Christophe Basso – Professional Seminar Collection
Toulouse – France
Rev. 1.32

Most of These seminars have been presented at IEEE-sponsored Applied Power Electronics Conferences (APEC) in the US and are targeting an engineering audience. Each presentation is tailored for a 3.5-hour session but the more recent ones are made for a 90-mn speech.

All these presentations are available for download from my personal webpage http://powersimtof.com/Spice.htm and a link is provided below each title.

« Dc-Dc Converters Feedback and Control » – APEC 2009

PDF

Abstract

Switch Mode Power Supplies are widely used in nowadays equipments, ranging from a few tens of watts in consumer applications to several hundred of watts and above in industrial applications. Despite the various architectures found in this field, they all share the need for a control circuit that maintains one or several delivered variables within a defined range. Because of extreme time pressure on their shoulders, engineers do not often take the necessary time to understand and analyze the constraints brought by the design of a robust control loop.

Targeting practicing engineers and graduating students, this seminar describes how to efficiently compensate a power converter whether it is operated from a dc or an ac source. The seminar starts by teaching how to optimally select the cross over frequency and the phase margin in relationship with your design specifications. Then, the presentation shows how poles and zeros must be placed depending on the kind of transient response you expect. Using Mathcad® and SPICE, the author maintains a permanent link between what theory dictates and what the market reality is. In particular, the compensation schemes are first described with an operational amplifier and then further modified to cope with a TL431.

The seminar balances analytical aspects and real case examples to show how to design a stable power supply. It targets an audience with an intermediate background in the presented subject.

« Designing Compensators for the Control of Switching Power Supplies » – APEC 2010

PDF

Abstract

Switch Mode Power Supplies are widely used in nowadays equipments, ranging from a few tens of watts in consumer applications to several hundred of watts and above in industrial applications. Despite the various architectures found in this field, they all share the need for a control circuit that maintains one or several delivered variables within a defined range. The compensator is the place where the designer will place the poles and zeros to shape the loop frequency response and ensure stability over the entire operating range. Depending on the selected controller, the available active element to perform the compensation can be an operational amplifier, a transconductance amplifier (OTA) or a TL431. Unfortunately, available textbooks solely focus on the first type, leaving both the TL431 and the OTAs apart despite their popularity in the power electronics field.

Targeting practicing engineers and graduating students, this seminar describes how to efficiently compensate a power converter using an operational amplifier, an OTA or a TL431. All compensator types such as 1, 2 and 3 are covered in great details, with design examples used as a support. The seminar starts by teaching how to optimally select the crossover frequency and the phase margin in relationship with your design specifications. The presentation then shows what poles and zeros are and how they must be placed to precisely

shape your compensator response. At the end of the presentation, the audience will have a complete description of the three compensators types implemented with the op amp, the OTA or the TL431. Using mathematical analysis and SPICE, the author maintains a permanent link between what theory dictates and what the market reality is. Up to four design examples are used to apply the theory described in the presentation.

The seminar balances analytical aspects and real case examples to show how to design a stable power supply. It targets an audience with an intermediate background in the presented subject.

« The Dark Side of Flyback Converters » – APEC 2011

PDF

Abstract

Switching Power Supplies are widely used in nowadays equipments, ranging from a few tens of watts in consumer applications to several hundred of watts and above in the industrial field. The consumer market with its DVD players, LCD TVs and portable computers make an extensive use of the flyback topology for its ease of implementation and associated low-cost. If the flyback noun often rhymes with simplicity and quick design, large-volume manufacturing requires rigor and design discipline. Too often, designers rely on recipes and rules of thumbs successfully applied to prototypes or low-volume productions. Unfortunately, these techniques will inexorably fail when ported to millions of units and their associated production spreads.

Targeting practicing engineers and graduating students, this seminar describes how to efficiently design ac-dc flyback converters. The seminar starts by a theoretical description of the basic structure, highlighting the harmful contribution of parasitic elements such as the leakage inductor. This element plays a role in the voltage stress of the switching devices but also in the maximum output power the converter can deliver. These aspects are thoroughly reviewed in the presentation materials. Loop stability being one of the most troublesome design issues, the seminar spends time to details the mechanisms of oscillations and the possible solutions to ensure long-term stable converters. Capitalizing on the popular association TL431 plus optocoupler, you will be taught how to successfully stabilize an isolated converter.

