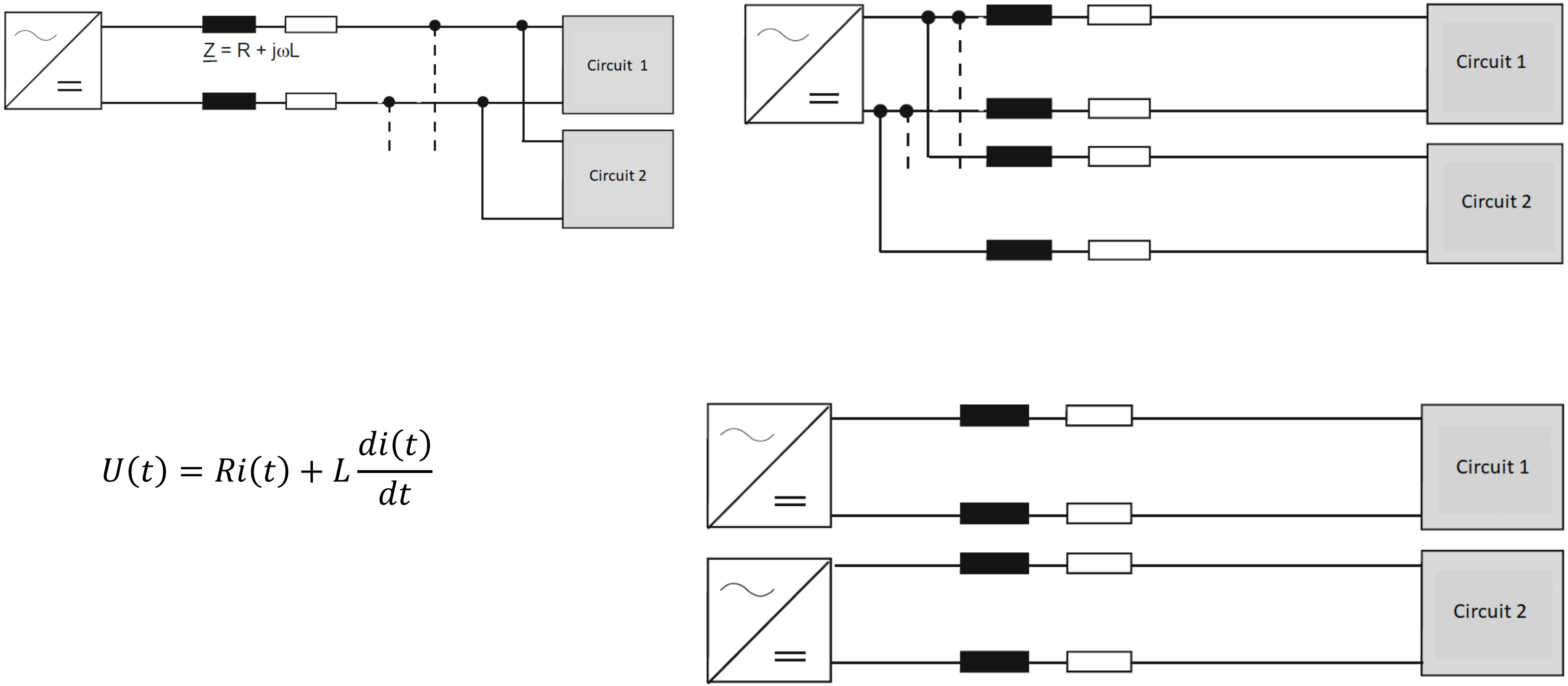


Fig. Coupling mechanism – outlining galvanic coupling

- **Galvanic**
- Capacitive
- Inductive
- Airborne

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

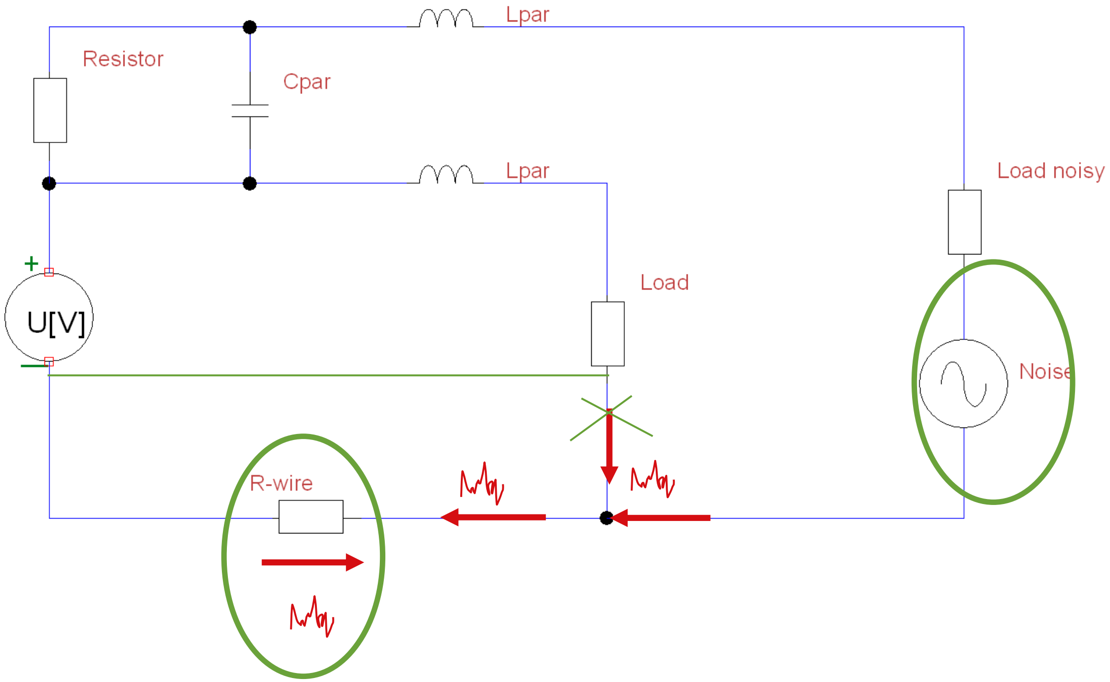
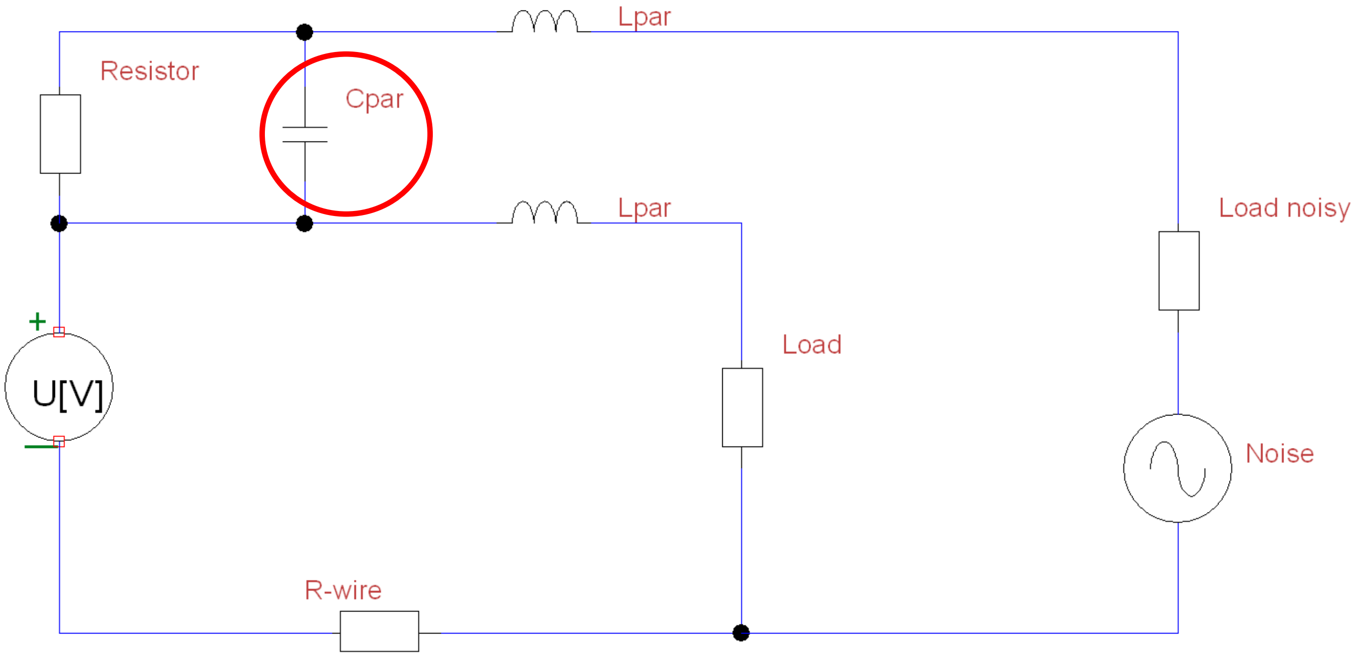


