ECE 3510 Final Exam Information

This sheet and the Information sheets from Exams 1 - 3 are the only reference materials allowed at exam. Bring this page. You **may add** whatever you want to this sheet (both sides).

Bode to transfer function

Slopes are always integer multiples of 20dB/decade

Complex poles an zeros $s^2 + 2\cdot\zeta\cdot\omega_n\cdot s + \omega_n^2 = (s+a)^2 + b^2 = s^2 + 2\cdot a\cdot s + a^2 + b^2$

Straight lines cross at natural frequency ω_n

Find max peaking at approx ω_n Change to factor $10^{\frac{max}{20dB}} = \frac{1}{2\cdot\zeta}$ damping factor $\zeta = \frac{1}{2\cdot 10^{\frac{max}{20dB}}}$

Find $2\cdot\zeta\cdot\omega_n$

Don't forget to find the constant multiplier of basic transfer function, usually done in a flat section of the plot.

GM, PM & DM

GM **G**ain Margin
Find freq. where phase plot crosses 180°
Magnitude should be less than 0dB at that frequency. GM in dB is amount that it is less than 0dB
GM in factor is 1/(magnitude as a factor)

PM **P**hase **M**argin
Find freq. where magnitude plot crosses 0dB ω_{PM} or f_{PM}
Phase should less negative than -180° at that frequency. PM is amount that it is less negative than -180°

DM **D**elay **M**argin

$$f_{PM} = \frac{\omega_{PM}}{2\cdot\pi} \qquad T = \frac{2\cdot\pi}{\omega_{PM}} \qquad DM = \left(\frac{PM}{360\cdot deg}\right)\cdot T$$

Feedback in Linear Amplifiers

Gain reduction and stabilization. Trade for other improvements. $A_f = \frac{A_o}{1 + A_o\cdot B}$

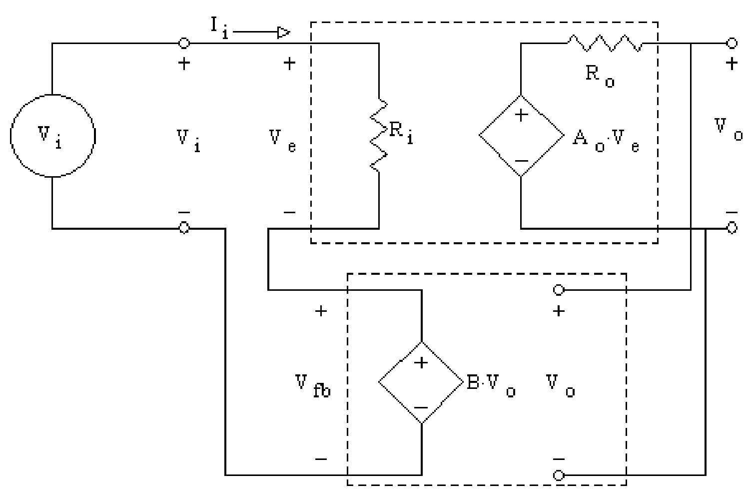
Bandwidth Extension

Op-amp compensation and resulting bandwidth Gain - Bandwidth product

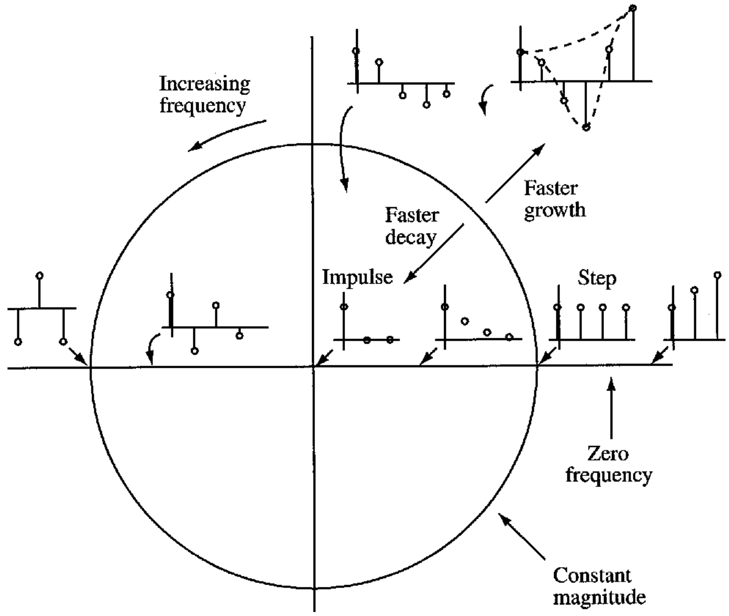
Input and Output Impedances For voltage amp with voltage feedback: Z_{in} Depends on how feedback is implemented
Z_{out} Decrease, usually by $(1 + A_o\cdot B)$

Reduce distortion, especially distortion caused by nonlinear gains

Reduce amplifier noise. The later the noise is introcuce in the amplifier, the greater the reduction.



