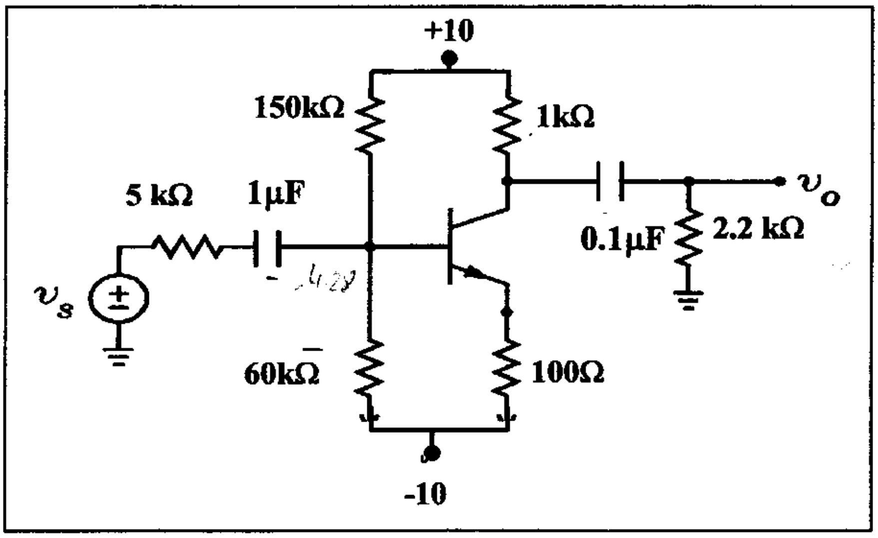
Q_1: For the circuit below, draw a two-port low-frequency small-signal equivalent-circuit model of the single stage amplifier. If the transistor has β=99, and VT=0.025V, find:

a) Mid band gain

b) Low cutoff frequency.



a) Mid band gain

$$A_v = \frac{-\beta R_L'}{r_\pi + (1+\beta)R_E}$$

$$R_L' = R_C // R_L = 1 // 2.2 = 0.6875\ k\Omega$$

$$r_\pi = \frac{\beta}{g_m}, \quad g_m = \frac{I_c}{V_T}, \quad I_c = \beta I_B$$

$$V_{BB} = V_{BB_1} + V_{BB_2}$$

$$V_{BB_1} = V_{cc} \times \frac{R_1}{R_1 + R_2} = 10 \times \frac{60}{60+150} = 2.86\ V$$

$$V_{BB_2} = -V_{cc} \times \frac{R_2}{R_1 + R_2} = -10 \times \frac{150}{150+60} = -7.14$$

$$V_{BB} = 2.86 - 7.14 = -4.28$$

$$R_{BB} = R_1 // R_2 = 60 // 150 = 42.86\ k\Omega$$

$$I_B = \frac{V_{BB} - V_{BE}}{R_{BB} + (1+\beta) R_E}$$

$$I_B = \frac{4.28 - 0.7}{42.86 + 100 \times 0.1} = 67.7 \mu A$$

$$\therefore I_C = 99 \times 67.7 = 6.7 mA$$

$$\therefore g_m = \frac{6.7}{25} = 0.268$$

$$r_\pi = \frac{99}{0.268} = 369.4 \Omega$$

$$\therefore A_v = \frac{-99 \times 687.5}{369.4 + 100 \times 100} = -6.56$$

$$A_{vs} = A_v \cdot \frac{R_{in}}{R_{in} + R_s}$$

$$R_{in} = R_{BB} // (r_\pi + (1+\beta) R_E)$$

$$= 42.86 // (369.4 + 100 \times 100) \times 10^{-3} = 8.35 K\Omega$$

$$A_{vs} = -6.56 \frac{8.35}{8.35 + 5} = -4.1$$

b)

$$F_{in} = \frac{1}{2\pi C_{in} (R_{in} + R_s)}$$

$$= \frac{1}{2\pi \times 1 \times 10^{-6} (8.35 \times 10^3 + 5 \times 10^2)} = 11.92 \text{ Hz}$$

$$F_{out} = \frac{1}{2\pi C_{out} (R_L + R_C)}$$

$$= \frac{1}{2\pi \times 0.1 \times 10^{-6} \times (1 + 2.2) \times 10^3} = 497.35$$

