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.

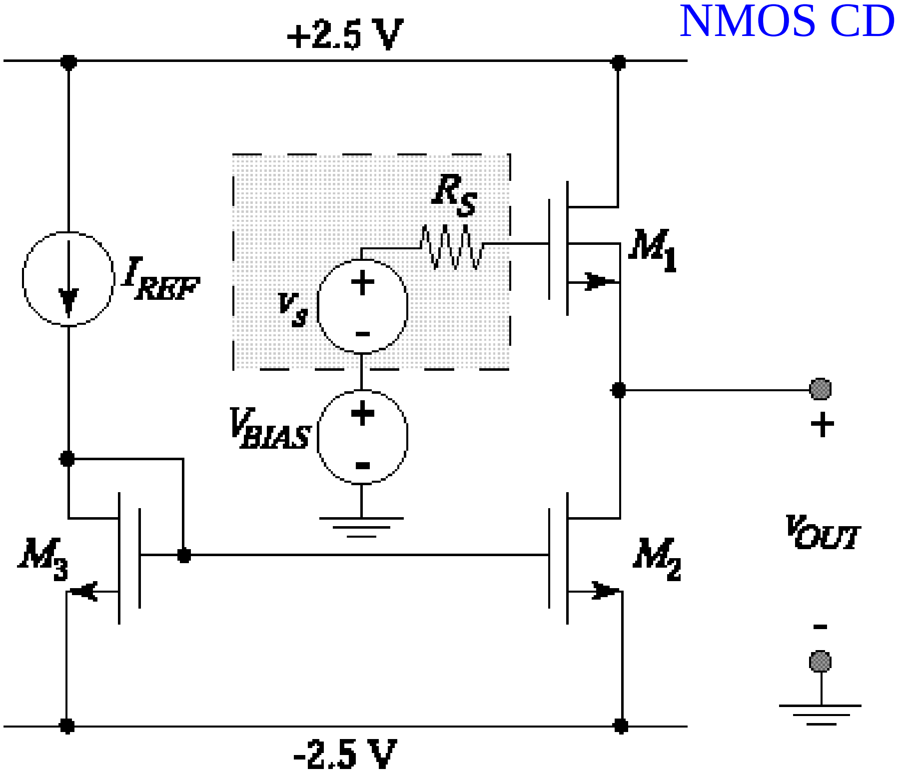
Multi-Stage Amplifier Analysis

- 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.

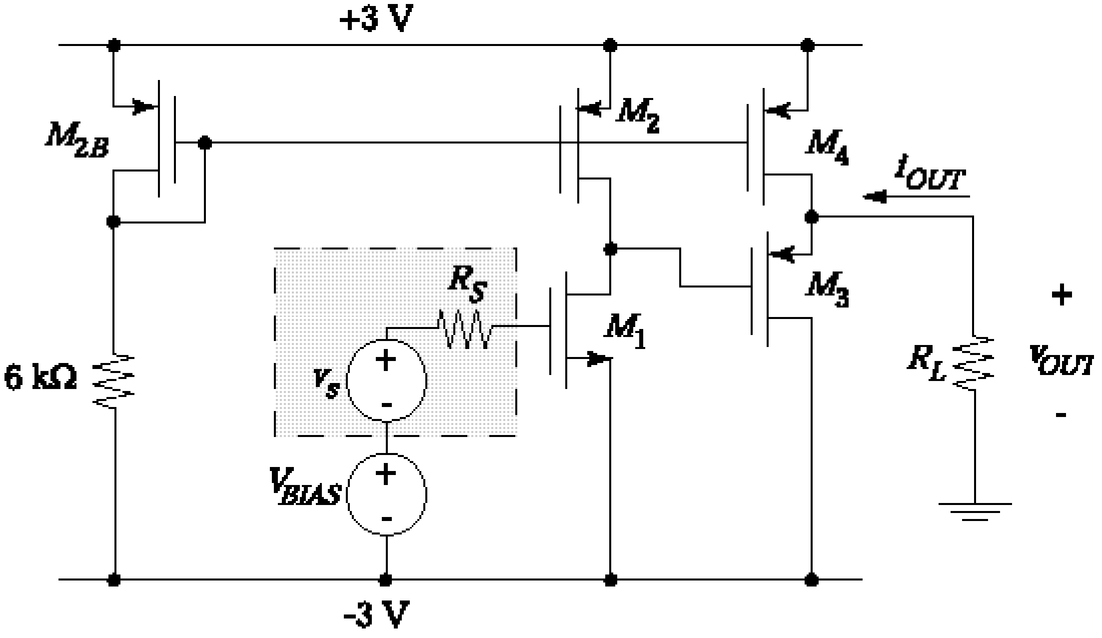
Can now understand more complex circuits?