Fig. Remedial actions against galvanic coupling (green)

Types of Coupling - Capacitive



- Galvanic
- **Capacitive**
- Inductive
- Airborne

Fig. Coupling mechanism – outlining capacitive coupling

Types of Coupling – Capacitive; Mechanism

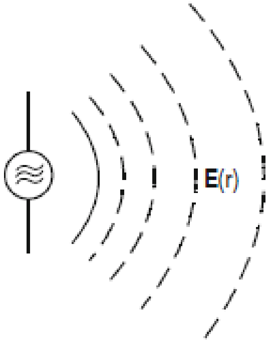
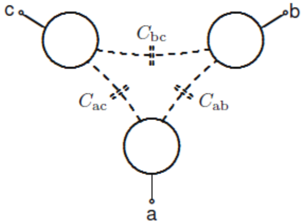


Fig. Mechanism of capacitive coupling [02]



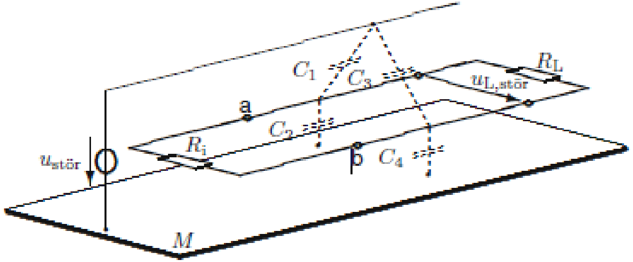


Fig. Mechanism of capacitive coupling [01]

$$I_{noise} = C\frac{dU_{Noise}(t)}{dt}$$

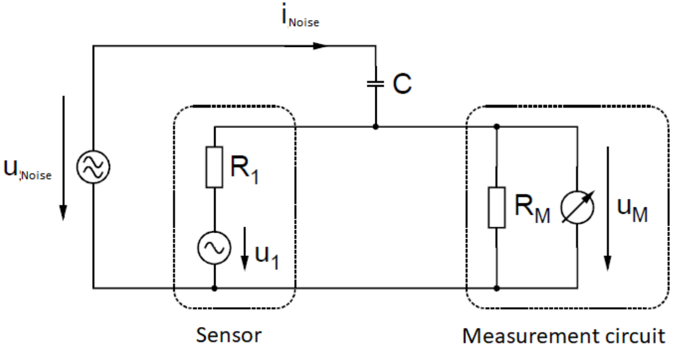


Fig. Mechanism of capacitive coupling [03]

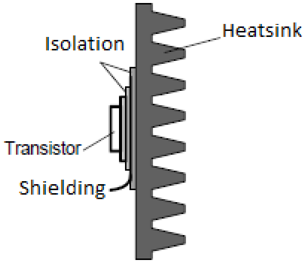


Fig. Mechanism of capacitive coupling [03]

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

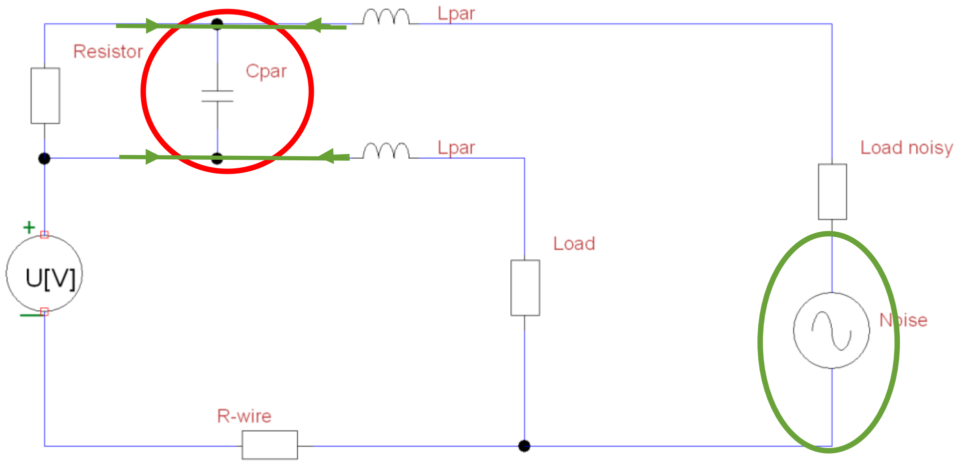


Fig. Remedial actions against capacitive coupling (green)

