Lab 2 – MOSFET Operation & Transistor Logic

CSE 3323 – Electronics for Computer Engineering

In this lab, we will cover the details of a **MOSFET's** characteristics and how it functions; including both **N-Channel** and **P-Channel** types. Transistors are often used to amplify signals, voltages, or currents but today we will only focus on using **MOSFETs as switches**. We will then combine multiple MOSFETs together and exploit their "switching capabilities" to create various **logic gates** and **flip-flops**.

Students work in pairs (except one group of 3) during lab time.

Each student will submit a PDF lab report (due by one week) regarding the lab measurements and the circuits built. Other required files are detailed on the last page.

What you specifically should include in your lab report is indicated in RED throughout this document. You should also elaborate to discuss the procedure of each individual circuit AND discuss your results/measurements/thoughts.

Lab reports are **individual work** but include your lab partner's name in your report.

Tools Used:

- **Digital Multimeters**
  - Thsinde 18B+ (yellow)
  - Mastech MS8268 (green)
- **Current-Limited Power Supplies**
  - DC Power Supply, Yihua YH-302D
  - DC Regulated Power Supply, Tekpower TP3005T
- **Digital Oscilloscope**
  - Siglent SDS 1202X-E, 200MHz
- **Wire cutters/strippers, probes, banana connectors, alligator clips, jumper wires, solderless breadboards, etc.**

Components Used:

Note: Mouser part numbers below link to their datasheets and specs

- LEDs and Resistors (various values)
- SPST Push Button Switch: 506-FSM4JH
- SPDT Slide Switch: 612-EG1218
- N-Channel MOSFET: 512-2N7000
- P-Channel MOSFET: 689-VP2106N3-G

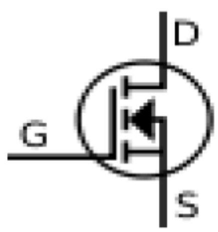
Directed Part of Lab:

1. **General MOSFET Discussion** (no breadboarding, only whiteboard/discussion)

Power Supply Labeling	FET	BJT	Examples
Positive Supply Voltage	V_{DD}	V_{CC}	V_{+}, V_{S+}, +12V, +5V, +3.3V, etc.
Negative Supply Voltage	V_{SS}	V_{EE}	V_{-}, V_{S-}, 0V, -12V, GND, COM, etc.

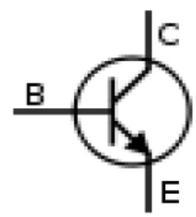
DD, CC, SS, and EE come from the transistor pin names below

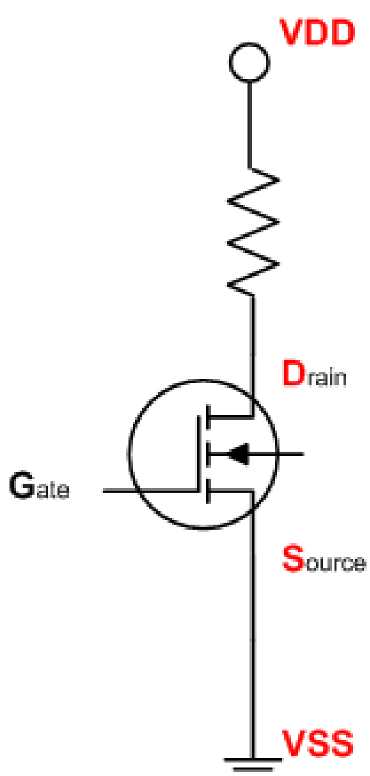
MOSFET
(N-channel)

