7 - 10 mark
IMP

positive
negative
amplifier

Chapter : 3

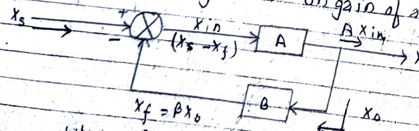
Feedback Amplifiers and Oscillators

A feedback amplifier is one in which the output signal is sampled & feedback to the input to form the error that drives the amplifier.

IMP
Advantages of negative feedback :

i) Highly stabilized gain.
ii) Increased bandwidth ie improved frequency response.
iii) Less amplitude distortion.
iv) Less frequency distortion.
v) Less phase distortion.
vi) Less harmonics distortion.
vii) Reduced noise.
viii) More linear operation.
ix) Input and output impedance can be modified as desired.

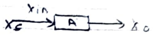
IMP
Effect of negative feedback on gain of an amplifier:-



where, β = feedback ratio

Without feedback,

open loop gain(A) $= \frac{X_o}{X_s} = \frac{X_o}{X_{in}}$



With feedback,

Here,

$X_{in} = X_s - X_f$

$\therefore X_{in} = X_s - \beta X_o$ —(I)

Also, $X_o = AX_{in}$

or, $X_o = A(X_s - \beta X_o)$

or, $X_o = AX_s - A\beta X_o$

without feedback

or, $(1+\beta A)X_o = AX_s$

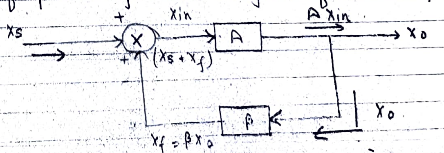
or, $\frac{X_o}{X_s} = \frac{A}{1+\beta A}$

$\therefore A_f = \frac{A}{1+\beta A}$ [Gain is decreased]

A = gain without feedback.

A_f = gain with feedback.

Effect of positive feedback on gain of an amplifier :-



where β = feedback ratio

$X_{in} = X_s + X_f = X_s + \beta X_o$

$X_o = A X_{in}$

or, $X_o = A(X_s + \beta X_o)$

or, $X_o = A X_s + A\beta X_o$

or, $X_o - A\beta X_o = A X_s$

or, $X_o(1 - A\beta) = A X_s$

$$\frac{X_o}{X_s} = \frac{A}{1 - A\beta}$$

$\therefore A_f = \frac{A}{1 - A\beta}$ [Gain is increased]

IMP

Effect of negative feedback on stability of gain :-

The gain of an amplifier with negative feedback is given by :-

$$A_f = \frac{A}{1 + \beta A} \quad \text{--- (I)}$$

Differentiating eqn (I) w.r.t A,

$$\frac{v\,du - u\,dv}{v^2}$$

$$\frac{dA_f}{dA} = \frac{(1+\beta A)\frac{dA}{dA} - A\frac{d(1+\beta A)}{dA}}{(1+\beta A)^2}$$

or, $\frac{dA_f}{dA} = \frac{1 + \cancel{\beta A} - \cancel{\beta A}}{(1+\beta A)^2}$

or, $\frac{dA_f}{dA} = \frac{1}{(1+\beta A)^2}$

$$dA_f = \frac{dA}{(1+\beta A)^2}$$

Now, dividing both side of A_f, we get,

$$\frac{dA_f}{A_f} = \frac{dA}{A_f(1+\beta A)^2}$$

or, $\frac{dA_f}{A_f} = \frac{dA}{(1+\beta A)^{\cancel{2}}} \times \frac{\cancel{(1+\beta A)}}{A}$

or, $\frac{dA_f}{A_f} = \frac{dA}{A} \times \frac{1}{1+\beta A}$ ——— II

% change in gain with feedback

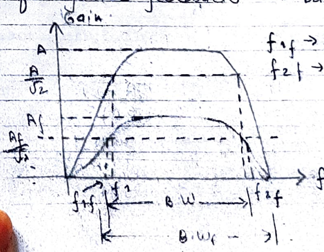
% change in gain without feedback

From eqn (II), it is clear that the percentage change in gain with negative feedback is less than the percentage change in gain without feedback.

Thus, negative feedback improves the gain stability of amplifier.

IMP.

Effect of negative feedback on bandwidth :



$f_{1f} \rightarrow f_1$ with feedback

$f_{2f} \rightarrow f_2$ with feedback

Without feedback,

Bandwidth $(B.W) = f_2 - f_1 \simeq f_2$ — I

where, f_1 = lower cut off frequency.
f_2 = upper cut off frequency.

After negative feedback, midband gain A is reduced by $(1+\beta A)$, lower cutoff frequency decreases by $(1+\beta A)$ and the upper cut-off frequency increases by $(1+\beta A)$.

Again,

$$\text{Bandwidth } (B.W_f) = f_{2f} - f_{1f}$$
$$= f_2(1+\beta A) - \frac{f_1}{1+\beta A}$$
$$\simeq f_2(1+\beta A) \left[\because f_1 \text{ negligible near to } 0\right]$$
$$\therefore B.W_f = B.W(1+\beta A) \quad \text{— (II)}$$

Thus, negative feedback extends bandwidth and improves the frequency response of the amplifier.

Effect of negative feedback on frequency distortion:

For a negative feedback system we have,

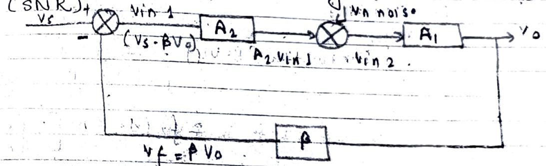
$$A_f = \frac{A}{1+\beta A}$$

If $\beta A >> 1$,

$$A_f = \frac{A}{\beta A} = \frac{1}{\beta}$$

If the feedback system is purely resistive, the gain with feedback is not dependent on frequency even though the basic amplifier gain is frequency dependent. Thus, the frequency distortion arises. Because of varying amplifier gain with frequency distortion is considerably reduced in a negative feedback amplifier circuit.

Effect of negative feedback on signal to noise ratio (SNR),



Let us consider a negative feedback system as shown in figure,

where,

V_s = Signal
V_n = Noise signal
A_2 = gain of the noise free amplifier.
β = feedback ratio.

Now,

$$V_{in1} = V_s - V_f = V_s - \beta V_o \quad \text{—(I)}$$
$$V_{in2} = V_n + A_2 V_{in}$$
$$= V_n + A_2(V_s - \beta V_o)$$
$$= V_n + A_2 V_s - \beta A_2 V_o \quad \text{—(II)}$$

$V_o = A_1 V_{in2}$.

or, $V_o = A_1(V_n + A_2 V_s - \beta A_2 V_o)$

or, $V_o = A_1 V_n + A_1 A_2 V_s - A_1 A_2 \beta V_o$

or, $V_o(1 + \beta A_1 A_2) = A_1 A_2 V_s + A_1 V_n$

$$\therefore V_o = \frac{A_1 A_2}{(1+\beta A_1 A_2)} V_s + \frac{A_1}{(1+\beta A_1 A_2)} V_n \quad \text{— (III)}$$

Thus, signal to noise ratio after negative feedback is,

$$\left(\frac{S}{N}\right)_f = \frac{A_1 A_2}{(1+\beta A_1 A_2)} V_s \times \frac{(1+\beta A_1 A_2)}{A_1} \times \frac{1}{V_n}$$

$$= A_2 \left(\frac{V_s}{V_n}\right) \quad \text{— (IV)}.$$

Thus, negative feedback increases the signal to noise ratio, i.e, for fix input signal, noise will be reduced.

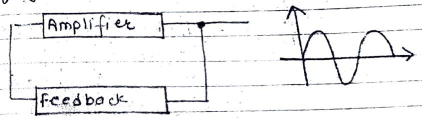
Sinusoidal Oscillator :-

An electronic device that generates sinusoidal oscillation of desired frequency is known as sinusoidal oscillator. Oscillation are produced without any external signal source. The only input power to an oscillator is the dc power supply. Oscillator doesn't create energy but merely acts as an energy converter. It receives dc energy & changes it into ac energy of desired frequency. The frequency of oscillation

depends upon the constants of the device.