Types of Coupling - Inductive

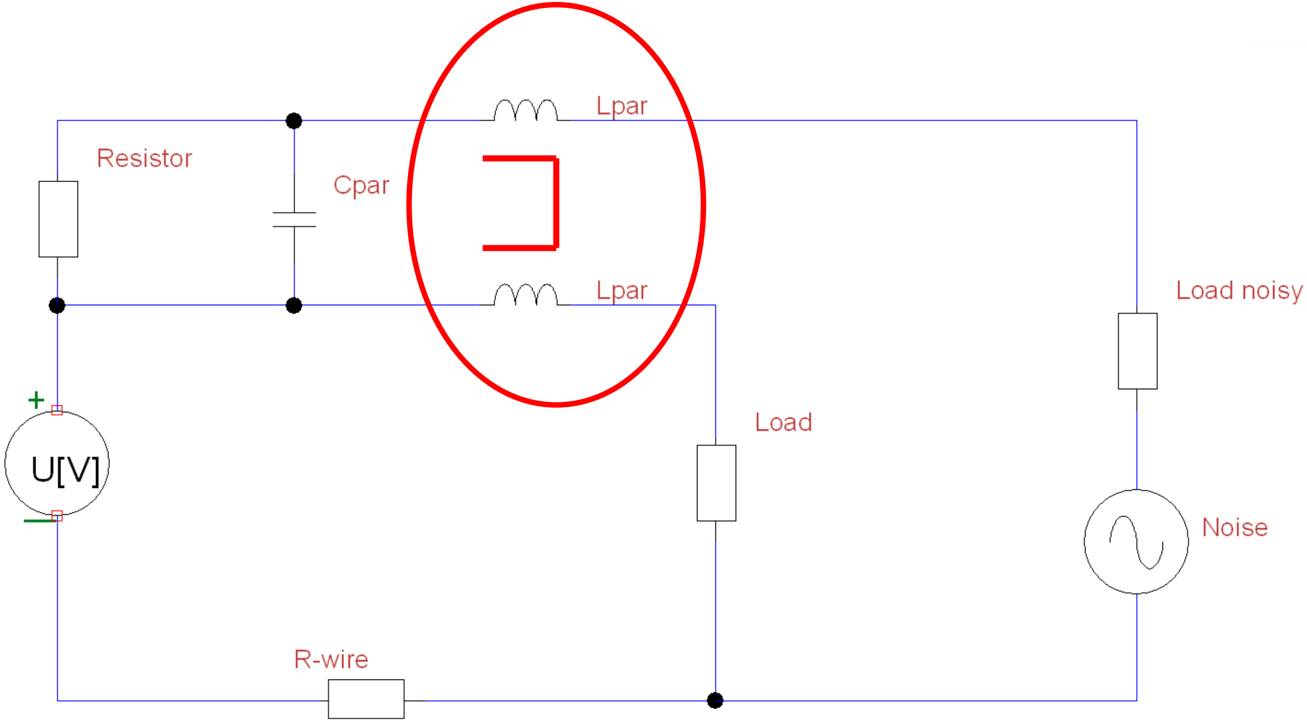


Fig. Coupling mechanism – outlining inductive coupling

- Galvanic
- Capacitive
- **Inductive**
- Airborne

Types of Coupling – Inductive; Mechanism

$$u_{L2}(t) = \frac{di_1(t)}{dt} M_{12} = \frac{d\varphi_{12}}{dt}$$

$$\varphi_{12} = \int_{A2} B_1 \cdot dA$$

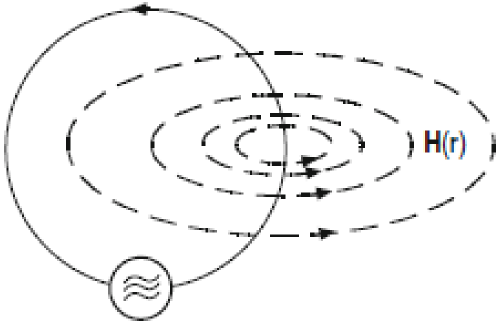


Fig. Mechanism of inductive coupling [02]

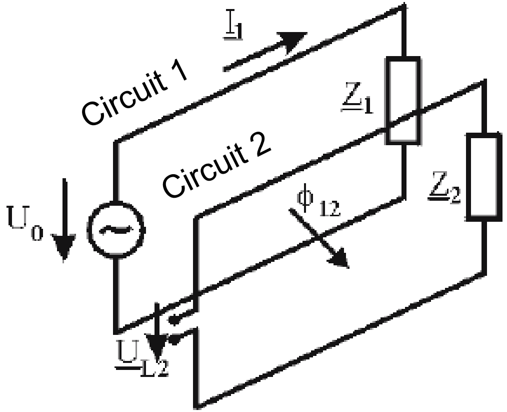


Fig. Mechanism of inductive coupling [04]

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)

