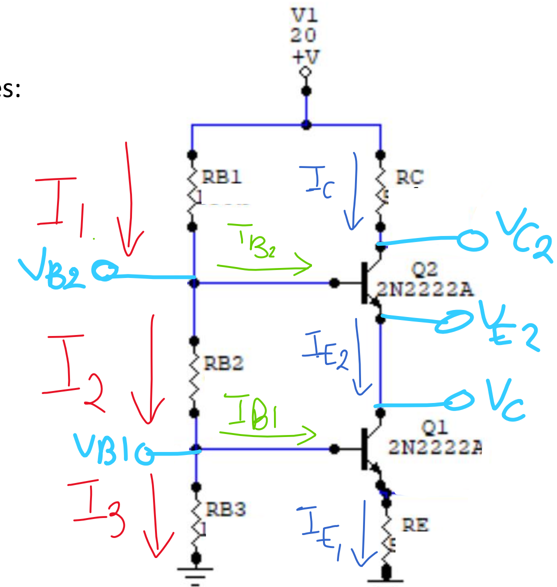
Contents

Part I: The Cascode Amplifier

Biasing the Cascode Amplifier using the 1/4th Rule

To bias the Cascode Amplifier, the 1/4th Rule will be used, which states:



Circuit 1.1: Bias Circuit for Cascode Amplifier

$$V_{CC} - V_C = \frac{V_{CC}}{4}$$

$$V_{E2} = \frac{V_{CC}}{4}$$

$$V_{B2} = \frac{V_{CC}}{2} + V_{BE2}$$

Therefore:

$$20\ V - V_{C2} = \frac{20}{4} = 5\ V$$

$$V_{C2} = 15\ V \qquad V_{E2} = 5\ V$$

$$V_{B2} = \frac{20}{2} + 0.7 = 10.7$$

We can then proceed to calculate currents and resistor values:

$I_{C2} = \frac{V_{CC}-V_{C2}}{R_C} = 1\ mA$ $\qquad I_{B2} = \frac{I_{C2}}{\beta} = 5.99\ \mu A \approx 6\ \mu A$ $\qquad I_{E2} = I_{B2}(\beta+1) = 1.006\ mA$

$I_{C1} = I_{E2} = 1.006\ mA$ $\qquad I_{B1} = \frac{I_{E2}}{\beta} = 6\ \mu A$ $\qquad I_{E1} = I_{B1}(\beta+1) = 1.006\ mA$

$I_1 = \frac{I_{E2}}{\sqrt{\beta}} = 77.85\ \mu A$ $\qquad I_2 = I_1 - I_{B2} = 71.85\ \mu A$ $\qquad I_3 = I_2 - I_{B1} = 65.85\ \mu A$

$R_{B1} = \frac{V_{CC}-V_{B2}}{I_1} = 119.5\ k\Omega$ $\qquad R_{B2} = \frac{V_{B2}-V_{B1}}{I_2} = 69.6\ k\Omega$ $\qquad R_{B3} = \frac{V_{B1}}{I_3} = 86.6\ k\Omega$

$R_E = \frac{V_{E1}}{I_{E1}} = 5\ k\Omega$ and $R_C = 5\ k\Omega$ given the condition for maximum output impedance.

$g_{m1} = \frac{I_{C1}}{V_T} = 0.040$ $\qquad g_{m2} = \frac{I_{C2}}{V_T} = 0.040$ $\qquad r_{\pi 1} = \frac{\beta}{g_{m1}} = 4175\ \Omega$ $\qquad r_{\pi 2} = \frac{\beta}{g_{m2}} = 4175\ \Omega$

The closest common resistor values are:

$$R_{B1} = 120\ k\Omega \quad R_{B2} = 68\ k\Omega \quad R_{B3} = 82\ k\Omega$$

$$R_E = 5.1\ k\Omega \quad \text{and} \quad R_C = 4.7\ k\Omega$$

Given that the maximum low frequency pole is 500 Hz, we can calculate the value of C_E, taking its associated pole as the dominant pole, as follows:

$$\omega_{Lp3} = \frac{1}{\tau_{C_E}} = \frac{1}{C_E\left(\frac{(Rs\ ||R_{B2}||R_{B3} + r_{\pi 1})}{\beta+1} + R_E\right)} = 500\ Hz$$

$$C_E = \frac{1}{\omega_{Lp3}\left(\frac{(Rs\,||R_{B2}||R_{B3} + r_{\pi 1})}{\beta + 1}||R_E\right)} = 12.7\ \mu F$$

The values of C_{C_1} and C_{C_2} can then be selected to be around 0.3 μF, to ensure that the pole associated with C_E remains the dominant pole. Moreover, using a higher value capcaitor for the coupling capacitors would be uunnecessairly expensive.

The closest common capcitor values are:

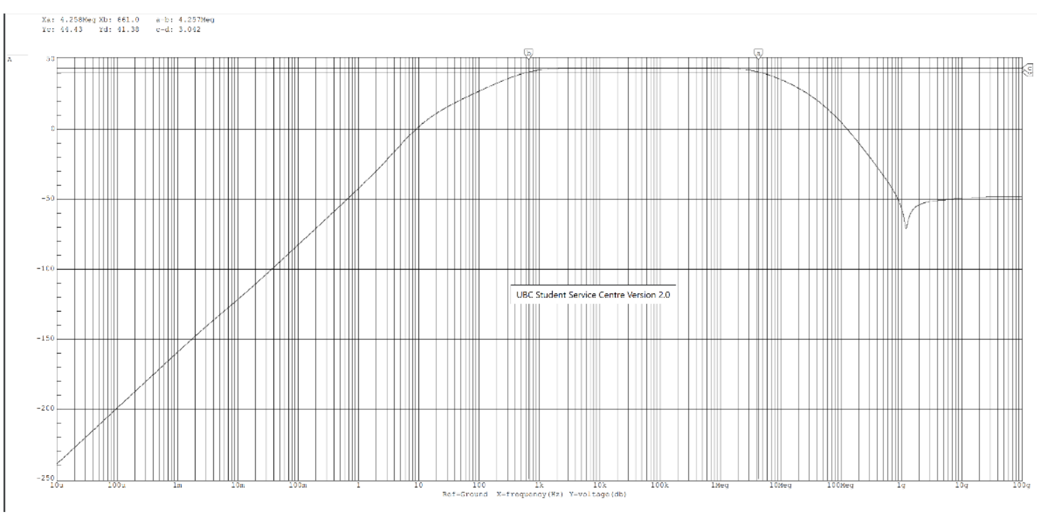
$C_E = 10\ \mu F \qquad C_{C_1} = 330\ nF \quad C_{C_2} = 330\ nF$

A. Measuring the D.C. Operating Point of the Cascode Amplifier

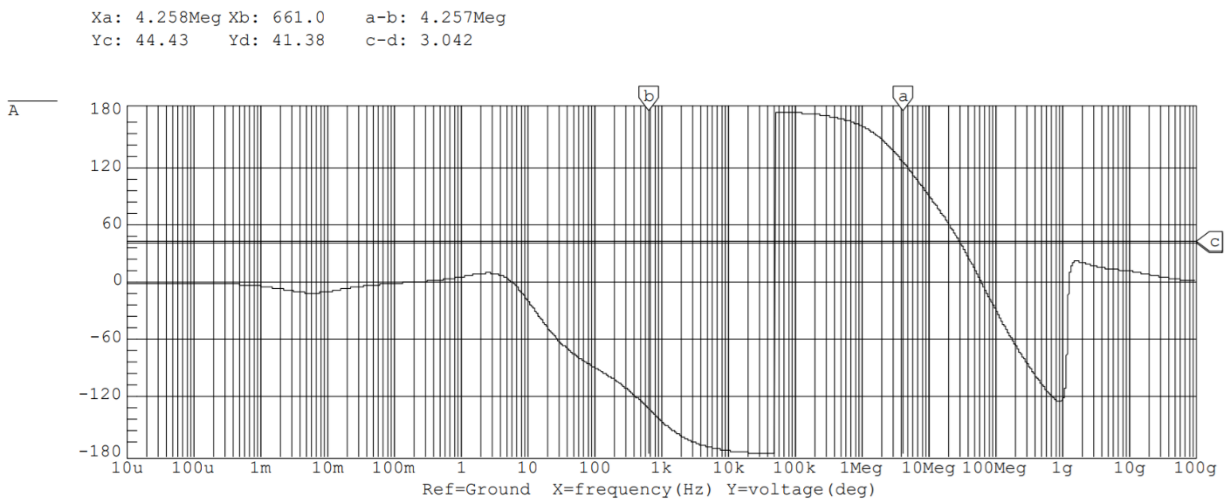
D.C. Operating Point	**1/4th Rule**	**Measured value**	**D.C. Operating Point**	**1/4th Rule**	**Measured value**
V_{B1}	$5.7\ V$	$5.794\ V$	V_{B2}	$10.7\ V$	$10.79\ V$
I_{B1}	6 μA	9.758 μA	I_{B2}	6 μA	$1.461\ mA$
V_{C1}	$10\ V$	$10.17\ V$	V_{C2}	$15\ V$	$17.81\ V$
I_{C1}	$1.006\ mA$	$1.793\ mA$	I_{C2}	$1\ mA$	$0.332\ mA$
V_{E1}	$5\ V$	$5.676\ V$	V_{E2}	$10\ V$	$10.17\ V$
I_{E1}	$1.006\ mA$	$0.997\ mA$	I_{E2}	$1.006\ mA$	$1.793\ mA$
I_1	$77.85\ \mu A$	$79.20\ \mu A$	I_2	$71.85\ \mu A$	$74.52\ \mu A$
I_3	$65.85\ \mu A$	$66.21\ \mu A$			

