LC Tuned Circuit Operation (LC Tank Circuit)

The LC tank circuit consists of elements L and C connected in parallel as shown below.

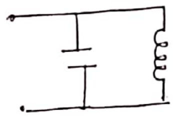


figure (a)

Let capacitor is initially charged from a dc source with the polarities as shown in below figure.

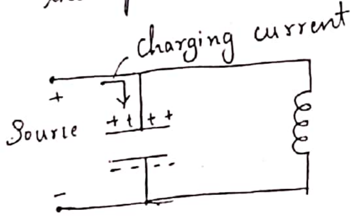


Figure (b)

When the capacitor gets fully charged energy stored in capacitor is electrostatic energy. Then the capacitor starts discharging through L in the direction of flow of conventional current I. in fig c. Due to such current the magnetic field gets set up around the inductor L. Thus inductor starts storing the energy when the capacitor is fully discharged, maximum current flows through the circuit and all the electrostatic energy get stored as a magnetic energy in the inductor L as shown in figure d.

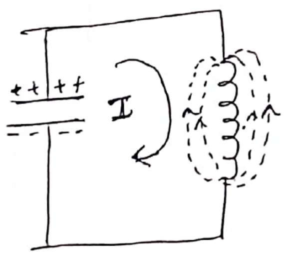


Figure (c)

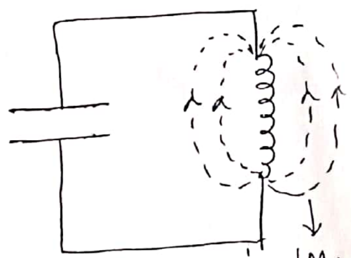


Figure (d)

Magnetic field built around L

Now the magnetic field around L starts collapsing per Lenz's law, this starts charging the capacitor with opposite polarity making lower plate positive and upper plate negative as shown in figure (e)

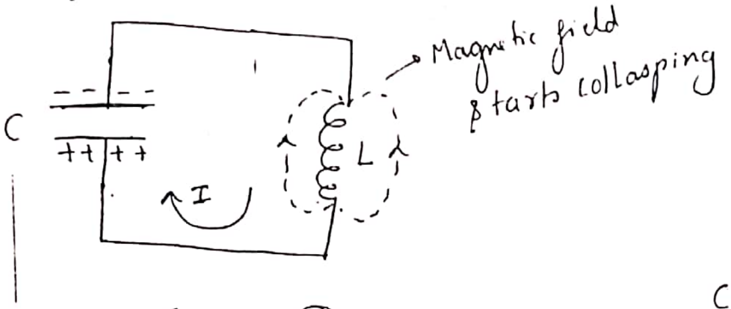


Figure (e)

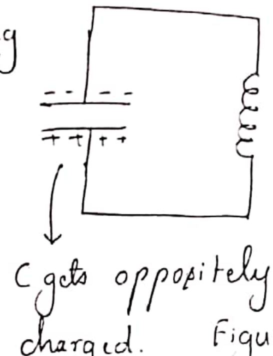


Figure (f)

After some time, capacitor gets fully charged with opposite polarity as compared to its initial polarity. as shown figure (f).

Now the capacitor again starts to discharge through inductor L, But in opposite direction as shown in figure (g)

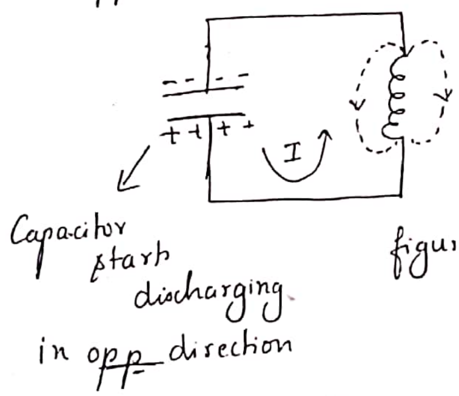
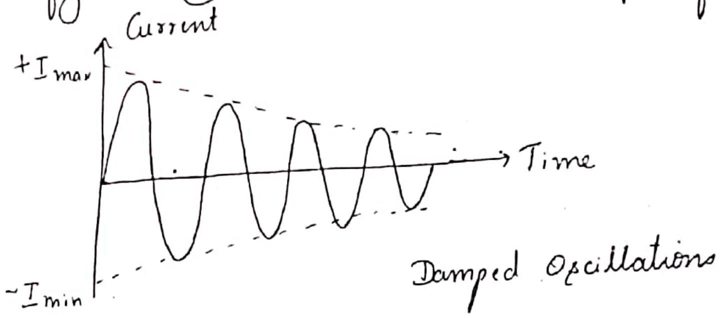


figure: (g)

This is nothing but oscillatory current. But every time when energy is transferred from C to L and L to C the losses occure due to which the amplitude of oscillating current keeps decreasing. Hence we get exponentially decaying signals called damped oscillations.

as shown in figure (h) Such oscillations stop after sometime.

