MOSFET Characteristics and Simple Circuits

1 Introduction

MOSFET's or Metal Oxide Semiconductor Field Effect Transistors, are at the heart of most complex digital integrated circuits. In this lab we will explore the operation of a MOSFET, and build a few simple circuits.

A physical schematic cross-section of an N-channel MOSFET is shown in Figure 1. Immediately below it is the symbol normally used for an n-MOSFET. You should learn to go back and forth between these two representations.

Consider the n-MOSFET shown in Figure 1. The source and drain each form a diode with respect to the substrate. In the absence of a channel, one of these diodes is always reverse-biased, so no current can flow from the source to the drain. However, if the gate of the MOSFET is biased positively, an n-type inversion layer can form at the surface of the p-type substrate, forming a conductive channel between the source and the drain. After this, current can flow. We will measure how much voltage is required to form a channel, referred to as the threshold voltage, or V_T. Figure 3 shows the resulting I-V characteristics of a MOSFET device. More detail on these characteristics can be found in textbooks on the subject.

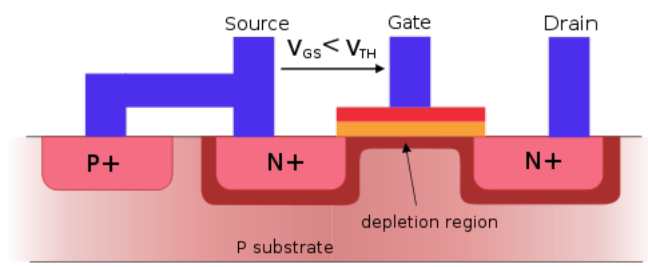

Figure 1: This is a schematic cross-section of an n-MOSFET.

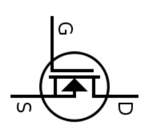

Figure 2: This is the symbol for an NMOSFET

2 Measuring the MOSFET Threshold Voltage

Set up the first circuit, shown in Figure 4. Use the supplied 2N7000 NMOS devices. The LED is not necessary for the operation of the circuit, but will allow you to see visually that current is flowing in the circuit. Connect

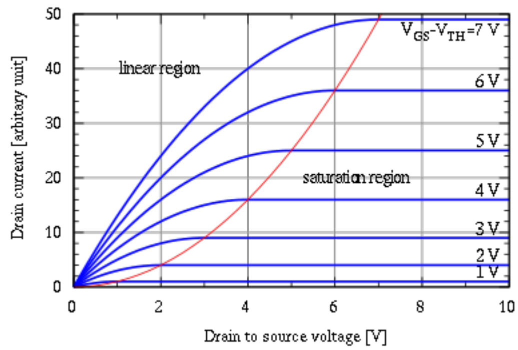

Figure 3: This shows the MOSFET I-V characteristics.

the +5V supply from your power supply to the drain leg of the MOSFET, and your variable voltage supply to the gate leg. The resistive divider connected to the gate (on the right side) divides down the variable voltage supply so that it is well below the threshold voltage of the device.

2.1 Experiments you should do:

- Attach the Ammeter between the 5V supply and the top of the drain stack. Attach a voltmeter (or use your oscilloscope) to the gate of the MOSFET. Measure the current through the drain of the MOSFET as a function of gate voltage, starting at about 0.75V, and continuing up to at least 3V.
- Make a plot of the results. What is the approximate threshold of the device?
- At what current does the LED begin to light?

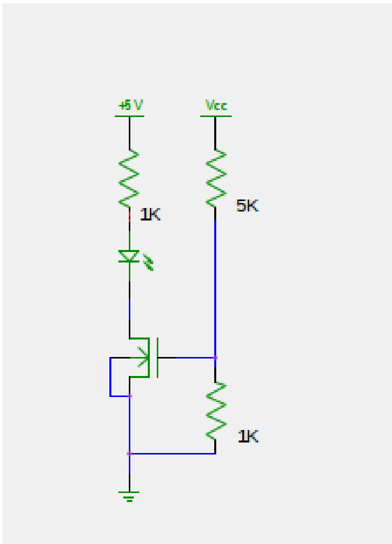

Figure 4: This is Circuit 1. It is used to measure the threshold voltage of the MOSFET.

