FACULTY OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

ENEE 3305

Power Electronics

Assignment 1

Power Devices Switching

Prepared by:

Karim Taha 1211155

Supervised by:

Dr. Muhammad Abu-Khaizaran

march 28, 2025

Abstract

This assignment aims to acquire knowledge about power devices switching using a power MOSFET in a chopper circuit with two different loads, one with a high inductive load and the other with a resistive load. Also, the mathematically conduction and the switching power losses were calculated, and the circuit was simulated using Orcad.

Contents

Table of Figures

List of Table

Theory

Chopper circuit

It is also known as a DC-DC converter. It is an electronic switch that has the capability of converting a constant DC input voltage directly to a variable DC output voltage The device is very efficient as it switches between on and off positions only, with minimal loss of energy in the form of heat it uses with power semiconductor (Mosfter,BIJTs,GTO). [1] [2]

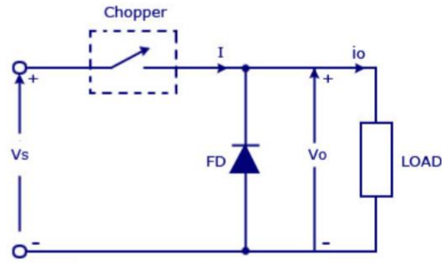


Figure 1:chopper circuit

MOSFET

Power Metal-Oxide-Semiconductor Field-Effect Transistors–Oxide–Semiconductor-Field-Effect-Transistor has two types, N-Channel and P-Channel. They can handle higher voltage and current than the regular MOSFET. The structure of the power MOSFET structure has a built-in Anti-parallel diode. This diode make the MOSFET does not have a reverse blocking capability in the N+ layer for reduce the resistance of the (N-). [1] [2]

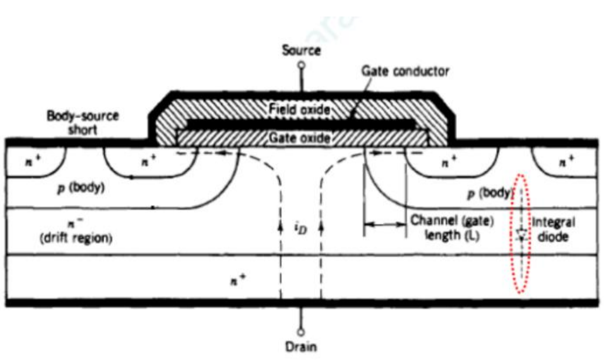


Figure 3: Power MOSFET structure

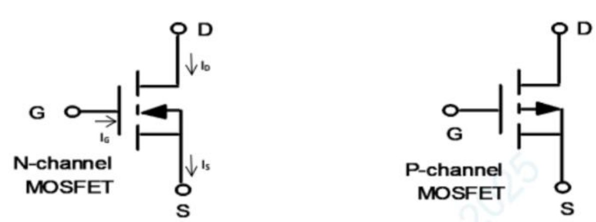


Figure 2: N,P Channel

Power Dissipation in a Chopper

When there is a pulse on the gate of the Switch there is a delay time called t_{don} The voltage will start to decrease after the Delay time, and at the same time, the current will increase until it reaches the I_O When the discharge occurs, there is a larger delay time because the charges on the switch the current will decrease, and at the same time the voltage increase until it equals Vd[1] [2]

