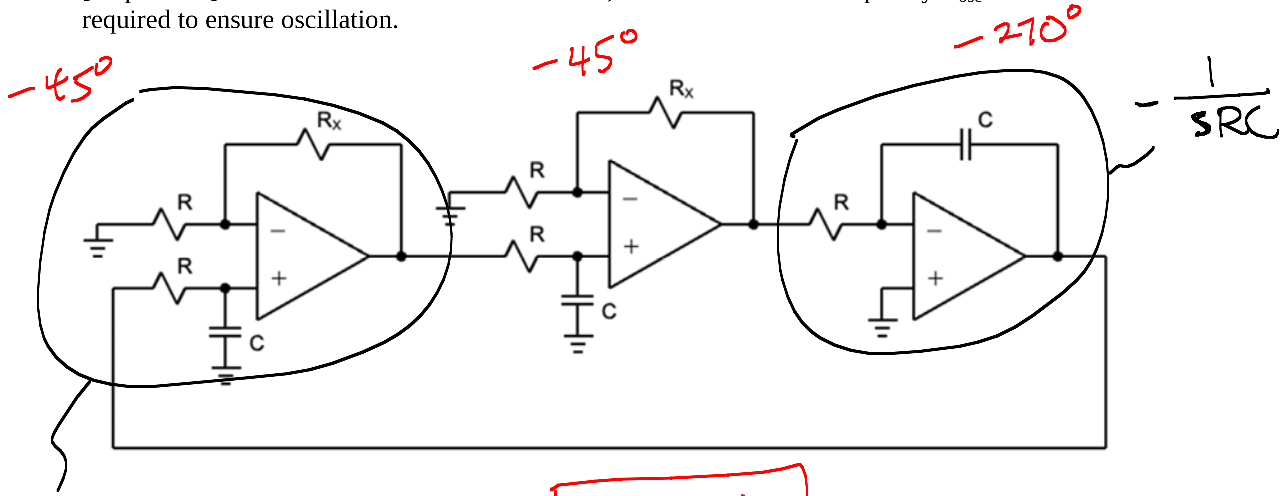
1. [10 pts total] In the linear oscillator shown below, find the oscillation frequency ω_{osc} and R_X value required to ensure oscillation.

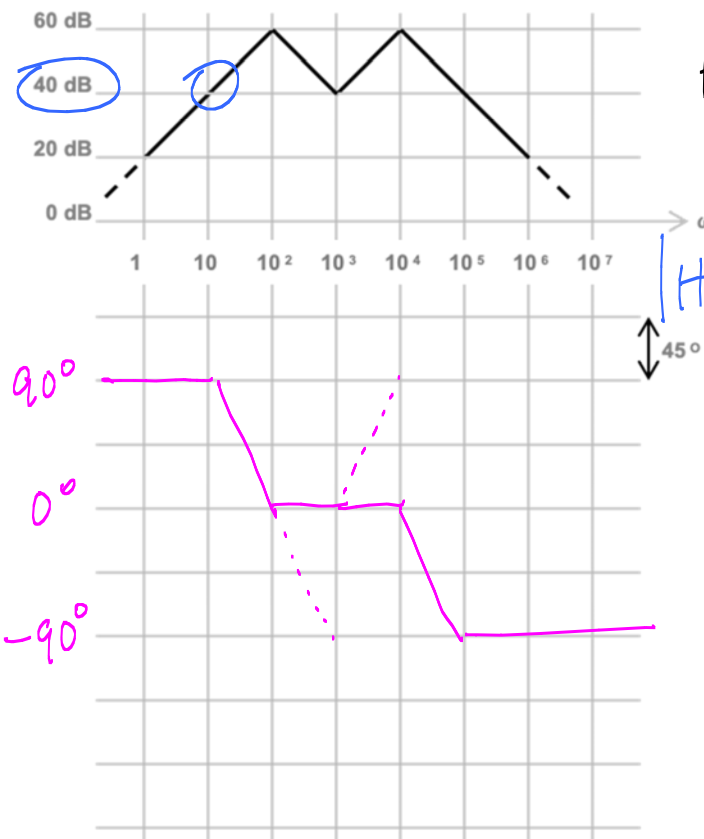


$$\frac{1}{1+sRC}\left(1+\frac{R_x}{R}\right) \rightarrow \omega_{osc} = \frac{1}{RC}$$

$$\left|\text{Loopgain} @ \omega_{osc}\right| = \left[\frac{1}{\sqrt{2}}\left(1+\frac{R_x}{R}\right)\right]^2 \cdot 1 \geq 1$$

$$\rightarrow 1+\frac{R_x}{R} \geq \sqrt{2} \rightarrow R_x \geq R(\sqrt{2}-1)$$

2. [10 pts total] Given the magnitude Bode plot shown below, find the corresponding transfer function and the phase plot that goes with it.



