FREQUENCY RESPONSE

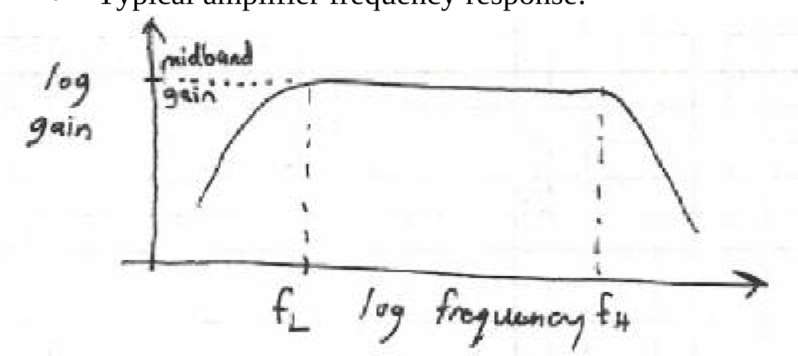
Chapter 6 taught us how to build amplifiers with

- Differential inputs
- Current sources
- High gain
- High R_{in}, low R_{out}

If these amplifiers are connected into a feedback loop, these amplifier's would oscillate? Why?

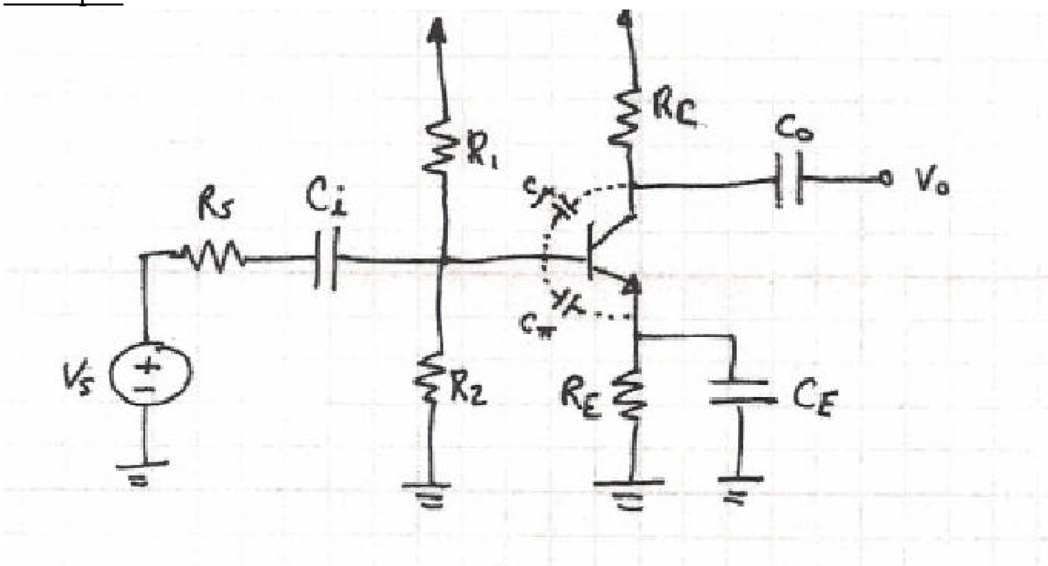
- An understanding of how the gain characteristics of an amplifier vary as a function of the input frequency.
- We will understand frequency better by understanding the following:
  - The low limit's will be determined by replacing "infinite capacitors" used to block DC (coupling & bypass caps) with finite capacitors
  - The high gain frequency limit will be determined by parasitic capacitors in BJTs and MOSFets.

- Typical amplifier frequency response:



FREQUENCY RESPONSE

Example:



Cμ => Collector-Base Capacitance
Cπ => Emitter-Base Capacitance

Which capacitor's contribute to low-frequency or high-frequency roll-off?

