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Sinusoidal Oscillators

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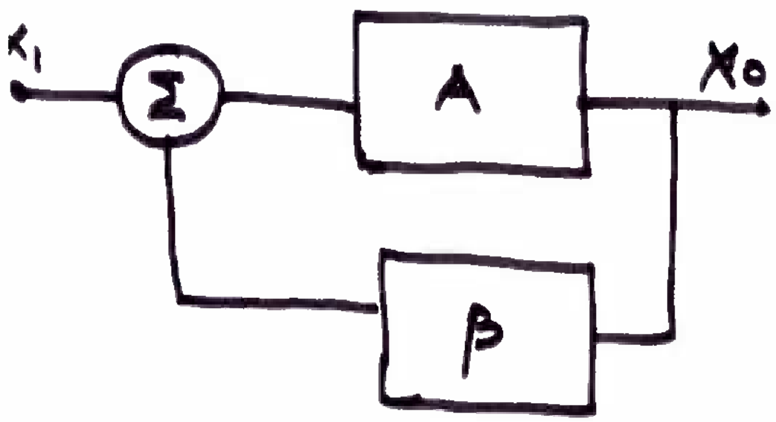

$$H(s) = \frac{x_o}{x_i}$$

$$= \frac{A(s)}{1 + A(s)\beta(s)}$$

$$T(s) = L(s) = A(s)\beta(s) \quad \text{Loop Gain}$$

Hence if $1 + A\beta = 0$, Then $H(s) \to \infty$

or Loop Gain $= -1$, we have $H(s) \to \infty$

This condition will lead to Oscillation.

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The Barkhausen Criterion

For Sinusoidal Oscillations will be possible

when $\quad T(s) = -1$

or $\quad |T(2\pi j f_1)| = 1 \quad$ and $\quad \angle T(2\pi j f_1) = -180^0 \quad$ — (A)

At Oscillator Frequency f_1

[redacted] $\quad |T(2\pi j f_1)| =$ Magnitude & $\angle T(2\pi j f_1) =$ Phase

OR $\quad$ Real Part of $T(2\pi j f_1) = -1$

& Imaginary Part of $T(2\pi j f_1) = 0 \quad$ — (B)

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That is to Say for Oscillations Conditions be —

(i) Phase Shift through Amplifier and Feedback Network must become $\underline{360^{\circ}}$ (In Phase of Input)

(ii) And $|A\beta| = 1$

These conditions are called Barkhausen Criterion.

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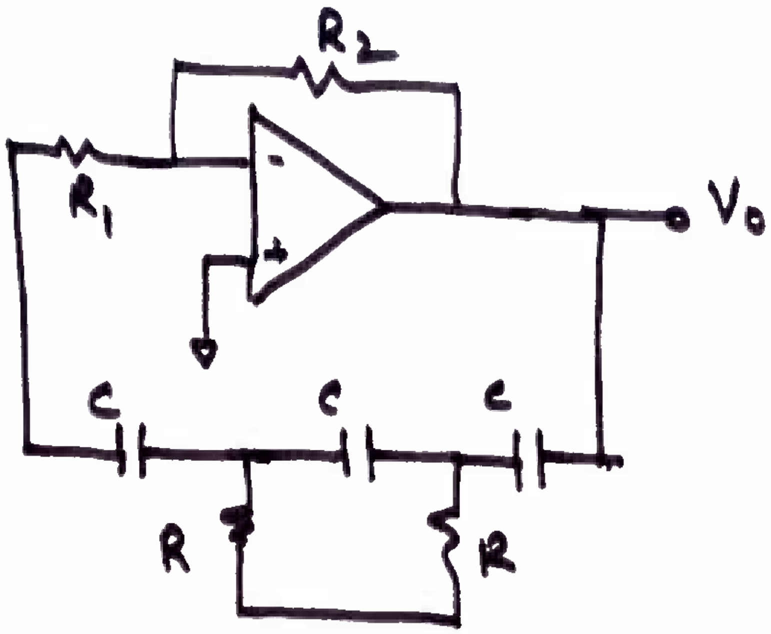
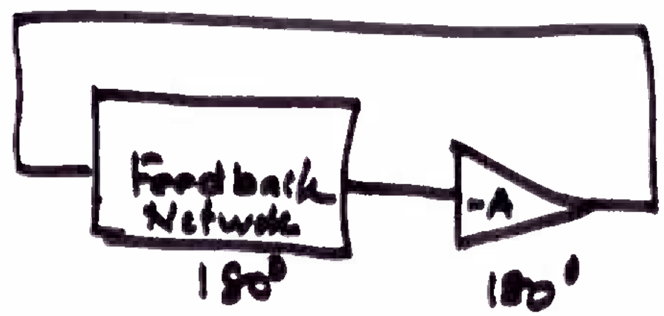
Phase - Shift Oscillator





