SEMICONDUCTOR DEVICE OPERATION AND CONTROL

Power Electronics Assignment 1 - DT021A/3

OCTOBER 25, 2020

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Lab 1: Transistor Switching

1.1. Bipolar Junction Transistors

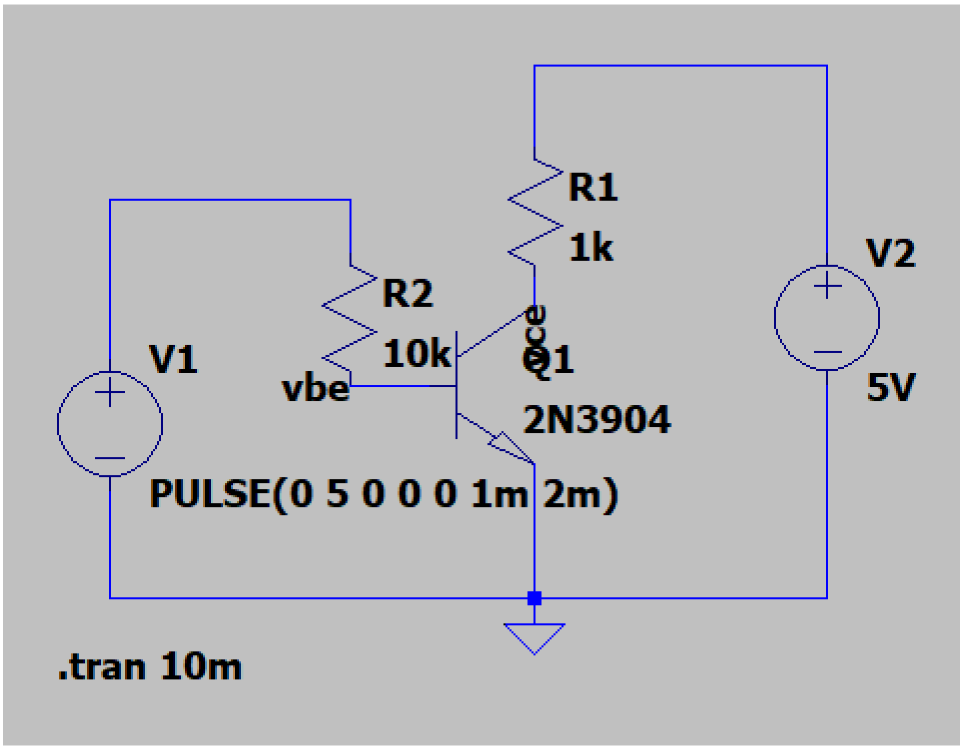


Figure 1 - Schematic diagram of BJT

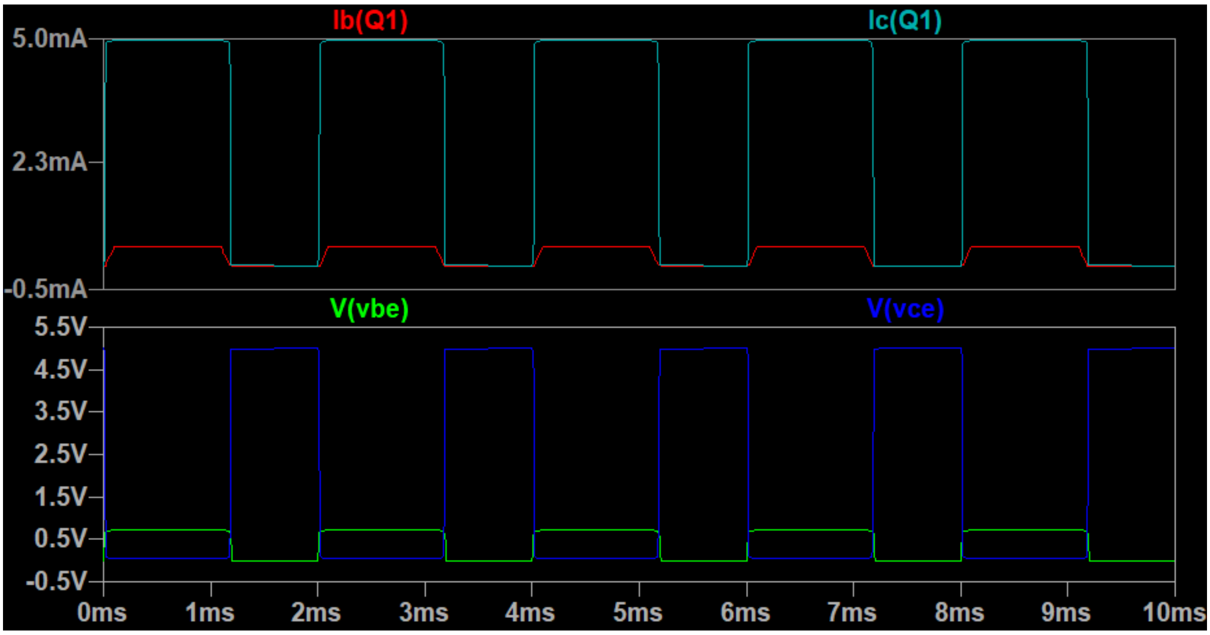
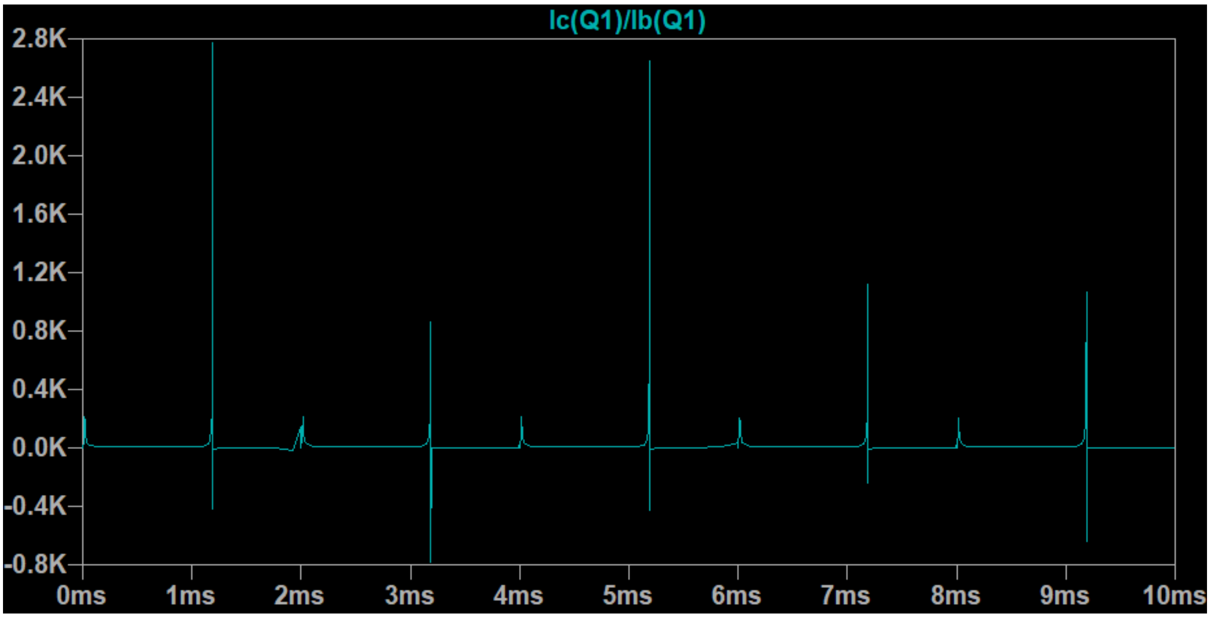