- Test each capacitor under 2 conditions:
  - Arbitrary low-frequency (DC): cap acts as open
  - Arbitrary high-frequency($f \rightarrow \infty$): cap acts as short

$C_i \rightarrow f$

$C_o \rightarrow f$

$C_E \rightarrow f$

$C_\mu \rightarrow f$

$C_\pi \rightarrow f$

Before we get quantitative, let's review:

- s-domain circuit analysis: $R \rightarrow R$; $C \rightarrow$; $L \rightarrow$

$s = j\omega$ $j^2 = -1$ $\omega = 2\pi f$

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Bode Plots:

1. Find Transfer Function in terms of s.
2. Determine the starting magnitude value: $|H(0)|$. If the DC gain of the transfer function is > 0, then the phase starts at 0^o. If the DC gain of the transfer function is < 0, then the phase starts at $\pm 180^o$.
3. Determine all critical frequencies (break frequencies). Start from the lowest value and draw the graphs as follows:

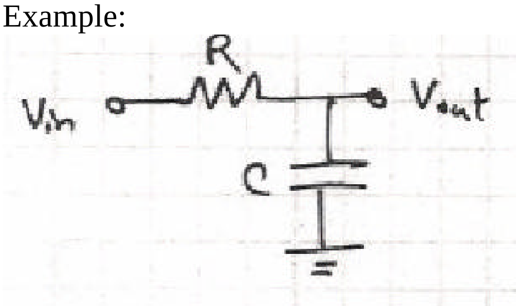
	Magnitude	Phase (create slope 1 decade below to 1 decade above $\omega_{critical}$)
Pole is negative	-20dB/dec	-45^o
Pole at origin	n*(-20dB/dec) @ω=1	n*(-90^o) at start *n=# poles at origin*
Zero is negative	+20dB/dec	$+45^o$
Zero at origin	n*(+20dB/dec) @ω=1	n*($+90^o$) at start *n=# zeroes at origin*

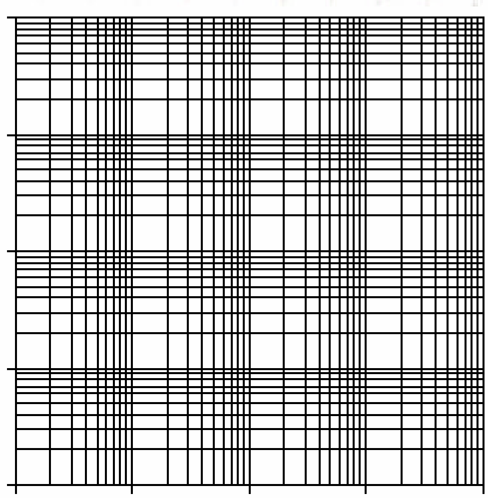
- For a zero/pole at the origin, if you need ω<1 then the magnitude start value can be determined also by => zero: $20*\log_{10}(|H(0)|\omega_{start}{}^{n}$
  pole: $20*\log_{10}(|H(0)|\omega_{start}{}^{-n}$
  where n=#pole/zero at origin, $\omega_{start} < 1$ and is set by the user: (e.g. ω=0.1)

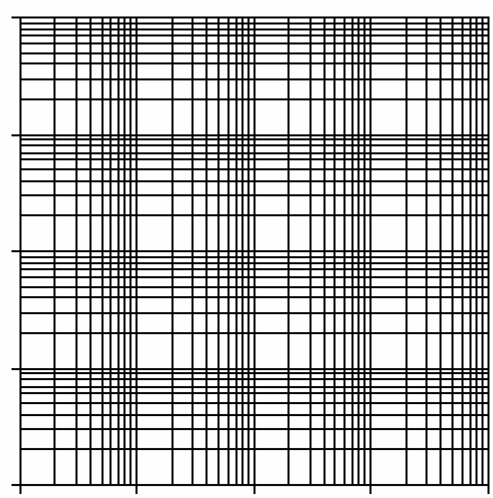
- Add each value to the previous value.

4. Graph:
   - 2 plots – both have logarithm of angular frequency on x-axis
     - y-axis magnitude of transfer function, H(s), in dB
     - y-axis phase angle

Example:







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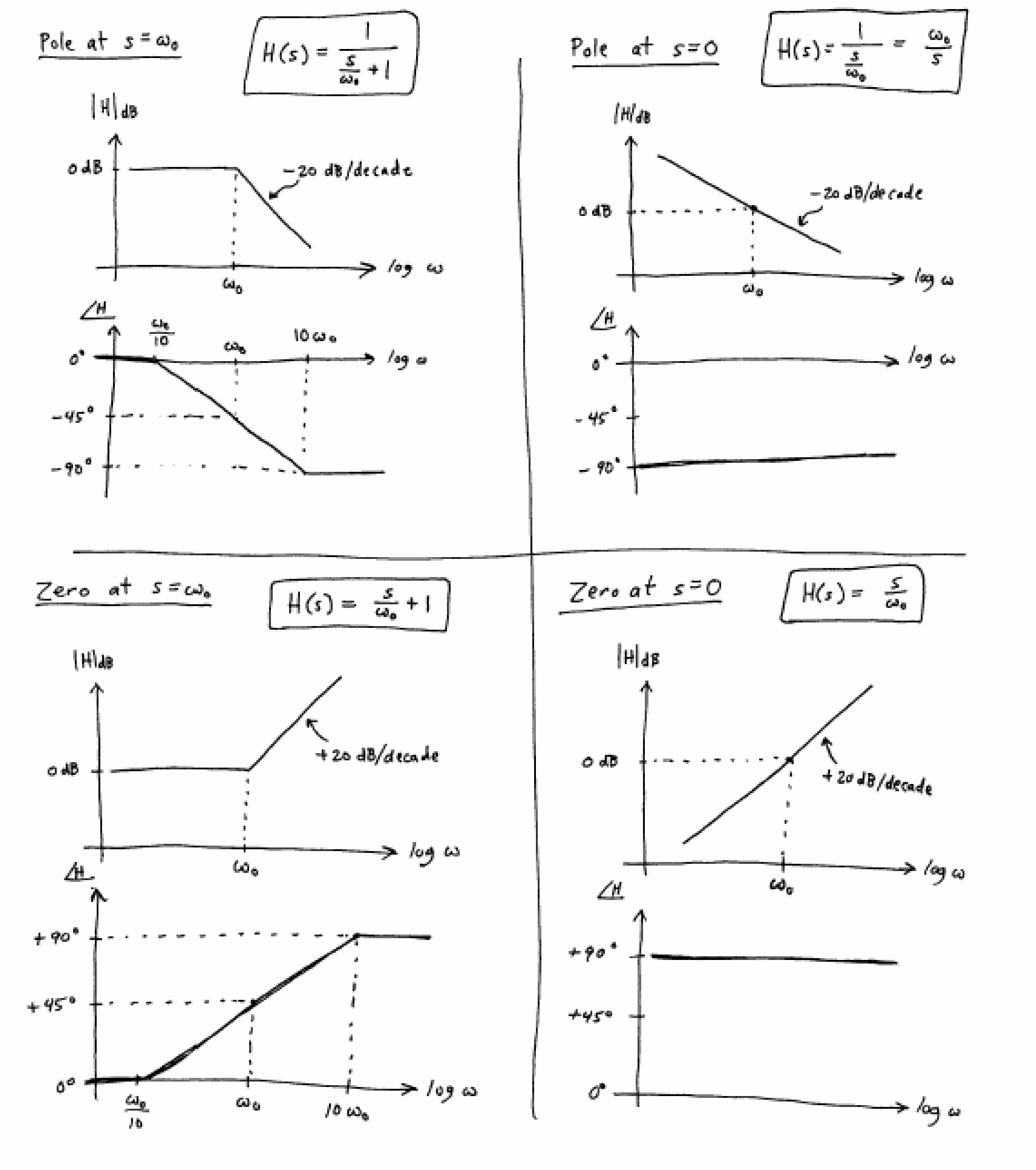
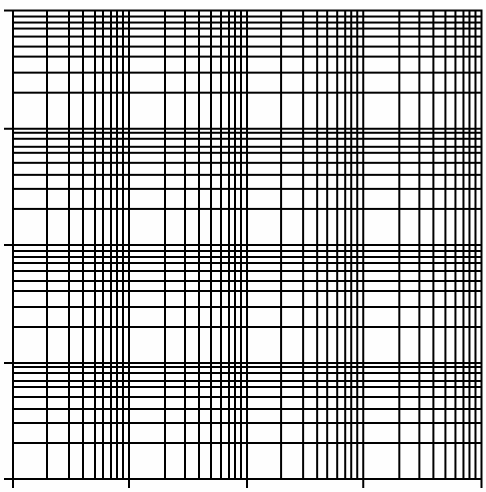