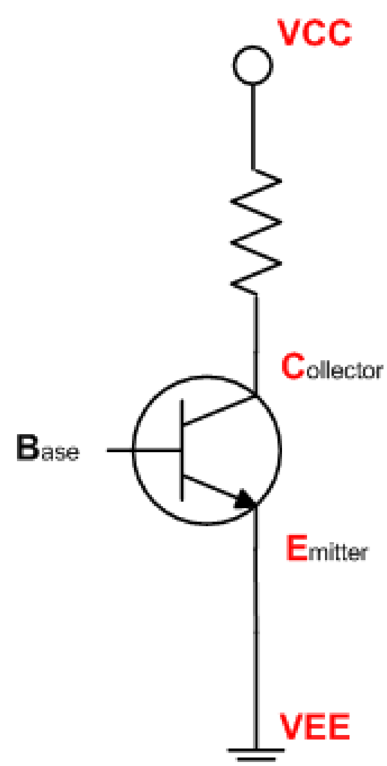


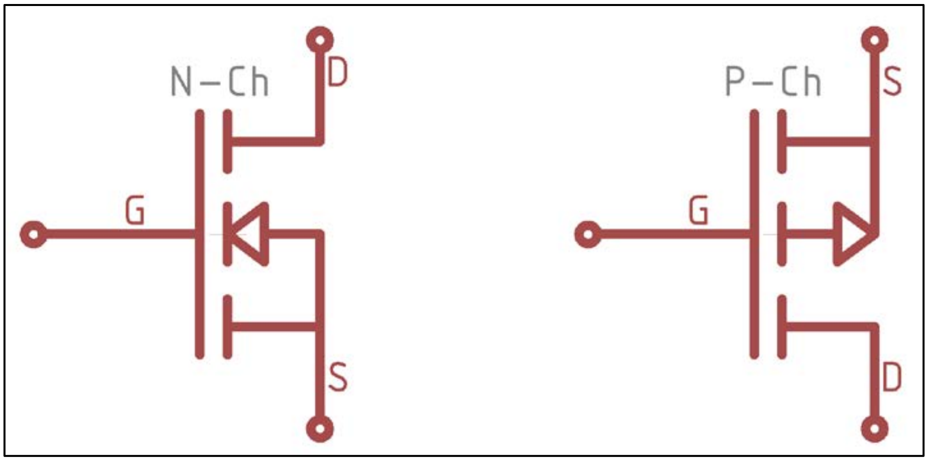
MOSFET	BJT
Drain	**C**ollector
Gate	**B**ase
Source	**E**mitter

BJT
(N-channel)









Each MOSFET has 3 pins: Gate, Drain, and Source

- **Gate**: Used as the "input" to control whether the MOSFET "activates".
    - By activate, we mean either forming a <u>closed short circuit</u> between the Drain and Source pins or forming an <u>open circuit</u> between Drain and Source pins.
- **Source**: Used as a voltage reference for the Gate input voltage to compare against.
- **Drain**: The terminal of the MOSFET where "the work is done". Where the load, device, or output voltage is connected. (usually)

Small Signal MOSFET

(TO-92 Package)
(Low Current/Power)

Power MOSFET

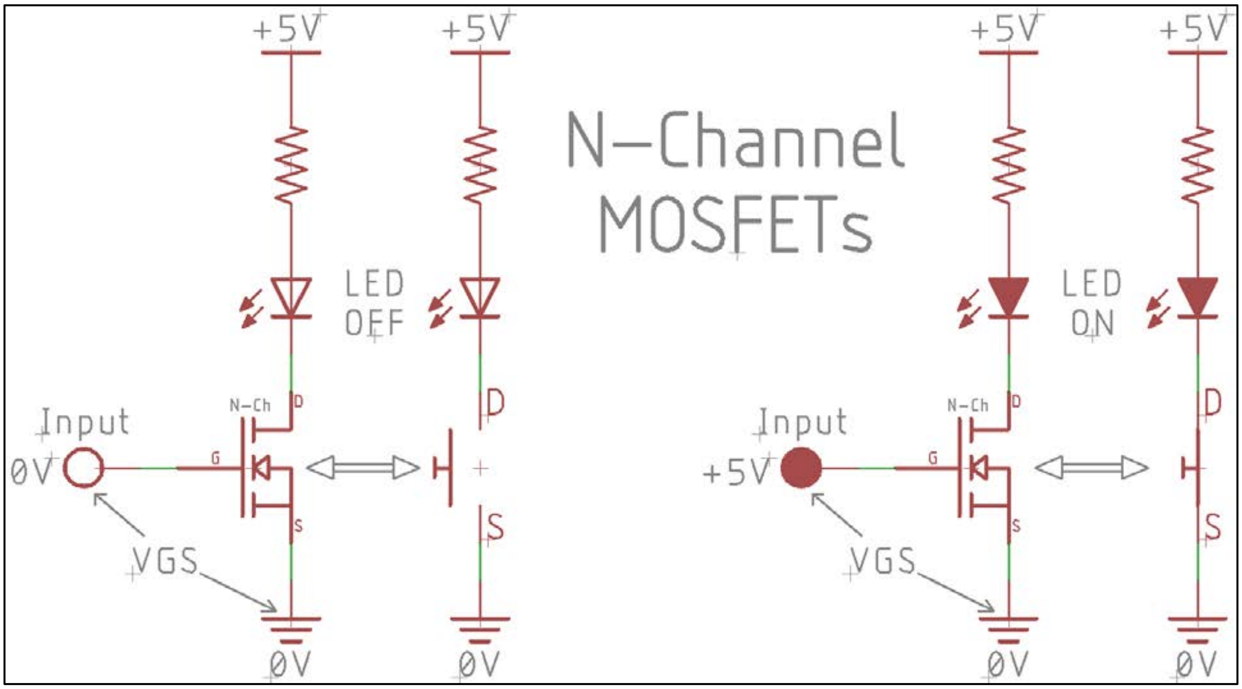
(TO-220 Package)
(High Current/Power)

