EE315 - Electronics Laboratory

Experiment - 6

BJT Differential Amplifier

Preliminary Work

1. A two-transistor current mirror circuit is given in Figure **1**. R_{E1} and R_{E2} are added for temperature stability and for compansation of differences in transistor characteristics.

1.a) Calculate the DC output current I_Q assuming that **Q3** and **Q4** are identical. You can simplify calculations by taking $\beta \gg 1$ or $\beta \approx \beta + 1$.

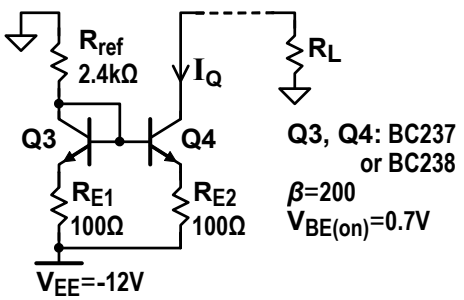


Figure 1. Current mirror with stabilizing emitter resistors.

1.b) What will be the actual value of I_Q compared to the current calculated above if,

i) β of **Q3** is greater than β of **Q4**

ii) $V_{BE(on)}$ of **Q3** is greater than $V_{BE(on)}$ of **Q4**

1.c) Describe an experiment to measure the output resistance of the current mirror.

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

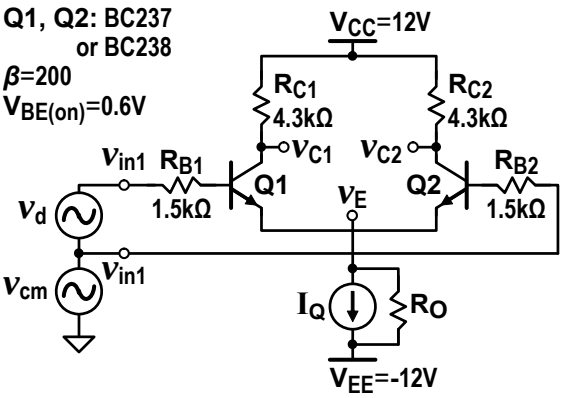
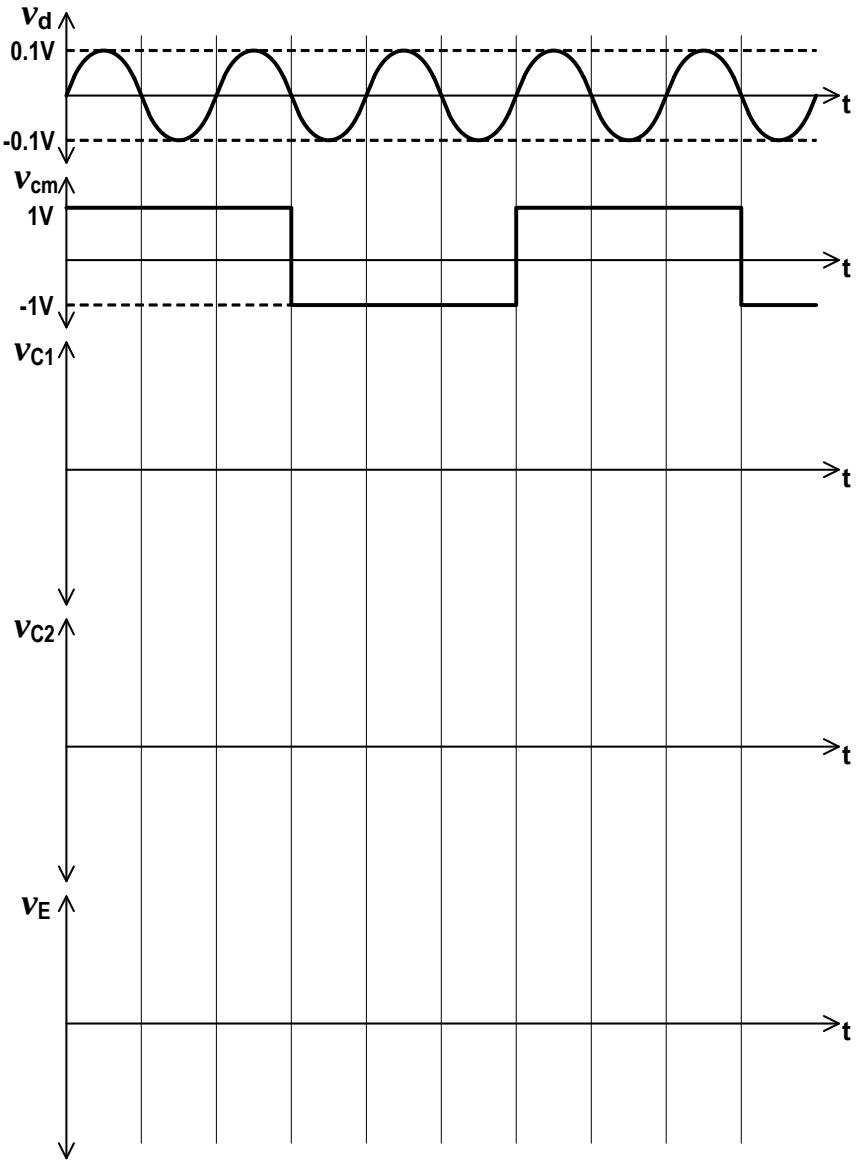


