ECE 65: Components & Circuits Lab

Lecture 14

MOSFET transfer function

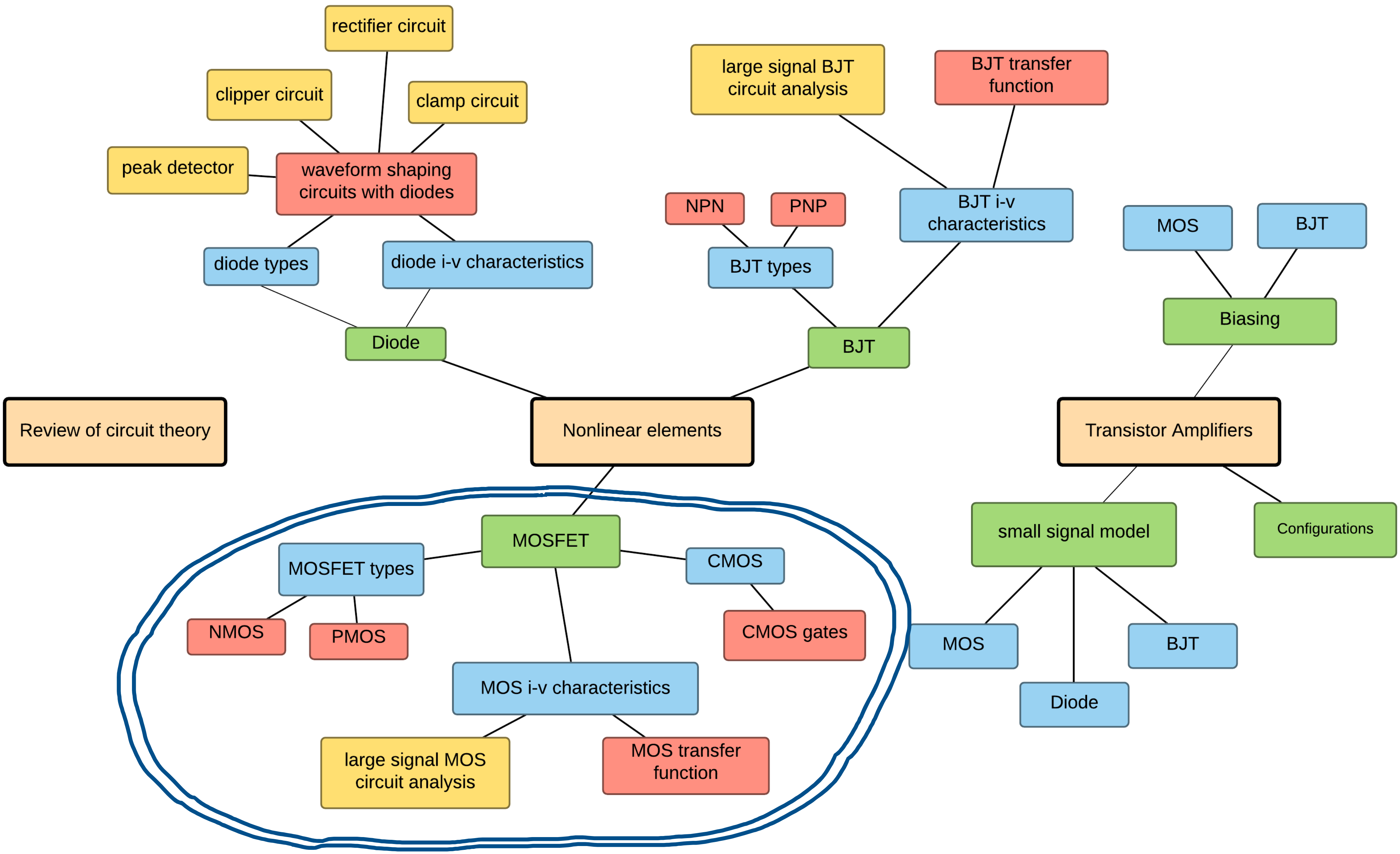
Reference notes: sections 4.2,4.3

Sedra & Smith (7th Ed): sections 5.3,7.1.3

Saharnaz Baghdadchi

Course map

4. Metal Oxide Semiconductor Field Effect Transistor (MOSFET)



NMOS Transfer Function

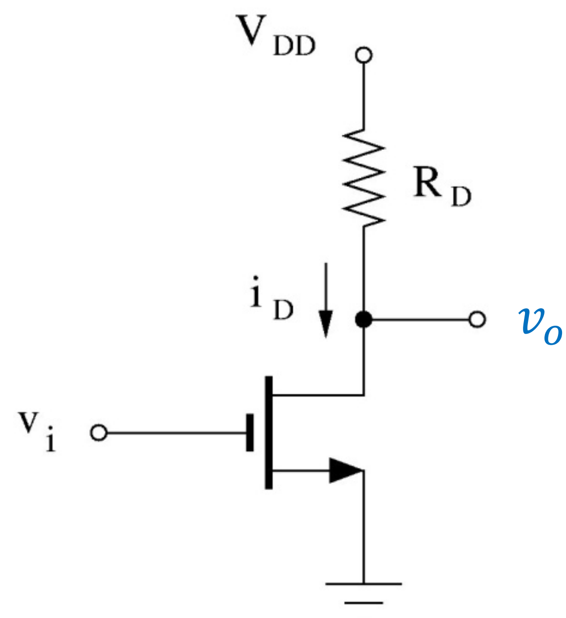
How does v_o change when v_i is changed from 0 to V_{DD}?

Circuit Equations:

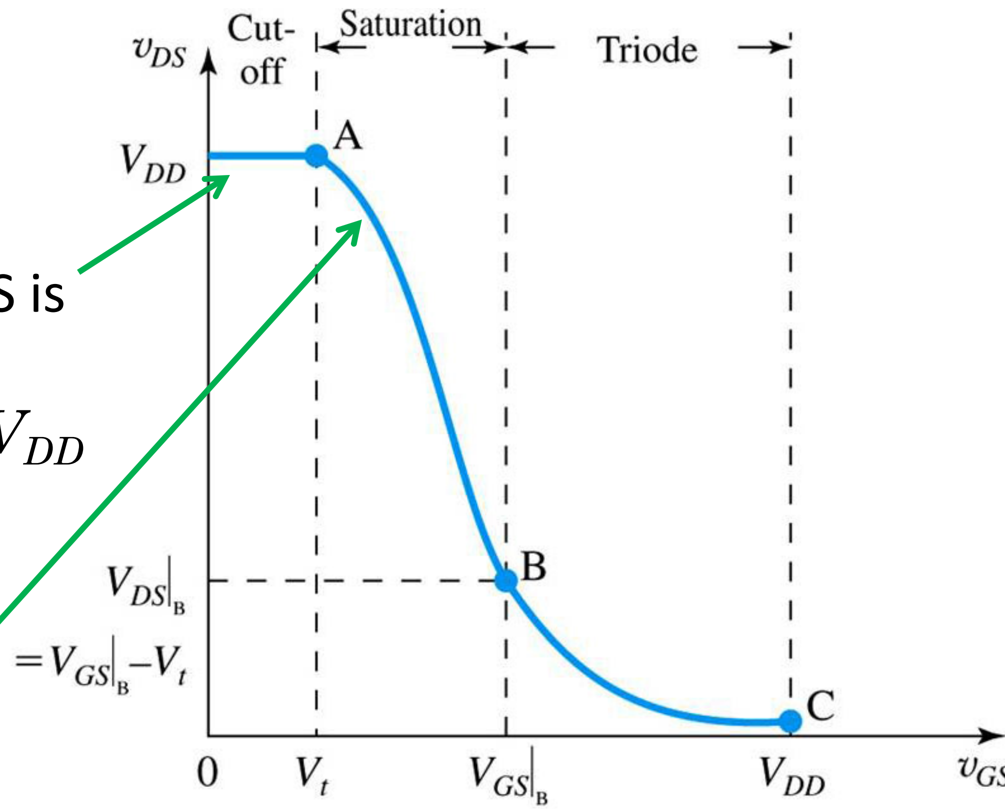
$$v_{GS} = v_i$$

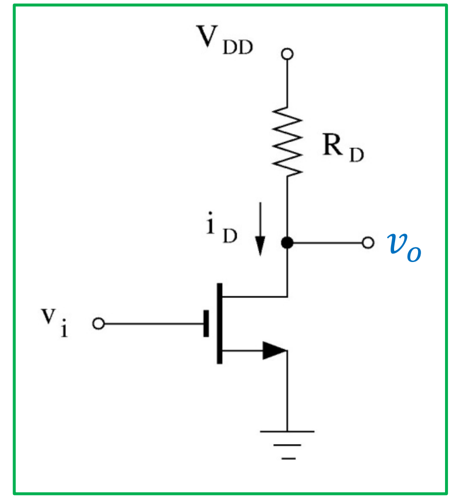
$$i_D = f\,(v_{GS}\ , v_{DS})$$

$$v_o = v_{DS} = V_{DD} - R_D\, i_D$$



NMOS Transfer Function





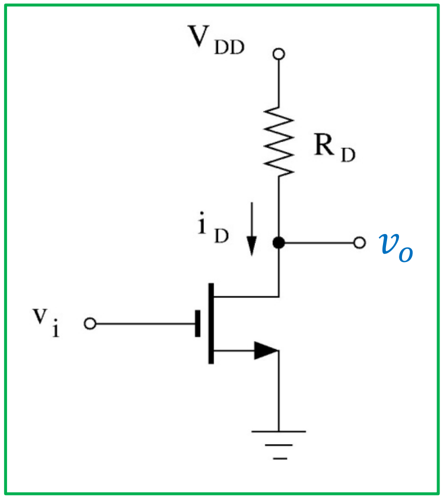
1) For $v_{GS} < V_t$, NMOS is in cutoff: $i_D = 0$ &

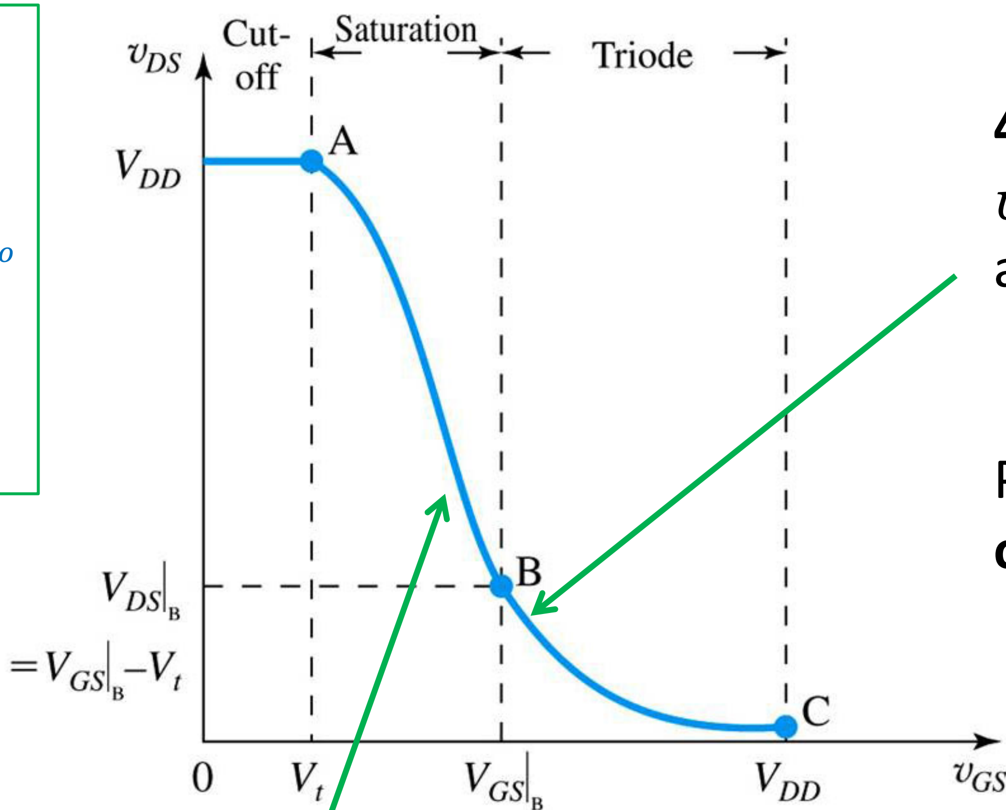
$v_{DS} = V_{DD} - R_D\, i_D = V_{DD}$

2) Just to the right of point A:

- $V_{OV} = v_{GS} - V_t$ is small, so i_D is small.
- $v_{DS} = V_{DD} - R_D\, i_D$ is close to V_{DD}
- Thus, $v_{DS} > V_{OV}$ and NMOS is in saturation.

NMOS Transfer Function





4) To the right of point B,
$v_{DS} < V_{OV} = v_{GS} - V_t$
and NMOS enters triode.

