

Bode & Ph in practice

- Example Bode plots
- Unity gain stability
(ω_c comp. cap)
- A_{out} vs. A_{in} & BW

Bode plot reminders

- Factor form
- Geometric Mag & phase interp.
- Fast draw example

Oscillators

- oscillation criteria
- phase shift oscillators
- Colpitts oscillators
↳ parasitics
- Monolithic: describing S_{11} /VCO

Announce

- Finals prep
- Final Mon. 9AM
- 3 hrs, 2 crib sheets
no calculators

You guys need to be quick @ Bode plots to use phase margin

Reminder of 2 fast ways to draw

E79: Break into factors & add them

pole factor - turn down -20 dB/dec , add -90° phase

zero factor - turn up 20 dB/dec , add $+90^\circ$ phase

integral - start @ -20 dB/dec , start @ -90° phase

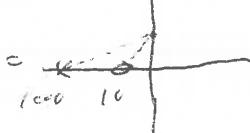
derivative - start @ $+20 \text{ dB/dec}$, start @ $+90^\circ$ phase

constant - shift up/down

$$\text{eg: } \frac{10^{105+10}}{s^{100}+1} = \frac{\text{---}}{\text{---}} + \frac{\text{---}}{\text{---}} + \frac{\text{---}}{\text{---}}$$

My way: tiny me running up f_w axis

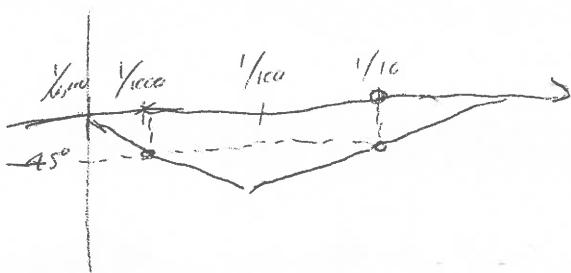
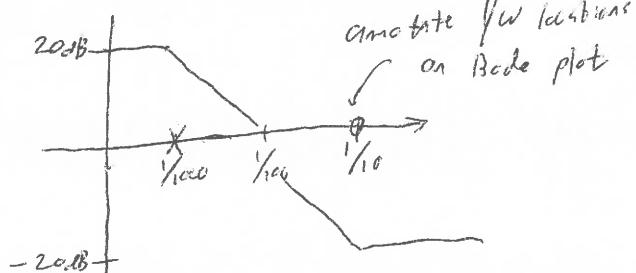
- ZPK formulation of Xfer fn is poles, zeros & gain

- From our example $k=10$, poles/zeros = 

geometric interpretation

- $|10s+1| = \sqrt{100s^2+1} = 10\sqrt{s^2+\left(\frac{1}{10}\right)^2}$ in FRF $\frac{1}{Z}\sqrt{(f_w)^2+B^2}$ where $Z=\frac{1}{10}$

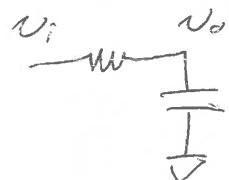
- Draw Bode plot by increasing ω & "turning on" terms as you pass them



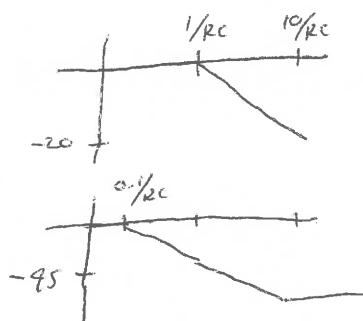
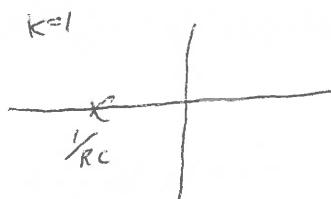
Let's do some Bode examples

- Draw ckt. implementation, Xfer fn., pole-zero plot, Bode plot
- Given one of the above

single pole

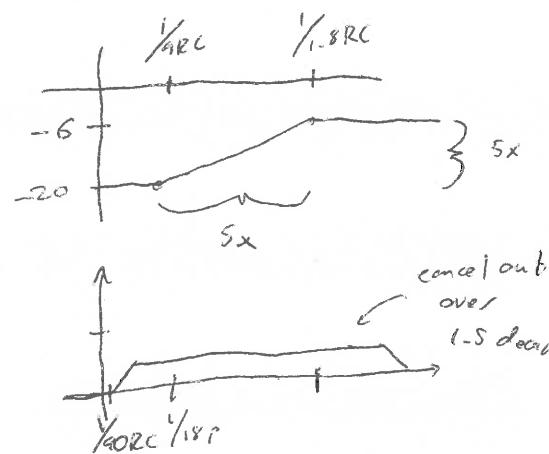
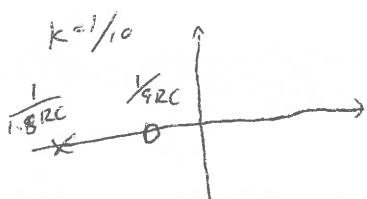


