Section 6-4 The Common-Collector Amplifier

20. $$V_B = \left(\frac{R_2}{R_1 + R_2}\right)V_{CC} = \left(\frac{4.7\text{ k}\Omega}{14.7\text{ k}\Omega}\right)5.5\text{ V} = 1.76\text{ V}$$

$$I_E = \frac{V_B - 0.7\text{ V}}{R_E} = \frac{1.76\text{ V} - 0.7\text{ V}}{1.0\text{ k}\Omega} = 1.06\text{ mA}$$

$$r'_e \cong \frac{25\text{ mV}}{1.06\text{ mA}} = 23.6\ \Omega$$

$$A_v = \frac{R_E}{R_E + r'_e} = \frac{1.0\text{ k}\Omega}{1.0\text{ k}\Omega + 23.6\ \Omega} = \mathbf{0.977}$$

21. $$R_{in} = R_1 \parallel R_2 \parallel \beta_{ac}(r'_e + R_E) \cong R_1 \parallel R_2 \parallel \beta_{ac}R_E = 10\text{ k}\Omega \parallel 4.7\text{ k}\Omega \parallel 100\text{ k}\Omega = \mathbf{3.1\text{ k}\Omega}$$

$$V_{OUT} = V_B - 0.7\text{ V} = \left(\frac{R_2}{R_1 + R_2}\right)V_{CC} - 0.7\text{ V} = \left(\frac{4.7\text{ k}\Omega}{14.7\text{ k}\Omega}\right)5.5\text{ V} - 0.7\text{ V} = \mathbf{1.06\text{ V}}$$

22. The voltage gain is **reduced** because $A_v = \dfrac{R_e}{R_e + r'_e}$.

23. $$V_B = \left(\frac{R_2}{R_1 + R_2}\right)V_{CC} = \left(\frac{4.7\text{ k}\Omega}{14.7\text{ k}\Omega}\right)5.5\text{ V} = 1.76\text{ V}$$

$$I_E = \frac{V_B - V_{BE}}{R_E} = \frac{1.76\text{ V} - 0.7\text{ V}}{1.0\text{ k}\Omega} = 1.06\text{ mA}$$

$$r'_e \cong \frac{25\text{ mV}}{I_E} = \frac{25\text{ mV}}{1.06\text{ mA}} = 23.6\ \Omega$$

$$A_v = \frac{R_E \parallel R_L}{r'_e + R_E \parallel R_L}$$

$$A_v\left(r'_e + R_E \parallel R_L\right) = R_E \parallel R_L$$

$$R_E \parallel R_L - A_v\left(R_E \parallel R_L\right) = A_v r'_e$$

$$\left(R_E \parallel R_L\right)\left(1 - A_v\right) = A_v r'_e$$

$$\left(R_E \parallel R_L\right) = \frac{A_v r'_e}{(1 - A_v)} = \frac{0.9(23.6\ \Omega)}{1 - 0.9} = 212.4\ \Omega$$

$$R_L R_E = 212.4R_L + 212.4R_E$$

$$R_L R_E - 212.4R_L = 212.4R_E$$

$$R_L = \frac{212.4R_E}{R_E - 212.4} = \frac{(212.4\ \Omega)(1000\ \Omega)}{1000\ \Omega - 212.4\ \Omega} = \mathbf{270\ \Omega}$$

24. (a) $V_{C1} = 10\text{ V}$

$$V_{B1} = \left(\frac{R_2}{R_1 + R_2}\right)V_{CC} = \left(\frac{22\text{ k}\Omega}{55\text{ k}\Omega}\right)10\text{ V} = 4\text{ V}$$

$V_{E1} = V_{B1} - 0.7\text{ V} = 4\text{ V} - 0.7\text{ V} = 3.3\text{ V}$

$V_{C2} = 10\text{ V}$

$V_{B2} = V_{E1} = 3.3\text{ V}$

$V_{E2} = V_{B2} - 0.7\text{ V} = 3.3\text{ V} - 0.7\text{ V} = 2.6\text{ V}$

(b) $\beta'_{DC} = \beta_{DC1}\beta_{DC2} = (150)(100) = 15{,}000$

(c) $$I_{E1} = \frac{V_{E1} - 0.7\text{ V}}{\beta_{DC2}R_E} = \frac{2.6\text{ V}}{100(1.5\text{ k}\Omega)} = 17.3\ \mu\text{A}$$

$$r'_{e1} \cong \frac{25\text{ mV}}{I_{E1}} = \frac{25\text{ mV}}{17.3\ \mu\text{A}} = 1.45\text{ k}\Omega$$

$$I_{E2} = \frac{V_{E2}}{R_E} = \frac{2.6\text{ V}}{1.5\text{ k}\Omega} = 1.73\text{ mA}$$

$$r'_{e2} \cong \frac{25\text{ mV}}{I_{E2}} = \frac{25\text{ mV}}{1.73\text{ mV}} = 14.5\ \Omega$$

(d) $R_{in} = R_1 \parallel R_2 \parallel R_{in(base1)}$

$R_{in(base1)} = \beta_{ac1}\beta_{ac2}R_E = (150)(100)(1.5\text{ k}\Omega) = 22.5\text{ M}\Omega$

$R_{in} = 33\text{ k}\Omega \parallel 22\text{ k}\Omega \parallel 22.5\text{ M}\Omega = 13.2\text{ k}\Omega$

25. $R_{in(base)} = \beta_{ac1}\beta_{ac2}R_E = (150)(100)(1.5\text{ k}\Omega) = 22.5\text{ M}\Omega$