Figure 2 - Simulation of the BJT circuit

The maximum voltage between base and emitter is 0.71v as the diode in the BJT requires 0.7v to turn on the forward bios by $Vbe = Vb - Ve$

$$Current\ Gain\ = \frac{Ic}{Ib}$$



The current gain shows noise along with the current gain of around 220.

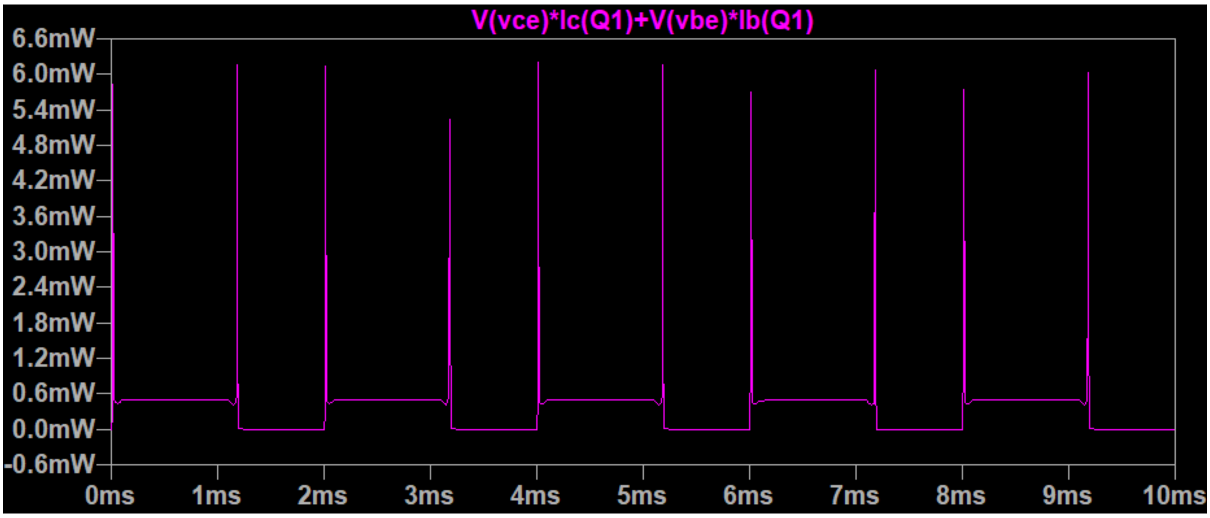


Figure 3 - Power dissipation in BJT

Power dissipation in the BJT is shown in figure 4. It shows that the BJT produces 0W power dissipation when the device is off, however, when the device is on then it produces steady 0.5mW power dissipation. When the device is transitioning between on and off the power boost is around up to 6.16mW which is known as switching power loss.

