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THE PERFORMANCE ANALYSIS OF THE SYNCHRONOUS RECTIFIERS

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Abstract – **Synchronous rectifiers can improve power supply efficiency, particularly in low-voltage, low-power applications. The paper presents the experimental results of testing MOSFET's with low Ron for power sources. The main applications of synchronous rectifiers are for DC-DC converter but we propose the extension to the general propose rectifier circuit. For low voltage output rectifiers (Smaller than 5V) the efficiency can increase with 25% by using synchronous technique. An integrated solution for the half wave synchronous rectifier is presented.**

Keywords: *synchronous rectifier, low dissipated power rectifiers, IC for synchronous rectifiers*

1. INTRODUCTION

A synchronous rectifier is an electronic switch that improves power-conversion efficiency by placing a low-resistance conduction path across the diode rectifier in a switch-mode regulator. MOSFET's usually serving this purpose. In Fig.1 is presented a diode rectifier circuit and a MOSFET synchronous rectifier circuit.

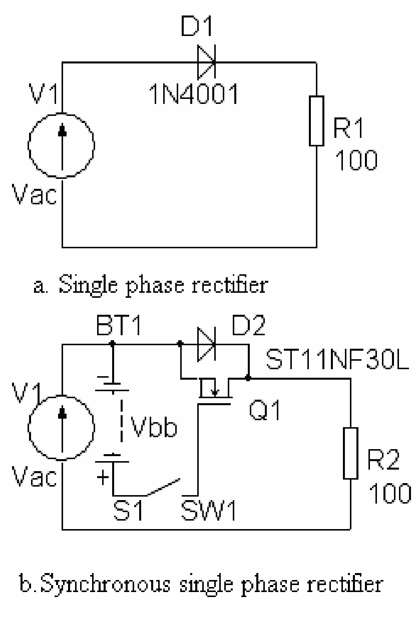


Figure 1. Single phase rectifier and MOSFET synchronous half wave rectifier circuits

In the Fig.2 is presented a comparison between the forward voltage for diode rectifier and forward voltage across a MOSFET device for different currents.

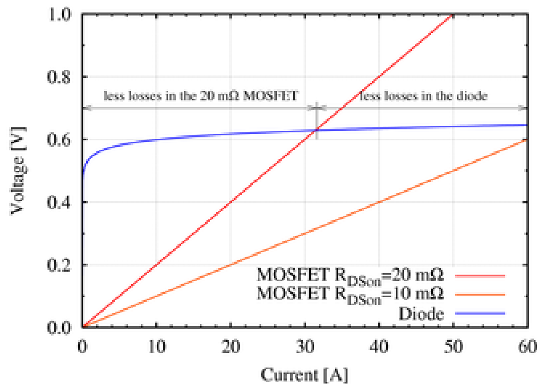


Figure 2. The comparison between the forward voltage for diode and MOSFET

For the load current between 10A and 20 A the efficiently of the synchronous rectifier increase 60% compared with diode rectifiers. The main biases circuits for synchronous rectifier are:

- Auto biasing for main transformer,
- Biasing for independent sources.

2. THE AUTO BIASING OF SYNCHRONOUS RECTIFIERS

The main auto biasing circuits for the half wave synchronous rectifier is presented in Fig.3.

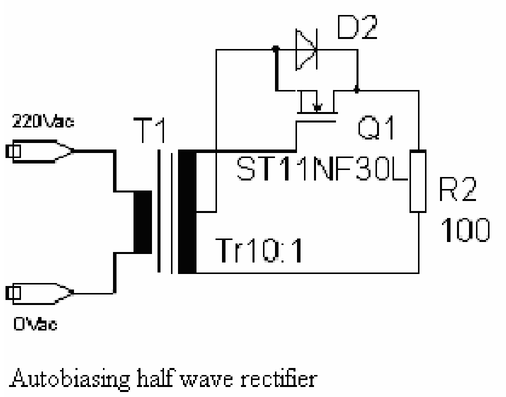


Figure 3. Simple auto biasing half wave rectifier circuit

The auto biasing circuit for the full wave synchronous rectifier is presented in Fig.4.