B. Bode Plots

Circuit 1.2 was simulated on Circuitmaker using the values calculated in part A, and its corresponding Bode plots for magnitude (**Graph 1.1**) and phase (**Graph 1.2**) were obtained.



Graph 1.1: Bode Magnitude plot of



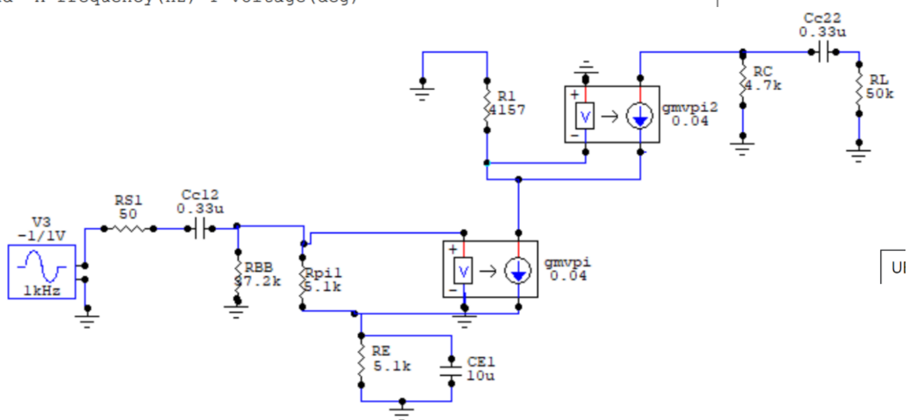
Graph 1.2: Bode Phase plot of **Circuit 1.2**

Using **Graph 1.1**, ω_{L3dB} and ω_{H3dB} were located:

$\omega_{L3dB} = 661\ Hz = 4153\ /sec$

$\omega_{H3dB} = 4.25\ MHz = 26.7\ M/sec$

Then, ω_{L3dB} was calculated using the low-frequency small-signal model as shown in **Circuit 1.3**:



Circuit 1.3: Low-frequency small signal model of **Circuit 1.2**

$$R_{BB} = R_{B2}||R_{B3}$$

$$\omega_{Lp1} = \frac{1}{\tau_{C_{C1}}} = \frac{1}{(R_S + R_{BB}||(r_\pi + R_E(1+\beta))\ \times C_{C1}} = 84.9\frac{rad}{sec} = 13.52\ Hz$$

$$\omega_{Lp2} = \frac{1}{\tau_{C_{C2}}} = \frac{1}{(R_C + R_L) \times C_{C2}} = 55.4\frac{rad}{sec} = 8.82\ Hz$$

For C_{C2}, the output stage is decoupled from the input stage:

$$\omega_{Lp3} = \frac{1}{\tau_{C_{C2}}} = \frac{1}{\frac{(R_S||R_{BB} + r_\pi)}{1+\beta}\ ||R_E \times C_E} = 4.437k\frac{rad}{sec} = 706\ Hz$$

The low frequency zeros due to C_{C1} and C_{C2} are 0, and the third zero can be calculated as follows:

$$\omega_{Lz3} = \frac{1}{R_E \times C_E} = 19.7\frac{rad}{sec} = 3.701Hz$$

$$\omega_{L3dB} = \sqrt{84.9^2 + 55.4^2 + 4437^2 - 2 \times 3.7^2} = 4438\frac{rad}{sec} = 706.3\ Hz$$

To find the High-Frequency poles, Miller's theorem was applied on the High-Frequency Small Signal model of **Circuit 1.2.** The value of C_μ and C_π, to be $C_\mu = 4.7\ pF$ and $C_\pi = 19\ pF$. These were then used to calculate the Miller capacitances, and calculate ω_{H3dB}:

$$\omega_{Hp1} = \frac{1}{\tau_{C_{19+4.7pf}}} = \frac{1}{(R_S||R_{BB}||r_\pi)\ \times (19 + 2 \times 4.7)pF} = 8.4M\ \frac{rad}{sec}$$

$$\omega_{Hp2} = \frac{1}{\tau_{C_{19+4.7\ pf2}}} = \frac{1}{(R_C||R_L)\ \times (19 + 2 \times 4.7)pF} = 8.43M\ \frac{rad}{sec}$$

$$\omega_{Hp3} = \frac{1}{\tau_{C_\mu}} = \frac{1}{(R_C||R_L)\ \times 4.7pF} = 8.39M\ \frac{rad}{sec}$$

$$\tau_{H3dB} = \sqrt{\frac{1}{\omega_{Hp1}}^2 + \frac{1}{\omega_{Hp2}}^2 + \frac{1}{\omega_{Hp3}}^2} = 1.19 \times 10^{-7}\ /sec$$

$$\omega_{H3dB} = \frac{1}{\tau_{H3dB}} = 8.39M\frac{rad}{sec} = 1.34\ MHz$$

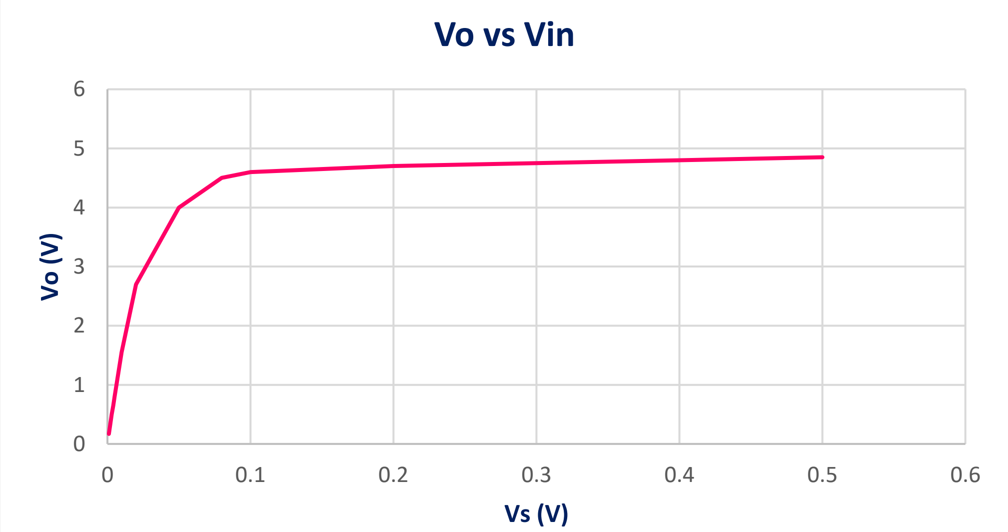
Table 1.1: Table Summarizing the calculated and measured values fo the low and high 3dB frequencies

	$\boldsymbol{\omega_{L3dB}\ (Hz)}$	$\boldsymbol{\omega_{H3dB}\ (Hz)}$
Measured Value	661	4.25 M
Calculated Value	706.3	1.34 M
% Error	6.9%	68.5%

The calculated value of the low frequency pole is quite accurate, with a very low % error. The high frequency pole, however, has a very large % error, which could be due to a multitude of reasons, one being that the standard capacitor value for C_E was used instead of the original calculated value. Other errors could be related to the low resolution for CircuitMaker Software which was used. Nevertheless, one can conclude in the real world, designing circuits is much more complex due to the availability of components with the desired characteristics and values, as seen with the value of C_E, and using an alternative "close" standard value could still yield a large error.

C. Mid-Band Frequency

From **Graph 1.1**, the point at 10 kHz on the curve is about exactly the middle of the band, which is why I chose a mid-band frequency of 10 kHz. I then proceeded to vary the source peak voltage from 0.1 to 1, which provided a reasonable range of data points, giving the desired shape of the Voltage Transfer Curve.



