Study of IGBT and MOSFET Switching Characteristics

Theory:

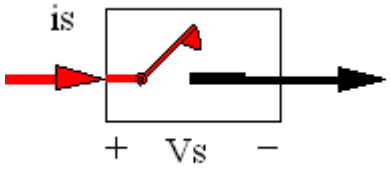

Fig. 1 Switch

Vs=voltage drop across the switch
is=Current through the switch

Properties of an ideal switch:

1. ON State Property: Vs=0, $-\grave{A} < is <$
2. OFF State Property: is=0, $-\grave{A} < Vs <$
3. From ON to OFF time, toff=0 i.e., (a) to (b) in zero time through the path shown by arrows in Fig. 2(a). Otherwise, power is dissipated as is and Vs both will be present.

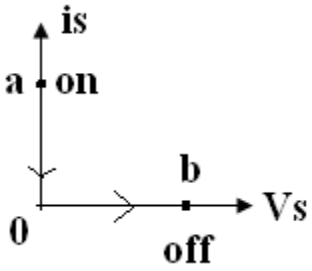

Fig. 2(a) Ideal Switch Turn OFF Characteristics

4. From OFF to ON, ton=0. Energy dissipated during turn ON process = turn ON loss=0.

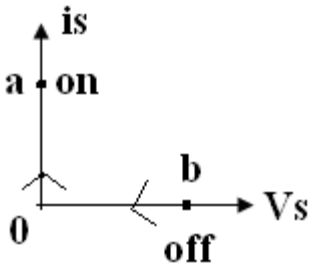

Fig. 2(b) Ideal Switch Turn ON Charactersitics

5. No energy is consumed in the driver circuit of the switch. (Gate or base current loss=0)

6. The characteristics should be stable with respect to ambient temperature.

For a practical switch, the following losses will occur.

a. Conduction loss
b. Blocking Loss
c. Turn on loss
d. Turn off loss
e. Driver circuit loss

Power electronic semiconductor switching devices are classified into three main categories:

1. Uncontrolled: Ex: Diode since its ON/OFF depends on external circuit. We cannot control.
2. Semi controlled: Ex: Thyristor since its ON state can be controlled but its OFF state cannot be controlled. It depends on external circuitry.
3. Fully Controlled/Controlled: All other semiconductor devices like MOSFET, IGBT, BJT etc.

I. Metal Oxide Semiconductor Field Effect Transistor (MOSFET):

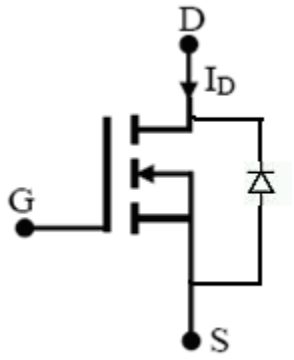

Fig. 3 n-channel enhancement type MOSFET

MOSFET is a three terminal (**G**ate, **D**rain and **S**ource) full controlled switch used for high frequency applications (>100 kHz)

Gate/Control Signal: Between Gate and Source
Switch Terminals: Between Drain and Source

ON State Equivalent Circuit of MOSFET:

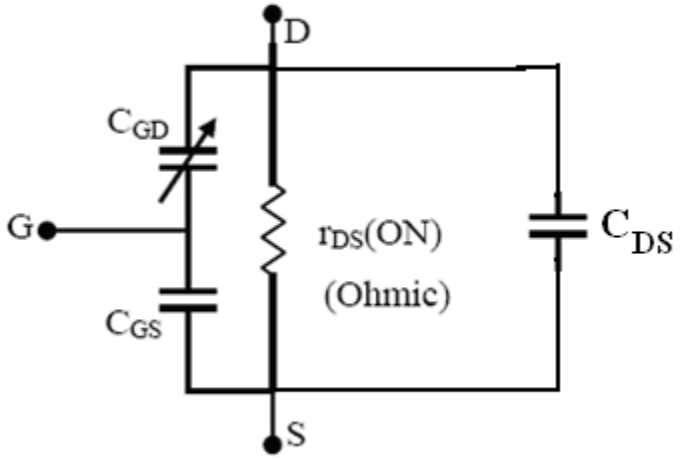

Fig. 4 ON state Equivalent Circuit of MOSFET

OFF State Equivalent Circuit of MOSFET:

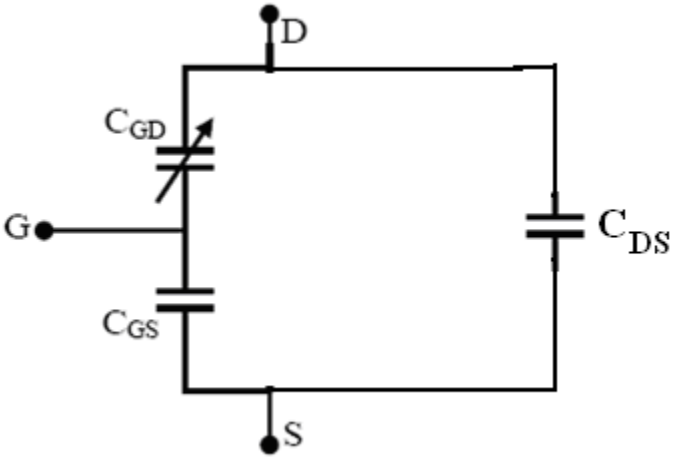

Fig. 5 OFF State Equivalent Circuit of MOSFET

Switching Characteristics:

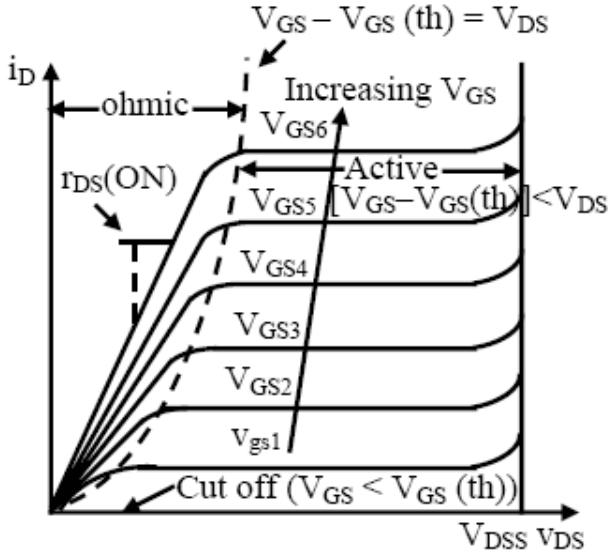

Fig. 6. Output Characteristics of a MOSFET

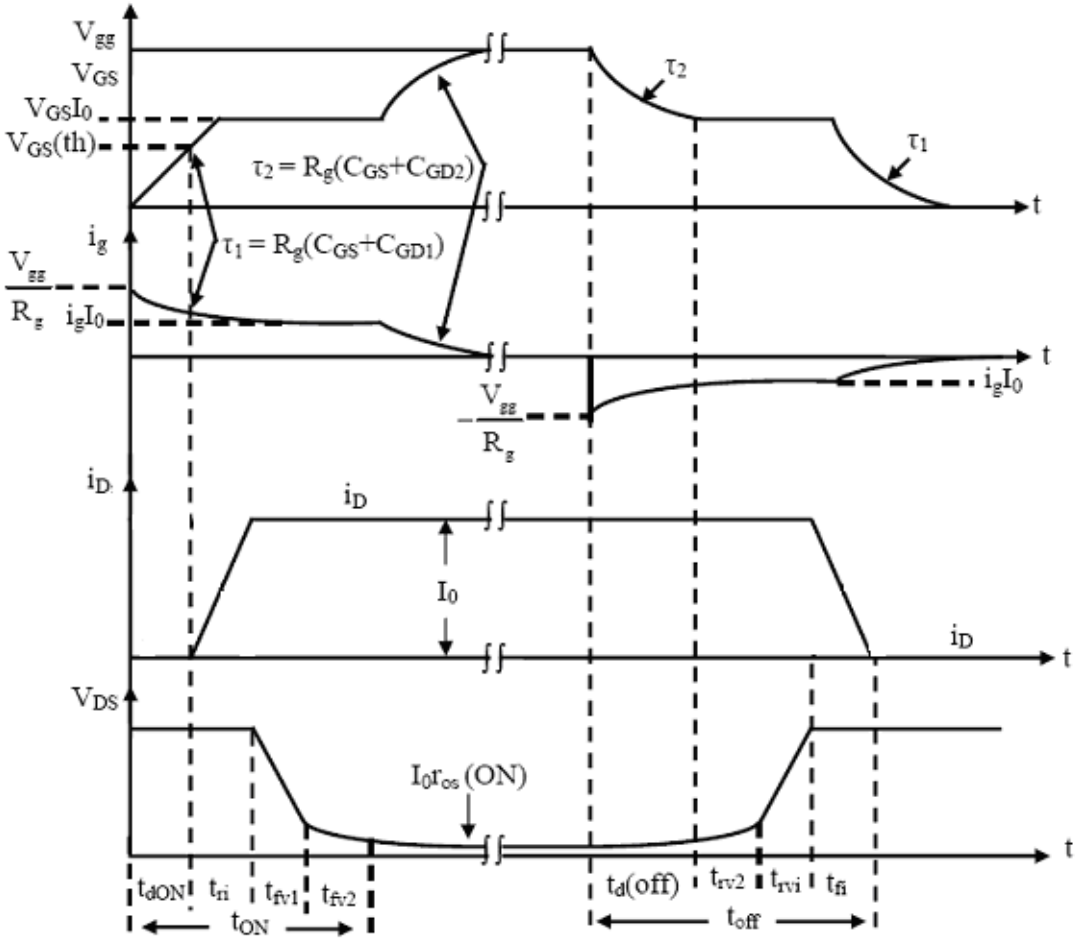

Fig. 7. Switching Characteristics of a MOSFET

Block Diagram:

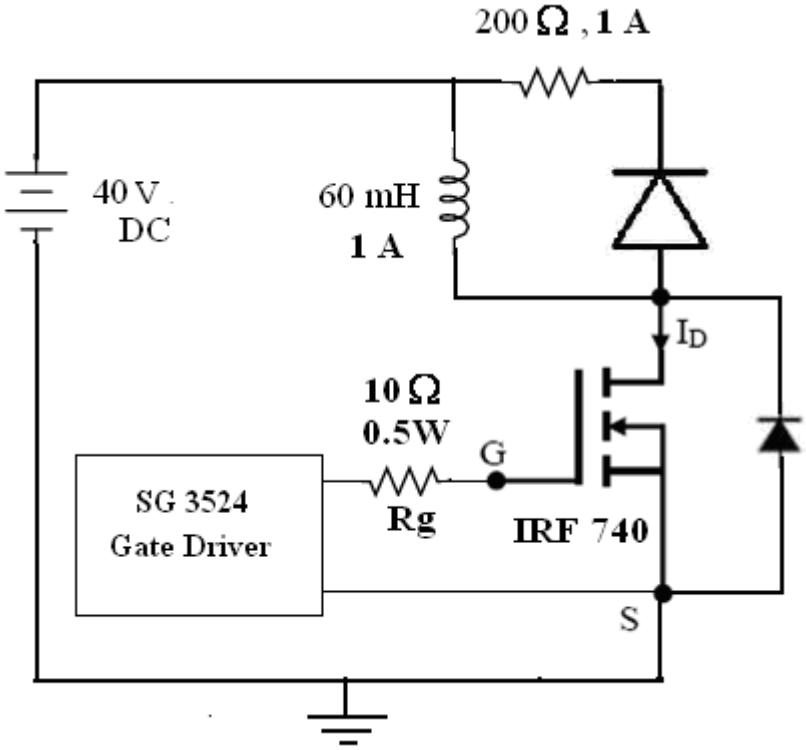

