Design Problem correction
- $R_{in} = 1k\Omega$
- Tend to max $R_{out}$
- $V_C$ reduces $g_m$ for $A_v$
- Highlight $I_c, V_{sw}$
- $A_v$ link again

Emitter Degeneration
- $V_{E} = V_B - 0.7 = 2.5V$

$g_m = \frac{B}{R_{in}} = \frac{B}{R_{out}} \rightarrow I_c = 2.5mA$

$V_{E} = V_B - 0.7 = 2.5V$

$L = b/c \times I_c$, $R_E$, $k_{m}$

- Need to pick $V_o$ so that $V_{max} = V_o + \frac{V_{sw}}{2} < V_{cc}$

- Propagated

- emitter follower
- multistage cmp
  - $A_V = 9R_c = \frac{I_c}{R_c}$
  - $R_{out} < 2k\Omega$
  - $V_{sw} > 4V$
  - $R_{out}$ is usually greater than $R_{in}$

- Constraints
  - $R_{in} = 1k\Omega$
  - $R_{out} < 2k\Omega$
  - $A_V = ?$

- Found easy constraint in $R_{in}$ equality

- $R_{in} = \frac{R}{g_m} = \frac{B}{I_c} \rightarrow I_c = 2.5mA$

- $V_{E} = V_B - 0.7 = 2.5V$

- $V_{min} = V_o - \frac{V_{sw}}{2} > V_E + V_{ce,sat}$
Want to set $V_o$ separate from $A_v$ — some gains could call for it

Note that if we don't

$A_v = g_m R_c = \frac{I_c R_c}{\Phi_{th}}$

$\Delta V_o = I_c R_c \rightarrow A_v = \frac{\Delta V_o}{\Phi_{th}}$

**Track #1 ~ Leverage mid-band**

- $V_o = V_{cc} - I_c (R_{c1} + R_{c2})$

- $A_v = g_m R_{c2}$

- set separate values for $V_{o0}$ and $A_v$

- similar parallel trick to move $V_o$ up

**Track #2 ~ Active Load**

- current mirror
- important we do later

**Big Issue: Throwing away gain to get swing w/o any benefit**

Other then $V_o$ shift — $R_m$ a Rout unaffected

**Track #3 ~ Emitter Degeneration**

- A better way to throw away gain

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We find $R_m$

Apply test src @ input

$V_{be} = I_b R_c$

$V_E = R_c (I_b + g_m R_c I_b) ~ \text{feedback!}$

$V_b = V_o + V_E = I_b (R_c + R_E + B R_E)$

Careful! really hard to start w/ $V_o$ and $I_b$

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$R_m = \frac{V_o}{V_{be}}$

You find $A_v = \frac{1}{R_m}$

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**Bad Rout!**

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$R_{out}$ is isolated by

- Current source
- Limited voltage
- Has no odd stuff here matters!
- Emitter Degen lets us trade gain for high Rin
- What if we want low Rout instead?
  → Emitter follower!

- Including Rs 6k, annoyingly Rout depends on Rs
- Kind of breaks our model where we separate analysis of amp from interaction between amp & world. More in 10 min.

\[ R_{in} = \text{calculated } \frac{u_o}{u_i} \text{ source} \]

\[ R_{in} = \frac{r^e_{\pi}}{1 + \frac{r^e_{\pi}}{r^e_o}} \]

\[ v_{be} = r^e_{\pi} \frac{u_i}{I} \]

\[ I_i = \frac{v_{o}}{r^e_{o}} + \frac{v_{o}}{r^e_{o}} + g_m v_{be} \]

\[ I_i (B+1) = v_{o} \left( \frac{1}{r^e_{o}} + \frac{1}{r^e_{o}} \right) = \frac{v_{o}}{R_{E1} R_{o}} \]

\[ v_{o} = I_i (B+1)(R_{E1} R_{o}) \]

\[ u_i = v_{o} + u_{be} = I_i (R_{\pi} (B+1)(R_{E1} R_{o})) \]

\[ R_{in} = \frac{1 + (B+1)(R_{E1} R_{o})}{R_{\pi} + (B+1)(R_{E1} R_{o})} \]

\[ A_{v} = \text{calculated } \frac{u_o}{u_i} \text{ source} \]

\[ u_{v} = I_i \frac{(B+1)(R_{E1} R_{o})}{r^e_{\pi} + (B+1)(R_{E1} R_{o})} \text{ from above} \]

\[ u_{v} = \frac{(B+1)(R_{E1} R_{o})}{r^e_{\pi} + (B+1)(R_{E1} R_{o})} \frac{u_{v}}{I_i} \]

\[ I_i = u_{v} / R_{in} \]

\[ \approx u_{v} \text{ so } A_{v} \approx 1 \]

- Makes sense in large signal \( \frac{u_{v}}{u_{i}} \approx u_{v} \approx 0.7 \)
- 5th order of 1 w/ level shift \( \Rightarrow \) Called a voltage buffer
  \( \Rightarrow \) High current

\[ g_{os} = (B+1) \]

\[ V_{be} = \frac{R_T}{R_s + R_T} V_b \]

- Backwards gain of \( \frac{r_T}{R_s + R_T} \)

- We say it's small & ignore in our model

\[ I_T = \frac{V_e}{R_e} + \frac{V_b}{R_o} + \frac{V_{be}}{r_T + R_s} - \frac{r_T}{r_T + R_s} V_{be} \]

\[ I_T = V_b \left( \frac{1}{R_e} + \frac{1}{R_o} + \frac{1}{r_T + R_s} + \frac{B}{r_T + R_s} \right) \]

\[ Rout = R_e \parallel R_o \parallel \frac{R_T + R_s}{R_T + R_s + R_b} \]

\[ \frac{V_e}{R_e} \leq \text{low!} \]

- What if we want big $A_v$ - small $Rout$?

- **Multistage amp**

- Small signal model would be big and complex... oh no!

- Can use general amp model to simplify!

(Nota: Some important large signal stuff @ end)

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- Capture interstage loading by voltage division \( \text{Rin}_1 \parallel \text{Rin}_2 \)

\[ A_v, \text{total} = A_v1 \times A_v2 \]

\[ = \frac{R_{in1}}{R_{in1} + R_s} \times \frac{R_{in2}}{R_{in1} + R_s} \times \frac{R_L}{R_L + R_s} \]

- \( R_L = R_s \)

- Represents rest of world

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- **Large signal notes**

- **Cap coupling** makes DC into separate probe for each amp

- **DC coupling** trickier design (stages link) but with fewer components

- BIAS POINT STABILITY

- \( I_C \) changes w/ \( T \) - keep it small

- \( R_E \) big as linear, \( I_B \) bias exponential

- FFT View to see if \( V_{sw} \) net, \( 180^\circ \) harmonics!