7 Nagendra Krishnapura Analog Notes

# Oscillators

We want natural response decays out in Amplifiers + Filters.
→ We need stability. Forced Response > Natural Response.

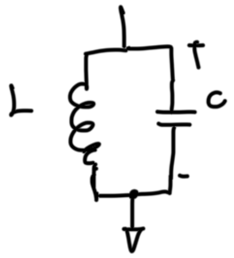
But sometimes, we need instability → Oscillators!!
Main place where we need ; Clocks + wave generators...

Input for oscillator → None! Except to change frequency.
Just source enough. Autonomous Circuit

## Utilities of the Oscillators :

* Clock source – Digital circuits, Sampling
* (Sinusoidal) RF carriers
* Sinusoidal signal sources

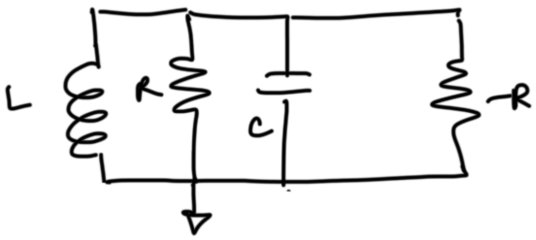
Let's dive right in :



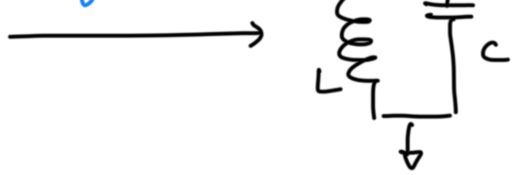

$$V_o = V_p \cos\left(\frac{t}{\sqrt{LC}}\right)$$

Lossless L & C. Ideal
Can't realise, ouch.

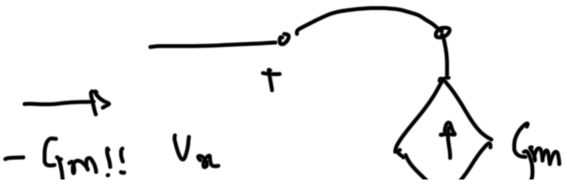
Now let us indicate the loss as an R $||^{el}$ to LC.




Lossy Tank

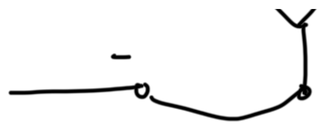



How –R?



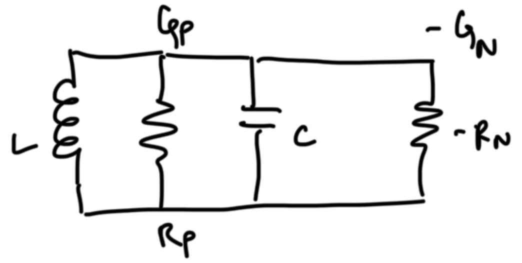

→ Non linear controlled source,

Fixes the Amplitude ⇒ R, –R.



Fixes the frequency ⇒ L, C.