Using mathematical analysis and SPICE, the author maintains a permanent link between theory and market reality. Several working design examples are used to apply the techniques described in the presentation. Balancing analytical aspects and real case examples, the seminar targets an audience with an intermediate background in the presented subject.

« The Dark Side of Loop Control Theory » – APEC 2012

PDF

Abstract

Loop control represents one of the most important topics in a power electronics student course. Classes and tutorials abound in this domain and the web can be an excellent source of information. However, most of the approaches are highly theoretical and the link to market reality is often overlooked. When you want to compensate a converter with a single op amp and you try to apply the coefficients calculation you learned at school, you quickly realize that, indeed, the link is missing. For instance, how many engineers compensate power converters still not realizing that a type III compensator is actually a filtered-PID compensator to which a high-frequency pole is added? Why a perfectly-well compensated converter still delivers a ringing-response, in conflict with a Bode or Nyquist prediction? Why are modulus margin and delay margin the only important parameters to deal with? All these untaught aspects of loop control will be detailed in this 3-hour tutorial, step-by-step explaining where problems can potentially appear and how to solve them.

Targeting practicing engineers and graduating students, this seminar describes how to efficiently compensate power converters and make them robust designs. The seminar starts by a theoretical description of the basic PID structure and quickly establishes the link between individual coefficients and classical poles-zeros placement. It then applies classical compensation recipes to a buck converter and shows how it can fail if the output impedance study is neglected. The presentation carries on with output impedance shaping and rarely-described stability criteria such as modulus margin or delay margin.

Using mathematical analysis and SPICE, the author maintains a permanent link between theory and market reality. Several working design examples are used to apply the

techniques described in the presentation. Balancing analytical aspects and real case examples, the seminar targets an audience with an intermediate background in the presented subject.

« Small-Signal Modeling and Analytical Analysis of Power Converters » – APEC 2013

PDF

Abstract

Loop control and stability analysis represent an important part of power converters design. However, the study can only be carried if a converter small-signal model exists. The derivation of such a model has always been perceived as “black magic” by numerous engineers. Perhaps the complex equations showed in founding papers played a role in this wrong perception. But still, it is an analysis step you cannot afford to miss if you want to build stable and rugged converters. Capitalizing on the author experience in this field, the seminar offers a step-by-step approach by introducing the mathematical tools needed throughout the presentation. Briefly introducing State-Space Averaging technique, the seminar quickly diverts to the PWM Switch model approach introduced in the 90’s. You will learn how to construct the basic averaged model and use it for dc point calculation or for complex ac transfer function derivation. Voltage-mode, current-mode but also quasi-square wave resonant converters (QR) will be explored during the session.

Using mathematical analysis and SPICE, the author maintains a permanent link between theory and practical aspects. Balancing analytical aspects and real case examples, the seminar targets an audience with an intermediate background in the presented subject.

« Small-Signal Modeling at Work with Power Converters » – APEC 2014

PDF

Abstract

Loop control and stability analysis represent an important part of power converters design. If the study cannot be overlooked during design phase, it can only be conducted if a converter small-signal model exists. Introducing the tools and techniques pertinent to small-signal

modeling has been the object of last year professional seminar. In this new seminar, we will quickly come back on the PWM switch model in the two popular structures, voltage (VM) and current-mode (CM) operated at a fixed switching frequency. A newly developed version will cover boundary conduction in both CM and VM architectures.

In this seminar, you will learn how to use the PWM switch model and how to step-by-step apply it to various converters types. We will start with a simple structure such as buck converter in current mode and slowly increase in complexity with the small-signal analysis of a DCM boost converter driving a LED string and a current-mode boost converter operated in boundary mode. We will end the session with the small-signal response of an active clamp forward converter operated in voltage mode.

Using mathematical analysis and SPICE, the author maintains a permanent link between theory and practical reality. Balancing analytical aspects and real case examples, the seminar targets an audience with an intermediate background in the presented subject.

« Practical Implementation of Loop Control in Power Converters » – APEC 2015

PDF

Abstract

Loop control and stability analysis represent an important part of power converters design. Small-signal analysis and tools to derive converters transfer functions have been introduced in seminars the author conducted in the previous years. In these theoretical seminars, practical details such as product gain-bandwidth or operational amplifier slew-rate limits were purposely ignored for the sake of simplicity. However, when you must build high-bandwidth systems, these aspects can no longer be ignored. Understanding their origins and accounting for them at design stage is always better than observing their deleterious impact once the prototype has been assembled. In this new seminar, the author covers some of the typical problems you will discover when stabilizing a converter. Op amp characteristics influence, fast lane ac pollution, monotonic start-up sequence or optocoupler response are among the subjects I will present.

