ECEN4827/5827 lecture 27

Zero-value time constant (ZVTC) method

\[ A(s) = A(0) \frac{1 + b_1 s + \ldots + b_n s^n}{1 + a_1 s + \ldots + a_n s^n} \]

\[ a_1 = \sum_{\text{all caps}} C_i R_{Di} \]

**Dominant-pole approximation**

\[ R_{Di} = \text{small-signal (incremental) resistance seen by } C_i \text{ when all other capacitances are set to zero} \]

\[ BW \approx f_{p1} \approx \frac{1}{2\pi a_1} \]

Dominant-pole approximation
Possible improvements?

\[ A(0) = -g_m \left( r_{o1} \parallel r_{o2} \right) = -100 \]

1. Insert a source follower in front of \( C_D \) and \( C_S \).
2. Insert a source follower at the output to reduce time constant with \( C_L \).
Improvement 1: Cascode

\[ +V_{DD} \]

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\[ R_{in} \]

\[ M_1 \]

\[ M_2 \]

\[ M_3 \]

\[ M_4 \]

\[ +V_{DD} \]

\[ V_{O+V_o} \]

\[ C_L \]

\[ V_{BIAS} \]

\[ V_{i} + v_i \]

\[ V_{i} + v_i \]

\[ V_{bias} \]

Active load

\[ R_2' = \text{out resistance.} \]

\[ = r_{o2} \parallel g_{m4} r_{o1} \]

\[ = r_{o2} \]

\[ A(0) = ? = -g_{m1} r_{o2} = -200 \]

\[ v_i \rightarrow i_1 \rightarrow i_4 \rightarrow v_o \]

\[ g_{m1} \quad 1 \quad -R_2' \]
\[ C_2 = C_L + C_{db1} + C_{db2} + C_{gd1} + C_{gd2} = \]

\[ \tau_{gs1} = C_{gs1} \cdot R_{in} = 5 \text{ nS}
\]

same as \( \tau_C \) amp.

\[ \tau_2 = 2 \cdot \tau_{C2} = 18 \text{ nS}
\]

2x larger compared to \( C_S \).

\[ \tau_4 = C_4 \cdot (\ ? \ )
\]

\[ \tau_{gd1} = C_{gd1} \cdot (\ ? \ )
\]

\[ C_4 = C_{db1} + C_{gs4} + C_{sb4} = 0.51 \text{ pF}
\]

\[ \approx \frac{1}{3} \text{ gain small!}
\]
\( V_{\text{test}} = R_{\text{on}} (i_{\text{test}} - g_{m4} V_{\text{test}}) + R_{02} i_{\text{test}}. \)

\( V_{\text{test}} (1 + g_{m4} R_{\text{on}}) = (R_{02} + R_{\text{on}}) i_{\text{test}} \)

\( R_{\text{sys}} = \frac{V_{\text{test}}}{i_{\text{test}}} = \frac{R_{02} + R_{\text{on}}}{1 + g_{m4} R_{\text{on}}} = \frac{2 R_{\text{on}}}{1 + g_{m4} R_{\text{on}}} \approx \frac{2}{g_{m4}} \)

\( \frac{2}{g_{m4}} \) small \( g_{m4} \) resistance!
\[
T_y = C_y R_y = C_y (R_{S1} || R_{O1}) \approx C_y \cdot \frac{2}{g_{m4}}
\]
\[
= 2.1 \text{ ns!}
\]

\[
T_{gds1} = C_{gds1} \left( R_{in} + \frac{2}{g_{m4}} + R_{in} g_{m4} \frac{2}{g_{m4}} \right)
\]

Look at lect. 26

Much smaller than 1\text{ns} (CS)

\[
\frac{f_{p1}}{B_{W}} = \frac{1}{2 a_{24}} = 630 \text{ kHz}
\]

\[
\alpha_1 = T_{gds1} + T_{gds4} + T_y + T_2
\]

\[
\alpha(1) = -200
\]

\[
|\alpha(1)| = -200
\]
Application of ZVTC when stages are decoupled

Cascade is an example of 2 stages in series with no interaction between them, no coupling capacitor.

\[ A_1(s) \times A_2(s) \]

\[ a_1 = \tau_1 + \tau_2, \quad BW_1 \propto \frac{1}{2\pi(t_1 + t_2)} \]

Stage 1 \[ a_{11} = \tau_1, \quad BW_1 \propto f_{p1} = \frac{1}{2\pi a_{11}} \]

Stage 2 \[ a_{12} = \tau_2, \quad BW_2 \propto f_{p2} \approx \frac{1}{2\pi a_{12}} \]

\[ A(s) = A_1(s) A_2(s) \]

Apply ZVTC to \( A_1(s) \) and \( A_2(s) \) separately.