Methodology for Switching Characterization of Semiconductor Power Devices

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Introduction

During the last 30 years, the technology of power electronics and drives has gone through intense technological evolution, although its history dates back to for nearly a century. Now, it seems to be one of the wide range well defined technologies. Many inventions in devices, components, circuits, controls, and systems have caused power electronics to emerge as a major technology in recent years.

Aim:

In this project, we are going to implement a series of testbeds in order to characterize the switching characteristic of selected power device.

Objective:

Power device is always used to build a power converter. In order to improve the performance of the power converter, we should improve the converter’s power density, increase the efficiency and reduce the passive component size. Switching frequency is an important factor, because if we increase the switching frequency, we can reduce the size of the passive components and we can improve the transient performance of the converter. We can greatly improve the performance of the converter by investigating the device switching characteristics. The main switching characteristics of the power device are the turn-on transients, turn-off transients and the safe operating area (SOA) of the device. We will investigate these characteristics by our testbeds.

Boost converter

Boost converter have a good source current but a bad tail current. It is because the inductor current is the source current so that it is continuous. But the tail current is the diode current which is not continuous. Since input power equals to the output power,

\[ V_s I_L = \frac{V_o^2}{R} = \frac{V_s}{(1-D)^2 R} \]

\[ I_{L,max} = I_L + \frac{\Delta I_L}{2} = \frac{V_i}{(1-D)^2 R} + \frac{1}{2} \left[ \frac{V_s}{L} DT \right] = \frac{V_s}{(1-D)^2 R} + \frac{V_s DT}{2L} \]

\[ I_{L,min} = I_L - \frac{\Delta I_L}{2} = \frac{V_i}{(1-D)^2 R} - \frac{1}{2} \left[ \frac{V_s}{L} DT \right] = \frac{V_s}{(1-D)^2 R} - \frac{V_s DT}{2L} \]

Figure: a boost converter
Gate Driver

There are two main types of Gate drivers. They are called high-side driver and low-side driver. High-side gate driver is used to drive a MOSFET that is connected to a positive supply. It is not referenced by ground but it is floating. Low-side gate driver is used to drive a MOSFET that its drain part is connected to the load and the source part is referenced by ground. High-side driver is more complicated than low-side driver because voltage translation to the supply is involved and it is more difficult to turn off a floating transistor.

Fig. A Testing Circuit

Fig. The wavefront generated by HO pin and it is connected to gate of IRF540
Gate Charge Circuit
For the power MOSFETs, a much more useful parameter in the circuit design point of view is the gate charge rather than capacitances.
In this circuit shown below, a constant current in the drain part of the device-under-test is placed by setting a fixed voltage on the gate of upper MOSFET, so the net measurement of the charge consumed by the gate of DUT is relative to a given current and voltage in the source-to-drain path.

Fig. Gate Voltage of Mosfet IRF830

Fig. A Gate Charge Testing Circuit

Fig. Gate Voltage of Mosfet IRF540

Conclusion
The gate charge circuit we built can obtain the result that was quite close to that in datasheet. The gate driver was also successfully built to generate an approximate square wave which ensured the tested transistor to be fully turned on. A negative gate bias circuit attached to the gate driver then was used to ensure the MOSFET to fully turn off.
The resistive load test circuit was built to determine how the gate resistance, load resistance and the drain-source voltage (Vds) affect the switching time ($t_{on}$, $r_{ds(on)}$, $I_{dss}$) of the IRF540 and IRF830.
The inductive load test circuit was also built in order to find out the relation with gate resistance to $t_{on}$, $r_{ds(on)}$, $I_{dss}$. The boost converter circuit was used to find out the relation of Vds of the switch and the performance of the converter.