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: $A = \frac{V_o}{V_i} = \frac{a_v}{1 + T} = \frac{1}{f} \left(1 + \frac{1}{T}\right) = \frac{1}{f}$

Electronic Feedback Circuit

- Careful with mapping circuit feedback to generic diagram...

$$f = \frac{R_1}{R_1 + R_2}$$
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:

\[ T = g_m \cdot \frac{Z_2}{Z_1 + Z_2} \]

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