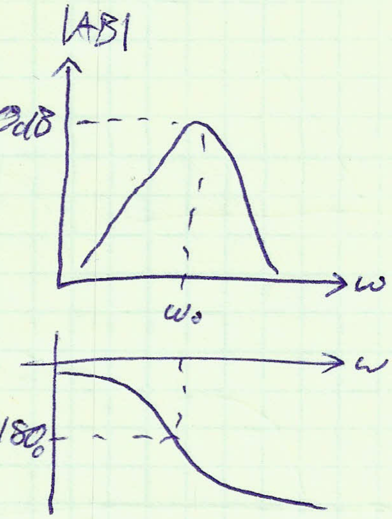
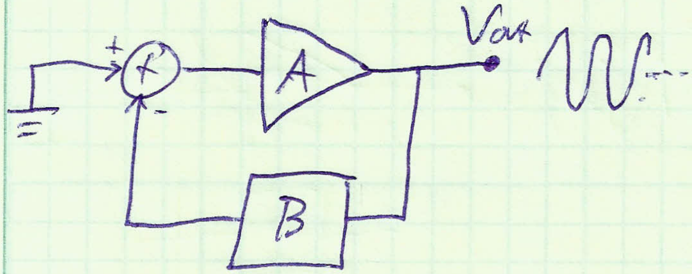
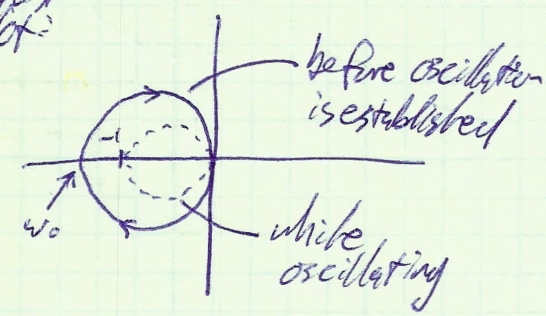
First, review midterm #2



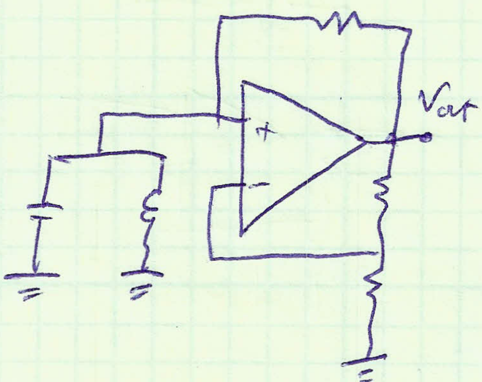
Oscillators:



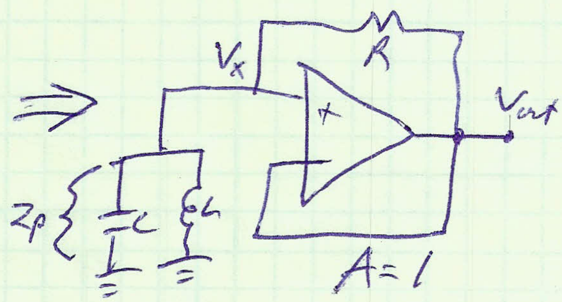
Nyquist plot:



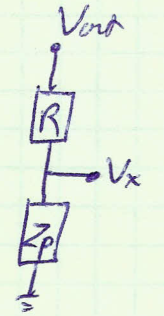
Example oscillators:



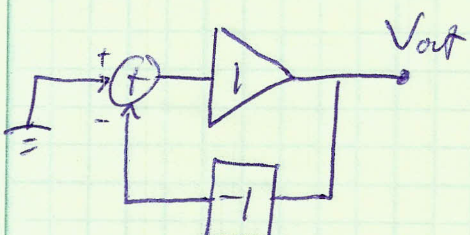
$\Rightarrow$



$A = 1$



$$B = \frac{-V_x}{V_{out}}$$



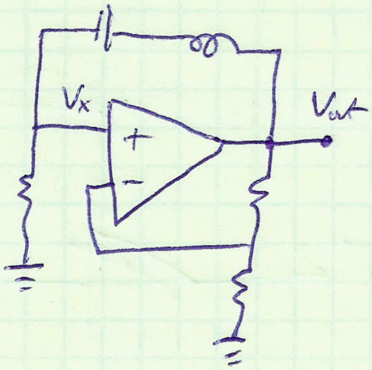
$$Z_p = \frac{1}{1/sL + sC} = \frac{sL}{1+s^2LC}$$

$$B = \frac{-sL/(1+s^2LC)}{R + sL/(1+s^2LC)}$$

$$B = \frac{-sL/R}{1 + sL/R + s^2LC}$$

$$\omega_0 = \frac{1}{\sqrt{LC}}, \text{ at } \omega_0 \Rightarrow B = -1$$

Another oscillator:

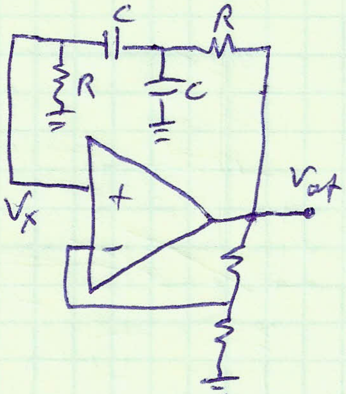


$$B = \frac{-V_x}{V_{out}} = \frac{-R}{R + sL + 1/sC}$$

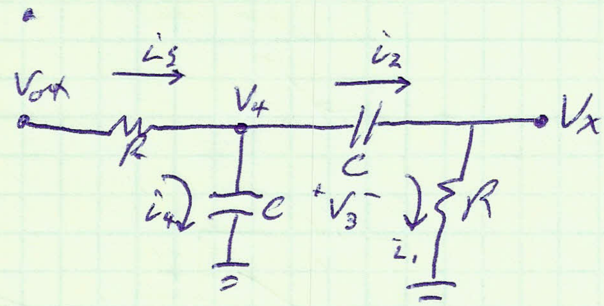
$$B = \frac{-sCR}{1 + sCR + s^2LC}$$

at $\omega = \frac{1}{\sqrt{LC}}$, $B = -1$ same as last case

phase shift oscillator:



Ladder network:



start at the output, and work backward to input

- assume V_x
- $i_1 = V_x/R$
- $i_2 = V_x/R$
- $V_3 = i_2/sC = \frac{V_x}{sCR}$
- $V_4 = V_x + V_3 = V_x + \frac{V_x}{sCR} = \left(\frac{1+sCR}{sCR}\right)V_x$
- $i_4 = V_4 sC = \left(\frac{1+sCR}{R}\right)V_x$
- $i_5 = i_4 + i_2 = \frac{V_x}{R} + \frac{V_x(1+sCR)}{R}$
  $= \frac{V_x(2+sCR)}{R}$
- $V_{out} = V_4 + i_5 R = V_x\left(\frac{1+sCR}{sCR}\right) + \frac{V_x(2+sCR)R}{R}$

$$\frac{V_{out}}{V_x} = \frac{(1+sCR) + (2+sCR)(sCR)}{sCR}$$

$$B = \frac{-V_x}{V_{out}} = \frac{-sCR}{1 + 3sCR + s^2C^2R^2}$$

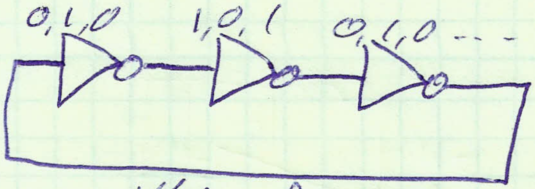
$$\omega_0 = \frac{1}{RC}$$

at ω_0, $B = -\frac{1}{3}$

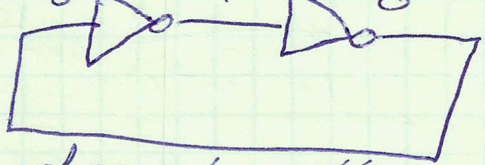
want AB to be -1

so $A = 3$

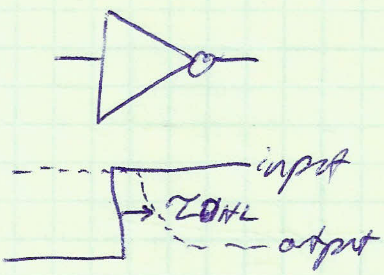
Ring Oscillator:

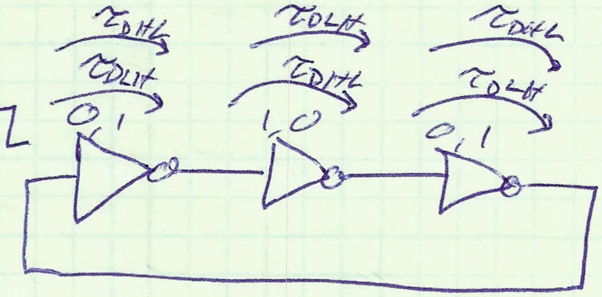


oscillates forever
$0 \to 1 \to 0 \to \ldots$



does not oscillate
need add number
of inverters





Period of square wave is

$$3\tau_{DHL} + 3\tau_{DLH} = 6\tau_D \quad \text{if } \tau_{DLH} \simeq \tau_{DHL}$$

we can also define average $\tau_D = \frac{1}{2}(\tau_{DLH} + \tau_{DHL})$

$$\text{frequency} = \frac{1}{6\tau_D} = \frac{1}{2n\tau_D} \quad \text{for } n\text{-stage oscillator}$$

More accurate model of inverter