EE315 - Electronics Laboratory

Experiment - 6 Simulation
BJT Differential Amplifier

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Preliminary Work

2.a) Calculate the differential gain $\mathbf{A_d = v_{c2}/v_d}$ and the common mode gain $\mathbf{A_{cm} = v_{c2}/v_{cm}}$ of the differential amplifier given in Figure **2**. Assume that output resistance $\mathbf{R_O}$ of the constant current source is **40 kΩ** in your calculations.

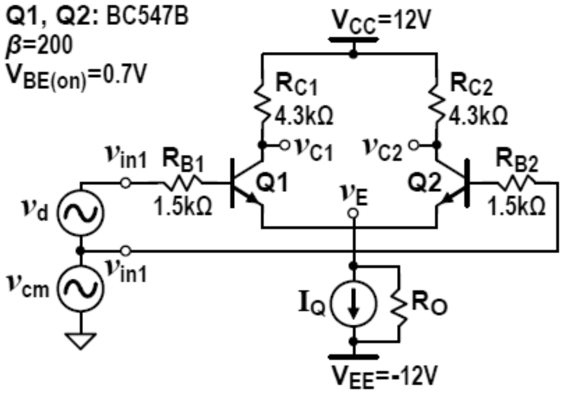


Figure 2. Differential amplifier

2.a=)

DC Analysis on Q1

$I_B \times 1.5k + V_{BE} + 40k \times I_Q - 12 = 0$

$I_B \times 1.5k + 0.7 + 40k \times (\beta+1) \times I_B - 12 = 0$

$I_B = \frac{12 - 0.7}{8041.5k} = 1.41 \mu A$

$I_C = 0.282 mA$

$g_m = \frac{I_C}{V_T} = \frac{0.282}{26} = 0.0108 S$

$r_\pi = \frac{\beta}{g_m} = 18.513 k\Omega$

Differential Gain

$V_{C2} = \frac{\beta R_C V_d}{2(r_\pi + R_B)}$

$A_d = \frac{V_{C2}}{V_d} = \frac{\beta R_C}{2(r_\pi + R_B)} = \underline{\underline{21.48}}$

Common Mode Gain

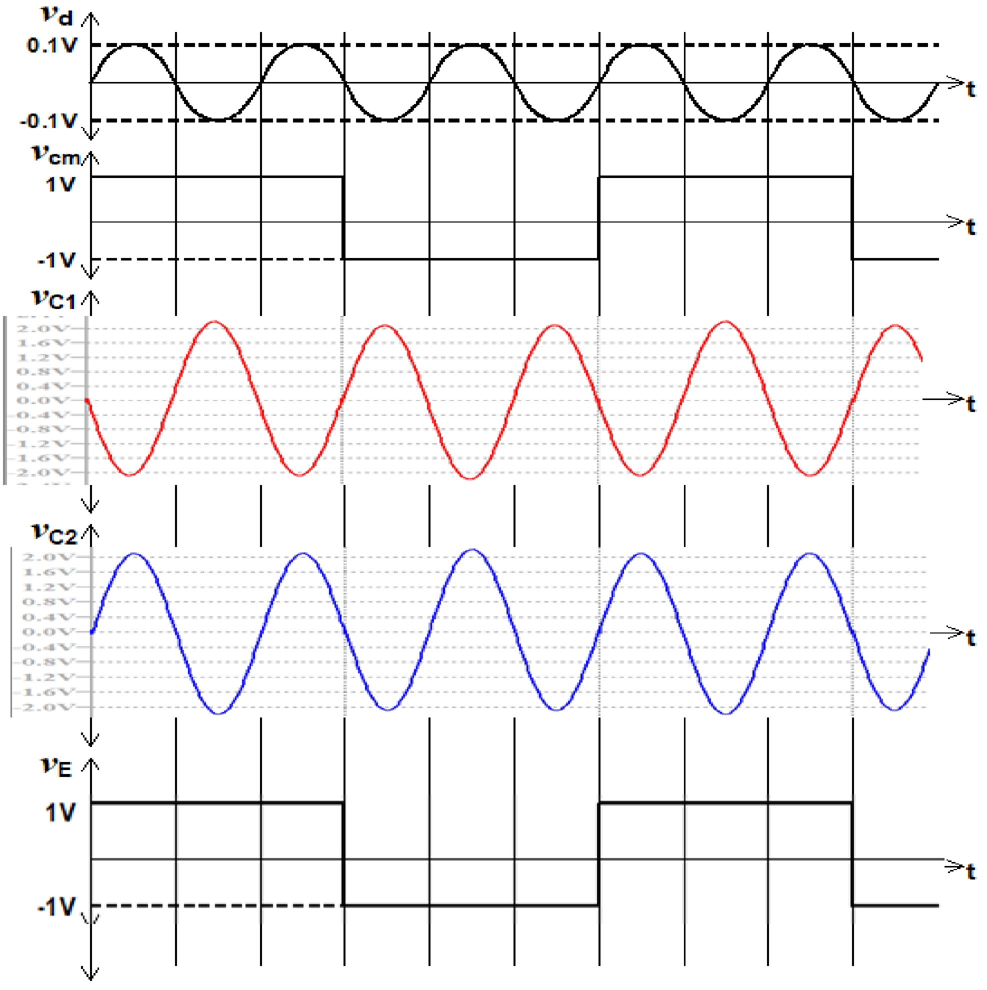
$A_{cm} = \frac{-\beta R_C}{r_\pi + R_B + 2(1+\beta)R_O} = \underline{\underline{-0.0534}}$