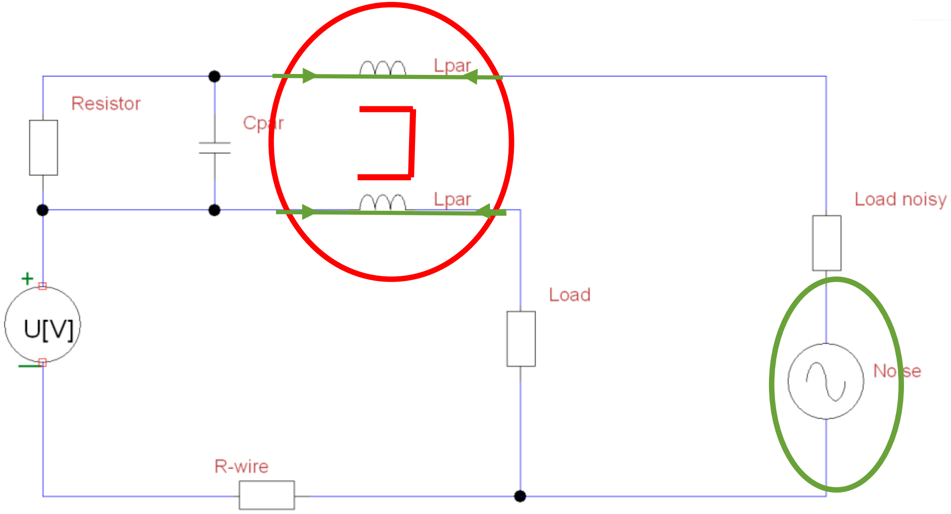


Fig. Remedial actions against inductive coupling (green)

Types of Coupling - Airbourne

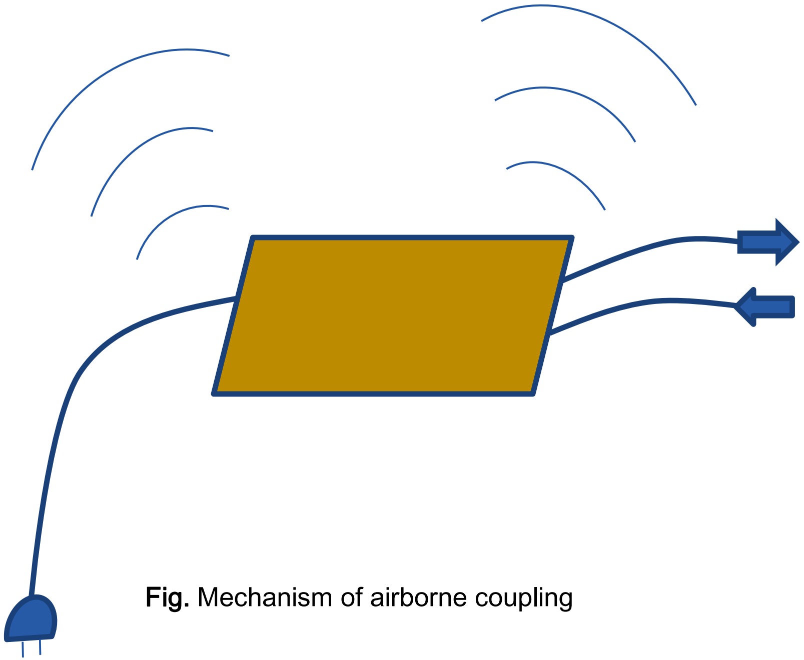
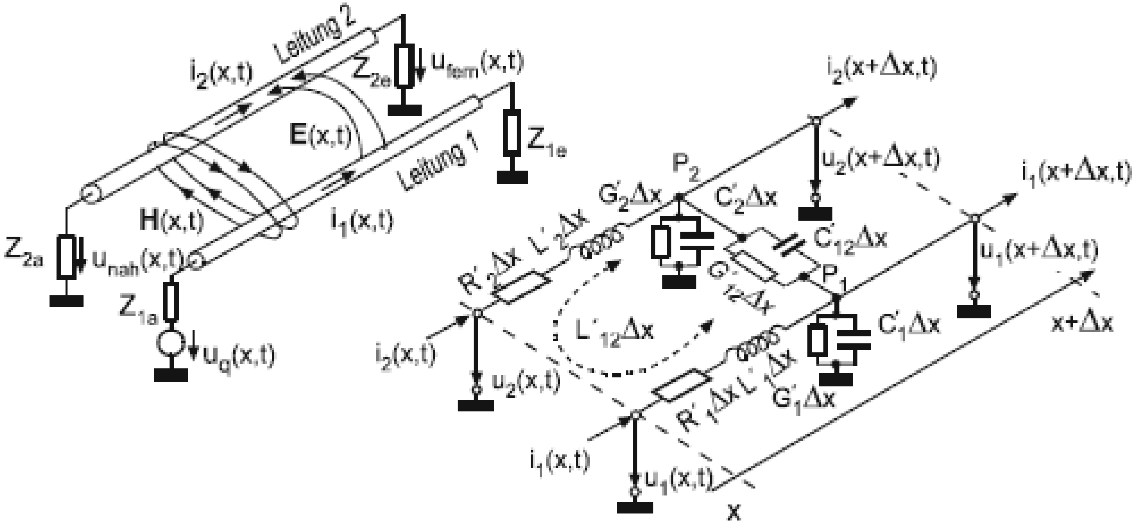


Fig. Mechanism of airborne coupling

- Galvanic
- Capacitive
- Inductive
- **Airborne**

Types of Coupling – Airborne; Mechanism



Field model

Net model

Fig. Mechanism of airborne coupling [02]

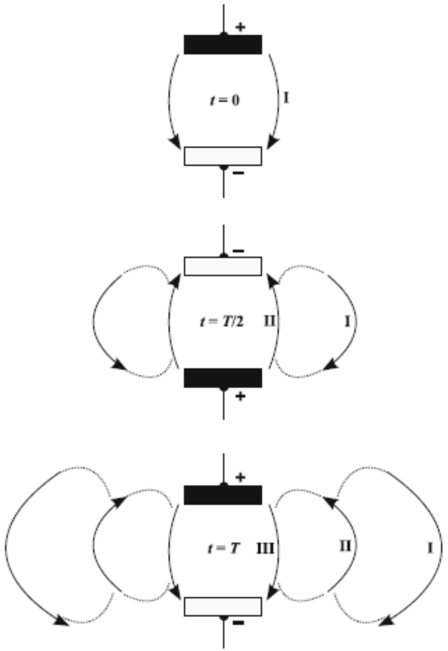


Fig. Mechanism of airborne coupling [05]

