ECE112 - Lab 7

Purpose

- Measure RC time constant behavior
- Capacitors in Series and Parallel
- Observe MOSFET switching behavior

Parts/tools needed:

- Power supply and wallwart
- Big Pad Protoboard
- Resistors: 1KΩ, 1MΩ, 220Ω
- Semiconductors: 2N7000 N-Channel MOSFET, Red LED
- Capacitors: 2, 10uF electrolytic capacitors
- Pushbutton Switch

Observing RC delay

First, let's understand how the circuit works and make some calculations on its behavior. Then we will power it up and see it in operation. Please refer to figure 2.

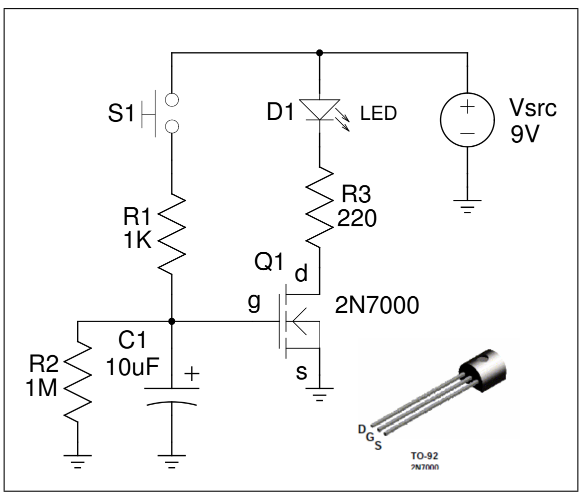

Figure 1: Lab 6 Schematic

When power is first applied, capacitor C1 has no charge on it and has zero volts across its terminals. Therefore, the gate to source voltage of MOSFET Q1 is at zero volts and is *off*. While it's off, the LED cannot light as there is no path to ground for the current trying to pass through the LED.

When the pushbutton is pressed, C1 will charge quickly through resistor R1. The time constant for charging, τ is determined by the value of R1 and capacitor C1. Calculate this time constant below.

Take note that the tolerance of the capacitor ($\pm 20\%$) may give quite a variation in the observed time constant. However, typical values are often quite close to those stated for the part.

If the pushbutton is depressed for say 10τ, the voltage on the positive end of the capacitor and the MOSFET gate will rise beyond the gate-source *on* voltage so that the resistance between the drain and source terminals will become very small and the LED will illuminate.

Once the pushbutton is released, the capacitor will begin to slowly discharge through the 1M resistor since the pushbutton is an open circuit and no current can flow into the gate of Q1. The time constant for the discharge of the capacitor is determined by the 1M resistor and the 10uf capacitor. However, Q1 will remain on until the voltage between its gate and source terminals falls below about 2 volts. Calculate the amount of time it will take for the LED to go out once the pushbutton is released.

Test the Theory

1. Build the circuit shown in figure 2 on the big pad protoboard.
2. Plug your power supply into the power buses on the protoboard.
3. Plug the wallwart into your power supply. Initially, the LED should be off. If not, something is wired wrong.
4. Briefly depress and release the pushbutton. The LED should light immediately as the capacitor charges quickly through R1 and Q1 turns on. Once the pushbutton is released, the voltage on the capacitor will decay below the MOSFET threshold voltage and the LED will go out. Using some timing device, measure the delay from pushbutton release to the LED turning off.

Delay from pushbutton release to LED going out: __________

5. Now, modify your circuit by putting the second 10uF capacitor *in series* with the first one. Be sure to observe proper polarity for the second capacitor. Both capacitors will have their positive ends oriented away from ground.

Delay from pushbutton release to LED going out (caps in series): __________

6. Now put the two capacitors in parallel and do the test in step 4 again.

Delay from pushbutton release to LED going out (caps in parallel): __________

Which connection of capacitors gave the biggest delay and why? ______________________________

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7. We would like to measure the resistance of the MOSFET in both *on* and *off* states, remembering that it should approximate a real switch. Thus, the resistance drain to source of the MOSFET should be:

-if *off*: nearly infinite ohms
-if *on*: a few ohms, probably < 10

To measure *off* resistance:
Power must be disconnected (not just cut off) from the circuit, otherwise you will be measuring the resistance through the power supply. Make sure the MOSFET gate is at zero volts by briefly shorting the gate terminal to ground. Then connecting the positive lead of the ohmmeter to the drain and the negative lead to the source, you can directly measure the resistance.

It is likely your ohmmeter will show an "out of range" indication (resistance greater than 2 Meg ohms) if you are making the measurement correctly.

Figure 2: DMM Showing Overrange Resistance Indictation

6a. Measure the *off* resistance of the MOSFET.

Off resistance of Q1: ____________

To measure *on* resistance:
MOSFET *on* resistance cannot be directly measured but is computed. We determine the *on* resistance by measuring the voltage from drain to source and then the current (drain to source) through the device. Using Ohm's law $R = \frac{V}{I}$, we can determine the resistance. You do not need to break the circuit to make the current measurement. The current through the 220 ohm resistor is identical to the MOSFET drain current. Thus, the drain current I_d through the MOSFET is $I_d = \frac{V_{r3}}{220}$.

Clearly, *on* resistance must be measured while the circuit is on. In addition, you will need to continuously hold the pushbutton down. If you push and release it, the voltage on the gate terminal will begin to creep down as the capacitor discharges and the resistance of the MOSFET will change.

6b. Making the *on* resistance measurement:

Voltage, drain to source of Q1: ____________

Current through 220 ohm resistor (show calculation):

On resistance of MOSFET (show calculation) :

7. Have your TA check off your work.