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Driver Requirement for Power MOSFET: A Study

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***Abstract*— Power MOSFET is a voltage-controlled device generally used for switching purpose. To obtain the MOSFET as operating, an appropriate voltage should be applied to the Vgs- terminal. The ON and OFF operation of MOSFET depends upon the charging and discharging behaviour of the parasitic capacitances. For low frequency, a normal pulse generating circuit without a driver is suitable but the switching losses can be an issue of concern. A suitable driver circuit is required for the proper switching at high frequency. This paper describes the practical observation for a switching circuit containing RL load and Power MOSFET in two different cases- with driver circuit and without driver circuit at two different switching frequencies (Low-50Hz and High-50kHz).**

***Keywords*— Driver, Power MOSFET, Parasitic Element, Switching Behaviour, Switching Frequency**

I. Introduction

Power Devices are the components, which are used as rectifier or switch in the power electronic systems. We can use the term ‗power' with all that components which are able to switch at least 1A current. The Power MOSFET (Metal Oxide Semiconductor Field Effect Transistor) is one of the most popular components used for this purpose by designers. It is diffused channel MOSFET, which offers an exceptionally wide range of voltage & current with low $R_{ds(on)}$, which is much differ than conventional MOSFET. This paper depicts the need of suitable gate-driver for proper operation of Power MOSFET using practical observations.

II. MOSFET‘s Significant And Switching Operation

When the MOSFET is used as a switch, its basic function is to control the drain current by the gate voltage. If we see the MOSFET internal architecture then it has a number of parasitic elements (Fig 1) and therefore driving a power MOSFET is same as driving a capacitive network. At higher frequency, the appropriate charge should be provided to gate based on the time constant. So the job cannot be done by the simple gate supply, a driver is requied

Parasitic Elements:

R_G: Distributive Resistance of the Gate
L_S & L_D: Source and Drain Lead Inductances
C_{GS}: Gate to Source Capacitance
C_{DS}: Drain to Source Capacitance
C_{GD}: Gate to Drain Capacitance
D: Body Diode

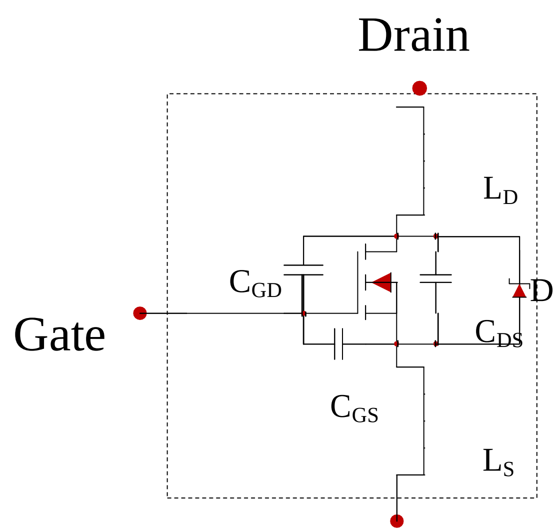

Fig 1: Power MOSFET with parasitic elements

The switching performance of a device is determined by the time required to establish voltage changes across capacitances. Unfortunately, none of the above mentioned capacitance values are defined directly in the transistor data sheets. Their values are given indirectly by the C_{ISS}, C_{RSS}, and C_{OSS} capacitor values, which are defined as:

Input Capacitance (C_{ISS}) = C_{GS} + C_{GD}; C_{DS} shorted
Reverse Transfer Capacitance (C_{RSS}) = C_{GD}
Output Capacitance (C_{OSS}) = C_{DS} + C_{GD}

Gate-to-drain capacitance, C_{GD}, is a nonlinear function of voltage and is the most important parameter because it provides a feedback loop between the output and the input of the circuit. C_{GD} is also called the Miller capacitance because it causes the total dynamic input capacitance to become greater than the sum of the static capacitances.

The switching behaviour of the Power MOSFET is shown in Fig 2, which can be divided into different span of periods as affected by capacitances.

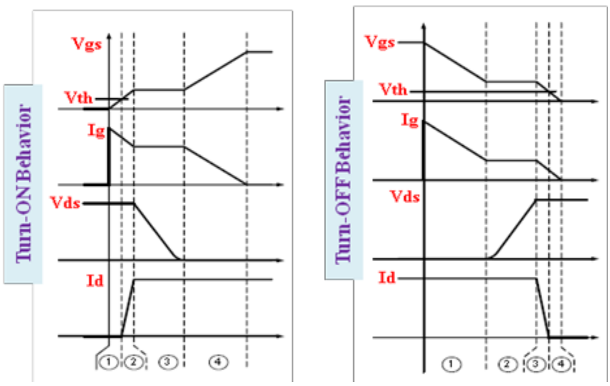

Fig 2: Switching Behaviour

III. System Description

The block diagram of the system with driver is shown in Fig 3. The output of pulse generator is fed to the driver circuit and then it is applied to the semiconductor switch of the power circuit. The output of driver circuit has high current capability and very fast rise and fall of the pulse that leads to fast charging and discharging of the internal capacitance. Therefore, the switching obtained is fast. Generally, ICs used for driver circuit that consists of logic input buffer that drives sufficient current gain stages to produce a high current output.

The block diagram of the system without driver is shown in Fig 4. The output of pulse generator is directly given to the semiconductor switch of the power circuit. It is only used for the circuit working on low frequency and the switching power loss is not a big issue. The pulse generated by the pulse generator is not sufficient for the gate circuit to operate at high frequency, as it may not help in fast charging and discharging of internal parasitic capacitances.

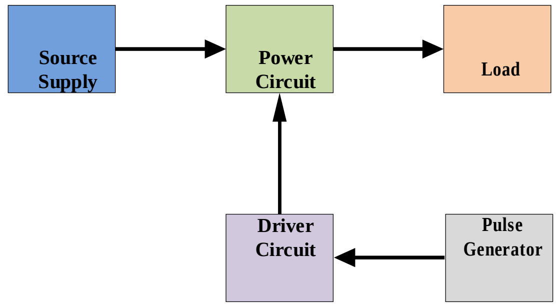

Fig 3: Block Diagram of the System with Driver Circuit

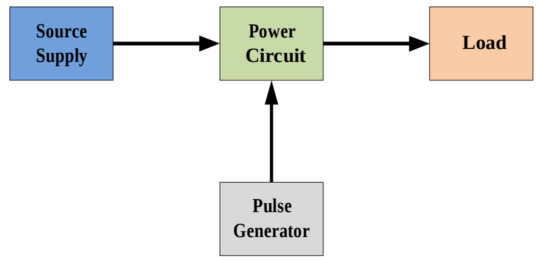

Fig 4: Block Diagram of the System without Driver Circuit

IV. Design And Simulation

To test the behaviour of Power MOSFET with or without driver circuit, a circuit is designed which contains R-L load. The assumed value of L/R is 2µs and the value of R is 100Ω at the V_{DC}=30V.

The circuit is simulated using the software LTspice and its behaviour was found to be as per design. Simulated circuit and its results are given in below figures.

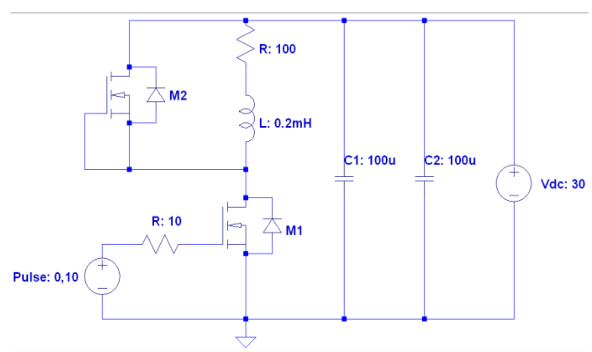

Fig 5: Simulated Circuit

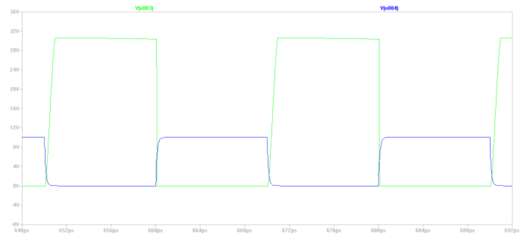

Fig 6: Waveforms (V_{DC} (Green) and V_{GS} (Blue)) at 50kHz

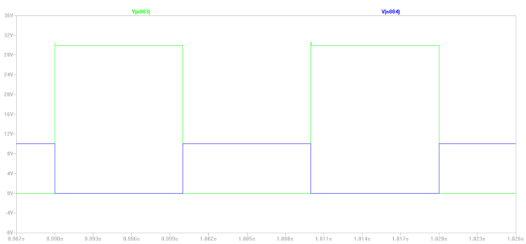

Fig 7: Waveforms (V_{DC} (Green) and V_{GS} (Blue)) at 50Hz

V. Test Results

The designed circuit is assembled as shown in Fig 8. The International Rectifier Power MOSFET IRFP240 (V_{DSS}= 200V, $R_{DS(on)}$= 0.18Ω, I_D= 20A) is used for switching and also for the freewheeling diode in proper circuit connections. The IC MC33153 is used to drive the circuit when tested with driver circuit, which has 1A source and 2A sink capability. The circuit is also tested without driver circuit and the fall time 2µs and rise time 6µs is obtained for operating frequency 50Hz while no output is obtained for higher frequency i.e. 50kHz. With driver circuit, the fall time obtained is about 40ns and the rise time is about 175ns for both operating frequencies 50Hz and 50kHz.