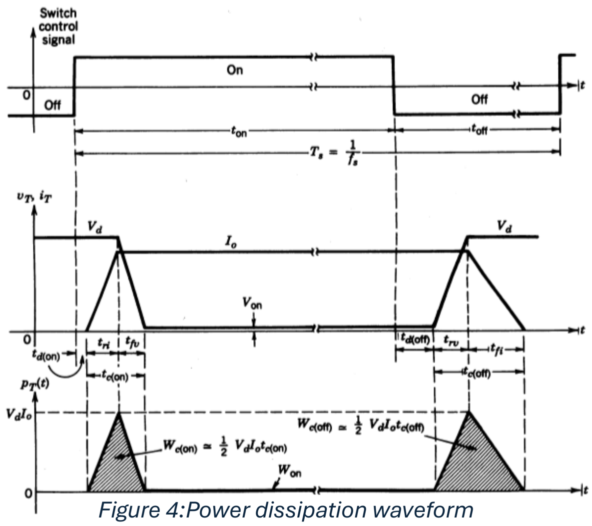


Figure 4:Power dissipation waveform

The conduction power losses

For inductive

$P_S = t_{on}. v_{on}\ I_o\ f_s$

For resistive

$P_S = t_{on}. v_{on}\ I_o\ f_s$

The switching power losses

For inductive

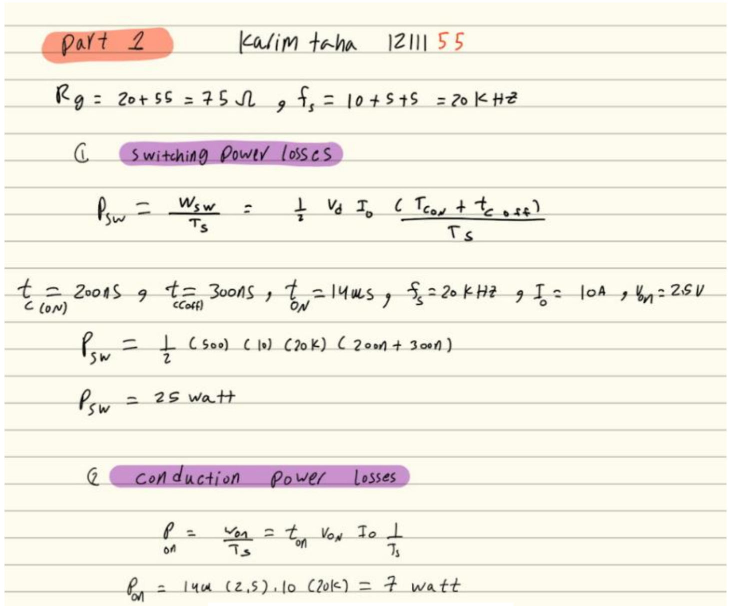
$P_{Sw} = \frac{V_d\ I_o\ f_S(\ t_{cON}+t_{cOFF})}{2}$

For restive

$P_{Sw} = \frac{V_d\ I_o\ f_S(\ t_{cON}+t_{cOFF})}{6}$

Part 1:high inductive load

by hand calculation



part 1 karim taha 1211155

$R_g = 20+55 = 75\,\Omega$, $f_s = 10+5+5 = 20\,kHz$

① switching power losses

$$P_{sw} = \frac{W_{sw}}{T_s} = \frac{1}{2} V_d I_o \frac{(T_{c\,on} + t_{c\,off})}{T_s}$$

$t_{c(on)} = 200nS$, $t_{c(off)} = 300nS$, $t_{ON} = 14\mu s$, $f_s = 20\,kHz$, $I_o = 10A$, $V_{on} = 2.5V$

$$P_{sw} = \frac{1}{2}(500)(10)(20k)(200n + 300n)$$

$$P_{sw} = 25\ watt$$

② conduction power losses

$$P_{on} = \frac{W_{on}}{T_s} = t_{on} V_{on} I_o \frac{1}{T_s}$$

$$P_{on} = 14u\,(2.5).10\,(20k) = 7\ watt$$

Figure 5: by hand calculation

Simulation and results

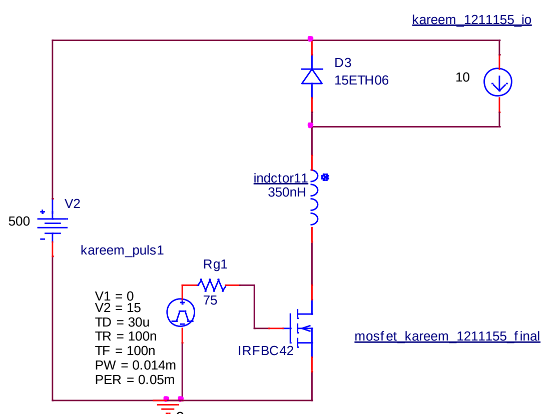


Figure 6: MOSFET With High inductive load simulation

IRFBC42: This MOSFET has a power rating (600V, 39A), and the diode 15ETH06 has a power rating (600V,15A) It is important to select the diode that can handle the current when the switch is off because the diode protects the component from the current that has been stored in the inductor where this large current could damage the component in the circuit the Rg restive to limiting charging and dischagrining current

