Lecture 26
Analyzing Complex Amplifiers

Outline

- Two-port hand analysis
- Examples
- What’s Next?
Multi-Stage Amplifier Analysis

• Draw circuit such that signal stages and biasing devices can be easily identified.

• Identify signal path and establish amplifier parameters.

• Determine function of all other transistors-usually current or voltage sources.

• Find high impedance nodes to estimate frequency response.
Can now understand more complex circuits?

Examples:

NMOS CD

NMOS CS - PMOS CD
Can now understand more complex circuits?

![PNP CE circuit diagram]

![PNP CC - PNP CE circuit diagram]
BiCMOS Voltage Amplifier

Qualitative View

- Identify signal path and establish amplifier parameters
- CS-CB-CD-CC - Good voltage amplifier
- Determine function of all other transistors-usually current or voltage sources
- Find high impedance nodes to estimate frequency response
Small Signal Voltage Gain
Cascode+Voltage Buffer

- Cascode-CS-CB
- $R_{in} \rightarrow \infty$

$$R_{out} = \beta_{o2} \beta_{o2} \| g_{m6} r_{o6} r_{o7}$$

$$A_{vo} \approx \frac{v_{out}}{v_s} - g_{m1} \left( \beta_{o2} \beta_{o2} \| g_{m6} r_{o6} r_{o1} \right) \approx \frac{v_{out}}{v_s}$$

- Voltage buffer CD-CC

$$R_{in}' \rightarrow \infty \quad A_{v} \approx 1$$

$$R_{out} = \frac{1}{g_{m4}} + \frac{1}{\beta_{o4} \left( g_{m3} + g_{mb3} \right)}$$
Frequency Response

\[ A_{vo} = \frac{v_{out}^2}{v_s} = -g_m \left( \beta o_2 r_o^2 \right| \left. g_m r_o \right) \approx \frac{v_{out}}{v_s} \]

\[ \omega_{3dB} = \frac{1}{\left( \beta o_2 r_o^2 \right| \left. g_m r_o \right)} \left[ \frac{1}{(C_{\mu 2} + C_{gd6} + C_{gd3} + (1-A_v C_{gs3}) C_{gs3} + C_{db6} + C_{cs2})} \right] \]
Bode Plot

\[ \omega_{3dB} = \frac{1}{\left( \beta_2 r_2 g_m r_6 r_7 \right)} \]

\[ \omega_{unity} = A_v \cdot \omega_{3dB} \]

\[ \omega_{unity} = \frac{g_{m1}}{\left( C_{\mu2} + C_{gd6} + C_{gd3} + \left( 1 - A_v C_{gs3} \right) C_{gs3} + C_{db6} + C_{cs2} \right)} \]
Large Signal DC Analysis

- Assume $V_{BE} = 0.7V$

$V_{GS} = 1.5V$
Wrap-up of 6.012

6.012: Introductory subject to microelectronic devices and circuits

- **MICROELECTRONIC DEVICES**
  - Semiconductor physics: *electrons/holes and drift/diffusion, carrier concentration controlled by doping or electrostatically*
  - Metal-oxide-semiconductor field-effect transistors (MOSFETs): *drift of carriers in inversion layer*
  - Bipolar junction transistors (BJTs): *minority carrier diffusion*

- **MICROELECTRONIC CIRCUITS**
  - Digital circuits (mainly CMOS): *no static power dissipation; power \( \downarrow \), delay \( \downarrow \) & density \( \uparrow \) as \( W & L \downarrow \)
  - Analog circuits (BJT and CMOS): \( f_t \uparrow \) and \( g_m \uparrow \) as \( L \downarrow \); however, \( A_{v_{max}} \downarrow \) as \( L \downarrow \)

**Follow-on Courses**

- **6.152J** — Microelectronics Processing Technology
- **6.720J** — Integrated Microelectronic Devices
- **6.301** — Solid State Circuits
- **6.374** — Analysis and Design of Digital ICs
- **6.775** — Design of Analog MOS ICs