## LC Oscillator

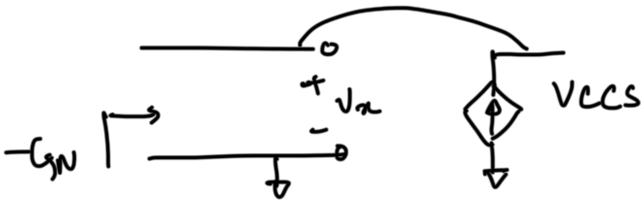


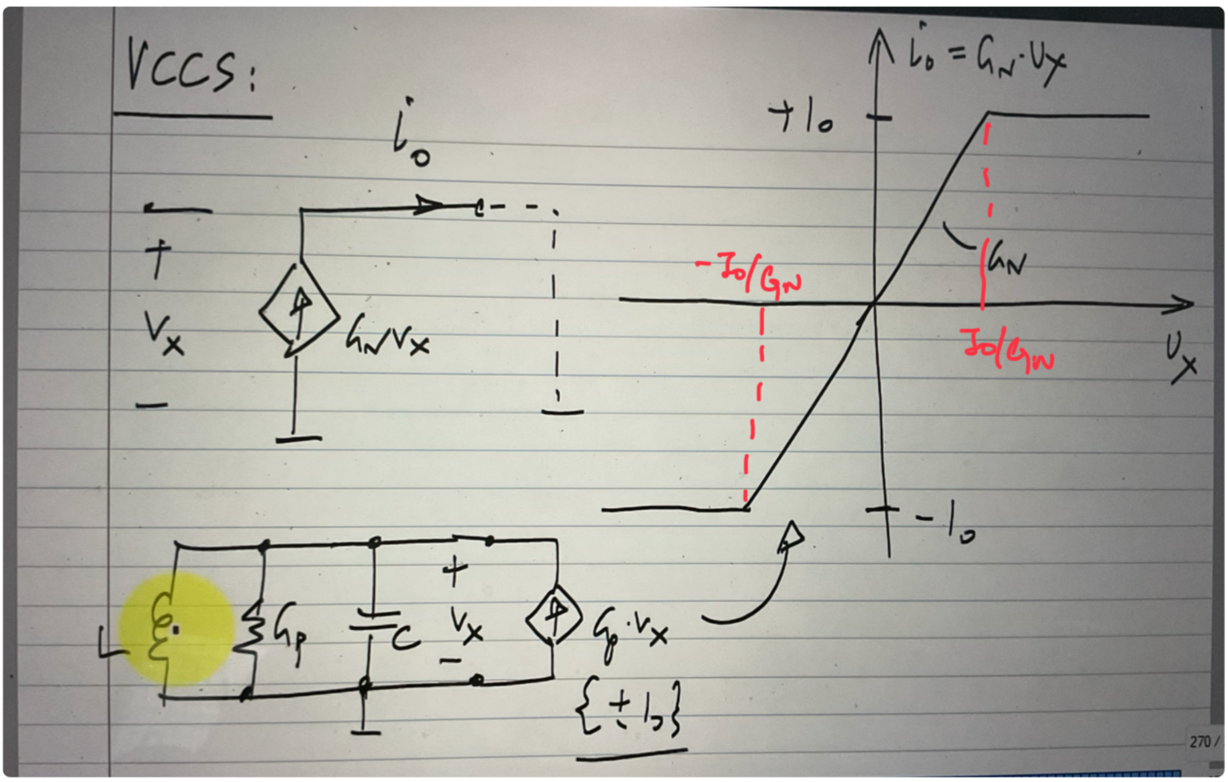

$R_P > 0$ (loss).

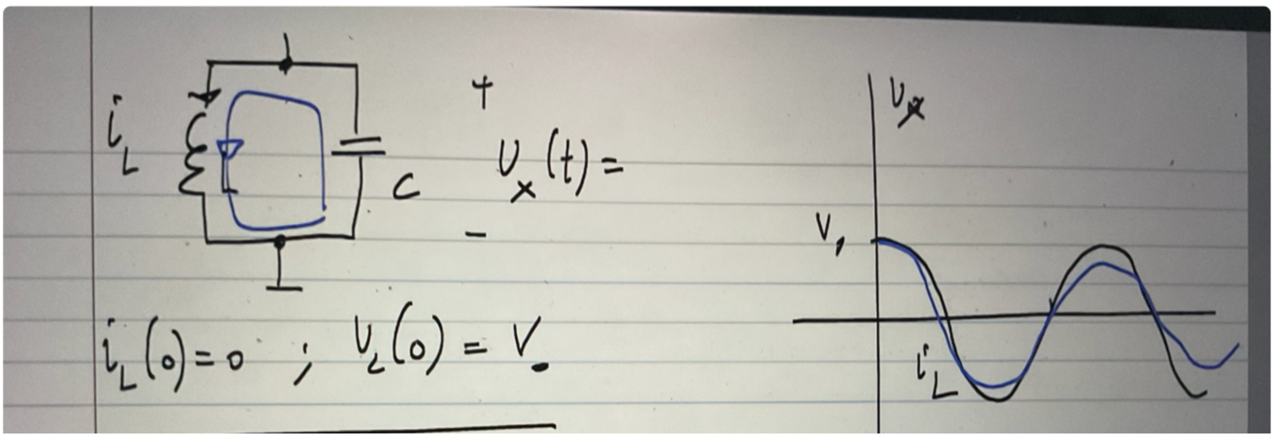
Condition for oscillation to start:

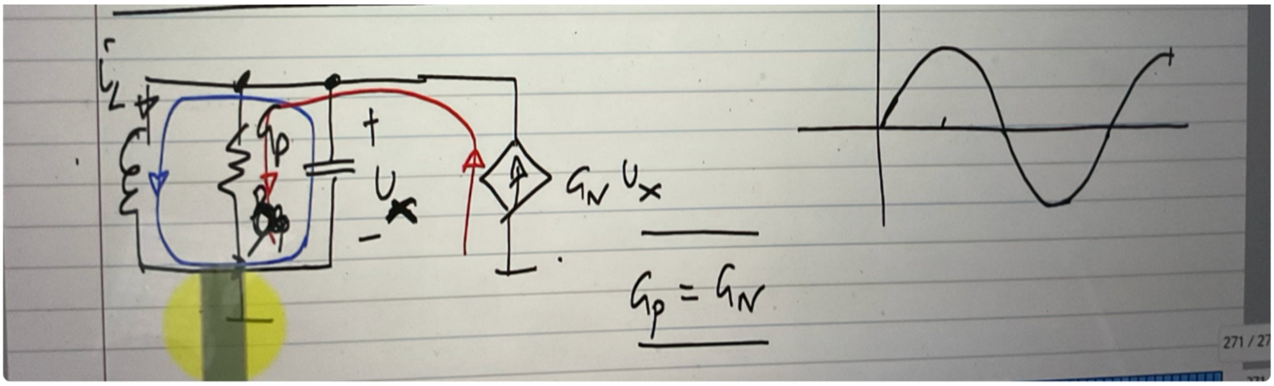
$G_N = G_P$ : Constant amp.
$G_N > G_P$ : Exp. inc. Amplitude

∴ $G_N \le G_P$ ⇒ Condition.

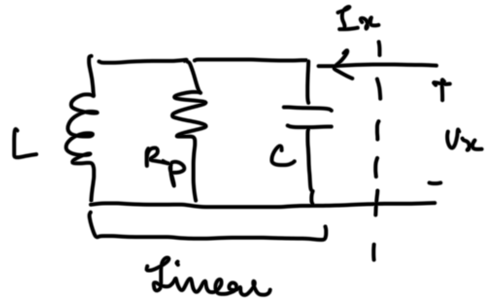


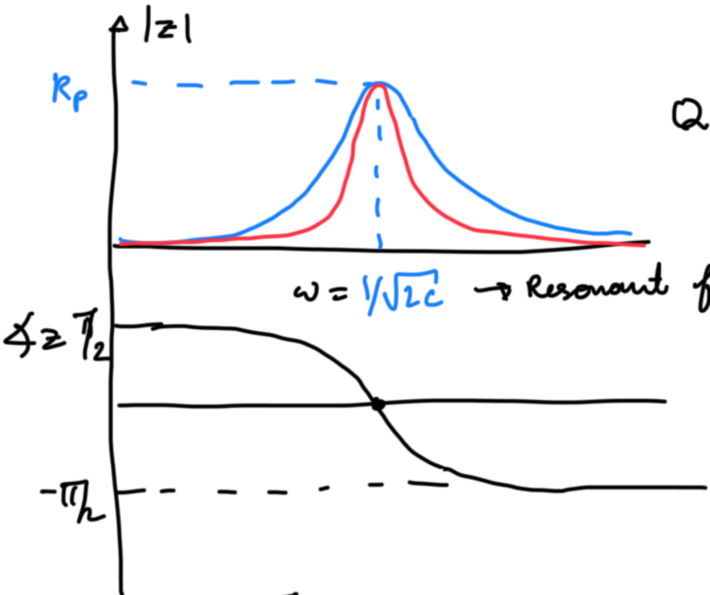



∴ As we can see, in the lossy Tank, the amplitude is still dependent on the initial conditions. We'll try to fix that by putting $G_N > G_p$.




$$\frac{V_x}{I_x} = R_p \frac{sL/R_p}{1 + \frac{sL}{R_p} + s^2 LC}$$

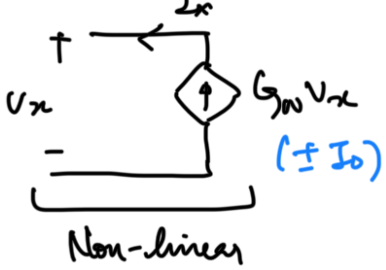
Let's bode plot:




$$Q = R_p\sqrt{\frac{C}{L}}$$

$$\boxed{\left.\frac{V_x}{I_x}\right|_{\omega=\frac{1}{\sqrt{LC}}} = R_p}$$

$\omega = 1/\sqrt{LC}$ → Resonant frequency.

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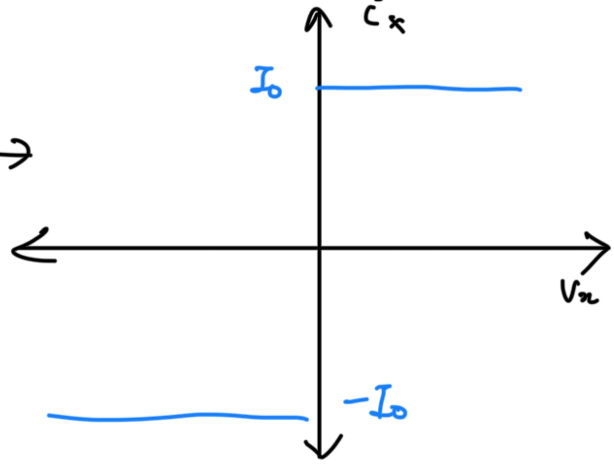
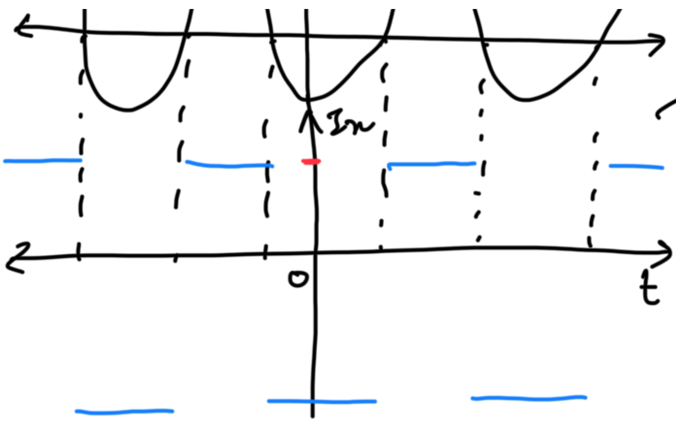



$\rightarrow I_x(t)$ = Fourier expansion?

$$= a_0 + \sum_{k=1}^{\infty} a_k \cos(k\omega_0 t + \phi_k)$$

$$= 0 + \sum_{k=1}^{\infty} (-1)^n \left(\frac{4}{k\pi}\right) \cos(k\omega_0 t)$$

FT of Squarewave.

$\therefore$ $V_x(t)$ output of this oscillator = ?

$$V_x = \frac{4 I_0 R_p}{\pi} \cos(\omega_0 t) \quad ; \quad \text{Amplitude} : \frac{4 I_0 R_p}{\pi}.$$

High Q $\rightarrow$ Only fundamental voltage exists across the tank.

$\rightarrow$ Tank voltage is of the form $V_p \cos(t/\sqrt{LC})$

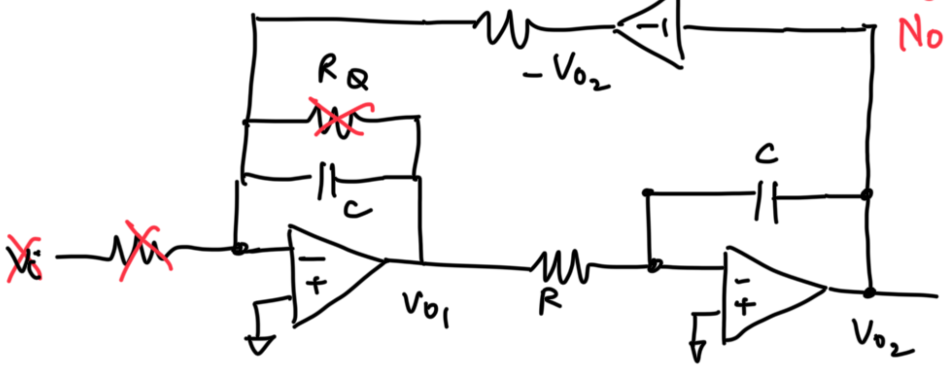
Current from $G_n$ : $\sum_k \left(\frac{4 I_0}{\pi}\right)(-1)^{(k-1)/2} \cos\left(\frac{kt}{\sqrt{LC}}\right)$

Fund. component : $\frac{4 I_0}{\pi} \cos\left(\frac{t}{\sqrt{LC}}\right)$

$$@ \frac{1}{\sqrt{LC}}, \left.\frac{V}{I}\right|_{tank} = R_p \quad ; \quad \frac{4 I_0}{\pi} R_p = V_p.$$

How to turn a 2nd order filter as an oscillator?