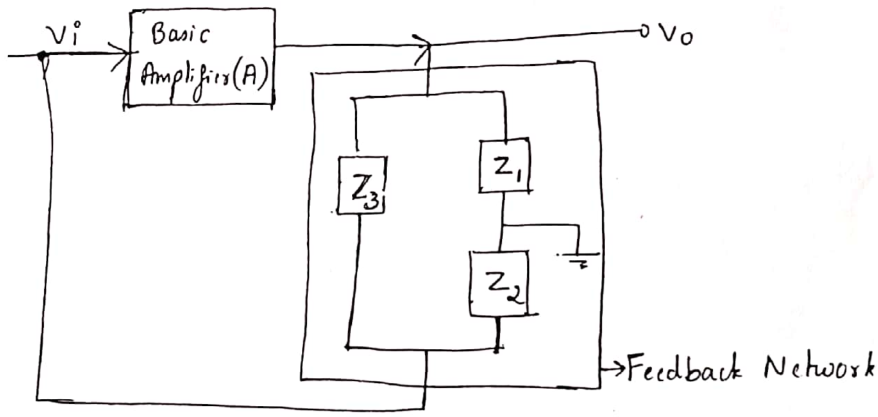


The LC tank circuit along with transistor amplifier can be used to obtain oscillators called LC oscillators.

The frequency oscillations generated by LC tank circuit depends on L and C

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

Basic form of LC oscillator



We assume that the feedback network uses three impedences which are practically pure reactances.

$$Z_1 = jX_1, \quad Z_2 = jX_2, \quad Z_3 = jX_3$$

Amplifiers provides the phase shift of 180° while the feedback network provides additional phase shift of 180°. to complete 360° phase shift around the loop.

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To satisfy Barkhausen criteria $(AB \geq 1)$, X_1 and X_2 must be of same type (C or L) and X_3 must be opposite.

Hence LC oscillators consist of two inductors and one capacitor or two capacitors and one inductor.

Depending on these combination there are two types of oscillators

Oscillator	Reactances X_1	X_2	X_3
Hartley	L	L	C
Colpits	C	C	L

To satisfy Barkhausen condition the open loop gain of amplifier

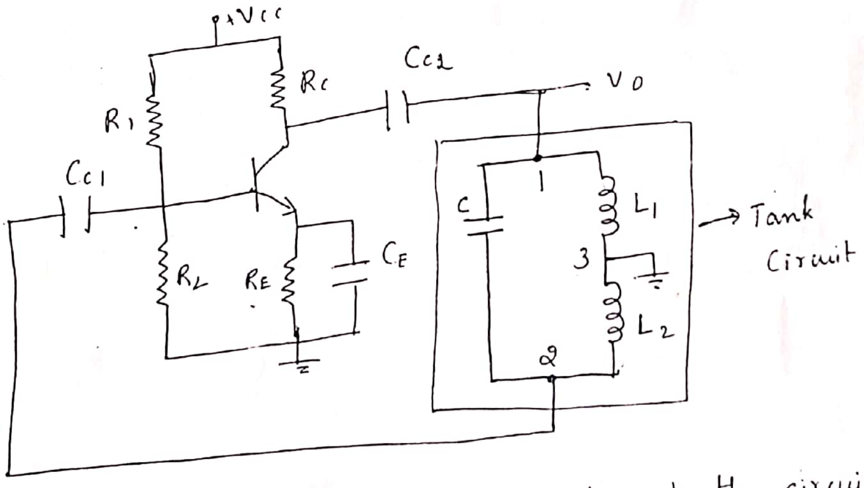
$$\boxed{A = \frac{X_1}{X_2}}$$

Hartley Oscillator

Hartley oscillator tank circuit uses $X_1 = X_2 = L$ and $X_3 = C$

The two inductors are L_1 and L_2 which are connected in series across the capacitor C to complete the tank circuit.

Below figure shows Hartley oscillator with CE amplifier.



The resistors R_1, R_2 and R_E provides proper bias to the circuit.

The capacitors C_{c1} and C_{c2} are coupling capacitors. C_E is bypass capacitor.

The feedback n/w consists of two inductors L_1 and L_2 and capacitor C.

The transistor amplifier provides a phase shift of 180°. when power supply V_{cc} is ON, Collector current starts rising and charges the capacitor when the capacitor is fully charged it discharges through coil L_1 and L_2. Thus damped oscillations are set up in the tank circuit. The oscillations across L_1 are applied to the input circuit and appeared in amplified form in the output circuit.

Continous undamped output is obtained as a result of continous supply of energy to the tank circuit to overcome occuring ~~it~~. in it!

