EE315 - Electronics Laboratory

Experiment - 6 Simulation
BJT Differential Amplifier

Preliminary Work

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

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

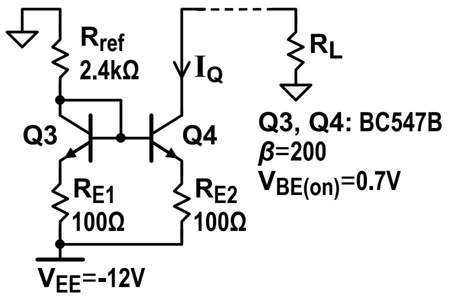


Figure 1. Current mirror with stabilizing emitter resistors.

1.b) What will be the actual value of $\mathbf{I_Q}$ compared to the current calculated above if,

i) $\boldsymbol{\beta}$ of **Q3** is greater than $\boldsymbol{\beta}$ of **Q4**

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

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

2.a) Calculate the differential gain $\mathbf{A_d} = v_{c2}/v_d$ 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.

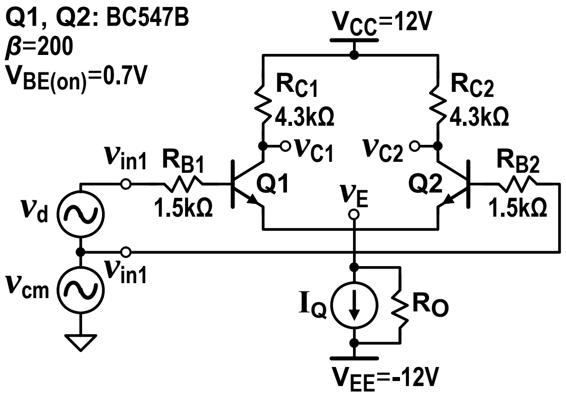
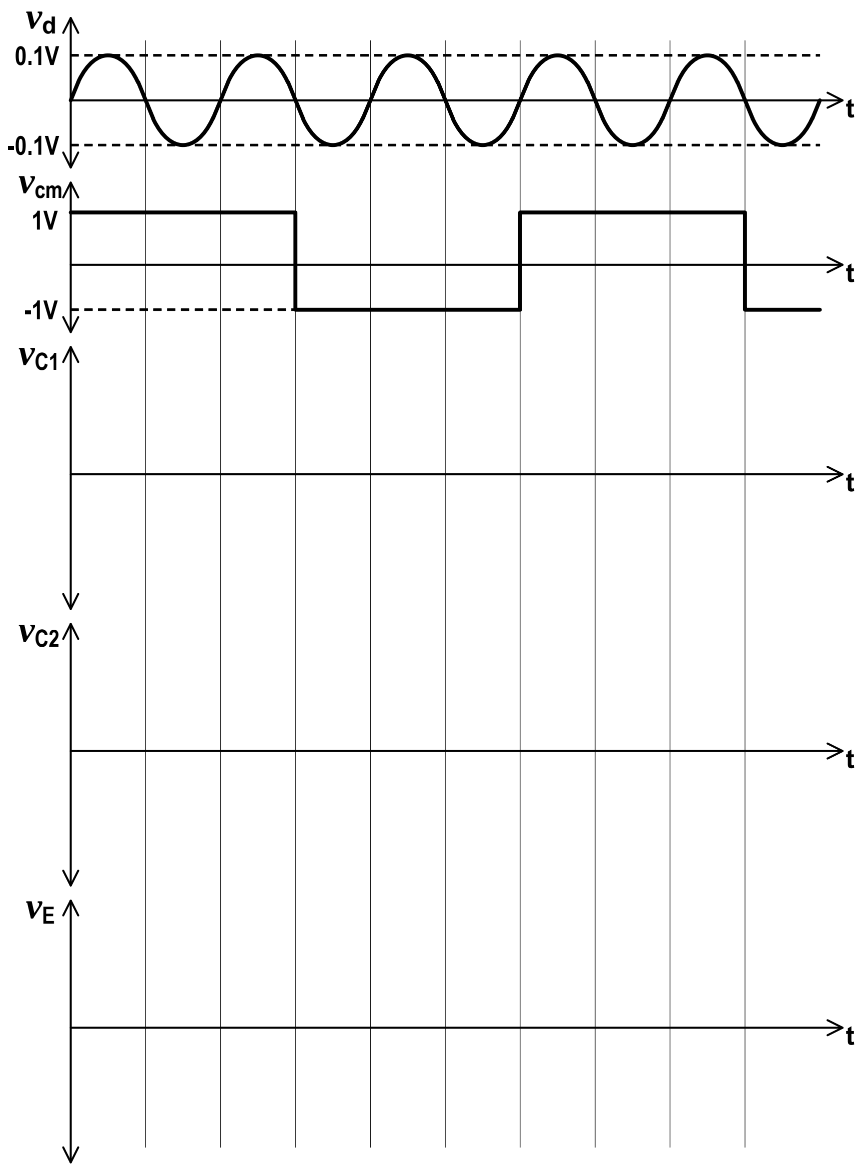


Figure 2. Differential amplifier

2.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** and select **BC547B** as the transistor model. 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 $\mathbf{R_L}$.

R_L used	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 sinusoidal test source v_{tst} to obtain **4 Vp-p** as shown in Figure **3**.

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

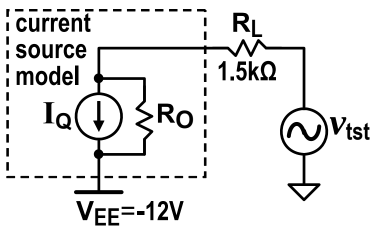


Figure 3. Test setup to measure current source output resistance

Frequency values in **MHz** range can be entered with the `Meg` scaling factor in LTspice. For example, **3 MHz** frequency setting for a sinusoidal source can be written as "`3Meg`" or "`3000k`".

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

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. Set the amplitudes of input sources v_d and v_{cm} to **0 V** and check the DC voltages at V_E, V_{C1}, and V_{C2}, comparing with their expected values to make sure that the circuit operates properly.

2.a) Measure the differential gain $A_d = v_{c2}/v_d$ 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		
30 kHz		
100 kHz		
300 kHz		
1 MHz		
3 MHz		

2.b) Measure the common mode gain $A_{cm} = v_{c2}/v_{cm}$ 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		
30 kHz		
100 kHz		
300 kHz		
1 MHz		
3 MHz		

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