$R_Q = \infty$.
No input




$$V_{o1} = \frac{1}{sCR} V_{o2} \quad ; \quad V_{o2} = -\frac{1}{sCR} V_{o1}$$

Double integrator

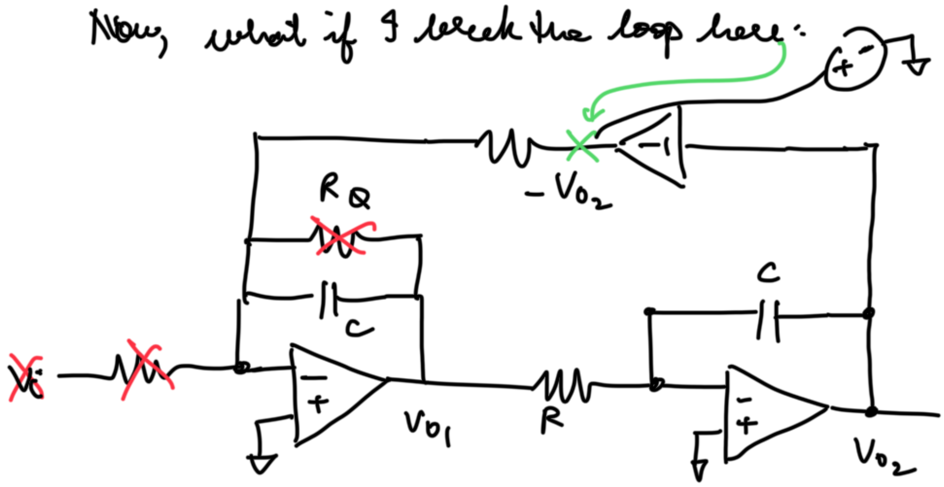
oscillator

This is very Close to:

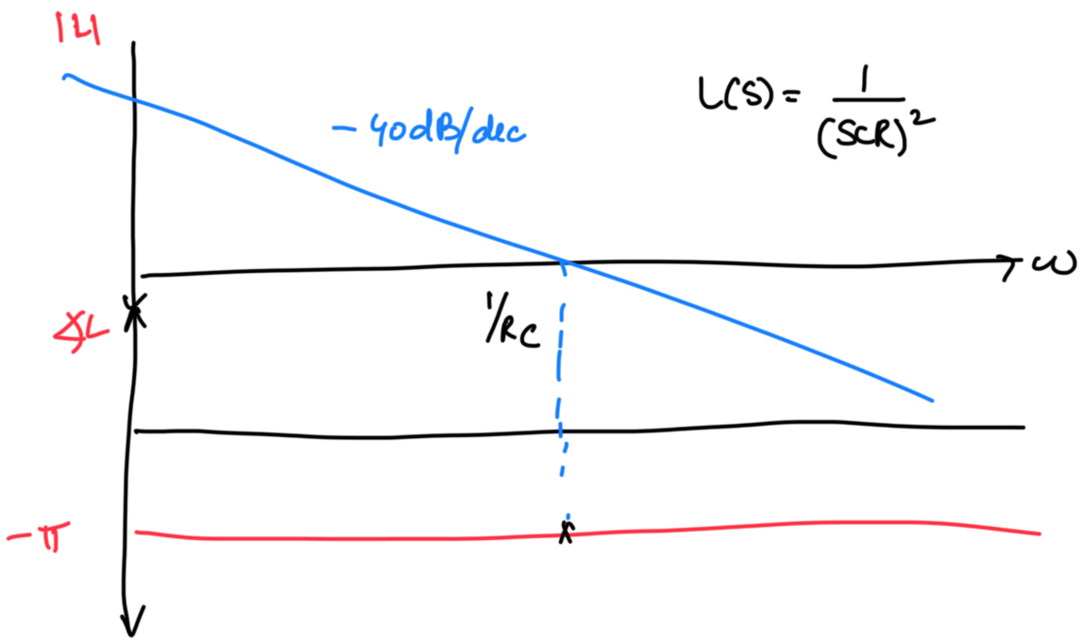

$$i_L(s) = \frac{1}{sL} \cdot V_C(s)$$

$$V_C(s) = -\frac{1}{sC}\, i_L(s)$$

Now, what if I break the loop here:

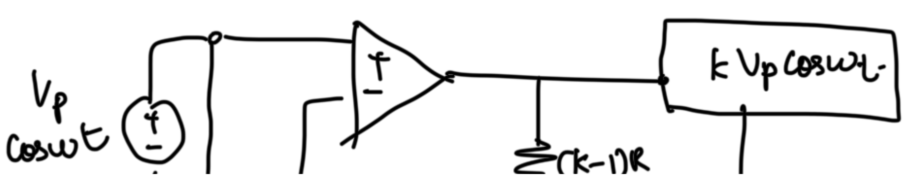


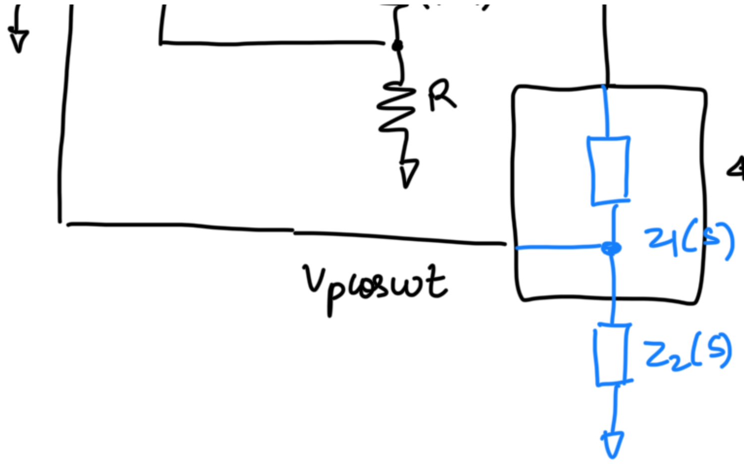

$\therefore V_{return} = -\left(\frac{1}{sCR}\right)^2 V_{test}$. $\quad \therefore \left(\frac{1}{sCR}\right)^2 \rightarrow$ Bode Plot this




$$L(s) = \frac{1}{(sCR)^2}$$

Consider this:

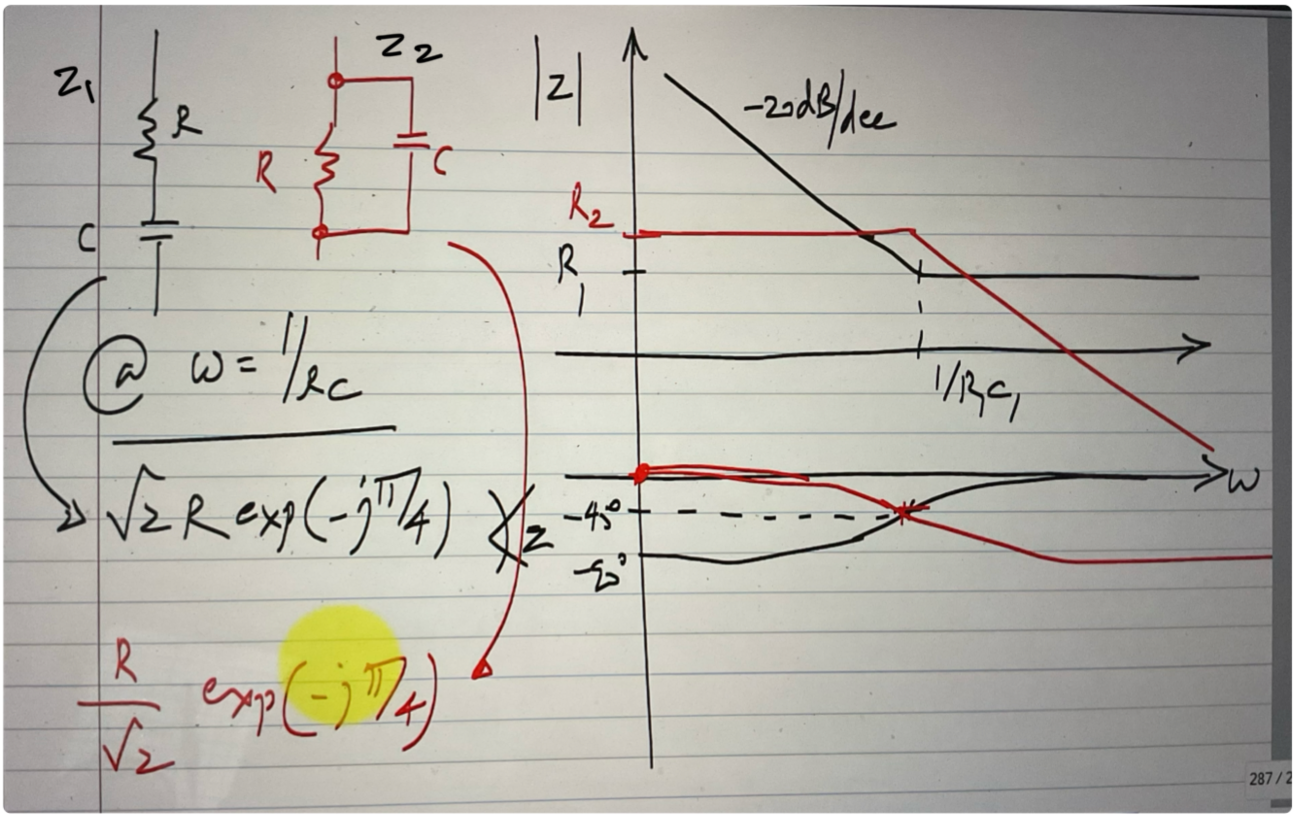





Some circuit? Again a Voltage divider!!

