Two-Port Model: CE Amplifier

- Use transconductance amplifier form for model (*not* mandatory)

- \( R_{in} = r_{\pi} \), \( R_{out} = r_o \parallel R_C \), \( G_m = g_m \) by inspection

\[
\begin{align*}
G_m & = g_m \\
R_{in} & = r_{\pi} \\
R_{out} & = r_o \parallel R_C \\
\end{align*}
\]

- Loaded ratio of \( i_{\text{out}} \) to \( v_{\text{in}} \)

\[
G_m \left( \frac{R_{out}}{R_{out} + R_L} \right) = g_m \left( \frac{r_o \parallel R_C}{r_o \parallel (R_C + R_L)} \right)
\]

Increasing \( R_C \) seems desirable for increasing \( i_{\text{out}} / v_{\text{in}} \) ... but note that the DC collector current decreases for a fixed \( V_{CC} \) \( \rightarrow g_m \) decreases
Common-Source Amplifier

Configuration is similar to common-emitter

Bias: remove source and load resistances (b)
Graphical Load-Line Analysis

- Load line is given by:

\[ I_D = \frac{(V_{DD} - V_{OUT})}{R_D} \]

![Graph](image-url)
Small-Signal Model of CS Amplifier

- Substitute parameters at operating point selected so that $V_{OUT} \approx V_{DD}/2$

Transconductance is proportional to $I_D^{1/2}$ unlike bipolar transistor
Two-Port Model of Common-Source Amplifier

- Use transconductance amplifier form for model (most natural choice)

\[ R_{in} = \text{infinty}, \quad R_{out} = r_o \parallel R_D, \quad G_m = g_m \text{ by inspection} \]

Infinite input resistance is ideal for a voltage input

Output resistance increases with \( R_D \) increasing, but DC drain current \( I_D \) will decrease and \( g_m \) will decrease with \( I_D^{1/2} \).
Current-Source Supplies

- A current source to supply current, rather than a resistor, allows a high DC current for the device with a large incremental (small-signal) resistance.
Common-Source with Current Source Supply

- $R_D$ is replaced with idealized current source with internal resistance

![Diagrams]

- For DC bias analysis, the small-signal source (with $R_S$) and the load resistor $R_L$ are eliminated, along with the internal resistance $r_{oc}$ of the current source
Graphical Analysis of CS Amplifier with Current-Source Supply

- The region of input bias voltage $V_{BIAS}$ for which the current source and the MOSFET are in their constant-current regions is extremely small ....
Common-Source/Current-Source Supply Models

- The small-signal model is identical to the resistor supply, except that the current source’s internal resistance $r_{oc}$ replaces $R_D$

- Two-port model in both transconductance and voltage amplifier forms (the latter by direct conversion from the former ... by applying procedure for finding $A_v$)

\[ A_v v_{in} = -G_m R_{out} v_{in} \]

\[ R_{out} \]
**p-Channel Common-Source Amplifier**

- Source of p-channel is tied to positive supply; current supply sinks $I_{SUP}$ to ground or to lower supply

![Diagram of p-Channel Common-Source Amplifier](image)

- Small-signal model: substitute p-channel model directly
p-Channel CS Small-Signal Model

- Source is at top, but circuit can be inverted to show correspondence with n-channel common-source amplifier

(a) Source is at top.

(b) Circuit inverted.

(c) Source is at bottom.