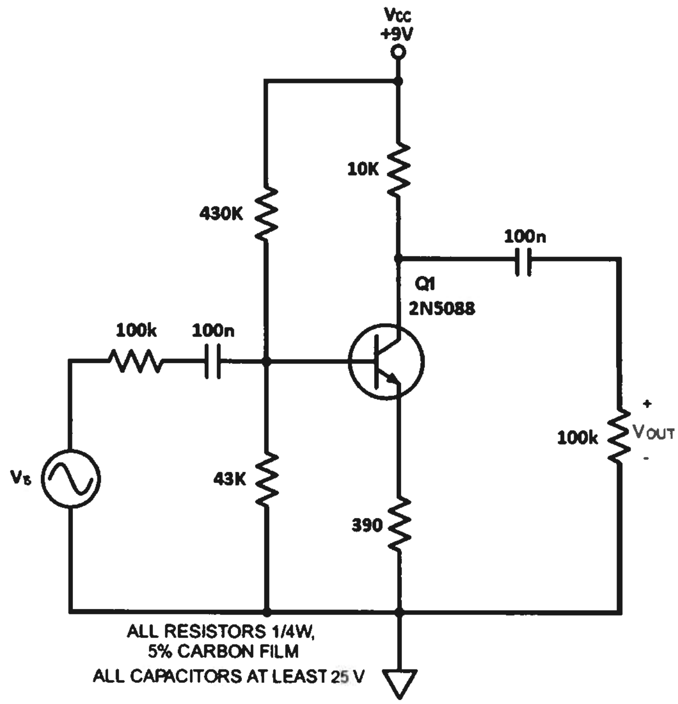
BME-ISE 3512 • Exam V • 11 April 2022 35 pts. NAME SOLUTION

The Electro-Harmonix LPB-1 is an electronic device used to increase the signal level of an electric guitar before feeding an amplifier. It was introduced in 1968 and is still manufactured today in NYC. Thus, it is older than your mom, but most *unlike* your mom it is still valid.



First, perform DC analysis. Determine V_B, V_E, I_C, V_C, and V_{CE} if 2N5088 is silicon and base current may be assumed negligible due to high β. Check P_{diss} and verify that the transistor is operating in the active region.

$$V_B = 9\left(\frac{43}{43+430}\right) = 0.8182\ \text{V} \quad (+1)$$

$$V_E = V_B - 0.7 \text{ (Si)} = 0.1182\ \text{V} \quad (+1)$$

$$I_E = \frac{V_E}{R_E} = \frac{0.1182}{390} = 0.000303 \text{ or } 0.303\ \text{mA} \quad (+1)$$

$$I_C \simeq I_E = 0.303\ \text{mA} \quad (+1)$$

$$V_C = V_{CC} - I_C R_C = 9 - .303 \cdot 10 = 5.97\ \text{V} \quad (+1)$$

$$V_{CE} = V_C - V_E = 5.97 - 0.1182 = 5.851\ \text{V} \quad (+1)$$

yes, active (+1)

$$P_{diss} = V_{CE} \cdot I_C = 5.851 \cdot 0.303 = 1.773\ \text{mW} \quad (+1)$$

Calculate the parameters g_m and r_b' if $\beta = 350$. Also compute R_{IN}' and R_{OUT}'. Note that the emitter is unbypassed. Include a unit with each answer. You may neglect r_o.

$$g_m = 35\, I_C = 35 \cdot .303$$

$$g_m = 10.605\ \text{mA/V} \quad (+2)$$

$$r_b' = \beta R_E = 350 \cdot 390 = 136500$$

$$\text{or } 136.5\ k\Omega \quad (+2)$$

$$R_{IN}' = R_1 \| R_2 \| r_b' = 430k \| 43k \| 136.5k = 30.39\ k\Omega \quad (+2)$$

$$R_{OUT}' \doteq R_C = 10k \quad (+1)$$

Compute the input and output transfers A_{V1} and A_{V2} and use them to determine the overall mid-frequency gain A_V(dB).

$$A_{V1} = \frac{R_{IN}'}{R_S + R_{IN}'} = \frac{30.39}{30.39 + 100} = 0.2331 \quad (+2)$$

$$= 9.091k \quad (+1)$$

$$A_{V2} = \frac{-R_C \| R_L}{R_E} = -\frac{10k \| 100k}{390} = -23.31 \quad (+2)$$

$$\therefore\ A_V = A_{V1} \cdot A_{V2} = 0.2331 \cdot -23.31$$

$$A_V = -5.434 \quad (+1)$$

or 14.7 dB inverting (+2)

Determine the high-frequency input capacitance using Miller's Theorem if C_{BC} = 4.0 pF and C_{BE} = 10 pF. Use it to compute the input HF cutoff frequency. You do not have to compute the output capacitance or cutoff frequency.

$$C_{BC(IN)}' = C_{BC}(1 - A_{V2})$$

$$= 4(1 - -23.31) = 97.24 \text{ pF}$$ +2

$$\therefore f_H = \frac{1}{2\pi \cdot C_{BC(IN)}' \cdot (R_S \| R_{IN}')} = \frac{1}{2\pi \cdot 97.24p \cdot \underbrace{(100k \| 30.39k)}_{=23.3k}}$$ +1

$$f_H = 70.25 \text{ kHz}$$ +2

Compute the LF cutoff frequencies due to the input and output capacitors.

$$f_{C\,IN}' = \frac{1}{2\pi C_{IN}(R_S + R_{IN}')} = \frac{1}{2\pi \cdot 100n\,(100k + 30.39k)}$$

$$f_{C\,IN}' = 12.2 \text{ Hz}$$ +2

$$f_{C\,OUT}' = \frac{1}{2\pi C_{OUT}(R_C + R_L)} = \frac{1}{2\pi \cdot 100n\,(10k + 100k)}$$

$$f_{C\,OUT}' = 14.47 \text{ Hz}$$ +2

Finally, determine the approximate overall cutoff frequency f_L and sketch the overall magnitude response of the Electro Harmonix LPB-1.

$$f_L \approx \sqrt{12.2^2 + 14.47^2}$$

$$= 18.93 \text{ Hz}$$

+1