Frequency stability:

The measure of ability of an oscillator to maintain desire frequency as precisely as possible for a long time is called frequency stability of an oscillator.

The factors which affect the frequency stability

1) Temperature changes → L and C values in feedback circuit changes Hence frequency changes.
2) If temperature changes, the parameters of BJT, FET changes Hence frequency changes.
3) changes in power supply causes change in frequency.
4) changes in atmospheric conditions, due to aging.
5) changes in load connected, the effective resistance in feedback circuit changes, Hence frequency changes.
6) collector base junction is in reverse bias condition. So there will be internal capacitance. The capacitance effect the capacitance in feedback circuit. Hence frequency changes.

The variation of frequency with temperature is given by a factor

$$S_\omega = \frac{\Delta\omega / \omega_r}{\Delta T / T_r}$$

where $\omega_r \rightarrow$ desired frequency

$T_r \rightarrow$ operating Temperature

$\Delta\omega \rightarrow$ change in frequency

$\Delta T \rightarrow$ change in Temp.

The frequency stability is defined as

$$S_\omega = \frac{d\theta}{d\omega}$$

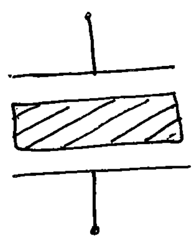
$d\theta$ = phase shift introduced for a small change in desired frequency.

Frequency stability can be improved by following modifications

1) Enclosing the oscillator circuit in a constant temperature chamber.
2) maintaining the constant voltage by using zener diodes.

Crystal oscillator:

Construction:



In nature, crystal is in the shape of hexagonal prism.

For practical use the prism is cut in to a rectangular slab, which is mounted on parallel metal plates.

Crystal materials : Quartz, Rochelle salt etc.

Crystal Exhibits a property called piezo Electric Effect.

1) when a mechanical pressure is applied on the crystal, the crystal tends to vibrate and develop a.c voltages across the opposite faces of the crystal.

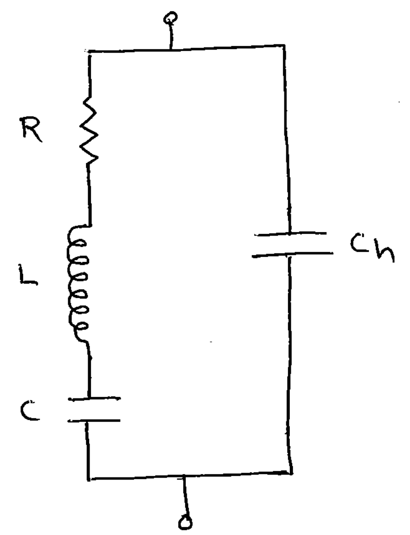
2) If we apply a.c voltages across the two faces of the crystal It vibrates causing mechanical distortion in the crystal state.

→ The crystal has the greater stability in holding the constant frequency (crystal oscillator is a stable oscillator

→ Generally we prefer Quartz as crystal because of less expensive and Quartz is usually available in nature.

Figure shows a crystal controlled oscillator circuit. Here it is a colpitts oscillator in which the inductor is replaced by the crystal. In this type, a piezo electric crystal, usually quartz, is used as a resonant circuit replacing an LC circuit.

The AC Equivalent circuit of a piezo electric crystal is shown in figure below.



when the crystal is not vibrating it is equivalent to capacitance C_M, because it has two metal plates separated by a dielectric. This capacitance is known as mounting capacitance.

when a crystal vibrates it is equivalent to RLC series circuit.

R $\rightarrow$ internal frictional losses

L $\rightarrow$ mass of the crystal, indication of inertia

C $\rightarrow$ stiffness.