For a sinusoidal oscillator, we require an amplifier with a positive feedback as shown in figure. If the loop gain ($\beta A = 1$) & phase shift ($0°$ or $360°$) are connect, there will be an output signal ~~went~~ ~~an~~ even through there is no input signal.

~~Importance of posit~~



Importance of positive feedback in oscillator circuit

For positive feedback, the closed loop gain A_f is given by :-

$$A_f = \frac{A}{1-\beta A} \quad \text{—(I)}$$

for negative $A_f = \frac{A}{1+\beta A}$

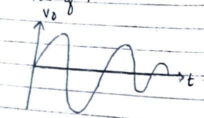
when, $\beta A = 1$

then $A_f = \infty$.

So, even a small noise signal can provide a measureable output voltage and the circuit acts as oscillator.

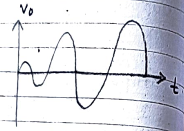
If $\beta A < 1$, the output signal will slowly vanish (die out).
If $\beta A > 1$, the output signal will build up.
If $\beta A = 1$, the output signal is obtained.

Figure below shows the output signal for various value of β.



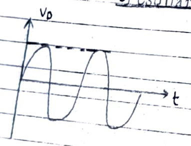
$\beta A < 1$

a) Oscillator die out



$\beta A > 1$

b) Oscillator build up.



$\beta A = 1$

c) Constant oscillation.

IMP
Essential Condition for Oscillation.

The essential condition for oscillation are:

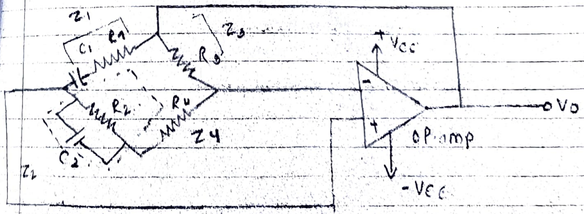
1. βA ie loop gain must be unity
2. The total phase shift (amplifier & feedback) must be 0° or 360°.

These conditions for oscillation are called **Barkhausen Criteria for Oscillation**.

Types of oscillator.

IMP
1. Wien - bridge oscillator
2. RC - phase shift oscillator
3. Tuned LC oscillator 3 types.
4. Crystal oscillator.

1) Wien- bridge Oscillator



Here,

$Z_1 = R_1 - jX_C = R_1 - \frac{j}{wC_1}$

$Z_3 = R_3, Z_4 = R_4, Y_2 = \frac{1}{R_2} + jwC_2$

Neglecting the effects of the OP-amp input & output impedence.

At balanced condition.

$$Z_1 Z_4 = Z_2 Z_3$$

or, $\frac{(R_1 - j/wC_1) R_4}{Z_2} = R_3$

or, $R_3 = \left(R_1 - \frac{j}{wC_1}\right) R_4 \cdot \left(\frac{1}{R_2} + jwC_2\right) \left[\because Y_2 = \frac{1}{Z_2}\right]$

or, $\frac{R_3}{R_4} = \frac{R_1}{R_2} + jwR_1C_2 - \frac{j}{wR_2C_1} + \frac{C_2}{C_1}$

or, $\frac{R_3}{R_4} + \frac{j}{wR_2C_1} = \frac{R_1}{R_2} + \frac{C_2}{C_1} + jwR_1C_2$ — I

Now, equating real & imaginary parts.

$\boxed{\frac{R_3}{R_4} = \frac{R_1}{R_2} + \frac{C_2}{C_1}}$ &

$\frac{1}{wR_2C_1} = wR_1C_2$

or, $w^2 = \frac{1}{R_1 R_2 C_1 C_2}$

∴ Frequency of oscillation (f) $= \frac{1}{2\pi\sqrt{R_1R_2C_1C_2}}$

If $R_1 = R_2$ & $C_1 = C_2$

∴ $f = \frac{1}{2\pi RC}$ & $\frac{R_3}{R_4} = 2$

Thus, the ratio of R_3 to R_4 greater than 2 will provide sufficient loop gain for the circuit to oscillate at the frequency calculated above.

