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# Electromagnetic Compatibility of Switched-Mode Power Supplies

**Presenter(s):** *Prof. Dr.-Ing. Günter Keller, Deggendorf Institute of Technology, Germany*

Starting with a brief overview of legal regulations, like CE mark and Declaration of Conformity, a selection of emission and immunity standards are presented. This includes the description of test set-ups, for example for conducted noise, and their test devices, like detector circuits, as well as tets parameters, like frequency ranges, based on European and international standards. Than the four coupling mechanisms (impedance, capacitive, magnetic and radiated) are discussed, based on components and PCB strucures. Subsequently principle countermeasures are proposed and evaluated according meaningful applicability to switched-mode power supplies. The section signals and characteristics explains common-mode and differential-mode interferences as well as the Fourier Transform in detail with a number of waveform, like rectangular, triangular and trapeziodal waveforms, which are typical for switched-mode power supplies. In particular switching transients are discussed against the background of wide band gap devices like GaN transistors. One large section discusses the origin of electromagnetic interferences referring to the previous sections. This section addresses some widely used circuits, their operating modes, like continuous conduction mode, discontinuous conduction mode ans boundary conduction mode, and also parasitics of passive components, using high frequency eqiuvalent circuits of capacitors, inductors and transformers, and active components, like junction capacitances and terminal inductances. A large number of examples is presented in form of measurements, simulations or calculations.

The second half of the presentation deals with EMC design of switched-mode power supplies, evaluating circuit and control issues. This section is subdivided into a number of subsections. Firstly the power factor correction is presented. A large subsection addresses the EMC filter, which is subdivided into pre filter and post filter. The filter filter structure is discussed according common-moe and differential-mode attenuation and source and load impedance. Followed by suitable components, which presents for example the impact of start of winding of a magnetic component, suitable circuits with soft-switching principles are compared to hard-switching circuits. After that shielding basics are presented, in particular the impact of holes for cooling purposes on electromagnetic shielding effectiveness. Fianlly PCB layout structures are evaluated and recommendations are presented. These investigations also addess grounding.

Each aspect is explained by measured, simulated or calculated examples. Many examples are discussed against the background of electromagnetic compatibility as well as their impact on efficiency, lifetime and costs of the power supply. The tutorial contains on the one hand practical examples and uses on the other hand the basic physics of Maxwell for a principle understanding.

Prof. Dr.-Ing. Günter Keller , Current Activities

- Educational Area Representative at the Deggendorf Institute of Technology for
  - Fundamentals of Electrical Engineering (Bachelor)
  - Electromagnetic Compatibility (Bachelor)
  - Systems Engineering for Renewable Energies (Bachelor)
  - Renewable Energies (Master)
  - Power Electronics (Bachelor, Master)
  - Power Supply Circuits (Bachelor)
- Laboratory Head for the Laboratory of Power Electronics
- Seminar Instructor for professional and universities, also lecture ships in switched-mode power supplies (basics, advanced and control), LTspice simulations, wordwide (mainly Europa and Asia)