- ***C_{gd1}***:

  $$R_{gd1}^{0} = R_S + R_{L1} + g_{m1}R_SR_{L1} = 320\ \text{k}\Omega$$

  $$\Rightarrow \tau_2 = R_{gd1}^{0}C_{gd1} = 320\ \text{ns}$$

- ***C_{db1} and C_{gs2} in parallel***

  $\Rightarrow$ ***Club them to a single capacitor*** $C_3 = C_{db1} + C_{gs2} = 12\ \text{pF}$

  $$R_3^{0} = R_{L1} = 10\ \text{k}\Omega$$

  $$\Rightarrow \tau_3 = R_3^{0}C_3 = 120\ \text{ns}$$

- ***C_{gd2}***:

  $$R^0_{gd2} = R_{L1} + R_{L2} + g_{m2}R_{L1}R_{L2} = 315\ \text{k}\Omega$$

  $$\Rightarrow \tau_4 = R^0_{gd2}C_{gd2} = 315\ \text{ns}$$

- ***C_{db2}***:

  $$R^0_{db2} = R_{L2} = 5\ \text{k}\Omega$$

  $$\Rightarrow \tau_5 = R^0_{db2}C_{db2} = 10\ \text{ns}$$

- Thus:

  τ_{net} = 815 ns and f_H = 195.3 kHz

- Such a ***low value*** of f_H is the ***result*** of the ***presence*** of a ***large number of capacitors*** in the circuit

- ***Limitations of the ZVTC Technique***:
  - ***One obvious limitation is the suppression of information of all other poles and zeros of the system except the DP***
    - ***This limitation is not that acute since we are actually interested in only the DP, which gives the information about f_H***
  - ***The other limitation is the error, which can reach as high as 22%***
  - However, ***this error is negative***, i.e., ***underestimation*** (far better than ***overestimation***)

- The ***maximum error*** of 22% occurs if the ***actual circuit*** has ***two overlapping poles***
- In ***real situations***, this is ***highly unlikely***, due to the effect of ***pole splitting*** caused by ***compensation*** (***to be discussed in the next chapter***)
- ***The resulting circuit after compensation would have a single DP***

➢ *Proof that the maximum error is 22%*

- Consider a circuit having ***2 negative real poles*** at the ***same angular frequency*** ω_x
- The ***Transfer Function***:

  $A(j\omega) = A_0/(1 + j\omega/\omega_x)^2$

  A_0: ***Midband gain***

  $\Rightarrow |A(j\omega)| = A_0/[1 + (\omega/\omega_x)^2]$
- At the ***upper cutoff frequency*** ω_H, the ***gain would drop to 1/√2 of its maximum value***

  $\Rightarrow 1 + (\omega_H/\omega_x)^2 = \sqrt{2}$

  $\Rightarrow \omega_H = [\sqrt{(\sqrt{2} - 1)}]\omega_x = 0.64\omega_x$

- Now, using the ***ZVTC technique***, the ***net time constant***

$$\tau_{net} = \sum_{i=1}^{n} \left(-1/p_i\right)$$

$i =$ ***number of poles***

$p_i =$ ***individual poles***

- For the ***given problem***, $i = 2$ and $p_i = -\omega_x$ (***for both***)
- Thus:

$\tau_{net} = 2/\omega_x$ and $\omega_H = 1/\tau_{net} = 0.5\omega_x$

- Therefore, the ***maximum error is about –22%***
- This being an ***underestimation***, is ***not that dangerous*** :)

- ***Rise/Fall Time***:
  - ***Recall***: ***f_L caused tilt/sag in the output for square-wave input***
  - ***On the other side of the frequency spectrum***, ***f_H causes rise/fall time of the output for square-wave input***
  - ***These two phenomena can be thought of as an interlinking between the analog and digital domains***
  - Assume that a circuit has some ω_H, with the ***corresponding pole*** at p_1 $(= -\omega_H)$

- The ***Transfer Function*** is ***single-pole***:

  $v_0(s)/v_i(s) = A_0/(1 - s/p_1)$

  A_0: ***Midband gain***

- Now, consider v_i to be ***step input*** of ***amplitude*** V_A ($\Rightarrow v_i = V_A/s$)

  $\Rightarrow v_0(s) = (A_0V_A/s)/(1 - s/p_1)$

  $= A_0V_A[1/s - 1/(s - p_1)]$

- Taking ***inverse Laplace Transform***:

  $v_0(t) = A_0V_A[1 - \exp(p_1t)]$

  $\Rightarrow$ ***Output approaches its maximum value of A_0V_A with a time constant $1/|p_1|$*** (***p_1 negative***)

➢ *Calculation of Rise/Fall Time*:

- *Time taken for the output to rise (fall) from 10% (90%) to 90% (10%)*
- *Can be calculated from the figure*