Graph 1.3: Voltage Transfer Curve for the Cascode Amplifier

From the graph, it appears that the graph stops being Linear at Vs = 20 mV.

D. Measuring Input Impedance

Now to calculate Input Impedance, I used the Input stage from **Circuit 2.1** to calculate the Input impedance as follows:

$$R_{in} = R_{BB}||r_{\pi} = 37.17k||4175 = 3.753\ k\Omega$$

Then, I measured the Input Impedance by simulating the circuit, which turned out to be:

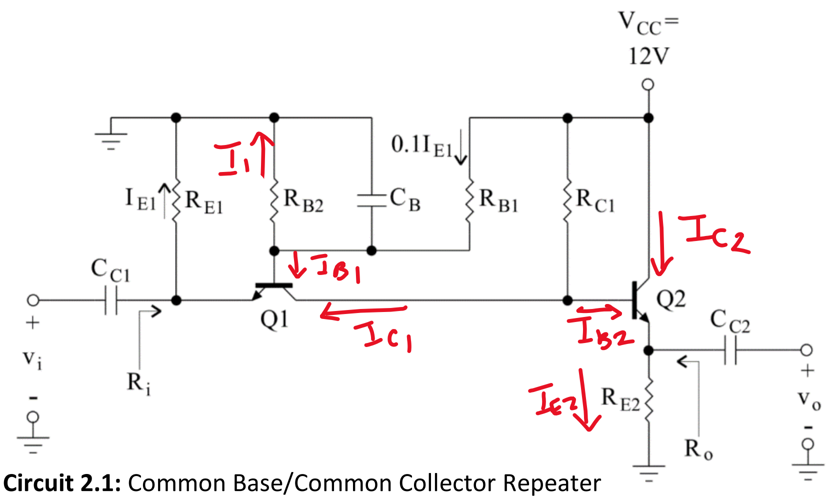
$$R_{in} = \frac{V}{I} = \frac{705.3\ \mu V}{106\mu A} = 6.651\ k\Omega$$

The calculated Input Impedance is smaller than the measure input impedance by about 43.5%, which is a large error. However, both values are in the same order of magnitude. This is, however, not surprising, since Miller's theorem only provides an approximation to the circuit. Moreover, the measured values may be quite inaccurate, due to the fact that the software used is quite old, and the transistor specifications for the 2N2222A on the software may be a different from software to software.

Part II: Cascaded Amplifiers

Determining Circuit Components of the Common Base/Common Collector Repeater

We will be using the 1/3rd Rule to calculate the voltages **Circuit 2.1** :



Circuit 2.1: Common Base/Common Collector Repeater

$V_{E1} = \frac{V_{CC}}{3} = 4V$ $\quad V_{c1} = \frac{2V_{CC}}{3} = 8V$ $\quad V_{B1} = V_{E1} + 0.7 = 4.7V$

$V_{E2} = V_{B2} - 0.7 = 7.3V$ $\quad V_{c2} = V_{CC} = 12V$ $\quad V_{B2} = V_{c1} = 8V$

We can then proceed to calculate currents and resistor values using the criteria that $R_i = R_o = 50 \pm 5\Omega$

$$R_i = R_{E1} \left|\left| \frac{v_{\pi 1}}{\beta + 1} = \frac{V_{E1}}{I_{E1}} \right|\right| \frac{V_T \times \beta}{I_{C1}(\beta + 1)} = \frac{V_{E1}}{I_{E1}} \left|\left| \frac{V_T}{I_{E1}} = \frac{4}{I_{E1}} \right|\right| \frac{25\ mV}{I_{E1}} = 50\Omega$$

Solving for I_{E1}, we get $I_{E1} = 0.5\ mA$

$I_{B1} = \frac{I_{E1}}{\beta} = 3.1\ \mu A$ $\quad I_{C1} = \beta I_{B1} = 0.5\ mA$ $\quad I_1 = 0.1 I_{E1} - I_{B1} = 0.05\ mA$

Now two equations were setup to calculate R_{E2}:

$$R_o = 50\Omega = \left(\frac{V_T \times R_{E2}}{V_{E2}} + \frac{R_{C1}}{\beta+1}\right) || R_{E2} \qquad \textbf{e.q. 1}$$

$$R_{C1} = \left(\frac{V_{E1} \times R_{E2}(\beta+1)}{R_{E2} \times I_{C1}(\beta+1) + V_{E2}}\right) \qquad \textbf{e.q. 2}$$

After solving **e.q.1** & **e.q.2**:

$R_{C1} = 7.605\ k\Omega$ $\quad R_{E2} = 1.543\ k\Omega$

Now:

$I_{E2} = \frac{V_{E2}}{R_{E2}} = 4.7mA$ $\quad I_{B2} = \frac{I_{E2}}{\beta+1} = 29\ \mu A$ $\quad I_{C2} = \beta I_{B2} = 4.7\ mA$

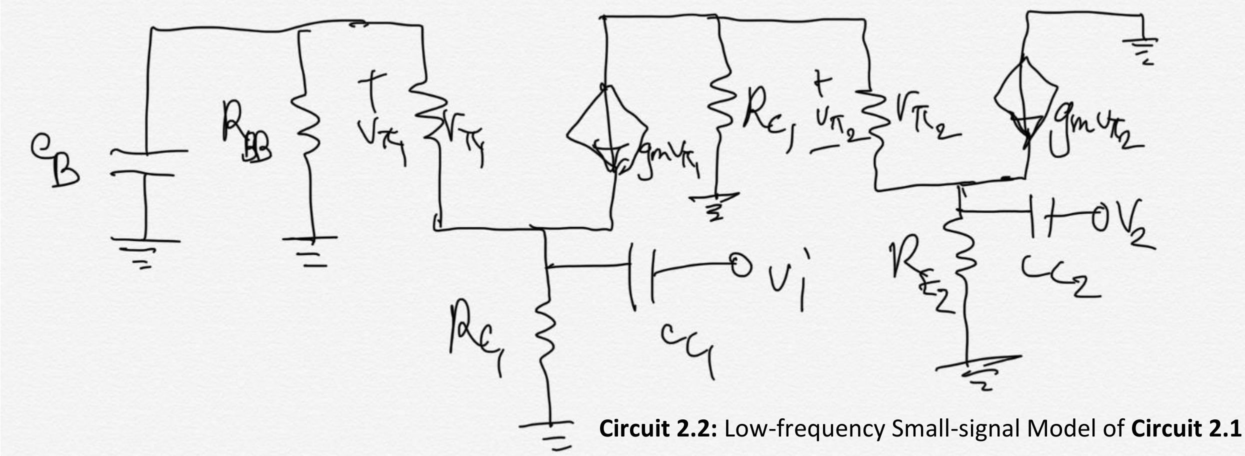
$R_{B1} = \frac{V_{CC} - V_{B1}}{0.1 I_{E1}} = 146\ k\Omega$ $\quad R_{B2} = \frac{V_{B1}}{0.1 I_{E1} - I_{B1}} = 100\ k\Omega$ $\quad R_{E1} = \frac{V_{E1}}{I_{E1}} = 8\ k\Omega$

$g_{m1} = \frac{I_{C1}}{V_T} = 0.020 \qquad g_{m2} = \frac{I_{C2}}{V_T} = 0.188 \qquad r_{\pi 1} = \frac{\beta}{g_{m1}} = 8100\,\Omega \qquad r_{\pi 2} = \frac{\beta}{g_{m2}} = 861.7\,\Omega$

The closest common resistor values are:

$$R_{B1} = 150\,k\Omega \qquad R_{B2} = 100\,k\Omega \qquad R_{E1} = 8.1\,k\Omega$$

Given that the maximum low frequency pole is 1000 Hz, we can calculate the values of C_{C_1}, C_{C_2} and C_B using the low-frquency small-signal model of the circuit as shown in **Circuit 2.2**:



Circuit 2.2: Low-frequency Small-signal Model of **Circuit 2.1**

$$\omega_{Lp1} = \frac{1}{\tau_{C_{C_1}}} = \frac{1}{C_{C_1}\left(\frac{r_{\pi 1}}{\beta + 1}||R_{E1}\right)} = \frac{1}{C_{C_1} \times 49.39}$$

$$\omega_{Lp2} = \frac{1}{\tau_{C_{C_2}}} = \frac{1}{C_{C_2}\left(\frac{r_{\pi 2} + R_{C1}}{\beta + 1}||R_{E2}\right)} = \frac{1}{C_{C_2} \times 50.21}$$

