



Switching Analysis of Synchronous Rectifier MOSFETs With Phase-Shifted Full-Bridge Converter and Current Doubler

By Patrick Chiang and Mark Hu

Abstract

This application note will analyze the switching behavior of synchronous rectifier MOSFETs in a phase-shifted full-bridge converter topology with a current doubler. Figure 1 shows the basic circuit of this application. An overview will describe the timing diagram of a phase-shifted full-bridge converter for achieving zero voltage switching (ZVS). Two topologies are introduced for gate driving of synchronous rectifier (SR) MOSFETs. The timing diagrams will introduce the SR MOSFET operations during every stage for both topologies. The body diode will be highlighted, and the operational phenomena that occur when the SR MOSFET turns off will be described. The power dissipation of SR MOSFETs will be presented as equations to assist in designs, while test results of waveforms will help in understanding the application. A

summary will include the advantages of SR MOSFETs, an efficiency comparison, and other design considerations.

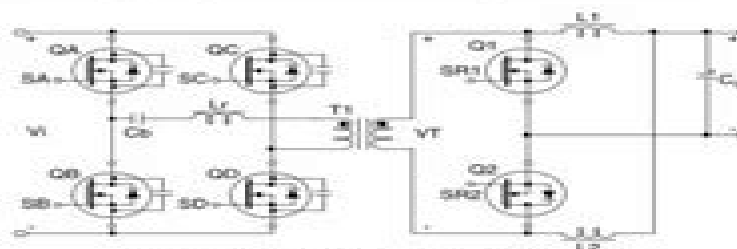


Figure 1 - Phase-Shifted Full-Bridge Converter

Introduction to the Phase-Shifted Full-Bridge Converter

The phase-shifted full-bridge converter has long been used to achieve high efficiency and high density in power supply designs with outputs from 500 W to 5000 W. The traditional full-bridge converter transfers power from primary bulk capacitors to secondary LC filters when its MOSFETs (QA and QD, or QB and QC) are turned on at the same time. This operation results in increased power dissipation (known as switching loss) when a primary MOSFET is turned on and off. The higher the switching frequency, the greater the switching losses.

The phase-shifted full-bridge converter introduces an almost 50 % fixed-duty cycle to QA, QB, QC, and QD. The pulse width modulation (PWM) duty is controlled by the overlapped duty of QA and QD, and QB and QC. There is a small amount of overlap between QA and QB, and QC and QD, which is called PWM delay (PWM delay AB, and PWM delay CD). PWM delay will prevent the same-side MOSFETs (QA and QB, or QC and QD) from turning on simultaneously, which would result in a short circuit that burns out the MOSFETs. In addition, the delay time helps

the MOSFETs to achieve zero voltage switching (ZVS). When the PWM pulse is off, the snubber inductance L_r , by way of storage energy, will resonate with the output capacitances of the MOSFETs and oscillate the MOSFET voltage to zero before the MOSFETs turn on at the next period. At this stage, ZVS (which means no switching loss) occurs and a significant improvement in efficiency is gained.

Due to high density (per W/inch³) and thermal considerations, most designers do not add an external snubber inductor in conjunction with the transformer (shown in Figure 1). The snubber inductance L_r results from the leakage inductance of transformer T1. Only if the primary current I_p is enough to let L_r be stored at a minimum energy, and an achieved ZVS transition, is the external inductor not necessary. Using the leakage inductance of the transformer, most power supplies can achieve ZVS with more than 50 % maximum load. It is necessary to add C_b to avoid an unbalance of the transformer flux and saturation of the transformer.

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Proceedings ,1969 *Government Reports Announcements & Index* ,1990-09 *Science Citation Index* ,1992 Vols for 1964 have guides and journal lists Power MOSFETs Duncan A. Grant,John Gowar,1989-04-25 Details the theory of power MOSFETs and their applications Explains the basis of MOSFET characteristics and the features that determine MOSFET behavior Examines the interaction of the MOSFET device with other elements in the circuit and how device characteristics influence circuit design Describes several circuits at length to highlight the practical details of power MOSFET use *High Speed, High Current Switching Using Power MOSFETs* Ethan Petersen (F.),1995 **Low Voltage Power MOSFETs** Jacek Korec,2011-03-30 Low Voltage Power MOSFETs focuses on the design of low voltage power MOSFETs and the relation between the device structure and the performance of a power MOSFET used as a switch in power management applications This SpringerBriefs close the gap between detailed engineering reference books and the numerous technical papers on the subject of power MOSFETs The material presented covers low voltage applications extending from battery operated portable electronics through point of load converters internet infrastructure automotive applications to personal computers and server computers The issues treated in this volume are explained qualitatively using schematic illustrations making the discussion easy to follow for all prospective readers Switching Characteristics of Power MOSFETS Under Different Load Conditions Kok Foo Leong,2000 *Improving Switching Performance of Power MOSFETs Used in High Rep-Rate, Short Pulse, High-Power Pulsers* E. G. Cook,2006 As their switching and power handling characteristics improve solid state devices are finding new applications in pulsed power This is particularly true of applications that require fast trains of short duration pulses High voltage 600 1200V MOSFETs are especially well suited for use in these systems as they can switch at significant peak power levels and are easily gated on and off very quickly MOSFET operation at the shortest pulse durations is not constrained by the intrinsic capabilities of the MOSFET but rather by the capabilities of the gate drive circuit and the system physical layout This project sought to improve MOSFET operation in a pulsed power context by addressing these issues The primary goal of this project is to improve the switching performance of power MOSFETs for use in high rep rate short pulse high power applications by improving the design of the gate drive circuits and the circuit layouts used in these systems This requires evaluation of new commercial gate drive circuits and upgrading the designs of LLNL developed circuits In addition these circuits must be tested with the fastest available high voltage power MOSFETs The Switching Function C.C. Marouchos,2006 This new book demonstrates the usefulness of the switching function in analyzing power electronic circuits in the steady state A procedure is suggested for the effective application of this method for the analysis of all types of power electronic circuits **BOOK JACKET** Analysis of the Ultra-fast Switching Dynamics in a Hybrid MOSFET/Driver ,2011 The turn on dynamics of a power MOSFET during ultra fast ns switching are discussed in this paper The testing was performed using a custom hybrid MOSFET Driver module which was fabricated by directly assembling die form components power

MOSFET and drivers on a printed circuit board By using die form components the hybrid approach substantially reduces parasitic inductance which facilitates ultra fast switching The measured turn on time of the hybrid module with a resistive load is 1.2 ns with an applied voltage of 1000 V and drain current of 33 A Detailed analysis of the switching waveforms reveals that switching behavior must be interpreted differently in the ultra fast regime For example the gate threshold voltage to turn on the device is observed to increase as the switching time decreases Further analysis and simulation of MOSFET switching behavior shows that the minimum turn on time scales with the product of the drain source on resistance and drain source capacitance $R_{DS(on)} C_{OSS}$ This information will be useful in power MOSFET selection and gate driver design for ultra fast switching applications

High Frequency Switching with Power MOSFETs Robert John Leedham,1996

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