Lecture Material

- Last lecture
  - Designing complete amplifiers
- This lecture
  - Differential amplifiers
- Next lecture
  - The semester at a glance
  - Review
Administrativia

- Make-up lecture December 11 at 2pm (203 McLaughlin)
- Extra office hours: Monday 11:30-1pm (511 Cory)
- Final: We December 13, 12:30-3:30pm, 105 North Gate
- Check your homework grades on the web!
- Last lab this week.

Announcement

- Research opening for undergraduates in Prof. King’s group.
- Similar is true in BWRC. Check if interested.

Ultra-low power design

Ubiquitous wireless
Some advanced topics …

- Metrics in designing amplifiers
  - Gain
  - Bandwidth
  - Others?

Differential amplifiers address
- power supply noise
- crosstalk

The differential amplifier

- One way of addressing some of the concerns

Source: Sedra & Smith
The differential amplifier with common-mode input

\[ v_{D1} - v_{D2} = 0 \]

Impact of varying common mode voltage

- **Example**

\[ V_T = 0.5 \text{ V} \]
\[ k' = 4 \text{ mA/V}^2 \]
\[ Q1 = Q2 \]
Impact of varying common mode voltage

- Example

[Diagram of electronic circuit showing voltage and current values]

Constraints?
Impact of DS Voltage?

Applying a voltage difference

[Diagram of electronic circuit showing voltage and current values]
**Input voltage range**

\[ |V_{\text{in, max}}| = \sqrt{2} V_{\text{GS}} \]

**Linear range as a function of overdrive**

- \( V_{\text{GS}} = 0.2 \, \text{V} \)
- \( V_{\text{GS}} = 0.3 \, \text{V} \)
- \( V_{\text{GS}} = 0.4 \, \text{V} \)
Small signal model

\[ V_{DD} \]
\[ R_D \]
\[ v_{v1} = -g_mR_D(v_{id}/2) \]
\[ g_m(v_{id}/2) \]
\[ +v_{id}/2 \]
\[ + \]
\[ Q_1 \]
\[ \text{Biased at } 1/2 \]
\[ v_{v1} = v_{id}/2 \]
\[ v_{v2} = -v_{id}/2 \]
\[ 0 \text{ V} \]
\[ -v_{v2} = -v_{id}/2 \]

(a)
Small Signal Model (alternative view)

Including $r_0$ and $R_{SS}$

Still perfectly symmetric
Virtual ground model is still valid
The Differential Half-Model

![Diagram of Differential Half-Model]

Common-Mode Gain

![Diagram of Common-Mode Gain]
Half-Circuit Model

(b) Biased at 1/2

Effect of Mismatch
The Bipolar version

$\begin{array}{c}
\text{The Bipolar version} \\
\text{IC versus } v_{id}
\end{array}$
Adding Emitter Resistance

Increases linear region