RC phase shift oscillator :-

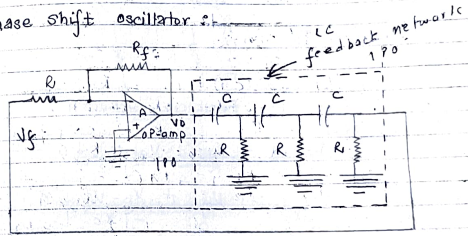


Fig: RC phase shift oscillator.

It consists of a negative gain operational amplifier and three section of RC network that produces 180° phase shift. The phase shift network is connected from OP-amp output back to it's inverting terminal.

As inverting OP-amp provides 180° phase shift and three RC network provides 180° phase shift, the total phase shift becomes 360° which is one of the criteria for oscillation. If all resistor R and capacitors C in the phase shift oscillator are equal in value, then the frequency of oscillation is given by:

$$f_r = \frac{1}{2\pi RC\sqrt{2N}}$$

where, R = resistance in Ω

C = Capacitor in F

N = number of RC stages.

f_r = output frequency in Hz.

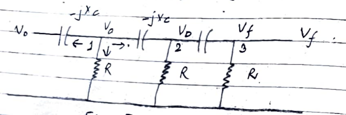


Fig: Feedback Network

Using KCL,

$$\frac{V_a - V_o}{-jX_c} + \frac{V_a}{R} + \frac{V_a - V_b}{-jX_c} = 0 \quad \text{—— (I)}.$$

$$\frac{V_b - V_a}{-jX_c} + \frac{V_b}{R} + \frac{V_b - V_f}{-jX_c} = 0 \quad \text{—— (II)}$$

$$\frac{V_f - V_b}{-jX_c} + \frac{V_f}{R} = 0 \quad \text{—— (III)}$$

Applying KCL at node 1, 2 and 3 and solving (I), (II) and (III), we get,

$$\frac{V_f}{V_o} = \beta = \frac{R^3}{(R^3 - 5RX_c^2) + j(X_c^3 - 6R^2X_c)}$$

β must be pure real for 180° phase shift.

ie $X_c^3 - 6R^2X_c = 0$

or, $X_c^2 = 6R^2$.

or, $\frac{1}{(2\pi fc)^2} = 6R^2$

or, $(2\pi fc)^2 = \frac{1}{6R^2}$.

$$\therefore f = \frac{1}{2\pi RC\sqrt{6}} \quad \text{—— (IV)} \quad \because f = \frac{1}{2\pi RC\sqrt{2N}}$$

Thus, for oscillation,

$$\beta = \frac{R^3}{R^3 - 5RX_c^2}$$

$$= \frac{R^3}{R^3 - 5R(6R^2)}$$

$$= \frac{R^3}{R^3 - 30R^3}$$

$$= \frac{-R^3}{29R^3}.$$

$$\therefore \beta = -\frac{1}{29}.$$

Since for oscillation, $A\beta = 1$.

$$\therefore A = \frac{1}{\beta} = -29$$

We have,

$$A = \frac{-R_f}{R_1}.$$

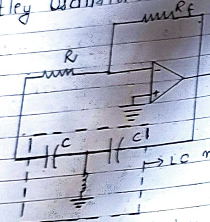
or, $-29 = \frac{-R_f}{R_1}$.

$$\therefore \boxed{R_f = 29R}$$

Tuned LC Oscillator :-

LC oscillator uses inductance capacitance circuit as their oscillatory circuit. LC oscillations are very popular for generation of high frequency output. There is large variety of LC oscillators.

