Good amp:
- $R_{in} \gg R_s$
- $R_{out} \ll R_L$
- $G(w) = \text{const}$

"Bare" op-amp problems:
- small active range
- large $G$ variations
- $G \propto \frac{1}{\omega}$ for $\omega_c \geq 10 \text{Hz}$
- $R_{out}$ is fairly large
\[ S_{out} = \]

\[ \text{throw away } \quad \text{to make} \]

\[ \text{a stable circuit, indep. of } \quad \]

\[ \text{Advantages of negative F.B.} \quad \]

\[ (\Sigma_m)_{\text{active}} = \]
\( G(\omega) = \frac{G_0}{1 + j\omega/\omega_0} \)

\( G_{cl} = \)

\[ R_{m, cl} = \]
\[ \text{Vout} = \]
\[ \text{Vout} = \]

\[ R_{\text{out}}, C_L = \]

Rules for analyzing negative F.B. circuits

1) current rule:
2) voltage rule:
Two basic configurations with negative feedback
Applications of neg. feedback

1. Voltage follower

\[ G_{CL} = \frac{G}{1+GH} \approx 1, \quad G \gg 1 \]

- draws no current
- drive low Z load with high Z source

2. Noninverting amplifier

\[ G_{CL} = \frac{R_1 + R_2}{R_1} \]

\[ R_{IN, CL} = R_m (1 + GH) \]

\[ R_{OUT, CL} = \frac{R_{OUT}}{1 + GH} \]
3 Inverting amplifier

\[ G_{CL} = -\frac{1}{H'} = -\frac{R_2}{R_1} \]

4 Summing circuit
Active filters

Feedback network contains $Z(\omega)$

Pros:

Cons:

Q: ideal integrator & differentiator: poles & zeros of $G(s)$?
Lecture 12

Integrator

\[ V_{out} \propto \int V_{in} dt \Rightarrow G(s) \propto \]

![Integrator Circuit Diagram]

AC response:

\[ G_{cl}(s) = \]

Problem 1:

Problem 2:

![Amp Icon]
Leaky integrator

\[ G_{cl}(\omega) \approx \]

\[ G_{cl}(\omega) = \]

\[ G_{cl}(\text{db}) \]

Pros:
Cons:

Differentiator

\[ V_{out} \propto \frac{d}{dt} V_{in} , \Rightarrow G_{cl}(s) \propto \]

AC response:

\[ G_{cl}(\omega) = \]
Problem:

$\frac{20\text{dB}}{\text{dec}}$

$\log w$

Solution:

$\frac{20\text{dB}}{\text{dec}}$

$\log w$

Pros:

Cons:

Stability

$H = \frac{Z_1}{Z_1 + Z_2}$

$H' = \frac{Z_1}{Z_2}$
\[
G_{cl} = \frac{1}{H} \left( \frac{1}{1 + \frac{1}{GH}} \right)
\]

\[
G_{cl} = -\frac{1}{H'} \left( \frac{1}{1 + \frac{1}{G}} + \frac{1}{GH'} \right)
\]

**Phase & gain margins**

- \(G_{Hdb}\)
- \(0\) dB
- \(\Phi\)
- \(\log w\)
- \(-180^\circ\)

**Nyquist plots**

- \(\text{Im}\{GH\}\)
- \((-1,0)\)
- \(\text{Re}\{GH\}\)

Nyquist criterion of stability: