EE5505

Current Mirror OTA Design

UNITS

$n := 10^{-9}$ $u := 10^{-6}$ $m := 10^{-3}$ $p := 10^{-12}$ $K := 10^{3}$ $p := 10^{-12}$ $M := 10^{6}$ $f := 10^{-15}$

Process and input specs $WI := 1$ $SI := 2$

$N := 1.8$ $UT := 26 \cdot m$ $kn := 79 \cdot u$ $kp := 19 \cdot u$ $vtn := 0.6$ $vtp := -0.84$

$lambda0 := 0.032$ $Lo := 6 \cdot u$ $cox := 35 \cdot \frac{10^{-12}}{305 \cdot 10^{-10}}$

$LAMBDA := 0.6 \cdot u$ $Wd := 5 \cdot LAMBDA$

$CL := 10 \cdot p$ $SR := \frac{2}{u}$ $UGF := 8 \cdot M$ $Ao := 10^{\frac{45}{20}}$ $Ao = 177.828$

$B := 1$

Increase Slew rate spec untill in edge of WI and SI

$SR := \frac{5.0}{u}$

From slew rate spec

$Ios := CL \cdot \frac{SR}{B} \cdot (1.0)$ $Ios = 50 \cdot u$

From BW spec in weak inversion

$Iow := 4 \cdot \pi \cdot CL \cdot UGF \cdot UT \cdot N$ $Iow = 47.048 \cdot u$

$Io := if(Iow > Ios, Iow, Ios)$ $Io = 50 \cdot u$

$OP := if(Iow > Ios, WI, SI)$ **Specifying operating region**

From bandwidth spec   **Strong Inversion**

$W1\_by\_L1s := \left(\frac{UGF \cdot CL \cdot 2 \cdot \pi}{B}\right)^2 \cdot \frac{1}{kn \cdot Io}$ $W1\_by\_L1s = 63.965$

$W1\_by\_L1w := 1000$ (This is from another place, no explanation **provided here. Only used for checking)**

$OP = 2$ $WI = 1$ $SI = 2$ **Variable to check for operating region**

In this case we will use strong inverison $W1\_by\_L1 := W1\_by\_L1s$

$L1 := 4 \cdot LAMBDA$ $L1 = 2.4 \cdot u$

20% overdesign

$W1 := L1 \cdot W1\_by\_L1 \cdot (\mathbf{1.20}) \qquad W1 := ceil\left(\frac{W1}{LAMBDA}\right) \cdot LAMBDA \qquad W1 = \mathbf{184.8} \cdot u$

$gm1s := \sqrt{Io \cdot kn \cdot \frac{W1}{L1}} \qquad gm1w := \frac{Io}{\mathbf{2} \cdot N \cdot UT} \qquad gm1 := if(gm1w < gm1s, gm1w, gm1s)$

$gm1 = \mathbf{534.188} \cdot u \qquad \frac{gm1 \cdot \frac{B}{CL}}{\mathbf{2} \cdot \pi} = \mathbf{8.502} \cdot M$

Just to confirm that gds1 << gm4

$gds1 := \frac{Lo}{L1} \cdot lambda0 \cdot \frac{Io}{\mathbf{2}} \qquad gds1 = \mathbf{2} \cdot u$

From phase margin 60 degrees => the second pole should be > 1.732 times larger than the UGF. Single pole assumption, 3X is a better approximation

$CJ := \mathbf{2.74} \cdot \mathbf{10}^{-\mathbf{4}} \qquad CJSW := \mathbf{1.73} \cdot \mathbf{10}^{-\mathbf{10}}$

$Cdb2 := CJ \cdot W1 \cdot L1 + [(\mathbf{2} \cdot Wd + W1) \cdot CJSW] \qquad CJ \cdot W1 \cdot L1 = \mathbf{121.524} \cdot f$

$Cdb2 = \mathbf{0.155} \cdot p$

Calculating L4 from gain spec

$lambda5 := \frac{gm1}{Io \cdot Ao} \qquad lambda5 = \mathbf{0.06}$

$L5 := \frac{lambda0 \cdot Lo}{lambda5} \qquad L4 := L5 \qquad L4 := ceil\left(\frac{L4}{LAMBDA}\right) \cdot LAMBDA$

$L4 := if[L4 < \mathbf{2} \cdot LAMBDA, (\mathbf{2} \cdot LAMBDA), L4] \qquad L4 = \mathbf{3.6} \cdot u$

$Vdd := \mathbf{3.0} \qquad Vo\_max := \mathbf{2.7}$

$DELV4 := Vdd - Vo\_max$

$W4 := L4 \cdot \frac{Io}{DELV4^{\mathbf{2}} \cdot kp} \qquad W4 := ceil\left(\frac{W4}{LAMBDA}\right) \cdot LAMBDA \qquad W4 := if[W4 < \mathbf{3} \cdot LAMBDA, (\mathbf{3} \cdot LAMBDA), W4]$

$Cgs4 := \frac{\mathbf{2}}{\mathbf{3}} \cdot W4 \cdot L4 \cdot cox \qquad (\mathbf{1} + B) \cdot Cgs4 = \mathbf{0.582} \cdot p \qquad W4 = \mathbf{105.6} \cdot u$

Need to worry about the Miller capacitance from output node?

$CGDO := 50 \cdot p$

$Cdg4 := W4 \cdot CGDO \quad Cdg5 := B \cdot Cdg4 \qquad Cdg5 = 5.28 \cdot f$

$gm4 := \sqrt{Io \cdot kp \cdot \frac{W4}{L4}} \qquad gm4 = 166.933 \cdot u$

$\left(1 + Ao \cdot \frac{gm4}{gm1}\right) \cdot Cdg5 = 0.299 \cdot p$

$$P2 := \frac{gm4}{Cdb2 + Cgs4 \cdot (1 + B) + \left(1 + Ao \cdot \frac{gm4}{gm1}\right) \cdot Cdg5}$$

$\frac{P2}{2 \cdot \pi} = 25.672 \cdot M \qquad \frac{P2}{UGF \cdot 2 \cdot \pi} = 3.209$

Clearly in this case phase margin is not met. One method is to reduce B.

$Power := (1 + B) \cdot Io \cdot Vdd \quad Power = 300 \cdot u$