Amplifier Design Example, Part 2

(continued from last week's notes)

Recall specs: \(|AV| > 18\, \text{dB}\)

-3\, \text{dB} \, \text{BW} > 150\, \text{MHz}

\[ C_L = 200\, \text{pF} \]

All devices sized \( \frac{W}{L} = \left( \frac{150}{0.5} \right) \mu \text{m}, \ I_D = 3\, \text{mA} \)

Gives

\[ C_{gs} = 220\, \text{pF}, \ C_{sb} = 130\, \text{pF}, \ C_{gd} = 48\, \text{pF}, \]

\[ C_{db} = 90\, \text{pF} \]

\[ R_0 = 2K52, \ g_m = 12\, \text{mS}, \ g_{mb} = 0.8\, \text{mS} \]

First we tried common source:

(see last week's notes)

Open circuit time constants give:

\[ \tau_{g8} = 440\, \text{ps} \]

\[ \tau_{gd} = C_{gd} \left[ R_s + r_{o1}/R_1 + g_m R_s (C_{ds}/R_s) \right] \]

\[ \approx 810\, \text{ps} \rightarrow \text{dominates due to Miller effect} \]

\[ \tau_L = 193\, \text{ps} \quad \Rightarrow \text{BW} = \frac{1}{2\tau_L} = 110\, \text{MHz} \]

Not good enough!
Try cascade to reduce $C_{gd}$:

- Make $M_1$ and $M_2$ identical
- Now have 3 nodes → added $V_{S2}$
- Gain to $V_{S2}$ from $V_S$ is just 1, so $C_{gd}$ doesn't get multiplied by much
- Remember impedance at $V_{S2}$ is just $\frac{1}{g_{m2}} \approx 83.52 \ll r_o, R_L$
- Because $M_2$ is a CG stage

S-5 model with capacitors:

- Note that $C_{gd}$ has one side grounded, can be combined with $C_{db1}$ and $C_{sb2}$
- $C_{gd}$ has one side grounded, can be combined with $C_{db2}$ and $C_L$
Cascade OCT BW estimation:

- $C_{gs,1} = C_{gs,1}R_S = (220\text{pF})(2k) = 440\text{ps} \quad \text{(unchanged from CS)}$

- $C_{gd,1} = C_{gd,1} \cdot R_S = (45\text{pF})\left(\frac{1}{g_{m1}} + g_{m1}R_S + \frac{1}{g_{m2}}\right)$
  
  $= 184\text{ps} \quad \text{(more than a factor of 4 better than CS!)}$

Note that this is approximate:
- Neglects body effect ($g_m \gg g_{mb}$)
- Assumes $\frac{1}{g_m} \gg R_o \gg \frac{1}{g_m} \quad (2k \gg 83\Omega)$

(OCT is an estimation technique anyway, so approximations are appropriate)

- $\tau_{W52} = (C_{gs2} + C_{db2} + C_{sb2})\left(\frac{1}{g_{m2}}\right) = (220\text{pF} + 90\text{pF} + 130\text{pF})(83\Omega)$
  
  $= 37\text{ps} \quad \text{(small compared to other } \tau)\$

- $\tau_L = (C_{gd2} + C_{db2} + C_L)(R_L) \quad \text{(remember } R_L \ll R_o(1 + g_{m2}R_o))$
  
  $= (45\text{pF} + 90\text{pF} + 200\text{pF})(1k) = 335\text{ps}$

- A little worse than CS due to higher output resistance

$\text{BW} = \frac{1}{2\tau} = \frac{1}{(400+184+37+335)\text{ps}} = 1.0\text{ Gnd/s}$

$= 160\text{MHz}$

$\Rightarrow$ Meets the $\ast 150\text{MHz spec}$

$\Rightarrow C_{gs}$ and $C_L$ are the next two biggest problems, could add CD stages at input and output to reduce $\tau$ there.