Tutorial - I.

(1) Three - identical stages in a multistage amplifier have an overall upper 3dB frequency of 40KHz and lower 3dB frequency of 15KHz. What is the operating Bandwidth of each amplifier stage?

Sol

no. of stages = 3

identical stages so,

$$f_l^1 = f_l^2 = f_l^3$$

$$f_h^1 = f_h^2 = f_h^3.$$

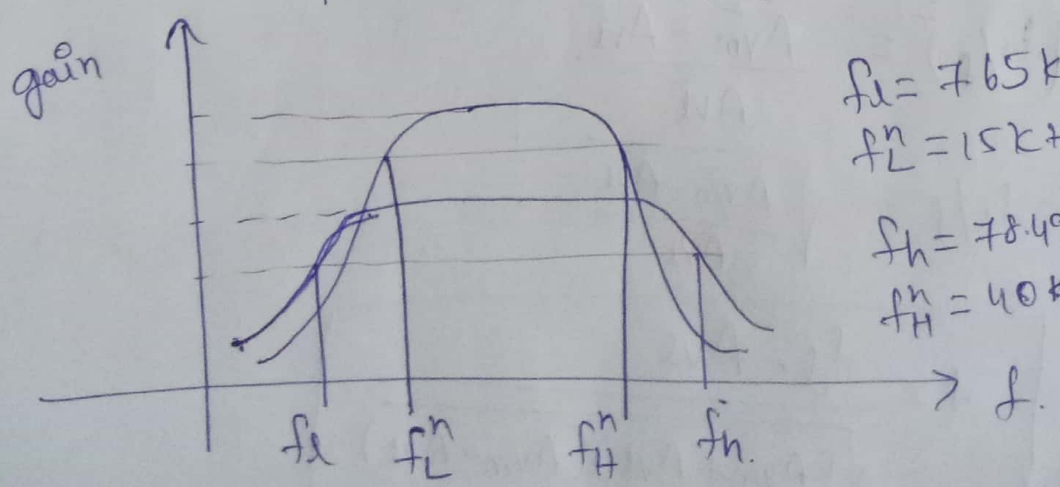
The overall lower 3dB frequency $f_L^3 = 15KHz$

The overall ~~lower~~ upper 3dB frequency $f_H^3 = 40\,KHz$.

$$f_l = f_L^n \left[\sqrt{2^{1/n} - 1}\right]$$

$$= 15\times10^3 \left[\sqrt{2^{1/3} - 1}\right] = 7.647KHz.$$

$$f_h = f_H^n \Big/ \sqrt{2^{1/n} - 1} = 40\times10^3 \Big/ \sqrt{2^{1/3} - 1} = 78.458KHz.$$



$f_l = 7.65\,KHz$
$f_L^n = 15KHz$

$f_h = 78.49\,KHz$
$f_H^n = 40\,KHz$

② The RC coupled amplifier has mid frequency gain = 100. The values of lower and upper cut off frequencies are $f_l = 80 Hz$ and $f_h = 80 KHz$. Find the frequency at which the gain is reduced to 80.

Sol Given lower cut off frequency $f_l = 80 Hz$.

upper cutoff frequency $f_h = 80 KHz$.

Mid frequency gain $A_{vm} = 100$.

where

$$\left(\frac{A_{vl}}{A_{vm}}\right) = \frac{1}{\sqrt{1+(f_l/f)^2}}$$

$$\left(\frac{A_{vl}}{A_{vm}}\right)^2 = \frac{1}{1+(f_l/f)^2}$$

$$1+(f_l/f)^2 = \frac{A_{vm}^2}{A_{vl}^2}$$

$$(f_l/f)^2 = \frac{A_{vm}^2}{A_{vl}^2} - 1$$

$$(f_l/f)^2 = \frac{A_{vm}^2 - A_{vl}^2}{A_{vl}^2}$$

$$f_l/f = \sqrt{\frac{A_{vm}^2 - A_{vl}^2}{A_{vl}^2}}$$

$$\boxed{f = \frac{f_l \cdot A_{vl}}{\sqrt{(A_{vm}+A_{vl})(A_{vm}-A_{vl})}}}$$

$$f = \frac{80 \times 80}{\sqrt{(100+80)(100-80)}} = 106.66\,Hz$$

at $f = 106.66\,Hz$, the gain is reduced to 80.

Similarly

$$\left(\frac{A_{vh}}{A_{vm}}\right) = \frac{1}{\sqrt{1+(f/f_h)^2}}$$

$$1+(f/f_h)^2 = \left(\frac{A_{vm}}{A_{vh}}\right)^2$$

$$(f/f_h)^2 = \left(\frac{A_{vm}}{A_{vh}}\right)^2 - 1$$

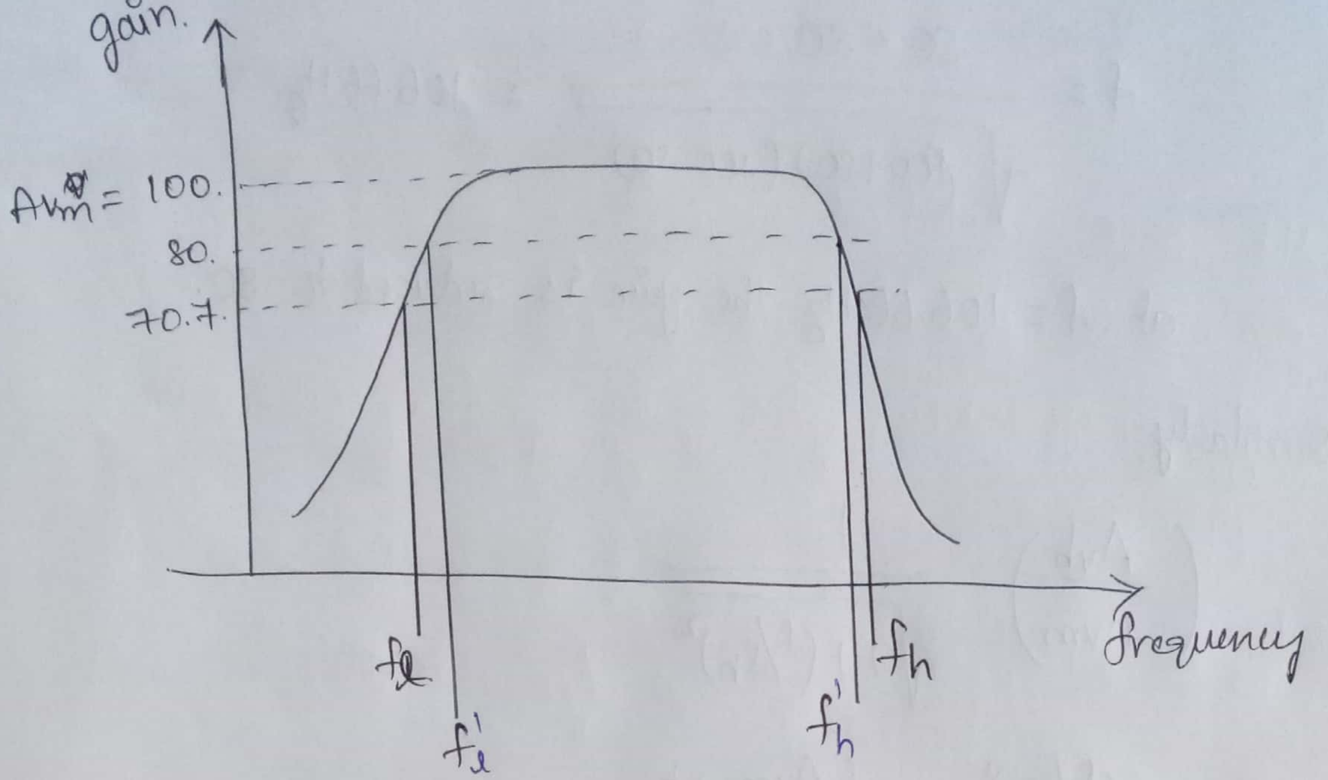
$$f/f_h = \sqrt{\frac{A_{vm}^2 - A_{vh}^2}{A_{vh}^2}}$$

