Lecture 26
Analyzing Complex Amplifiers

Outline

• Two-port hand analysis
• Examples
• What’s Next?

Announcement: Final Examination
Monday, May 21, 9:00 am - 12:00am, Johnson;
Open Book, Calculator Required.
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?

The diagram shows two different types of PNP configurations:

- **PNP CE (Common Emitter)**: The circuit includes a reference current source $I_{REF}$, a PNP transistor $Q_1$, and a load resistor $R_L$. The bias voltage $V_{BIAS}$ is applied to control the transistor's operation.

- **PNP CC - PNP CE**: This configuration involves a PNP transistor in common collector (CC) connection with another PNP CE configuration. The circuit includes a reference current source $I_{REF}$, PNP transistors $Q_1$ and $Q_2$, and a load resistor $R_L$. The bias voltage $V_{BIAS}$ is also present to bias the transistors.

The diagrams illustrate the flow of current $I_{OUT}$ and illustrate how these configurations can be used in various electrical circuits.
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
- $R_{in} \rightarrow \infty$

$$R_{out} = \beta_2 r_2 \| gm6r_6r_7$$

$$A_{vo} = \frac{v_{out}^2}{v_s} = -gm1 \left( \beta_2 r_2 \| gm6r_6r_7 \right) \approx \frac{v_{out}}{v_s}$$

- 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

\[ A_{vo} = \frac{v_{out2}}{v_s} = -g_m \left( \beta o_2 r_{o2} \parallel g_{m6} r_{o6} r_{o7} \right) \approx \frac{v_{out}}{v_s} \]

\[ \omega_{3dB} = \left| \frac{1}{(\beta o_2 r_{o2} \parallel g_{m6} r_{o6} r_{o7})} \right| \left[ \frac{1}{(C_{\mu2} + C_{gd6} + C_{gd3} + (1 - A_v C_{gs3}) C_{gs3} + C_{db6} + C_{cs2})} \right] \]
Bode Plot

\[\omega_{3dB} = \left| \frac{V_{out}}{V_s} \right| \approx g_m \beta_0 r_2 r_0\]

\[\omega_{3dB} = \left| \frac{1}{(\beta_0 r_2 r_0 g_m r_6 r_7)} \right| \left| \frac{1}{(C_{\mu2} + C_{gd6} + C_{gd3} + (1 - A_v C_{gs3}) C_{gs3} + C_{db6} + C_{cs2})} \right|\]

\[\omega_{unity} = A_{vo} \times \omega_{3dB}\]

\[= \left| \frac{g_m}{(C_{\mu2} + C_{gd6} + C_{gd3} + (1 - A_v C_{gs3}) C_{gs3} + C_{db6} + C_{cs2})} \right|\]
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 ↓, delay ↓ & density ↑ as W & L ↓*
  - Analog circuits (BJT and CMOS): *fτ ↑ and gm ↑ as L ↓: however, A_{vomax} ↓ as L ↓*

**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