Surface Mount MOSFET

(Various SMD/SMT Packages)

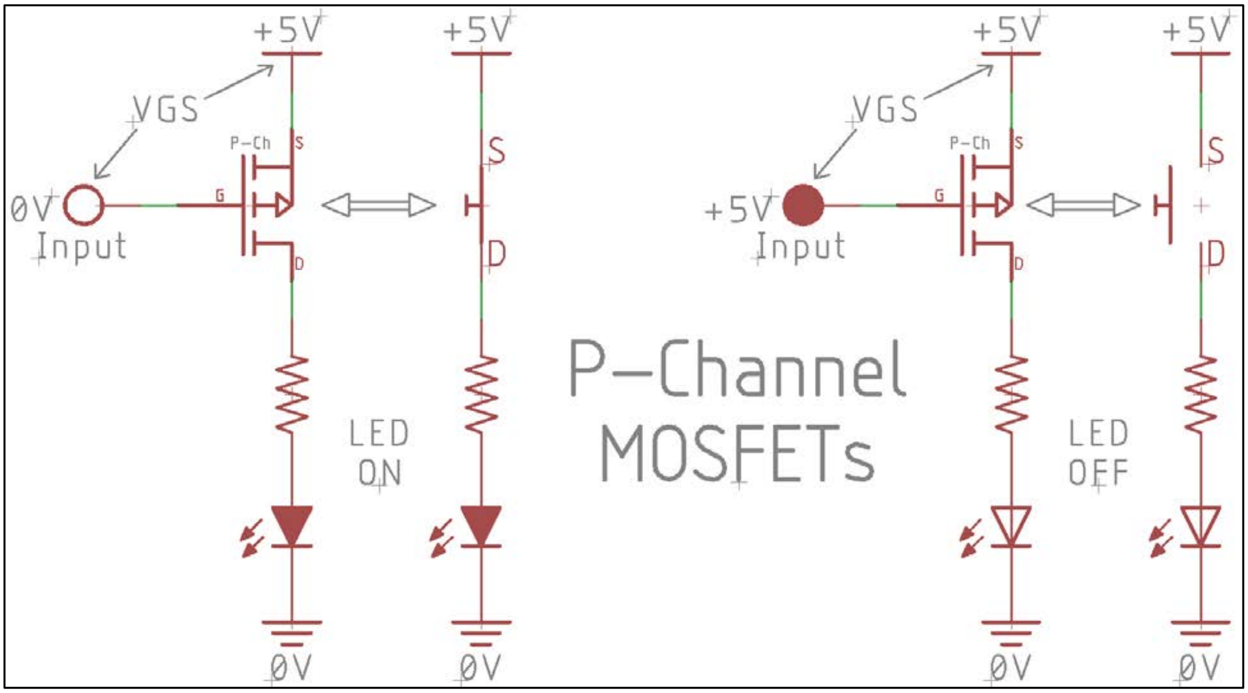
Note: Using the part number links on the 1st page for our two MOSFETs, find their datasheets to learn their pinouts (Gate, Drain, and Source pin assignments)

For N-Channel, we need a POSITIVE voltage (V_{GS}) to ACTIVATE the MOSFET.



"Open Switch"	"Closed Switch"
No current flowing between D and S	**Current is flowing between D and S**
MOSFET is "OFF"	**MOSFET is "ON"**
$V_{GS} = V_G - V_S$	$V_{GS} = V_G - V_S$
$V_{GS} = 0V - 0V = 0V$	$V_{GS} = +5V - 0V = +5V$
If the $V_{GS(th)}$ or V_{TH} is +3.0V then…	If the $V_{GS(th)}$ or V_{TH} is +3.0V then…
$V_{GS} < V_{TH}$ → $0V < +3.0V$ so…	$V_{GS} > V_{TH}$ → $+5V > +3.0V$ so…
MOSFET is NOT activated	**MOSFET IS activated**
"The V_{GS} isn't positive enough, so the MOSFET stays OFF"	"The V_{GS} is positive enough to turn the MOSFET ON"

For P-Channel, we need a <u>NEGATIVE</u> voltage (V_{GS}) to ACTIVATE the MOSFET.



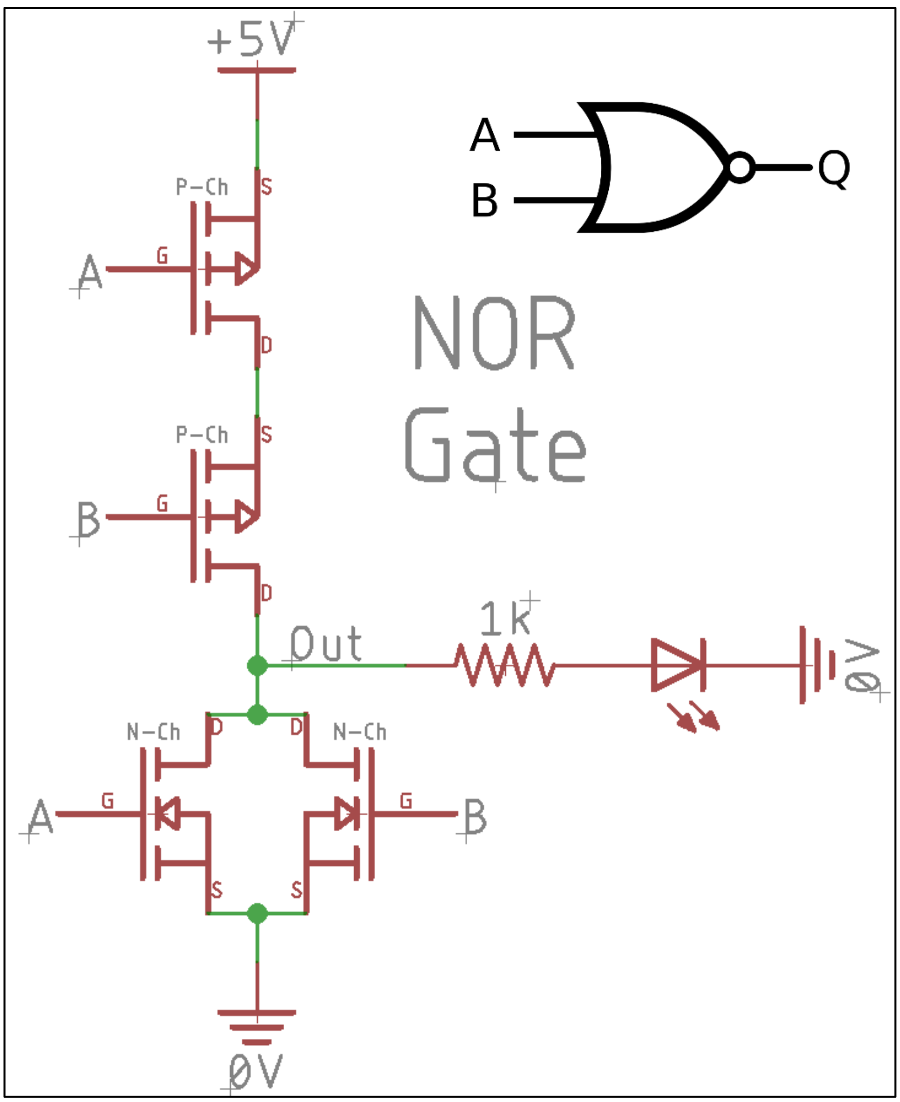
"Closed Switch"	"Open Switch"
Current is flowing between D and S	**No current flowing between D and S**
MOSFET is "ON"	**MOSFET is "OFF"**
$V_{GS} = V_G – V_S$	$V_{GS} = V_G – V_S$
V_{GS} = 0V – +5V = -5V	V_{GS} = +5V – +5V = 0V
If the $V_{GS(th)}$ or V_{TH} is -3.5V then…	If the $V_{GS(th)}$ or V_{TH} is -3.5V then…
$V_{GS} < V_{TH}$ → -5V < -3.5V so…	$V_{GS} > V_{TH}$ → 0V > -3.5V so…
MOSFET IS activated	**MOSFET is NOT activated**
"The V_{GS} <u>is negative enough</u> to turn the MOSFET ON"	"The V_{GS} <u>isn't negative enough</u>, so the MOSFET stays OFF"