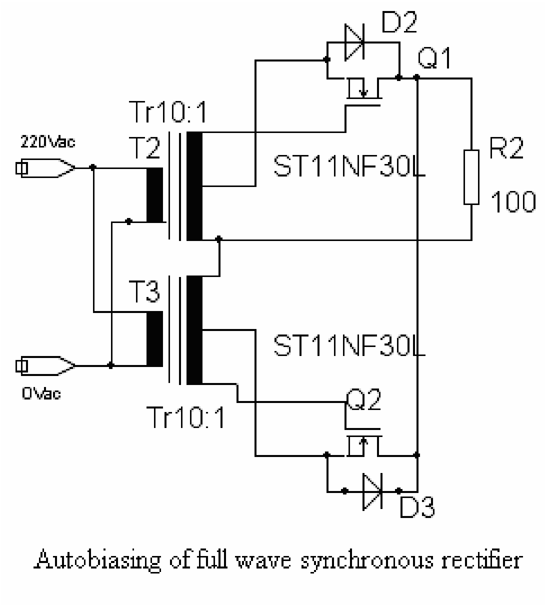


Figure 4. Full wave synchronous rectifier circuit

The main disadvantage of the auto biasing circuits is the variable Ron resistance of the MOSFET's because the variable gate to source voltage.

2.1. The DC regime for power MOSFET

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. The DC test circuit is presented in Fig.5.

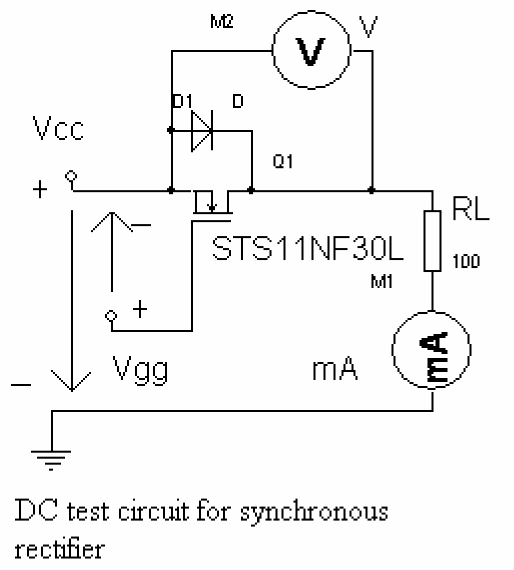


Figure 5. DC test circuit for MOSFET

The input voltage Vcc are varied between 2V et 10V and the gate to source voltage (Vgg) are changed between 0 and 6V. The experimental results are presented in the next table for two input voltages (Vcc).

V_{gg} (V)	0	1	2	2,5	3	4	6
V_{DS} (V)	0,6	0,5	0,3	0,17	57mV	6mV	6mV
I_L (mA)	13,6	14,3	16,4	17,6	18	19	19,2
Ron (Ohm)	∞	34	18,29	9,6	3,1	0,31	0, 35

Table 1.1 Vcc= 2 V

V_{gg} (V)	0	1	2	2,5	3	4	6
V_{DS} (V)	0,63	0,55	0,33	0,2	89mV	15mV	15mV
I_L (mA)	42,8	43	45	46,9	4 8,2	48,8	48,8
Ron (Ohm)	∞	12,7	7,33	4,26	1,8	0,3	0, 3

Table 1.2 Vcc=5 V

From the above table we observe that for Vgg bigger than 2V the MOSFET go in conduction but the Ron resistance in not very small. 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 (Vgg=4V, V_{DSmax}=30V, I_{dmax}=6A) [6]

2.2 The dynamic regime for power MOSFET

The main circuit for study the dynamic regime for half wave rectifier is presented in Fig.6

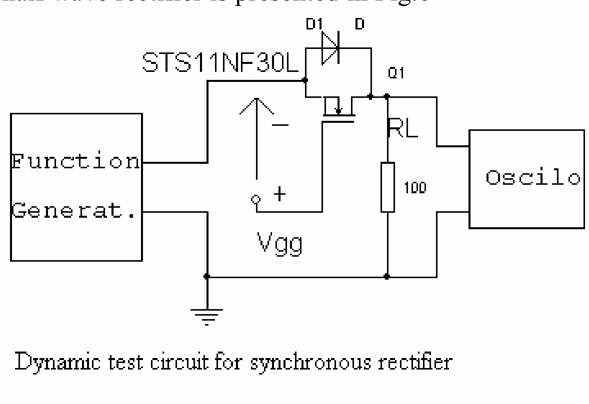
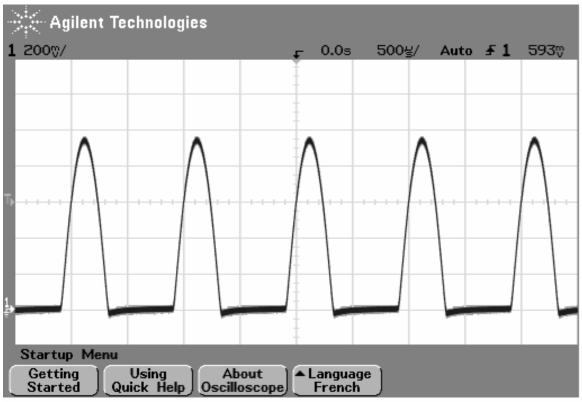