3 A MOSFET memory circuit

Set up the second circuit, shown in Figure 5. Again, the LED's will allow you to see the state of the circuit. You should be able to switch the circuit repeatedly into two stable states.

3.1 Experiments you should do:

- Measure the voltage at each circuit node in each of the two states.
- Draw two copies of the schematic, and write these voltages on the two schematic.
- Label the state of each MOSFET (on or off) in each of the two states.

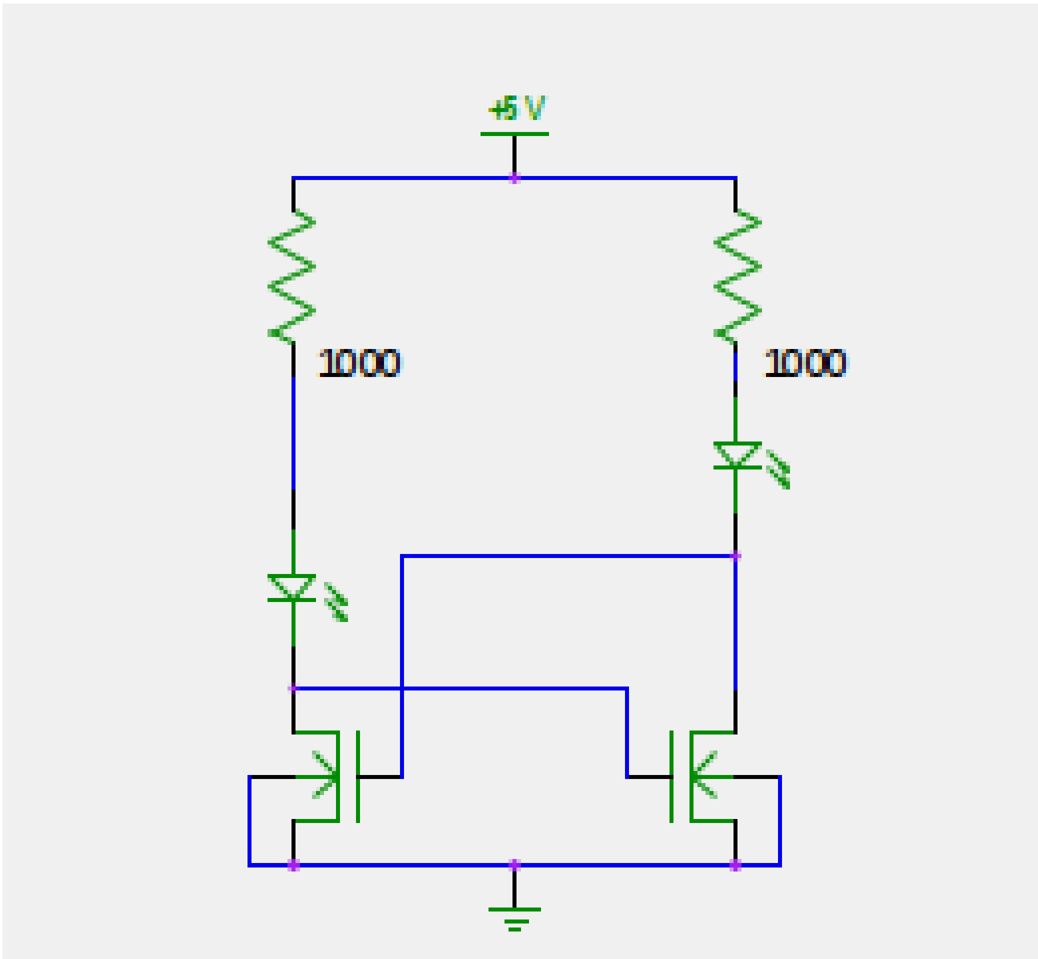

Figure 5: This is Circuit 2. It is a bistable circuit called a flip-flop or latch.

4 A MOSFET oscillator

Set up the third circuit, shown in Figure 6. Again, the LED's will allow you to see the state of the circuit. The wires which connected the opposite gates in the bistable circuit have been replaced with capacitors. This circuit now has no stable state, but oscillates contnuously between the two states.

4.1 Experiments you should do:

- Build the circuit with C values of 4.7μF. You should be able to see the circuit oscillating.
- What is the period of the oscillation? How does it compare to the time constant RC? Use the 100K resistors to calculate RC.
- Now use a capacitor value of 1nF. Can you still see the circuit oscillating?
- Use your oscilloscope to measure the waveforms at the two gate nodes. Sketch them in your notebook.
- How does the period compare to the RC time constant in this case?

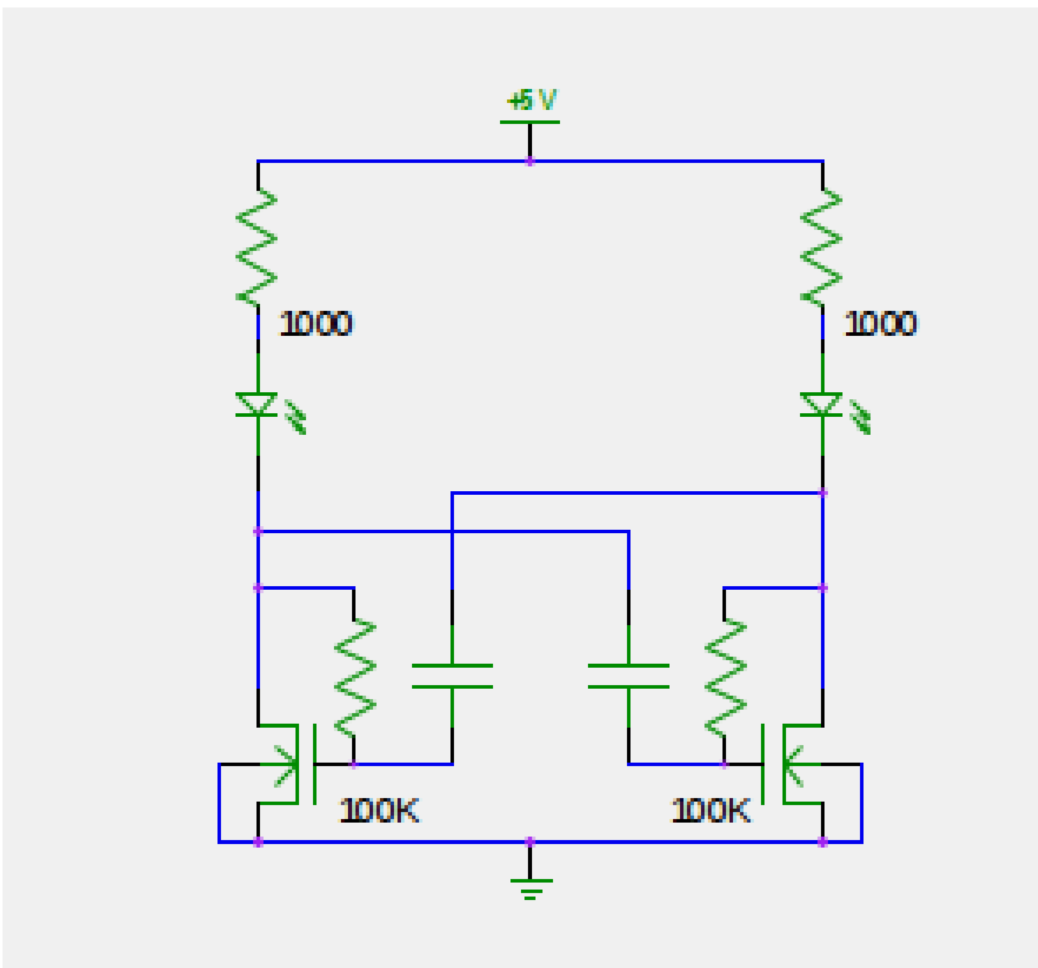

Figure 6: This is Circuit 3. It is an unstable circuit called a multivibrator.