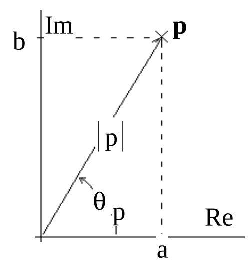
Discrete Signals, Systems and z-transforms



$$f(k) \qquad F(z) = \sum_{k=0}^{\infty} f(k)\cdot z^{-k}$$

f(k)	**F(z)**
$\delta(k)$	1
$u(k)$	$\frac{z}{z-1}$
p^k	$\frac{z}{z-p}$
$(\lvert p\rvert)^k\cdot\cos(\theta_p\cdot k)$	$\frac{z\cdot(z-\lvert p\rvert\cdot\cos(\theta_p))}{z^2-2\cdot\lvert p\rvert\cdot\cos(\theta_p)\cdot z+(\lvert p\rvert)^2}$
$(\lvert p\rvert)^k\cdot\sin(\theta_p\cdot k)$	$\frac{z\cdot(\lvert p\rvert\cdot\sin(\theta_p))}{z^2-2\cdot\lvert p\rvert\cdot\cos(\theta_p)\cdot z+(\lvert p\rvert)^2}$
$(\lvert p\rvert)^k\cdot\cos(\theta_p\cdot k)$	$\frac{z\cdot(z-a)}{z^2-2\cdot a\cdot z+(a^2+b^2)}$
$(\lvert p\rvert)^k\cdot\sin(\theta_p\cdot k)$	$\frac{z\cdot b}{z^2-2\cdot a\cdot z+(a^2+b^2)}$

Finite-length signals have all poles at zero



Damping factor $\zeta = \frac{-\ln(\lvert p\rvert)}{\sqrt{\ln(\lvert p\rvert)^2-\theta_p^{\,2}}}$

Time constant: $\tau = -\frac{1}{\ln(\lvert p\rvert)}$

Settling time: $T_s = 4\cdot\tau$

Inverse z-transforms (partial fractions & long division)

Divide by z first: $\frac{F(z)}{z}$

F(z)	**f(k)**
A	$A\cdot\delta(k)$
Poles on real axis (not at zero): $\frac{B\cdot z}{(z-p)}$	$B\cdot p^k$
$\frac{B\cdot p\cdot z}{(z-p)^2}$	$k\cdot p^k$
Complex poles: $\frac{B\cdot z}{(z-p)}+\frac{\overline{B}\cdot z}{(z-\overline{p})}$	$2\cdot\lvert B\rvert\cdot(\lvert p\rvert)^k\cdot\cos(\theta_p\cdot k+\theta_B)$

Properties of the z-transform
- linear
- Right-shift = delay = multiply by $z^{-1} = \frac{1}{z}$
- Left-shift = advance = multiply by z
- Initial value = $f(0) = \mathbf{F}(\infty)$ Final value (DC) = $f(\infty) = (z-1)\cdot\mathbf{F}(z)\Big|_{z:=1}$

Signals are bounded if all poles in inside unit circle, no double poles on unit circle
Converge to 0 if all poles inside unit circle. Converge to a non-zero value if a single pole is at 1

Discrete-time systems, FIR (all poles at zero), IIR (some poles not at zero)

BIBO Stability, all poles inside unit circle.

Integration $\mathbf{H}(z) = \frac{z}{z-1}$ Differentiation $\mathbf{H}(z) = \frac{z-1}{z}$

Difference equations, Right-shift = delay = D = multiply by $z^{-1} = \frac{1}{z}$

Step & Sinusoidal responses, effects of poles & zeros, etc.

DC gain = $\mathbf{H}(1)$ sinusoidal: $\mathbf{H}\left(e^{j\cdot\Omega_o}\right) = \lvert\mathbf{H}\rvert\,\underline{/\,\theta_H}$ multiply magnitudes and add angles

Same Feedback system as in continuous-time and Root locus works the same but is interpreted very differently.