1.2. BJT Push-Pull pairs

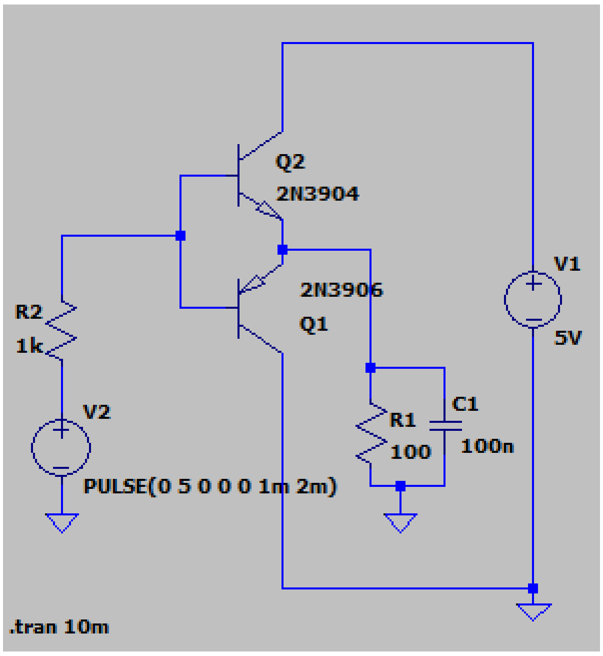


Figure 4 – Schematic diagram of BJT Push-Pull pairs

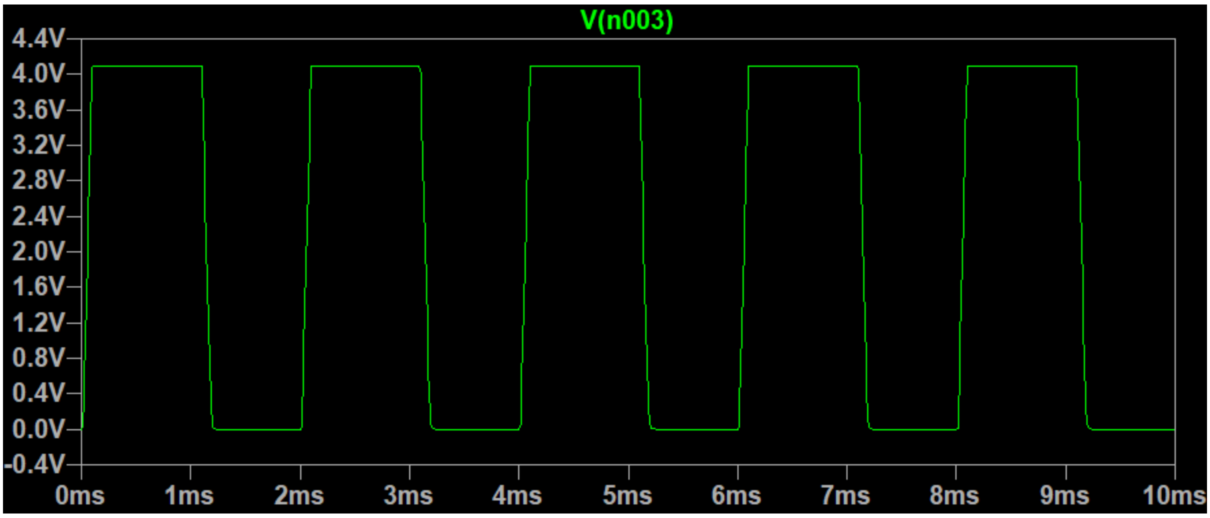


Figure 5 – Simulation of the Voltage across load R1

The peek voltage amplitude of R1 is 4.01v where the 0.7v is the drop across the diode and the rest of the voltages are dropped in the collector and emitter.

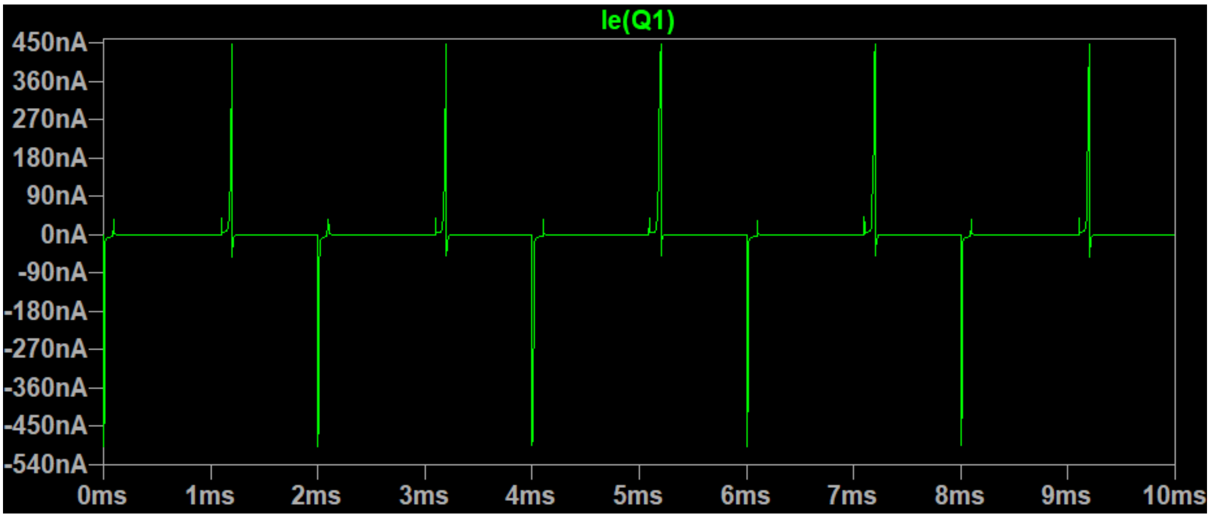


Figure 6 - Simulation of the emitter current in BJT (Q1)

The emitter current is made up of, current that is coming in from a capacitor which discharges very quickly and the waveform is oscillating from +447nA to -497nA as it is really small due to the short discharge period.

