Basic BJT Gain Cells with Ideal Current Source Load

\[ R_m = r_s \]
\[ R_e = r_o \]
\[ A_v = -g_m r_o \]

\[ g_m = \frac{I_C}{V_T} \quad \text{and} \quad r_o = \frac{V_A}{I_C} \]

\[ A_v = -\frac{V_A}{V_T} \]

In modern IC, \( V_T \) ranges from 5 to 35V

\[ |A_m| \approx 200 \text{ to } 1400 \text{ V/V} \]

In discrete BJT, \( V_A \) ranges from 100 to 130V

\[ |A_m| \text{ up to } 5000 \text{ V/V} \]
Basic Gain Cells with Ideal Current Source Load

\[ g_m = \frac{2I_D}{V_{ov}} = \sqrt{2\mu C_{ox} (W/L) I_D} \]
\[ r_o = \frac{V_A}{I_D} \]
\[ |A_v| = \frac{2V_A}{V_{ov}} \]

\( V_{ov} \approx 0.15 \text{ to } 0.3 \text{ V} \Rightarrow \) MOSFET gain is about 5x lower than BJT

Note: Early voltage in MOSFET is proportional to channel length, \( V_A = V_I L \)

Output Resistance of Current Source Load

Active load behaves like current source with finite output resistance, \( r_o \)
\[ A_v = -g_{m1} (r_o || r_o) \]
Graphical Solution of Voltage Transfer Curve

Output Swing:
\[ V_{Q1} \leq v_i \leq V_{DD} - V_{Q2} \]

Slope = \frac{\Delta v_o}{\Delta v_i} = \text{voltage gain}

\[ \text{Slope} = A_v = -\frac{r_o}{g_m} \left( \frac{r_1}{r_1} \right) \]

Q: Cutoff
II: Quasi-active
III: Triode
IV: Saturation
V: Saturation
VI: Triode
VII: Saturation