Hartley Oscillator :-



→ LC network inductive

Fig: Hartley Oscillator

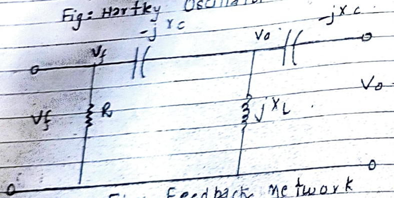


Fig: Feedback network

$\beta = -1$
$A = -1$
$R_f = R$

Using KCL,

$$\frac{V_f}{R} + \frac{V_f - V_a}{-jX_C} =$$

$$\frac{V_a - V_f}{-jX_C} + \frac{V_a}{jX_L} + V$$

Solving eq^n (I) & (II), we get,

$$\frac{V_f}{V_o} = \beta = \frac{-RX_CX_L}{(RX_C^2 - RX_CX_L) + j(2X_LX_C^2 - X_C^3)} \quad \text{—(III)}$$

β must be pure real for 180° phase shift.

$$\text{ie } 2X_LX_C^2 - X_C^3 = 0$$

$$2X_L\cancel{X_C^2} = X_C^{\cancel{3}}$$

$$2X_L = X_C$$

$$\therefore X_L = \frac{X_C}{2}$$

$$\therefore X_C = 2X_L$$

$$2\pi fL = \frac{1}{2}\left(\frac{1}{2\pi fC}\right)$$

$$2\pi fL = \frac{1}{4\pi fC}$$

$$f = \frac{1}{2\pi\sqrt{2LC}}$$

$$\beta = \frac{-RX_CX_L}{RX_C^2 - RX_CX_L} = \frac{-RX_C \cdot \frac{X_C}{2}}{RX_C^2 - RX_C \cdot \frac{X_C}{2}}$$

$$= \frac{-\frac{RX_C^2}{2}}{RX_C^2 - \frac{RX_C^2}{2}} = -1$$

Now,
Since for oscillation, $A\beta = 1$

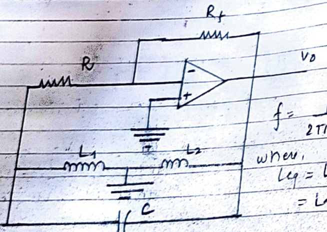
$$A = \frac{1}{\beta} = -1$$

We have,

$$A = \frac{-R_f}{R} \quad \text{or,} \quad -1 = \frac{-R_f}{R}$$

$$\therefore R_f = R_1$$

For numerical:-



$$f = \frac{1}{2\pi\sqrt{L_{eq}C}}$$

where,

$$L_{eq} = L_1 + L_2 + 2M$$
$$= L_1 + L_2$$

Mutual inductance (given in question)

Colpitt's Oscillator :-

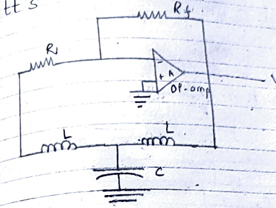


Fig: Colpitt's oscillator.

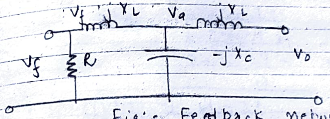


Fig:- Feedback network.

KCL:

$$\frac{V_f}{R} + \frac{V_f - V_a}{-jX_L} = 0 \quad \text{—(I)}$$

$$\frac{V_a - V_b}{jX_L} + \frac{V_a}{-jX_c} + \frac{V_a - V_f}{jX_L} = 0 \quad \text{—(II)}$$

Solving eqn (I) and (II), we get,

$$\frac{V_f}{V_0} = \beta = \frac{1}{(1-\omega^2LC) + j\left(\frac{2\omega L - \omega^3L^2C}{R}\right)} \quad \text{—(III)}$$

For 180° phase shift, β must be pure real number ie, $\frac{2\omega L - \omega^3 L^2 C}{R} = 0$

$\omega^2 LC = 2$

$\omega^2 = 2/LC$

$\therefore f = \frac{1}{2\pi\sqrt{\frac{LC}{2}}}$ — (IV)

Now, $\beta = \frac{1}{1-\omega^2 LC} = \frac{1}{1-2}$ $[\omega^2 LC = 2]$

$\boxed{\therefore \beta = -1}$

Since, βA must be unity for oscillation,

$\beta A = 1$

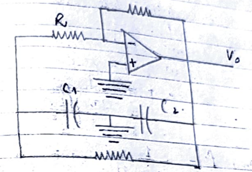
$\boxed{A = -1}$

ie $-\frac{R_f}{R_1} = -1$

$\boxed{\therefore R_f = R_1}$ — (V)

A ~~pratic~~ practical consideration is that the component values should be such that 'Q' of the β network given by $Q = R\sqrt{\frac{C}{L}}$ is not too low or too high. ~~The~~ The value of Q from 2 to 10 is very adequate.

