ECE 320 - Homework #8

Schmitt Triggers, MOSFET's, MOSFET Switch. Due Monday, October 17th

Schmitt Trigger:

1) Assume you have a light sensor whose resistance is

$$R = \left(\frac{100{,}000}{Lux}\right)\ \Omega$$

Design a circuit which is capable of driving a 1k Ohm load where

- The output goes to +10V when the light level drops below 20 Lux and
- The output goes to 0V when the light level goes above 25 Lux.

Assume you are using a voltage divider with a 5k resistor:

At 20 Lux:

R = 5000

$$V_a = \left(\frac{5000}{5000+5000}\right)10V = 5V$$

At 25 Lux:

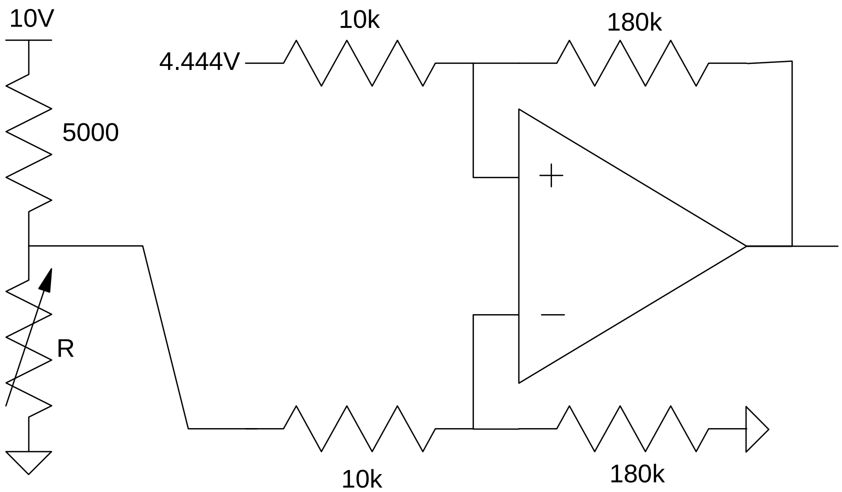
R = 4000

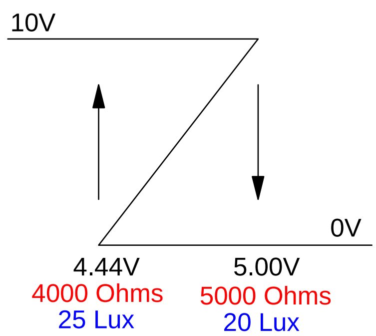
$$V_a = \left(\frac{4000}{4000+5000}\right)10V = 4.444V$$

The gain is

$$gain = \left(\frac{10V-0V}{5V-4.444V}\right) = 18.0$$

When the output is 0V, you're on the verge of switching at 4.444V. The offset is 4.444V.





MOSFET: The VI characteristics for a MOSFET are shown below.

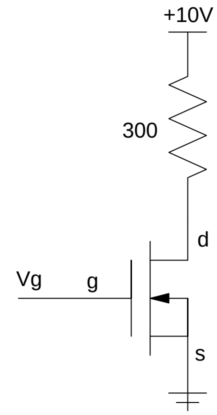
2) Label the off / saturated / and ohmic regions.

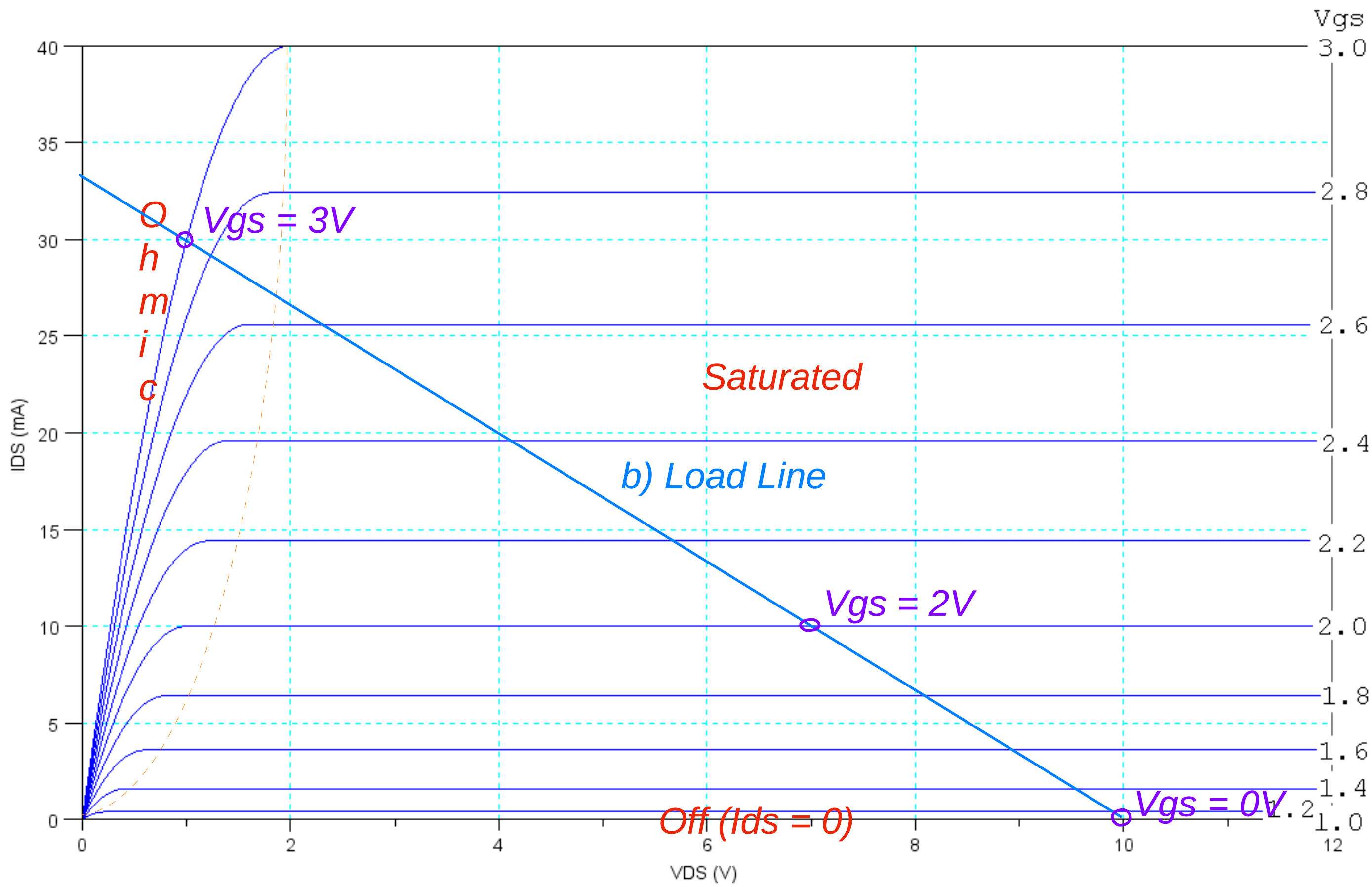
3) Determine the turn-on voltage and transconductance gain, gm