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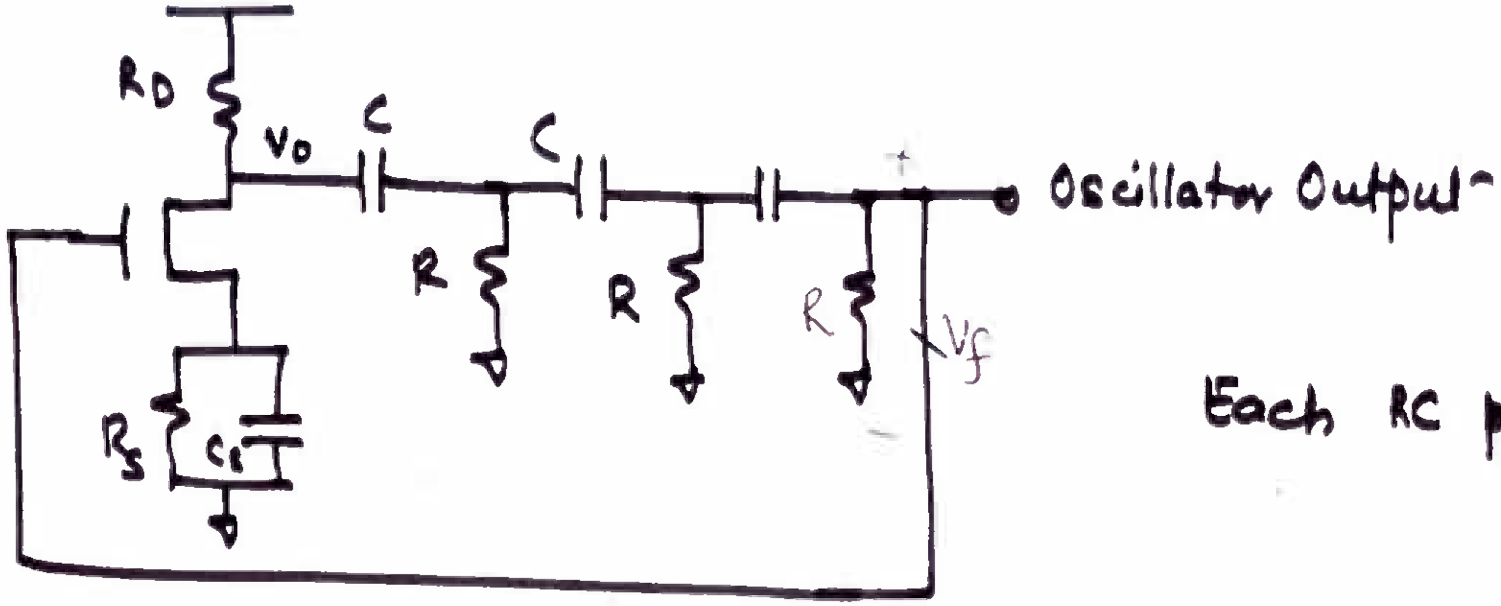
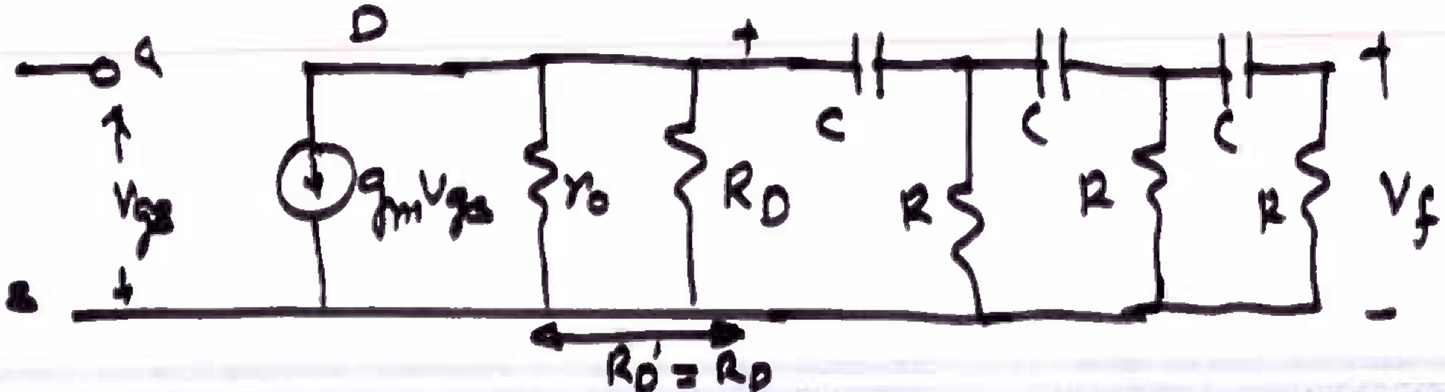
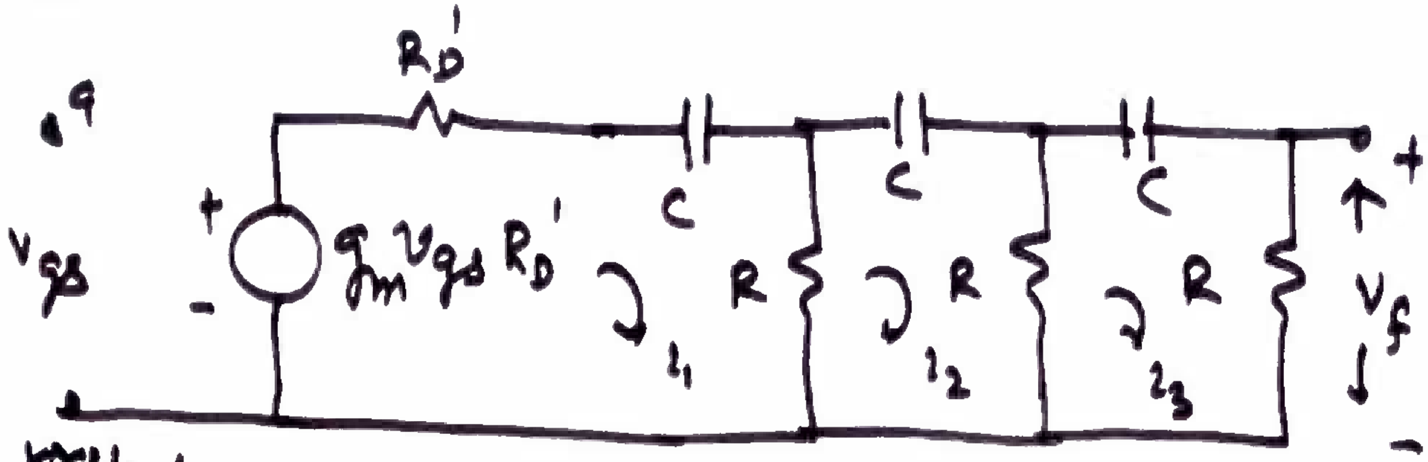
MOSFET Phase Shift Oscillator