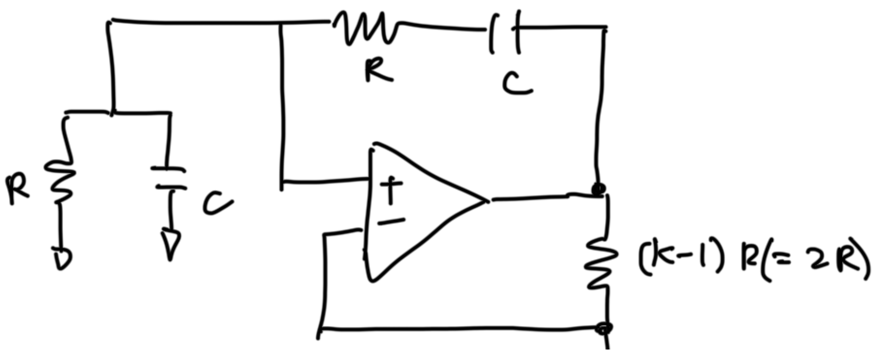
But we need this oscillation only for a particular frequency.

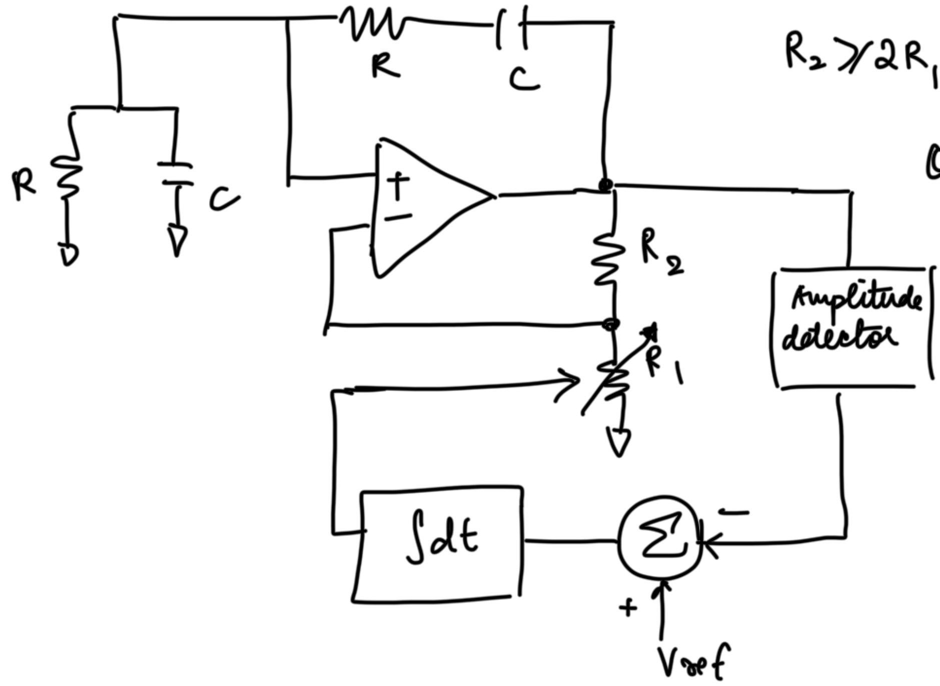
So, how to design $z_1$ & $z_2$?




$$K = \frac{z_1}{z_1+z_2} \Rightarrow \frac{1}{3} \quad [\text{If } R \,\&\, C \text{ are equal in } z_1 \,\&\, z_2].$$