$$H(s) = K \frac{s \cdot (s+1000)^2}{(s+100)^2 (s+10000)^2}$$

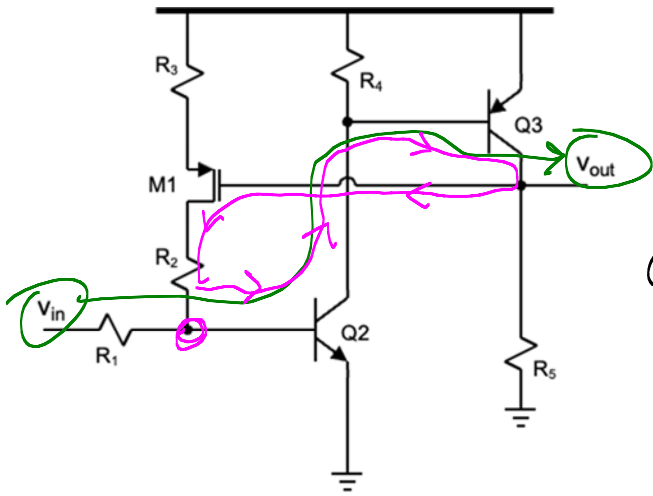
$$|H(s=j10)| = \left| K \frac{s \cdot (s+1000)^2}{(s+100)^2 (s+10000)^2} \right|$$

$$= K \frac{10 \cdot (1000)^2}{(100)^2 (10000)^2} = 100$$

↑ 40dB

→ $K = 10^7$

3. [10 pts total] Find the input to output small-signal gain.

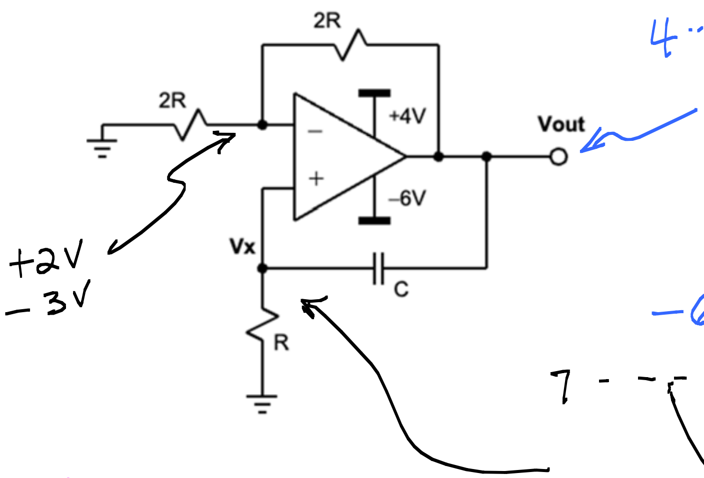


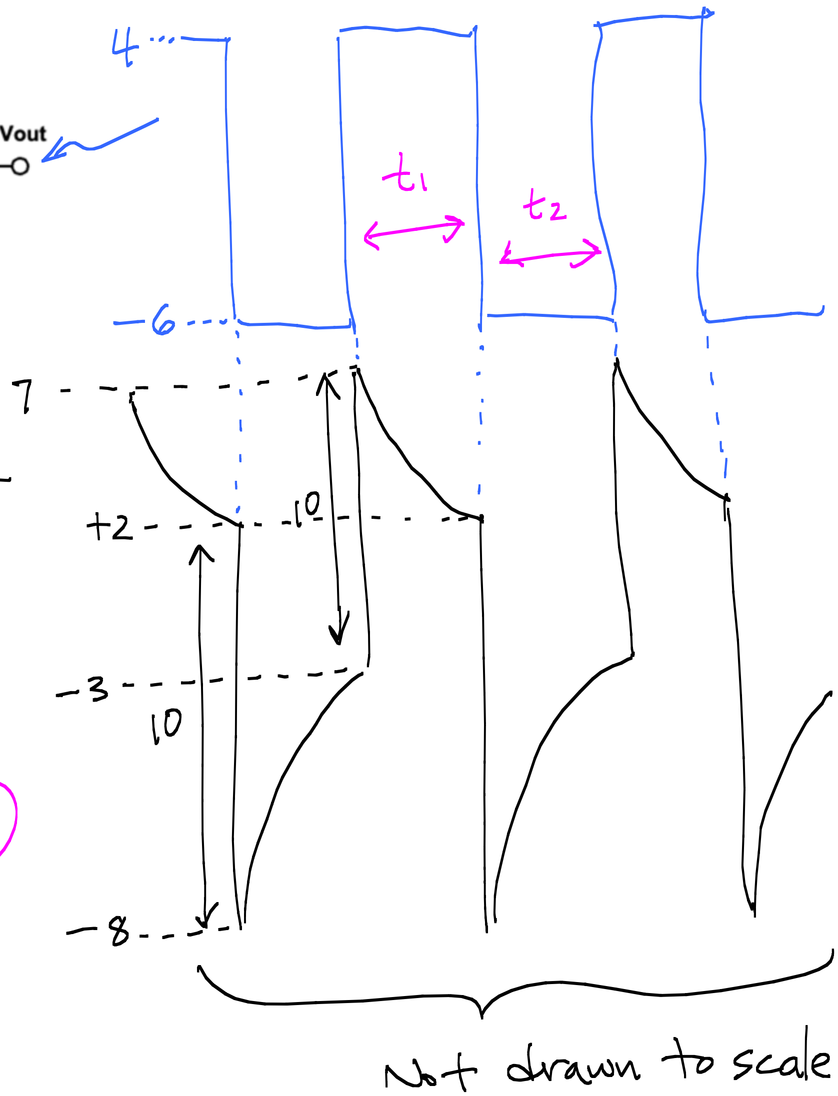
$$\text{Gain} = \frac{\text{F.P.}}{1 - \text{Loop}}$$