Fig. 8. Block Diagram for finding the Switching Characteristics of a MOSFET

Actual Gate Circuit Diagram:

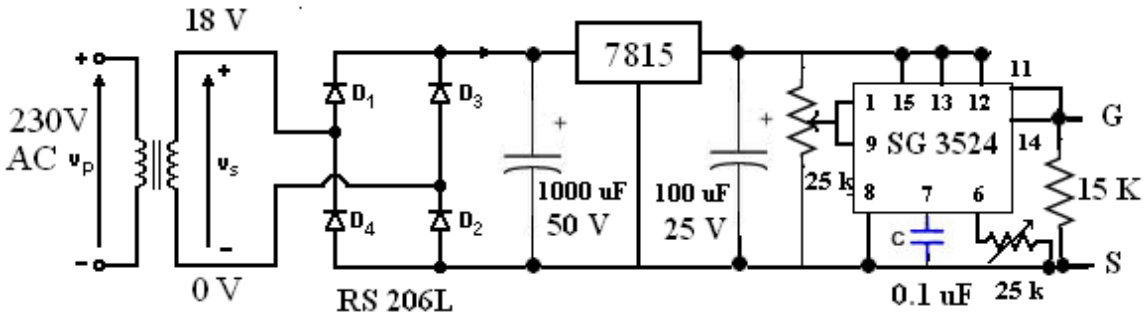

Fig. 9. SG 3524 Gate Driver Circuit

Experimental Procedure:

1. Release the gate pulses from SG 3524 IC to gate driver card. Select suitable switching frequency (100 kHz) and duty ratio (<0.5).

