10/16/2024

ECE 5610
Lab 3
Switching Characteristics of MOSFETs and Diodes using the Power-Pole Board

Objective

The objective of this experiment is to study the switching characteristics of power MOSFETs and power diodes using a buck converter. The circuit will be operated in open loop conditions (no feedback). Our main goal is to understand the switching behavior of these two power devices.

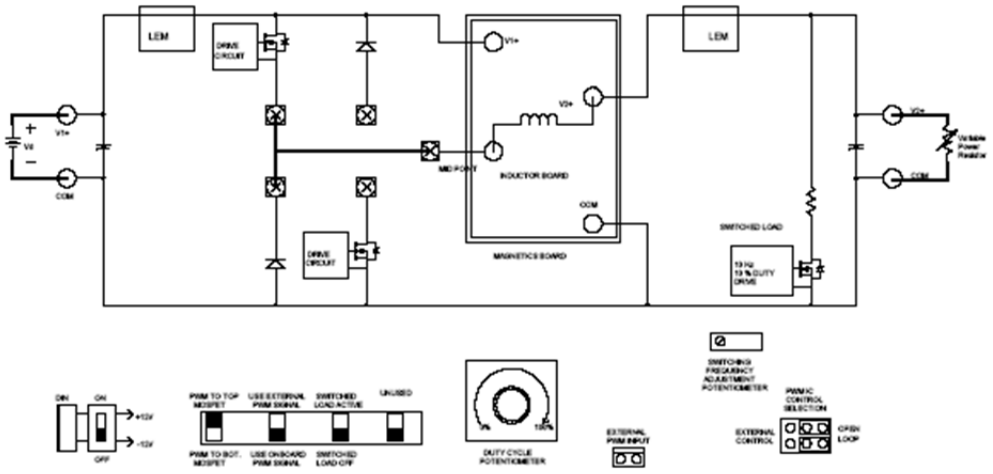

Figure 2.1: Schematic of Buck Converter

Note 1: The oscilloscope channels share the same signal GND. Therefore, it is recommended to take precautions while measuring two quantities having separate reference potentials. Students are advised to use the circuit connections shown in Figure 3 of Lab 1 if you need to take two measurements simultaneously in the oscilloscope.

3.1 Preparing the setup

Make the connections on the power-pole board as shown in Fig. 2.1.
- Use the magnetic board BB board for the buck converter circuit. The inductor is 100 μH.
- Use a variable load resistor (R_L) as a load.
- Use onboard PWM signals.
- Connect the ±12 signal supply at the *DIN* connector. Signal supply switch S90 should be in the OFF position.

3.2 Checks before powering the circuit

- Check the circuit connections as per the schematics.
- Have your circuit checked by your ***Lab TA***.

3.3 Powering the circuit

- Switch ON the signal supply. The green LED should illuminate.
- Adjust the duty ratio to 50%.
- Adjust the switching frequency to 100 kHz.
- Set the load resistance R_L = 10 Ω.
- Apply input voltage V_d of 15 V at terminals *V1+* and *COM*.

3.4 Measurement and waveforms

Take the following measurements,

1. Observe and make a copy of the Anode-Cathode diode voltage V_{AK} and the diode current *CS3* using oscilloscope connections shown in Figure 2 of Lab 1. Adjust the time base to show the switching details during turn-ON and turn-OFF.
2. Measure the forward voltage drop across the diode V_{FM}.
3. Observe and make a copy of the Drain-Source MOSFET voltage V_{DS} and MOSFET current *CS1* using oscilloscope connections shown in Figure 2 of Lab 1. Adjust the time base to show the switching details during turn-ON and turn-OFF.
4. Measure the voltage drop across the MOSFET during turn-ON period and estimate the $R_{DS(ON)}$ of the MOSFET.
5. Measure the average load current I_o, and the duty cycle of operation.

3.5 Lab report

The lab report should have a brief abstract detailing what has been done in the experiment. The remaining part of the report should consist of the information asked below along with any discussion you feel is necessary.

1. Attach the waveforms for turn-ON and turn-OFF of the diode showing the switching details by expanding the time base.
2. Calculate the conduction loss of the diode using the measurements obtained from step 1 & 2 of section 3.4.
3. Attach the waveforms for turn-ON and turn-OFF characteristics of the MOSFET showing the switching details by expanding the time base.
4. Estimate the $R_{DS(ON)}$ of the MOSFET from step 3 & 4 of section 3.4 and compare with the datasheet of MOSFET *IRF640N*.
5. Calculate the conduction loss of the MOSFET using the measurements obtained from step 4 of section 3.4.
6. Using the values of conduction losses of the MOSFET and the Diode obtained through measurements, and switching losses of the MOSFET and the Diode obtained through PSpice simulation, estimate the efficiency of the converter. Compare the estimated efficiency with the efficiency obtained for the buck converter in the “Buck Converter Experiment” (Lab 2).

