APPENDIX 1

Design of two stage miller compensated op-amp

Assume Power dissipation 1mW  \[ V_{DD} I_{total} \]

\[ = 1.8 \times I_{total} \]

\[ I_{total} = 0.555mA \]

\[ I_{D0} = I_1 + I_2 = 0.5mA \]

\[ (V_{oD7} + V_{oD5} + V_{oD3} + V_{oD1}) + V_{oD0} = 1.8V \]

\[ 0.35 + 0.3 + 0.35 + 0.2 + 0.7 = 1.8V \]

\[ V_{oD7} = V_{oD8} = 0.35V \]

\[ V_{oD5} = V_{oD6} = 0.3V \]

\[ V_{oD3} = V_{oD4} = 0.25V \]

\[ V_{oD1} = V_{oD2} = 0.2V \]

\[ V_{oD0} = 0.7V \]

\[ V_{oD11} = V_{oD12} = 1V \]

\[ V_{oD9} = V_{oD10} = 0.8V \]

\[ k' = \frac{60 \mu A}{V^2} \text{ for PMOS} \]
$k' = \frac{110 \mu A}{V^2}$ for NMOS

$V_{oD11} + V_{oD9} = 1.8V$

$1 + 0.8 = 1.8V$

$I_1 = 250 \mu A$

For $M_7$ & $M_8$

$$\frac{W}{L} = 2 \frac{I_d}{K^1(V_{DD}^2)} = \frac{2 \times 250 \mu A}{60 \mu A(0.35^2)}$$

$$\frac{W}{L} = 68.027$$

$L = 180 \text{nm}$

$W_{7,8} = 12.24 \mu m$

For $M_5$ & $M_6$

$$\frac{W}{L} = 2 \frac{I_d}{K^1(V_{DD}^2)} = \frac{2 \times 250 \mu A}{60 \mu A(0.35^2)}$$

$$\frac{W}{L} = 92.5925$$

$L = 180 \text{nm}$

$W_{5,6} = 16.67 \mu m$
For $M_3$ & $M_4$

\[
\frac{W}{L} = 2 \frac{I_d}{K^1(V_{dd})^3} = \frac{2 \times 250 \mu A}{110 \mu A (0.25^2)}
\]

\[
\frac{W}{L} = 72.727
\]

$L = 180\text{nm}$

$W_{3,4} = 13.0909\mu m$

For $M_0$

$I_o = 0.5mA$

\[
\frac{W}{L} = 2 \frac{I_d}{K^1(V_{dd})^3} = \frac{2 \times 0.5mA}{110 \mu A (0.7^2)}
\]

\[
\frac{W}{L} = 18.5529
\]

$L = 80\text{nm}$

$W_0 = 3.3395\mu m$

For $M_1$ & $M_2$

\[
\frac{W}{L} = 2 \frac{I_d}{K^1(V_{dd})^3} = \frac{2 \times 250 \mu A}{110 \mu A (0.2^2)}
\]

\[
\frac{W}{L} = 113.63
\]
\[ L = 180\text{nm} \]
\[ W_{1,2} = 3.3395\mu\text{m} \]

For \( M_{11} \) & \( M_{12} \)

\[
\frac{W}{L}_{11} = 2 \frac{I_d}{K^1(V_{DD})_{11}} = \frac{2 \times 0.0275mA}{110\mu A(1^2)}
\]

\[
\frac{W}{L} = 0.91667
\]
\[ L = 180\text{nm} \]
\[ W_{11,12} = 65\text{nm} \]

For \( M_9 \) & \( M_{10} \)

\[
\frac{W}{L}_9 = 2 \frac{I_d}{K^1(V_{DD})_9} = \frac{2 \times 0.0275mA}{110\mu A(0.8^2)}
\]

\[
\frac{W}{L} = 0.78125
\]
\[ L = 180\text{nm} \]
\[ W_{9,10} = 140\text{nm} \]

\[ V_{\text{cas}(\text{min})} = V_{DD} - [V_{\text{ss}} + V_{OD}] \]

\[ = V_{DD} - [V_{OD}5 + V_{th} + V_{OD}] \]
\[
= 1.8 - [0.3 + 0.512279 + 0.35] \\
= 0.637721 V \\
V_{\text{cmf_1}} = V_{\text{GS3}} + V_{\text{oD1}} + V_{\text{oD0}} \\
= V_{\text{oD3}} + V_{\text{th}} + V_{\text{oD1}} + V_{\text{oD0}} \\
= 0.25 + 0.54263 + 0.2 + 0.7 \\
= 1.69263 V \\
V_{\text{cmf_2}} = [V_{\text{oD0}} + V_{\text{th}}] \\
=0.7 + 0.54263 \\
= 1.24263 V
\]

Minimum allowable input Common mode level

\[
= V_{\text{GS1}} + V_{\text{oD0}} \\
= V_{\text{oD1}} + V_{\text{th}} + V_{\text{oD0}} \\
= 0.2 + 0.54263 + 0.7 \\
= 1.44263V \\
V_{\text{cmf_1}} = [V_{\text{oD0}} - V_{\text{GS11}}] \\
= V_{\text{DD}} - V_{\text{oD11}} + V_{\text{th}} \\
= 1.8 - [1 + 0.512279] \\
= 0.287721 V
\]