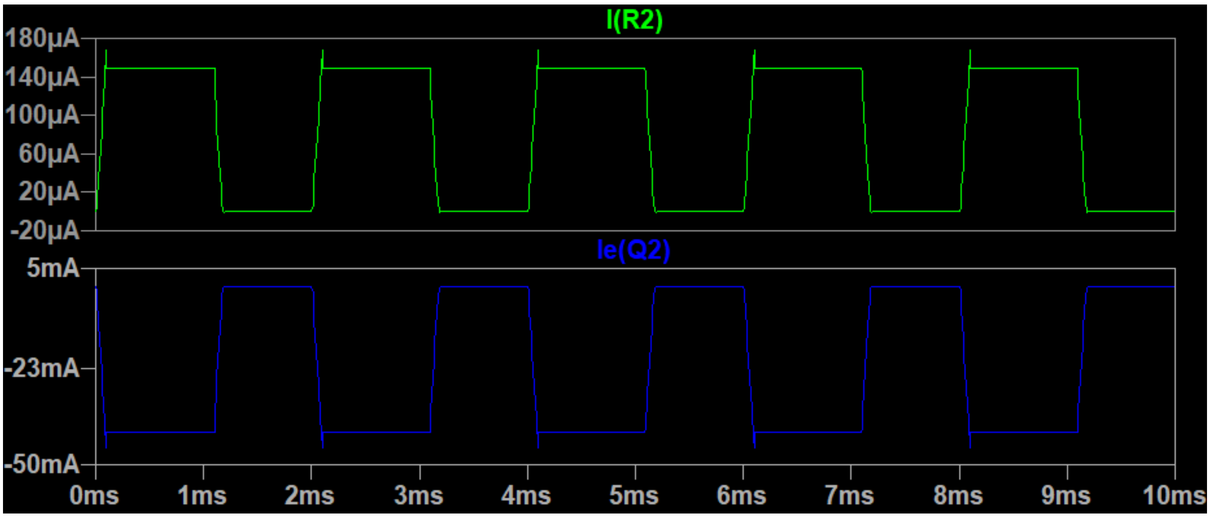


Figure 7 - Current that is going to BJT in over going out

This device might not be the best when it comes to the voltage gain, However, this circuit produces a lot more current out than you put in. The input current across the resistor steadies at 149uA & the output current peak amplitude steadies at 42mA, which is quite high when compared with the input current.

$$Current\ Gain = \frac{output\ current}{Input\ current}$$

$$Current\ Gain = \frac{42 * 10^{-3}}{149 * 10^{-6}}$$

$$Current\ Gain = 281.8$$

Lab 2: MOSFET Switching and gate drivers

2.1. Circuit 1

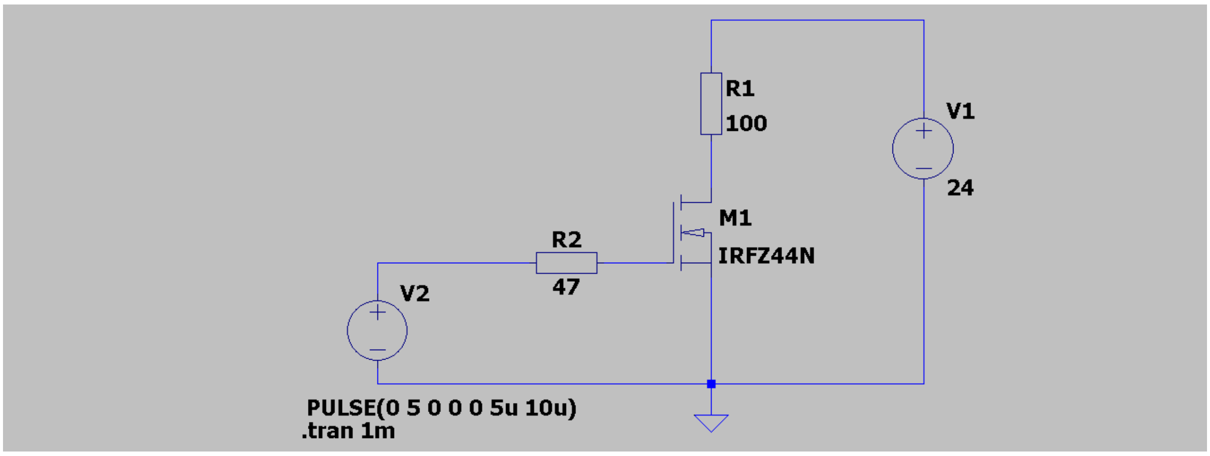


Figure 8 - Schematic diagram of MOSFET in circuit 1

The voltage across the R2 is still 5v as the resistance is too small.