Examples:

NMOS CD

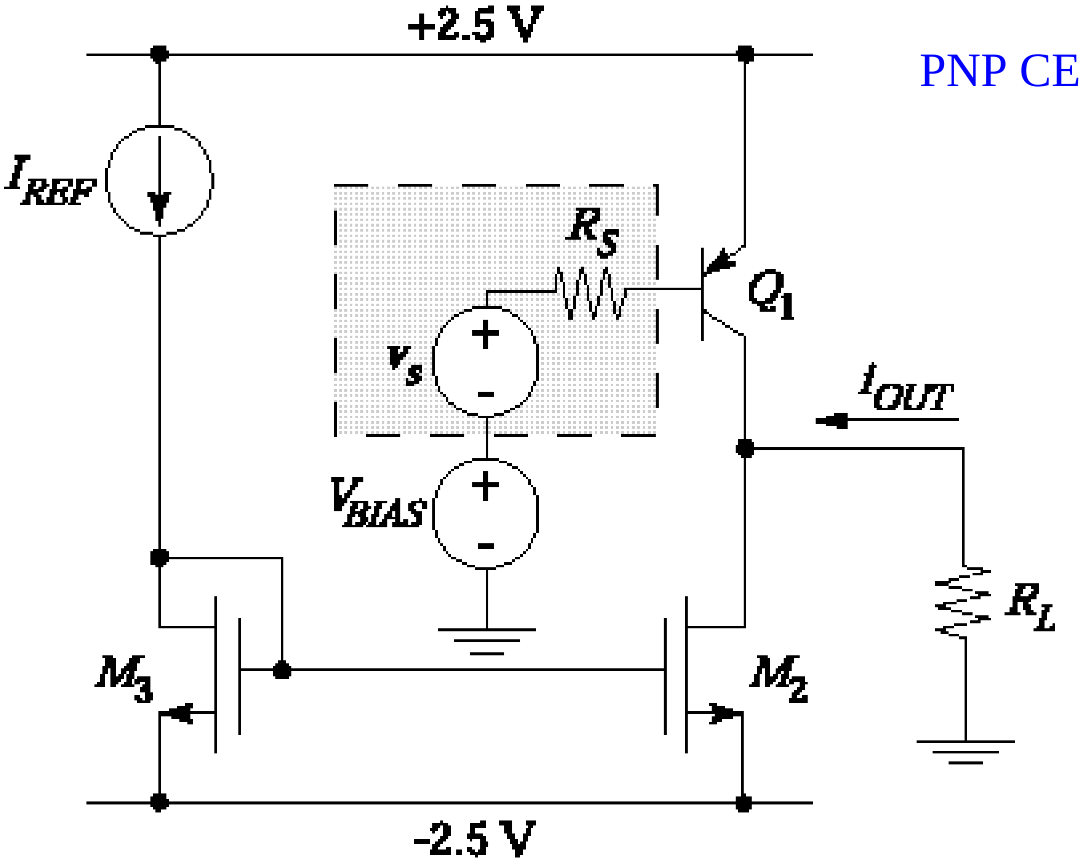


NMOS CS - PMOS CD

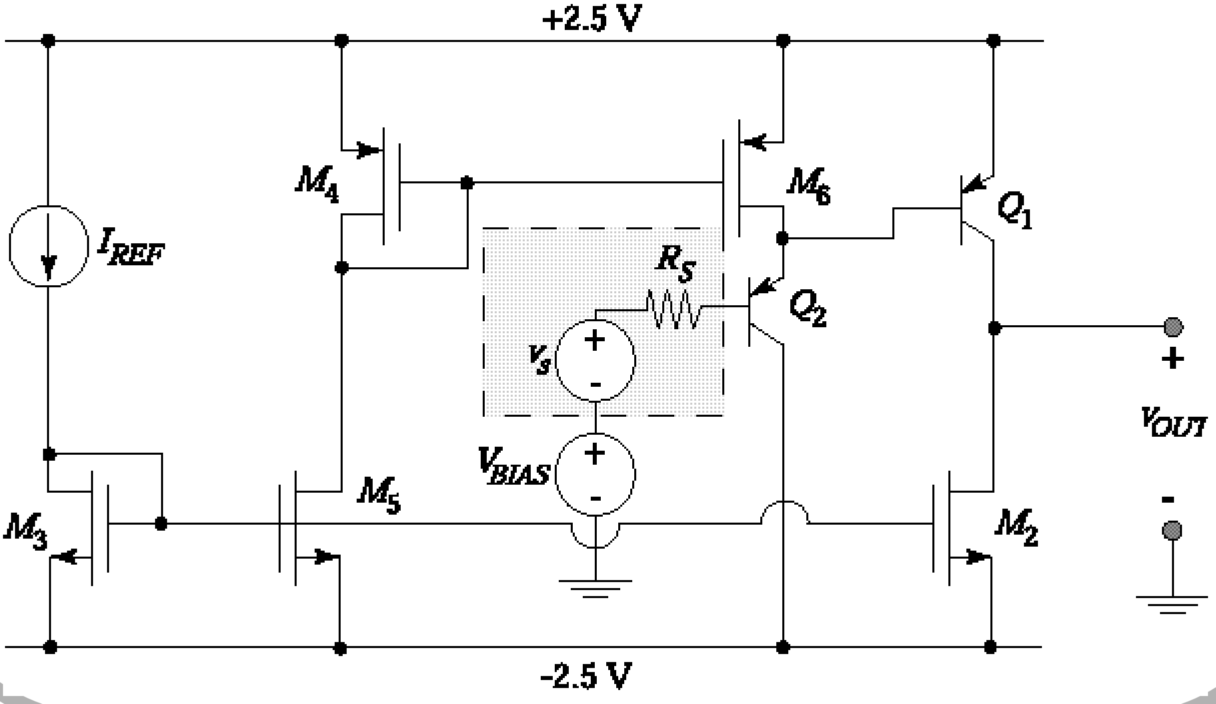


Can now understand more complex circuits?