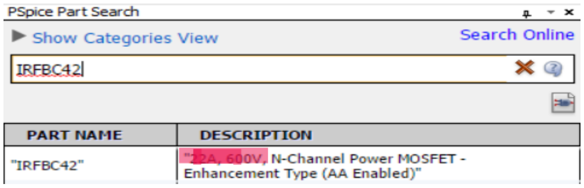


Figure 7:power rating of the MOSFET

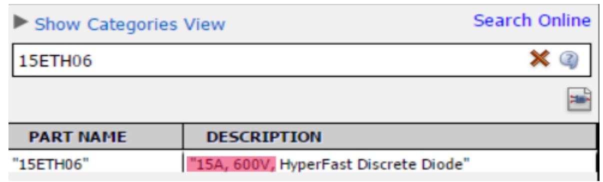


Figure 8:power rating for the diode

The power rating can be known from (taskbar > place>pspice component>>search)

Pulse

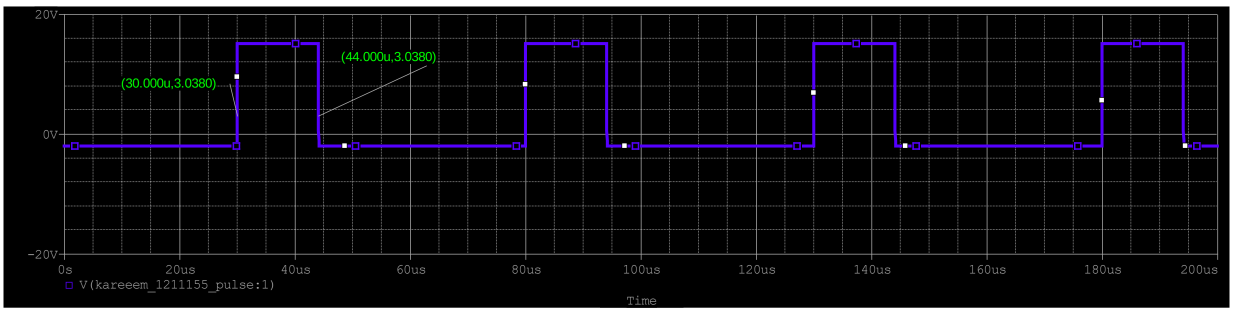


Figure 9:Puls wave

30-44=14u, the control signal is a square wave. When it is increased to 15V, it will give the MOSFET the signal to work (TURN ON) when it is decrease the zero the mosfet will switch to OFF

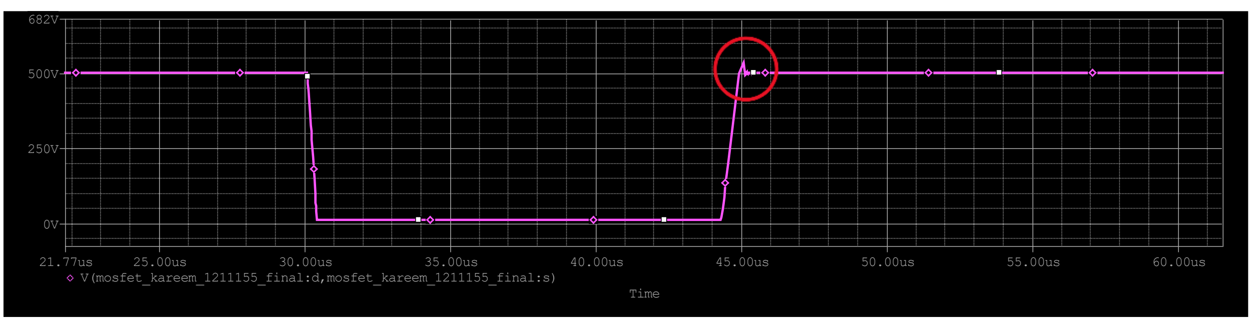


Figure 10: voltage switching with inductive load

When the switch is turned on the voltage decrease until it reach zero when the switch turned OFF the voltage increase to VD but there is samll overshot and this come from the inductince in the wier(stray inductance) where this inductance storge the current until the switch off at this time the indctoance resist this change by voltage spike

