NEW POWER MODULE AND IC FOR SYNCHRONOUS RECTIFIERS WITH CAPACITIVE FILTERS

Mircea Ilie Mihaiu, Carlos Alberto Valderrama

University of Craiova, Romania, Faculty Polytechnic of Mons, Belgique

Abstract: Synchronous rectifiers can improve power supply efficiency, particularly in low-voltage, low-power applications. The paper presents the power module and a specialized Integrated Circuit for driving full wave synchronous rectifier. The main applications of synchronous rectifiers are for DC-DC converter but we propose the extension to the general propose rectifier circuit. The power module can works as a diode bridge or as a MOSFETs controlled bridge. The specialized Integrated Circuit can be made as a proprietary IC. The simulation results by MULTISIM 10 software are presented in the paper.

Keywords: Synchronous rectifier, Power module, Integrated Circuits, Simulation of the synchronous rectifier,

1. INTRODUCTION

As logic integrated circuits (ICs) have migrated to lower working voltages in the search for higher operating frequencies, and as overall system sizes have continued to decrease, power supply designs with smaller and higher efficiency power modules are in demand. In an effort to improve efficiencies and increase power densities, synchronous rectification has become necessary for these types of applications. Synchronous rectification has gained great popularity in the last ten years as low voltage semiconductor devices have advanced to make this a viable technology. Some transistors, such as the MOSFET, also have an anti-parallel body diode inherent in their structure that can carry current when the transistor is turned off. Sometimes a Schottky diode is placed in anti-parallel with the transistor to carry this latter current because it has a lower on-state voltage and a faster turn-off recovery time than the transistor's own body diode. Whether internal or external, this anti-parallel diode will be referred to herein as an "uncontrolled rectifier "to distinguish it from the active part of the transistor, which will be referred to herein as a "controlled rectifier”. In order to obtain the full benefit from synchronous rectification, components with low drain to source resistance have to be selected. In the Fig.1 is presented a comparison between the forward voltage for diode rectifier and forward voltage across a MOSFET device for different currents and different Ron resistance.

To the Polytechnic Faculty of Mons we are studying the behaviour of some MOSFET (STS11NF30L) to the different variable voltages applied between drain-source and gate-source (Mihaiu 2007).

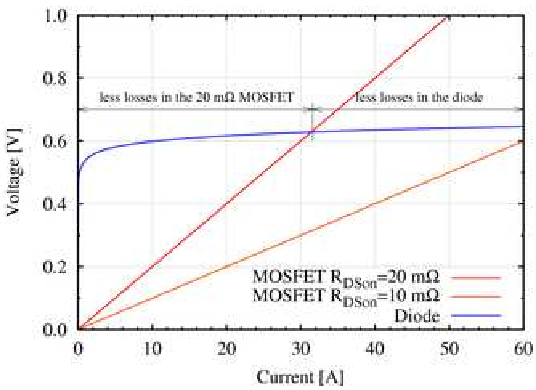

Figure 1. The comparison between the forward voltage for diode and MOSFET

If the gate to source Vgg voltage is bigger than 4V Ron became a constant value and the rectifier diode is not in conduction because the forward voltage V_{DS} is smaller than the diode threshold voltage. For the STS11NF30L transistor the smallest value for Ron is 250 mOhm but in 2007 Toshiba announces a MOSFET (TPCT 4203) with 27 mOhm Ron resistance. There are many patents in the field of synchronous rectifiers (Farrington 2001, Bretz 2001) and also many application notes and research papers (MAXIM 2001, On Semiconductor, 2001, 2005, Bridge 2002). There are also some integrated circuits for driving synchronous rectifier such AP436 circuit from Ana Chip (Ana Chip 2005). In the Fig.2 is presented the main application of AP436.

We study and simulate the power module and a specialized IC for full wave synchronous rectifier with capacitive output filter.

2. POWER MODULE

The power module represent a MOSFETs bridge with the two posible functions : diode rectifier or „uncontrolled rectifier” and MOSFET rectifier or „controlled rectifier”. In Fig.3 is presented the power module.