Since the impedance seen by both C_{C_1}& $C_{C_2}$are more or less the same, we can approximate them to be equal:

$$\omega_{L3dB} = \sqrt{2 \times \omega_{Lp2}} = 2000\pi = \sqrt{2 \times \frac{1}{C_{C_2} \times 50.21}^2}$$

$$C_{C_1} \approx C_{C_2} = \frac{1}{2000\pi(49.39)} = 4.48\,\mu F$$

Now:

$$\omega_{Lp1} = \frac{1}{\tau_{C_{C_1}}} = \frac{1}{C_{C_1} \times 49.39} = 4.519\,\frac{krad}{sec} = 719.3\,Hz$$

$$\omega_{Lp2} = \frac{1}{\tau_{C_{C_2}}} = \frac{1}{C_{C_2} \times 50.21} = 4.445\,\frac{krad}{sec} = 707.5\,Hz$$

The value of C_B needs to be selected such that its associated pole is at least a decade lower than that of C_{C_1} & C_{C_2}:

$$\omega_{Lp3} = \frac{1}{\tau_{C_B}} = \frac{1}{C_B((R_{E1}(\beta+1)+r_{\pi 1})||R_{BB})} = 70\ Hz$$

$$C_B = \frac{1}{140\pi \times 59081} = 38\ nF$$

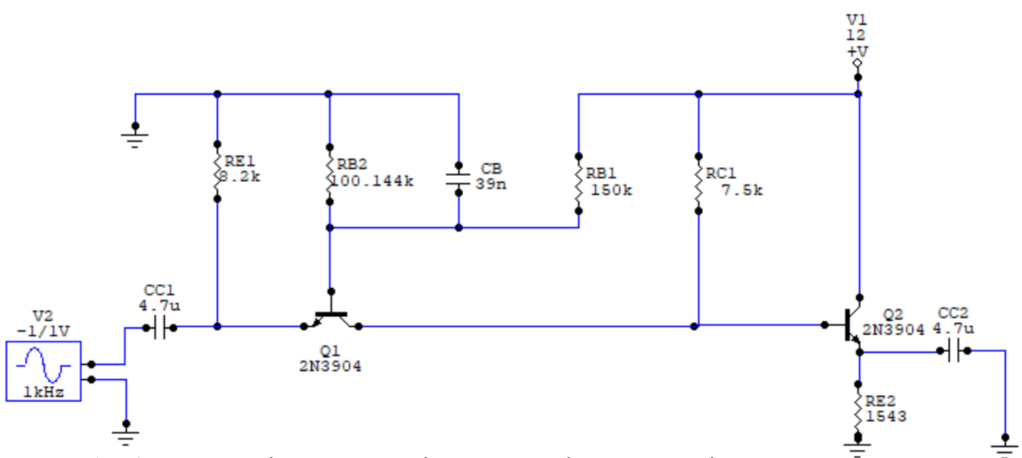
B. Measuring R_i and R_o

The closest common resistance and capacitance values that will be used are as follows:

$R_{B1} = 150\ k\Omega$ $R_{B2} = 100\ k\Omega$ $R_{E1} = 8.2\ k\Omega$ $R_{C1} = 7.5\ k\Omega$

$R_{E2} = 1.5\ k\Omega$ $C_B = 39\ nF$ $C_{C_1} = C_{C_2} = 4.7\ \mu F$

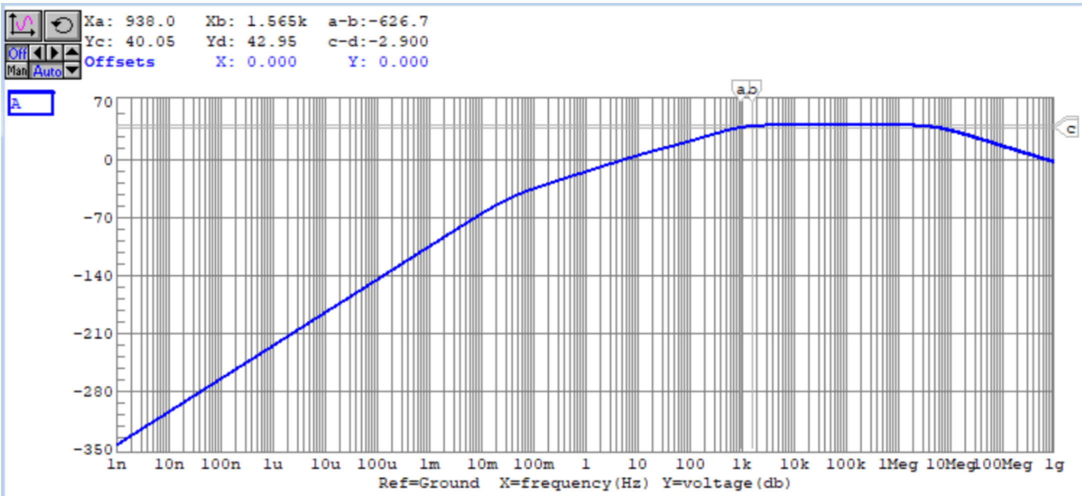
The wired up circuit is shown in **Circuit 2.3**.



Circuit 2.3: Complete circuit with resistor and capacitor values

After simulating tis circuit, the low frequency 3dB pole was measured to be 1.19 kHz, which does not match our specifications, thus, the resistor and capcitor values were altered untilt he desired specifications were met, yielding a frequency of 938 Hz:

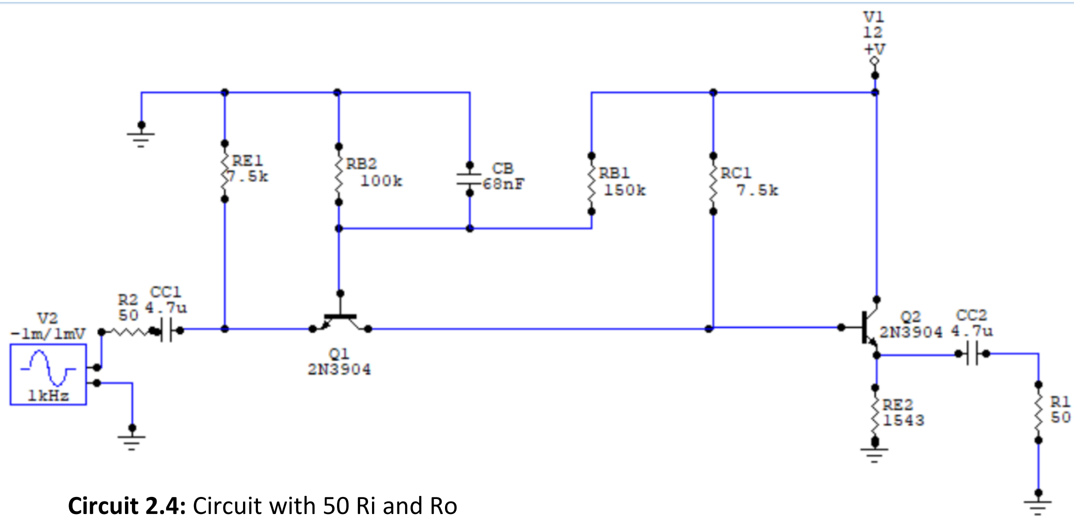
$R_{E1} = 7.5\ k\Omega$ $C_B = 68\ nF$



Graph 2.1: Magnitude Bode plot of the circuit with desired

C. Low Frequency Cut-in and High Frequency Cut off

Now, an input impedance of 50 ohms and an output impedance of 50 ohms were added to **Circuit 2.4:**



Circuit 2.4: Circuit with 50 Ri and Ro

This yielded:

$\omega_{L3dB} = 726\ Hz$ $\omega_{H3dB} = 3.59\ MHz$

To bring those values closer to the specifications, the following values were changed:

$$C_B = 33\ nF$$

And now $\omega_{L3dB} = 921\ Hz$, which is closer to the desired characteristic of a low cut off frequency of 1000 Hz.