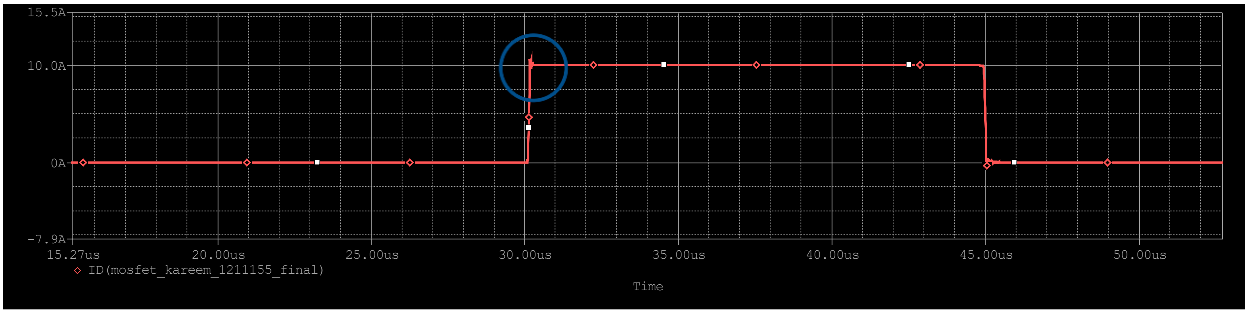


Figure 11: current switching with inductive

The current matches the puls wave in the shape on the MOSFET is ON it allow the current to flow the current increase until it reach the IO the is samll over shot on it switch one it is come from the stray inductince , when the MOSFET is off the current decrease until it reach zero.

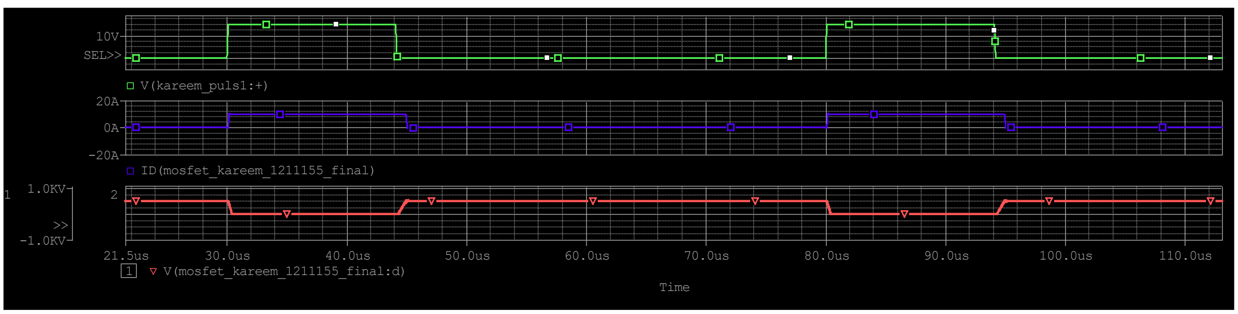


Figure 12: switching with pulse wave in inductive load

When the pulse gives a signal to the mosfet at the gate, there is small time before the voltage and the current switch After this delay the current will start to increase while the voltage will begin to decrease until it reach zero when a nigtive puls ta the gate there is a larger delay will be on the switching time because the charges after this delay ending the voltage increas toVD and the current decrease to Zero