2.1.1. Resultant output when R2 is 47Ω

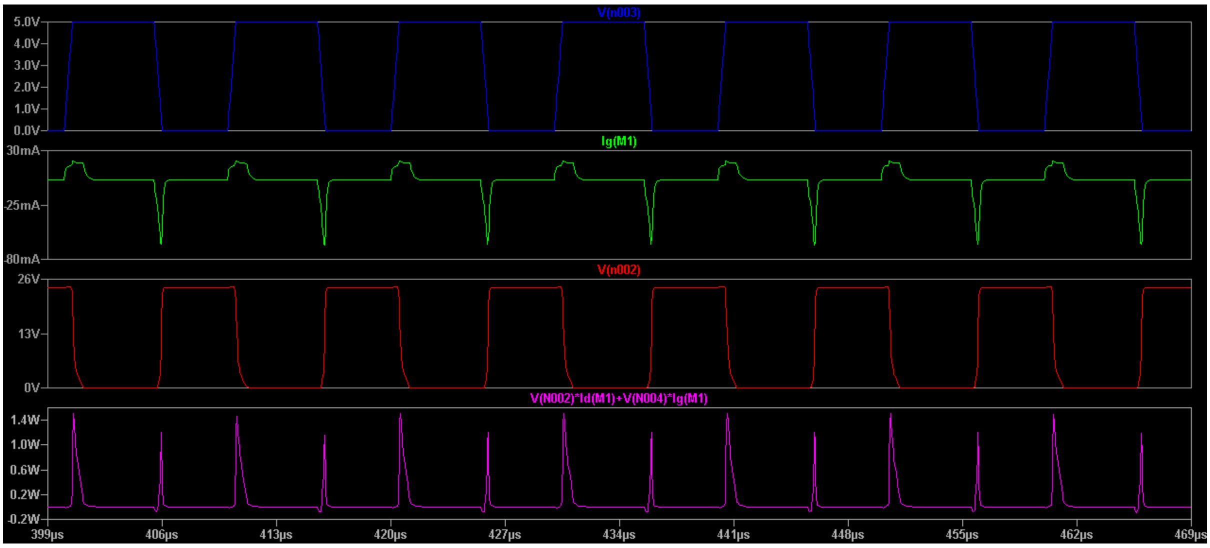


Figure 9 - Captured screenshot of the multiple graphs, V2, Ig, Vds, Power loss in M1

The blue waveform is the controlling voltage coming from the Square voltage supply. When the V2 goes high the MOSFET turns on causing the voltage across the source and drain to be at 0 volts as the drain terminal is connected to the ground. When the V2 goes low the MOSFET voltage is high (24v) as behaves like an open circuit, and this can be observed in the red waveform figure 9.

The gate current in the green waveform is approximately zero except for its switching edges. Switching edges are formed when the current enters and leaves the gate and it behaves like a charging & discharging capacitor.

Power loss in MOSFET is peeking around 1.6W as power is loss is given by $(V_d * I_d) + (V_g * I_g)$. The power loss only occurs when the MOSFET transitions from on to off or off to on as it consumes most of the energy between those transitions. If MOSFET switches faster the average power loss will be much higher as it increases the unwanted propagation delay.

2.1.2. Resultant output when R2 is 470Ω

The voltage across the R2 is 4.1v as the resistance has increased.

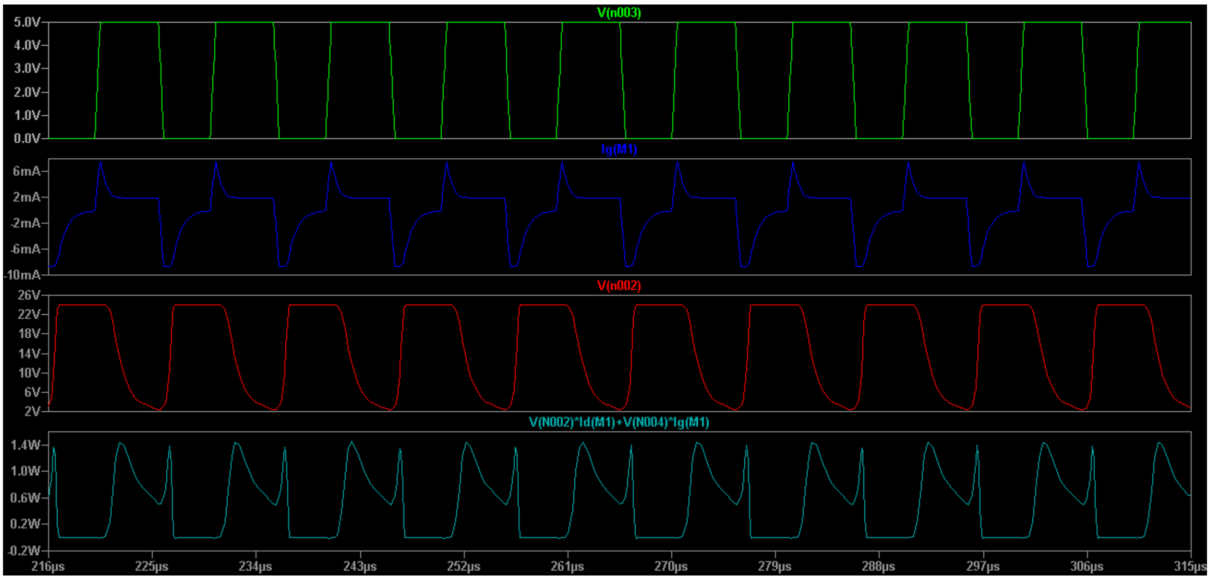


Figure 10 - Simulation of the circuit when R2 is 470 Ω

As the R2 Resistance increases the gate current reduces to 7mA. The Power loss is averaging around 1.5W and most of the time the power loss is high as it takes longer for the voltage to discharge in M1 when V2 is high.

