ECE 3150 Lab 3 Solution (By Ryan Frink)

Note: Obviously, the problem numbers should be 3.X and not 4.X

Pre-Lab:

4.1:

a)

Here we use the current equations to solve for voltage values V_1 and V_2:

$$I_{ref} = \frac{k_n}{2}(V_1 - V_{TN})^2(1 + \lambda_n V_1)$$

Since the value of I_{ref} has been provided here, one can easily solve for V_1 = 1.2 V.

Similarly, to solve for the voltage V_2, I once again write:

$$I_{ref} = -\frac{k_p}{2}(V_2 - V_{DD} - V_{TP})^2\left(1 - \lambda_p(V_2 - V_{DD})\right)$$

Now one can solve for V_2 = 8.5 V.

Now that voltages V_1 and V_2 are known, one can solve for the desired value of R_{ref}:

$$R_{ref} = \frac{V_2 - V_1}{I_{ref}}$$

The value obtained should be R_{ref} = 72 kΩ.

b)

From part a), we already know the voltages V_1 = 1.2 V and V_2 = 8.5 V. When one solves for V_3, it becomes clear that $V_3 = V_2$ = 8.5 V. To solve for V_4, one can once again turn to the current equation:

$$I_{ref} = \frac{k_n}{2}(V_3 - V_4 - V_{TN})^2(1 + \lambda_n V_4)$$

Upon solving, one finds that V_4 = 7.2 V.

c)

To solve for the small signal open circuit voltage gain of the amplifier, we break the circuit into independent stages, a common source stage and a common drain stage, and use the input/output resistances of the stages to solve for the total voltage gain.

$$A_v = A_{v1}A_{v2}\frac{R_{in2}}{R_{out1} + R_{in2}}$$

When one works through the analysis, they will find that here $A_{v1} = -g_{m1}(r_{o1}||r_{o4})$ and given the characteristics of the circuit, $A_{v2} \approx 1$. Since was also know the input/output resistance behavior of the common source/drain amplifiers, the expression for the small signal voltage gain further reduces to:

$$A_v = A_{v1}A_{v2}\frac{R_{in2}}{R_{out1} + R_{in2}} \approx A_{v1} = -g_{m2}(r_{o2}||r_{o4}) = -g_{mn}\left(r_{on}||r_{op}\right)$$

Now one can use relations: $g_{mn} = (2k_nI_D(1 + \lambda_nV_{DS}))^{1/2}$ and $r_{on,op} = 1/(I_D\lambda_{n,p})$ to solve for all necessary values. Upon doing so, the value obtained for the small signal voltage gain should be around $A_v \approx -83$.

Post-Lab:

4.4:

a)

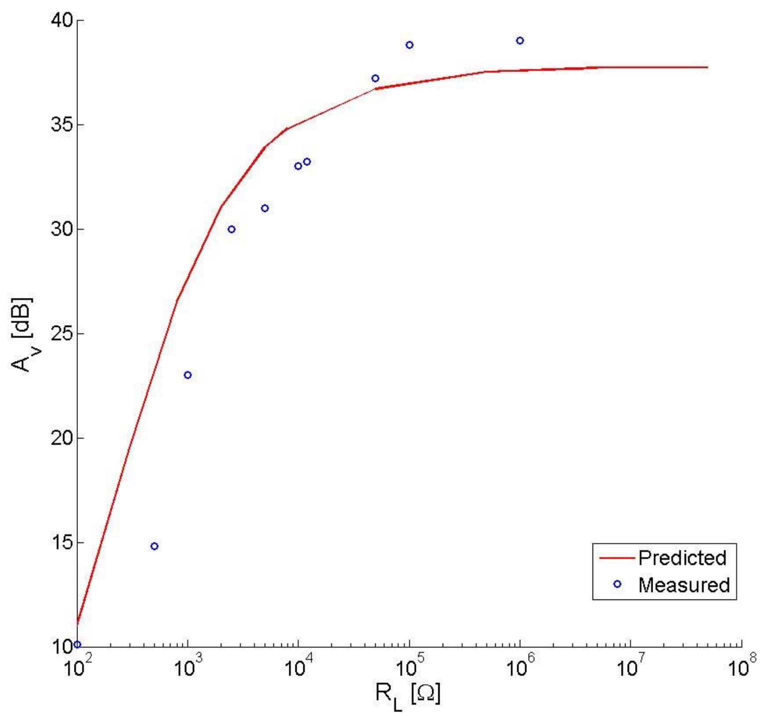
	V_1	V_2	V_3	V_4
Predicted	1.2 V	8.5 V	8.5 V	7.2 V
Measured	0.94 V	8.42 V	5.89 V	4.92 V