2. Turn ON the 40V Dc source.
3. Observe the wave forms of voltage across and current through the MOSFET.
4. Tabulate the losses occurring in the switching device.
5. Repeat steps 1-4 for different switching frequencies and duty ratio.

Observation:

1. Observe the turn ON and turn OFF transient in the practical MOSFET in CRO
2. Note the loss occurred during conduction, blocking, and switching in the device.
3. Also, see the reverse recovery characteristics of the diode

Results to be Reported:

Input Voltage Vin (volts)	Switching Frequency fs hz	Duty Ratio D	Conduction Loss (W)	Blocking Loss (W)	Turn ON Loss (W)	Turn OFF Loss (W)	v_{DS} volts	i_D Amps

1. Report the measured threshold voltage, v_{th}
2. Plot i_D vs. v_{DS} characteristics.

II. Insulated Gate Bipolar Transistor (IGBT):

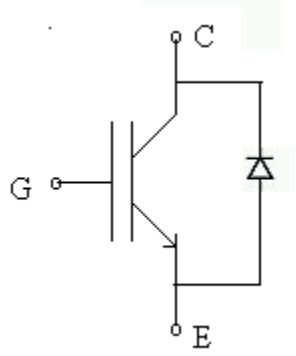

Fig. 10 n-channel IGBT

An IGBT is a three terminal (**G**ate, **C**ollector and **E**mitter) full controlled switch and can be used for applications up to 1700 V and 1200 A

Gate/Control Signal: Between Gate and Emitter
Switch Terminals: Between Drain and Emitter

Equivalent Circuit of IGBT:

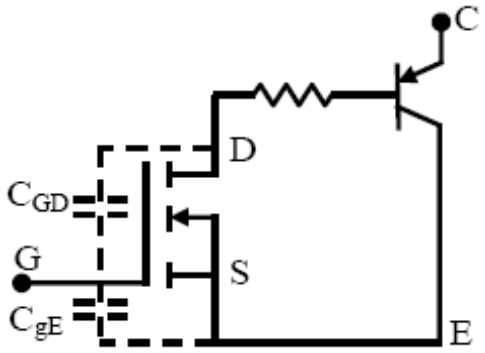

Fig. 11 Equivalent Circuit of IGBT

Switching Characteristics:

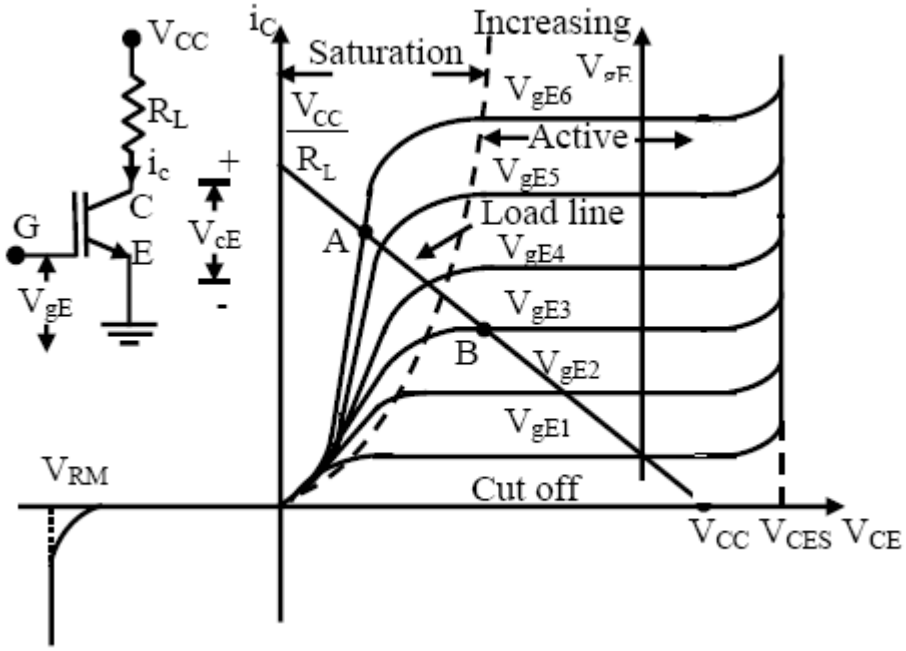

Fig. 12. Output Characteristics of IGBT

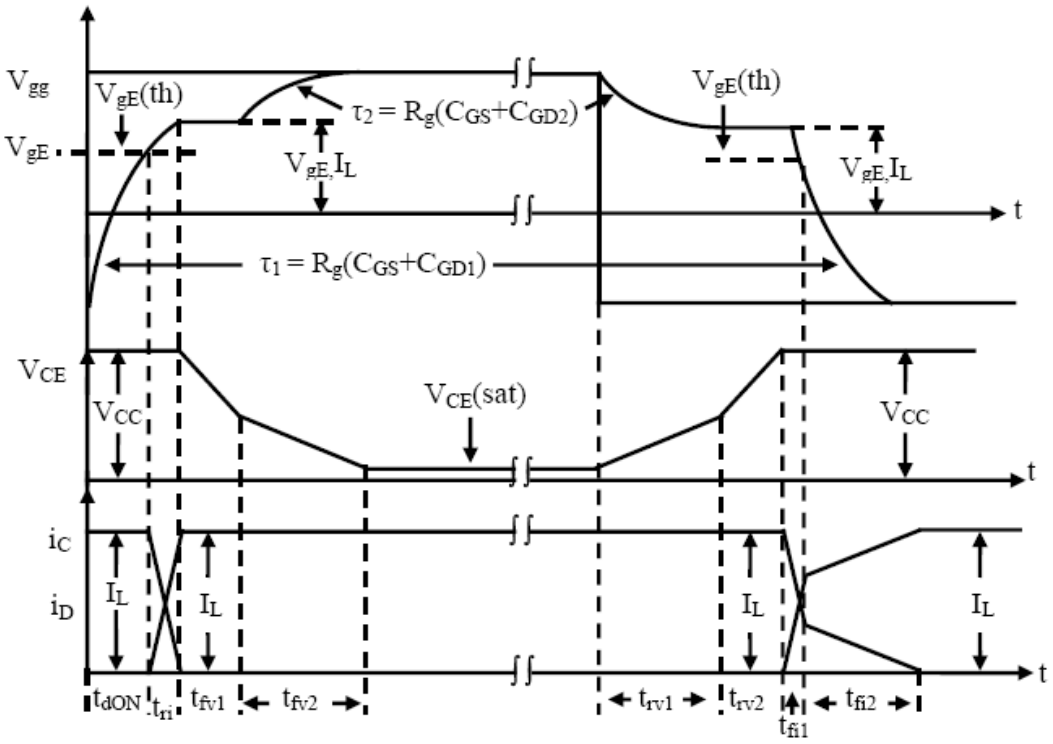

Fig. 13. Switching Characteristics of an IGBT

Block Diagram:

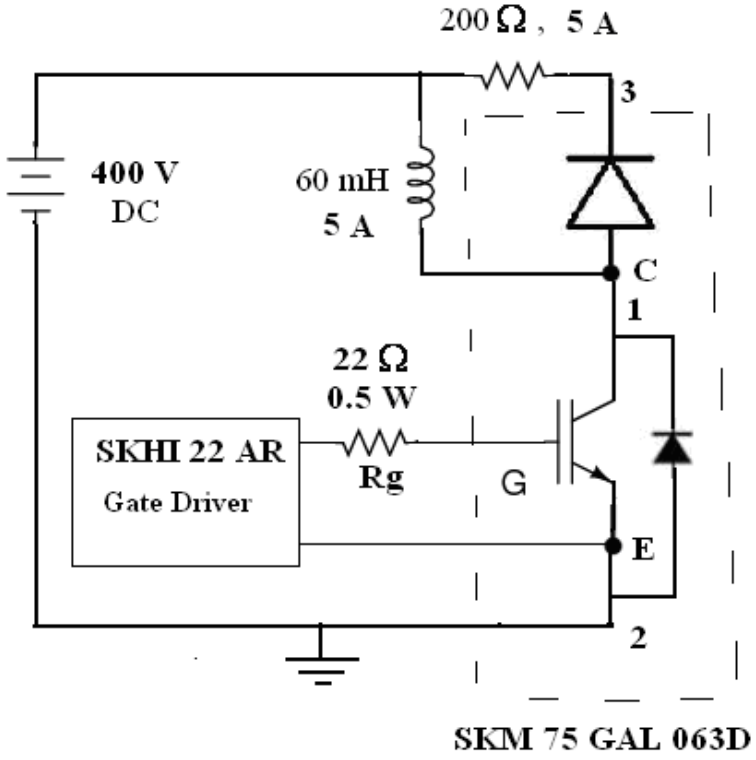

Fig. 14. Block Diagram for finding the Switching Characteristics of an IGBT

Actual Gate Circuit Diagram:

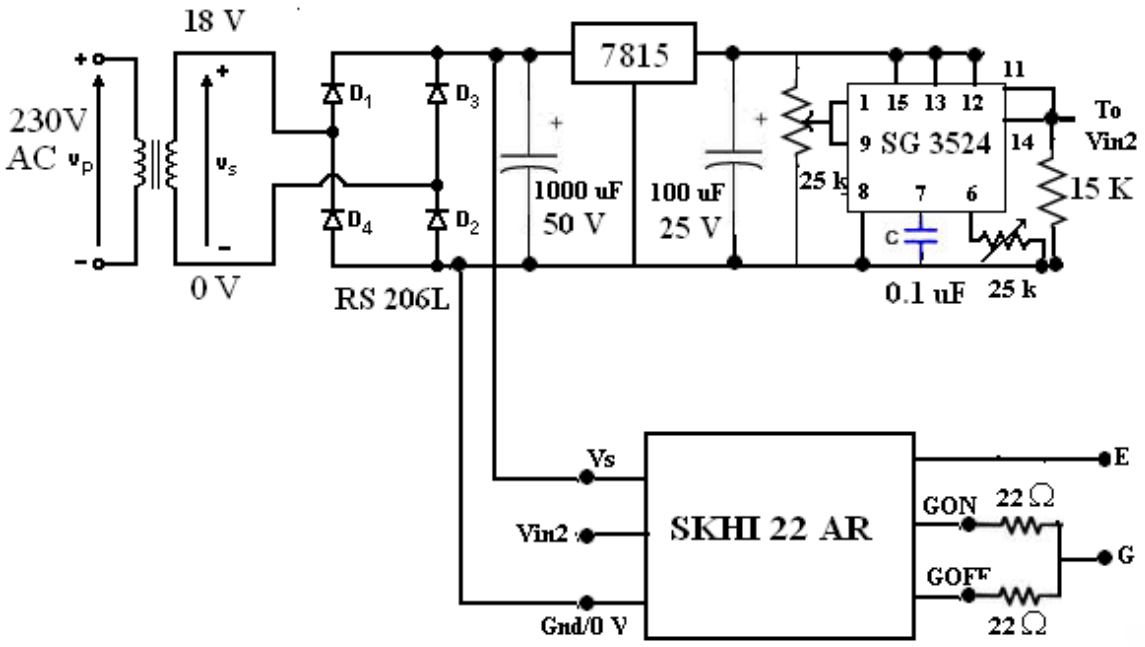

Fig. 15. Gate Drive Circuit of IGBT

Experimental Procedure:

1. Give power supply to the Gate Driver Card and SG 3524. Select suitable switching frequency (10 kHz) and duty ratio (<0.5).
2. Turn ON the 400V Dc source obtained from diode rectifier.
3. Observe the wave forms of voltage across and current through the IGBT.
4. Tabulate the losses occurring in the switching device.
5. Repeat steps 1-4 for different switching frequencies and duty ratio.

Observation:

1. Observe the turn ON and turn OFF transient in the practical MOSFET in CRO
2. Note the loss occurred during conduction, blocking, and switching in the device.
3. Also, see the reverse recovery characteristics of the diode

Results to be Reported:

Input Voltage Vin (volts)	Switching Frequency fs hz	Duty Ratio D	Conduction Loss (W)	Blocking Loss (W)	Turn ON Loss (W)	Turn OFF Loss (W)	Efficiency %	v_{CE} volts	i_C Amps

1. Report the measured threshold voltage, v_{GEth}
2. Plot i_C vs. v_{CE} characteristics.