2.1.3. Resultant output when R2 is 4700Ω

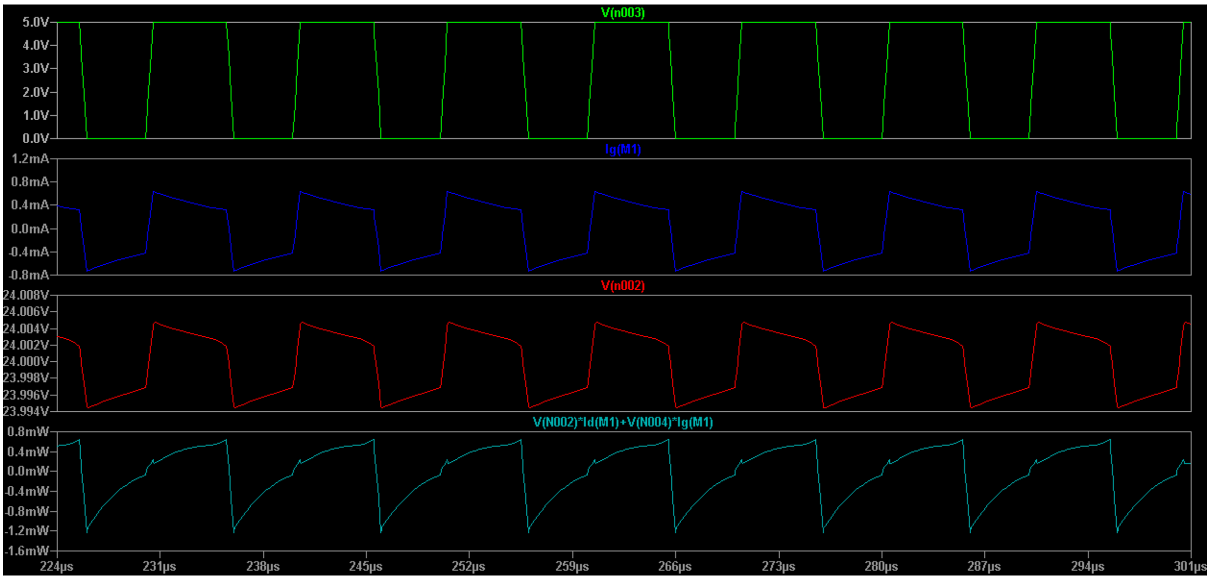


Figure 11 - Simulation of the circuit when R2 is 4.7k Ω

The R2 Resistance has increased by 4.7k ohms and the gate current has reduced, peeking around 0.7mA.

The Power loss is averaging around 0.7mW and most of the time the power loss is high as it takes longer for the voltage to discharge in M1 when V2 is high. Meaning that if the resistance is high then power loss reduces magnificently in the MOSFET as the MOSFET can be operated with small currents.

