Feedback

- Assume you are familiar with feedback benefits, issues
  - Review: G&M Ch. 8 & 9, Razavi Ch. 8

- Focus here on:
  - Stability
    - Analysis and simulation
  - Settling
    - Often amplifying pulses and not sinusoids
    - More next lecture
Generic Feedback Circuit

- Open-loop gain: $a_v$
- Feedback factor: $f$
- Loop gain: $T = a_v f$
- Closed-loop gain: 
  $$A = \frac{V_o}{V_i} = \frac{a_v}{1 + T} = \frac{1}{f} \frac{1}{1 + \frac{1}{f}} \approx \frac{1}{f}$$

Electronic Feedback Circuit

- Careful with mapping circuit feedback to generic diagram…

  $$f = \frac{R_i}{R_i + R_2}$$
Is This Circuit “Stable”? 

Stability

• Nearly all circuits are actually non-linear and time-varying
  • “Poles” only accurate for given bias, temp., etc.

• What we usually mean by stability:
  • Circuit always converges to the “origin” for zero input within finite time
    • (Exponential stability)
  • Another common definition: BIBO stability
Stability In Practice

- Linearize the circuit and look at its poles

- Remember: this is only an approximation!
  - Perform linear analysis over several corners, temps, supplies, etc.
  - May want to do a couple of transient sims too

Linear Circuit Stability

- Stability set by T(s)

- T(s) is an open-loop parameter - need to break the loop
  - Easy to do in hand analysis: break at controlled source
  - Not as easy in simulation...
Simulating Stability

Common Approach
Middlebrook Method (1975)

True Loop Gain:
\[
\begin{align*}
\frac{v_y}{v_x} & \equiv T_v = g_m \cdot \frac{Z_2}{Z_1} \\
\frac{i_y}{i_x} & \equiv T_i = g_m \cdot \frac{Z_1}{Z_2}
\end{align*}
\]

Solving yields:
\[
T = \frac{T_v T_i - 1}{T_v + T_i + 2}
\]

• Measure $T_v$ and $T_i$, then calculate actual $T$

Phase Margin

• Approximate method to evaluate stability: phase margin

• Works well for most circuits of interest
  • Sometimes have to use Nyquist stability test
Multi-Loop Feedback
Multi-Loop Feedback Example