$$\boxed{f = \frac{f_h}{A_{vh}} \sqrt{(A_{vm}+A_{vh})(A_{vm}-A_{vh})}}$$

$$f = \frac{80 \times 10^3}{80} \sqrt{(100+80)(100-80)}$$

$$f = 60\,KHz$$

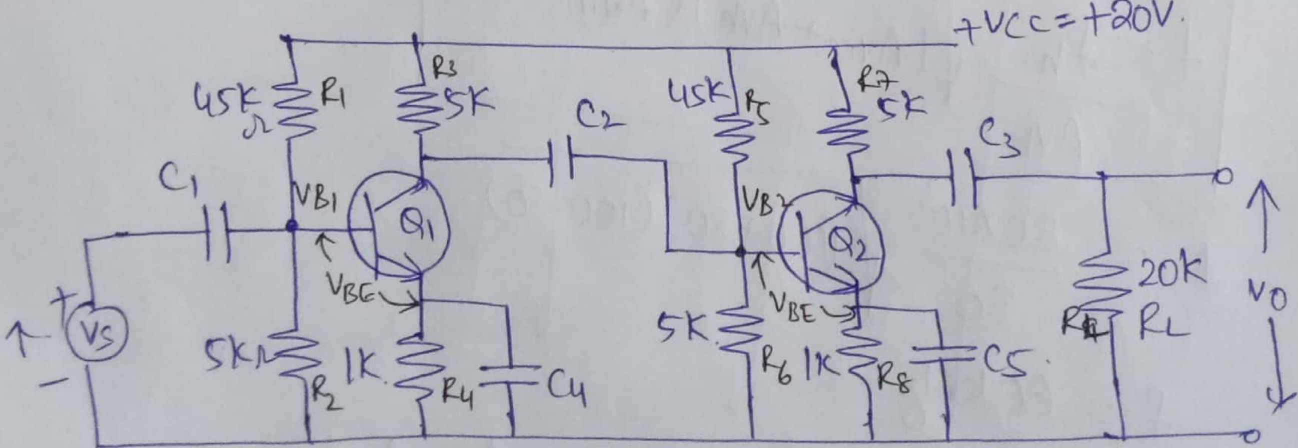
At $f = 60\,KHz$, the gain is reduced to 80.



$f_l = 80Hz$. $f_l' = 106.6Hz$.

$f_h = 80KHz$ $f_h' = 60KHz$.

(3) Compute the overall voltage gain for the 2-stage RC coupled amplifier shown in below figure. Express the gain in dB by considering $V_{BE} = 0.7V$, $\beta_1 = \beta_2 = 100$.



sol To find the overall gain of the above circuit, Initially individual stages gains will be calulated as a function of impedance ratio's.

Due to Vcc the voltage across Base of second transistor Q_2 V_{B2} is given as

$$V_{B2} = \frac{V_{CC} \cdot R_6}{R_5 + R_6} = \frac{20 \times 5 \times 10^3}{50 \times 10^3} = 2V.$$

$$V_{B2} = V_{BE} + V_{E2}.$$

$$V_{E2} = V_{B2} - V_{BE} = 2V - 0.7 = 1.3V.$$

Now the current through R_8 is given as

$$I_{E2} = \frac{V_{E2}}{R_8} = \frac{1.3V}{1k} = 1.3mA.$$

The internal forward resistance r_{e2} is depends on the thermal voltage and the current I_{E2}.

$$r_{e2} = \frac{V_T}{I_{E2}}$$

where $V_T \rightarrow$ Thermal voltage at $T = 27^\circ$

$$V_T = \frac{T}{11,600} = \frac{300}{11,600} = 25.86mV.$$

Then

$$r_{e2} = \frac{25.86m}{1.3m} = 19.89\Omega.$$

The transistor having $\beta_2 = 100$, then the the impedance at base of second transistor is

$$Z_{in(B2)} = r_{e2} \times \beta_2 = 1.989k\Omega.$$

The total i/p impedance to the second stage is the parallel combination of $Z_{in(B2)}$, R_5 & R_6.

$Z_{in2} = R_5 || R_6 || Z_{in(B2)}$

$Z_{in2} = 1.378 k\Omega$

The Effective collector load for 2nd stage

$R_{ac2} = R_7 || R_L$

$R_{ac2} = 4k\Omega$.

Then the voltage gain of second stage

$$Av_2 = -\frac{R_{ac2}}{r_{e2}} = \frac{4k}{19.89} = -201.1$$

$$\boxed{Av_2 = -201.1}$$

Similarly the base voltage at ~~transistor~~ base terminal of the first transistor Q_1 is

$$V_{B1} = \frac{R_2}{R_1+R_2} \cdot V_{CC} = \frac{5 \times 10^3 \times 20}{50 \times 10^3} = 2V.$$

