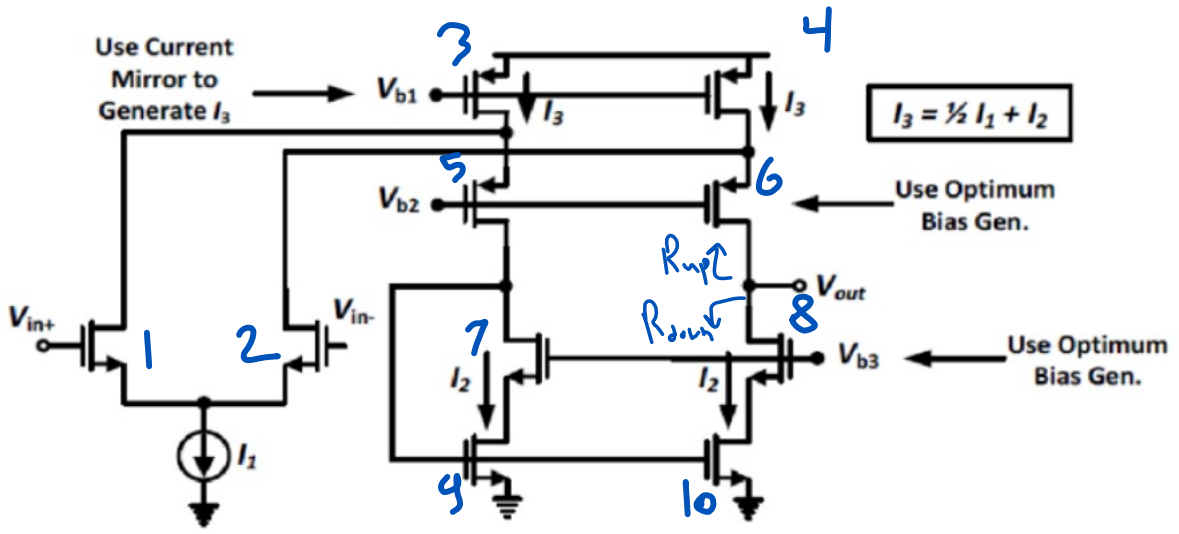
- Design steps
- Given specs
- Equations
- Assumptions
- Equivalent



1 , 2 same
⋮
n , 2n same

1- VDD= 3.3V
2- VinCM= 0.5*VDD
3- ADC (DC gain) > 58dB
4- GBW>150MHz for a load capacitance of 1pF
5- Slew rate > 100 V/usec
6- Output swing > 1.5 VPP
7- Input refered noise density < $30nv / \sqrt{Hz}$ (include thermal and flicker only)
8- PM > 60deg
9- GM > 12deg
10- Minimal power consumption and area.

① $A = G_m R_{out}$

② ✱ $G_m = g_{m_2}$

③ ✱ $R_{out} \approx (g_{m_6} r_{o_6} (r_{o_4} // r_{o_2})) // (g_{m_8} r_{o_8} r_{o_{10}})$ (R_{up}, R_{down})

⑤ → $R_{out} = \frac{A}{g_{m_2}} = \frac{58\,dB}{950\,\mu} = 836.14\,k$

let $R_{out} = 836k$

④ ✱ $GBW = \frac{G_m}{2\pi C_p} \rightarrow \frac{g_{m_2}}{2\pi * 1pf} > 150M \rightarrow g_{m_2} > 942.5\,\mu S$

↳ let $g_{m_2} = 950\,\mu S$

⑥ ✱ $SR = \frac{I_{ss} \rightarrow I_1}{C_p} \rightarrow \frac{I_1}{1pf} > 100\,V/\mu \rightarrow I_1 > 100\,\mu A$

↳ let $I_1 = 110\,\mu A$ also let $I_2 = \frac{1}{2} I_1 = 55\,\mu A$

Then $I_3 = \frac{1}{2} I_1 + I_2 = 110\,\mu A$

⑦ ✱ $V_{out_{max}} = V_{DD} - (V_{Dsat_4} + V_{Dsat_6})$ (V_{Dsu} that makes 4 in sat)

$V_{out_{min}} = V_{Dsat_8} + V_{Dsat_{10}}$

⑥ swing ↑

→ $V_{out\,max} - V_{out\,min} > 1.5\,VPP$

assum all V_{Dsat} are equal

we get $3.3 - 4 V_{Dsat} > 1.5$

∴ $V_{Dsat} < 0.45\,V$

→ while sizing if got one bigger must consumbtion with one smaller and etc... So overall is achieved

(8)