2.1.4. Resultant output when R2 is 47k Ω

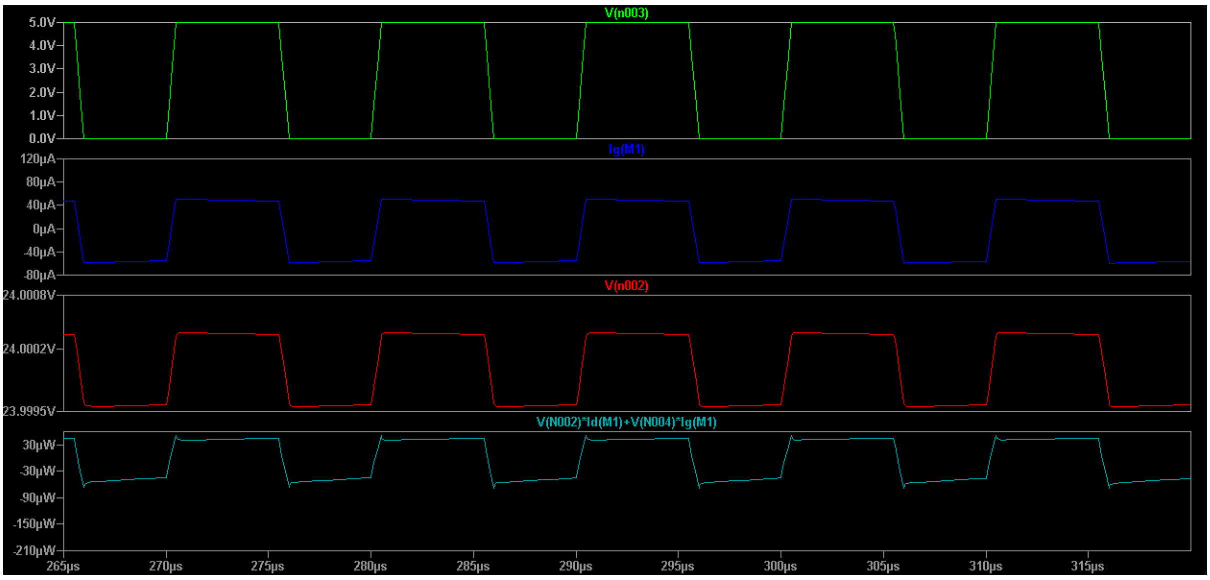


Figure 12 - Simulation of the circuit when R2 is 46k Ω

The R2 Resistance has increased by 47k ohms and the gate current has reduced significantly, peeking around 50uA. The Power loss is averaging around 45uW and most of the time the power loss is quite low. Power loss reduces in the MOSFET when the resistance is high.

2.1.5. Circuit diagram 1 when Vin -12v to +12v & R2 is 47Ω

When changing the Vs pulse amplitudes from +12v to -12v the Gate Current in MOSFET increases along with power dissipated in MOSFET.

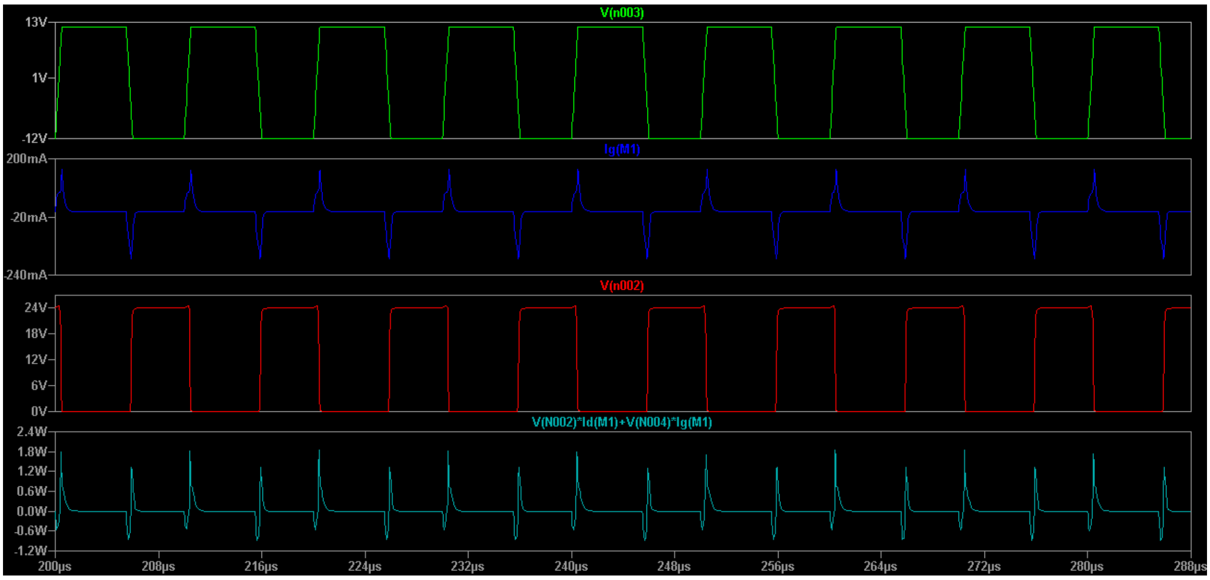


Figure 13 - Simulation of the MOSFET circuit when 12vpp is applied

The R2 resistance is 47 ohms which increase the gate current significantly, peeking around 159mA. The Power loss is averaging around 1.8W. Power loss is much greater in the MOSFET during the time of switching edges when the voltage source is 12v is applied to the gate. All that energy is been lost in the MOSFET, which can be avoided with the following circuits.

