Lab 4

P&Z wrap up

Supply indep.

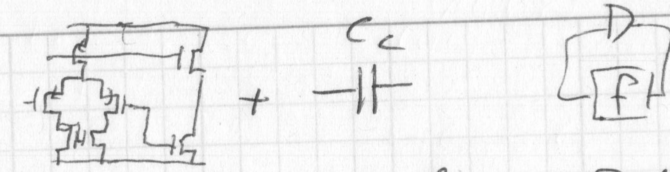
current

Voltage.

Midterm friday 3/24 3:10 - 4:30

See me if that is a problem

2 stage



~~Open~~ Uncompensated

$\omega_{p1} = \frac{1}{R_o C_1}$

$\omega_{p2} = \frac{1}{R_{o2} C_2}$

mirror doublet

$\omega_{pm} = \frac{g_{m2}}{2C_{ss}}$

$\omega_{zm} = 2\omega_{pm}$

$\omega_u = ?$

Compensated

$\omega_{p1c} = \frac{1}{R_{o1} G_{m2} R_{o2} C_c}$

$\omega_{p2c} = \frac{G_{m2}}{C_1 + C_2 + \frac{C_1 C_2}{C_c}}$

doublet: same

RHP zero: $\frac{G_{m2}}{C_c}$

unless x, y, z,

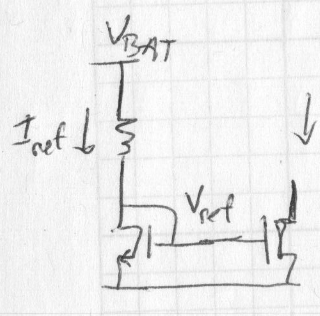
$\omega_u = \frac{G_{m1}}{C_c}$

Feedback

$\omega_{p1fb} \approx f\omega_u$

$\omega_u \approx$ same

what about the reference current? (Lab 4)
and voltage?



like to have supply-indep.

current
Voltage } separately

current: to set device performance.

Voltage: to know what "1V" means.

challenge:

Variations in { Process V_t, μC_{ox}, λ

Voltage $V_{BAT} = n \times \{1.6 \to 0.8\}$

Temperature 0 - 70C consumer

-40 - 85C indust

-55 - 125C mil

auto

I_{ref} varies ~ V_{BAT}; $R(T)$, $V_{tn}(T)$, V_{to}?

V_{ref} varies $V_t + V_{ov}$

Sensitivity of y to x $S_x^y = \lim_{\Delta x \to 0} \frac{\Delta y / y}{\Delta x / x}$

$= \frac{x}{y} \frac{dy}{dx}$

e.g.

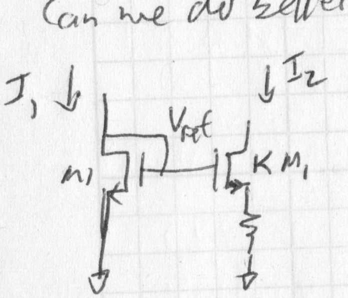
$I_{ref} = \frac{V_{BAT} - V_{tn} - V_{ov1}}{R}$

$S_{V_{BAT}}^{I_{ref}} = \frac{V_{BAT}}{I_{ref}} \frac{\partial I_{ref}}{\partial V_{BAT}}$

$= \frac{V_{BAT}}{\left(\frac{V_{BAT} - V_{tn} - V_{ov1}}{R}\right)} \frac{1}{R} = \frac{V_{BAT}}{V_{BAT} - V_{tn} - V_{ov1}} \geq 1$

140/2404 17 50 W9L2

Can we do better?



assume both in saturation.

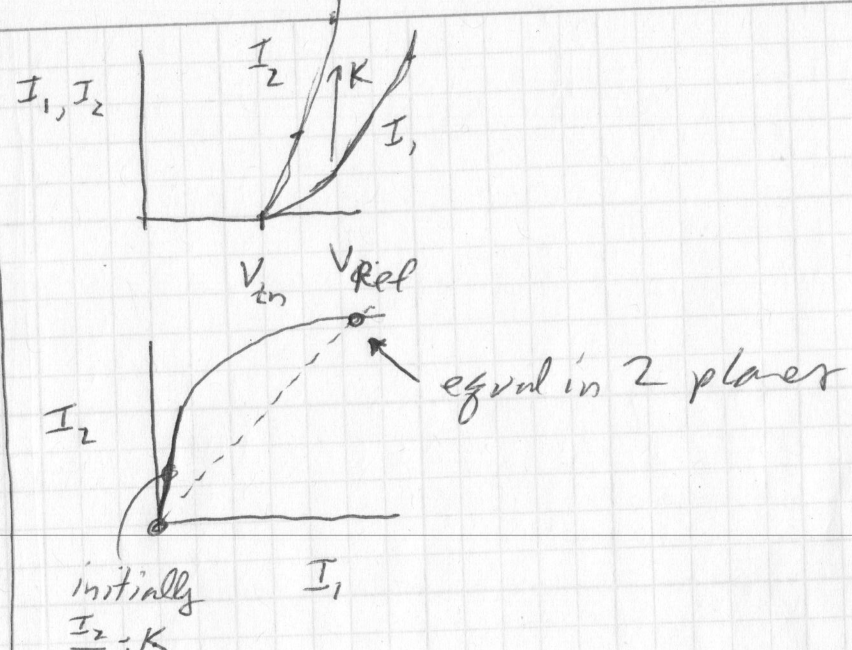
$$I_1 = \frac{\mu_n C_{ox}}{2}\left(\frac{W}{L}\right)_1 V_{ov1}^2$$

$$I_2 = \frac{\mu_n C_{ox}}{2} K\left(\frac{W}{L}\right)_1 \left(V_{ov1} - I_2 R\right)^2$$