Part III: The Differential Amplifier

A. Bode Plot for Differential Small Signal Inputs

The Differential Amplifier circuit was set up as shown in **Circuit 3.1**, using a current mirror as a current source:

$I_{E1} = I_{E1} \approx 1\ mA$

$V_O = V_{C1} - V_{C2}$ **e.q. 1**

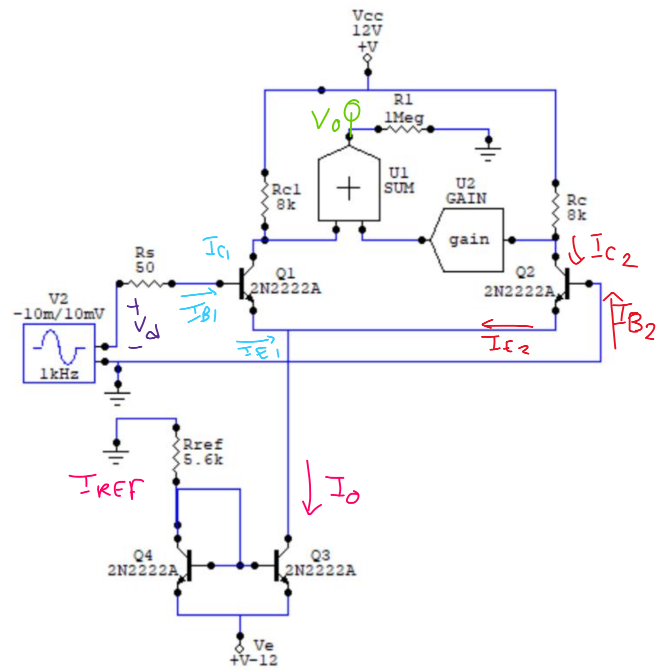
Equation 1 must be true for a differential amplifier, which is why an adder block was used to add V_{C1} and V_{C2}, and a gain block of value -1 was added after V_{C2} to ensure that it is subtracted from V_{C1}.

R_{REF} can be calculated as follows:

$$I_{REF} = I_O\left(1+\frac{2}{\beta}\right) = 2mA\left(1+\frac{2}{167}\right) = 2.02\ mA$$

$R_{REF} = \frac{V-(V_E+V_{BE})}{I_{REF}}$, where $V_E = -12$, $V_{BE} = 0.7$ and $V = 0V$

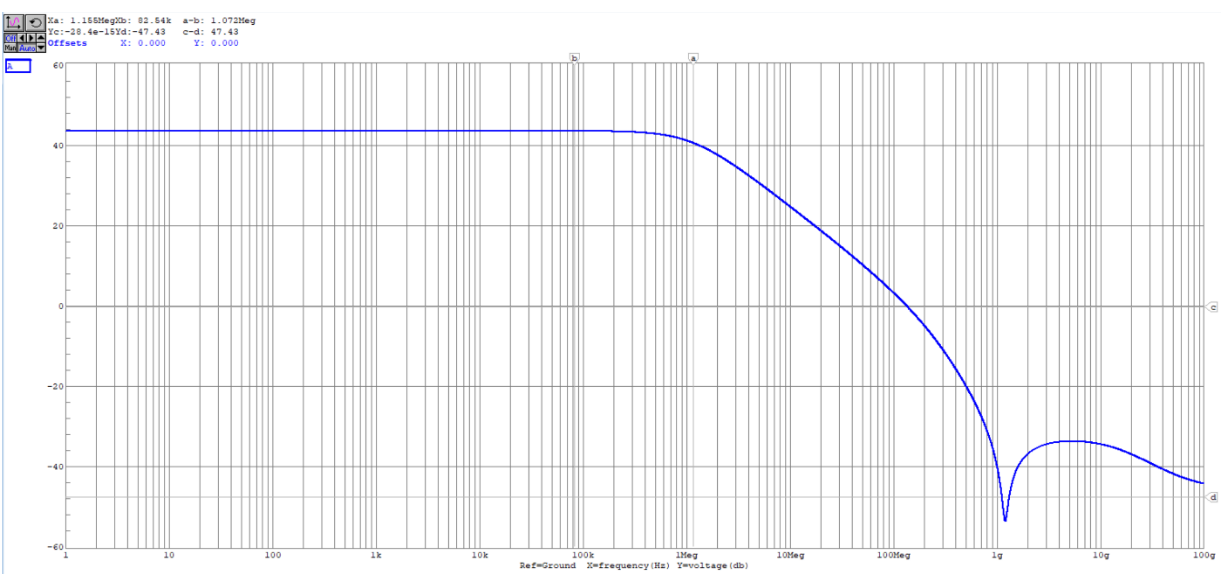
$$R_{REF} = \frac{-11.3}{I_{REF}} = 5.594\ k\Omega$$



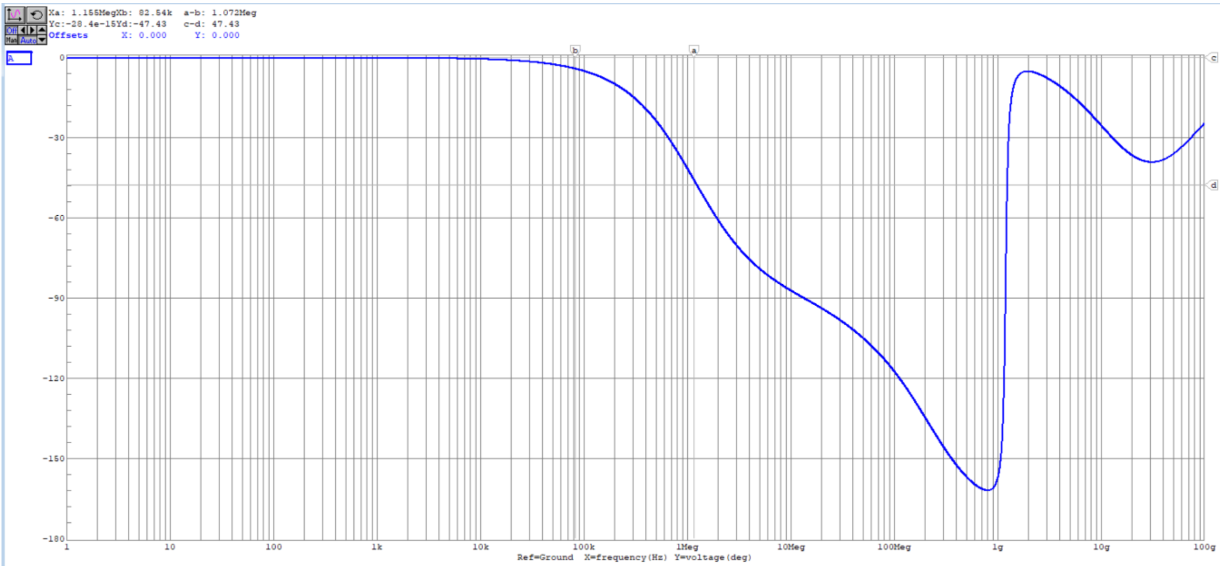
Circuit 3.1: The Differential Amplifier

The closest common resistor value is 5.6 $k\Omega$.

After simulating **Circuit 3.1**, the Bode Plot for Magnitude (**Graph 3.1**) and Phase (**Graph 3.2**) were generated.



Graph 3.2: Bode Plot of Magnitude (dB)