$$VE_1 = V_{B1} - V_{BE} = 2 - 0.7 = 1.3V.$$

$$IE_1 = \frac{VE_1}{R_4} = \frac{1.3}{1k} = 1.3mA.$$

$$r_{e1} = \frac{V_T}{IE_1} = 19.89$$

$$Av_1 = \frac{-R_{ac1}}{r_{e1}}$$

$R_{ac1} = R_3 || Z_{in2} = 1.080 k\Omega$

$$Av_1 = \frac{-1.080 \times 10^3}{19.89} = -54.31$$

The overall voltage gain is given as

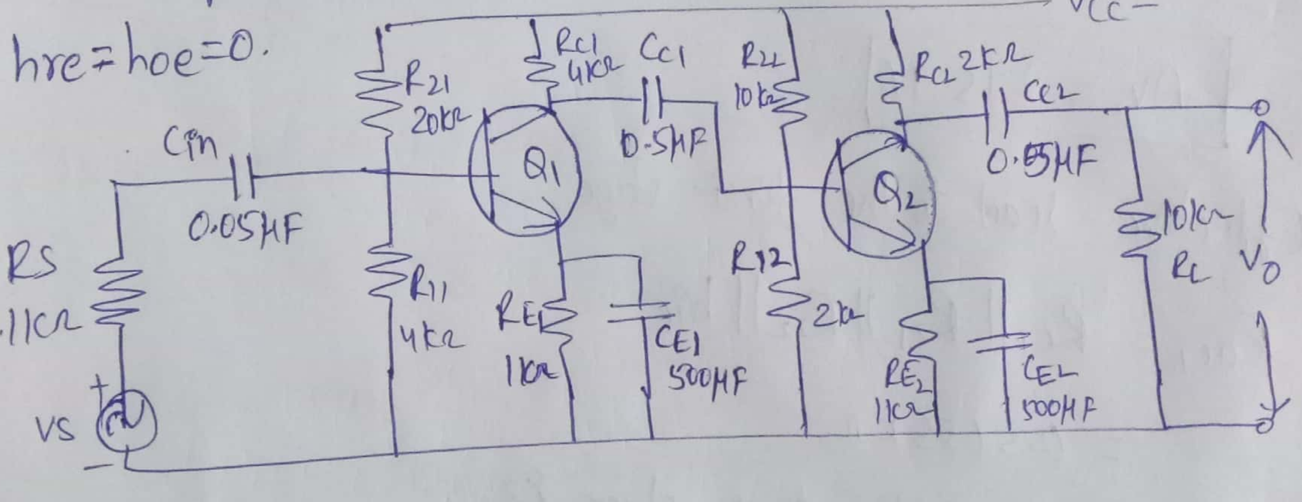
$$A_V = A_{V_1} \cdot A_{V_2}$$

$$= (-201.1)(-54.31)$$

$$A_V = 10,922.2$$

$$(A_V)_{dB} = 8.76 \text{ dB.}$$

(4) Determine the input impedance, output impedance and overall voltage gain for a 2-stage RC coupled amplifier shown in below figure. Load resistance connected across the output terminals of the amplifier is of $10K\Omega$. $h_{ie} = 1.1K\Omega$, $h_{fe} = 50$, $h_{re} = h_{oe} = 0$.



Sol when looking into the base terminals of the transistor Q_1, h_{ie} is seen to be in series with $h_{re}V_{out}$. Since $h_{re} = 0$, so the i/p impedance to the transistor base

$$Z_b = h_{ie}.$$

Input impedence to the circuit is

$$Z_{in} = R_{11} \| R_{21} \| h_{ie} = 827\Omega$$

The output impedance ~~of~~ of the circuit is

$$Z_{out}\ \frac{1}{h_{oe}} \| R_{C2} = R_{C2}$$

$$Z_{out} = 2k\Omega.$$

voltage gain of the second stage is

CE amplifier

$$\left[A_V = -\frac{h_{fe}}{h_{ie}} . R_L \right.$$

$$A_{V_2} = \frac{-h_{fe}}{h_{ie}} . (R_{C2} \| R_L)$$

$$= \frac{-h_{fe}\ R_{C2} . R_L}{h_{ie}\ (R_{C2} + R_L)} = \frac{-50 \times 2 \times 10^3 \times 10 \times 10^3}{1.1 \times 10^3 (12) \times 10^3}$$

$$\boxed{A_{V_2} = -75.76}$$

Effective load to the first stage,

$$R_{ac1} = R_{C1} \| R_{21} \| R_{22} \| h_{ie}.$$

$$= 0.5685 k\Omega$$

voltage gain of the first stage is

$$A_{V_1} = \frac{-h_{fe}}{h_{ie}} . R_{ac1} = \frac{-50}{1.1 \times 10^3} \times 0.5685 \times 10^3 = -25.84$$

