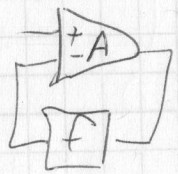
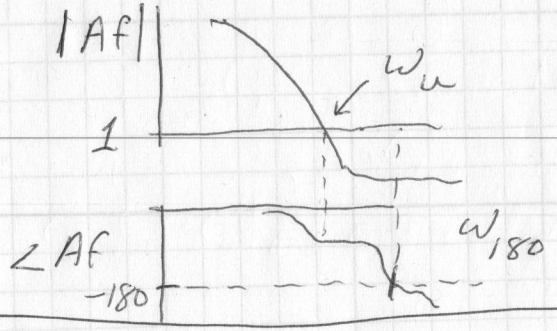
feedback/stability
gain & phase margin
compensation

Last time:



if $Af = -1$ at some frequency, your amp becomes an oscillator

What does that mean in Bode land?



Phase margin: How far from -180 when $|Af| = 1$

common design targets: 45, 60, 70°

gain margin: How far from 1 when $\angle Af = -180$

Simple-pole amplifiers (idealized): never unstable (-90 phase)

2 stage amplifiers: very common to have stability issues

→ 2 poles for sure

→ other negative phase as well (later)

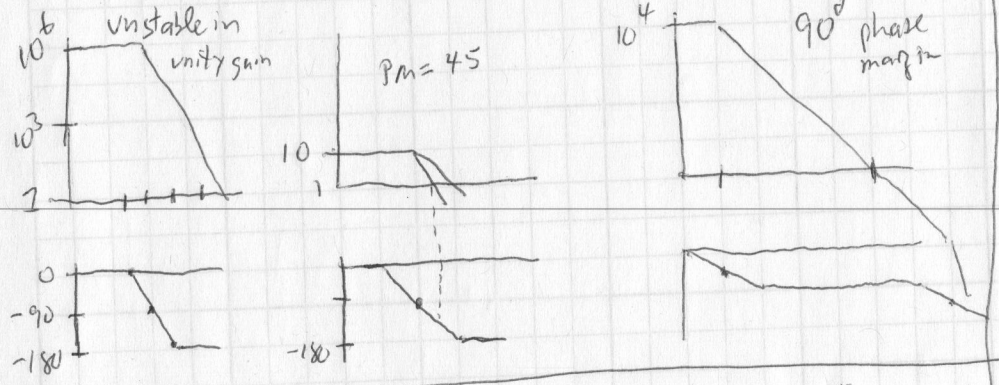
almost guaranteed to hit -180 phase

What about gain?

Example co-located poles, gain of 10^6

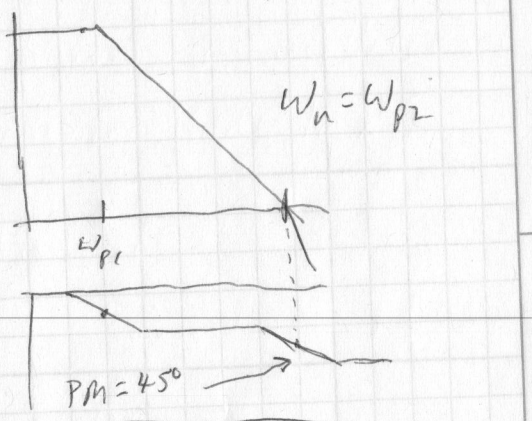
co-located poles, gain of 10

poles separated by 10^6, gain of 10^4

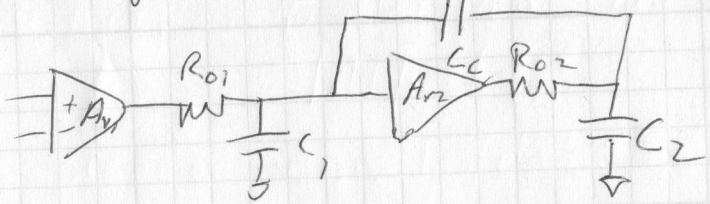


If you just have 2 poles, to set 45° PM you need them separated by the DC gain

$\frac{P_2}{P_1} = A_{VO}$



for 2 stage amp, 3 obvious options, (1 special)



Intentionally moving the open loop poles of an amplifier to make the closed-loop system stable is compensation

If C_C is "small"

$\omega_{P1} = \frac{1}{R_{O1} C_1}$ $\quad \| \quad (1 + G_{m2} R_{O2}) C_C << C_1$

$\omega_{P2} = \frac{1}{R_{O2} C_2}$ $\quad C_C << C_2$

Add to C_1 ω_{p1} moves to lower freq.

e.g. keep adding to C_1 until ω_u is less than ω_{p2} (PM > 45°)

but don't let anyone add more to C_2!