3.4

1) V_{ak} → CS3 Diode

input:

ch-1: Pwm output

ch-2: V diode (CS3 & GND) → CS3

↳ 15.63V (flat line) - top
-0.700 (flat line) - bottom
— manual cursor measurement

460mV Peak to Peak CS3

↳ 14.57V - top flat line
-0.700V - bottom flat line
— manual cursor measurement

PSU: 15V @ 0.28A (source Vin)

↳ 15(0.3) = 6V (.700)

— diode current: CS3 & bottom source
— 760mV peak to peak

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2) MOSFET: ch2: drain & source : Top MOSFET

— avg : 140mV
Pk-Pk: 9.6V

3) ch 2: drain & source of top MOSFET 50 tV triangle wave

> 14.257 V

> 13.82 V } average

$I_{ds} = \frac{140m}{.05} = 2.8A$

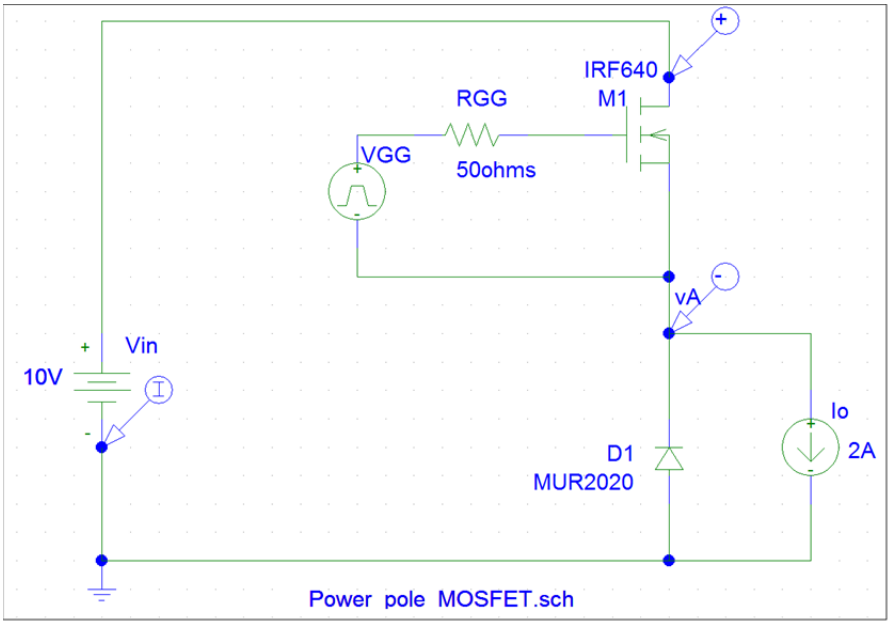
4) $V_{FM} = 0.7V$

5) $I_o = .623A$

$V_o = 6.22$ @ 10A

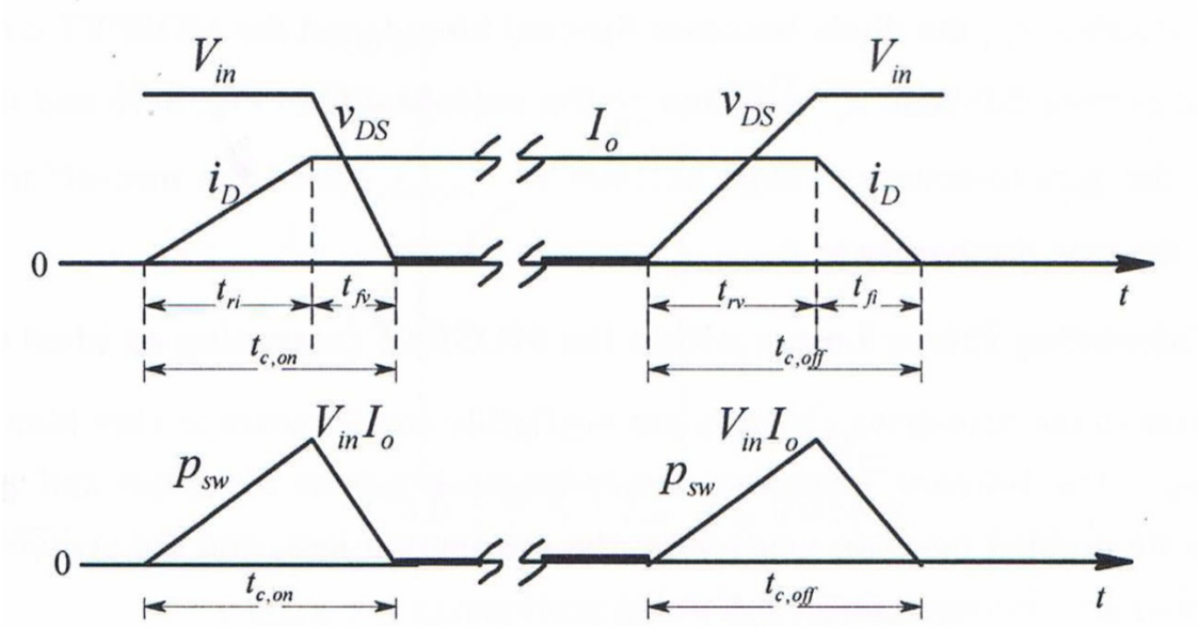
3.6 Spice simulation

3.6.1 Open the file **Power_pole_PSpice_MOSFET.sch**. Take a moment to examine the circuit, and then perform the following measurements.



Assignments:

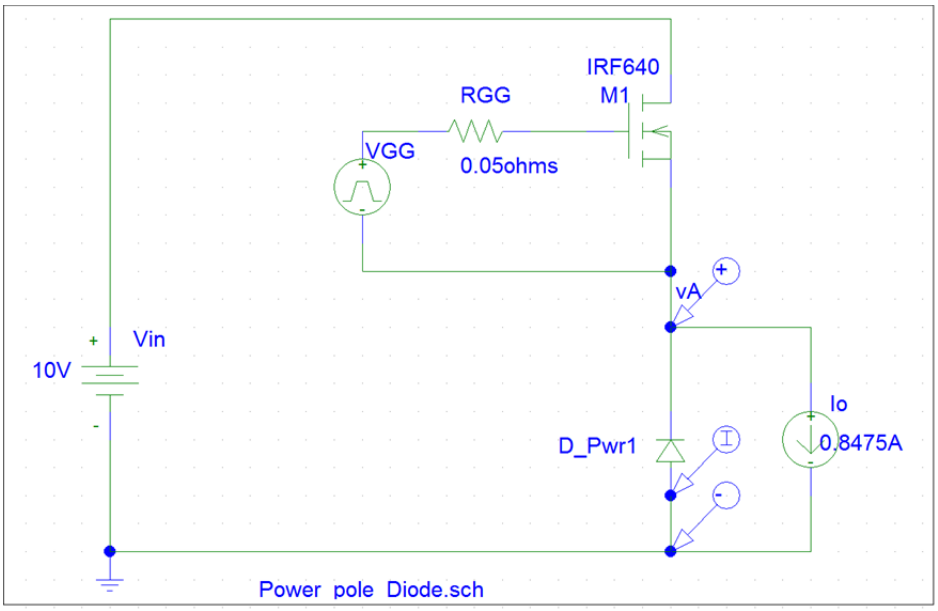