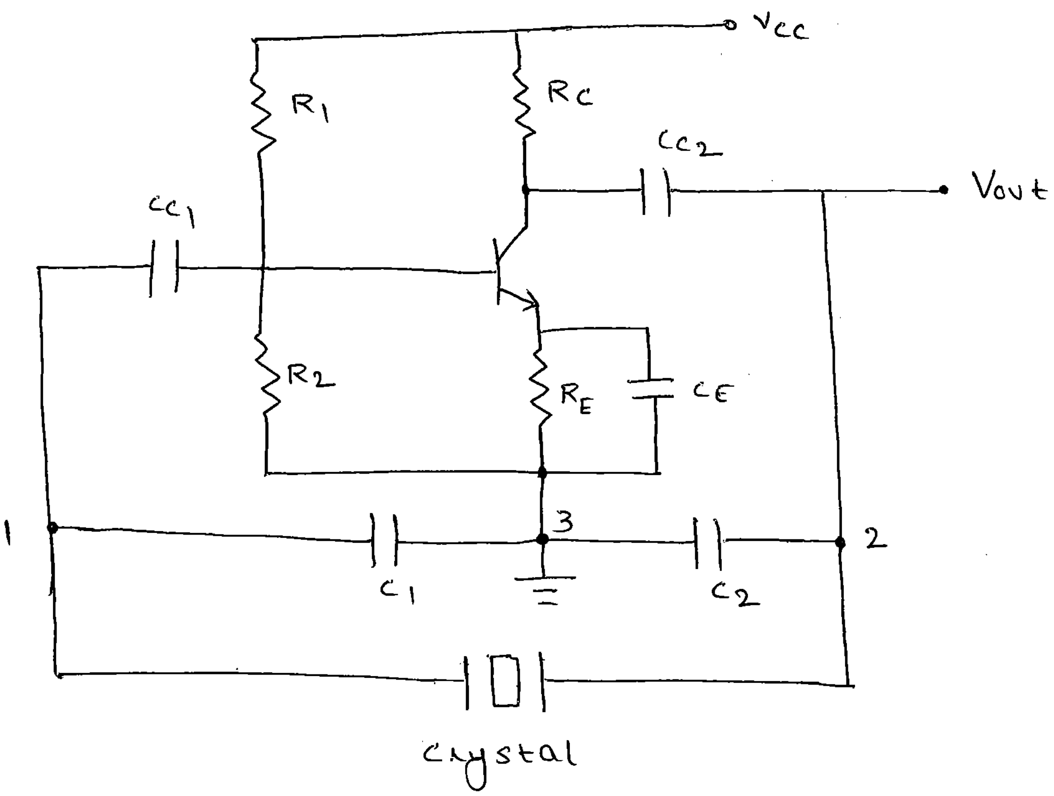


Fig: crystal oscillator.

Here the resonant frequency f_r is given by

$$f_r = \frac{1}{2\pi\sqrt{LC}\sqrt{\frac{Q^2}{1+Q^2}}}$$

$Q \rightarrow$ Quality factor $= \frac{X_L}{R} = \frac{\omega L}{R}$

In general Q-value is very high

If $Q^2 >> 1$, then f_r becomes

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

<u>Series Resonance</u> :

$$X_L = X_C \quad (X_L - X_C = 0)$$

$$\omega_s L = \frac{1}{\omega_s C}$$

$$\omega_s^2 = \frac{1}{LC} \Rightarrow \omega_s = \frac{1}{\sqrt{LC}}$$

$$f_s = \frac{1}{2\pi\sqrt{LC}}.$$

Parallel Resonance :-

$$X_{series} = X_{CM}$$

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

$$\omega_p L - \frac{1}{\omega_p C} = \frac{1}{\omega_p C_M}$$

$$\omega_p^2 LC - 1 = \frac{C}{C_M}$$

$$\omega_p^2 LC = 1 + \frac{C}{C_M} = \frac{C + C_M}{C_M}$$

$$\omega_p^2 = \frac{C + C_M}{LCC_M} \Rightarrow \omega_p^2 = \frac{1}{L C_{eq}}$$

where $C_{eq} = \frac{CC_M}{C + C_M}$

$$\therefore \omega_p = \frac{1}{\sqrt{L C_{eq}}} \Rightarrow f_p = \frac{1}{2\pi\sqrt{L C_{eq}}}$$

Problem: In hartley oscillator calculate L_2 with $L_1 = 15\,mH$, $C = 50\,PF$ and $M = 5\,\mu H$ and the frequency of oscillator is $168\,KHz$.

Solution:

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

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

$f_r = 168\,KHz$, $C = 50\,PF$, $L_1 = 15\,mH$, $M = 5\,\mu H$

$$\therefore L_2 = 2.94\,mH.$$

pb) In transistorized Hartley oscillator the two inductors are 2mH and 20μH. while the frequency is change from 950 KHz to 2050 KHz. Calculate the range over which the capacitor is to be varied.

Solution: Given data

$L_1 = 2\,mH$, $L_2 = 20\,\mu H$, $M = 0$ | $f_{r_1} = 950\,KHz$

$L_{eq} = L_1 + L_2 = 2.02 \times 10^{-3}$ | $f_{r_2} = 2050\,KHz$

$$f_{r_1} = \frac{1}{2\pi\sqrt{L_{eq} C_1}} \Rightarrow C_1 = 0.139\,\mu F.$$

$$f_{r_2} = \frac{1}{2\pi\sqrt{L_{eq} C_2}} \Rightarrow C_2 = 2.98\,PF.$$

problem: In a Hartley oscillator the value of capacitor in tuned circuit is 500 PF and two sections of coil have inductances 38μH and 12μH Find the frequency of oscillator and feed back factor β.