$$\boxed{A_{V_1} = -25.84}$$

overall voltage gian $A_V = A_{V_1} . A_{V_2}$

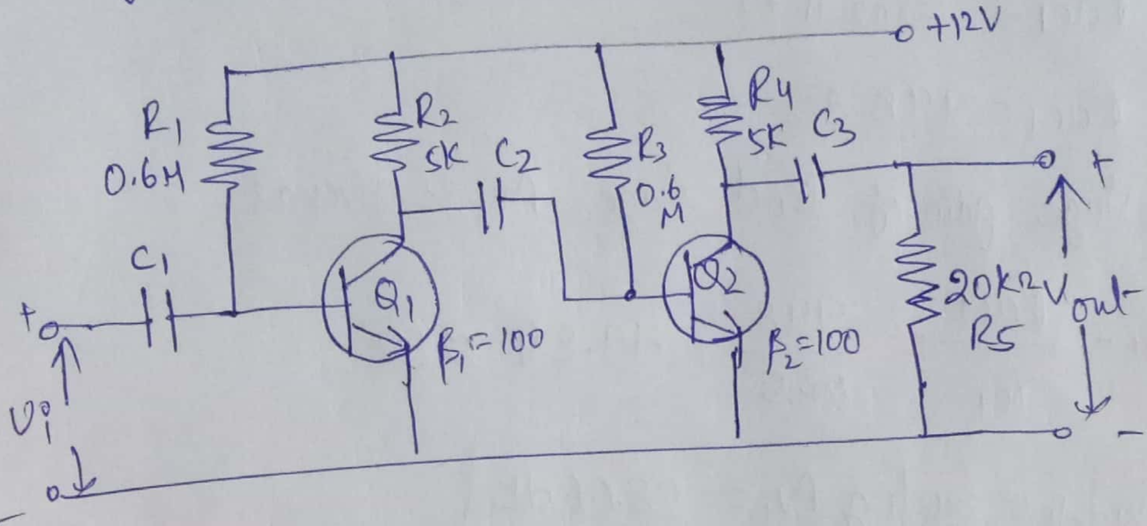
$$A_V = -75.76 \times -25.84$$

$$\boxed{A_V = 1958}$$

5) For the two-stage RC coupled two level audio amplifier shown in below figure. Find the following

(i) r_i (ii) A_{v_1} (iii) A_{v_2} (iv) A_v in dB.

Neglect V_{BE} and take $r_e = 25mV/I_E$.



Sol

The current at the base of first transistor Q_1

$$I_{B1} = \frac{V_{CC}}{R_1} = \frac{12}{0.6M} = 0.02mA.$$

Emitter current in fixed bias

$$I_{E_1} \approx I_{C_1} = \beta_1 \cdot I_{B_1} = 100 \times 0.02m = 2mA.$$

$$r_{e_1} = \frac{25mV}{2m} = 12.5\,\Omega$$

$$Z_{B_1} = \beta_1 \cdot r_{e_1} = 100 \times 12.5 = 1250.$$

The i/p impedance r_i is given as

$$r_i = R_1 \,\|\, Z_{B1}$$

$$= \frac{0.6 \times 10^6 \times 1250}{1250 + 0.6 \times 10^6} = 1247\Omega$$

$$\boxed{r_i = 1.247\,k\Omega}$$

As $R_1 = R_3$, the base current

$I_{B2} = 0.02mA$.

$Z_{B2} = 1250$.

$Z_{in2} = 1.247k\Omega$

$r_{e2} = 12.5$.

then $R_{ac1} = Z_{in2} \parallel R_2$.

$R_{ac1} = 998\,\Omega$.

The voltage gain of first stage A_{v1} is given as

$$A_{v1} = \frac{R_{ac1}}{r_{e1}} = \frac{998}{12.5} = 79.84 \approx 80.$$

$$\boxed{(A_{v1})_{dB} = 20\log A_{v1} = 38.06\,dB.}$$

The $R_{ac2} = R_4 \parallel R_5$.

$= 4000\,\Omega$.

The voltage gain of second stage A_{v2} is given as

$$A_{v2} = \frac{R_{ac2}}{r_{e2}} = \frac{4000}{12.5} = 320.$$

$$\boxed{(A_{v2})\,dB = 20\log 320 = 50.1\,dB.}$$

The overall voltage gain $A_V = A_{v1} \cdot A_{v2}$

$A_V = 80 \times 320 = 25.6K$.

$$\boxed{(A_V)\,dB = 20\log A_V = 88\,dB.}$$

$$\boxed{(A_V)\,dB = 88\,dB}$$