Individual Part of Lab:

1. **NOR Gate**

   NOTE: For this part, set your Power Supply's current limit to 10mA

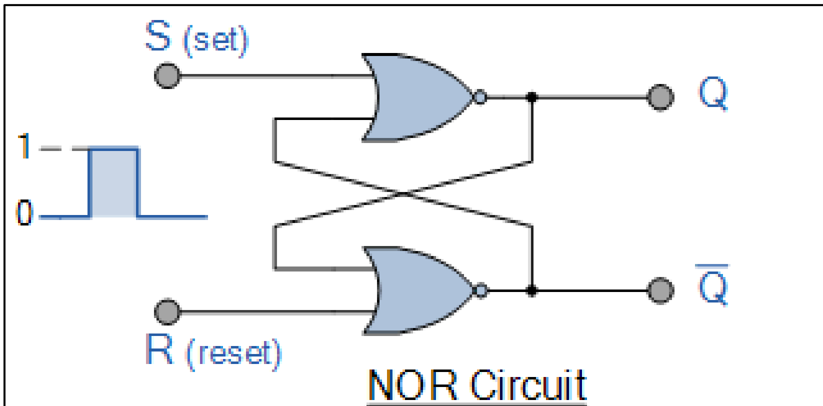
   a. Using 2 N-Channel and 2 P-Channel MOSFETS, construct the NOR Gate shown below using a +5V supply
   b. For the A and B inputs, use two **SPDT slide switches** (0V or 5V output)
   c. Use a resistor and an LED to show the NOR gate's output
   d. For every A/B input combination record...
      i. A voltage
      ii. B voltage
      iii. OUT voltage
   e. Discuss in your own words how this circuit operates
   f. Does the standard NOR gate truth table match your (d) recordings?
   g. Draw the FULL circuit (SCH in EAGLE) to include in your report



2. **SR Flip-Flop (Latch)**

   NOTE: For this part, set your Power Supply's current limit to 20mA

   a. Construct 2 of the NOR Gate circuits and connect them together in the manner shown below to create a SR Flip-Flop
   b. For the S and R inputs, use two **push-button switches** (0V or 5V output)
      i. You must use a **pull-down resistor** configuration for each switch
      ii. Do not use the slide switches, the "pulsing nature" of the push-buttons helps illustrate how this circuit "has memory"
   c. Use resistors and LEDs to show the Q and $\overline{Q}$ outputs
   d. Discuss in your own words how this circuit operates
   e. Does the standard SR Flip-Flop truth table match your LED outputs?
   f. Draw the FULL circuit (SCH in EAGLE) to include in your report
      i. Not the high-level logic gate version (shown below); draw the FULL MOSFET version of the Flip Flop including switches, LEDs, etc.



S	R	Q	$\overline{Q}$
0	0	No change	
0	1	1	0
1	0	0	1
1	1	X	X
		(Invalid)	

Additional Submission Details:

ZIP up all 3 of these files into a single zip file and upload to Blackboard

1. **Lab Report (.pdf)**
   a. Include all of the details indicated above in RED
2. **Schematic File (.sch)**
   a. Using EAGLE, draw the final full circuit of the SR Flip-Flop (part 2)
   b. Including all the MOSFETs, power connections, push-button switches, resistors, LEDs, etc.
   c. Include part numbers and component values if applicable
   d. Include text labels to help explain and indicate "what your circuit does"
3. **PCB File (.brd)**
   a. Convert your .SCH file into a PCB
   b. Arrange all the components in a logical and efficient manner
   c. Keep the overall blueprint (size) of the board small and tight
   d. You may use either single or double layer routing