$$\frac{1}{RCs+1}$$

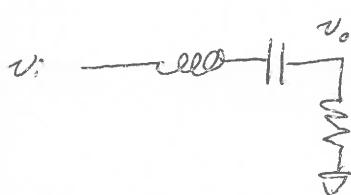


equalizer

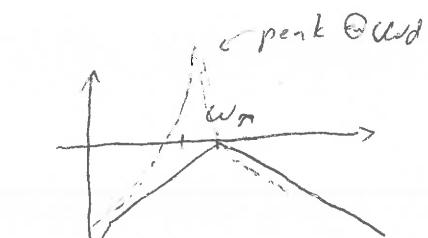
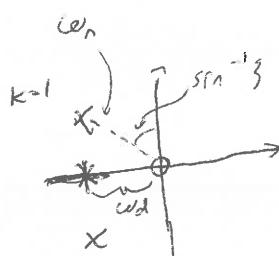
$$\begin{aligned} \frac{V_o}{V_i} &= \frac{\frac{R}{RCs+1}}{\frac{R}{RCs+1} + \frac{9R}{9RCs+1}} \\ &= \frac{9RCs+1}{9RCs+1 + 9RCs + 9} \\ &= \frac{9RCs+1}{18RCs + 10} \end{aligned}$$



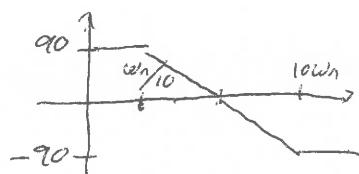
passive BPF



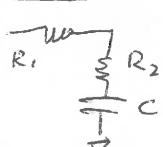
$$\begin{aligned} &= \frac{R}{R + Ls + \frac{1}{Cs}} \\ &= \frac{R Cs}{LCs^2 + RCs + 1} \end{aligned}$$



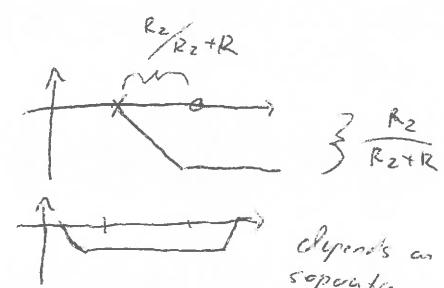
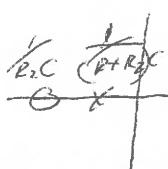
$$\omega_d = \omega_n \sqrt{1 - Q^2} = \omega_n \sqrt{1 - \frac{R^2}{4LC}}$$



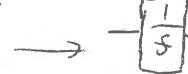
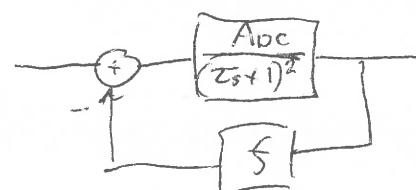
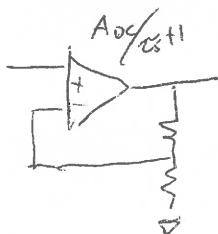
Composite zero/doublet



$$\frac{R_2 + \frac{1}{Cs}}{R_2 + R + \frac{1}{Cs}} = \frac{R_2 Cs + 1}{(R_2 + R)Cs + 1}$$



- Is an op-amp unity gain stable?

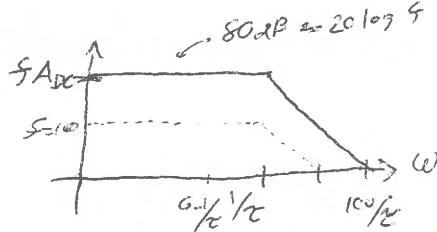


$$(L(s))$$

$$\frac{A_{Dc} s}{(Z_s + 1)^2}$$

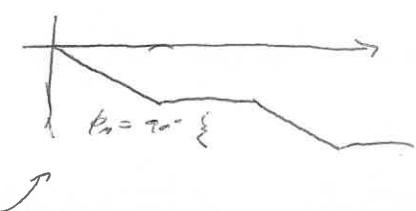
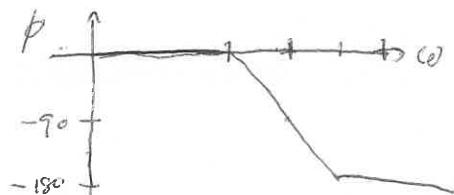
- overdriven, but designed like your last 2 w/ all poles @ high f

