Exact EF
- $R_n \times A_v$
- easy analysis

- $Z_{out}$ + negative
values

OCTC
- cascade w/ bias turns
- pole locate
- picking caps
- Test on CE (they)

SCTC
- If we get these

- $\omega = \sum_{i} \frac{1}{C_i R_i}$, short cap

Lab Manual Expectations
- rail-to-rail vs. stay
  cap
- Re evaluate model to
  make it plausibly match
- Boxes points 6

We're doing better approx techniques today

Need to do one more exact analysis first for EF

$\rightarrow$ EF is kind of approximation resistant bc it has a zero

$\rightarrow$ $C_a$ is grounded which makes life easier

Follow same analysis as DC, but use $Z_{\pi}$ in place of $R_{\pi}$

\[ V_o = \left( R_{\pi} + \frac{1}{Z_{\pi}} \right) R_E \]
\[ V_o = V_{be} + V_E = \left( R_E + Z_{\pi} + \frac{1}{Z_{\pi}} \right) R_E \]
\[ Z_{in} = \frac{1}{C_{ms}} \frac{1}{R_E + \frac{1}{1 + f_T C_{ms}}} \]
\[ A_v = \frac{V_E}{V_i} = \frac{R_E + \frac{1}{Z_{\pi}} R_E}{R_E + Z_{\pi} + \frac{1}{Z_{\pi}} R_E} \]

Commentary
- Has a zero
- Pole + zero very high
  $f_\pi \approx \frac{1}{C_{ms}} > f_T$
- Bode
- $C_{ms}$ limits
  BW $V_R$
For $Z_{out}$

$$Z_{out} = \frac{Z_0}{1 + \frac{Z_0}{Z_{in} + Z_s}}$$

$$Z_{out} = \frac{Z_0}{1 + \frac{Z_0}{Z_{in} + Z_s}} = \frac{G_s + R_s}{G_s C_s + 1 + \frac{1}{R_s / \alpha}}$$

- In reality $C_m$ in parallel with $R_s$ is ignored near more poles
- Zero $\delta$ pole, like gain, but locations can swap depending on $R_s$
- Big $R_s \rightarrow \text{Zero before pole} \rightarrow \text{Inductive } Z_{out} \text{ (works unstable!)}$

(Large capacitive loads?)

$$\frac{1}{\alpha} \frac{1}{s}$$

**OCTC**

- Miller was not conservative, also specific to CE
- Open circuit the constants from MIT 60's, better
- Approx assumes term of $X_T$ for $s$

Real CE: $H(s) = A_v \frac{(1 - s\beta)}{(1 - s\beta_1)(1 - s\beta_2)}$

Miller: $H(s) = A_v \frac{1}{1 - s\beta}\ \text{lose info, use}$

**OCTC**: $H(s) = A_v \frac{1}{(1 - s\beta_1)(1 - s\beta_2)} = A_v \frac{1}{1 + \left(\frac{s}{\beta_1} + \frac{s}{\beta_2} + \cdots + \frac{s}{\beta_n}\right)s + \cdots + \left(\frac{s}{\beta_{n-1}\beta_n}\right)s^n}$

- OCTC Assumes 1-term $\beta_1$ is dominant
- Means higher $s^2 \rightarrow s^n$ terms irrelevant vs $s$ term

so have $H(s) \approx A_v \frac{1}{1 + (s + \frac{1}{\beta_1}) + \cdots + \frac{1}{\beta_n}s^n}$
Okay this approach is great but we don't know $\chi_1, \chi_2,$ etc.

- Remarkably can find these w/ ackt trick
- Sum of $\sum \chi_i = \sum \text{OCTC}_i$ where open acket time const is:

$$\text{OCTC}_i = C_i \left( R_{TH} \text{ seen from } C_i \right) \text{ for each cap in acket.}$$

- Use other caps open
- Tricky, more later
- OCTC not associated w/ 1 pole

**Example (trivial)**

$$\begin{align*}
\text{Exact} & \quad \chi = R (C_1 + C_2) \\
\text{OCTC} & \quad \text{OCTC}_1 = C_1 R \\
& \quad \text{OCTC}_2 = C_2 R \\
\end{align*}$$

- Perfect!
- Expect right for 1st order...

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**Last trivial example**

$$\begin{align*}
\text{Exact} & \quad Z_{TH} = R_2 + R_1 \frac{1}{C_{TH}} \\
& \quad \frac{V_{TH}}{V_i} = \frac{1}{1 + R_{TH} C_{TH}} \\
& \quad \frac{V_0}{V_i} = \frac{1}{1 + R_1 C_{TH}} \\
V_{TH} & = \frac{V_0}{V_i} V_i = \frac{V_i}{1 + R_1 C_{TH}} \\
\end{align*}$$

- Got 1st order term!
- Works great if $\chi_1 > \chi_2$
- Systems often designed that way
- Miller effect makes it likely
- What happens if poles are close?
\[
\frac{1}{1 + (2 \zeta + 2 \omega_0 + 2 \zeta \omega_0^2)} \rightarrow \frac{1}{(2 \zeta + 2 \omega_0 + 2 \zeta \omega_0^2 \delta^2)^{3/6}}
\]

1. By definition of \( \delta \), each of \( \zeta + \omega_0 \) must be less than 1.
2. So, \( \delta \) product much smaller.
3. Exact case, \( \zeta = \omega_0 \rightarrow \) this is \( \frac{1}{(2 \zeta + 2 \omega_0 \delta^2)^{3/6}} \).

- Also, even if this doesn't give us the exact answer, it does give us:
  1. A good guess
  2. Design insight about which caps cause trouble.

Let's apply this to a CE amplifier.

- This cap causes a zero in addition to a pole.
- We assume an all-pole system w/ OCTC.
- Short @ high freq. causes problems, so we ignore.
- Same w/ coupling caps (SETC next time).

- \( R_C \)

You guys find OCTC \( \pi \)
\[
= \left( \frac{R_{11} R_{12}}{R_{12}} \right) C \pi
\]
- Circuit trouble cap
  - Written in specific way:
    - \( R_{12} \) + \( R_{11} + \frac{g_m R_{12}}{\pi} \)
  - Note: \( g_m \) is

\[
\bar{x} = \frac{g_m (\bar{v}_e + (\bar{v}_c - \bar{v}_e))/R_{11} R_{12}}{R_{12}}
\]

\[
\bar{x} = -\frac{g_m \pi \bar{v}_e + (\bar{v}_c - \pi \bar{v}_e)}{R_{11} R_{12}}
\]

\[
\bar{x} = \frac{(1 + g_m \pi + \pi g_m + \pi^2) R_{11} R_{12}}{R_{11} - g_m} R_{12} + \bar{v}_c + \frac{1}{\pi^2} R_{11} R_{12}
\]