solution:

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

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

$M = 0$

$L_{eq} = 0.5\,\mu H.$

$$f_r = \frac{1}{2\pi\sqrt{0.5 \times 10^{-6} \times 500 \times 10^{-12}}} = 1\,MHz$$

feed back factor $\beta = \frac{V_f}{V_o}$

Feed back voltage V_f is proportional to X_{L_1}

output Voltage V_o is proportional to X_{L_2}

$$\frac{V_f}{V_o} = \frac{X_{L1}}{X_{L2}} = \frac{j\omega L_1}{j\omega L_2} = \frac{L_1}{L_2}$$

$$\beta = 3.166.$$

Problem: In colpitts oscillator $C_1 = 0.2\,\mu F$, $C_2 = 0.02\,\mu F$ If the frequency of oscillator is 10 KHz. Find the value of inductor. and also find the required gain for oscillation.

Solution: $C_1 = 0.2\,\mu F$, $C_2 = 0.02\,\mu F$

$$C_{eq} = \frac{C_1 C_2}{C_1 + C_2} = 0.01\,\mu F$$

$$f_r = \frac{1}{2\pi\sqrt{L\,C_{eq}}} \Rightarrow L = 14.07\,mH.$$

$$A_V = \frac{V_o}{V_i} = \frac{V_o}{V_f}$$

V_o is proportional to $X_{C2} = \frac{1}{j\omega C_2}$

V_f is proportional to $X_{C1} = \frac{1}{j\omega C_1}$

$$A = \frac{1/j\omega C_2}{1/j\omega C_1} = \frac{C_1}{C_2} \Rightarrow A = \frac{0.2\,\mu F}{0.02\,\mu F} = 10$$

$$A \geq \frac{C_1}{C_2} \Rightarrow A \geq 10$$

Problem: colpitts oscillator is designed with $C_1 = 7500\,PF$, $C_2 = 100\,PF$, the inductance is variable. Determine the range of inductance values if the frequencies of oscillation is to vary between 950 KHz to 2050 KHz.

Solution: $$f_{r_1} = \frac{1}{2\pi\sqrt{L_1 C_{eq}}}$$

$$C_{eq} = \frac{C_1 C_2}{C_1 + C_2} = 9.86 \times 10^{-11} \quad , \quad f_{r_1} = 950\,kHz$$

$$\Rightarrow \quad L_1 = 0.28\,mH.$$

Ily $$f_{r_2} = \frac{1}{2\pi\sqrt{L_2 C_{eq}}} \quad , \quad f_{r_2} = 2050\,KHz$$

$$\Rightarrow \quad L_2 = 0.06\,mH.$$

Problem: The frequency sensitive arms of wien bridge oscillator $C_1 = C_2 = 0.001\,PF$, $R_1 = 10\,K\Omega$, R_2 is kept variable. The frequency is varied from 10 KHz to 50 KHz. By varying R_2 find the minimum and maximum values of R_2.

Solution: $$f = \frac{1}{2\pi\sqrt{R_1 R_2 C_1 C_2}}$$

$f_1 = 10\,KHz$, $R_1 = 10\,K\Omega$, $C_1 = C_2 = 0.001\,PF$

$$R_2 = 2.53 \times 10^{16}\,\Omega$$

$f_2 = 50\,KHz$, $R_1 = 10\,K\Omega$, $C_1 = C_2 = 0.001\,PF$

$$R_2 = 1.013 \times 10^{15}\,\Omega.$$

Problem: A crystal oscillator has $L = 0.4\,H$, $C = 0.085\,PF$, $C_M = 1\,PF$, $R = 5\,K\Omega$. Find series and parallel resonating frequencies. By what percent does the parallel resonating frequency exceeds series resonating frequency and also find quality factor of the crystal.

Solution:

Series resonating frequency $f_s = \dfrac{1}{2\pi\sqrt{LC}}$

$$\therefore f_s = 863.13 \text{ KHz}$$

Parallel resonating frequency $f_p = \dfrac{1}{2\pi\sqrt{L\,C_{eq}}}$

$$C_{eq} = \frac{C\,C_M}{C + C_M} = 7.83 \times 10^{-14}$$

$$f_p = \frac{1}{2\pi\sqrt{L\,C_{eq}}} = \frac{1}{2\pi\sqrt{0.4 \times 7.83\times10^{-14}}}$$

$$f_p = 899.3 \text{ KHz}$$

$$\text{percentage} = \frac{f_p - f_s}{f_s} \times 100 = 4.19\,\%$$

Quality factor $Q = \dfrac{X_s}{R}$

$$Q = \frac{\omega_s L}{R} = \frac{2\pi f_s L}{R} = 433.8.$$