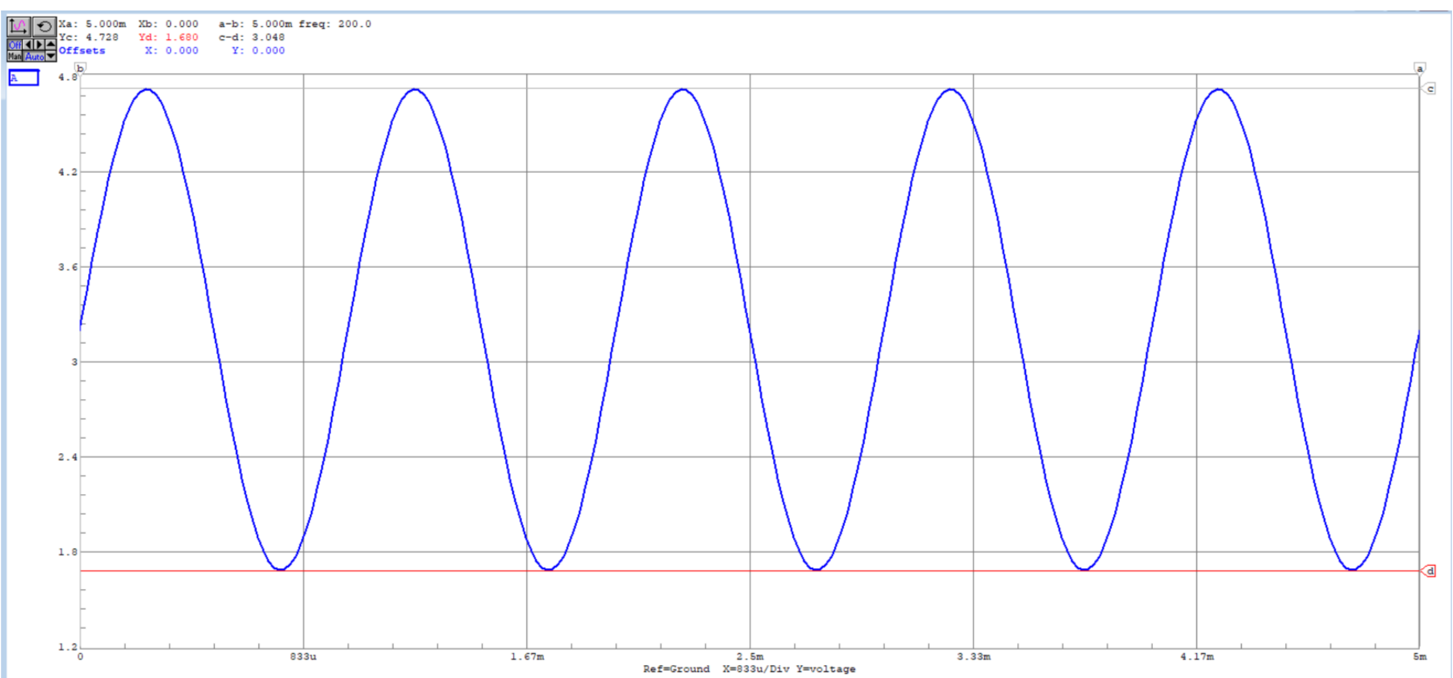


Graph 3.2: Bode Plot of Phase (degrees)

Then, ω_{H3dB} graphically obtained from **Graph 3.1** to be $f_{H3dB} = 1.212\ MHz$.

To find the differential gain, the source was first set to a small voltage signal of 10 mV. Then, the amplitude of the Voltage output, $V_p = \frac{V_{pp}}{2}$, and V_{pp} can be measured from the transient graph (**Graph 3.3**):

$V_{pp} = 3.048\ V$ $\qquad\qquad$ $V_p = \frac{3.048}{2} = 1.524\ V$



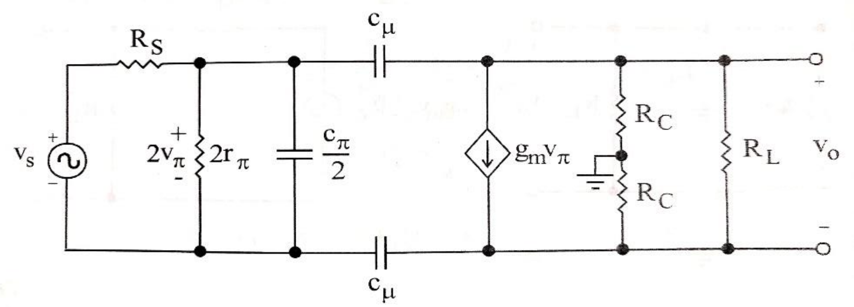
Graph 3.3: Transient graph of the Circuit

Now, using V_p, we can find the differential gain, A_d:

$$|A_d| = \left|V_p \times \frac{1}{V_S}\right| = 152.4\ \frac{V}{V}$$

B. Comparing Predicted and Calculated Values

To calculate ω_{H3dB}, Miller's theorem is applied on **Circuit 3.2**:



Circuit 3.2: High-frequency Small Signal Model (From Handout 14)

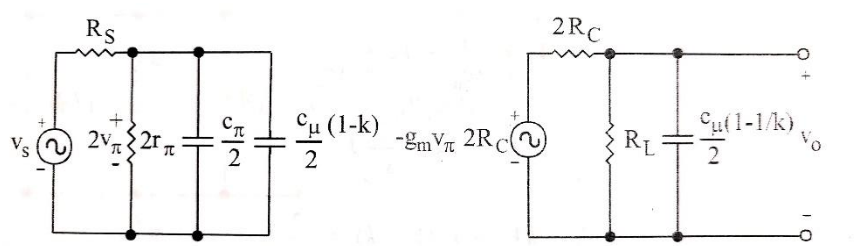
As done in previous sections, C_μ and C_π were found from the datasheet

$C_\mu = 4.7\ pF$ and $C_\pi = 19\ pF$

Now, applying Millers Theorem:

$\beta = 167$ $\quad I_E = 1\ mA$ $\quad I_C = \frac{\beta}{\beta+1} I_E = 0.99\ mA$ $\quad g_m = \frac{I_C}{V_T} = 0.0396 \approx 0.04$

$r_\pi = \frac{\beta}{g_m} = 4.217\ k\Omega$ $\quad k = -g_m R_C \frac{R_L}{R_L + 2R_C} = -318.1$



$\frac{C_\mu}{2}(1-k) = 750\ pF$

Circuit 3.3: Miller's theorem (From Handout 14)

$$\omega_{Hp1} = \frac{1}{\tau_{C_{19/2+750pf}}} = \frac{1}{(R_S||2r_\pi)\ \times (759)pF} = 26.5M\ \frac{rad}{sec} = 4.23\ MHz$$

$$\omega_{Hp2} = \frac{1}{\tau_{C_\mu}} = \frac{1}{2R_C\ \times 4.7pF} = 13.3\ M\ \frac{rad}{sec} = 2.12\ MHz$$

$$\tau_{H3dB} = \sqrt{\frac{1}{\omega_{Hp1}}^2 + \frac{1}{\omega_{Hp2}}^2} = 5.29 \times 10^{-7}\ /sec$$

$$\omega_{H3dB} = \frac{1}{\tau_{H3dB}} = 11.9\ M\frac{rad}{sec} = 1.89\ MHz$$

Finally, to calculate gain, we use the small-signal mid-band model:

$$\frac{V_o}{V_S} = \frac{V_o}{V_\pi} \times \frac{V_\pi}{V_S} = -318.1 \times \frac{\frac{r_\pi}{2r_\pi+50} \times V_S}{V_S} = -158.1$$

$$|A_d| = 158.1\frac{V}{V}$$

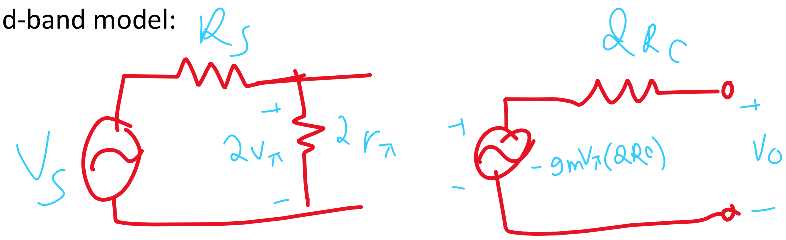


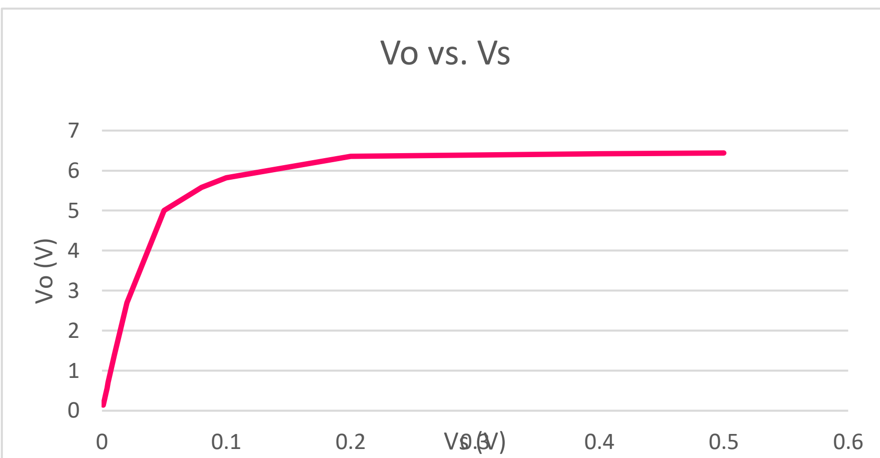
Table 3.1: Table comparing the measured and calculated values of f_{H3dB} and A_d

	$f_{H3dB}\ (Hz)$	$A_d\ (\frac{V}{V})$
Measured Value	$1.212\ M$	152.4
Calculated Value	$1.89\ M$	158.1
% Error	55.9%	3.74%

As shown in **Table 3.**1, the calculated value of the high frequency 3dB pole is off by a large error, which could be due to estimation of miller capacitor values from the graphs. This could also be due to the measure value being inaccurate, since it was found on Circuit Maker, a very old software, with very low resolution, which can give rise to large errors. Nevertheless, the calculated value of the differential output is quite accurate, with a very low error that can be neglected.