Figure 2. Differential amplifier

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)		
v_{c2} (Vpeak)		
v_e (Vpeak)		



Procedure

1. Build the current mirror circuit given in Figure **1**. You will use the resistor values specified for $\mathbf{R_L}$ in step-**1.a**.

1.a) Measure the DC current output $\mathbf{I_Q}$ of the current mirror for the following values of $\mathbf{R_L}$. Use the measured resistor values and the DC voltage across $\mathbf{R_L}$.

R_L used	R_L measured	V_{RL} (V_{DC})	I_Q (mA)
750 Ω			
1.5 kΩ			
2.2 kΩ			
3.3 kΩ			

1.b) Explain any major change in the DC current output $\mathbf{I_Q}$.

1.c) Apply an AC test signal, and measure the AC voltage and current at the current mirror output to find the current source output resistance. Use $\mathbf{R_L}$**=1.5 kΩ**, and set the function generator to obtain **4 Vp-p** sinusoidal test source v_{tst} as shown in Figure **3**.

Find the output resistance of the constant current source model at the frequency settings specified for v_{tst} in the following table.

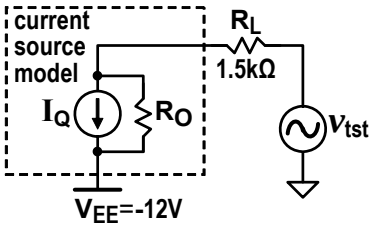


Figure 3. Test setup to measure current source output resistance

v_{tst} frequency	v_{RL} (mVp-p)	R_O (kΩ)
3 kHz		
10 kHz		
30 kHz		
100 kHz		
300 kHz		

1.d) If this current mirror is used for biasing a differential amplifier, how should the CMRR change depending on the frequency of the common-mode input? Why?

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. Short the two amplifier inputs v_{in1}, and v_{in2} to the ground 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.

2.a) Measure the differential gain $\mathbf{A_d = v_{c2}/v_d}$ of the differential amplifier. Short the common mode input to the ground and apply a **10 kHz** or **100 kHz** differential input. Make sure that the amplifier output is not saturated keeping the input signal small enough. You may need the **20 dB** or **30 dB** output attenuator of the signal generator to make the amplitude adjustments easily.

at 10 kHz: $\mathbf{V_{dp\text{-}p}}$ = $\mathbf{V_{c2p\text{-}p}}$ = $\mathbf{A_d}$ =

at 100 kHz: $\mathbf{V_{dp\text{-}p}}$ = $\mathbf{V_{c2p\text{-}p}}$ = $\mathbf{A_d}$ =

2.b) Measure the common mode gain $\mathbf{A_{cm} = v_{c2}/v_{cm}}$ of the differential amplifier. Connect the two amplifier inputs v_{in1}, and v_{in2} together and apply a **4 Vp-p** common mode input at the frequency settings given in the following table.

v_{cm} frequency	v_{c2} (V p-p)	A_{cm}
3 kHz		
10 kHz		
30 kHz		
100 kHz		
300 kHz		

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