Each RC provides 60° Phase shift





<u>KVL</u> :

$$i_1 \left(R_D' + \frac{1}{Cs} \right) - i_2 R = - g_m R_D' v_{gs} \qquad \text{— (i)}$$

$$- i_1 R + i_2 \left(R + R + \frac{1}{Cs} \right) - i_3 R = 0 \qquad \text{— (ii)}$$

$$- i_2 R + i_3 \left(2R + \frac{1}{Cs} \right) = 0 \qquad \text{— (iii)}$$

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Feedback Voltage $V_f = i_3 R \quad -(iv)$

$\therefore$ Loop Gain $T(s) = A_{OL}\beta = \frac{V_0}{V_{gs}} \frac{V_f}{V_0}$

$$= +\frac{V_f}{V_{gs}} = \frac{-g_m R_D'}{(1 - 5/\omega^2R^2C^2) + j\left[\left(\frac{1}{\omega RC}\right)^3 - 6\left(\frac{1}{\omega RC}\right)\right]}$$

For Loop Gain to be Real Quantity

$$\frac{1}{(\omega RC)^3} - \frac{6}{\omega RC} = 0 \quad \text{or} \quad \omega^2R^2C^2 = \frac{1}{6} \quad \text{or} \quad \omega^2 = \frac{1}{6R^2C^2}$$

