Add Load Line

Optional) Small signal model review in FAR

\[ I_c = \beta I_b \]

\[ I_c = I_c + I_b \]

\[ I_b = I_{ES} \left( e^{\frac{V_{BE}}{V_A}} - 1 \right) \left( 1 + \frac{V_{CE}}{V_A} \right) \]

\[ I_c = \beta I_{ES} \left( e^{\frac{V_{BE}}{V_A}} - 1 \right) \left( 1 + \frac{V_{CE}}{V_A} \right) \]

\[ \frac{\Delta I_c}{\Delta V_{BE}} = \frac{I_c}{\Phi_{th}} = g_m \]

\[ a \text{ conductance, } g_m = \frac{\Phi_{th}}{I_b} = \frac{B}{g_m} \]

\[ \frac{\Delta I_c}{\Delta V_{CE}} = \frac{I_c}{V_A} \]

We've been ignoring in'

\[ \frac{\Delta I_c}{\Delta V_{BE}} = \frac{I_c}{\Phi_{th}} = g_m \]

\[ \text{on large signal plots} \quad \Rightarrow \quad r_o = \frac{V_A}{I_c} \]

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All same for NPN & PNP b/c of wackr sign conventions making large signal plots same (upside down large signal models only issue)
GET HYPE, WE'RE DOING AMPLIFIERS!

Let's sort of why we're here!

Roadmap

- 3 terminals = 3 key functions (in, out & bias)

\[
\begin{array}{c}
\text{in} & \text{out} & \text{bias} \\
\text{60\%S} & \text{60\%S} & \text{bias} \\
\end{array}
\]

Common-emitter \hspace{1cm} \text{Common-collector} \hspace{1cm} \text{Common-base}

or emitter follower

Always use \( V_{in} \) to modulate the junction

Amplifier Design Parameters

- Each configuration does different things well, want a quantitative description of these things

- A most common parameters are \( R_{in}, R_{out} \) & \( A_{v} \) & \( V_{sw} \)

\( \rightarrow \) technically \( Z_{in} \) & \( Z_{out} \) \hspace{1cm} \( \rightarrow \) small signal GNY, \( R_{in} \) & \( R_{out} \) limits

\[ \begin{array}{c}
R_{in} \hspace{1cm} \frac{\Delta V_{in}}{\Delta V_{in}} \hspace{1cm} \frac{\Delta V_{out}}{\Delta V_{in}} \hspace{1cm} \frac{\Delta V_{out}}{\Delta V_{in}} \hspace{1cm} \frac{\Delta V_{out}}{\Delta V_{in}} \\
R_{out} \hspace{1cm} \frac{\Delta V_{out}}{\Delta V_{out}} \hspace{1cm} \frac{\Delta V_{out}}{\Delta V_{out}} \hspace{1cm} \frac{\Delta V_{out}}{\Delta V_{out}} \hspace{1cm} \frac{\Delta V_{out}}{\Delta V_{out}} \\
\end{array} \]

- Recall our 2 port amplifier model

- Can rep. as

Thevenin/Norton

- Circuit portion of these derivatives is small signal test sources

- 2 port model lets us separate analysis from loading
- Solve $V_{SW}$ ($\approx$ oddities: $A_f, f_b$ - simple thing slow)

until after we apply this

$$V_C \rightarrow V_R \rightarrow I_C \rightarrow V_O$$

- Let $V_B$ be picked such that we have $I_C$ flowing into $BJT$

**CE Amplifier!**

- You says find $R_{in}, R_{out} \approx AV$ (symmetrically)
- Find values if $I_C = 1mA, V_A = 50V, B = 100, R_L = 1k$

**Small signal model**

$$R_{in} = r_{II}$$

$$R_{out} = R_{out} \parallel R_L$$

**$R_{out} \approx 1k \approx AV \approx 40$**

$$AV = -g_m (R_{out} \parallel R_L)$$

- $V_i$ controls $V_{be}$ directly

$$-W/ HSB \rightarrow g_m = \frac{I_C}{V_{be}} \approx 40 \text{ mS} \approx 25 \text{ mV/ft}$$

$$r_o = 50k \Omega \left( \frac{50V}{1mA} \right)$$

Find $V_{be}$:

- $V_{be}$ controls $I_C$
- $V_{be}$ is

$V_{be}$ controls $I_C$

$$I_C \approx \frac{V_{ee} - V_{o}}{R_L}$$

- Men's cutout transistor

$V_{be}, \mu_n = 0.7V$

- Propagate $V_B - V_{be}, \mu_n$ to our pub

$V_o \approx V_{CE, SAT}$

- Voltage swing, $V_{SW}$, is $\approx V_{be} - V_{min}$
- Other amplifier specs.
  - Short circuit current gain, $A_i$
    \[ A_i = \frac{i_{\text{short}}}{i_{\text{in}}} \]
    $A_i > 50 \pi$
  - Input bias current, $I_{\text{in}}$
    - Large signal, DC, parameter
    - How much current does the amp input need?
    - For us: $I_{c/B}$ in CE amp
  - Low frequency corner frequency
    - Where does mid-band approx break?

- Large Signal Behavior
  - Looks like logic gate X'or curve, some early logic gates made this way

- Let's try practical CE amplifier w/ series bias
  \[ A_v = \frac{R_i}{R_i + R_{\pi}} \frac{g_m}{R_L} R_L \]
  \[ R_{\text{in}} = R_b + R_{\pi} || R_1 || R_2 \]
  \[ R_{\text{out}} = R_c || R_L \]