Equivalent Circuit for PCB Tracks

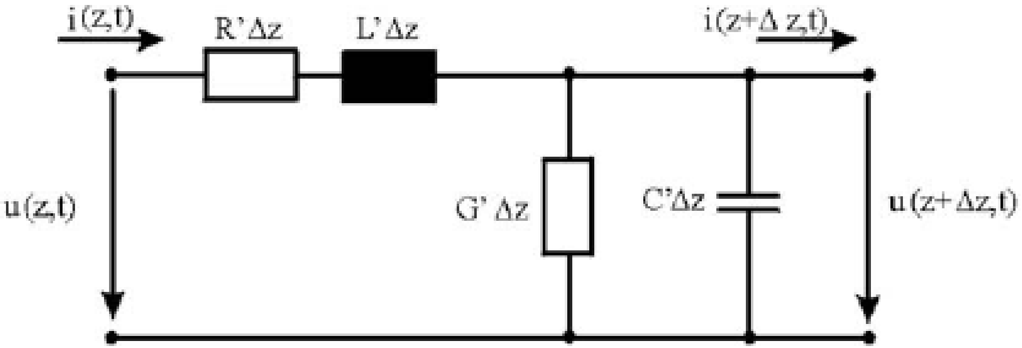


Fig.: Impedance per unit length [04]

$$Z = \sqrt{\frac{R + j\omega L}{G + j\omega C}}$$

$$\lambda = \frac{c}{f}$$

DC-Converters Topologies

- **Galvanic non isolated**
  - Boost
  - Buck
  - Buck-Boost
  - SEPIC
  - …
- **Galvanic isolated**
  - Flyback
  - Forward Converter
  - Push-Pull
  - Bridges
  - …

Boost-Converter: Analysis – Coupling mechanism

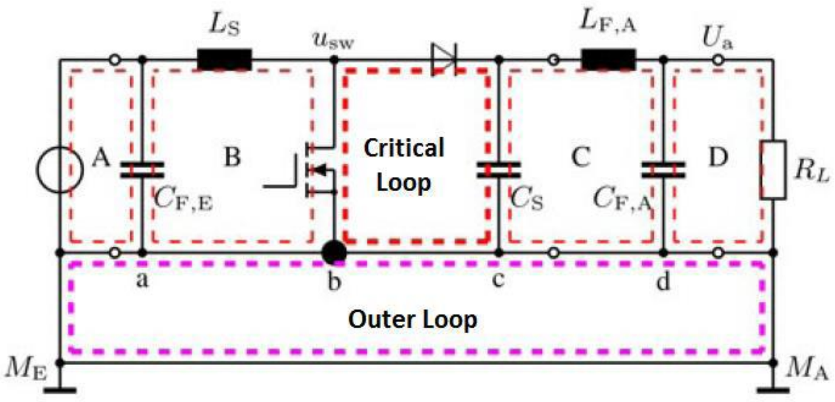
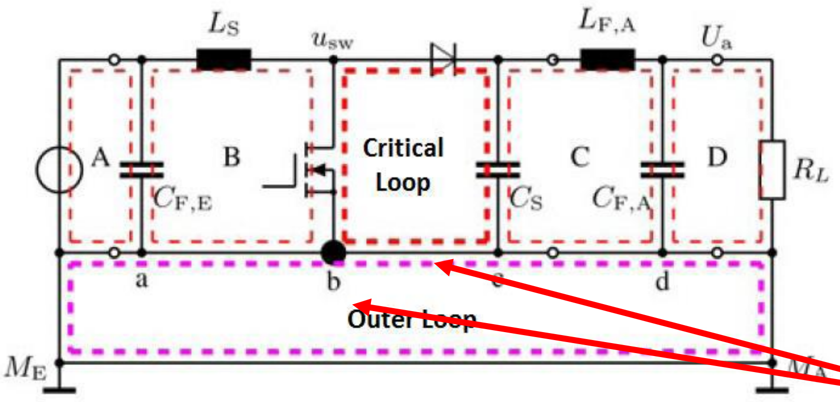


Fig.: Schematic of Boost converter [01]

Boost-Converter: Analysis – Coupling mechanism



Galvanic coupling

Fig.: Schematic of Boost converter [01]

Boost-Converter: Analysis – Coupling mechanism

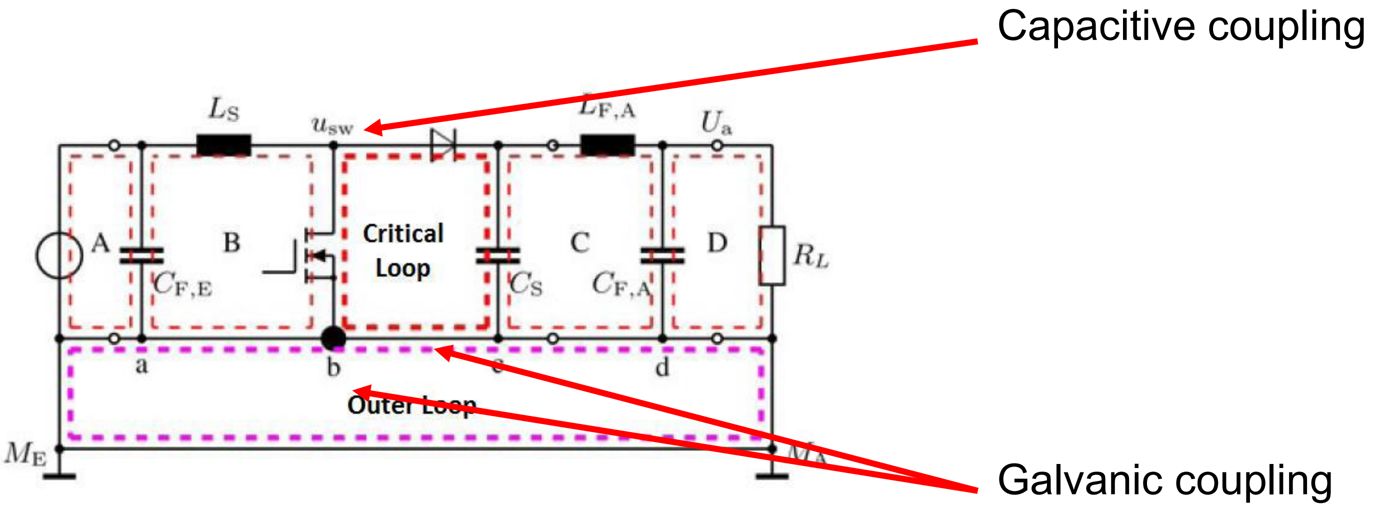


Fig.: Schematic of Boost converter [01]