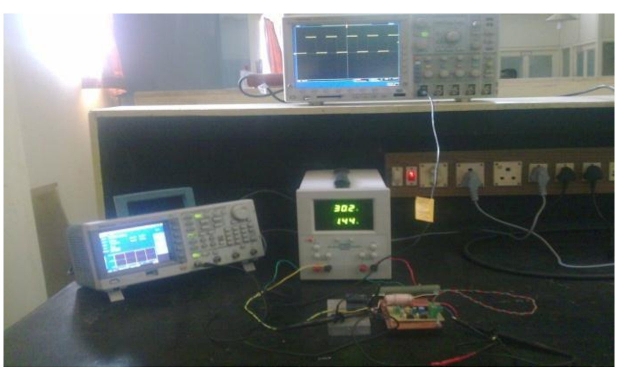

Fig 8: Test Setup

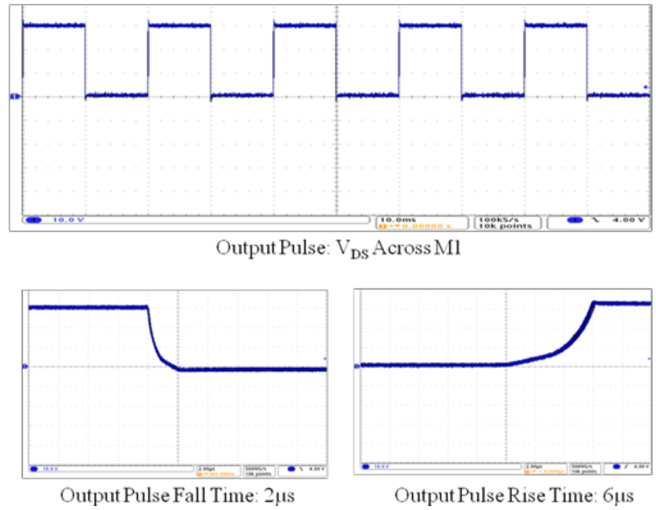

Fig 9: Waveforms without Driver Rg=10Ω, f=50Hz, Duty cycle=50%

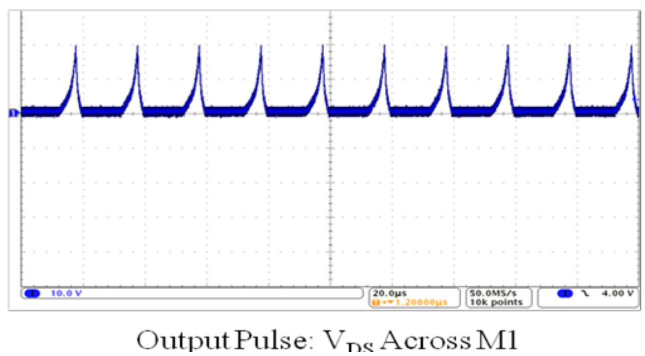

Fig 10: Waveforms without Driver Rg=10Ω, f=50kHz, Duty cycle=50%

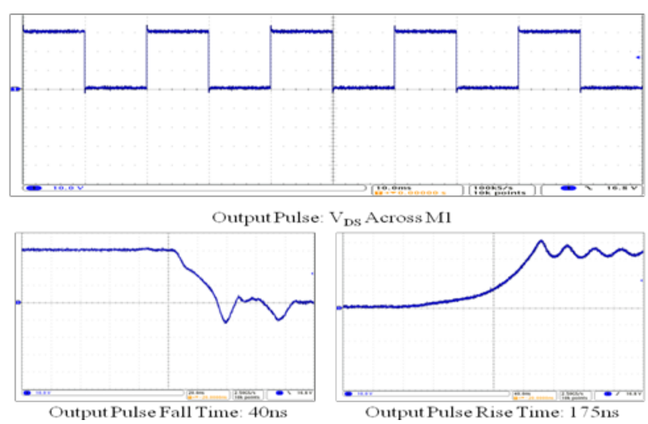

Fig 11: Waveforms with Driver circuit Rg=10Ω, f=50Hz, Duty cycle=50%

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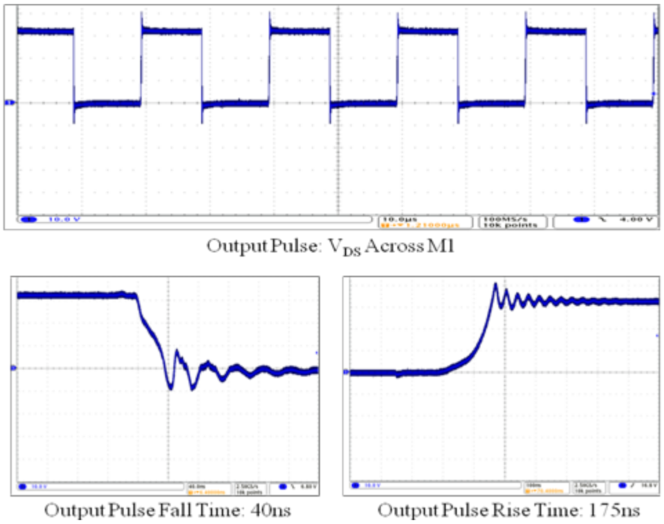

Fig 12: Waveforms with Driver circuit Rg=10Ω, f=50kHz, Duty cycle=50%

CONCLUSION

The above theoretical and practical observations illustrate that the parasitic elements available in the Power MOSFET change the behavior of the device. Therefore, to avoid the losses and undesirable switching the suitable gate driver should be used in the application with proper isolation, if desire.

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