Last time looked at simply biased CE amplifier

- Specified 3 parameters we cared about:
  - Colloquial name: 2-port
  - $R_{in}$ Input resistance: The mean resistance seen at input
  - $R_{out}$ Output resistance: The mean resistance seen at output

$A_v$ Voltage Gain: How much bigger (small signal) does my signal get? $\frac{dV_o}{dV_i}$ at output

- Derivative definitions: come from an ideal small signal amplifier

- We make small signal model to find $R_{in}$, $R_{out}$, $A_v$ of our amp
  - Need to find large signal model to know small sig
  - Ckt. central large signal called biasing/bias network, self called bias point

Given $V_b \rightarrow I_c$

$V_o = V_{cc} - I_c R_C$
Lec 8 - CE w/ dosen

Other design params we care about: $I_i$, $S_{low}$, $A_i$, $V_{sw}$

$V_{sw}$ most important, all others 1st quick

$I_i$ Input Leakage/ bias current

$S_{low}$ Low frequency

$A_i$ Small signal current gain

Large signal current going into input port

Frequency @ which mid and assumption fails - start seeing cap high pass

How much more current does amp split out than was sent in?

Find pole associated w/ each mid-band cap

$V_{sw}$ Output Voltage swing

- How much can $V_o$ change w/o breaking small signal model?

Max swing 6$V_{ss}$

1. $V_{cc}/2$

2. $V_{cc}/(R_{dc}+R_{ac})$

$-12V$.

$V_{cc}$ as rough cut

$V_{dd}$ Bridges large $\alpha$ small signal model, so it's tracky

$\alpha$ Tracky and easy

- Rely on $V_{ce}$, set for downswing

- Upswing by (load)

- by reflecting to input

- OR by $V_{ce}$ as rough cut
Output Swing Example

\[ V_{cc} = 5V \]
\[ R_L = 1 \text{ k}\Omega \]
\[ I_c = 2.5 \text{ mA} \]

- Find top allowed voltage, bottom allowed voltage
  \[ V_{SW} \]

1. Find \( V_o \)
   \[ V_o = V_{cc} - I_c R_L = 2.5 \text{ V} \]

2. Minimum voltage (set by \( V_{cc, SAT} \))
   \[ V_{min} = V_{cc, SAT} = 0.1 \text{ V} \]

3. Maximum voltage
   \[ V_{max} = V_{cc} = 5 \text{ V} \]
   \[ V_{SW} = 4.9 \text{ V} \]

- Measure distortion
  - Use FFT. Harmonic peaks
  - 26 mV at 100 = 2.6 V ~ so 2.5 V or approx here

Let's design an amplifier

So far we've moved from circuits → amp specs.

Your job is to move from amp specs to circuits.

Example:

\[ R_{out} < 2 \text{ k}\Omega \]
\[ R_{in} > 1 \text{ k}\Omega \]
\[ A_v = \frac{V_o}{V_i} \]
\[ V_{SW} > 4 \text{ V} \]

1. Start w/ easy constraints
   - In this case, \( R_{in} \sim R_L \) →
   \[ r_{in} = \frac{B}{g_m} = \frac{R_P}{I_c} = \frac{100 - 25 \text{ mV}}{2.5 \text{ mA}} > 1 \text{ k}\Omega \rightarrow I_c > 2.5 \text{ mA} \]
   - Usually, easy constraints are found @ output: \( V_{SW} \) or \( R_{out} \)

2. Propose
   - Know \( V_c = 2.5 \text{ V} \)
   - Need \( R_E = 1 \text{ k}\Omega \)

(Real-world circuit notes: \( V_o < 8 \text{ V} \) + down swings, says \( V_o > 4.8 \text{ V} \), \( \frac{1}{2} \) way is 6.4 V)
Have on odd issue —

- Specifying $R_{in} \propto V_{sw}$ every, specifies $R_{out} \propto A_V$

$$1.6k\Omega \cdot \text{IC} \cdot s = A_V = 160 \quad \Rightarrow \quad R_{out} = 1.6k\Omega$$

- We'd like to build amps where $R_{in}$ we can set $V_{sw}$ input, $A_V$

**Trick #1 — Leverage the midband**

- Works dc, trickier high pass

**Trick #2 — Emitter degeneration**

- Crazy new small signal
- Ignoring $R_o$ for now, you'll add it back in on your HW

Find $R_{in}$, $R_{out}$, $A_V$

*Note $V_{in} \neq V_{be}$
- Lends to feedback
  (Could do fin here)

$$V_{be} = i_1 \cdot R_{\pi}$$

$$V_E = (9nF_\pi i_1 + i_1) R_E$$

$$V_i = V_E + V_{be} = i_1 (R_{\pi} + R_E + B_{RE})$$

**You Try** $A_V$

$$V_{be} = \frac{1}{R_{\pi}} \frac{V_i}{R_{in}}$$

$$V_o = -\frac{9nF_\pi \frac{V_i}{R_{in}} R_L}{R_{\pi} + R_E + B_{RE}}$$

$$A_V = \frac{-B_{RE}}{R_{\pi} + (R_\pi + 1) R_E} \approx \frac{-R_L}{R_E} \frac{1}{9nF_\pi \frac{V_i}{R_{in}}}$$