Boost-Converter: Analysis – Coupling mechanism

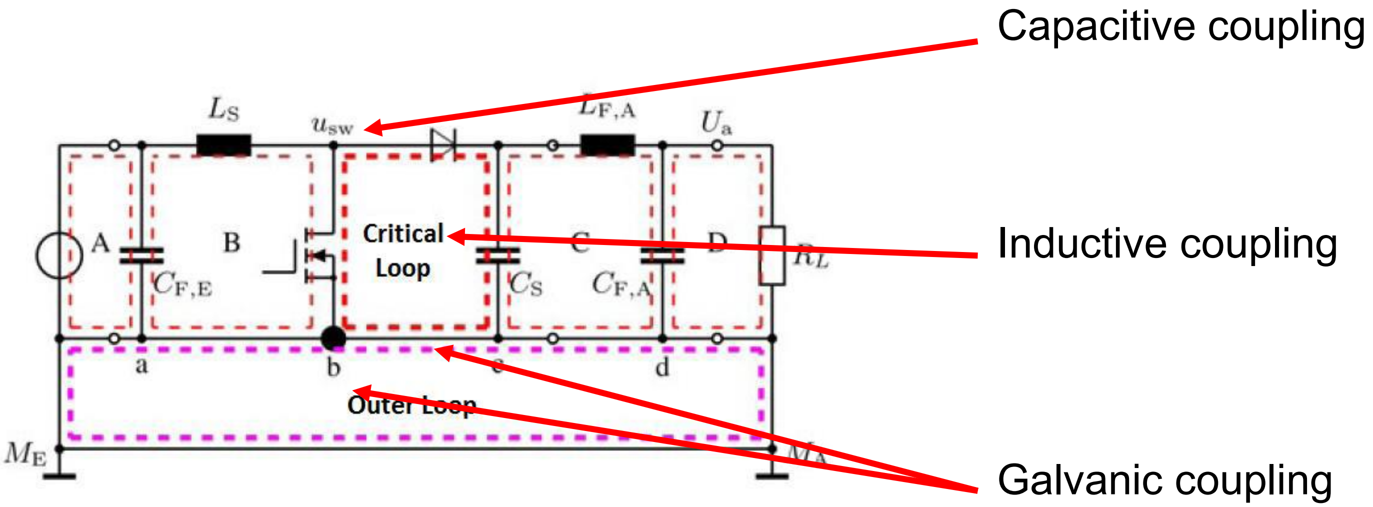


Fig.: Schematic of Boost converter [01]

Boost-Converter: Analysis

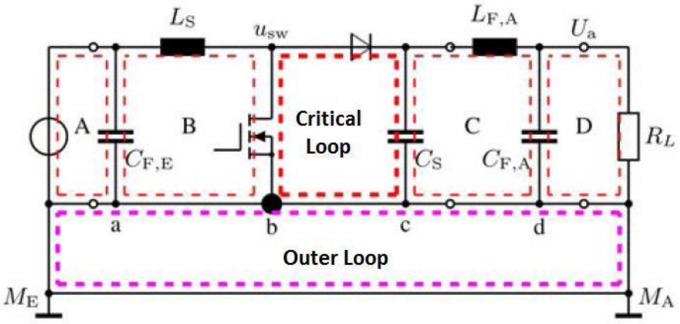


Fig.: Schematic of Boost converter [01]

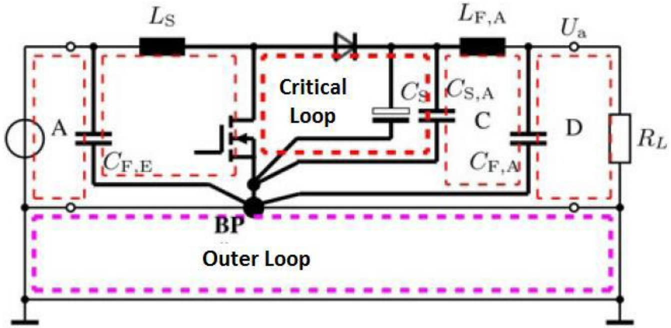


Fig.: Schematic of Boost converter [01]

- 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

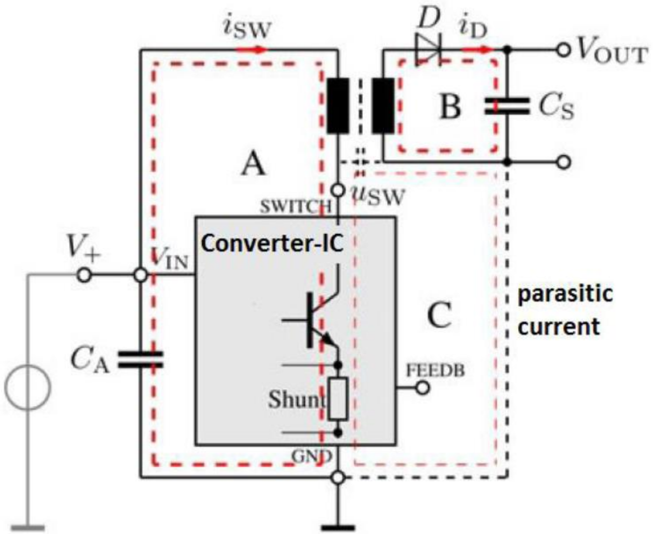
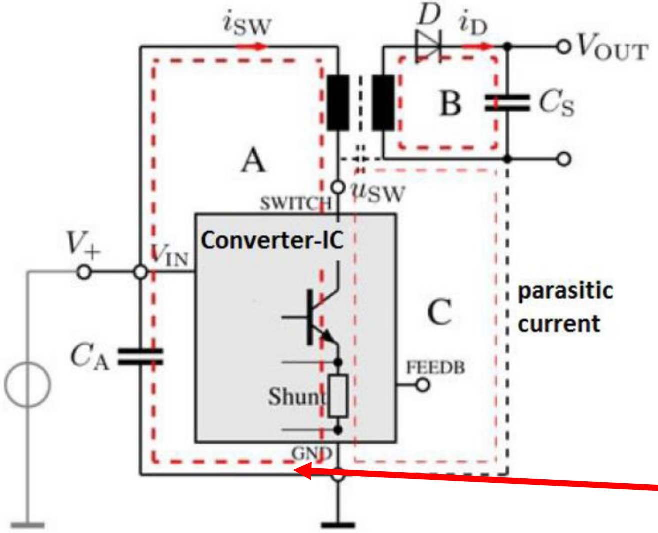


Fig.: Typical schematic of Flyback [01]