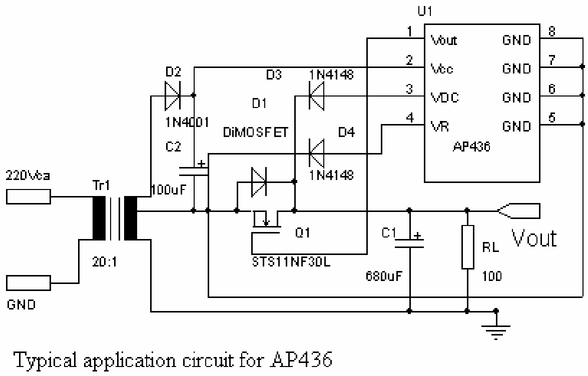

Figure 2. The tipical aplication of MA436

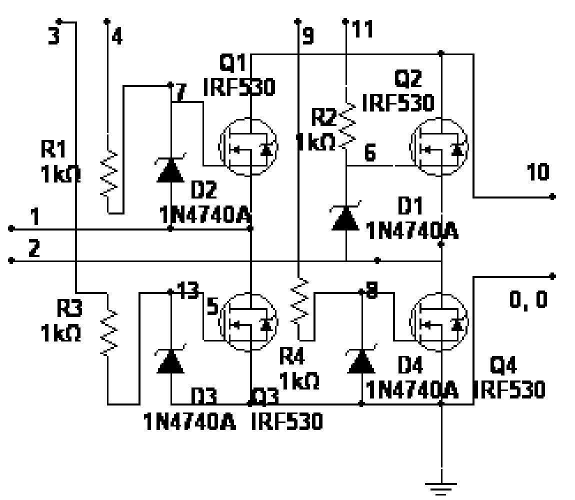

Figure 3 Power module for synchronous rectifier

There are 4 inputs for control the gate-source voltage of the MOSFETs. For each input is a Zener protection circuit designed to 10 V because the thresold test gate to source voltage V_{GS} of the IRF 530 transistors is 10 V. The thresold voltage can be choosed as the minumum V_{GS} voltage for obtain the low Ron resistance. The gate to source voltage must be V_{GSth} V bigger than the voltage applied to the source of the MOSFETs. For the low position MOSFETs Q3 and Q4 can be used output voltage for gate control but for the high position MOSFETs Q1 and Q2 we need a power control source bigger than the output voltage of the syncronous rectifier. For inprove the performance of the diode rectifier we can use Shottky diode in paralel with each MOSFET. The circuit can be used as a diode bridge without MOSFETs control and can be made as a power integrated or hybrid module.

3. THE CONTROL CIRCUIT

The control circuit must control the conduction angle of the MOSFET as a function of the capacitive filter and load resistance. In Fig. 4 is presented the control circuit.

We use two voltage comparator and four analog gates to control the power module. For each negative input voltage the voltage comparator drive two MOSFETs in conduction. The noniverting inputs of the voltage comparators are protected from large positive voltage with diodes. The power source of the circuit is choosed as a constant power source only for the simulation procedure. The second power source (5V) is only for ADG411 circuit. The control circuit can be made as an integrated circuit based on CMOS technology. Before the implementation of such circuit we simulate the behaviour of the circuit with MULTISIM 10 software. In the Fig. 5 is presented the electronic circuit with some instruments used to visualise the waveforms and some waveforms. The simulation results (fig. 6) are not wery well because the gate to source capacitance of the MOSFET. Sometime the MOSFET are in conduction and a large current are demanded from the power source.