$$\therefore F_L = \sqrt{F_{in}^2 + F_{out}^2}$$

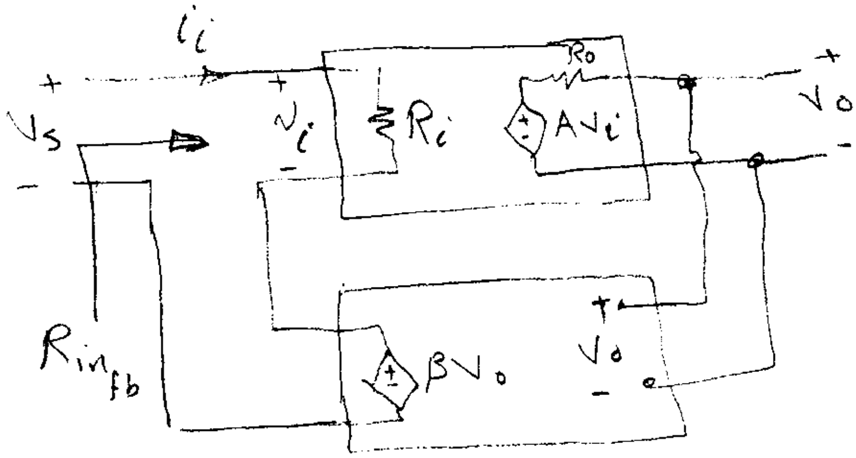
$$= \sqrt{(11.92)^2 + (497.35)^2}$$

$$= 497.5 \text{ Hz}$$

Q2. For series-Shunt feedback amplifier, prove that:

a) $R_{ifb} = R_i \cdot (1+A\beta)$

b) $R_{ofb} = R_o \cdot (1+A\beta)$



a)

$$R_{ifb} = \frac{V_s}{i_i} = \frac{V_s}{V_i / R_i}$$

$$= R_i \cdot \frac{V_s}{V_i}$$

But $V_s = V_i + V_f$

$$V_f = \beta V_o$$

$\therefore$ $V_s = V_i + \beta V_o$

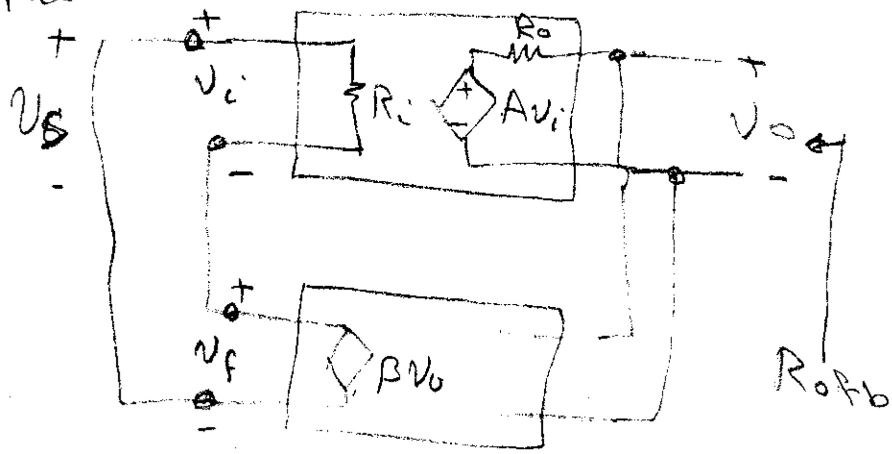
$\therefore$ $R_{ifb} = R_i \dfrac{V_i + \beta V_o}{V_i}$, But $V_o = A V_i$

$$R_{ifb} = R_i \frac{V_i + \beta A V_i}{V_i}$$

$$= R_i (1 + A\beta)$$

b)

We Consider Shorting the input source.



$$v_i = -\beta v_o$$

$$i_o = \frac{v_o - Av_i}{R_o}$$

$$= \frac{v_o + A\beta v_o}{R_o}$$

$$\therefore \frac{v_o}{i_o} = R_{ofb} = \frac{v_o}{\frac{v_o + A\beta v_o}{R_o}}$$

$$\therefore R_{ofb} = \frac{R_o}{1 + A\beta}$$

Q₃: A class-B amplifier drives a load of 100Ω. If collector – emitter voltage $V_{CE(sat)}$= 0.5V and the average value of the load current =100mA, calculate:

a) The maximum power it can deliver to the load, (4 marks)

b) The efficiency, (4 marks)

c) The power dissipated by the transistor. (2 marks)

a) $P_{L(max)} = I_o^2 R_L$

$$I_o = \frac{1}{2} I_{o(max)}$$

$$I_{o(max)} = \frac{V_{o(max)}}{R_L}$$

$$I_{o(avg)} = \frac{I_{o(max)}}{\pi}$$

$$100 \times 10^{-3} = \frac{I_{o(max)}}{\pi} \Rightarrow I_{o(max)} = 314 \times 10^{-3}$$

$$I_o = \frac{314 \times 10^{-3}}{2} = 157\ mA$$

$$\therefore P_{L(max)} = (157 \times 10^{-3})^2 \times 100 = 2.465\ Watt$$

b) $$\eta = \frac{P_L}{P_s}$$

$$P_s = I_{o(Avg)} \times V_{cc}$$

$$V_{cc} = V_{o(max)} + V_{CE(sat)}$$

$$= I_{o(max)} R_L + 0.5$$

$$= 314 \times 10^{-3} \times 100 + 0.5 = 31.9\ V$$

$\therefore \; P_S = 100 \times 10^{-3} \times 31.9$
$= 3.19 \text{ Watt}$, $\eta = \frac{2.465}{3.19} = 0.782$

c) $P_T = P_S - P_L$
$= 3.19 - 2.465 = 0.725 \text{ watt}$

Q5: Design a triangular waveform generator running with frequency of 5kHz and amplitude of output wave is 6V peak to peak, by using Op-Amp have saturation voltage $\pm 10V$.

