Lecture 41

• Last time:
  – Applications of open-circuit time constant analysis: CE amplifier and cascode amplifier

• Today:
  – The four-stage voltage amplifier: using OCTC to find the dominant pole
  – Introduction to differential amplifiers
Qualitative Insight

Could always do “brute force” open-circuit time constants

CS*-CB is a wideband stage … so is the CD-CC buffer

Look for large $R_{Tx} C_x$ products: high-impedance nodes are likely candidates

Node X

CS*-CB is a wideband stage … so is the CD-CC buffer

“High impedance node” is node X … look at $R_{Tx} C_x$

Capacitance:

$$C_x = C_{gd6} + C_{db6} + C_{\mu2} + C_{cs2} + C_{gd3} + C_{M3}$$

Miller for CD stage ($M_3$)
Finding the Miller Capacitance $C_{M3}$

Gain across $C_{gs3}$:  $A_{vC_{gs3}} = \frac{R_{L3}}{1/g_{m3} + R_{L3}}$

$R_{L3} = R_{in4} =$

Dominant Pole of Voltage Amplifier

Thévenin resistance for $C_X$:

$R_{Tx} = R_{out2} \parallel R_{in3} = R_{out2,CB} \parallel R_{in,CD}$

$R_{Tx} = r_{oc} \parallel r_{o2}(1 + g_{m2}(r_{\pi2} \parallel R_{S2})) \cong r_{o6}(1 + g_{m6}r_{o7}) \parallel r_{o2}\beta_0$

Dominant pole:  $\omega_1^{-1} \approx R_{Tx}C_x$
Magnitude Bode Plot

Low-frequency voltage gain was found in Lecture 38:

\[ A_v = -g_{m1} \left( \beta_6 r_{o2} \parallel r_{o6} \left( 1 + g_{m6} r_{o7} \right) \right) \]

(neglect loading at output \( R_L >> R_{out} \))

\[ |A_v(j\omega)| \]

Gain-Bandwidth product = unity gain frequency

Differential Amplifiers

What’s wrong with our EE 105 amplifiers?

1. Customer must supply \( V_{BIAS} \) or \( I_{BIAS} \) – impractical!

2. The input signals and output signals are referenced to ground or “single-ended” →

they’re easily corrupted by a variety of interfering signals (e.g., loops in your circuit picking up radio stations or cell phones, \( V_{DD} \) has high-frequency components from lightning strikes in the Sierra, etc.)
The Differential Amplifier Concept

The basic idea: amplify the *difference* between two inputs and reject the common component

\[ v_{out, \text{diff}} = A_{v, \text{diff}} (v_{in, \text{diff}}) = A_{v, \text{diff}} (v_{in1} - v_{in2}) \] ... large

\[ v_{out, \text{comm}} = A_{v, \text{comm}} (v_{in, \text{com}}) = A_{v, \text{comm}} [(v_{in1} + v_{in2})/2] \] ... small

A Simple MOS Differential Amplifier

![A Simple MOS Differential Amplifier Diagram]