(*) For any mos to be designed we need two values of $\{g_m, r_o, I_D\}$

OR one and ratio of two of them

lets start with input pair (1,2)

we have $I_{D_2} = \frac{1}{2} I_1 = 55\,\mu A$ And $g_{m_2} = 950\,\mu S$

Design ≡ get W & L of mos

But there is too much constraints that we need to consider

but as farmers in cadence we skip most of them

and follow known suggestion of experts in analog design

so for input pair we want relativly small L but min ≃ 400n → ≃ 600n

let $L_2 = 400n$ for low cap

in test bench we can't get reall valus for g_m but its ratio with I_D we can

so $\frac{g_m}{I_D}\Big|_2 = 17,27$ → let $\frac{g_{m2}}{I_{D2}} = 18$

now we plot $\frac{g_m}{I_D}$ vs V_{GS} also I_D vs V_{GS}

↳ $I_D \propto W$ let basic $W = 10\mu$ For refrenc

we get $V_{GS} = 634\,mV \rightarrow I_D = 13,42\,\mu A$

↳ but we need 55 μ

so $W_{new} = \frac{I}{(I_D/W)_{old}} = 41\,\mu$

now edit W and rerun to get V_{Dsat} and r_o as we need them in next steps

Got $I_D = 54,45\,\mu A$ ✓, $V_{Dsat} = 78,57\,mV$ ✓ + 100mV for stability = 0,17857 V, $r_o = 112,74\,K$

(9) (3,4)

(*) Lets assume $r_{o_4} = r_{o_2} = 112,7\,k\Omega$ and we got $I_3 = 110\,\mu A$

but r_o changes greatly with I_D So we assum $g_{m4} r_{o4} = 75$

which is weakly changes with I_D

Run plot $g_m r_o$ vs V_{GS} & I_D Vs V_{DS} with let $L_4 = 400n$

and $V_{DS_4} = 3,7/4$

@ $g_m r_o = 80 \rightarrow V_{GS} = 680,1\,mV, I_D = 17,83\,\mu A$

↳ $W_{new} = \frac{110}{\frac{17,83}{10}} = 61,7\,\mu$

$I_{D new} = 109,6\,\mu A$ ✓, $V_{Dsat} = 141,5\,mV$ ↳ 241,5 mV, $r_o = 51,38\,K$

↳ Not what was intendet but will be considered

10) as for (5,6) we got $R_{up} = g_{m6} r_{o6} (r_{o4} // r_{o2})$

$R_{down} = g_{m8} r_{o8} r_{o10}$

assume $R_{up} = 2 R_{down}$

∴ $R_{out} = \frac{1}{3} R_{up} = 836{,}14\,k \rightarrow R_{up} = 2{,}508\,M\Omega$, $R_{down} = 1{,}254\,M\Omega$

we $r_{o4} // r_{o2} = 35{,}29\,k \rightarrow g_{m1} r_{o6} = 71 \rightarrow$ perfect

assume $g_{m6} r_{o6} = 75$

Run with $V_{DS} = \frac{3{,}3}{4}$, $I_{D6} = I_2 = 55\,\mu A$

Let $L_6 = 400\,n$ same as the 3,4 but half current → half width

$W = 30{,}85\,\mu$

we Got $I_D = 55\,\mu A$, $V_{GS} = 681{,}249\,mV$, $V_{Dsat} = 141{,}679\,mV$ → $241{,}679\,mV$, $r_o = 102{,}46\,k$

11) (*) (7,8) $R_{down} = g_{m8} r_{o8} r_{o10} = 1{,}254\,M\Omega$

assume $g_{m8} r_{o8} = 85 \rightarrow r_{o10} = 14{,}75\,k$

Run with $V_{DS} = \frac{2{,}2}{4}$, $I_D = I_2 = 55\,\mu$,

Let $L = 700\,n$ for low nois

Got $V_{GS} = 931{,}26\,mV$, $I_D = 150{,}79\,\mu$

→ $w_{new} = 3{,}65\,\mu$

Final → $I_D = 54{,}75$ ✓, $V_{Dsat} = 282{,}45\,mV$ → $382{,}45\,mV$, $r_o = 270{,}35\,k$

12) (X) (9,10) $r_{o10} = 14{,}75\,k$, $I_D = 55\,\mu$, $V_{DS} = \frac{3{,}3}{4}$

let $g_{m_6} r_{o_{10}} = 75$ ise

$L = 400\,n$

we get $V_{GS} = 740{,}118\,mV$, $I_D = 58{,}96\,\mu A$

→ $w_{new} = 9{,}34\,\mu$

Final → $I_D = 54{,}9\,\mu$ ✓, $V_{Dsat} = 136{,}48\,mV$ → $236{,}48\,mV$, $r_o = 123{,}77\,k$

final R_{out}

$= 2{,}646\,M // 10{,}5\,M$

$= 2{,}1\,M$ good for now

(*) Current mirror pair of I_1

$V_{DS} = 1.45V$,