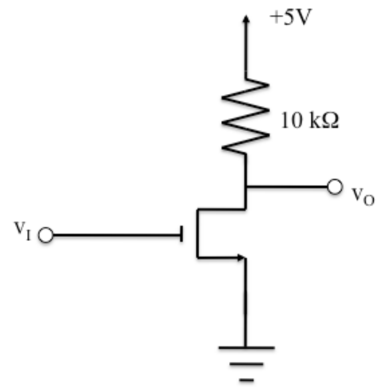
Module 6: Homework

EE 315

1. Consider the following common source amplifier, where $V_t$= 1.5V, $k'_nW/L$ = .2 mA/$V^2$.




a. Sketch the voltage transfer characteristic, clearly labeling the transition points, A, B and C.
b. The device is biased for a 0.15 mA drain current. Find the Q-point.
c. Find the voltage gain at this bias point.

2. A common source amplifier uses an NMOS transistor with $k'_n$=0.4mA/$V^2$, W/L = 10, $V_t$=0.4V, $V_{DD}$=2.5 Vand $V_A$=10V. The amplifier Q-point is at $I_{DQ}$=0.2mA and uses a drain resistor of 6.2kohms.

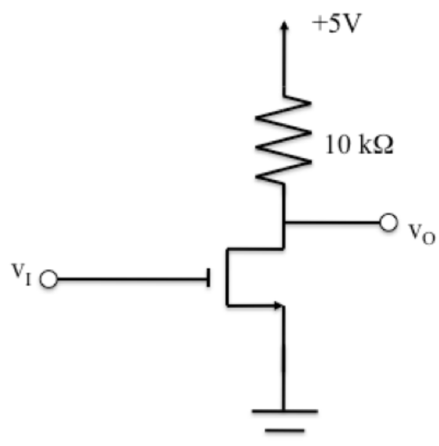
a. Find $V_{GSQ}$ and $V_{DSQ}$.
b. Draw the small signal model and find $g_m$, $R_{in}$, $A_{vo}$, and $R_o$.
c. If a load resistor is connected to the drain where $R_L$ = 15kohms, what is the gain, $A_v$. Update your small signal model.
d. If a source signal, $v_{sig}$ in series with a resistance of $R_{sig}$ = 300kohms is connected to the gate, what is the gain, $G_v$.

3. A common gate amplifier uses an NMOS transistor with $g_m$=4mA/V and a drain resistor of 5kohms and a load resistor of 7.5 kohms. The amplifier is driven by a source, $v_{sig}$, that has $R_{sig}$ = 500 ohms.

a. Find the input resistance ($R_{in}$) and the overall voltage gain, $G_v$. Draw the small signal model.
b. Suppose we want the input resistance to equal the signal resistance at the Q-point, $I_{DQ}$. What would the drain current Q-point need to change to for this to happen?

4. A common drain amplifier has the following characteristics: $k'_n$=0.1mA/V$^2$ and $V_t$ = 0.6V. The operating point is $V_{GSQ}$=0.85 V.
   a. What is the W/L ratio for an output resistance of 300 ohms?
   b. What is the drain current at the operating point?
   c. This amplifier is connected to a 10kohm potentiometer as the load. What is the range of possible overall voltage gain?

1. Consider the following common source amplifier, where $V_t$= 1.5V, $k'_nW/L$ = .2 mA/V$^2$.




a. Sketch the voltage transfer characteristic, clearly labeling the transition points, A, B and C.

$V_t = 1.5v$

$k'_n \frac{W}{L} = 0.2 \, mA/V^2$

Point A: $\boxed{\text{Cutoff}}$

$V_I = V_t$

$V_O = V_{DD}$

$(5, 1.5)$

Point B:

Edge of Saturation

$\underset{V_{DS}}{V_O} = \underset{V_{GS}}{V_I} - V_t$

$V_I = V_{GS} = V_t +$

$$V_I = V_{GS} = V_t + \frac{\sqrt{1 + 2(R_O k'_n \frac{W}{L} V_{DD})} - 1}{R_O k'_n \frac{W}{L}}$$

$$V_I = 1.5 + \frac{\sqrt{1+2(10)(.2)(5)} - 1}{10 \times .2} \Rightarrow V_I = 3.29v$$

$$V_o = V_{DS} = V_I - V_t$$

$$V_o = 3.29 - 1.5 = 1.79v \qquad (1.79, 3.29)$$

Point C:

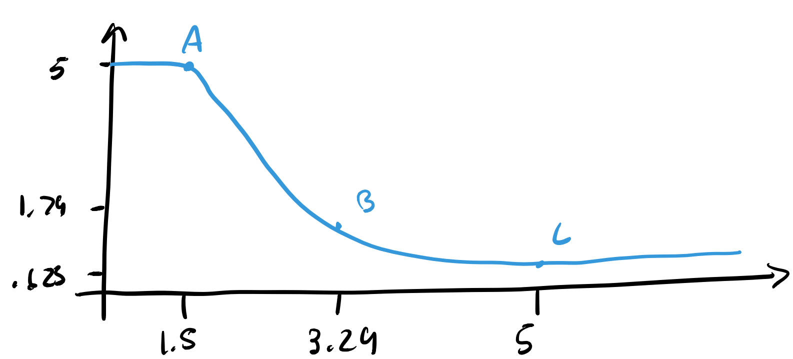
Triode $\qquad V_{GS} = V_I = V_{DD} = 5v$

$$V_{DS} = V_o = \frac{V_{GS}}{1 + R_D k'_n \frac{W}{L}(V_{GS} - V_t)}$$

$$V_o = \frac{5}{1 + (.2)(5 - 1.5)(10)}$$

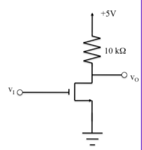
$$V_o = 0.625\ v$$

| Point | $V_o$ | $V_I$ |
|---|---|---|
| A | 5 | 1.5 |
| B | 1.79 | 3.29 |
| C | .625 | 5 |



$V_t = 1.5v$

$k'_n \frac{W}{L} = 0.2\, mA/V^2$




b. The device is biased for a 0.15 mA drain current. Find the Q-point.

$I_{DQ} = 0.15\ mA$

$V_{DQ} = V_{DSQ} = V_{DD} - I_{DQ} R_D$

$V_{DSQ} = (5) - (.15)(10)$

$\boxed{V_{DQ} = 3.5v}$

$V_{IQ} = V_{GSQ}$

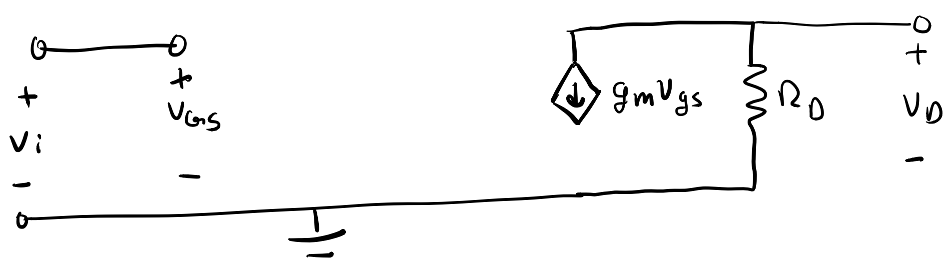
$I_{DQ} = \frac{1}{2} k'_n \frac{W}{L} (V_{IQ} - V_t)^2$

$.15 = \frac{1}{2} (.2) (V_{IQ} - 1.5)^2$

$1.5 = (V_{IQ} - 1.5)^2 \quad \sqrt{1.5} + 1.5 = V_{IQ}$

$V_{IQ} = 2.72v$

c. Find the voltage gain at this bias point.




$A_{vo} = \frac{V_o}{V_i} = -g_m R_D$

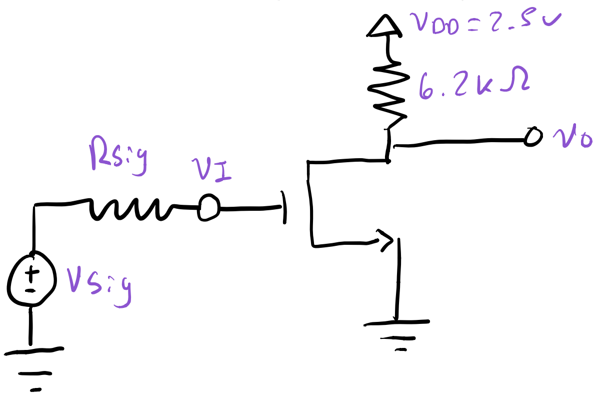
$= -(k'_n \frac{W}{L} (V_{IQ} - V_t)) R_D$

$A_{vo} = -(.2)(2.72 - 1.5)(10)$

$A_{vo} = -2.45 V/V$

2. A common source amplifier uses an NMOS transistor with $k'_n$=0.4mA/V², W/L = 10, $V_t$=0.4V, $V_{DD}$=2.5 Vand $V_A$=10V. The amplifier Q-point is at $I_{DQ}$=0.2mA and uses a drain resistor of 6.2kohms.

a. Find $V_{GSQ}$ and $V_{DSQ}$.