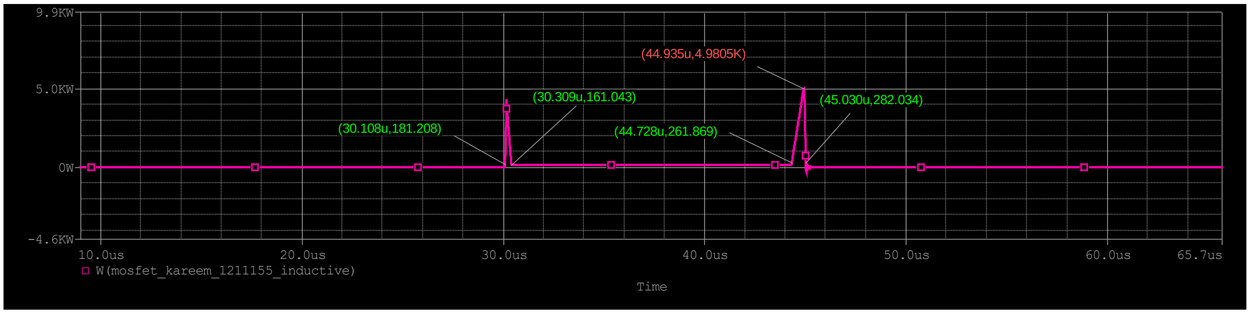


Figure 13: switching power losses in inductive load

Table 1:limiting time of the power inductive

t_{ri}	t_{fv}	t_{rv}	t_{fi}	Vd.io
30.108u	30.309u	44.728u	45.030u	4995W

$t_{CON} = t_{ri} - t_{fv}$ = (30.108 - 30.309)=0.201µs

t_{COFF} =(45.030- 44.728)=0.302µs

$t_{CON} + t_{COFF}$= 0.503 µs

$P_{Sw} = \frac{V_d\, I_o\, f_s(\, t_{cON} + t_{cOFF})}{2} = \frac{(4995)(20k)(0.503\mu)}{2}$= 25.1 Watt

$P_S = t_{on}.\, v_{on}\ I_o\ f_s$ =7 watt

The power loses in the inductive load is close to the by hand calculation where it is equal to the triangular area between the switching of the voltage and current

Part 2: resistive load

by hand calculation

Part 2 karim taha 1211155

$R_L = 49\,\Omega$, $V_d = 500V$, $f_s = 20kHz$, $t_{on} = 14\mu s$, $t_{con} = 200ns$, $t_{coff} = 300ns$

$L_s = 350nH$, $V_{on} = 2.5V$

conductive: $P_{on} = V_{on} I_o f_s t_{on} = (2.5)(10)(20k)(14\mu) = 7$ watt

switching: $P_{sw} = \frac{f_s V_d I_o (t_{con} + t_{coff})}{6} = 20k \frac{(10)(500)(500n)}{6} = 8.33$ watt