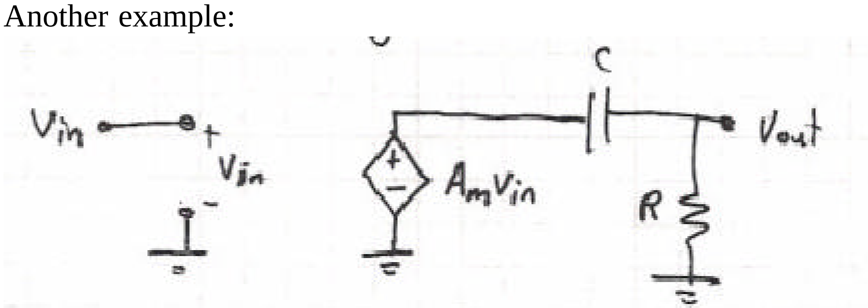
FREQUENCY RESPONSE

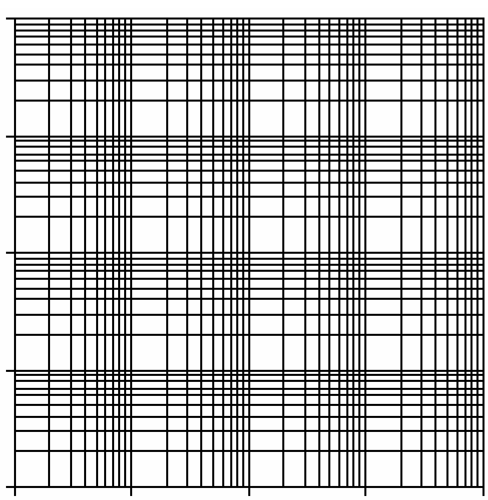
- What if we have an amplifier with the following transfer function?

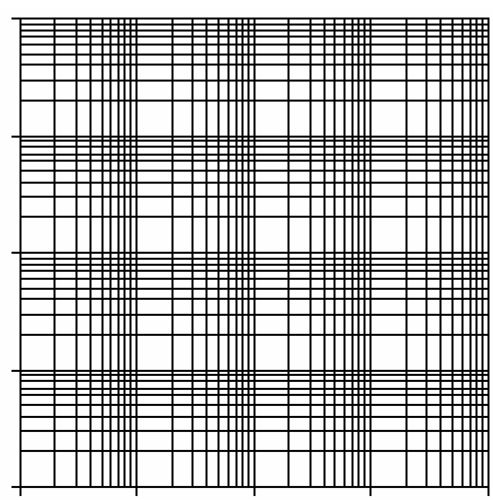
$$H(s) = \frac{A_m\left(\frac{s}{\omega_3}+1\right)}{\left(\frac{s}{\omega_1}+1\right)\left(\frac{s}{\omega_2}+1\right)} \quad \text{where } \omega_3 \gg \omega_2 \gg \omega_1$$



Another example:



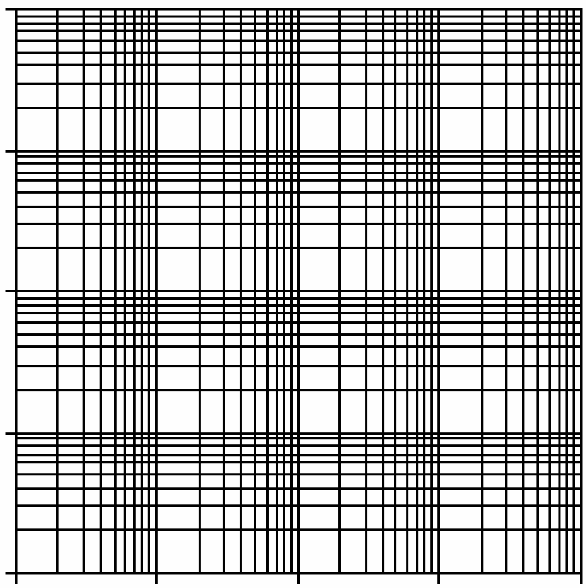




FREQUENCY RESPONSE

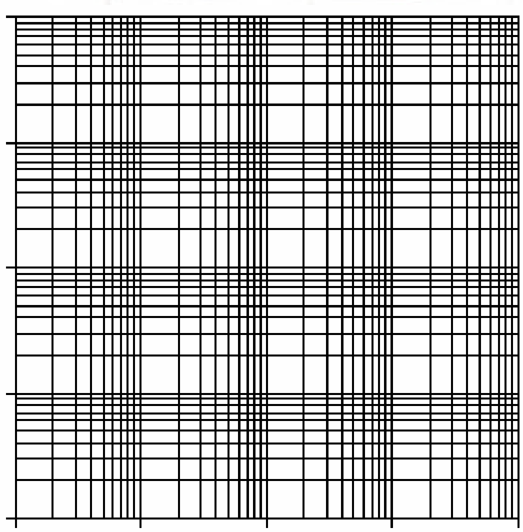
- What if we have an amplifier with the low-frequency behavior:

$$H(s) = \frac{A_m \left(\frac{\omega_3}{s} + 1\right)}{\left(\frac{\omega_1}{s} + 1\right)\left(\frac{\omega_2}{s} + 1\right)} \qquad \text{where } \omega_3 \ll \omega_2 \ll \omega_1$$



- A common form for the amplifier transfer function:

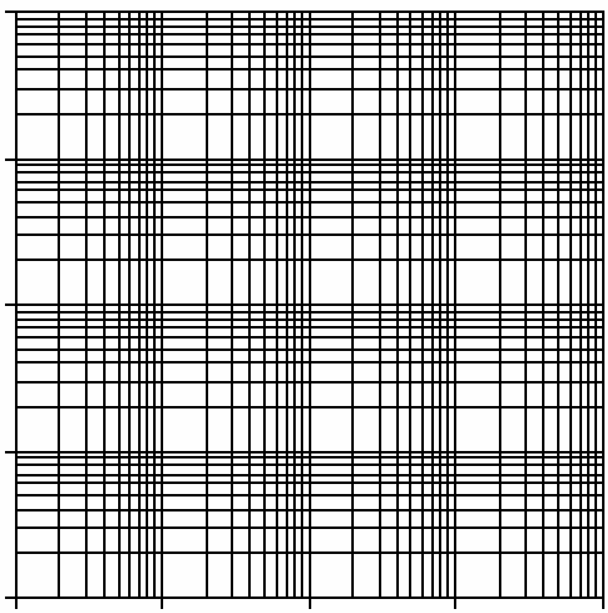
$$H(s) = \frac{A_m}{\left(\frac{\omega_1}{s} + 1\right)\left(\frac{s}{\omega_2} + 1\right)} \qquad \omega_2 \gg \omega_1 .$$



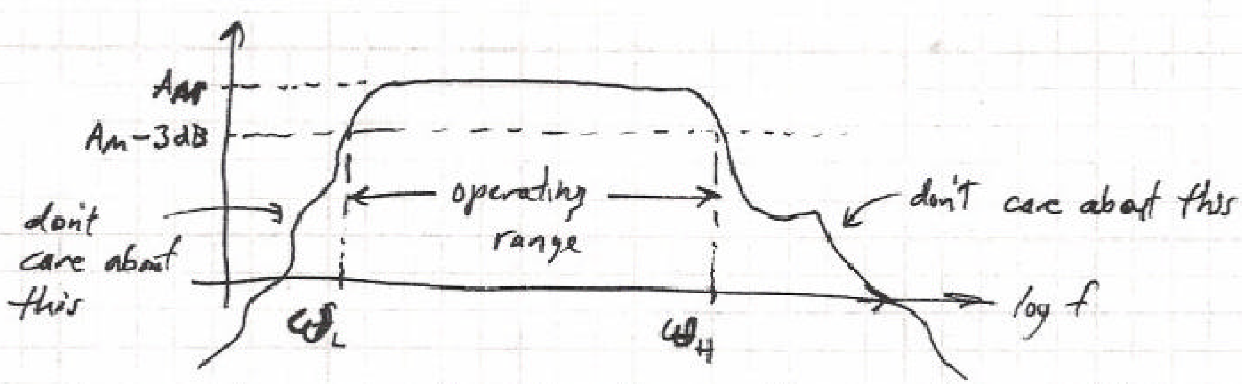
FREQUENCY RESPONSE

Example:

$$H(s) = \frac{s(s+10)\left(1+\frac{s}{100\,000}\right)}{(s+100)(s+25)\left(1+\frac{s}{10000}\right)\left(1+\frac{s}{40000}\right)}$$



- For many amplifier designs, we only desire to find ______________________________ the 3dB points



(signal is weak outside of midband — don't care how weak)