For numerical:



$f = \frac{1}{2\pi\sqrt{LC_{eq}}}$

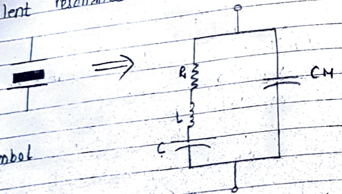
where, $C_{eq} = \frac{C_1 C_2}{C_1 + C_2}$

Crystal Oscillator:

A crystal oscillator uses a piezoelectric crystal as a resonant tank circuit. The crystal has a greater stability in holding constant at whatever frequency, the crystal is originally cut to operate. Crystal oscillators are used where greater stability is required such as in communication transmitters and receivers.

A quartz crystal exhibits the property that when mechanical stress is applied across the one set of it's faces, a potential difference is develop across the opposite faces. This property of crystal is called piezoelectric effect. Conversely when a potential difference is applied across it's two opposite faces it causes the crystal either to expand or contract. If an alternating voltage is applied the crystal is set into vibration. The frequency of vibration is equal to the resonant frequency of the crystal as determined by it's structural characteristics. When the frequency of applied ac voltage is equal to the natural ~~fr~~ resonant frequency of crystal, the amplitude of vibration will be maximum.

Although the crystal has electron mechanical resonance, we can represent the crystal action by an equivalent resonance circuit as shown in figure.



a) Symbol

b) Equivalent circuit

$\Rightarrow X_L - X_C = X_{cm}$ - series

$\Rightarrow X_L = X_C$

The crystal as represent by an electrical equivalent circuit can have two resonance frequency. One resonance condition occur when the reactance of the series RLC leg are equal (and opposite). For this condition, the series impedance is very low. The other resonance occur at higher frequency when the reactance of series leg equals the reactance of capacitor C_M. This is parallel resonance or antiresonance condition of a crystal. At this frequency, crystal offers very high impedance to the external circuit.

At series resonance condition.

$$X_L = X_C$$

$$\text{or, } 2\pi f_1 L = \frac{1}{2\pi f_1 C}$$

$$f_1^2 = \frac{1}{4\pi^2 LC}$$

$$\boxed{\therefore f_1 = \frac{1}{2\pi\sqrt{LC}}} \quad \text{--- (1)}$$

Similarly, at parallel resonance condition.

$$X_L - X_C = X_{CM}$$

$$\text{or, } \omega L - \frac{1}{\omega C} = \frac{1}{\omega C_M}$$

$$\text{or, } \frac{\omega^2 LC - 1}{\cancel{\omega} C} = \frac{1}{\cancel{\omega} C_M}$$

$$\text{or, } \omega^2 LC - 1 = \frac{C}{C_M}.$$

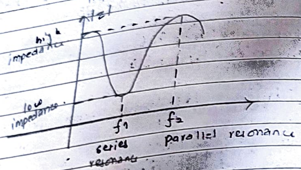
$$\text{or, } \omega^2 LC C_M - C_M = C$$

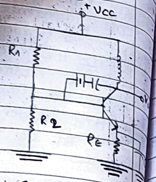
$$\text{or, } \omega^2 LC C_M = C + C_M.$$

or, $\omega^2 = \frac{C + C_M}{L C C_M}$

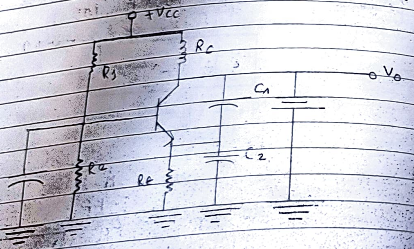
$$\omega^2 = \frac{1}{LC}\left[1 + \frac{C}{C_M}\right]$$

$$\therefore f_2 = \frac{1}{2\pi}\sqrt{\frac{1 + C/C_M}{LC}} \quad \text{——— (II)}$$





a) Series resonance circuit



b) Parallel resonance circuit

Numericals :-

1* When a negative feedback is applied to an amplifier of gain 100, The overall gain fall to 50.