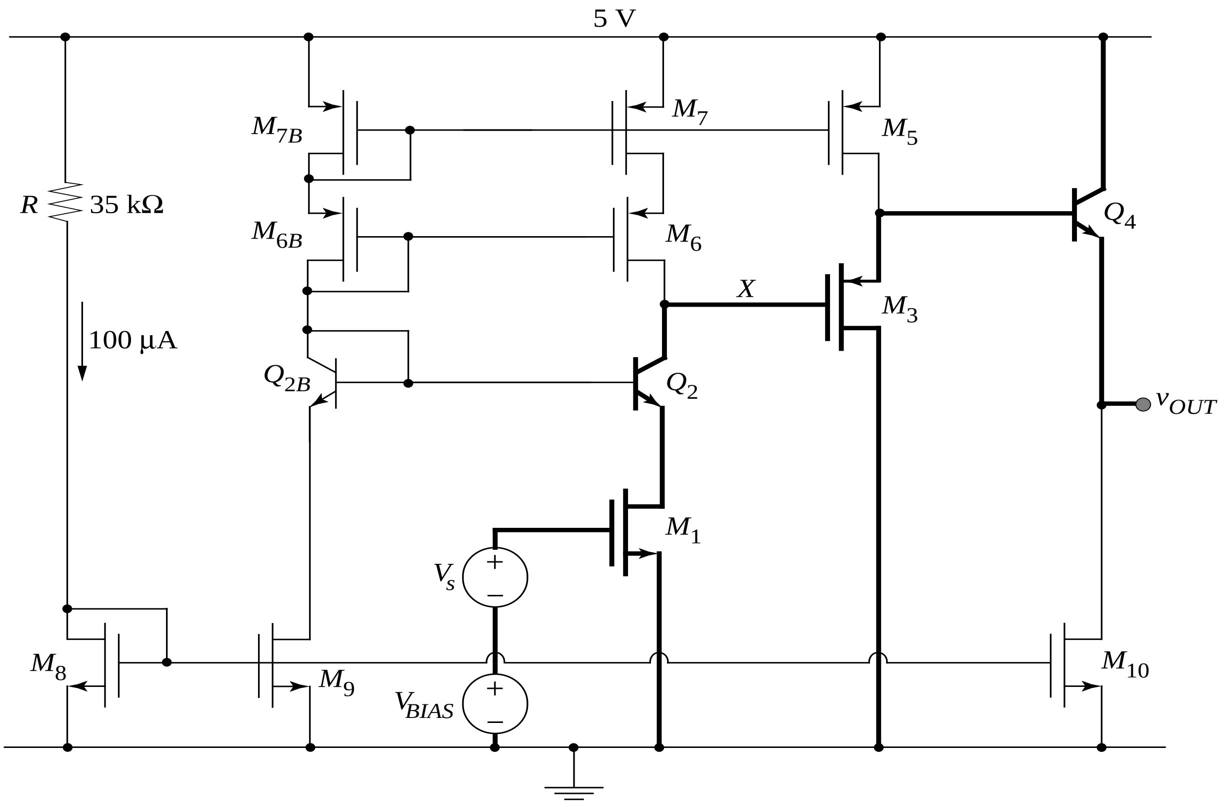
PNP CE



PNP CC - PNP CE



BiCMOS Voltage Amplifier

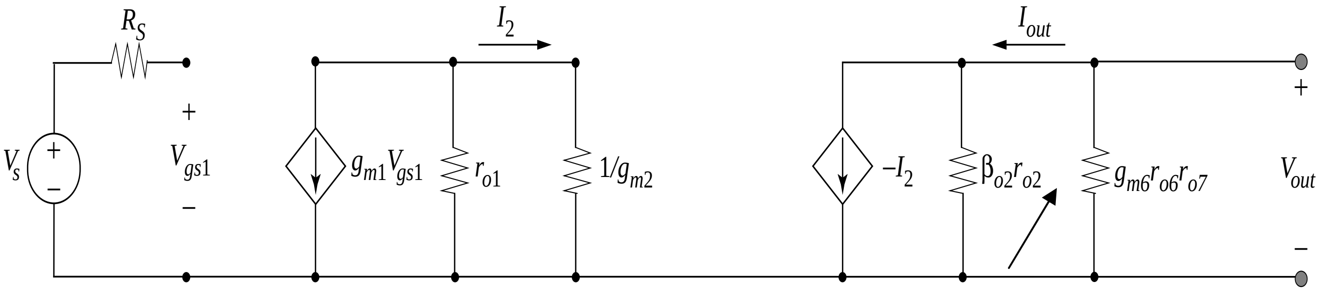


Qualitative View

- 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

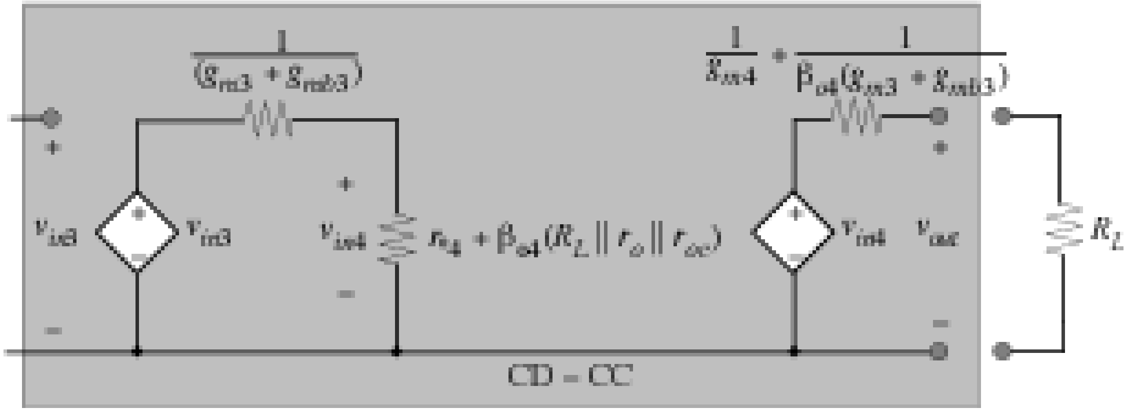
- Cascode-CS-CB
- $R_{in} ---> \infty$



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

$$A_{vo} = \frac{v_{out2}}{v_s} = -g_{m1}\left(\beta_{o2} r_{o2} \| g_{m6} r_{o6} r_{o7}\right) \approx \frac{v_{out}}{v_s}$$