2.2. Circuit 2

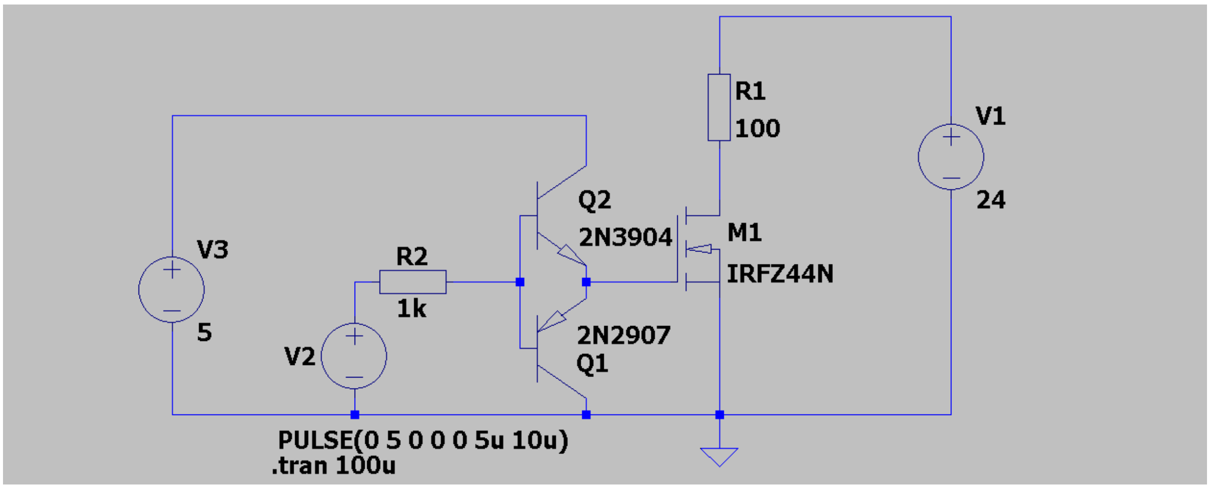
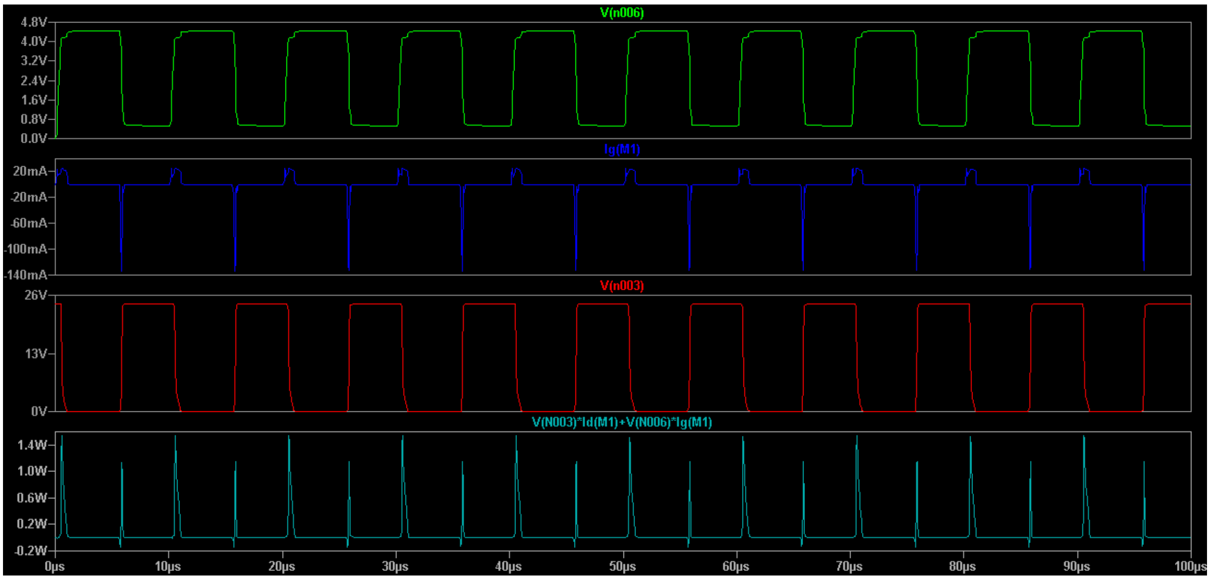
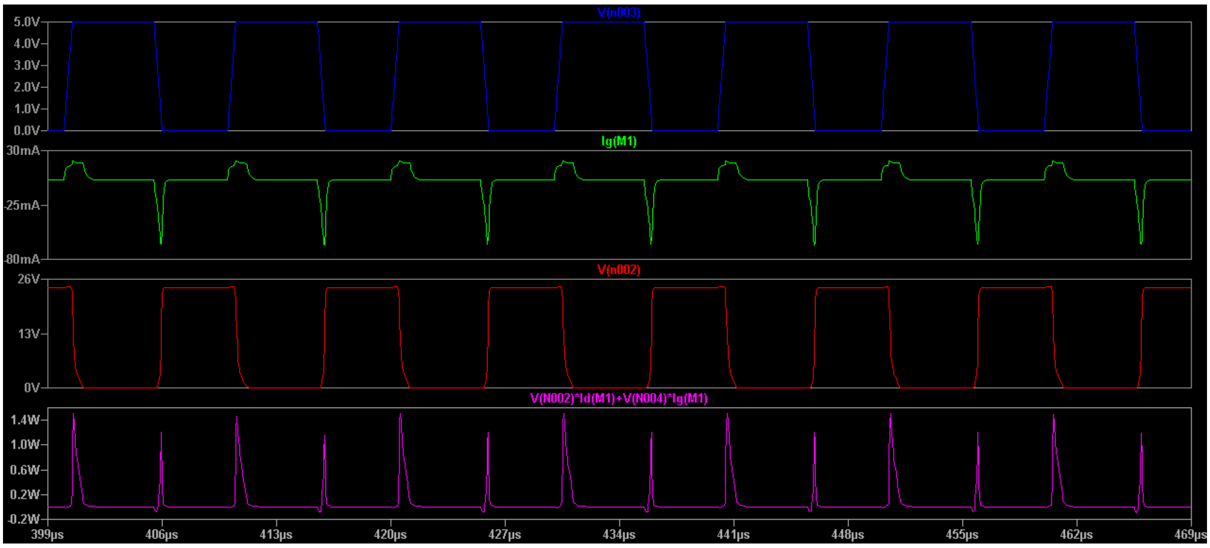


Figure 14 - Circuit Diagram of the MOSFET along with BJT





+26mA to -132mA

1.5W to -145.7mW

+19.6mA to -65.4mA

1.5W to -86.4mW