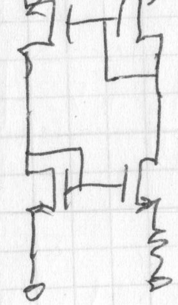
$$I_2 = K I_1 \quad \text{if} \quad I_2 R \ll V_{ov1}$$

as I_1 increases, $I_2 R$ increases, V_{ov1} increases

but V_{ov2} increases more slowly



enforce that $I_2 = I_1$. How? current mirror



When $I_1 = I_2$

$$V_{ov1}^2 = K\left(V_{ov1} - I_2 R\right)^2$$

$$V_{ov1} = \sqrt{K}\left(V_{ov1} - I_2 R\right)$$

$$\frac{V_{ov1}}{\sqrt{K}} = V_{ov1} - I_2 R$$

$$I_2 R = \left(1 - \frac{1}{\sqrt{K}}\right) V_{ov1}$$

$$K = 4 \Rightarrow I_2 R = \frac{1}{2} V_{ov1} = V_{ov2}$$

Fig 12.3
(11.3 1st ed.)

if $K = 4$

$$g_{m1} = \frac{2 I_{D1}}{V_{ov1}} = \frac{2 I_2}{2 I_2 R} = \frac{1}{R} \quad \text{nice!}$$

"constant g_m biasing"

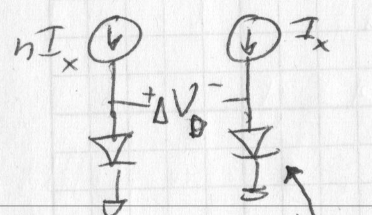
→ generally use long channel devices

→ put resistor on PMOS side to avoid body effect in N-well process

→ startup: tie gates together w/ low current path to avoid $I_1 = I_2 = 0$

Temperature Sensors,
Temp independent bias voltage

In week 2 we saw that

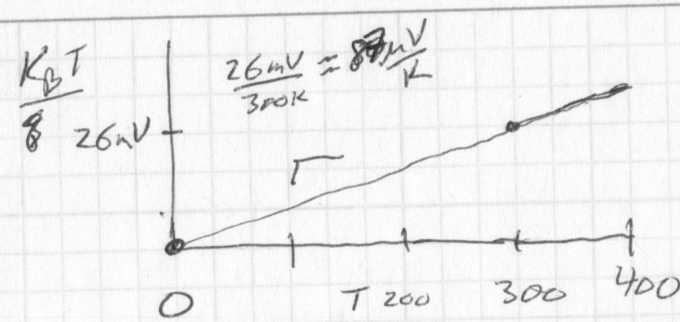


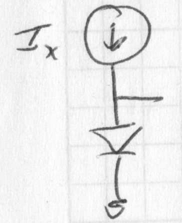
$\Delta V_D = \ln(n)\, V_{TH} = \ln(n) \frac{K_B}{q} T$

PTAT (12.16)

put m in parallel $\Rightarrow V_0 = \ln(n \cdot m)\, V_{TH}$

(12.19)

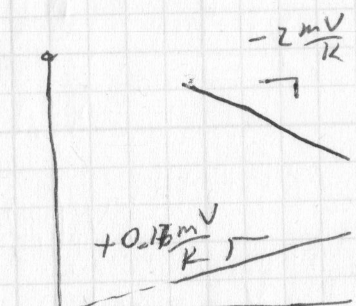


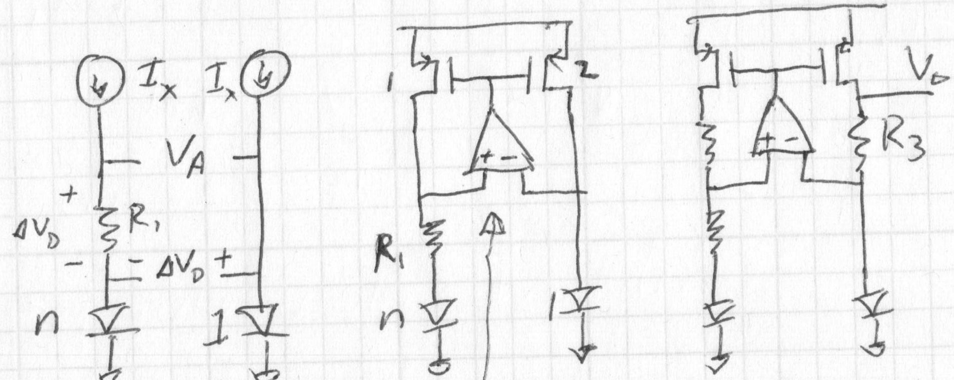


$V_D(T) \cong V_D(300K) + \alpha \Delta T$

$\alpha = (-1.5 \text{ to } -2)\, mV/K$

goal: $V_D(T) + \frac{\alpha}{\ln(n)\frac{K_B}{q}} \Delta V_D$





increase I_x until $V_A = 0$

$I_x R_1 = \ln n\, V_{TH}$

PTAT!

$V_0 = V_D + I_x R_3$

$= V_D(T) + \frac{R_3}{R_1} \ln n\, V_{TH}$

choose R_3/R_1 right

$\Rightarrow$ no temp co!!