C. Finding Saturation Voltage

The small differential signal was applied to the amplifier, and was varied between 1 mV and 500 mV, to produce the voltage transfer curve (**Graph 3.4**)

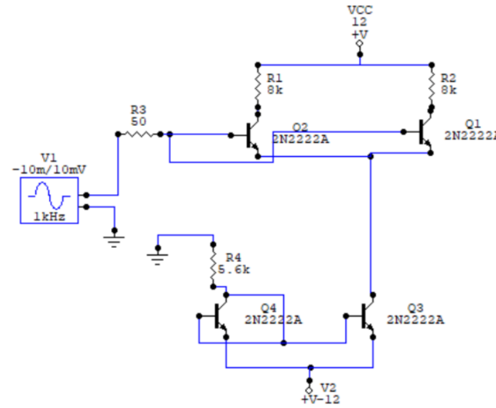


Graph 3.4: Voltage Transfer Curve for the Differential Amplifier

From the graph, we can see that the curve stops being linear around Vs= 40 mV, which is its saturation voltage.

D. Common-Mode Signal

We will be using the following formulas to calculate the Common Mode gain and Common-Mode Rejection Ratio:



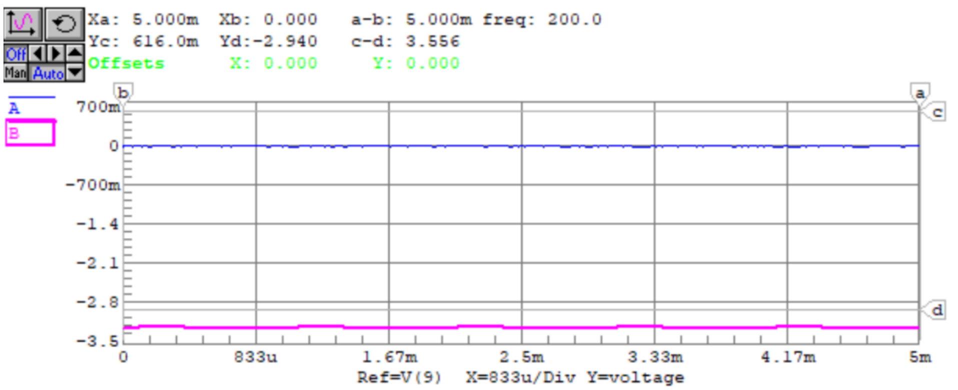
Circuit 3.2: Common Mode Circuit

$$|A_{CM}| = \frac{\triangle R_C}{2R} \quad \textbf{e.q. 1}$$

$$CMRR = 20\log_{10}\left(\frac{|A_{CM}|}{|A_D|}\right) \quad \textbf{e.q. 2}$$

I. CM Gain and CMRR No Resistance Difference

In Common Mode, since both base junctions receive the same shorted signal, we expect the gain tot be 0, since V_o is 0, and when applying the gain formula (**e.q.** 1) we get the same result. This is also the result we get from the transient graph (**Graph 3.5**).



Graph 3.5: Transient Graph Showing $V_o = 0$

Using **e.q. 2**, we can see that $CMRR$ is infinity.

II. CM Gain and CMRR for +%1/2 Resistance Difference

The values of A_{CM} and CMMR can be calculated for the Resistance difference using the same method as used in part I. The values are summarized in **Table 3.2**.

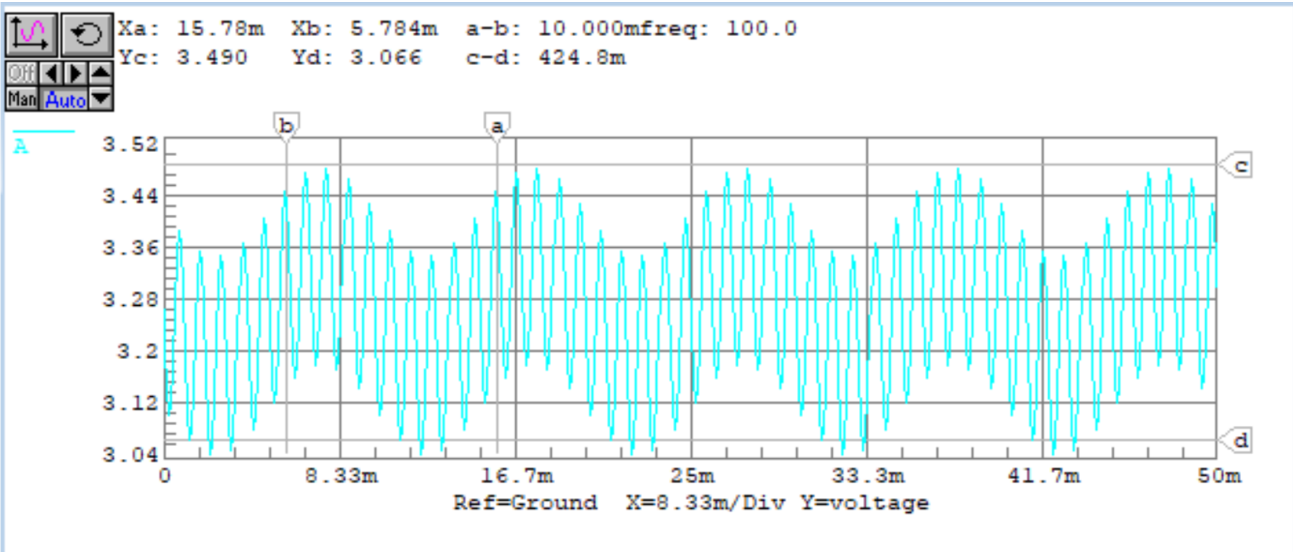
Table 3.2: Table comparing CM and CMRR

	A_{CM}	$\lvert CMRR \rvert$
No Resistance Difference	0	∞
0.5 % Resistance Difference	$7.14\ m$	86.58

E. Differential x Common Mode Signal

A 0.5mVP differential signal and a 0.5VP common-mode signal were applied to the inputs of the to the amplifier from part ii), above, and differential signal was at a frequency of 1 kHz and the common-mode signal was at 100 Hz.

The following output was observed (**Graph 3.6**)



Graph 3.6: Graph showing the differential output voltage

In this graph, we can clearly see how the wave appear modulated, which means that the lower frequency wave is “carried” by the higher frequency wave. This phenomena is explained in Part 4 below.

Part IV

Using this circuit we can use the inputsignal to encode info and we can carry it with the carrier signal

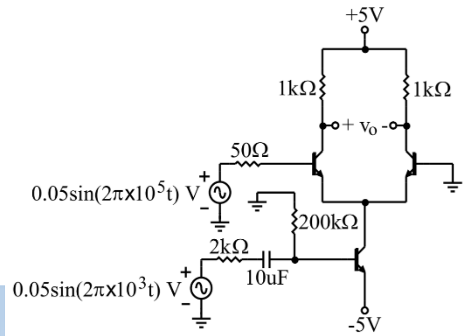
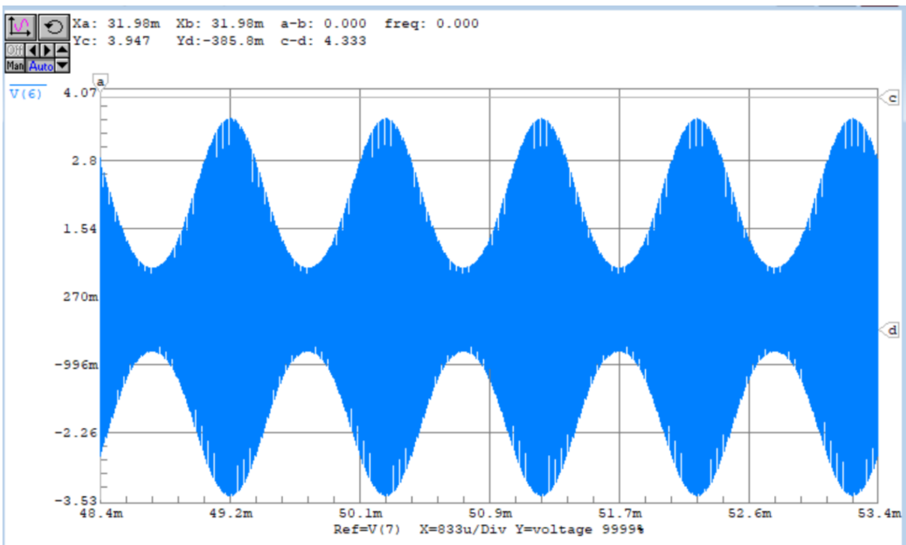


Figure 3.3. The AM Modulator.