1. In the schematic shown above, the circuit consists of a MOSFET IRF640 and a diode MUR2020 in the PSpice Library with R_s *(Source resistance)* =1 mΩ. Obtain the turn-ON switching characteristics as shown in Fig. below. Plot the drain-source voltage of M1, and the current through M1 to obtain the switching characteristics.



2. Measure $t_c(ON)$, t_{ri} and t_{fv} in the turn-ON switching characteristics.

3. Measure $v_{GS(th)}$ and $v_{GS(lo)}$. Compare these with the values obtained from the datasheet of *IRF640*.
4. Estimate the average switching power loss during the turn-ON.
5. Obtain the turn-off switching characteristics as shown in the figure above.
6. Measure $t_c(OFF)$, t_{rv} and t_{fi} in the turn-OFF switching characteristics.
7. Calculate the average switching power loss during the turn-OFF.

3.6.2 Open the file **Power_pole_Diode.sch**. Take a moment to examine the circuit, and then perform the following measurements.



Assignments:

1. The schematic above has a diode MUR2020. Obtain the turn-ON and turn-OFF switching characteristics of the diode similar to the way used for obtaining the MOSFET characteristics.
2. Estimate the average switching power loss during turn-ON and turn-OFF switching characteristics of the diode similar to the way used for obtaining the MOSFET characteristics.