Experiment 3
Active Loading

Laboratory Report for ENGE 312
Applications of Electronic Devices
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I. RESULTS: SAMPLE CALCULATIONS

A. 1. Resistor Biased “CE” Amplifier

Given:

- $V_{\text{CC}} = 15\ \text{V}$
- $R_1 = 47\ \text{k}\,\Omega$, $R_2 = 33\ \text{k}\,\Omega$
- $R_C = 2.2\ \text{k}\,\Omega$, $R_E = 1.8\ \text{k}\,\Omega$, $R_L = 2.2\ \text{k}\,\Omega$
- Transistor Q_1 (2N3904): Assume $\beta \approx 130$, $V_{\text{BE}} \approx 0.7\ \text{V}$

Thevenin Equivalent Base Circuit:

$$R_B = R_1 \parallel R_2 = \frac{47\ \text{k} \cdot 33\ \text{k}}{47\ \text{k} + 33\ \text{k}} \approx 19.39\ \text{k}\,\Omega \tag{1}$$

$$V_{\text{BB}} = V_{\text{CC}} \cdot \frac{R_2}{R_1 + R_2} = 15\ \text{V} \cdot \frac{33}{80} = 6.19\ \text{V} \tag{2}$$

Q-Point Analysis:

$$\begin{aligned} I_{\text{CQ}} &= \frac{V_{\text{BB}} - V_{\text{BE}}}{R_E + \frac{R_B}{\beta}} \\ &= \frac{6.19\ \text{V} - 0.7\ \text{V}}{1.8\ \text{k}\,\Omega + \frac{19.39\ \text{k}\,\Omega}{130}} \\ &= \frac{5.49\ \text{V}}{1.8\ \text{k}\,\Omega + 0.15\ \text{k}\,\Omega} \\ &= 2.81\ \text{mA} \end{aligned} \tag{3}$$

$$\begin{aligned} V_{\text{CE}} &= V_{\text{CC}} - I_{\text{CQ}}(R_C + R_E) \\ &= 15\ \text{V} - 2.81\ \text{mA}(2.2\ \text{k}\,\Omega + 1.8\ \text{k}\,\Omega) \\ &= 15\ \text{V} - 11.24\ \text{V} \\ &= 3.76\ \text{V} \end{aligned} \tag{4}$$

AC Gain (A_V):

$$V_T \approx 26\ \text{mV} \tag{5}$$

$$g_m = \frac{I_{\text{CQ}}}{V_T} = \frac{2.81\ \text{mA}}{26\ \text{mV}} \approx 0.108\ \text{S} \tag{6}$$

$$R_{\text{ac}} = R_C \parallel R_L = \frac{2.2\ \text{k} \cdot 2.2\ \text{k}}{2.2\ \text{k} + 2.2\ \text{k}} = 1.1\ \text{k}\,\Omega \tag{7}$$

$$\begin{aligned} A_V &= -g_m(R_{\text{ac}}) \\ &= -(0.108\ \text{S})(1100\Omega) \\ &= -118.8 \end{aligned} \tag{8}$$

Output Swing:

$$V_{o,\ \max} = V_{\text{CE}} - V_{\text{CE,\ sat}} \approx 3.76\ \text{V} - 0.2\ \text{V} = 3.56\ \text{V} \tag{9}$$

$$V_{o,\ \min} = I_{\text{CQ}}(R_C \parallel R_L) = (2.81\ \text{mA})(1.1\ \text{k}\ \Omega) = 3.09\ \text{V} \tag{10}$$

$$\begin{aligned} V_{o,\ \text{p-p}} &= 2 \cdot \min\big(V_{o,\ \max}, V_{o,\ \min}\big) \\ &= 2 \cdot 3.09\ \text{V} = 6.18\ \text{V} \end{aligned} \tag{11}$$

B. 2. Current Mirror (Active Load Setup)

Given:
- Target $I_o \approx I_{\text{CQ}} \approx 2.81\ \text{mA}$ (matching the “CE” stage)
- $V_{\text{CC}} = 15\ \text{V}$
- Q_2, Q_3 (2N3906): Assume $\beta \approx 150$, $V_{\text{BE}} \approx 0.7\ \text{V}$

Reference Current Setting: To match I_o to I_{CQ}, we calculate the required R_{ref}:

$$\begin{aligned} R_{\text{ref}} &= \frac{V_{\text{CC}} - V_{\text{BE}}}{I_{\text{ref}}} \\ &\approx \frac{15\ \text{V} - 0.7\ \text{V}}{2.81\ \text{mA}} \\ &= 14.3\frac{\text{V}}{2.81}\ \text{mA} \\ &= 5.09\ \text{k}\ \Omega \end{aligned} \tag{12}$$

(Note: In lab, use a potentiometer or series resistors to approximate $5.1\ \text{k}\ \Omega$*)*

Output Current:

$$I_o = \frac{I_{\text{ref}}}{1 + \frac{2}{\beta}} = \frac{2.81\ \text{mA}}{1 + \frac{2}{150}} \approx 2.77\ \text{mA} \tag{13}$$

C. 3. “CE” Amplifier with Active Load (Current Source Biasing)

Given:
- Load $R_L = 2.2\ \text{k}\ \Omega$
- Bias $I_C \approx 2.8\ \text{mA}$
- Assume Early Voltage resistance $r_o = 30\ \text{k}\ \Omega$ for all transistors[cite: 49].

Voltage Gain with Active Load: The “ac”tive load repl“ac”es R_C with the output resistance of the current mirror (r_o of PNP).

$$\begin{aligned} R_{\text{eff}} &= r_{o,\ \text{NPN}} \parallel r_{o,\ \text{PNP}} \parallel R_L \\ &= 30\ \text{k}\ \Omega \parallel 30\ \text{k}\ \Omega \parallel 2.2\ \text{k}\ \Omega \\ &= 15\ \text{k}\ \Omega \parallel 2.2\ \text{k}\ \Omega \\ &= \frac{15\ \text{k} \cdot 2.2\ \text{k}}{15\ \text{k} + 2.2\ \text{k}} \approx 1.92\ \text{k}\ \Omega \end{aligned} \tag{14}$$

$$\begin{aligned} A_V &= -g_m(R_{\text{eff}}) \\ &= -(0.108\ \text{S})(1920\Omega) \\ &= -207.4 \end{aligned} \tag{15}$$

(Note: The gain increases significantly compared to the resistor biased version (119 *vs* 207*) due to the higher "eff"ective AC impedance at the collector, even though* R_L *dominates in this loaded case.)*

II. DISCUSSION

III. APPENDIX