Using mathematical analysis and SPICE, the author maintains a permanent link between theory and practical reality with bench results presented through the documents.

Balancing analytical aspects and real case examples, the seminar targets an audience with an intermediate background in the presented subject.

« Introduction to Fast Analytical Techniques: Application to Small-Signal Modeling » – APEC 2016

PDF

Abstract

Loop control is an essential part of power converter design and requires the transfer function of the system you want to stabilize. The control-to-output transfer function can be obtained in the laboratory with a hardware prototype or analytically derived with a small-signal model. A hardware prototype gives you the exact dynamic response at a given operating point but does not explicitly tell you what affects magnitude or phase. You need to know what elements contribute poles or zeros in the plant dynamic response so that natural production spreads and temperature drifts of components do not jeopardize stability once the loop is closed. On the other hand, determining a small-signal model can be done in different ways, all leading to similar dynamic responses. However, what matters is the ability to format the final transfer function in a compact form in which gains, poles and zeros are apparent. This is the concept of *low-entropy* expressions as defined by Dr. Middlebrook in his papers and seminars. This seminar will introduce you to Fast Analytical Circuits Techniques, or FACTs, exercised in determining the transfer functions of some typical circuit examples, up to the order two. The second part shows how you can apply these techniques to unveil switching converters transfer functions of buck and buck-boost converters.

Using mathematical analysis and different tools such as SPICE and Mathcad®, the author maintains a permanent link between theory and practical reality. Balancing analytical aspects and real case examples, the seminar targets an audience with an intermediate background in the presented subject.

« Input Filter Interactions with Switching Regulators » – APEC 2017

PDF

Abstract

An ElectroMagnetic Interference (EMI) filters is an essential part of a power supply structure. Designed to filter out switching noise and build an isolation barrier between the noisy converter and the power source, its impact on the converter's performance is often overlooked. If naturally-present damping elements often hide potential problems, the interaction of the filter and the switching converter is a reality which shall be considered at the first stage of power supply design. Failure to understand and counteract filter effects at an early design stage can affect the converter overall performance and stability in particular.

This seminar will start by explaining why teaming an inductive filter with a switching converter can be a problem and how some of the closed-loop parameters are impacted. Fast Analytical Circuits Techniques will be applied along the seminar and briefly introduced as one of the tools used by the author. Optimum damping techniques will then be explained in a second part, exemplified with a design example. Finally, practical experiments will show damping at work on a typical case.

Using mathematical analysis and different tools such as SPICE and Mathcad®, the author maintains a permanent link between theory and practical reality. Balancing analytical aspects and real case examples, the seminar targets an audience with an intermediate background in the presented subject.

« Closing the Feedback Loop through Simulation and Analysis » – APEC 2018

PDF

Abstract

Loop control represents an important part of power converters design. However, among the long list of things to consider when developing a new product, it is often ignored until the very end of the design process. Attempting to stabilize a converter in emergency without a thorough understanding of its operating mechanisms can be a perilous exercise when trial and error is involved. Despite the power of nowadays simulation engines, nothing replaces the thorough analytical analysis of a control loop to identify where the offenders are and how to neutralize them via an adequate compensation policy.

Capitalizing on the author experience in this field, the seminar describes several paths to let you efficiently stabilize a converter through the combination of analytical analysis,

simulation and bench experiments. The seminar starts by introducing the tools we need – small-signal models, fast analytical circuits techniques (FACTs) and simulation models – and quickly dive into the subject through application examples. At the end of this seminar, you will know the basic steps for stabilizing a typical switching converter.

« Simulation and Analysis Applied to the Design of Buck Topologies » – APEC 2019

PDF

Abstract

This seminar continues the detailed exploration of switching converters using simulation, analysis and practical experiments. The buck converter is selected as a topology vehicle to explore different voltage- and current-mode control schemes (fixed frequency, quasi-square wave resonance, COT and FOT), highlighting pros and cons of each solution. Small-signal models are then presented with a discussion on performance and implementation of past and more modern models. The four transfer functions of the CCM buck operated in peak-current-mode-control are derived using fast analytical circuits techniques. The seminar ends with the presentation of measurements carried on prototypes and nicely bridges theory with practical aspects.