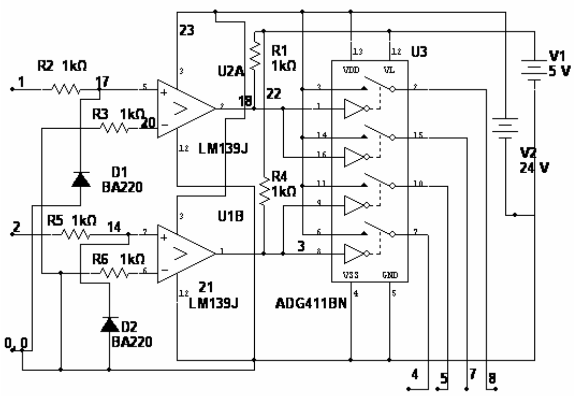

Figure 4 The control circuit for synchronous rectifier

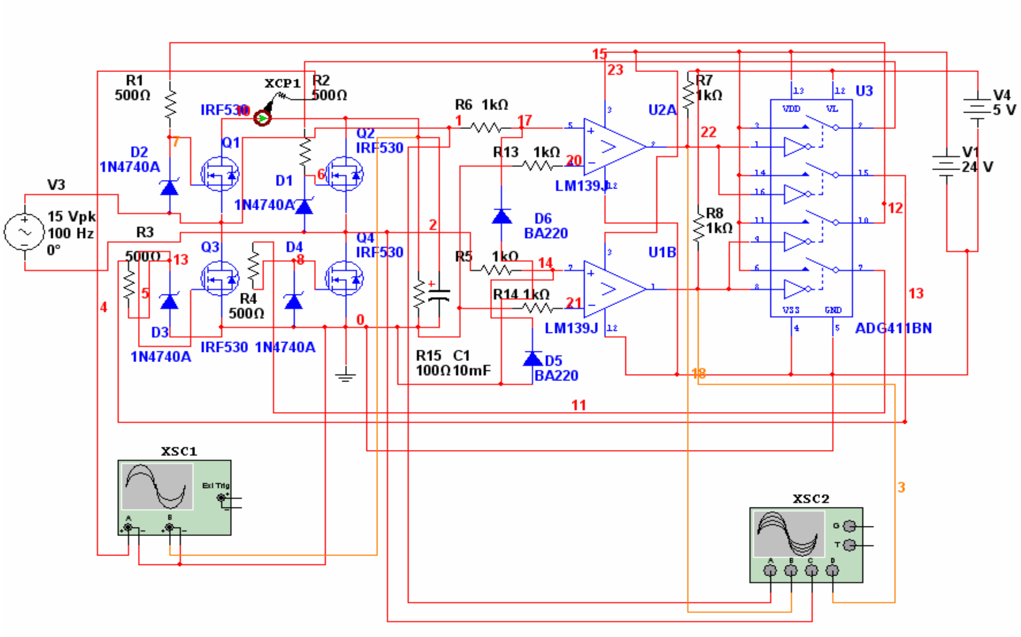

Figure 5 The electronic circuit with some instruments used to visualise the waveforms

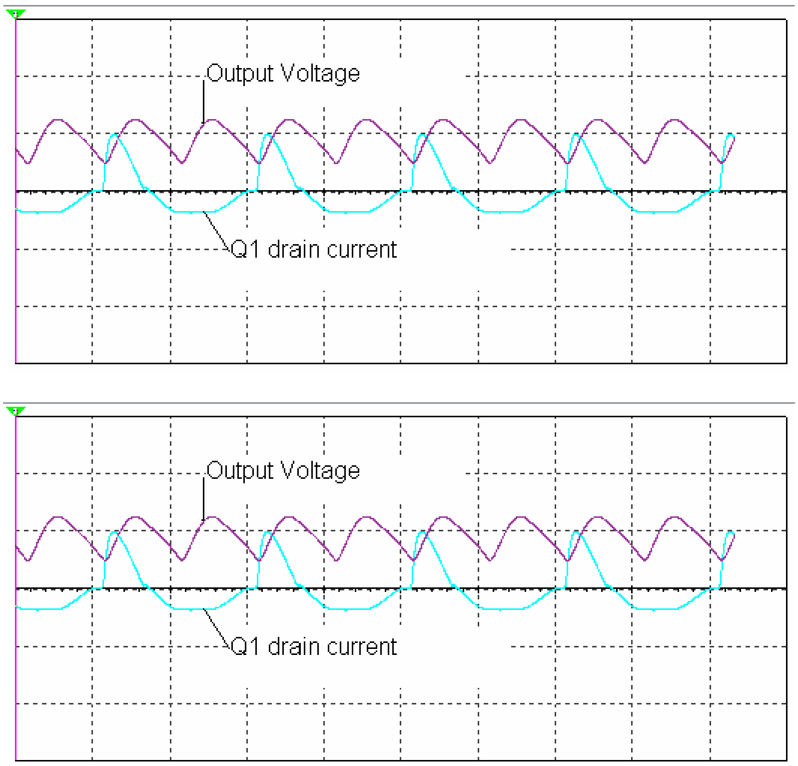

Figure 6 The Input and Output voltages of the voltage comparators

We simulate the main circuit in diffrent conditions but we need new models for MOSFETs.

4. CONCLUSIONS

From a circuit standpoint, a synchronous rectifier is more complicated and usually costs more than the Schottky rectifier. Yet at the system level, the synchronous rectifier competes favorably on cost because of thermal and packaging considerations. Accurately detecting the current zero-crossing is among the most challenging tasks for a synchronous-rectifier design. Delays in detecting and processing the zero crossing allow current to circulate in the secondary circuit, which reduces the converter's efficiency. Because the MOSFET's conduction losses are ideally proportional to $R_{DS(ON)}$, that parameter is key to synchronous rectification circuits. MOSFET gate charge is also important because the amount of current required to fully enhancing the MOSFET channel directly influences non-idealities.

For low frequency synchronous rectifiers (50 Hz or 60Hz) the R_{DSon} and gate to source capacitance C_{GS} are important. We think that for low output voltage some integrated control circuits must be developed and our team work to the development of such circuits. Some circuits are under development.

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