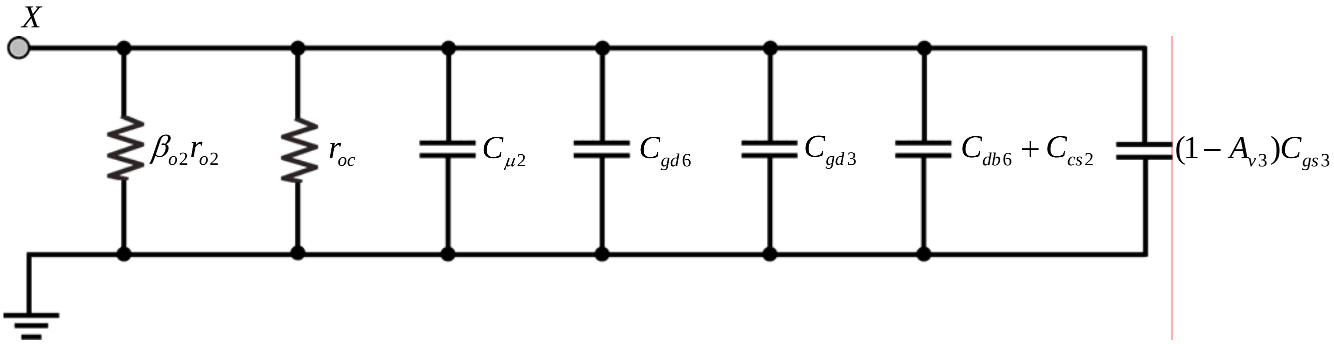
- Voltage buffer CD-CC



$$R_{in}' \to \infty \qquad A_v \approx 1$$

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

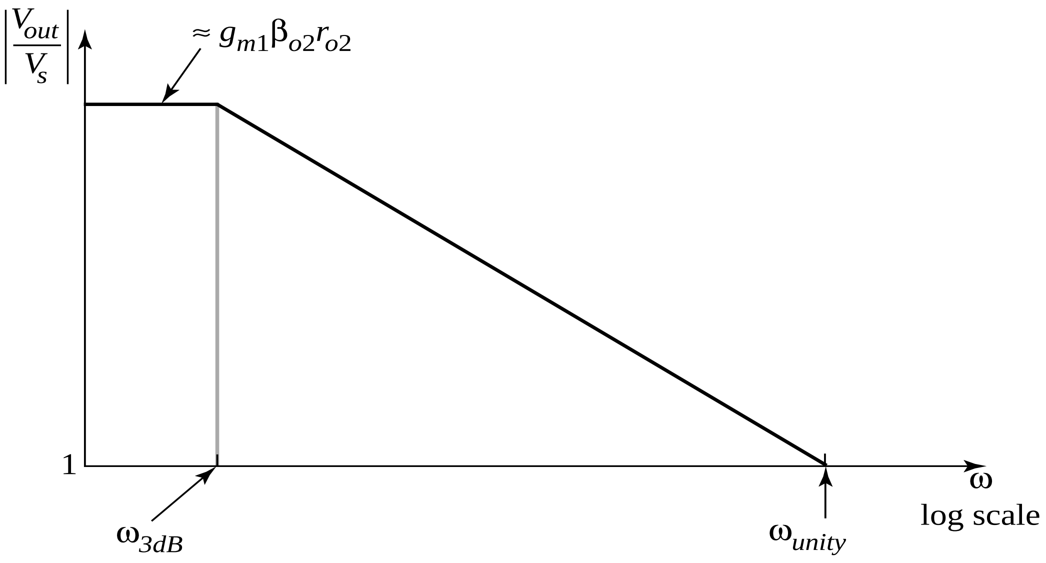
Frequency Response



$$A_{vo}=\frac{v_{out2}}{v_s}=-g_{m1}\left(\beta_{o2}r_{o2}\,\|\,g_{m6}r_{o6}r_{o7}\right)\approx\frac{v_{out}}{v_s}$$

$$\omega_{3dB}=\left[\frac{1}{\left(\beta_{o2}r_{o2}\,\|\,g_{m6}r_{o6}r_{o7}\right)}\right]\left[\frac{1}{(C_{\mu 2}+C_{gd6}+C_{gd3}+\left(1-A_{vCgs3}\right)C_{gs3}+C_{db6}+C_{cs2}}\right]$$

