HW #8 Due Today

HW #9 will be assigned Mon MARCH 6
Due Friday MARCH 10

Midterm 2 Mon MARCH 6 (50 min)
(more later)

Help Session Sun MARCH 5 3-4 PM
KEC 1007

$I_C = I_S e^{\frac{V_{BE}}{V_T}}$

MOSFET ON $V_{GS} \geq V_T$

The MOSFET as an amplifier

CS amplifier $I_D = \frac{V_{DD}}{R} I_C$

The region of operation is saturation:

$I_D = \frac{k'}{2} \frac{W}{L} (V_{GS} - V_T)^2$

Small-signal analysis

$\frac{\partial I_D}{\partial V_{GS \text{ op. pt.}}} = \frac{k'}{2} \frac{W}{L} 2 (V_{GS} - V_T) |_{\text{op. pt.}}$

$= \frac{k'}{2} \frac{W}{L} (V_{GS \text{ op. pt.}} - V_T) = g_{m}$

$V_{DS} \geq V_{GS} - V_T$

$\text{transconductance}$
\[
I_{DS} = 0.5\text{mA} \\
V_T = 1\text{V}, \quad k' = 50\mu\text{A/V}^2; \quad \frac{W}{L} = \frac{100\text{mm}}{10\mu\text{m}}
\]

\[V_{GS} = ? \quad A_V = \frac{V_O}{V_i} = \frac{V_O}{V_i}
\]

\[V_O = 10\text{V} - 0.5 \times 10 = 5\text{V}
\]

Recall that \( V_g \leq 5 + V_T = 6\text{V} \Rightarrow \text{Saturation}\)

Assume saturation:

\[
V_{GS} = V_T + \sqrt{\frac{2I_D}{k'W/L}} = V_{GG}
\]

\[= 1 + \sqrt{\frac{2 \times 0.5\text{mA}}{50\mu\text{A}} (10)} = 2.41\text{V}
\]

Transistor is in saturation \(\Rightarrow V_{GS} = 2.41\text{V}\)

\[
V_{QS} = V_i \\
V_O = -g_m V_{QS} (10\text{k}\Omega)
\]

\[A_V = \frac{V_O}{V_i} = -g_m (10\text{k}\Omega)
\]

\[g_m = k' \frac{W}{L} (V_{GS} - V_T) = 50\mu\text{A} (10) (2.41 - 1)
\]

\[= 7.1 \times 10^{-4} \ \text{A/V}
\]

\[A_V = -7.1 \ \text{V/V}
\]
Compare with a BJT version:

\[ I_{CA} = 0.5 \text{ mA} \Rightarrow g_m = \frac{I_{CA}}{V_m} = 20 \text{ mA/V} \]

\[ A_v = -g_m \left( 10 \text{ k} \Omega \right) = -20 \times 10 = -200 \]

Amplifier configurations:

- **CS**: Common Source
- **CG**: Common Gate
- **CD**: Common Drain (source follower)

**CG**

\[ A_v = \frac{v_o}{v_i} \]

\[ A_v = g_m R_o \]

\[ R_o = R_o \]

\[ R_i = \frac{1}{g_m} \]

Current:

\[ i_t = -g_m v_{gs} \]

\[ v_{gs} = -v_t \]

\[ R_i = \frac{v_t}{i_t} = \frac{1}{g_m} \]
Midterm: includes everything up to HW #8 (included)

Closed book/note: Reference note sheet provided (posted)

Calculators are allowed

BJTs

Analysis of BJT circuits
1) DC operating point analysis
2) Small signal analysis

Amplifier configurations
CE, CB, CC (emitter follower)

↑ with emitter degeneration

Calculate $R_i, R_o, G_m, A_v$

Current sources $\quad$ Current mirrors $\quad$ Current steering

MOSFETs

Identify regions of operation
- Cutoff, linear/triode, Saturation

Given a current $i$ and voltages
find $\frac{k'W}{L}, V_T$

Given $\frac{k'W}{L}, V_T, I_D$ calculate $V_G$,

""", $V_A, V_{OS}$ "" $I_D$

Sample exam posted on class web page

1. Transistor (BJT) amplifier
   - DC op pt analysis
   - Small signal calculations
     $R_i, R_o, G_m, A_v$

2. Current mirrors/current steering

3. MOSFETs
   - regions of operation
   - Simple calculations