Using mathematical analysis and different tools such as SPICE and Mathcad®, the author maintains a permanent link between theory and practical reality. Balancing analytical aspects and real-case examples, the seminar targets an audience with an intermediate background in the presented subject.

« Designing Compensators for the Control of Switching Power Supplies » – APEC 2021

PDF

Abstract

Switching power supplies are widely used in nowadays equipments, ranging from a few tens of watts in consumer applications to several hundred of watts and above in industrial

applications. Despite the various architectures found in this field, they all share the need for a control circuit that maintains one or several delivered variables within a defined range. The compensator is the place where the designer shapes the loop frequency response and ensures stability over the entire operating range. Depending on the selected controller, the active element used to perform compensation can be an operational amplifier, a transconductance amplifier, a TL431 or digital code.

Targeting practicing engineers and graduating students, this seminar describes how to efficiently compensate a power converter using an active amplifier and extends the reach to digital implementations. All compensator types such as 1, 2 and 3 are covered in great details, with design examples used as a support.

Using mathematical analysis and different tools such as SPICE and Mathcad®, the author maintains a permanent link between theory and practical reality. Balancing analytical aspects and real case examples, the seminar targets an audience with an intermediate background in the presented subject.

« A Tutorial Introduction to Switching Converters » – 2022

90 mn – 95 slides

Abstract

PDF

Switching power supplies are widely used in nowadays equipments, ranging from a few tens of watts in consumer applications to several hundred of watts and above in industrial applications. For companies transitioning from a linear world to a switching environment, it is important to lay the proper foundations before starting to design. This seminar smoothly introduces you to the world of switching converters, starting from linear regulators and exploring the basic switching cells. Loop control then EMI are not forgotten and covered before information on simulation tools is delivered.

This seminar targets beginners in the switching converters field. No specific mathematical background is required to attend the presentation.

« An Introduction to Power Supplies Simulations with SIMPLIS » – 2022
90 mn – 93 slides

Abstract

PDF

A simulation engine is a convenient and powerful tool when designing switching power supplies. If many simulation engines are nowadays available, few can deliver all the needed information to design the entire circuit: SPICE is surely a valuable assistant but it is prone to convergence issues and has difficulties with long-run PFC simulations. Besides, you need to resort to an equivalent small-signal model to explore a compensation strategy to safely close the feedback loop. If this is easy for the basic switching cells, the exercise complicates when no average model exists like in the LLC converter case for instance. SIMPLIS, on the other hand, builds on a different simulation engine and lets you simulate at a quicker speed than SPICE and, furthermore, can extract the small-signal response of any switching converter. This seminar offers an introduction on how SIMPLIS operates compared to SPICE and how it can improve your design cycle.

This seminar targets switching power supplies designers and requires an intermediate background in simulation.

« Starting with Elements – The Free SIMPLIS Demonstration Version » – 2022
90 mn – 60 slides

Abstract

PDF

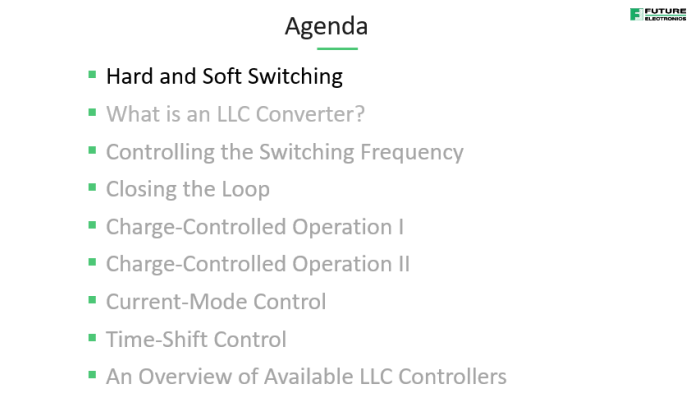
Capitalizing on the above presentation which describes what SIMPLIS can do in terms of simulation capabilities, this seminar teaches how to start simulating basic designs with Elements, the free demonstration version of SIMPLIS. The seminar starts smoothly with basic functions (creating a sheet, placing components and so on) then gradually increases complexity to let you simulate switching circuits and run ac analyses. Finally, the seminar introduces you to one of 60+ free simulation templates which, for most of them, work on this demonstration version.