$R_D = 6.2k\Omega$ $V_{DD} = 2.5v$

$k'_n = .4mA/v^2$ $V_A = 10V$

$W/L = 10$ $I_{DQ} = .2mA$

$V_t = .4v$

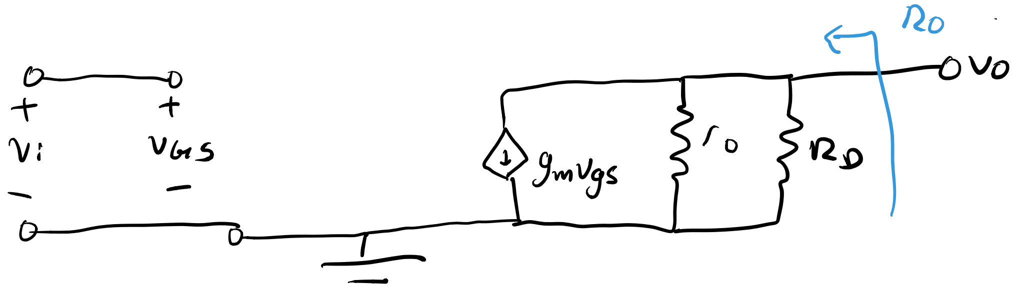
$$I_{DQ} = .2mA = \frac{1}{2} k'_n \frac{W}{L} (V_{GSQ} - V_t)^2$$

$$.2mA = \frac{1}{2} (.4)(10)(V_{GSQ} - .4)^2$$

$$\sqrt{.1} + .4 = V_{GSQ} \; ; \; \boxed{V_{GSQ} = 0.716v}$$

$$V_{DSQ} = 2.5 - I_{DQ} R_D \quad \boxed{V_{DSQ} = 1.26v}$$

b. Draw the small signal model and find $g_m$, $R_{in}$, $A_{vo}$, and $R_o$.



$R_{in} = \infty$

$g_m = k'_n \frac{W}{L}(V_{GSQ} - V_t) = (.4)(10)(.716 - .4)$

$g_m = 1.264\ mA/V$

$r_o = \frac{V_A}{I_{DQ}} = \frac{10}{.2E-3} = 50k\Omega$

$R_o = r_o \| R_D = 50 \| 6.2 = 5.52\ k\Omega$

$A_{vo} = \frac{v_o}{v_i} = -g_m(r_o \| R_D)$

$= -1.264(5.52)$

$A_{vo} = -6.98\ V/V$

c. If a load resistor is connected to the drain where $R_L$ = 15kohms, what is the gain, $A_v$.
Update your small signal model.