$$\text{F.P.} = \frac{r_{\pi 2}}{R_1 + r_{\pi 2}} \, g_{m2} \, (R_4 \| r_{\pi 3}) \, g_{m3} \, R_5$$

$$\text{Loop} = -\, g_{m2} \, (R_4 \| r_{\pi 3}) \, g_{m3} \, R_5 \, \frac{g_{m1}}{1 + g_{m1} R_3} \, (R_1 \| r_{\pi 2})$$

4. [10 pts total] In the nonlinear oscillator shown below, sketch the waveforms at node **Vx** and **Vout**. Note all critical voltage levels especially in the **Vx** waveform. Find the resulting period (T_{osc}) of oscillation.



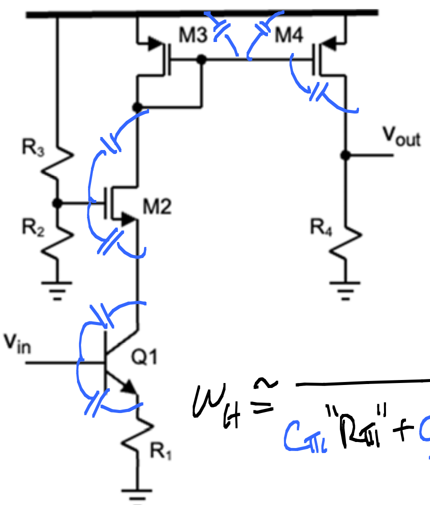


$$T_{osc} = t_1 + t_2$$

$$\frac{2}{7} = e^{-\frac{t_1}{RC}} \rightarrow t_1 = RC \cdot \ln\left(\frac{7}{2}\right)$$

$$\frac{3}{8} = e^{-\frac{t_2}{RC}} \rightarrow t_2 = RC \cdot \ln\left(\frac{8}{3}\right)$$

5. [10 pts total] Find the input to output small-signal gain expression, then find the "upper 3dB frequency" ω_H (considering the intrinsic capacitances).



$$\text{gain} = \frac{r_{\pi 1}}{r_{\pi 1} + R_1(1+\beta_1)} \, g_{m1} \, \frac{g_{m4}}{g_{m3}} R_4$$

$$\omega_H \simeq \frac{1}{C_{\pi 1}\text{"}R_{\pi 1}\text{"} + C_{\mu 1}\text{"}R_{\mu 1}\text{"} + C_{gs2}\text{"}R_{gs2}\text{"} + C_{gd2}\text{"}R_{gd2}\text{"} + (C_{gs3}+C_{gs4})\text{"}R_{gs3}\text{"} + C_{gd4}\text{"}R_{gd4}\text{"}}$$

$$\text{"}R_{\pi 1}\text{"} = R_1 \,\Big\|\, \frac{r_{\pi 1}}{1+\beta_1} \qquad \text{"}R_{\mu 1}\text{"} = \frac{1}{g_{m2}} \qquad \text{"}R_{gs2}\text{"} = \frac{(R_2 \| R_3) + \infty}{1 + g_{m2}\cdot\infty} = \frac{1}{g_{m2}}$$

$$\text{"}R_{gd2}\text{"} = (R_2 \| R_3)(1-0) + \frac{1}{g_{m3}} = (R_2 \| R_3) + \frac{1}{g_{m3}}$$

$$\text{"}R_{gs3}\text{"} = \frac{1}{g_{m3}} \qquad \text{"}R_{gd4}\text{"} = \frac{1}{g_{m3}}(1 + g_{m4}R_4) + R_4$$