i) Calculate the fraction of output voltage feedback.

ii) If this fraction is maintain calculate the value of the amplifier gain require if the overall ~~volt~~ stage gain is to be 75.

Here,

Open loop gain $(A) = 100$

Overall gain $(A_f) = 50$

Now,

i) $A_f = \dfrac{A}{1 + A\beta}$ [negative feedback]

for positive feedback $\left[A_f = \dfrac{A}{1 - \beta A}\right]$

or, $50 = \dfrac{100}{1 + 100\beta}$

or, $50 + 5000\beta = 100$

$\beta = \dfrac{50}{5000} = 0.01$

(ii) $\beta = 0.01$

$A_f = 75$

$A = ?$

We know,

$$A_f = \frac{A}{1 + \beta A}$$

or, $A_f + A_f \beta A = A$

or, $A_f = A(1 - \beta A_f)$

$75 = \frac{1}{4} A$

$\therefore A = 300$ #

$j^2 = -1$

2) The gain of a certain amplifier as a function of frequency is $A(j\omega) = \frac{-16\times10^6}{j\omega}$. A feedback path connected around it has $\beta(j\omega) = \frac{10^3}{(2\times10^3+j\omega)^2}$

Will the system oscillate? If so at what frequency?

Here,

$$A\beta = \frac{-16\times10^6}{j\omega} \times \frac{10^3}{(2\times10^3+j\omega)^2}$$

180° 180°

$$= \frac{-16\times10^9}{j\omega(2\times10^3+j\omega)^2}$$

$$= \frac{-16\times10^9}{j\omega((4\times10^3)^2 + 2\cdot2\times10^3\cdot j\omega + j^2\omega^2)}$$

$$= \frac{-16\times10^9}{4\times10^6 j\omega + 4\times10^3 j^2\omega^2 + j^3\omega^3}$$

$$= \frac{-16\times10^9}{4\times10^6 j\omega - 4\times10^3\omega^2 - j\omega^3} \quad \text{——— (I)}$$

$$= \frac{-16\times10^9}{-4\times10^3\omega^2 + j\underbrace{(4\times10^6\omega-\omega^3)}_{\to 0}}$$

For oscillation, βA must be have 0° or 360° phase shift, ie.

$$4\times10^6\omega - \omega^3 = 0$$

or, $\omega(4\times10^6-\omega^2) = 0$

Since, $\omega \neq 0$

$$4\times10^6 - \omega^2 = 0$$

$\therefore \omega = 2\times10^3$ rad/sec

substituting the value of ω in eq^n (I),

$$A\beta = \frac{-16\times10^9}{-4\times10^3\times4\times10^6}$$

$$A\beta = 1.$$

Since, $\beta A = 1$ and total phase shift is 360°, Barkhausen criteria is satisfied at $\omega = 2\times10^3$ rad/sec

$\therefore$ Frequency of oscillation, $f = \frac{\omega}{2\pi}$

$$= \frac{2\times10^3}{2\pi} = 318.30$$

8 or 7 marks

3) Design a wien-bridge that we oscillate at 25 KHz.

Here,

$$f = \frac{1}{2\pi RC}, \quad R_1 = R_2, \quad C_1 = C_2$$

Frequency of oscillation (f) = 25 KHz.