$$P_{sw\,resstive} = \frac{P_{sw\,high\,inductive}}{3}$$

Figure 14: by hand calculation resistive load

Simulation and results

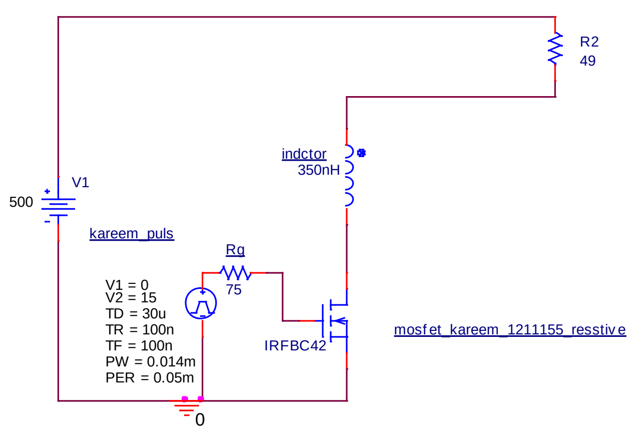


Figure 15: MOSFET with resistive load simulation

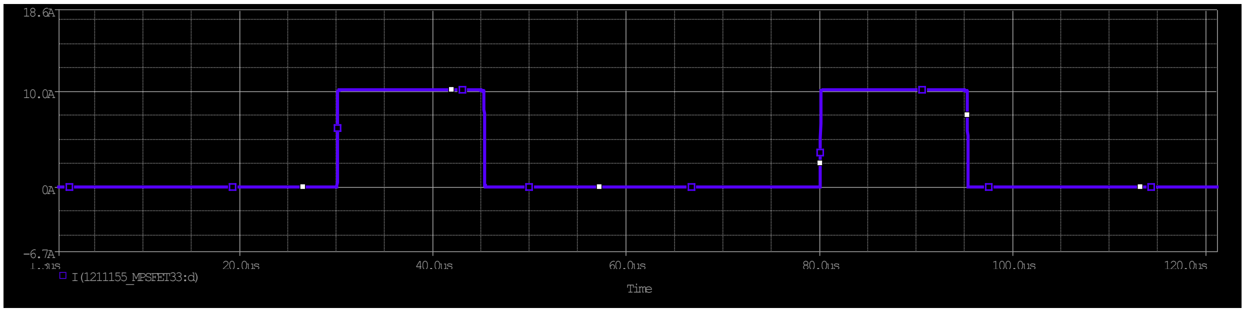


Figure 16: pulse wave

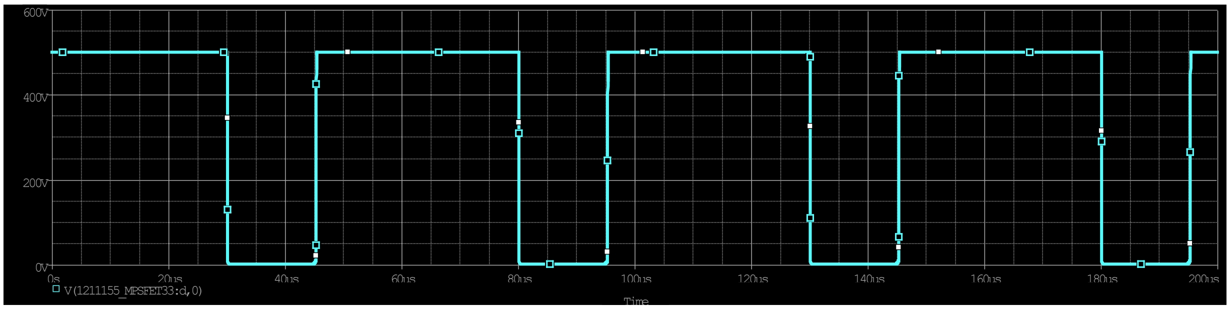


Figure 17: voltage at the MOSFET with resistive load

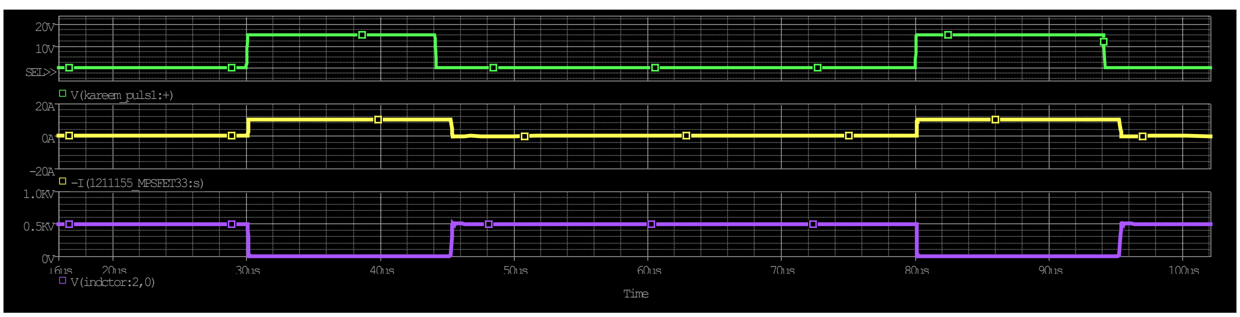


Figure 18:puls , voltage and current on the MOSFET

The pulse switch, ranging from 0 to 15V it is controls the MOSFET to be turned on or off. When the pulse reaches 15V, the MOSFET enters the saturation region, resulting in the MOSFET being ON. Where the voltage and current are in phase with the resistive load, and they have clean switching without attenuation. When the MOSFET is ON, the voltage decreases to zero, and the current increases to Io, while when the MOSFET turns OFF, the current decreases to zero, and the voltage increases to VD=500v There is no small over shoot since the resistive load does not have inductance to store current. When the MOSFET is not in the saturation region (During turn-off), it takes more time because the MOSFET takes more time to sweep the electrons.

