ECE 320 - Homework #9

MOSFET Switches, CMOS logic. Due Monday, March 20th
Please email to jacob.glower@ndsu.com, or submit as a hard copy, or submit on BlackBoard

MOSFETs

1) The VI characteristics for an n-channel MOSFET are shown below.

- Label the off / ohmic / and saturated regions
- Determine the transconductance gain, kn. Assume Vth = 1.00V

kn Calculations: Point A (Ohmic Region)

$$I_{ds} = k_n\left(V_{gs} - V_{th} - \frac{V_{ds}}{2}\right)V_{ds}$$

$$10mA = k_n\left(5V - 1V - \frac{2V}{2}\right)2V$$

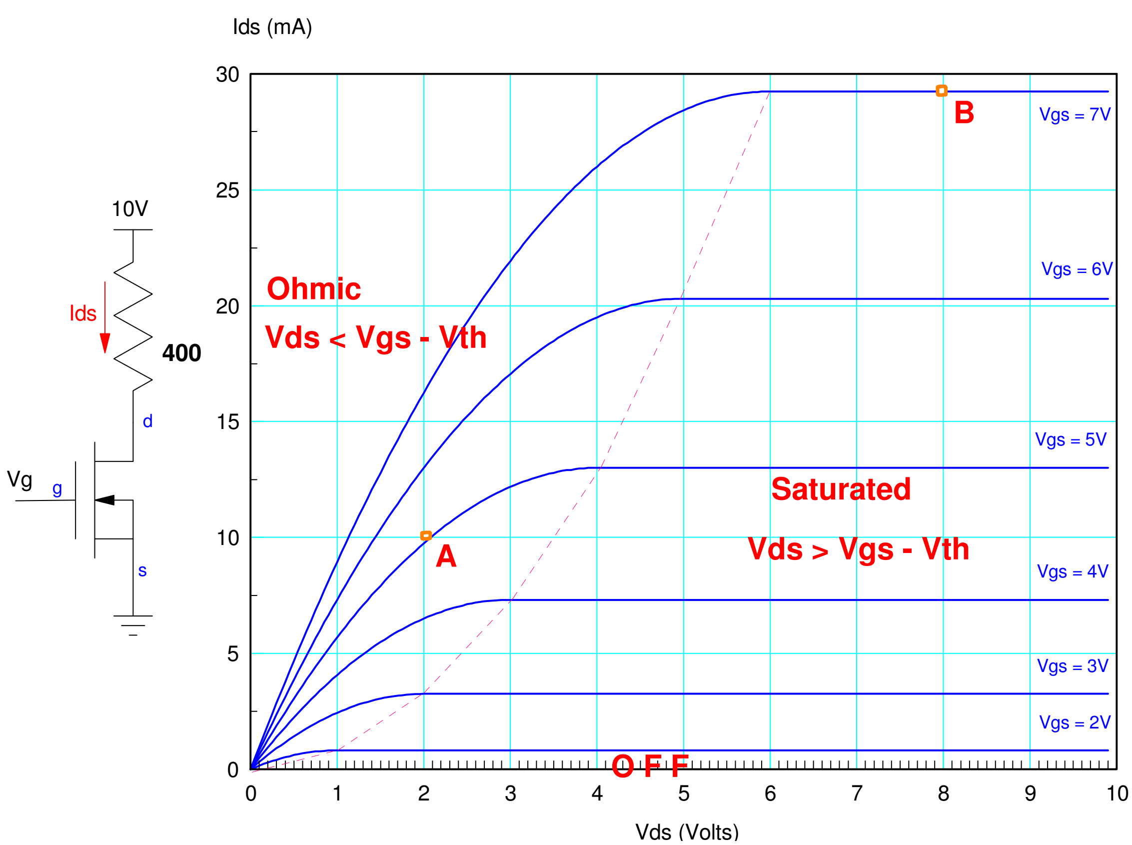
$$k_n = 1.667\frac{mA}{V^2}$$

Point B (Saturated Region)

$$I_{ds} = \frac{k_n}{2}(V_{gs} - V_{th})^2$$

$$29mA = \frac{k_n}{2}(7V - 1V)^2$$

$$k_n = 1.611\frac{mA}{V^2}$$



2) Draw the load-line for the circuit below. From the load line, determine the Q-point (Vds, Ids) when

A: Vg = 0V

Vds = 10V, Ids = 0mA

Off Region

Vg = 4V

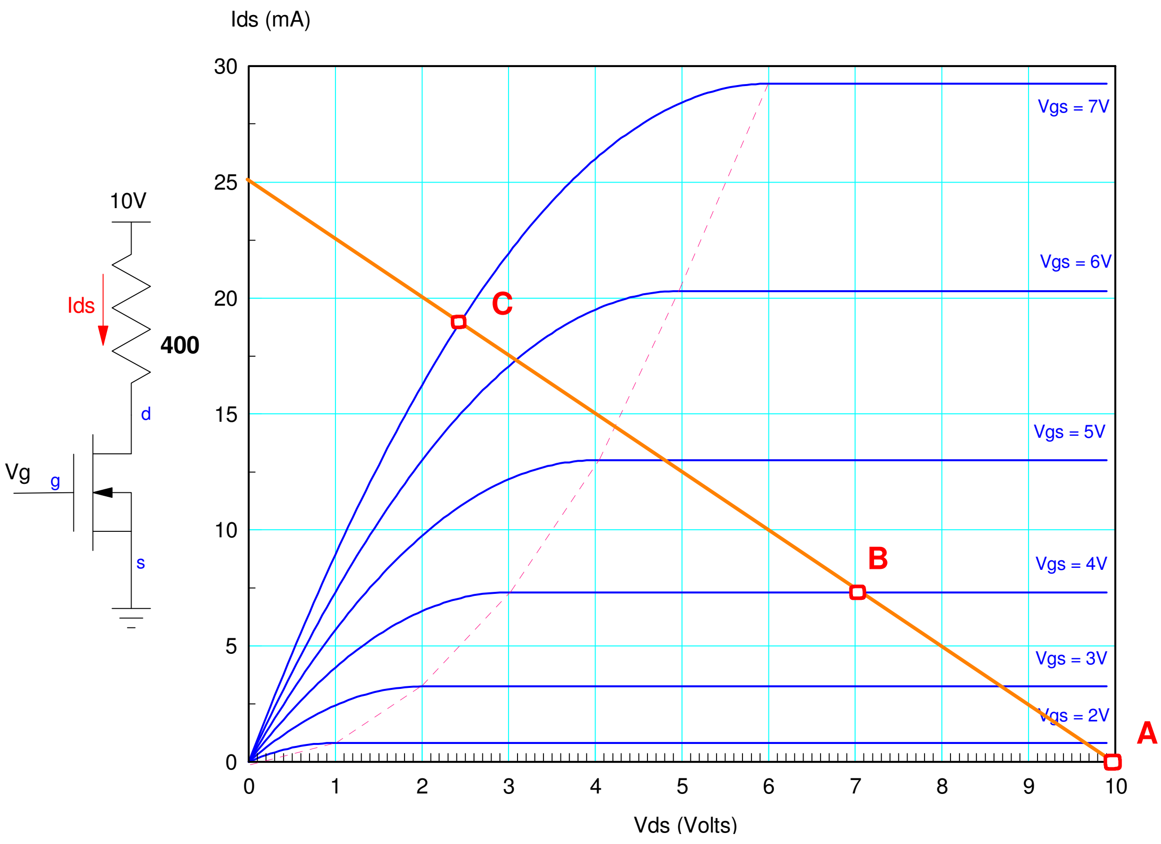
Vds = 7V, Ids = 7.5mA

Saturated Region

Vg = 7V

Vds = 2.4V, Ids = 18mA

Ohmic Region



MOSFET Switch

The characteristics for a IRF3710 MOSFET are

- Max Current = 57A continuous (180A pulsed)
- Rds = 0.023 Ohms @ 6Vgs = 10V @ Id = 28A
- 2V < Vth < 4V *assume Vth = 3V*