$A_v = \frac{V_o}{V_i} = -g_m(r_o \| R_D \| R_L)$

$= -1.264(50 \| 6.2 \| 15)$

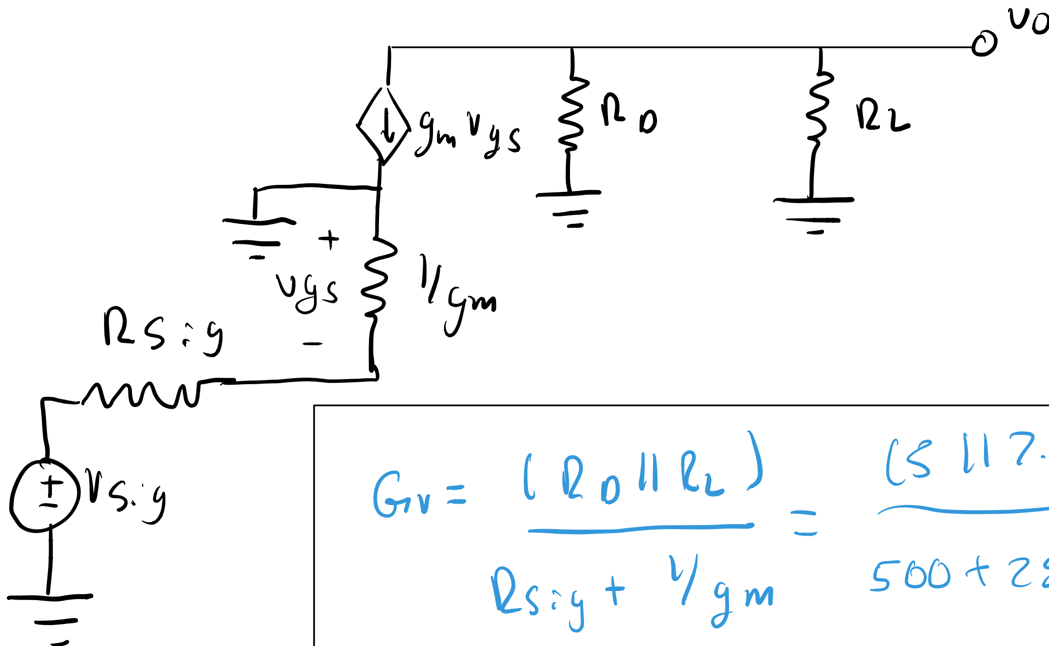
$A_v = -5.1\ V/V$

d. If a source signal, $v_{sig}$ in series with a resistance of $R_{sig}$ = 300kohms is connected to the gate, what is the gain, $G_v$.

$G_v = \frac{V_o}{V_{sig}} = -5.1\ V/V$

3. A common gate amplifier uses an NMOS transistor with $g_m$=4mA/V and a drain resistor of 5kohms and a load resistor of 7.5 kohms. The amplifier is driven by a source, $v_{sig}$, that has $R_{sig}$ = 500 ohms.

a. Find the input resistance ($R_{in}$) and the overall voltage gain, $G_v$. Draw the small signal model.




$$G_v = \frac{(R_o \| R_L)}{R_{sig} + 1/g_m} = \frac{(5 \| 7.5)}{500 + 250}$$

$$G_v = 4 \text{ V/V}$$

b. Suppose we want the input resistance to equal the signal resistance at the Q-point, $I_{DQ}$. What would the drain current Q-point need to change to for this to happen?

$R_{in} = R_{sig}$

$R_{sig} = 500$

$R_{in} = 250 = \frac{1}{g_m}$ $g_{m_1} = 4\,mA/V$

$\frac{1}{g_m} = 500,$ $g_m = 2\,mA/V$

$I_{DQ} = \frac{1}{2} k'_n \frac{W}{L} (V_{GSQ} - V_t)^2$

$g_m = k'_n \frac{W}{L} (V_{GSQ} - V_t)$

$g_m = \frac{2 I_{DQ}}{(V_{GSQ} - V_t)}$ $(V_{GSQ} - V_t) = \sqrt{\frac{2 I_{DQ}}{k'_n W/L}}$

$g_m = \sqrt{2 k'_n \frac{W}{L} I_{DQ}}$

$g_m$ reduces by $1/2$

$I_{DQ}$ reduces by $1/4$

4. A common drain amplifier has the following characteristics: $k'_n$=0.1mA/V$^2$ and $V_t$ = 0.6V. The operating point is $V_{GSQ}$=0.85 V.
   a. What is the W/L ratio for an output resistance of 300 ohms?
   b. What is the drain current at the operating point?
   c. This amplifier is connected to a 10kohm potentiometer as the load. What is the range of possible overall voltage gain?

$k'n = 0.1\ mA/V^2$

$Vt = 0.6V$

$V_{GSQ} = 0.85v$

a) $W/L$ $\quad R_O = 300\Omega$

$R_O = \frac{1}{gm} = 300;$

$gm = 3.33mA = k'n \frac{W}{L}(V_{GSQ} - Vt)$

$\frac{W}{L} = \frac{3.33}{(.1)(.85-.6)}$

$\frac{W}{L} = 133.2$

b) drain current?

$I_{DQ} = \frac{1}{2} k'n \frac{W}{L}(V_{GSQ} - Vt)^2$

$I_{DQ} = \frac{1}{2}(.1)(133.2)(.85-.6)^2$

$I_{DQ} = 0.416\ mA$

c) $G_V = \frac{R_L}{R_L + 1/gm} =$

$G_V = \frac{0}{0 + 3.33}$ $\quad R_L = 0 \quad G_V = 0$

$G_V = \frac{10}{10 + 3.33}$ $\quad R_L = 10k\Omega \quad G_V = .97\ V/v$