Point B is called the **"Edge of Saturation"**

3) As v_{GS} increases:

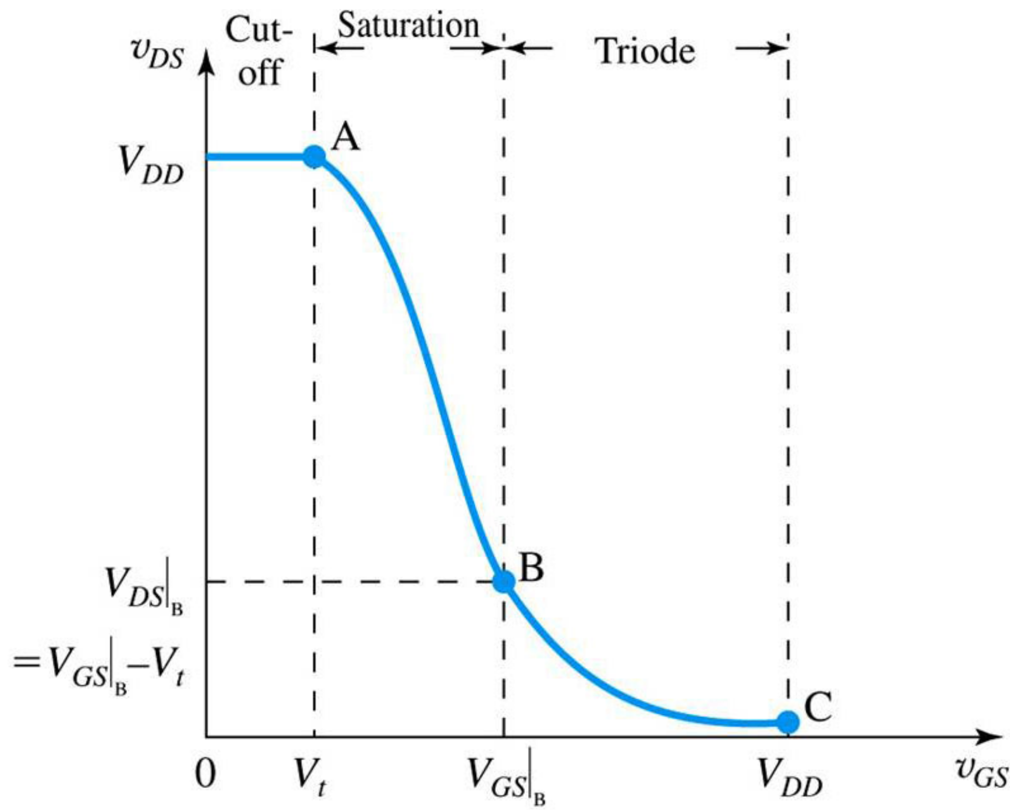
- $V_{OV} = v_{GS} - V_t$ and i_D become larger;
- $v_{DS} = V_{DD} - R_D\, i_D$ becomes smaller.
- At point B, $v_{DS} = V_{OV}$

NMOS Functional circuits

Transition from cut-off to triode can be used to build NMOS switch circuits.

- Voltage at point C (see graph) depends on NMOS parameters and the circuit (in BJT $v_o = V_{sat}$)!

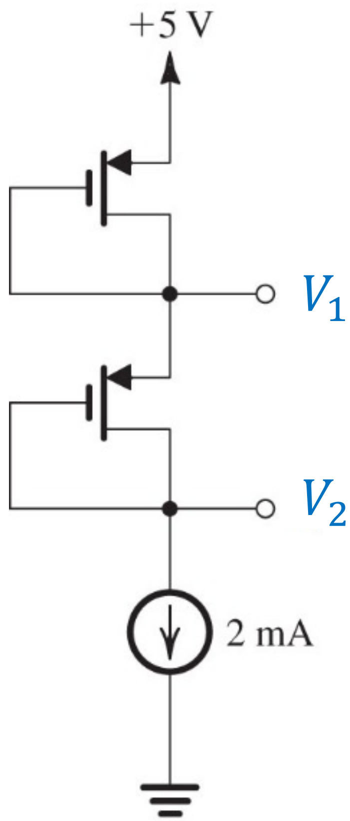
We can also build NMOS logic gates similar to a BJT. But there are much better gates based on CMOS technology!