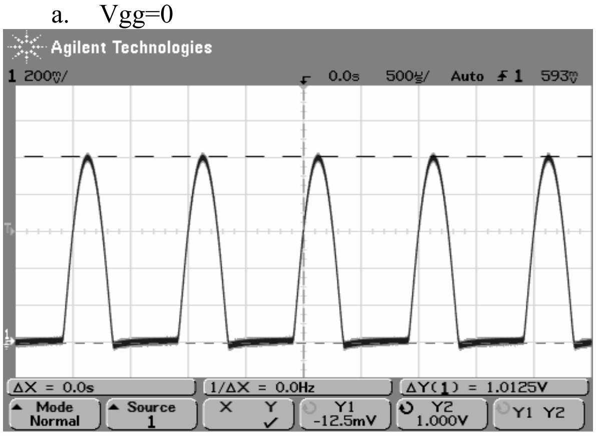
Figure 6. Dynamic test circuit for synchronous rectifier

In the first step we used variable input voltages Vcc and a constant Vgg voltage. We study many waveforms in laboratory but in this paper are presented only a few. The waveform for different Vgg voltages is presented in the Fig.7. The first waveform is for Vcc (pick to pick) = 2V and Vgg=0, the second is for Vgg=2V and the third is for Vgg=4V. For the voltage above 3V the MOSFET is in conduction all the time and the rectifier function is eliminated.



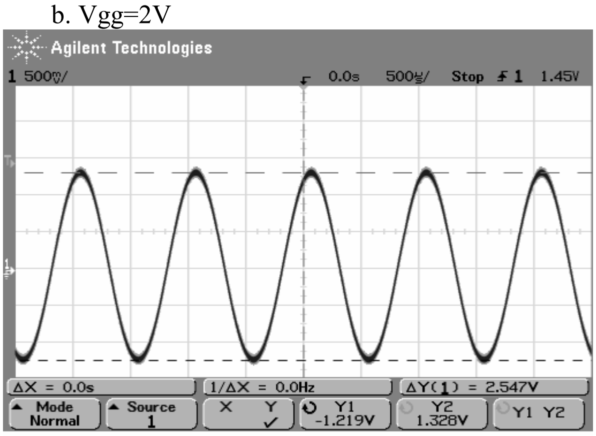
VGS= 0V - Diode Rectifier

a. Vgg=0



VGS=2V The MOSFET not yet in conduction

b. Vgg=2V



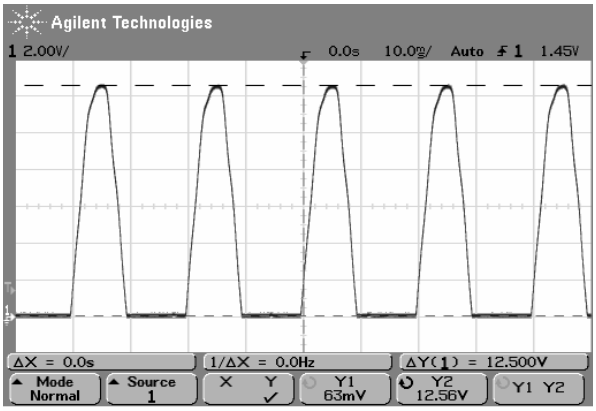
VGS=4V The MOSFET acts as a court-circuit with low ron.

c. Vgg = 4V

Figure 7. Waveform for dynamic test circuit with constant Vgg voltage

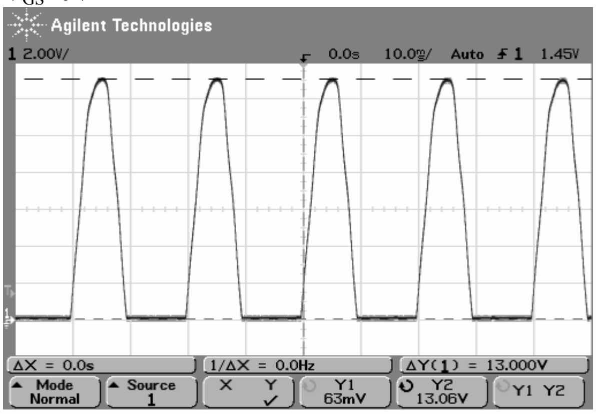
In some application the reverse conduction of the MOSFET can be used, but in normal way the reverse conduction of the MOSFET must be eliminated.

In the second step we used a step down transformer (Fig.3) with the main Vcc voltages 13V and the control voltage Vgg=6V. In the Fig. 8 is presented the waveforms without and with MOSFET control.



VGS=0V Half wave rectifier (Diode rectifier)

V_{GS}=0V



VGS=6V Half wave synchron rectifier

V_{GS}=6V

Figure 8 Waveform for dynamic test circuit with variable Vgg voltage

From the above figure we observe that the peak voltage increase with 0.5V when the MOSFET is controlled by the auto biasing circuit. We study also the full wave rectifier and the results are similar. The main disadvantage of the auto biasing circuit is the variable Ron resistance of the MOSFET. The output waveform is distorted; the efficiency is increased, but not enough.

3. BIASING FOR INDEPENDENT SOURCES

As we are presented in the previous part the auto biasing circuits are simple but the MOSFET Ron resistance is variable as a function of variable gate to source voltage. If we use an independent biasing source larger than 5V we obtain an approximately constant low Ron resistance. The first solution is to use a battery but this source must be replaced in time. We can obtain a large control voltage by using a step-up

DC-DC converter connected to the output of the synchronous rectifier. In Fig.9 is presented a typical application circuit that uses a synchronous driver IC for control the MOSFET in half wave rectifier circuit.

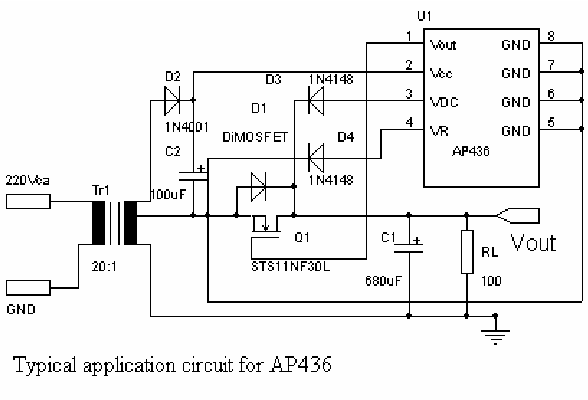


Figure 9. The synchronous rectifier MOSFET driver IC- AP436

The power of the IC driver is obtained from the transformer but we have a power source at the output of the synchronous rectifier circuit. The output voltage of the synchronous rectifier is not enough to obtain a positive gate to source voltage greater than 5V. We propose to use a step-up converter connected to the output of the synchronous rectifier as is presented in Fig.10.

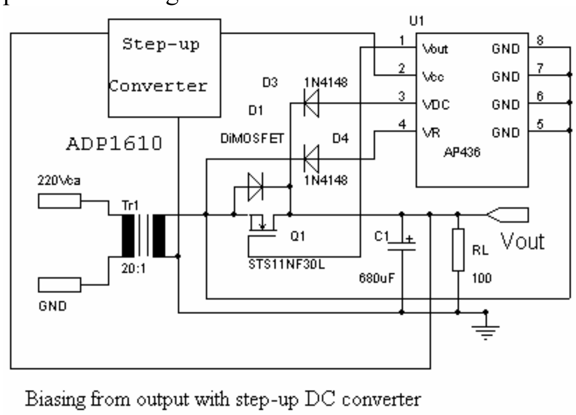


Figure 10 Biasing from output with step-up converter.

There are many available step-up converters. We choose the step-up converter from Analog Devices ADP 1610 circuit. The ADP 1610 circuit is used to generate a 10V output voltage for input voltages between 2.5 and 5.5V. The typical application can be found to Ana Chip website. The ADP circuit operates in modulation (PWM) current mode with 92% efficiency. The output voltage of the step-up converter can be easily controlled to obtain an output voltage greater than input voltage (minim 5V).

4. CONCLUSIONS

We think that the circuit presented in Fig. 10 can be realized as an integrated IC. The IC can contain the power MOSFET, the synchronous driver, the step-up converter and some additional controls. The IC circuit can work as a diode rectifier or as a synchronous rectifier. Our team work to the development of such IC for full wave rectifier circuit with different output filters as capacitors or inductors.

Acknowledgments

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