It is quite clear to see that I had difficulty in adjusting V_{BIAS} to the correct value to produce the expected voltage values from the pre-lab work.

b)

	|Voltage Gain| dB
Predicted	83
Best Measured	92.3

c)



My measured values were only in rough agreement with the predicted ones, which is likely due to issues associated with matching the transistors in the circuit.

4.5:

a)

Solving for these DC voltage values was done in a similar manner as those in pre-lab. Voltage value $V_1 = I_{ref}R_{ref} = 6.7$ V. Voltage value V_2 is once again solved for using the current equation, upon doing so one obtains $V_2 = 8.5$ V. Similarly, V_3 is again solved for using the current equation, which yields $V_3 = 5.5$ V. Voltage value $V_4 = V_1 = 6.7$ V.

b)

This problem is solved in the same manner as that of 4.1 c). Once again:

$$A_v = A_{v1}A_{v2}\frac{R_{in2}}{R_{out1} + R_{in2}}$$

Since the first stage is a common source amplifier and the second stage is a common gate amplifier, the necessary expressions for A_v and input/output resistance are well known.

$$A_{v1} = -g_{mn} r_{on}$$

$$A_{v2} = g_{mn} r_{on}$$

$$R_{in2} \approx \frac{1}{g_{mn}}\left(1 + \frac{g_{mp} r_{op}^2}{r_{on}}\right)$$

$$R_{out1} = r_{on}$$

Upon evaluating, one should find the value of small signal voltage gain to be somewhere around A_v = -10,000 or 80 dB.

c)

	V_1	V_2	V_3	V_4
Predicted	6.7 V	8.5 V	5.5 V	6.7 V
Measured	6.89 V	8.42 V	3.82 V	3.66 V

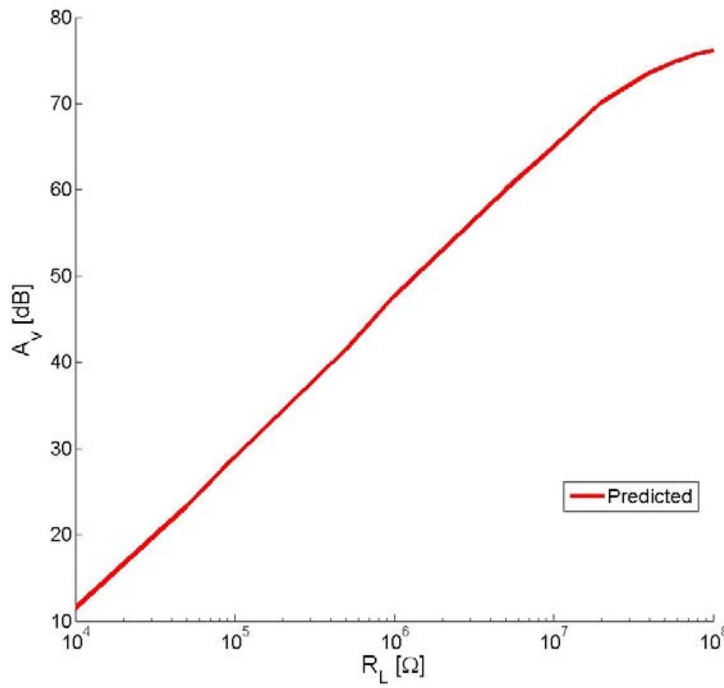
The same problem that was observed in 4.5 a) is also seen here. A possible explanation to this issue is that differences between chip packages made balancing the circuit very difficult to do with an external voltage bias.

d)

	|Voltage Gain| dB
Predicted	80
Best Measured	86.2

The measured (in the limit of an infinite load resistor i.e. open circuit) voltage gain and the predicted are fairly close.

e)



Here I have not included all my measured values due to the issue of the transistors leaving saturation producing undesired results. However, those groups able to maintain the correct region of operation in all transistors used should have been able to measure values of A_v which are close to the predicted values (if one includes the loading of the circuit by the scope due to the high output resistance of the amplifier).