EE315 - Electronics Laboratory

Experiment - 6 Simulation

BJT Differential Amplifier

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Preliminary Work

1a=) $\beta \approx \beta + 1 \Rightarrow I_C \approx I_E \approx I_Q$:

$$2.4k \times I_C + 0.7 + 100 \times I_E = 12$$

$$I_Q = I_C = I_E = \frac{12 - 0.7}{2.4k + 100} = \underline{4.52mA}$$

1b=) $2.4k \times I_{CQ3} + V_{BEQ3} + 100 \times I_{EQ3} = 12$

$- \quad 2.4k \times I_{CQ3} + V_{BEQ4} + 100 \times I_{EQ4} = 12$

$$V_{BEQ3} + 100 \times I_{BQ3} \times \beta_{Q3} = V_{BEQ4} + 100 \times I_{BQ4} \times \beta_{Q4}$$

i=) If $\beta_{Q3} > \beta_{Q4} \Rightarrow I_{BQ4} > I_{BQ3}$

However, $100 \times I_{BQ3} \times \beta_{Q3} = 100 \times I_{BQ4} \times \beta_{Q4} \Rightarrow I_{Q3} = I_{Q4}$

Thus, I_Q does not change.

ii=) If $V_{BEQ3} > V_{BEQ4} \Rightarrow 100 \times I_{BQ3} \times \beta_{Q3} < 100 \times I_{BQ4} \times \beta_{Q4}$

Thus, $I_{Q3} < I_{Q4}$, I_Q would increase.

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

>>We can do the same thing as 1c in procedure to measure the output resistance. If we add a test AC voltage after load resistance, the current mirror circuit act as an independent DC current source. Thus, AC voltage creates an AC current and AC voltage in the circuit. If we divide the AC voltage difference to AC current on the circuit, we can find the output resistance of the current mirror circuit.

Results

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 $\mathbf{R_L}$.

$\mathbf{R_L}$ **used**	$\mathbf{I_Q}$ **(mA)**
750 Ω	4.5280725mA
1.5 kΩ	4.5140141mA
2.2 kΩ	4.50027mA
3.3 kΩ	3.5069648mA

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

>>When we have 2.2k ohm R_L, we observe I_Q as 4.5mA and V_{CE} as 1.65V. On the other hand, when we have 3.3k ohm R_L, we observe I_Q as 3.5mA and V_{CE} as 31.35mV. It means that, because of high resistance of R_L, it draws higher values and this result in lack of voltage on V_{CE} to make the transistor in forward active region. Thus, we can deduce that, when we have 3.3k ohm R_L, transistor gets into saturation region and I_{CQ4} becomes less than beta times I_{BQ4}.

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 $\boldsymbol{v_{tst}}$ as shown in Figure **3**.

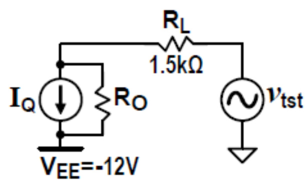

Figure 3. Test setup to measure current source output resistance

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

$\boldsymbol{v_{tst}}$ **frequency**	$\boldsymbol{v_{RL}}$ **(mVp-p)**	$\mathbf{R_O}$ **(kΩ)**	$\mathbf{V_{Ro}}$**(**$\mathbf{V_{p\text{-}p}}$**)**	$\mathbf{I_{Ro}}$**(**$\mathbf{uA_{p\text{-}p}}$**)**
10 kHz	29.260654	232.852	3.9623	17.016
30 kHz	56.026762	231.496	3.9660	17.132
100 kHz	133.67936	206.280	3.9575	19.185
300 kHz	126.75296	127.957	3.9549	30.943
1 MHz	213.23238	45.334	3.9496	87.121
3 MHz	464.05871	15.384	3.9174	254.626

>>To find R_O I divide $V_{Ro\_ACp\text{-}p}$ with $I_{Rl\_ACp\text{-}p}$. That gave us the small signal resistance of the current mirror which is R_O.

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?

>>Common mode rejection ratio is the rate of differential mode gain over the common mode gain. And the common mode gain is dependent to R_O of the current mirror circuit. The higher R_o results in less common mode gain. Thus, we can say that, if we have higher frequency, we would have lower R_O, and this results greater s… F… to be as high as t… : …R and the

$$A_d = \frac{\beta R_C}{2(r_\pi + R_B)} \qquad A_d = \frac{\beta R_C}{2(r_\pi + R_B)} \qquad A_d = \frac{\beta R_C}{2(r_\pi + R_B)}$$

$$A_d = \frac{\beta R_C}{2(r_\pi + R_B)} \qquad A_{cm} = \frac{-\beta R_C}{r_\pi + R_B + 2(1+\beta)R_o}$$

$$\mathrm{CMRR} = \left| \frac{A_d}{A_{cm}} \right|$$

Conclusion

>>In this experiment, firstly we observed the effect of R_L on I_Q and we figured out that when R_L is high enough to make transistor in saturation, we see dramatic difference.

Secondly, to observe the output resistance of the current mirror circuit, we sat an experiment and found out output resistance in difference frequency. We saw that the higher the frequency is, the lower the output resistance.

Finally, we figured out the effect of frequency on the common mode input and CMRR. We conclude that there is an inverse proportion on them.