Bode Plot



$$\omega_{3dB} = \left|\frac{1}{\left(\beta_{o2} r_{o2} \| g_{m6} r_{o6} r_{o7}\right)}\right| \left[\frac{1}{\left(C_{\mu 2} + C_{gd6} + C_{gd3} + \left(1 - A_{vCgs3}\right) C_{gs3} + C_{db6} + C_{cs2}\right.}\right]$$

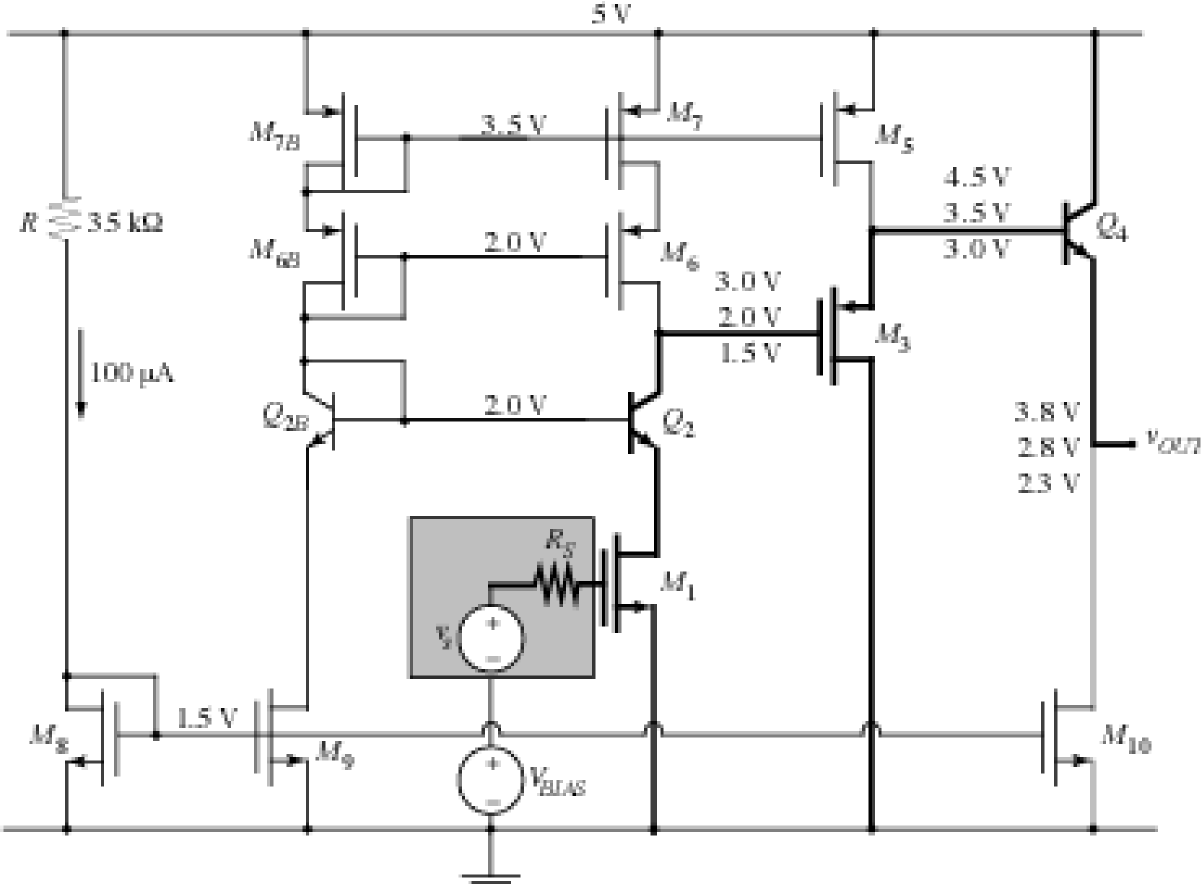
$$\omega_{unity} = A_{vo} * \omega_{3dB}$$

$$= \frac{g_{m1}}{\left(C_{\mu 2} + C_{gd6} + C_{gd3} + \left(1 - A_{vCgs3}\right) C_{gs3} + C_{db6} + C_{cs2}\right)}$$

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 ↓, delay ↓ & density ↑ as W & L ↓**
  - Analog circuits (BJT and CMOS): **$f_\tau \uparrow$ and $g_m \uparrow$ as L ↓: however, $A_{vomax} \downarrow$ 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