Add to C_2 until $\omega_{p2} \cdot A_v = \omega_u \leq \omega_{p1}$

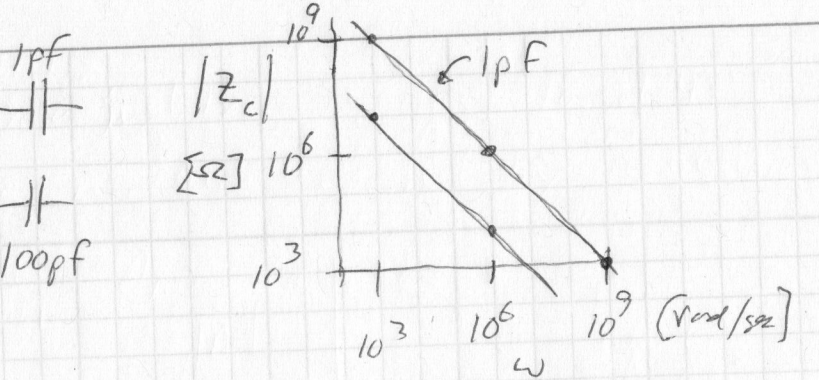
to get $\geq 45°$ PM

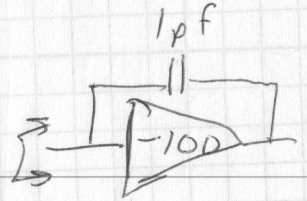
don't let anyone added to C_1 (probably easy)

If you overcompensate you give up performance

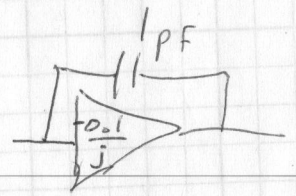
- lower bandwidth

third option: increase C_c

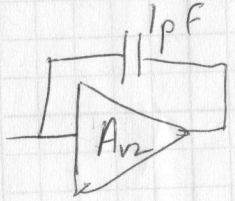




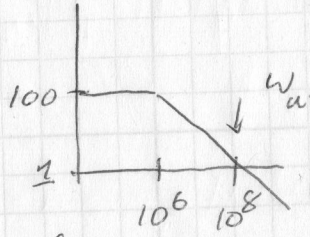
$Z_{in} = \frac{1}{j\omega(101pf)}$

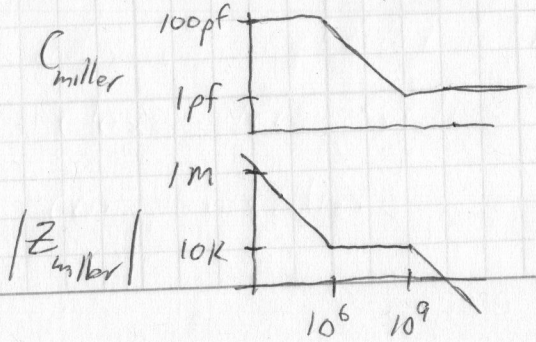


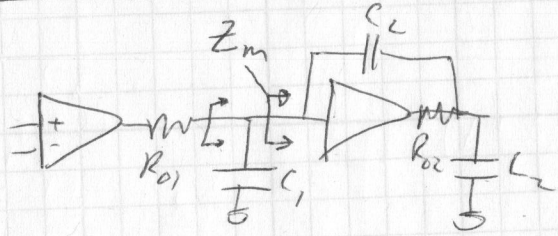
$Z_{in} \simeq \frac{1}{j\omega(1pf)}$



$$A_{v2} = \frac{-100}{1 + s/10^6} \simeq \begin{cases} -100 & \omega < 10^6 \\ -\frac{0.1}{j} & \omega = 10^9 \end{cases}$$







Adding to C_c moves ω_{p1} lower with smaller capacitance than would be necessary if adding to C_1 (smaller by $|A_{v2o}|$)

Even more magical, it pushes ω_{p2} higher! (or more accurately, it cancels $\omega_{p2\,o2}$ and adds a new pole)