Flyback Converter



Galvanic coupling

Fig.: Typical schematic of Flyback [01]

Flyback Converter

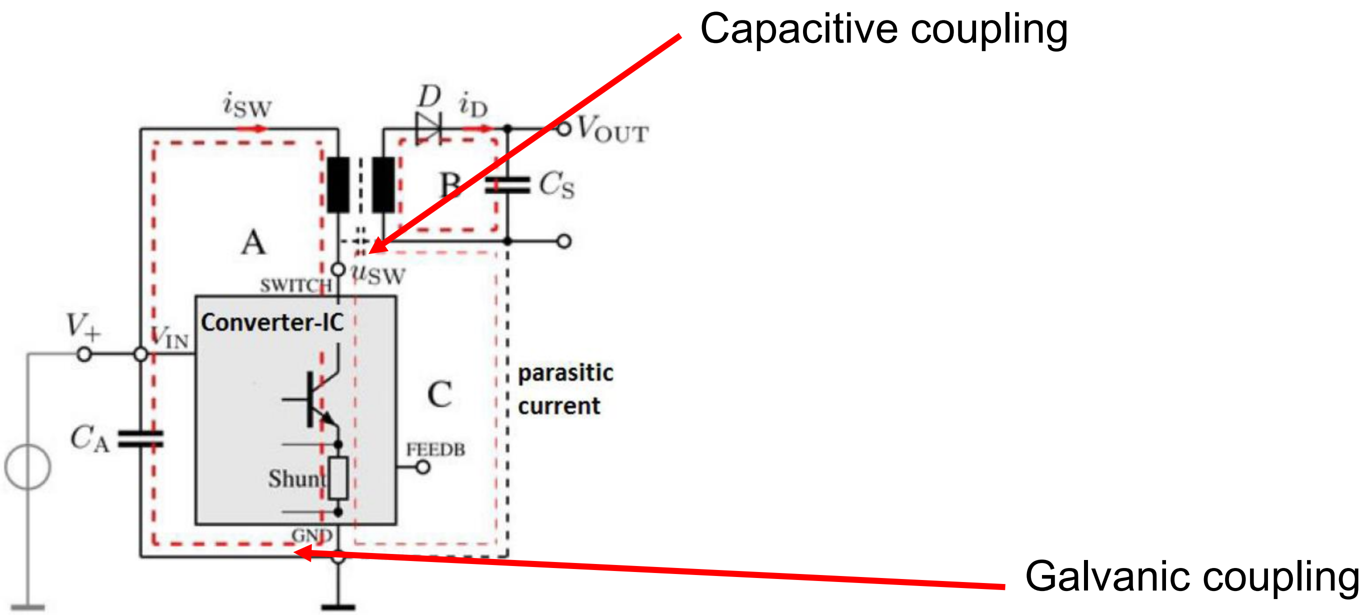


Fig.: Typical schematic of Flyback [01]

Flyback Converter

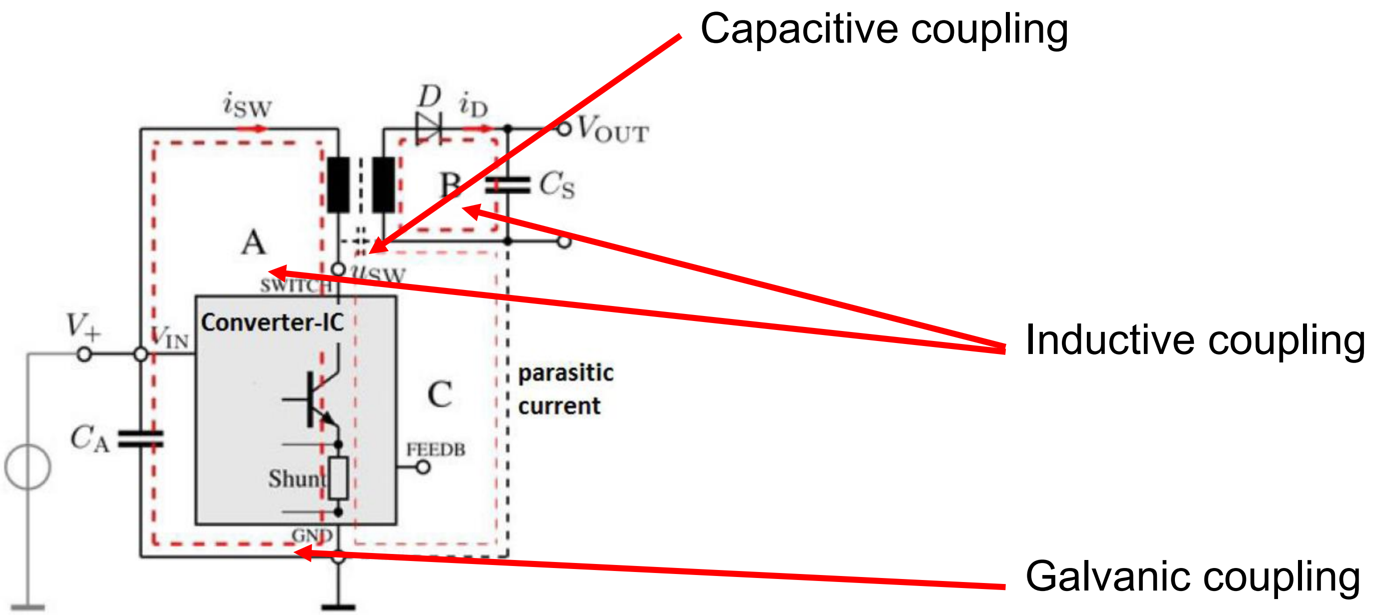


Fig.: Typical schematic of Flyback [01]