Lecture 14 reading quiz

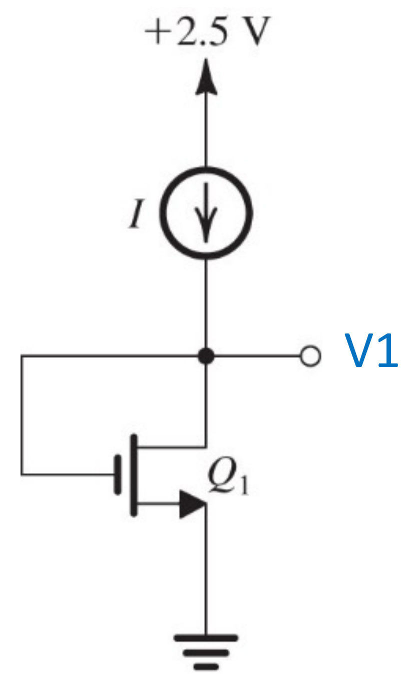
The transistors in the below circuit are characterized by $|V_t| = 0.5\ V$

k_p= $4\ mA/V^2$, $\lambda = 0$. Find the labeled node voltages.



Discussion question 1.

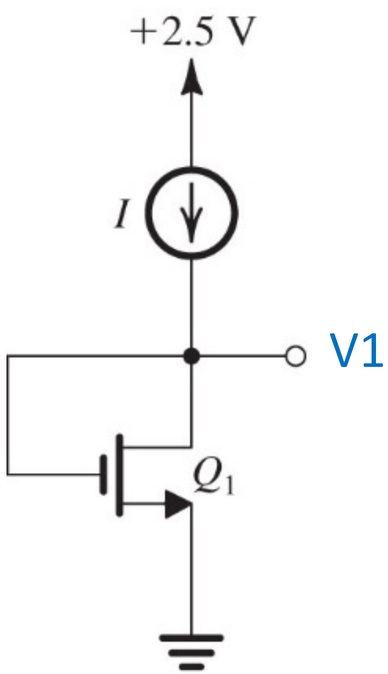
In the below MOSFET circuit, find the node voltage V1. How large a resistor can be inserted in series with the drain while maintaining saturation? $V_t = 0.5\ V$, $I = 0.1\ mA$, $V_{GS} = 1\ V$



Hints:

Discussion question 1.

In the below MOSFET circuit, find the node voltage V1. How large a resistor can be inserted in series with the drain while maintaining saturation? $V_t = 0.5\ V$, $I = 0.1\ mA$, $V_{GS} = 1\ V$



- Label I_D and I_G, V_{GS} and V_{DS}.

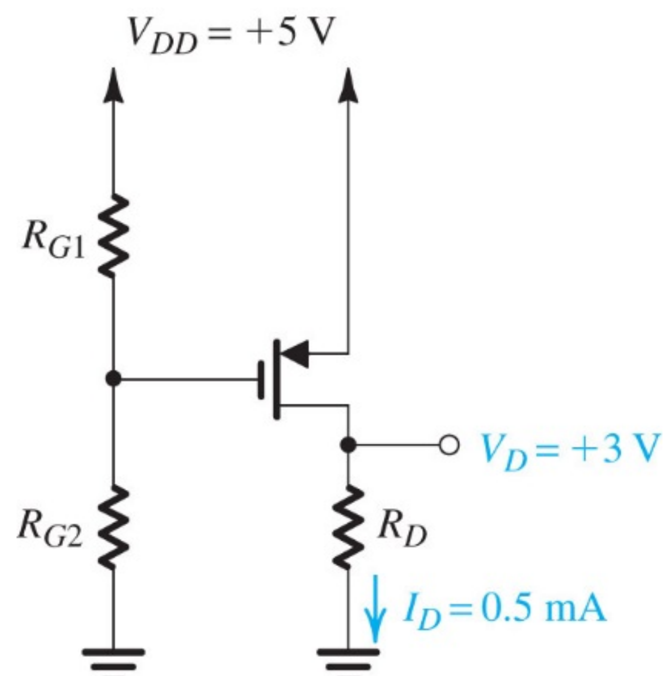
- What is I_G in MOSFETs (what we use in ECE 65)?

- Add the resistor between the node labeled with V1 and the drain of the transistor.

- Write the condition of V_{DS} when MOSFET is in saturation, and use it to find the maximum value of R for the MOSFET to stay in saturation.

Discussion question 2.

Design the following MOSFET circuit so that the transistor operates in saturation with $I_D = 0.5\ mA$ and $V_D = +3\ V$. Let PMOS have $V_{tp} = -1\ V$, k_p= $1\ mA/V^2$, $\lambda = 0$.



Discussion question 3.

In the MOSFET circuit that you designed, what is the largest value that R_D can have while maintaining saturation-region operation with the same $I_D = 0.5\ mA$?

Let PMOS have $V_{tp} = -1\ V$, k_p= $1\ mA/V^2$, $\lambda = 0$.