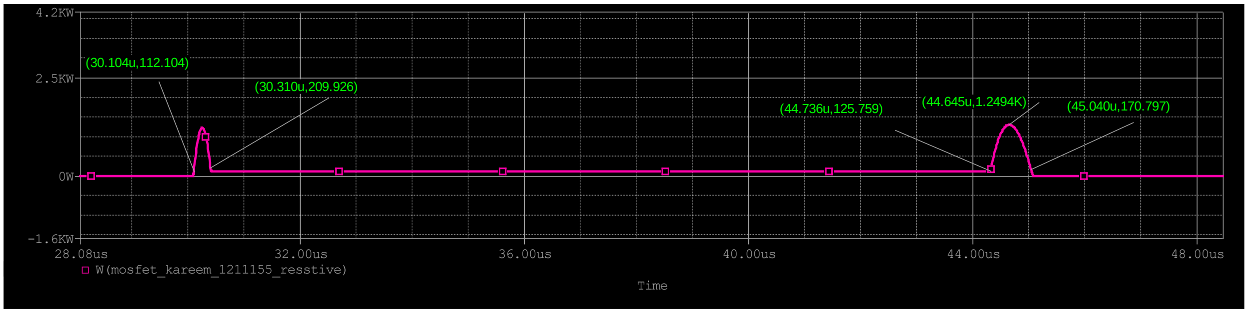


Figure 19: power of the MOSFET

Table 2: limiting time of the power resistive

t_{ri}	t_{fv}	t_{rv}	t_{fi}	$\frac{vd.io}{4}$
30.104u	30.310u	44.736u	45.04u	1249W

t_{CON} = t_{ri}- t_{fv} = (30.104 - 30.310)=0.206 µs

t_{COFF} =(45.04 - 44.736)=0.304 µs

t_{CON} +t_{COFF}= 0.51 µs

vd.io =1249*4=4996watt

$P_{Sw} = \frac{V_d\, I_o\, f_s(\,t_{cON}+t_{cOFF})}{6} = \frac{(4996)(20k)(0.51\mu)}{6}$= 8.49 Watt

$P_S = t_{on}.\, v_{on}\; I_o\; f_s$ =7 watt

The power loss in the resistive load is less than the inductive load

$P_{SW\ resistive} = \frac{1}{3}\, P_{sw\ inductive}$

The power loses in the inductive load is close to the by hand calculation where it is equal to the triangular area between the switching of the voltage and current

Conclusion

The power MOSFET is the fastest power switching device; it has no reverse blocking capability because the built-in diode, the switching state in the MOSFET depend on the signal that has been sanded from the controller when the pulse the sanded at the gate of the MOSFET positive the switch turn ON the voltage will star to fill to zero and the current and the current will start to increase until it reach the IO but small overshoot with inductive load while in the resistive it will has a clean switching, when the control give a negative pulse the MOSFET will turn OFF at this state the voltage will start to increase to Vd and the current start to decrease until reach zero there is also small over shoot while switching that become from the stray inductance that stored current, there is small delay in the turn on that become from the switching time there is a larger delay this because the charges, the power losses in the inductive load is higher than the in the restive load .

References

[1]https://www.elprocus.com/a-brief-introduction-to-chopper-circuits/. (n.d.).

khaizaran, m. a. (n.d.). acess at 2025/04/07

[2]*https://drive.google.com/file/d/1DoPZqwIrWmYzdV8OKkYr4RDLY7kUN82D/view.* acess at 2025/04/07