$$\therefore \omega_0 = \frac{1}{\sqrt{6}RC}$$

$$\therefore |T(2\pi j\omega_0)| = -\frac{g_m R_D'}{-29} = \frac{g_m R_D'}{29}$$

Hence for Sustained Oscillation $g_m R_D' = \text{Gain} \geq 29$

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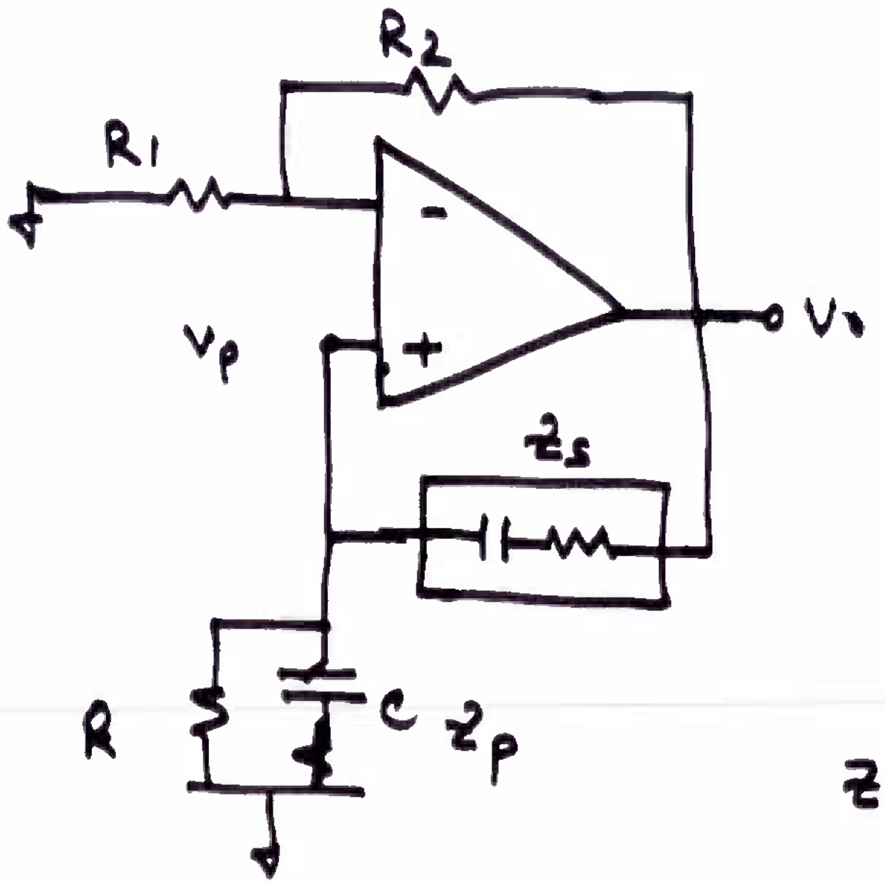
Wien Bridge Oscillator



$$A_{OL} = \left(1 + \frac{R_2}{R_1}\right)$$

$$\beta = \frac{Z_p}{Z_p + Z_s}$$

$$Z_p = \frac{R}{1+RCs}, \quad Z_s = \frac{1+RCs}{sC}$$

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$$\therefore\ T(s) = \left(1+\frac{R_2}{R_1}\right)\left[\frac{\left(R/1+RCs\right)}{\left(\frac{R}{1+RCs}\right)+\frac{1+RCs}{sC}}\right]$$

$$= \left(1+\frac{R_2}{R_1}\right)\left[\frac{RCs}{RCs+(1+RCs)^2}\right]$$

$$= \left(1+\frac{R_2}{R_1}\right)\left[\frac{RCs}{RCs+1+2RCs+R^2C^2s^2}\right]$$

$$= \left(1+\frac{R_2}{R_1}\right)\left[\frac{1}{\left(3+RCs+\frac{1}{RCs}\right)}\right]$$

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At Oscillation frequency ω_0

$T(j\omega_0) = -1$ and hence Real

$\therefore \quad j\omega_0 RC + \frac{1}{j\omega_0 RC} = 0$

or $\quad \omega_0^2 R^2 C^2 = 1 \quad \therefore \omega_0 = \frac{1}{RC}$ or $f_0 = \frac{1}{2\pi RC}$

& $|T(j\omega_0)| = 1$

$= \left(1 + \frac{R_2}{R_1}\right)\frac{1}{3}$ or $\boxed{\frac{R_2}{R_1} = 2}$ for Sustained Oscillations

To Start Oscillations $\frac{R_2}{R_1} \geq 2$

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LC Oscillators

(i) High Q - (than RC Oscillators)

$\left(\frac{\omega L}{R}\right)$ or $\left(\frac{1}{\omega RC}\right)$

(ii) Higher Frequency possible

(iii) Tunable range smaller.

Two Famous LC Oscillators are

(1) Colpitts Oscillator (2) Hartley Oscillator

Major Oscillator in Many Electronic Systems is "CRYSTAL OSCILLATOR".