$R_{in} = R_2 \parallel R_1 \parallel R_{in(base)} = 22\text{ k}\Omega \parallel 33\text{ k}\Omega \parallel 22.5\text{ M}\Omega = 13.2\text{ k}\Omega$

$$I_{in} = \frac{V_{in}}{R_{in}} = \frac{1\text{ V}}{13.2\text{ k}\Omega} = 75.8\ \mu\text{A}$$

$$I_{in(base1)} = \frac{V_{in}}{R_{in(base1)}} = \frac{1\text{ V}}{22.5\text{ M}\Omega} = 44.4\text{ nA}$$

$I_e \cong \beta_{ac1}\beta_{ac2}I_{in(base1)} = (150)(100)(44.4\text{ nA}) = 667\ \mu\text{A}$

$$A'_i = \frac{I_e}{I_{in}} = \frac{667\ \mu\text{A}}{75.8\ \mu\text{A}} = 8.8$$

27. $V_E = \left(\dfrac{R_2}{R_1 + R_2}\right)V_{CC} - V_{BE} = \left(\dfrac{10\text{ k}\Omega}{32\text{ k}\Omega}\right)24\text{ V} - 0.7\text{ V} = 6.8\text{ V}$

$$I_E = \frac{6.8\text{ V}}{620\ \Omega} = 10.97\text{ mA}$$

$$R_{in(emitter)} = r'_e \cong \frac{25\text{ mV}}{I_E} = \frac{25\text{ mA}}{10.97\text{ mA}} = \mathbf{2.28\ \Omega}$$

$$A_v = \frac{R_C}{r'_e} = \frac{1.2\text{ k}\Omega}{2.28\ \Omega} = \mathbf{526}$$

$$A_i \cong \mathbf{1}$$

$$A_p = A_i A_v \cong \mathbf{526}$$

31. (a) $V_E\left(\frac{R_2}{R_1 + R_2}\right)V_{CC} - V_{BE} = \left(\frac{8.2\ \text{k}\Omega}{33\ \text{k}\Omega + 8.2\ \text{k}\Omega}\right)15\ \text{V} - 0.7\ \text{V} = 2.29\ \text{V}$

$$I_E = \frac{V_E}{R_E} = \frac{2.29\ \text{V}}{1.0\ \text{k}\Omega} = 2.29\ \text{mA}$$

$$r_e' \cong \frac{25\ \text{mV}}{I_E} = \frac{25\ \text{mV}}{2.29\ \text{mA}} = 10.9\ \Omega$$

$$R_{in(2)} = R_6 \parallel R_5 \parallel \beta_{ac} r_e' = 8.2\ \text{k}\Omega \parallel 33\ \text{k}\Omega \parallel 175(10.9\ \Omega) = 1.48\ \text{k}\Omega$$

$$A_{v1} = \frac{R_C \parallel R_{in(2)}}{r_e'} = \frac{3.3\ \text{k}\Omega \parallel 1.48\ \text{k}\Omega}{10.9\ \Omega} = \mathbf{93.6}$$

$$A_{v2} = \frac{R_C}{r_e'} = \frac{3.3\ \text{k}\Omega}{10.9\ \Omega} = \mathbf{303}$$

(b) $A_v' = A_{v1}A_{v2} = (93.6)(303) = \mathbf{28{,}361}$

(c) $A_{v1(\text{dB})} = 20\log(93.6) = \mathbf{39.4\ dB}$

$A_{v2(\text{dB})} = 20\log(303) = \mathbf{49.6\ dB}$

$A'_{v(\text{dB})} = 20\log(28{,}361) = \mathbf{89.1\ dB}$

32. (a) $A_{v1} = \dfrac{R_C \parallel R_{in(2)}}{r'_e} = \dfrac{3.3\text{ k}\Omega \parallel 1.48\text{ k}\Omega}{10.9\ \Omega} = \mathbf{93.6}$

$$A_{v2} = \frac{R_C \parallel R_L}{r'_e} = \frac{3.3\text{ k}\Omega \parallel 18\text{ k}\Omega}{10.9\ \Omega} = \mathbf{256}$$

(b) $R_{in(1)} = R_1 \parallel R_2 \parallel \beta_{ac} r'_e = 33\text{ k}\Omega \parallel 8.2\text{ k}\Omega \parallel 175(10.9\ \Omega) = 1.48\text{ k}\Omega$

Attenuation of the input network is

$$\frac{R_{in(1)}}{R_{in(1)} + R_s} = \frac{1.48\text{ k}\Omega}{1.48\text{ k}\Omega + 75\ \Omega} = 0.95$$

$$A'_v = (0.95)A_{v1}A_{v2} = (0.95)(93.6)(256) = \mathbf{22{,}764}$$

(c) $A_{v1(\text{dB})} = 20\log(93.6) = \mathbf{39.4\ dB}$

$A_{v2(\text{dB})} = 20\log(256) = \mathbf{48.2\ dB}$

$A'_{v(\text{dB})} = 20\log(22{,}764) = \mathbf{87.1\ dB}$

$V_d = 1\ mV \longrightarrow V_o = 120\ mV$

$V_c = 1\ mV \longrightarrow V_o = 20\ \mu V$ CMRR(dB) ??

$$A_d = \frac{V_o}{V_d} = \frac{120\ mV}{1 mV} = 120$$

$$A_c = \frac{V_o}{V_c} = \frac{20\ \mu V}{1 mV} = 20 \times 10^{-3}$$

$$CMRR\ (dB) = 20 \log\left(\frac{A_d}{A_c}\right) = 20 \log\left(\frac{120}{20 \times 10^{-3}}\right)$$

$$= 75.56\ dB$$