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Tutorial Title

Electromagnetic Compatibility of Switched-Mode Power Supplies

Instructor Team

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Abstract

The tutorial "Electromagnetic Compatibility of Switched-Mode Power Supplies" is subdivided into several sections.

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 measuring conducted emissions using conventional or STFFT based test receivers and their detector circuits, as well as test parameters, like frequency ranges, based on European and International standards. Than four coupling mechanisms (impedance, capacitive, magnetic and radiated) are discussed, based on components and PCB structures. Subsequently basic 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 waveforms, like rectangular, triangular and trapezoidal waveforms, which are typically 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 and boundary conduction mode, and also parasitics of passive components, using high frequency equivalent 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 results of measurements, simulations or calculations.

The second half of the presentation deals with EMC design of switched-mode power supplies, also evaluating efficiency and control issues. This section is subdivided into a number of subsections. Firstly the power factor correction is briefly presented. A large subsection addresses EMC filters, which is subdivided into pre filters and post filters. The filter structure is discussed according common-mode and differential-mode attenuation and source and load impedance. Problem solving approaches of the gap between measurements according standards and filter effectiveness are presented. Additionally an outlook to active EMI filters is given. Also design aspects of magnetic components are discussed. 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. Finally PCB layout structures are evaluated and recommendations are presented. These investigations also address grounding, one of the most discussed topics in PCB design among engineers, as well as component placing and component selection, e. g. based on integrated circuit pin out and return current paths. Most aspects are 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. Many principles can be transferred to other electronic circuits.

Instructor Biography

Guenter Keller received the Diploma degree in 1988 in electrical engineering from the Friedrich-Alexander University in Erlangen-Nuremberg. From 1989 to 1997 he was a research fellow at the Institute of Solar Power Supply, where he was working almost nine years in the field of power electronics for photovoltaic applications in a large number of research projects including responsibility of conducted emissions in the EMC laboratory of the Institute. In 1997 he received the Doctor Degree from Kassel University, Germany, in the field of photovoltaic inverters. Also in 1997, he was appointed as a professor at the Faculty of Electrical Engineering of the Deggendorf Institute of Technology, Germany, and is Head of the Laboratory for Power Electronics. He has more than 20 years teaching experience in electromagnetic compatibility, power electronics and power supply circuits. Since 2000 he has been working in the field of switched- mode power supplies with focus on electromagnetic compatibility and control. Since 2010 he instructed worldwide more than 60 industrial and university workshops and seminars as well as conference workshops or tutorials.

Past Tutorials or Workshops

EMV 2013	Stuttgart	Germany
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APEMC 2016	Shenzhen	China
APEMC 2017	Seoul	Korea
EMV 2019	Stuttgart	Germany
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