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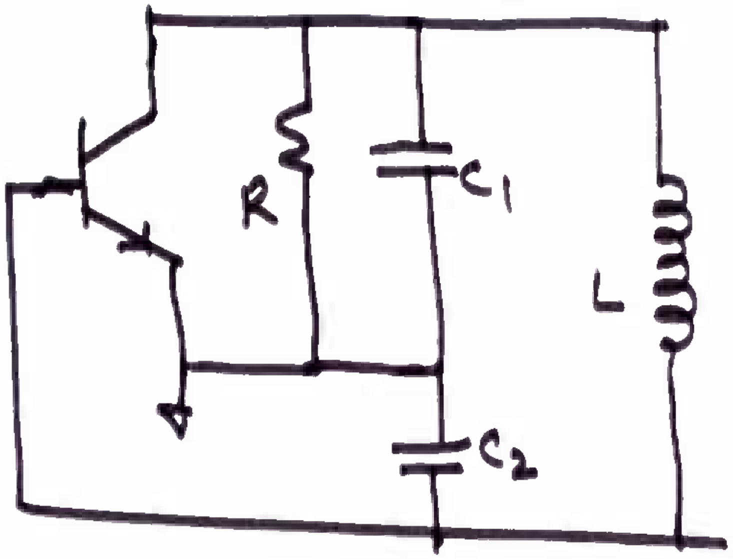
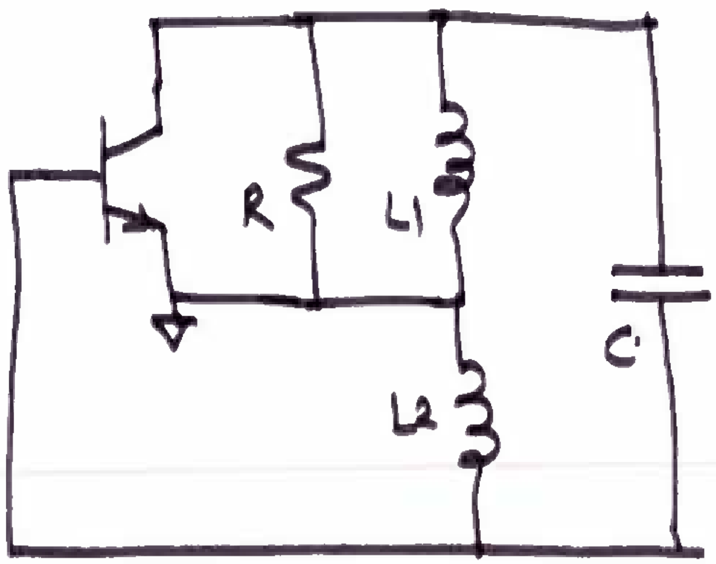
BJT based Oscillators are



Colpitts Oscillator



Hartley Oscillator

Colpitts Oscillator (LC Oscillator)

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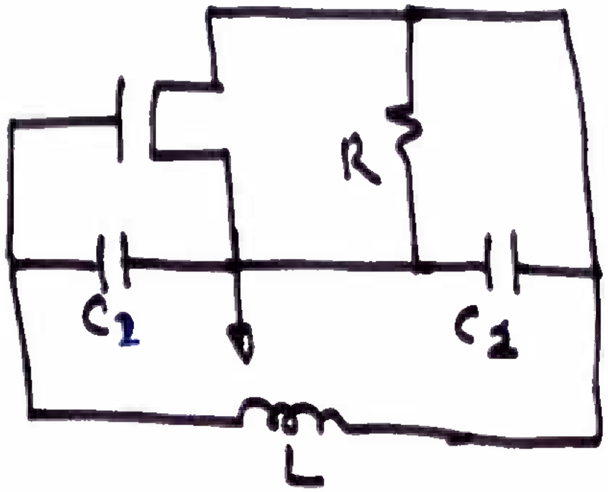