4) Draw the load-line for the circuit shown to the right.

5) Determine the Q-point for

- Vg = 0V Vds = 10V Ids = 0mA off
- Vg = 2V Vds = 7V Ids = 10mA saturated
- Vg = 3V Vds = 1V Ids = 30mA Ohmic





6) Design a circuit to turn on and off a 12V DC motor which draws 3A. Assume the MOSFET characteristics are:

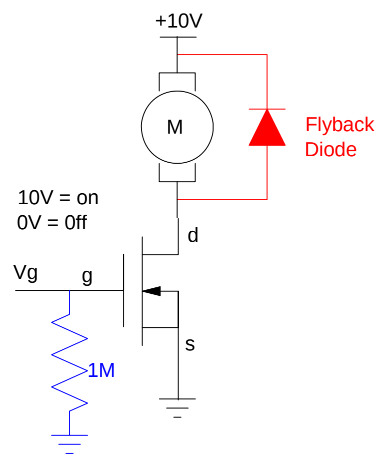
- V_{DS} max = 100V
- $I_{D\,max}$ = 11A (continuous)
- R_{DS} = 173 mOhm @ I_D = 5A, V_{GS} = 10V
- V_T = 2V @ 1mA

MOSFET's are actually really easy to use as a switch:

- The motor acts like a 4 Ohm resistor (12V @ 3A)
- The MOSFET acts like a 0.173 Ohm resistor when Vgs = 10V.
- The net current when on (Vgs = 10V) is approximately:

$$I_{ds} \approx \left(\frac{10V}{4\Omega + 0.173\Omega}\right) = 2.39A$$

- The current when Vgs = 0V is 0 (the MOSFET is off)



More Exact Solution: The resistance changes when you change Ids - so it's not exactly 0.173 Ohms in this case. To get a more accurate answer, first, find Kn. In the ohmic region

RDS = 0.173 when Vgs = 10V and Ids = 5A (meaning Vds = Rds * Ids = 0.865V)

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

$$5A = k_n\left(10V - 2V - \frac{0.865V}{2}\right)0.865V$$

$$k_n = 0.7638\,\frac{A}{V^2}$$

For the above circuit with a 4 Ohm resistor

$$I_{ds} = 0.7638\left(10V - 2 - \frac{V_{ds}}{2}\right)V_{ds}$$

$$V_{ds} = 10 - 4I_{ds}$$

Solving 2 equations for 2 unknowns numerically:

Ids = 2.3993A (vs. 2.39A computed above)

Vds = 0.4028V

$$R_{ds} = \left(\frac{V_{ds}}{I_{ds}}\right) = 0.168\Omega$$ (vs. 0.173 Ohms assumed above)

More Fun: What if you change the input voltage at Vg to 0V / 5V?

Repeating the previous calculations

kn = 0.7638

$$I_{ds} = 0.7638\left(5V - 2 - \frac{V_{ds}}{2}\right)V_{ds}$$

$$V_{ds} = 10 - 4I_{ds}$$

Solving numerically:

Ids = 2.200A (vs. 2.39A)

Vds = 1.200V

Rds = Vds / Ids = 0.5455 Ohms

Term Project (part 1)

Lab: 7-10) Design, build, and test one part of your term project

7) Requirements: Specify

- Inputs
- Outputs
- How they relate

8) Analysis: Give calculations for resitors, capacitors, etc. for a circuit which meets these requirements.

9) Testing: Simulate your circuit in PartSim (or similar software) to check if you calculations were correct.

10) Validation: Build your circuit and collect data to verify your design meets your requirements.