Discussion Outline

• 4-Resistor Biased Transistors
• Small signal parameters
• High frequency performance & Device structures
• PNP BJT & PMOS
• Miller Capacitor
4-Resistor Biased Transistors

- Know how to **derive** all the currents and voltages within the circuit
- Know how properties of BJT **affect** the bias point
- Know **small signal model**

\[
I_c = I_s \cdot e^{\frac{V_{BE}}{V_T}} \cdot (1 + \frac{V_{BE}}{V_T})
\]

\[
\alpha = \beta + 1
\]

\[
I_c = \frac{V_{BB} - V_{BE}}{R_E + \frac{R_B}{\beta}}
\]

\[
R_B = R_1 \cdot R_2
\]

\[
V_{BB} = \frac{I_c}{\beta} \cdot R_B
\]
4-Resistor Biased Transistors

- Know how to derive all the currents and voltages within the circuit
- Know how properties of MOSFET affect the bias point
- Know small signal model

Figure PS9.1

\[ V_{GS} = (V_{DD} - V_{SS}) \cdot \frac{R_2}{R_1 + R_2} + V_{SS} \]

\[ I_D = \frac{I}{3} \cdot R_{L} \cdot V_{GS} \]

\[ (V_{GS} - V_{th})^2 \rightarrow (V_G - I_D R_S - V_{SS}) \]

\[ I_{D1}, I_{D2} \]

\[ V_{DS} > V_{DV} \] Check
Small signal model

- Hybrid Pi model vs. T model
- MOSFET vs. BJT

- Know the derivation of $g_m$ and $r_o$ of a general device, or read them off given graphs
- Know the derivation of $r_\pi$, $r_e$, $C_\pi$, $C_\mu$, $C_{GS}$, $C_{DS}$
Small signal model

\[ V_{be} = \hat{i_b} \cdot r_\pi \]

\[ r_\pi = \frac{1}{g_m} \]

\[ V_{be} = (\hat{i_b} + \alpha \cdot i_e) \cdot r_E \]

\[ \hat{i_b} \cdot r_\pi \Rightarrow r_E = \frac{\hat{i_b}}{\hat{i_b} + \alpha \cdot i_e} \]

\[ \frac{1}{g_m} = \frac{1}{\alpha \cdot \beta} \]

\[ r_E \neq r_\pi \]
High frequency performance & Device structures

\[ n^+ \quad p \quad n \]

**BJT**

\[ C_{Tn} = C_{je} + C_b = C_{je} + q_n Z_F \]

**Forward Transition Time**

\[ C_{j} = \frac{C_{je0}}{1 + \frac{V_R}{V_{je0}}} \]

**MOSFET**

\[ C_{GS} = \frac{1}{2} w \cdot L_{eff} \]

\[ C_{GD} = C_{GS} \]
Complete Hybrid- PI model

\[ I_c = \beta I_B \]

\[ \omega_T = \frac{g_m}{C_{gs} + C_{go}} \]

\[ \omega_T = \beta \omega_B \]
OCTC & SCTC

\[ \omega_H = \frac{1}{\tau_H} \quad \text{or} \quad \frac{1}{\tau_L} \]

\[ \omega_L = \sum_{i=1}^{n} \omega_n \]

Figure 1

OCTC: High-freq

- Short cage cap.
- Open small cap.
- Replace cap interested in w/ a fast source.
- Determine Ref.

SCTC: Low-freq

- Short cage cap.
- Open small cap.
- Replace cap interested in w/ a fast source.
- Determine Ref.
Exercise

\[ \beta = 200 \]
\[ V_A = 200V \]

\[ K_P = 1\text{mA}/(V \cdot s) \]
\[ V_{TP} = -3V \]
Exercise

\[ \beta = 200 \]
\[ V_A = 200V \]
\[ K_P = 1mA/(V \cdot s) \]
\[ V_{TP} = -3V \]

\[ \frac{V_g}{V_s} = -g_{m1} \left( \frac{r_o}{R_l} \right) \]
\[ \frac{V_d}{V_s} = -g_{m2} \left( \frac{r_o}{R_l} \right) \]
Exercise

\[ L_d = 10\mu m, L_{ov} = 1\mu m, W = 100\mu m \]
\[ C_{OX} = 1fF/\mu m^2 \]

\[ C_{jc,0} = 4pF, C_{je,0} = 4pF, \tau_F = 200ps \]
\[ \phi_{jc} = 0.8V, \phi_{je} = 0.9V \]
Inspection Analysis

\[
R_p = \frac{R_{in}}{1 + \frac{R_{in}}{R_2}}
\]

\[
\frac{V_b}{V_s} = \frac{R_p}{R_p + R_s}
\]

\[
\frac{V_c}{V_s} = -gm \cdot R_c
\]

\[
R_d || R_{in} = *
\]