The frequency of oscillation is produced by LC tank circuit

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

There are two inductors L_1 and L_2. There exists a mutual inductance M between two inductors the total inductance is

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

Hence frequency of oscillation becomes

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

To satisfy Barkhausen criteria The open loop gain

$$A = \frac{X_1}{X_2} = \frac{2\pi f L_1 + 2\pi f M}{2\pi f L_2 + 2\pi f M} = \frac{L_1 + M}{L_2 + M}.$$

$$\boxed{A = \frac{L_1 + M}{L_2 + M}}$$

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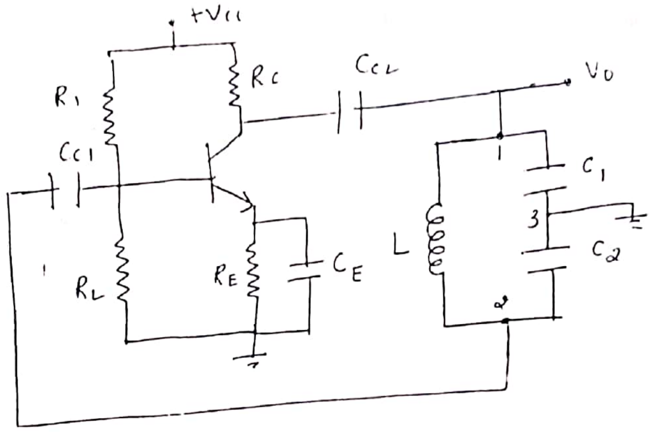
Colpitts Oscillator

The tank circuit of Colpitts oscillator uses two capacitors and one inductor. The two capacitors are C_1 and C_2 which are connected in series across inductor L.

The circuit below shows Transistorised Colpitts oscillator.



When the power supply switch is ON, capacitors C_1 and C_2 are charged and then discharged through the inductor L, there by generating damped harmonic oscillations in the tank circuit. The CE amplifier produces a phase change of 180° between input and output and tank circuit provides additional phase change of 180° so total change at the input of amplifier is 360° and positive feedback is established. Hence continous undamped oscillations are produced.

The frequency of oscillations in colpitts oscillator is

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

There are two capacitors ~~with~~ C_1 and C_2 in series hence

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

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$$\therefore f = \frac{1}{2\pi\sqrt{L C_{eq}}}$$

Condition of maintenance of oscillations, the open loop gain

$$A = \frac{X_1}{X_2} = \frac{\frac{1}{2\pi f C_1}}{\frac{1}{2\pi f C_2}} = \frac{C_2}{C_1}$$

$$\boxed{A = \frac{C_2}{C_1}}$$

Crystal Oscillator

→ Frequency of oscillation of Hartley and Colpitts oscillator depends on the values of tank circuit parameters. These parameters change with time, temperature etc. For higher stability crystal oscillators are used.

→ The crystals are naturally occuring or synthetically manufactured circuit component. The oscillations are produced by the crystals due to Piezoelectric Effect.

→ The piezoelectric effect means under the influence of mechanical pressure ac voltage gets generated across the opposite faces of the crystal. Conversely if the crystal is subjected ac voltage it vibrates causing mechanical distortion in its sh

Every crystal has its own resonating frequency associated with it depending on its cut.

When frequency of applied ac voltage is equal to natural frequency of the crystal, the amplitude of mechanical oscillations become maximum.

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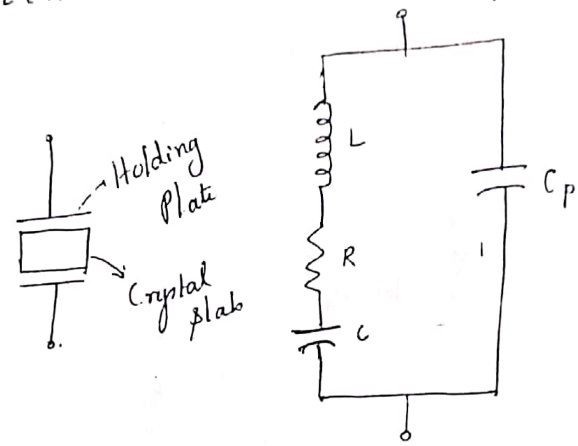
AC equivalent circuit of vibrating crystal is represented by a series of LCR circuit shunted by capacitor C_p as shown below.



→ The shunt capacitance C_p represents the electrostatic capacitance between two metal plates separated by a dielectric like crystal slab. It is called Mounting capacitance.

→ When crystal is vibrating, there will be internal friction losses denoted by a resistance R. The inductor L indicates the crystal mass (indication of its inertia). In vibrating the crystal will have mechanical stiffness indicated by C.

The expression for resonating frequency is in range of few KHz to 100 MHz, Eg: Rochelle salt, Quartz crystal, tourmaline

The crystal has 2 frequencies associated with.

a series resonance frequency

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

a parallel resonance frequency

$$f_P = \frac{1}{2\pi\sqrt{L C_{eq}}} \quad \text{where } C_{eq} = \frac{C C_p}{C + C_p}.$$

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