## Wien Bridge Oscillator

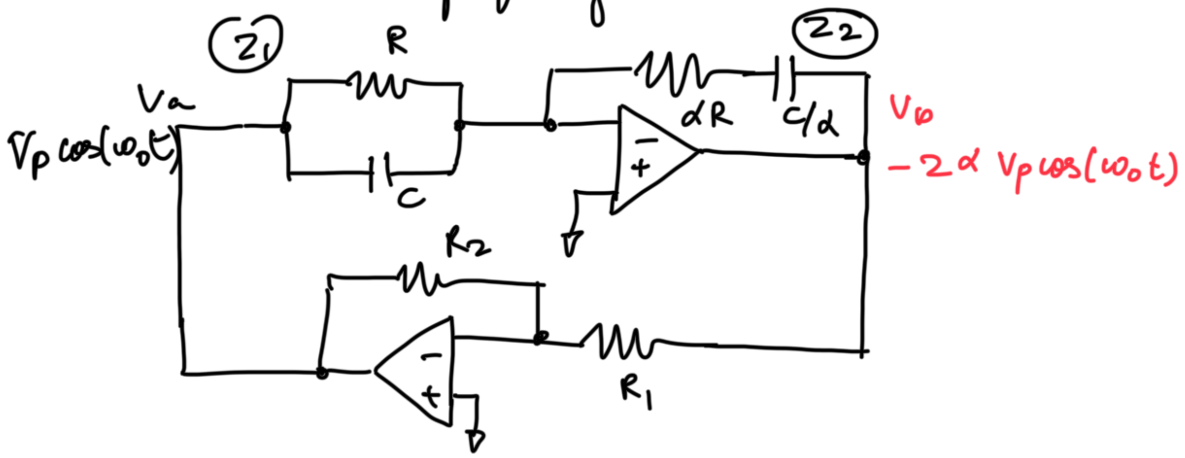



$R_2 \geq 2R_1$ for oscillation

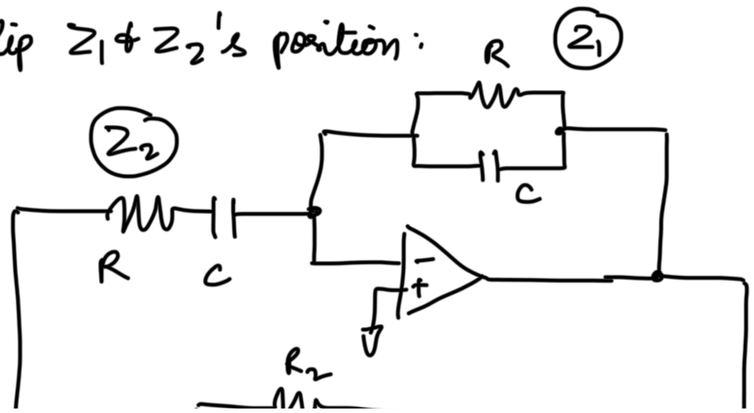
Oscillate @ $\omega_0 = 1/RC$, amplitude $V_{ref}$.

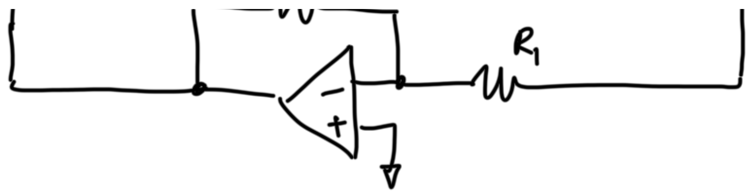
Now consider this frequency selective circuit:



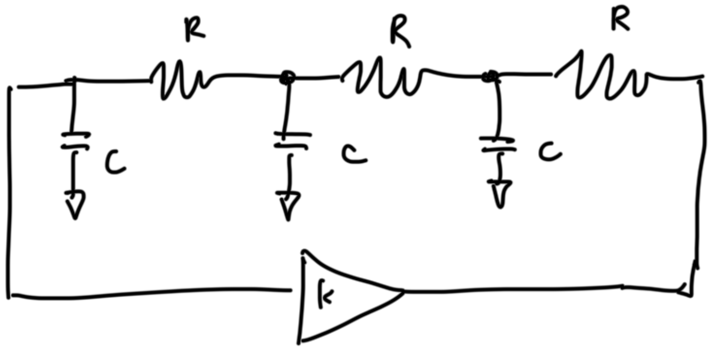

$$\frac{V_b}{V_a} = -\frac{Z_2}{Z_1} \quad ; \ @ \ 1/RC \Rightarrow -2\alpha \quad , \quad \frac{R_2}{R_1} = \frac{1}{2\alpha}.$$

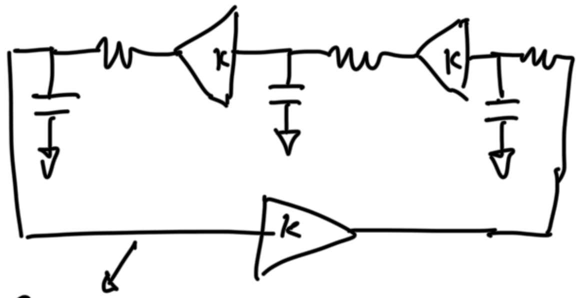
Flip $Z_1$ & $Z_2$'s position:






See this new one:




$$\frac{8}{\left[1+\left(s/p_1\right)\right]^3}$$

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## Oscillators:

- LC : Very "good" periodicity
- Ring oscillators
- Harmonic Oscillators
  - Double integrator (opamp)
  - Wien Bridge
- Relaxation Oscillators : Schmitt trigger oscillator.