« Control Methods of the LLC Converters » – 2022
90 mn – 72 slides

PDF

Abstract

This seminar starts with a review of soft-switching definitions and explains how the LLC converter operates. The description of the direct-frequency control opens the discussion on control methods and more recent approaches are covered such as charge control and current-mode control. Control-to-output transfer functions are plotted and show the disadvantages of the direct-frequency method.



« A Tutorial Introduction to Power Factor Correction » – 2022

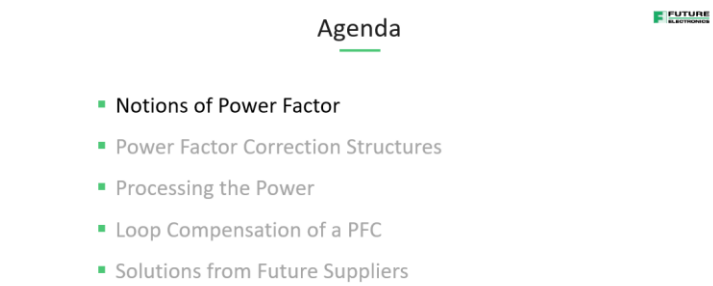
90 mn – 72 slides

PDF

Abstract

This seminar will teach you why power factor is required by utility companies and how to correct it with passive and active methods. The slides start with a simple mathematical treatment explaining the benefit of a near-unity power factor and how to achieve it with switching converters operating in different modes. Various examples of popular structures are

given with simulation examples including average and cycle-by-cycle models. Recent implementations such as totem-pole PFC are also covered in details.

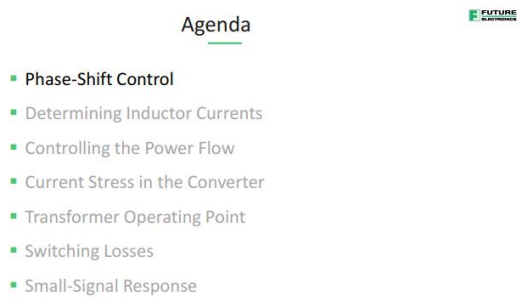


« Introduction to the Dual Active Bridge Converter » – 2023
50 mn – 44 slides

PDF

Abstract

This presentation goes through the operating principles of the dual active bridge converter and highlights the calculation of current stresses of the components, including conduction and switching losses for the semiconductors. The last section spends time on the small-signal response of the converter with a SIMPLIS simulation of a compensated version.



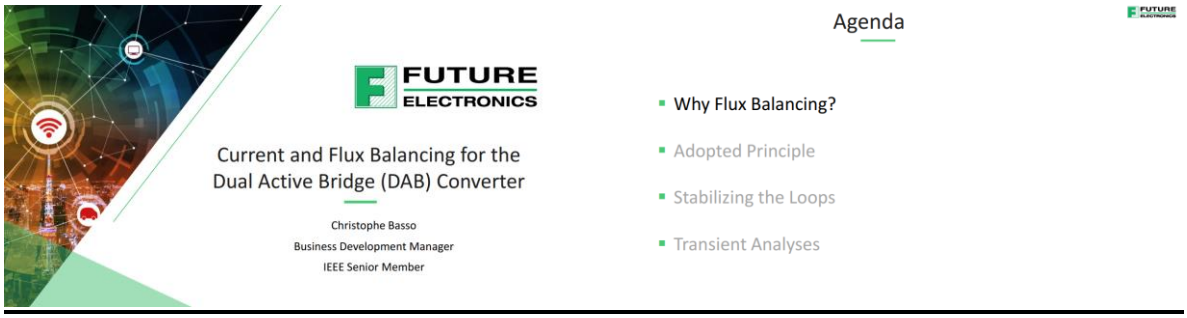
« Current and Flux Balancing for the Dual Active Bridge (DAB) Converter » – 2023

30 mn – 27 slides

PDF

Abstract

In this short presentation, I review the origins of the dc component present in the transformer magnetizing current and how to reduce it down to zero. The primary- and secondary-side currents are also part of the compensation scheme which is implemented in the analogue way. This presentation is a very good complement to the one introducing the DAB converter above.



About the author

Christophe Basso has been a Technical Fellow with *onsemi* in Toulouse, France, where he led an application team dedicated to developing new offline PWM controller specifications. He has originated numerous integrated circuits among which the NCP120X series has set new standards for low standby power converters. He is now with Future Electronics and works as a business development manager (BDM) providing expertise in ac-dc and dc-dc converters for customers located in EMEA.

Further to his 2008 book *Switch-Mode Power Supplies: SPICE Simulations and Practical Designs,* published by McGraw-Hill, he released in 2012 a new title with Artech

House, “Designing Control Loops for Linear and Switching Power Supplies: a Tutorial Guide”. His previous covers Fast Analytical Techniques and was published by Wiley in 2016 in the IEEE Press imprint under the title *Linear Circuit Transfer Function: An Introduction to Fast Analytical Techniques*. He has just released a new title *Transfer Functions of Switching Converters: Fast Analytical Techniques at Work with Small-Signal Analysis* with Faraday Press.

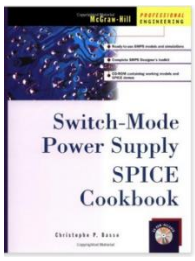
Christophe has over 25 years of power supply industry experience. He holds 25 patents on power conversion and often publishes papers in conferences and trade magazines including How2Power and PET. Prior to joining ON Semiconductor in 1999, Christophe was an application engineer at Motorola Semiconductor in Toulouse. Before 1997, he worked as a power supply designer in the European Synchrotron Radiation Facility in Grenoble, France, for 10 years. He holds a *Diplôme Universitaire de Technology* from the Montpellier University (France, 1985) and a MSEE from the Institut National Polytechnique of Toulouse (France, 2007). He is an IEEE Senior Member.

Christophe Basso occupait le poste de Technical Fellow au sein de la société ON Semiconductor à Toulouse. Il animait une équipe constituée d'ingénieurs applications qui travaillaient au développement de circuits de contrôle pour des convertisseurs à découpage isolés et non-isolés. Il a introduit de nombreux circuits intégrés parmi lesquels le NCP1200 qui excellait en puissance de veille.

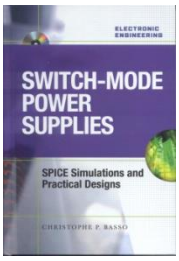
A la suite de son livre publié en 2008 avec McGraw-Hill et intitulé *Switch-Mode Power Supplies: SPICE Simulations and Practical Designs*, il publie un nouvel ouvrage en 2012 avec Artech House, *Designing Control Loops for Linear and Switching Power Supplies: a Tutorial Guide*. Un nouveau livre entièrement consacré aux techniques de calculs rapides a récemment été publié by Wiley dans la collection presse de l'IEEE sous le titre *Linear Circuit Transfer Function: An Introduction to Fast Analytical Techniques*. Il a fait l'objet d'une traduction en français chez Dunod en 2017. Son dernier ouvrage traite des fonctions de transfert des convertisseurs à découpage *Transfer Functions of Switching Converters: Fast Analytical Techniques at Work with Small-Signal Analysis* et il vient de sortir chez Faraday Press.

Christophe possède plus de 25 ans d'expérience dans l'industrie de la conversion d'énergie. Il a déposé une vingtaine de brevets dans la conversion de puissance et publie souvent des articles dans les revues spécialisées comme How2Power et PET. Avant de rejoindre ON Semiconductor en 1999, Christophe était ingénieur en applications chez Motorola Semiconductor à Toulouse. Jusqu'en 1997, il a travaillé comme concepteur d'alimentations à l'European Synchrotron Radiation Facility de Grenoble pendant 10 ans. Il possède un DUT obtenu en 1985 à l'université de Montpellier et un master II délivré par l'Institut National Polytechnique de Toulouse en 2007. Il est Senior Member de la société IEEE.

<u>Books by Christophe Basso</u>

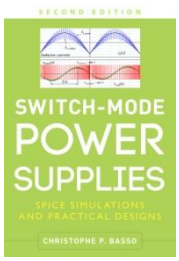


1996

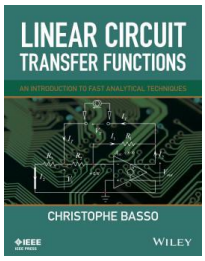


2008 (1st ed.)

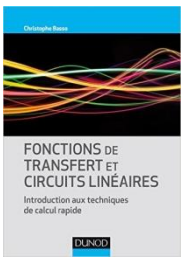
2012



2014 (2nd ed.)



2016



2017


TRANSFER FUNCTIONS OF SWITCHING CONVERTERS
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