Bode plot of $L(j\omega)$



- only marginally stable when

$$f = 1/100, \text{ huge gain}$$



- Adding compensation cap makes op-amp

$$\frac{A_{Dc}}{(Z_s + 1)(Z_s^2 + 1)}$$

Oscillators

- oscillate if closed loop poles on j\omega axis

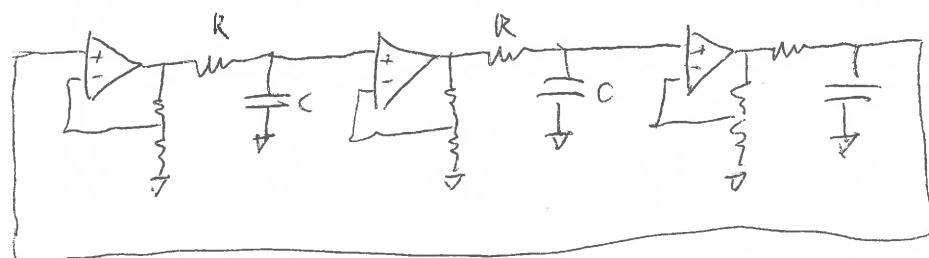
- same as $L(j\omega) = -1$, Not same as Barkhausen criterion ($kF(j\omega) = 1$)

- As before $L(j\omega) = -1 \rightarrow |L(j\omega)| = 1 \Rightarrow \angle L(j\omega) = \pi$

* in (-ve) fb

* need $L(j\omega) = -1$ in (+ve) fb

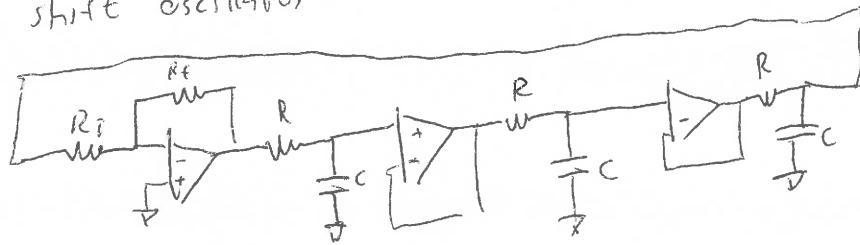
You try Can you pick a set of gain resistors (R_x) so this oscillates?



* No

* +ve feedback & net total phase shift is 270°

Phase shift oscillator



$$L(s) = + \frac{R_f}{R_i} \frac{1}{(RCs+1)^3} \text{ in -ve fb}$$

$$\left(-\frac{R_f}{R_i}\right)^{1/3} + j\omega_c$$

- Need 60° of phase from each pole $\rightarrow \omega_{osc} = \frac{1.732}{12C} \sqrt{3}$

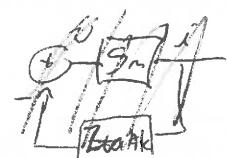
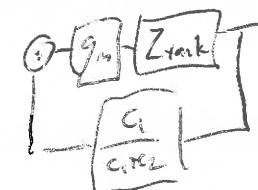
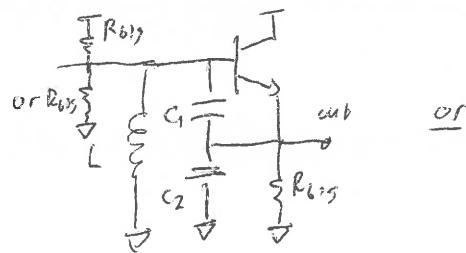
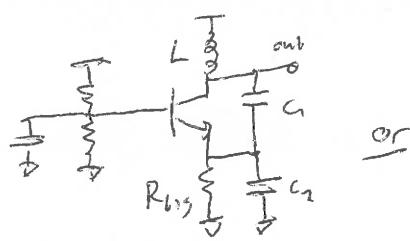
- @ 60° phase have magnitude $\frac{1}{2} \rightarrow \frac{R_f}{R_i} = 8$

- Bigger $\frac{R_f}{R_i}$ probability

Colpitts oscillator

L from tank w/ C_2
 C_1 from load cap

- Discussed b/c easy to make accidentally \rightarrow possible oscillations



- Capacitive divider makes feedback across base-emitter junction

$$Z_{tank} = R_s L_s \parallel \frac{1}{C_{ext}s} \quad \%C_{ext} = \frac{C_1 C_2}{C_1 + C_2}$$

$$= \frac{L_s R_s}{LC_{ext}s^2 + 1}$$

- passes through 0° @ $\frac{1}{\sqrt{LC_{ext}}}$

- can also analyze w/ 1-port impedance