Flyback-Converter – EMC Analysis

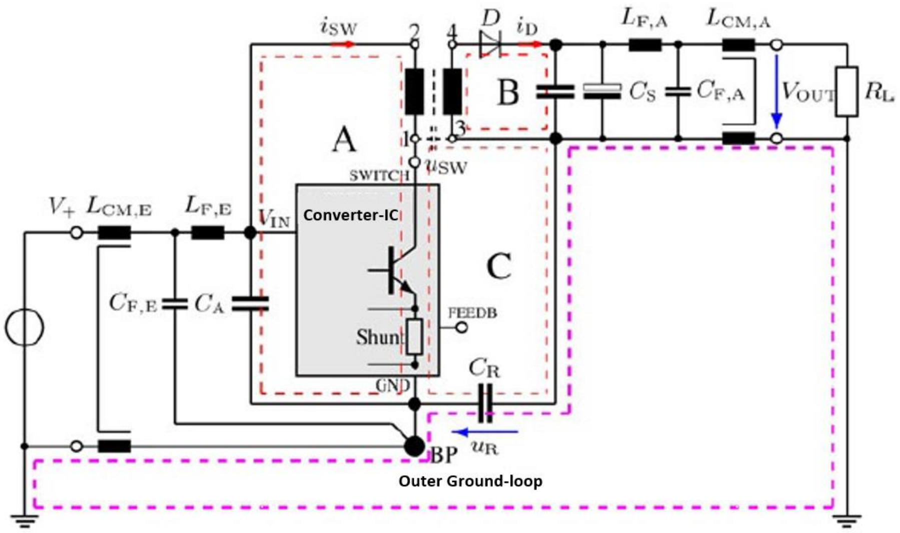


Fig.: EMC-improved schematic [01]

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

Buck Converter – Resonant circuit

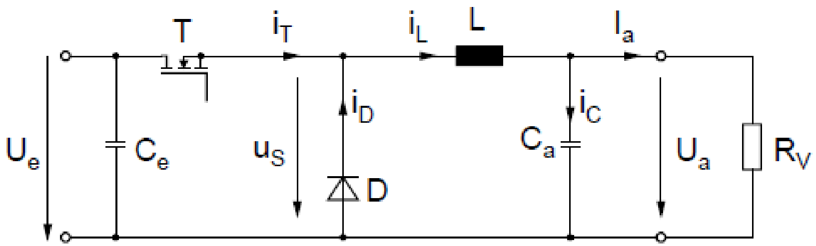


Fig.: Basic Buck-Converter-Schematic [06]

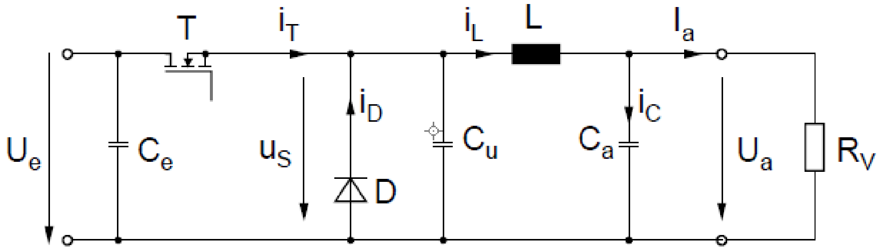


Fig.: Basic Buck-Converter-Schematic including resonant capacitor [06]

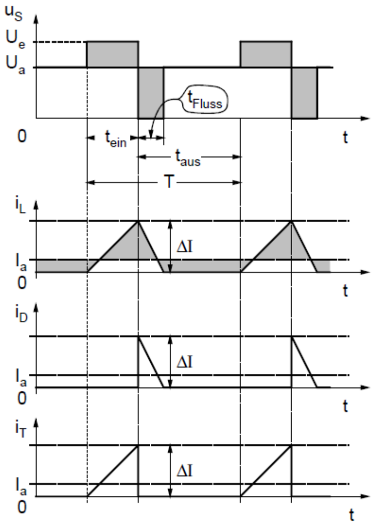


Fig.: Current & Voltage – Basic [06]

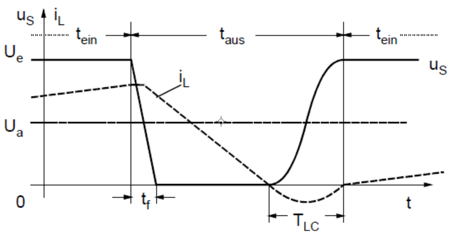


Fig.: Current & Voltage – improved [06]

Conclusion

- 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

1. EMV – Störungssicherer Aufbau elektronischer Schaltungen
   Franz, Joachim; Springer Vieweg, 5. Auflage, 2013

2. Elektromagnetische Verträglichkeit;
   Adolf J. Schwab ; Springer Verlag 2011; 6. Auflage

3. Schaltnetzteile und ihre Peripherie
   Schlienz, Ulrich; Vieweg Praxiswissen, 3. Auflage, 2007

4. EMV für Geräteentwickler und Systemintegratoren
   Gonschorek, K. H.; Springer, 2005

5. Elektromagnetische Verträglichkeit in der Praxis;
   Dieter Stotz; Springer Verlag, 2013

6. Schaltnetzteile und ihre Peripherie
   Schlienz, Ulrich; Vieweg Praxiswissen, 3. Auflage, 2007

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Q & A

PSMA

Thank You

Please take the survey

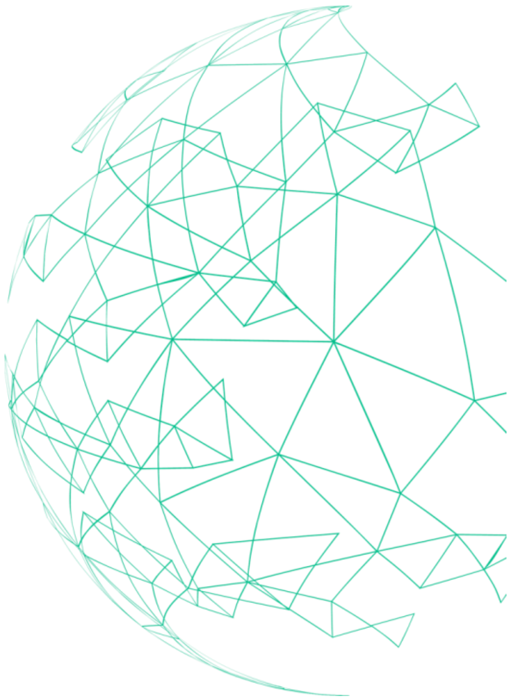
We appreciate any ideas or suggestions for improvement.

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

Webinar Presented by

PSMA



<u>Thank You and hope you have enjoyed the webinar</u>

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

Check to see if your company is a member, there is a lot more available to PSMA member companies

If not a member, membership is very low cost for the benefits to you and your company as a whole.

As a member you become part of a team with over 100 companies
Be part of the industry voice.

Contact info: power@psma.com

"Individual commitment to a group effort--that is what makes a team work, a company work, a society work, a civilization work." --Vince Lombardi