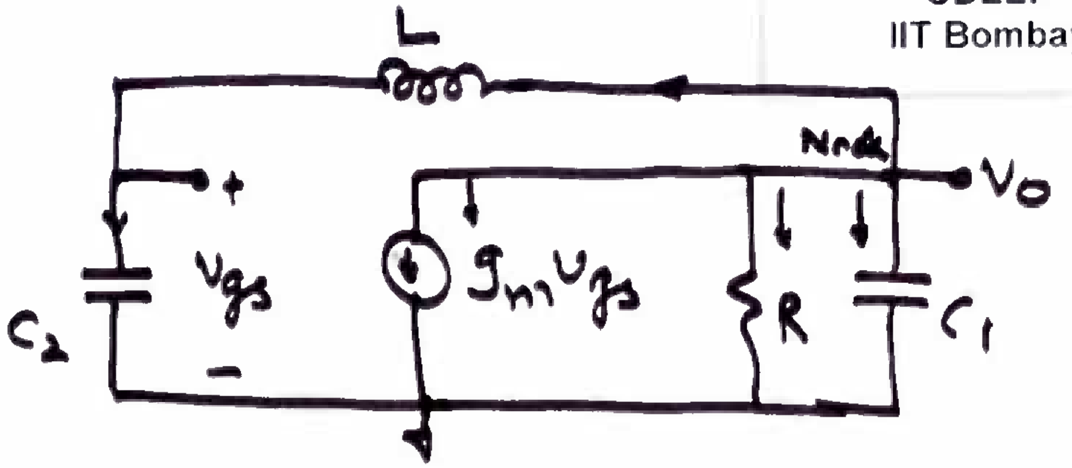

At Node V_o

$$\frac{V_o}{1/sC_1} + \frac{V_o}{R} + g_m v_{gs} + \frac{v_o}{Ls + \frac{1}{sC_2}} = 0 \quad \text{—} (1)$$

&

$$v_{gs} = \frac{1/sC_2}{Ls + \frac{1}{sC_2}} \cdot V_o = \frac{V_o}{LC_2 s^2 + 1} \quad \text{—} (2)$$

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substituting (ii) in (i)

$$V_0\left[g_m + sC_2 + (1 + LC_2 s^2)\left(\frac{1}{R} + sC_1\right)\right] = 0$$

If oscillations has started than V_0 is finite

$$\therefore \quad g_m + sC_2 + \frac{1}{R} + \frac{LC_2}{R}s^2 + sC_1 + LC_1C_2s^3 = 0$$

or $$\left|\left(g_m + \frac{1}{R} - \frac{\omega^2 LC_2}{R}\right)\right| + j\omega\left[(C_1+C_2) - \omega^2 LC_1C_2\right] = 0$$

For oscillations to sustain at ω_0 both 'Real' & 'Imaginary' parts be zero. Hence $\frac{\omega_0^2 LC_2}{R} = g_m + \frac{1}{R}$ or $\boxed{\omega_0^2 LC_2 = 1 + g_m R}$

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& Imaginary part = 0

$$(C_1 + C_2) - \omega_0^2 L C_1 C_2 = 0$$

or $$\omega_0^2 = \frac{C_1 + C_2}{L C_1 C_2}$$

or $$\boxed{\omega_0 = \frac{1}{\sqrt{L\left(\frac{C_1 C_2}{C_1 + C_2}\right)}}}$$

Substituting ω_0 in Real part

or $$\frac{(C_1 + C_2)}{L C_1 C_2} L C_2 = 1 + g_m R$$ or $$1 + \frac{C_2}{C_1} = 1 + g_m R$$

$$\therefore \boxed{\frac{C_2}{C_1} = g_m R}$$

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Hartley Oscillator

$$\omega_0 = \frac{1}{\sqrt{(L_1+L_2)C}}$$

Crystal Oscillator

Quartz crystal exhibits Electro-mechanical Resonance.
It's natural frequency is stable with
(i) Temperature (ii) Time
The frequency depends upon 'size' (Mass) of the Crystal
Most important Quality of this is that it has v. large 'Q'.

Equivalent Circuit of Crystal.

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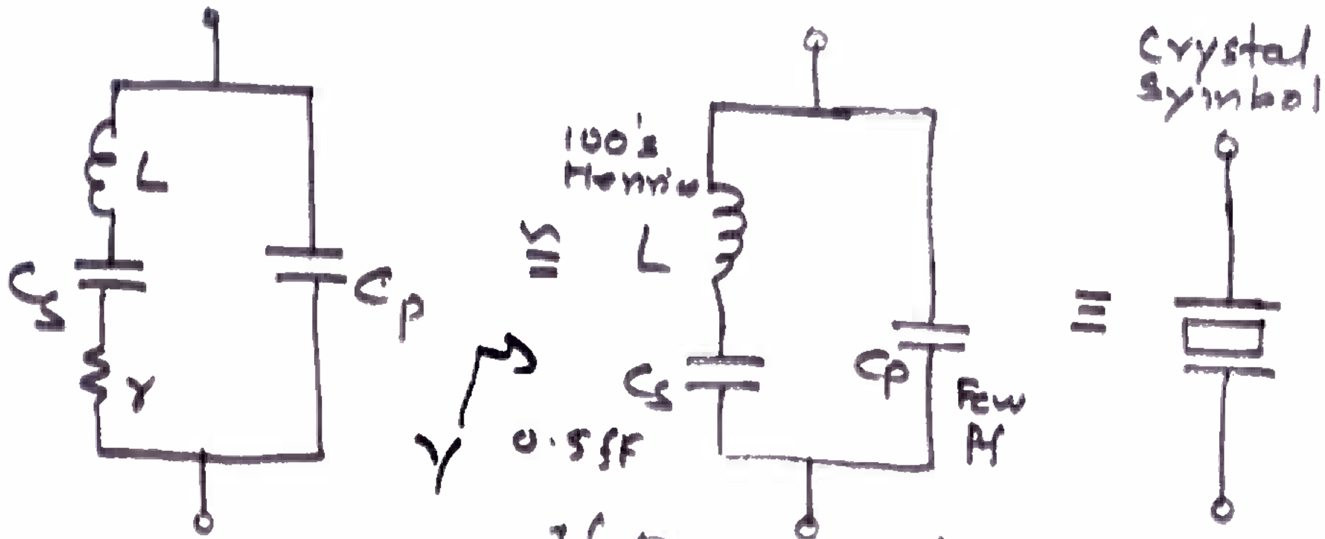