Circuit 4.1: AM Modulator Circuit

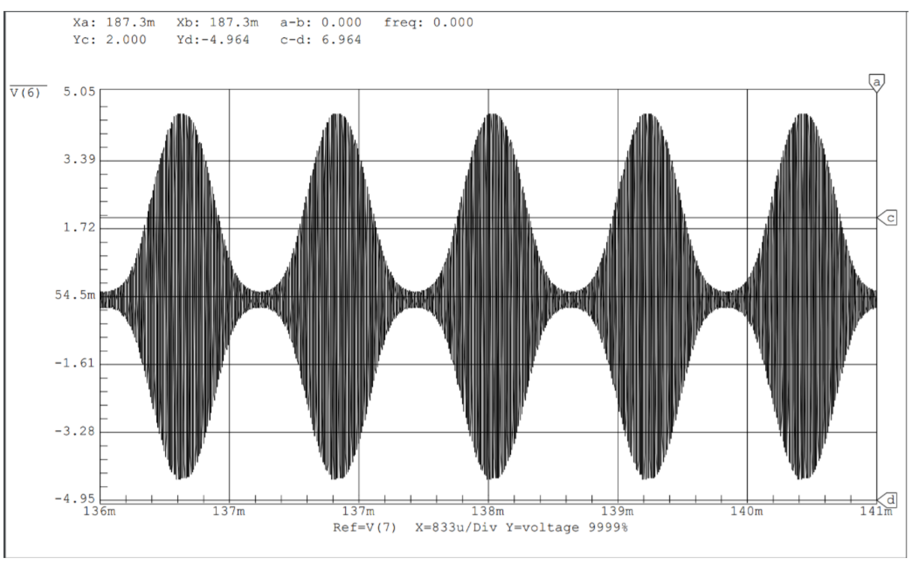
A. Sine Wave Input to Modulator



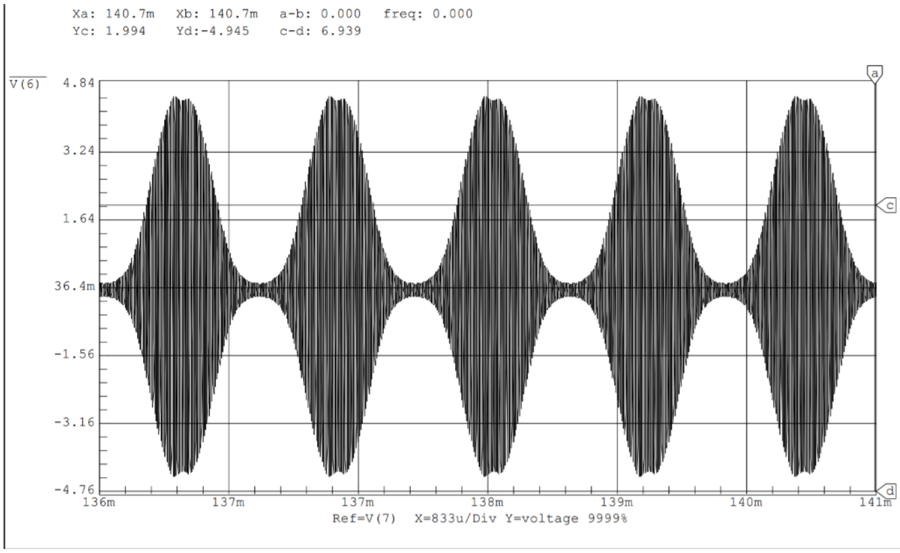
Graph 4.1: Differential Voltage Output of the Circuit with a Sine wave Input at 50 mV

B. Largest Input Signal at which Undistorted Output Signal Occurs – Sine Wave

The Input signal was varied from 10 mV to 100 mV, and the distortion of the signal happened to occur at 95 mV input signal. **Graph 4.2** shows the input signal at 90 mV, just before the distortion, and **Graph 4.3** shows the first observed instance at which the voltage distortion occurred, at 95 mV.



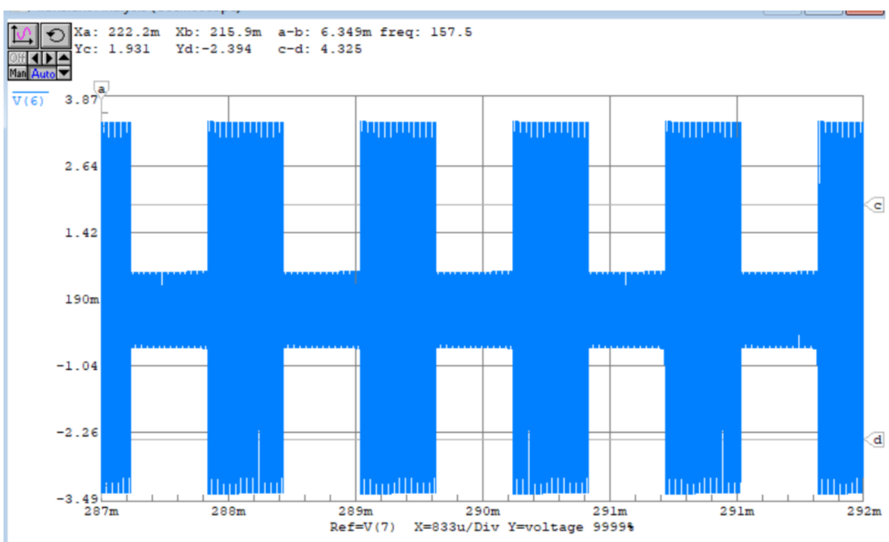
Graph 4.2: Differential Voltage Output of the Circuit with a Sine wave Input at 90 mV



Graph 4.3: Differential Voltage Output of the Circuit with a Sine wave Input at 95 mV

Examining the difference between the output signal at 90 mV and 95 mV, we see that we have lost some information when we increased the input frequency above 90 mV, which is not desirable. So, the largest input signal that results in an undistorted output in 90 mV

C. Largest Voltage at which Distorted Output Signal Occurs – Square Wave



Graph 4.4: Differential Voltage Output of the Circuit with a Square wave Input at 50 mV

Repeating the same steps in part B, the first observed instance of a distorted signal occurred at 90 mV. As discussed earlier, in order to retain all information contained in this wave , for this specific Modulator, the frequency of the input signal should not exceed 90 mV.

Discussion

The AM Modulator's main function is to produce a "carrier" Signal, which transports the input signal to the destination receiver at a frequency that can be detected by the receiver. In other words, we can use a Modulated Signal to encode information, and send it to a receiver. For example, if we want to transport a DC signal, the carrier signal would simply be a sine wave (**Figure 4.1 (b)**). However, if we want to transport a sine wave (**Figure 4.1 (a)**) at a particular frequency, we would still have a carrier sine wave, but its amplitude would be "modulated" (**Figure 4.1 (c)**), such that the output signal retains the original amplitude of the Input signal, and so there is no loss of information. Ideally, one may think that this "transport" of the signal can be done for any frequency. However, looking at the modulator signal and seeing that it consists of multiple transistors, we cannot ignore the fact that BJT's eventually reach a saturation voltage, at which the output voltage no longer increases, but always retains that value of V_{SAT}. This is an undesirable result in signal modulation, since the resultant carrier signal would be distorted, and thus would not retain all the information of the input signal.

An interesting application of this is radio transmission. The radio user sets the radio frequency to a particular frequency to receive signals from a specific radio station, which operates at that frequency. Am Modulation is used of Modulate all of the radio signals transmitted by the radio stations and carry them at the frequency that can be detected by the radio receivers as set by the radio user.

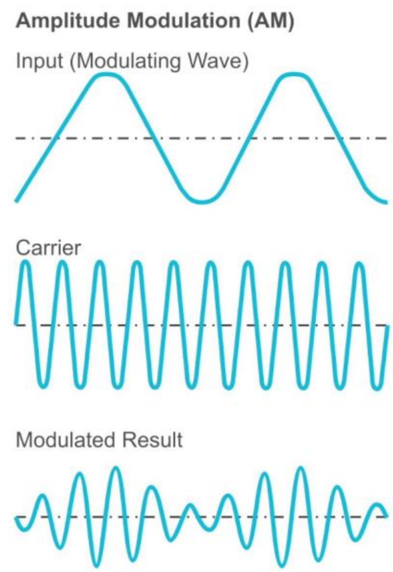
Overall, this project highlights the importance of choosing design parameters wisely in order to achieve the desired characteristics. It also introduces some of the many challenges that real engineers in the industry face when designing circuits, which is important to understand.

Figure 4.1:

(a)

(b)

(c)



https://www.taitradioacademy.com/topic/how-does-modulation-work-1-1/