2.b) Draw the v_{C1}, v_{C2}, and v_E (both AC and DC components) versus time plots for the differential and common mode inputs shown below. Calculate the amplitudes (including polarities) of differential and common mode AC signals and write the results in the table provided below.

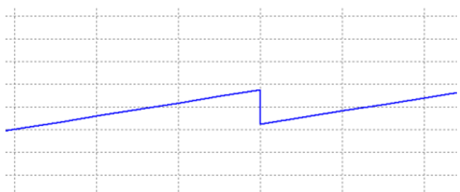
	differential	**common-mode**
v_{c1} (Vpeak)	2.148V	0.0534V
v_{c2} (Vpeak)	2.148V	0.0534V
v_e (Vpeak)	0	1V

$V_{C2} = -V_{C1} = V_O = A_d V_d + A_{cm} V_{cm} = 21.48*V_d - 0.0534*V_{cm}$

$$V_E = \frac{V_{b1}+V_{b2}}{2+\frac{r_\pi+R_B}{(1+\beta)R_o}} = 2*V_{cm}/2.0025 \simeq V_{cm}$$



There is some small cracking just like below for every pulse signal period on Vc1 and Vc2. However, we can not see them because they are too small to see in this size of graphs.



Results

2. Build the differential amplifier given in Figure **2** using the current mirror you built in part-**1** as the $\mathbf{I_Q}$. current source. Set the amplitudes of input sources v_d and v_{cm} to **0 V** and check the DC voltages at $\mathbf{V_E}$, $\mathbf{V_{C1}}$, and $\mathbf{V_{C2}}$, comparing with their expected values to make sure that the circuit operates properly.

>>VE = -671.81396mV
Vc1 = 2.2749205V
Vc2 = 2.2749205V

2.a) Measure the differential gain $\mathbf{A_d} = v_{c2}/v_d$ of the differential amplifier. Set the amplitude of common mode input v_{cm} to **0 V** and apply a **20 mVp-p** sinusoidal input as v_d source at the frequency settings given the following table.

v_d frequency	v_{c2} (Vp-p)	A_d
10 kHz	2.1223199V	106.1155
30 kHz	2.1030266V	105.151
100 kHz	1.8641548V	93.207
300 kHz	1.1862092V	59.31
1 MHz	384.36376mV	19.218
3 MHz	129.14455mV	6.457

2.b) Measure the common mode gain $\mathbf{A_{cm}} = v_{c2}/v_{cm}$ of the differential amplifier. Set the amplitude of differential input v_d to **0 V** and apply a **4 Vp-p** common mode input at the frequency settings given in the following table.

v_{cm} frequency	v_{c2} (mVp-p)	A_{cm}
10 kHz	31.0677mV	0.007767
30 kHz	31.186223mV	0.007796
100 kHz	32.901516mV	0.008253
300 kHz	42.182279mV	0.010545
1 MHz	100.42568mV	0.025106
3 MHz	289.76051mV	0.072440

2.c) How does the CMRR of the differential amplifier change depending on the frequency? Why?

>>As we know that $\mathrm{CMRR} = \left|\frac{A_d}{A_{cm}}\right|$. When the frequency increase, we observe decrement on A_d and increment on A_{cm}. That makes CMRR dependent to the frequency. And we can clearly say that CMRR is directly proportional to the frequency. So, in higher frequency, we have more ideal differential amplifier.

frequency	CMRR
10 kHz	13662.35
30 kHz	13487.81
100 kHz	11293.71
300 kHz	5624.47
1 MHz	765.47
3 MHz	89.16

Conclusion

>>In this experiment, we learned how to analyze BJT differential amplifier circuit by hand and by simulation. We saw similar results on 1MegHz because in the last experiment, we found Ro as 40k ohm at 1Meg Hz. However, in this lab, our frequency was changing. Thus, we observed change on common mode and differential gain when we change the frequency. So that, we found CMRR directly proportional and dependent to the frequency.