EE 240B – Spring 2018

Advanced Analog Integrated Circuits

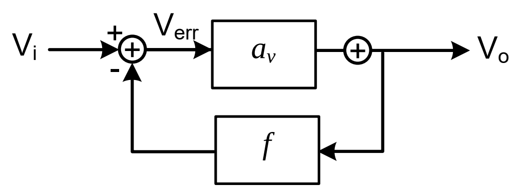
Lecture 9: Feedback

Elad Alon
Dept. of EECS

Feedback

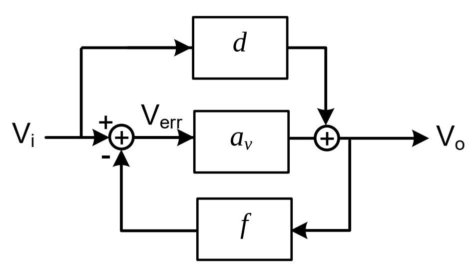
- Assume you are familiar with feedback benefits, issues
  - Review: G&M Ch. 8 & 9, Razavi Ch. 8
- Focus today on stability analysis and simulation

Generic Feedback System

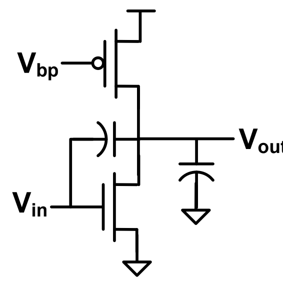


- **Open-loop gain: a_v**
- **Feedback factor: f**
- **Loop gain: $T = a_v f$**
- **Closed-loop gain:** $A = \frac{V_o}{V_i} = \frac{a_v}{1+T} = \frac{1}{f}\frac{1}{1+\frac{1}{T}} \approx \frac{1}{f}$

Feedback + Feedforward

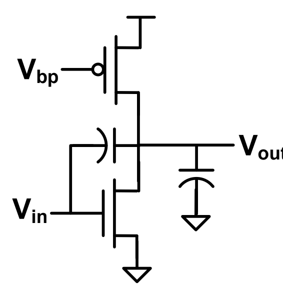


Is This Circuit "Stable"?



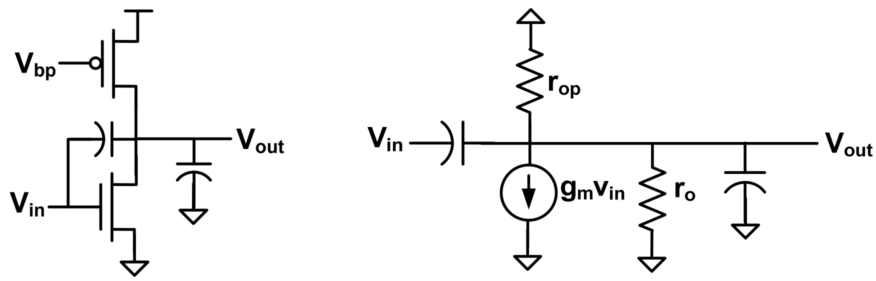
Stability

- 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

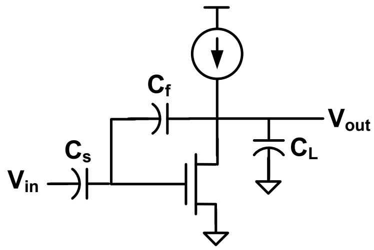


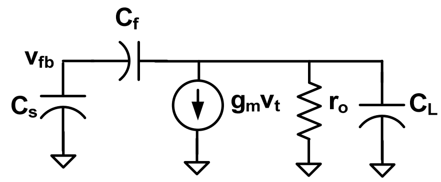
- Linearize the circuit and look at its poles
- Remember: this is only an approximation!
  - Perform linear analysis over several corners, temps, supplies, etc.
  - Likely need to do a couple of transient sims too

Linear Stability: Phase Margin

- Approximate method to evaluate stability
- Works well for most circuits of interest
  - Sometimes have to use Nyquist stability test

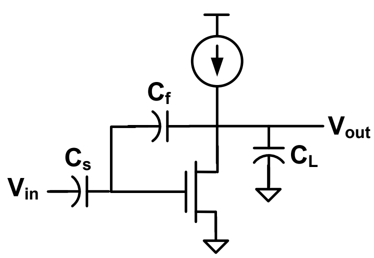
Simulating Stability (1)

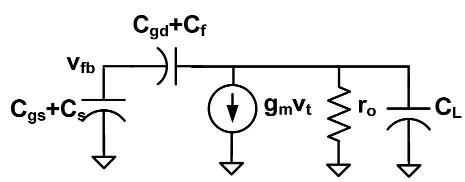




- **Stability set by T(s)**
- **T(s) is an open-loop parameter - need to break the loop**
  - **Easy to do in hand analysis: break at controlled source**
  - **Not as easy in simulation…**

Simulating Stability (2)

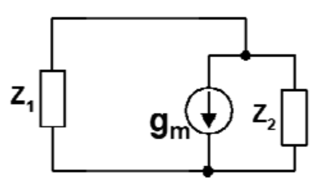




Common Approach

General Setup

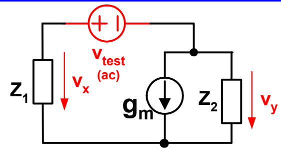
- Any single loop feedback circuit can be represented as:



$$T(s) = g_m \cdot \frac{Z_1 Z_2}{Z_1 + Z_2}$$

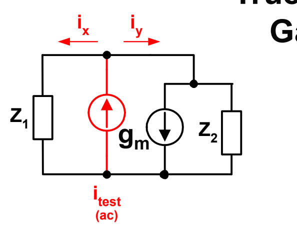
- Can't break the loop at the g_m, but can break it between Z_1 and Z_2

Middlebrook Method (1975)



$$\left|\frac{v_y}{v_x}\right| \equiv T_v = g_m \cdot Z_2 + \frac{Z_2}{Z_1}$$

True Loop Gain: $$T = g_m \cdot \frac{Z_1 Z_2}{Z_1 + Z_2}$$



$$\frac{i_y}{i_x} \equiv T_i = g_m \cdot Z_1 + \frac{Z_1}{Z_2}$$

Solving yields:

$$T = \frac{T_v T_i - 1}{T_v + T_i + 2}$$

- **Measure T_v and T_i, then calculate actual T**
- **Implemented in many simulators (e.g., stb)**

Multi-Loop Feedback