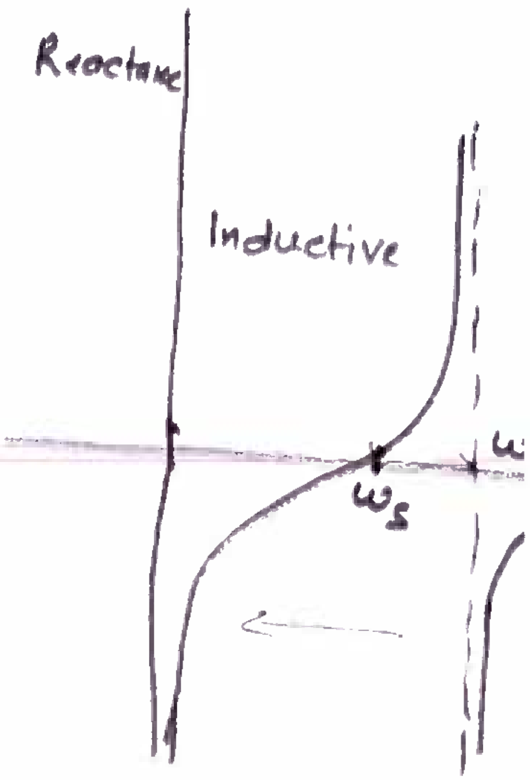

If Q is very large

Series and parallel frequencies are normally v. close.

Also normally $C_p \gg C_s$

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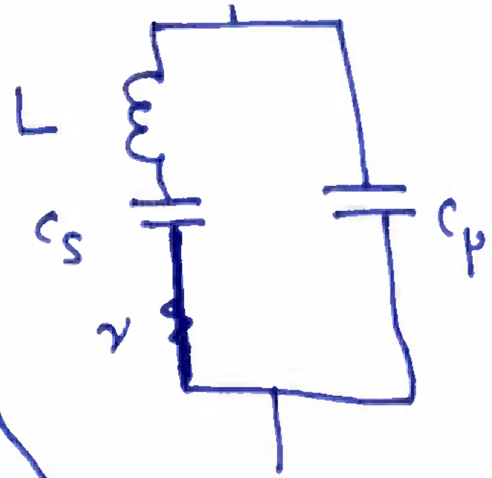
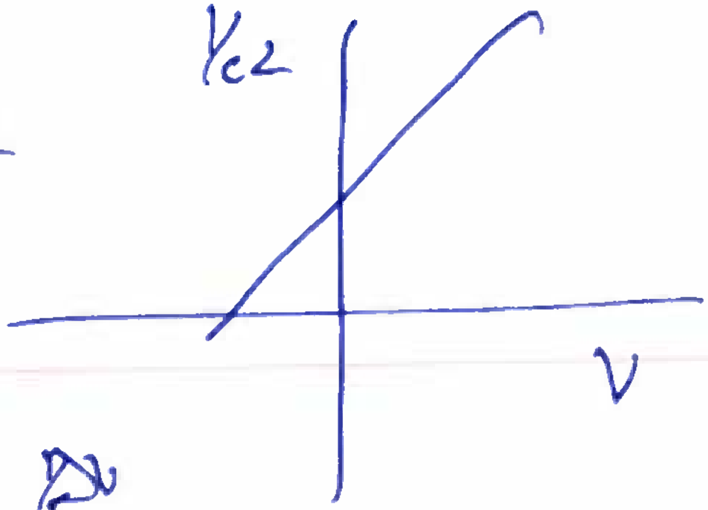
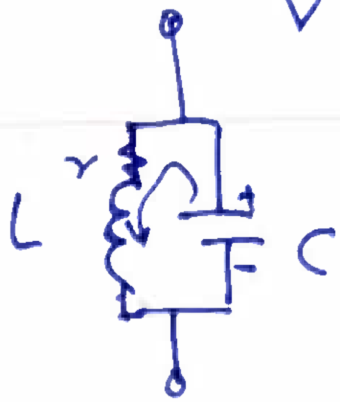


$Q > 10^4$



$$Q = \frac{\omega L}{R}$$

$$\omega_0 = \frac{1}{\sqrt{LC}}$$



$\frac{1}{2} C v^2$

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If 'r' is neglected (High $Q \simeq 10^4$),
Impedance of the Circuit is

$$Z(s) = \frac{1}{\left[sC_p + \frac{1}{Ls + \frac{1}{C_s s}} \right]}$$

$$= \frac{1}{sC_p} \cdot \frac{s^2 + (1/LC_s)}{s^2 + [(C_p + C_s)/(LC_sC_p)]}$$

Series Resonance Occures at

$$\omega_s = \frac{1}{\sqrt{LC_s}}$$

& Parallel resonance Occures

at

$$\omega_p = \frac{1}{\sqrt{L\left(\frac{C_sC_p}{C_s+C_p}\right)}}$$

$\omega_s \simeq \omega_p$ if $C_p >> C_s$

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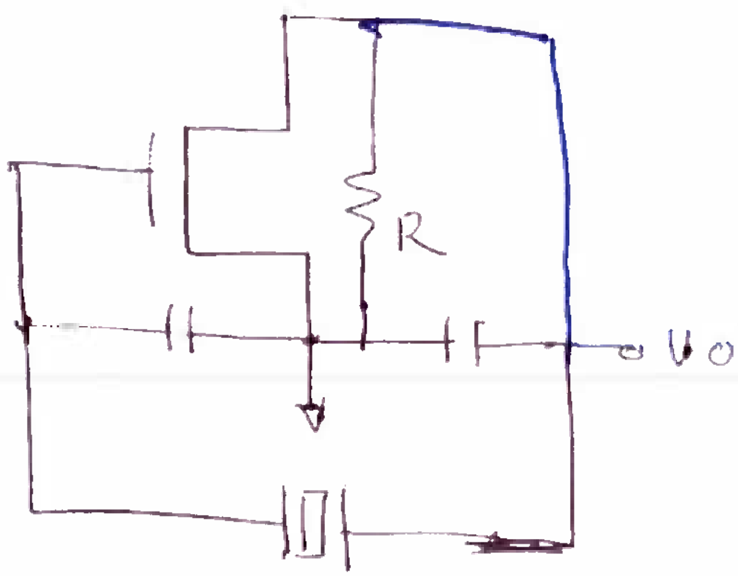
Crystal behaves as Inductor

for Frequencies between ω_s & ω_p (Narrow Band)

We use this Inductor in Colpitts Oscillator for fixed Frequency Oscillator which is Stable



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Ring Oscillator (Sq. Wave Generator)

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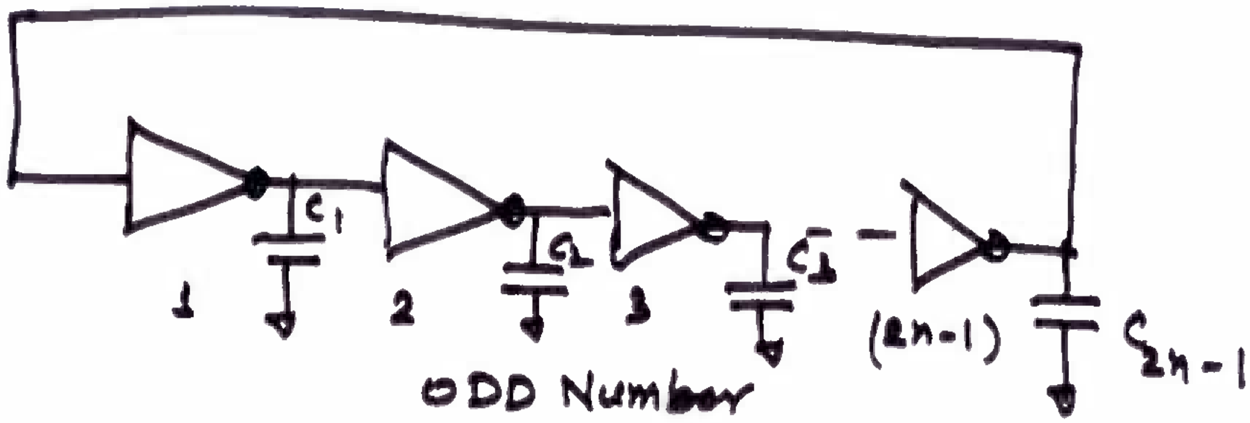

We now look into other Non Sinusoidal Oscillators.

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