$$V_o = \beta V_{sat}$$

one peak is 3V

$$\therefore \; 3 = \beta \times 10 \Rightarrow \beta = \frac{3}{10} = 0.3$$

$$\beta = \frac{R_1}{R_1 + R_2}$$

assume $R_1 = 10kHz$

$$\frac{3}{10} = \frac{10}{10 + R_2} \Rightarrow R_2 = \frac{100 - 30}{3} = \frac{70}{3} = 20.33K\Omega$$

$T_1 = T_2$ becaus $V_{sat+} = V_{sat-}$

$$T = \frac{1}{F} = \frac{1}{5KHz} = 0.2\,msec$$

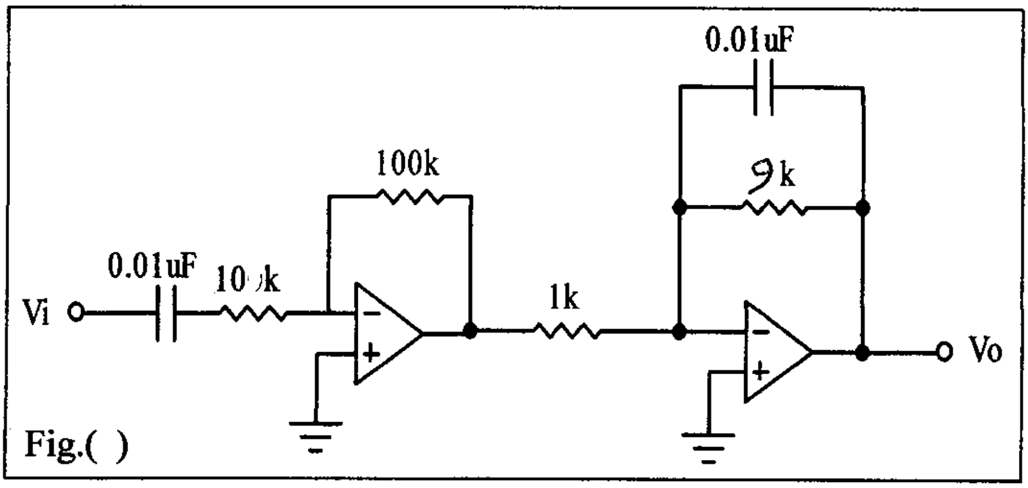
$$\therefore \; T_1 = 0.1\,msec$$

$$T_1 = CR \frac{V_{TH} - V_{TL}}{V_{sat+}}$$

$$0.1 \times 10^{-3} = CR \frac{3 - (-3)}{10}$$ let $C = 1nF$

$$R = \frac{0.1 \times 10^{-3}}{0.6 \times 1 \times 10^{-9}} = 166.7\,K\Omega$$

Q_6: For first order band pass filter is shown in Fig.( ), calculate the center frequency, bandwidth and quality factor. **(10 marks)**



$$F_o = \sqrt{F_L F_H}$$

$$F_L = \frac{1}{2\pi R_1 C_1} = \frac{1}{2\pi \times 0.01 \times 10^{-6} \times 10 \times 10^{3}}$$

$$= 1592 \text{ Hz}$$

$$F_H = \frac{1}{2\pi R_2 C_2} = \frac{1}{2\pi \times 0.01 \times 10^{-6} \times 9 \times 10^{3}}$$

$$= 1768.9 \text{ Hz}$$

$$f_o = \sqrt{1592 \times 1768.9} = 1678 \text{ Hz}$$

$$B.W = F_H - F_L = 1768.9 - 1592$$
$$= 176.9 \text{ Hz}$$

$$Q = \frac{f_o}{B.W} = \frac{503.4}{1432.25} = 9.5$$

$$V_+ = V_o \times \frac{R_1}{R_1 + R_f} - V_i \times \frac{R_f}{R_1 + R_f}$$

$$V_{Ref} =$$

$$-3 = \cancel{12}^{6} \times \frac{8}{\cancel{20}_{10}} - V_i \times \frac{\cancel{12}^{6}}{\cancel{20}_{10}}$$

$$-3 = 4.8 - V_i \times 0.6$$

$$V_i = \frac{3 + 4.8}{0.6} = \frac{\cancel{7.8}}{\cancel{0.6}} = 13$$

$$-3 = -11.8 \times \frac{8}{20} - V_i \times \frac{6}{10}$$

$$V_i = \frac{3 + \cancel{7.866}\ 4.72}{0.6} = -12.87$$

$$V = \frac{-4.72 - 3}{0.6}$$