3) Determine the transconductance gain, kn

Rds is given in the Ohmic region

$$I_{ds} = k_n\left(V_{ds} - V_{th} - \frac{V_{ds}}{2}\right)V_{ds}$$

$$V_{ds} = 28A \cdot 0.023\Omega = 0.644V$$

$$28A = k_n\left(10V - 3V - \frac{0.644V}{2}\right) \cdot 0.644V$$

$$k_n = 5.663\frac{A}{V^2}$$ Vth = 2V

$$k_n = 6.511\frac{A}{V^2}$$ Vth = 3V

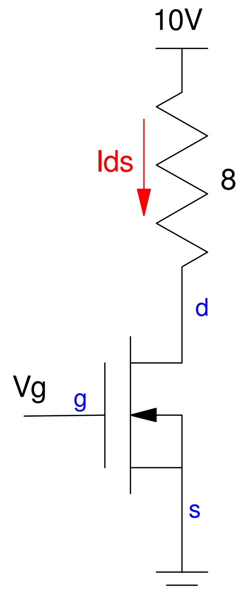
$$k_n = 7.657\frac{A}{V^2}$$ Vth = 4V

4) The CircuitLab model for an IRF3710 MOSFET is

- $k = 48.1147 \frac{A}{V^2}$
- $V_{th} = 3.39715V$

Using the CircuitLab parameters, determine the voltages for the following circuit for

- Vin = Vg = 0V
- Vin = Vg = 5V
- Vin = Vg = 10V



Vin = 0V

Off region

Vds = 10V

Ids = 0mA

Vin = 5V

Assume saturated region

$$I_{ds} = \frac{k_n}{2}(V_{gs} - V_{th})^2$$

$$I_{ds} = \frac{48.1147 \frac{A}{V^2}}{2}(5V - 3.39715V)^2$$

$$I_{ds} = 61.806A$$

$$V_{ds} = 10 - 8I_{ds} = -484.45V$$

which is nonsense - meaning it's not in the saturated region. Assume Ohmic region. Write two equations for two unknowns.

$$I_{ds} = k_n\left(V_{gs} - V_{th} - \frac{V_{ds}}{2}\right)V_{ds}$$

$$10 = 8I_{ds} + V_{ds}$$

Solving using numerical methods

Vds = 0.0163V

Ids = 1.2480A

Check:

Vds < Vgs - Vth

0.0163V < 5V - 3.39715V

Vgs = 10V

Also Ohmic region

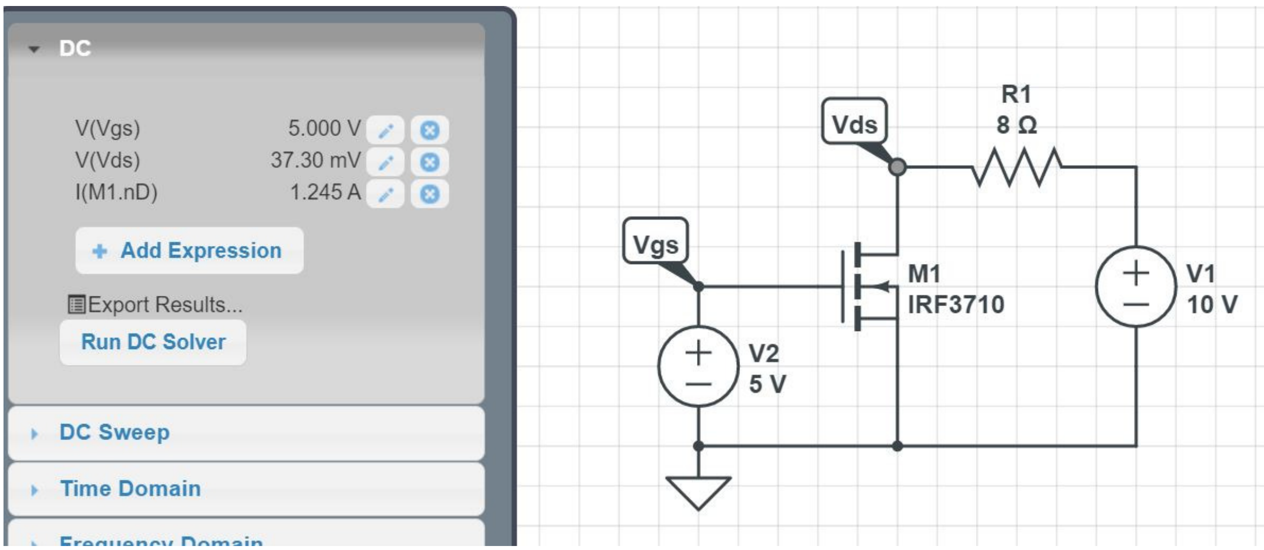
Vds = 0.0039V

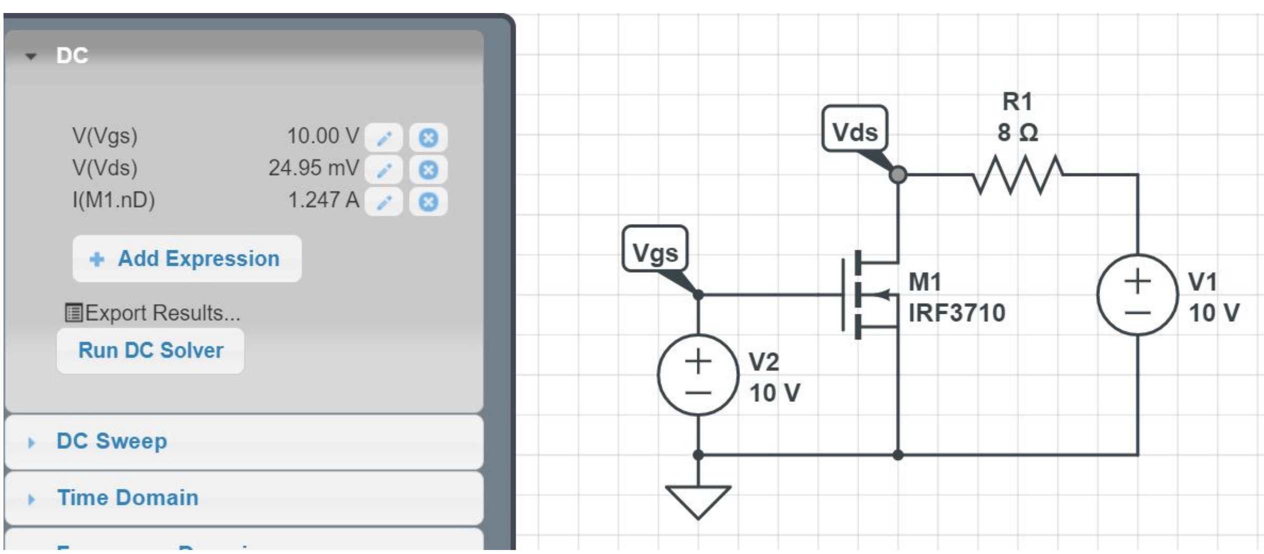
Ids = 1.2495A

5) Simulate this circuit in CircuitLab using an IRF3710. Determine the voltages and currents when

- Vin = Vg = 0V
- Vin = Vg = 5V
- Vin = Vg = 10V

Vgs		Vds	Ids	Rds
0V	Calculated	10V	0mA	n/a
	Simulated	10V	0mA	n/a
5V	Calcuated	16.3mV	1.248A	13.1 mOhm
	Simulated	37.30mV	1.245A	30.0 mOhm
10V	Calculated	3.99mV	1.2495A	3.2 mOhm
	Simulated	24.95mV	1.247A	20.0 mOhm





CMOS Logic

6) Design a CMOS gate to implement the function: Y(A, B, C, D)

Y(A,B,C,D)	CD 00	01	11	10
AB 00	1	0	0	x
01	1	0	x	1
11	1	x	1	0
10	0	1	x	0

Start with circling the ones or zeros. I prefer zeros, but either one works

$$\overline{Y} = \overline{A}D + A\overline{B}\overline{D} + AC\overline{D}$$

Use DeMorgan's law to get Y

$$Y = \left(A + \overline{D}\right)\left(\overline{A} + B + D\right)\left(\overline{A} + \overline{C} + D\right)$$

Implement these using CMOS gates (series = and, parallel = or).

- Use ~Y for the n-channel MOSFETs (tied to ground)
- Use Y for the p-channel MOSFETs (tied to 5V)