Now,

For wien-bridge,

Let $C = 0.01\,\mu F$

$C_1 = C_2 = 0.01\,\mu F = 0.001\,\mu F$

Now,

$$f = \frac{1}{2\pi RC} \quad \text{or,} \quad 25\times10^3 = \frac{1}{2\times\pi\times R\times0.01\times10}$$

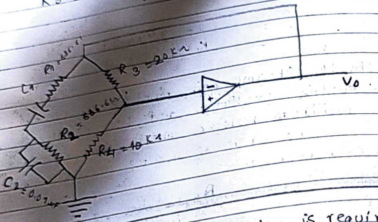
$$R = 636.61\,\Omega.$$

$R_1 = R_2 = R = 636.61\,\Omega$

Now,

Let $R_4 = 10\,k\Omega$ then,

$R_3 = 2R_4 = 2\times 10 = 20\,k\Omega$



4* A 3-stage RC phase shift oscillator is required to produce an oscillation frequency of 6.5 kHz. If 1 nF capacitor are used in the feedback circuit, calculate the value of the frequency determining resistors and the value of the feedback resistor required to sustain oscillation.

Here,

$f = 6.5\,kHz$

feedback capacitor $(C) = 1\,nF = 1\times 10^{-9}\,F$

feedback resistor $(R) = ?$, $R_f = ?$

For 3-stage RC oscillator,

$$f = \frac{1}{2\pi RC\sqrt{6}}$$

or, $$R = \frac{1}{2\pi f C\sqrt{6}}$$

$$= \frac{1}{2\pi \cdot 6.5\times 10^{3}\times 1\times 10^{-9}\sqrt{6}}$$

$$= 9996.11$$

$$\therefore R_1 = 10\,k\Omega$$

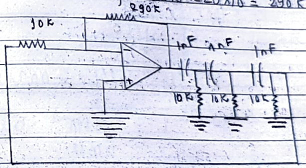
Now,

As the op-amp gain must be equal to −20 in order to sustain oscillation and the resistive value of 3 oscillation resistors are 10 kΩ.

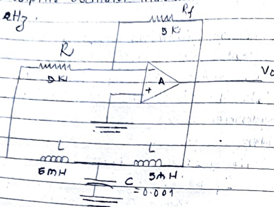
The value of op-amp feedback resistor R_f is calculated as

$$A_v = -\frac{R_f}{R_1}$$

or, $R_f = 29R_1 = 29\times 10 = 290\,k\Omega$.



5) Design a colpitts oscillator that will oscillate at 100 kHz.



$F = 100\,kHz$.

Let $C = 0.001\,\mu F$, $R = R_f = 5k\Omega$.

Now,

$$f = \frac{1}{2\pi\sqrt{\frac{LC}{2}}}$$

$$2\pi \times 100\times10^3 = \frac{1}{\sqrt{\frac{LC}{2}}}$$

$$3.94\times10^{11} = 1/\frac{L\times0.001\times10^{-6}}{2}$$

or, $L = 5\times10^{-3}\,H$

$= 5\,mH$.

Now,

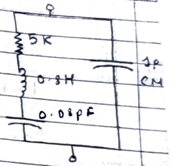
Q of the β-network,

$$Q = R\sqrt{\frac{C}{L}} = 2.23$$

So, the design is practicable.

6 The series log parameter of a crystal oscillator equivalent circuit are $L = 0.8H$, $C = 0.08\,pF$ and $R = 5k\Omega$ and parallel capacitor $C_M = 1\,pF$. Calculate the series and parallel resonance frequencies.

Here,



For series resonance frequency,

$$f_1 = \frac{1}{2\pi\sqrt{LC}}$$

$$= 6.29\times10^5\,Hz$$

$$= 629\,kHz.$$

For parallel resonance frequency,

$$f_2 = \frac{1}{2\pi}\sqrt{\frac{1+C/C_M}{LC}}$$

$$= \frac{1}{2\pi}\sqrt{\frac{1+0.08\times10^{-12}/1\times10^{-12}}{0.8\times0.08\times10^{-12}}}$$

$$= \frac{1}{2\pi}\sqrt{\frac{1.08}{0.8\times0.08\times10^{-12}}}$$

$$= \frac{410\times10^4}{2\pi}$$

$$f_2 = 654\,kHz.$$

$\therefore f_2 > f_1$.