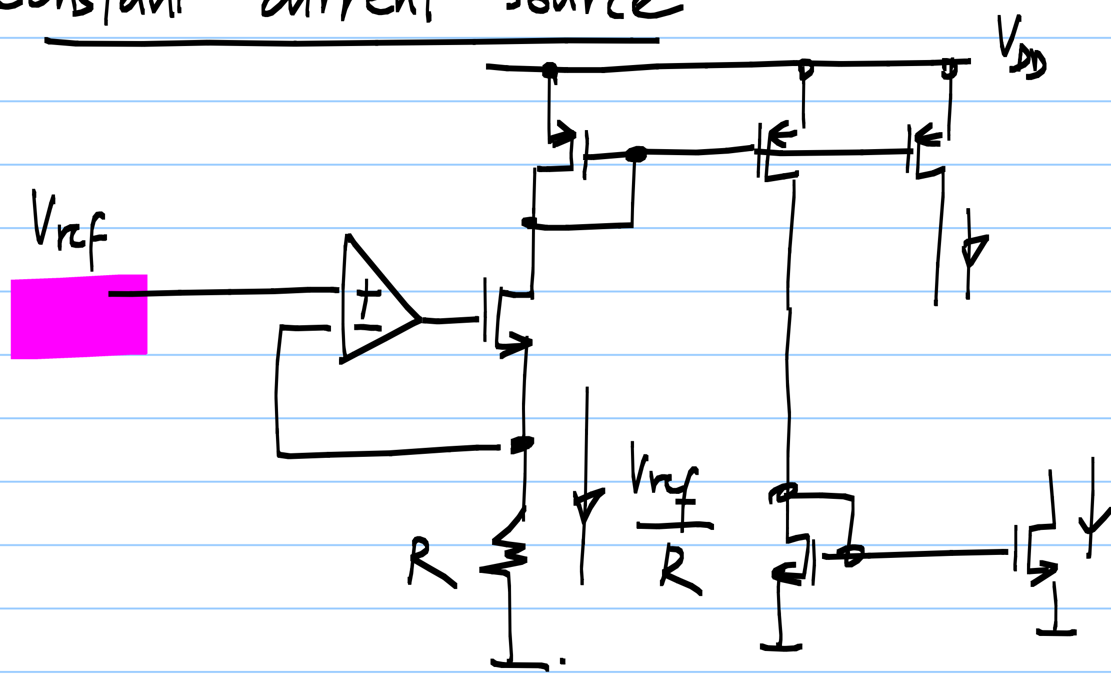
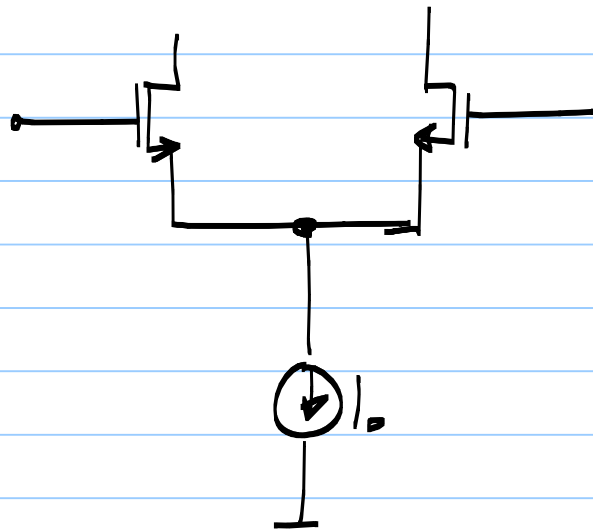
Lecture 53:

Constant current source → Constant over process, supply voltage & temperature





I_0: constant over temp.

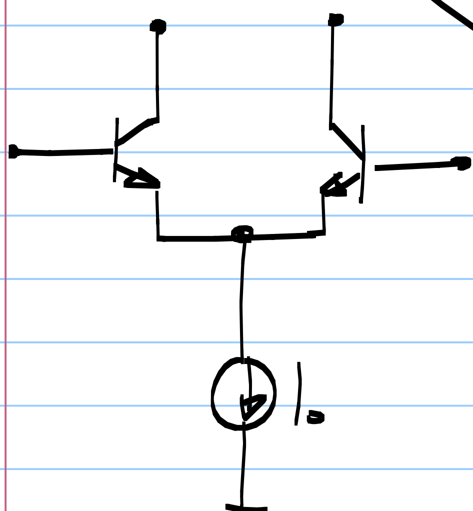
$$g_m = \sqrt{\frac{2 \cdot I_0/2}{\mu C_{ox} W/L}}$$ varies with temp

(μ) reduces as $T \uparrow$

$$g_m = \frac{I_0/2}{V_t} = \frac{I_0/2}{kT/q}$$

To keep g_m constant,

$$I_0 \propto T$$

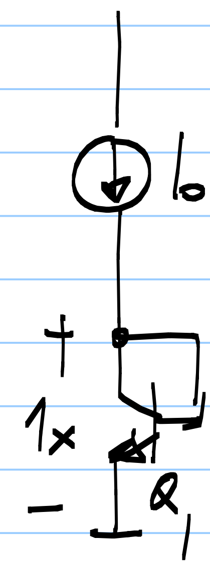


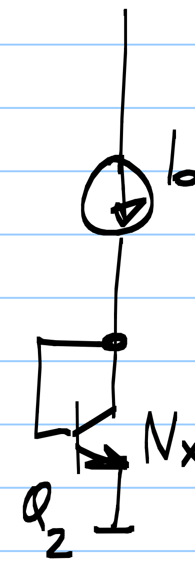
$$V_t = \frac{kT}{q} \propto T$$

$$V_{BE_1} = V_t \ln\left(\frac{I_0}{I_s}\right)$$

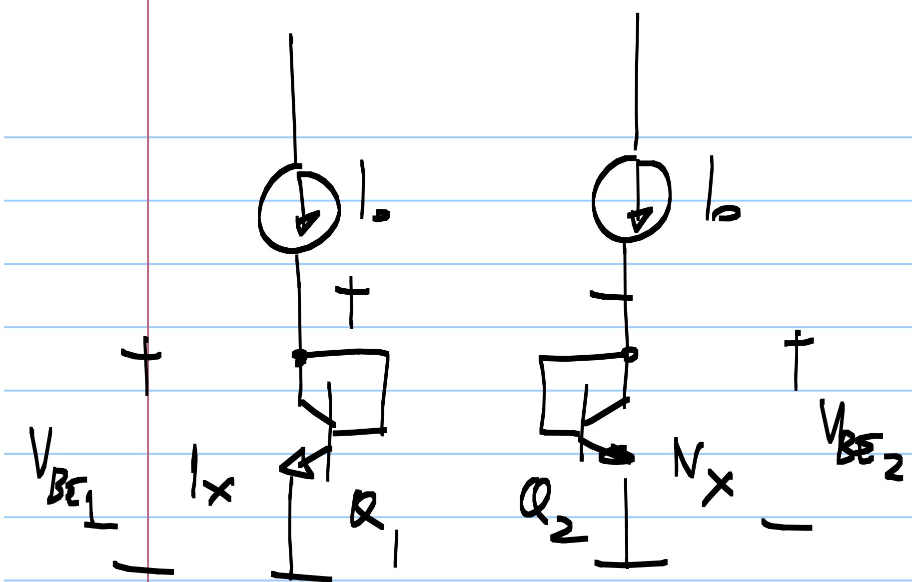
$$\propto T$$

depends on T





$$V_{BE_2} = V_t \ln\left(\frac{I_0}{N \cdot I_s}\right)$$



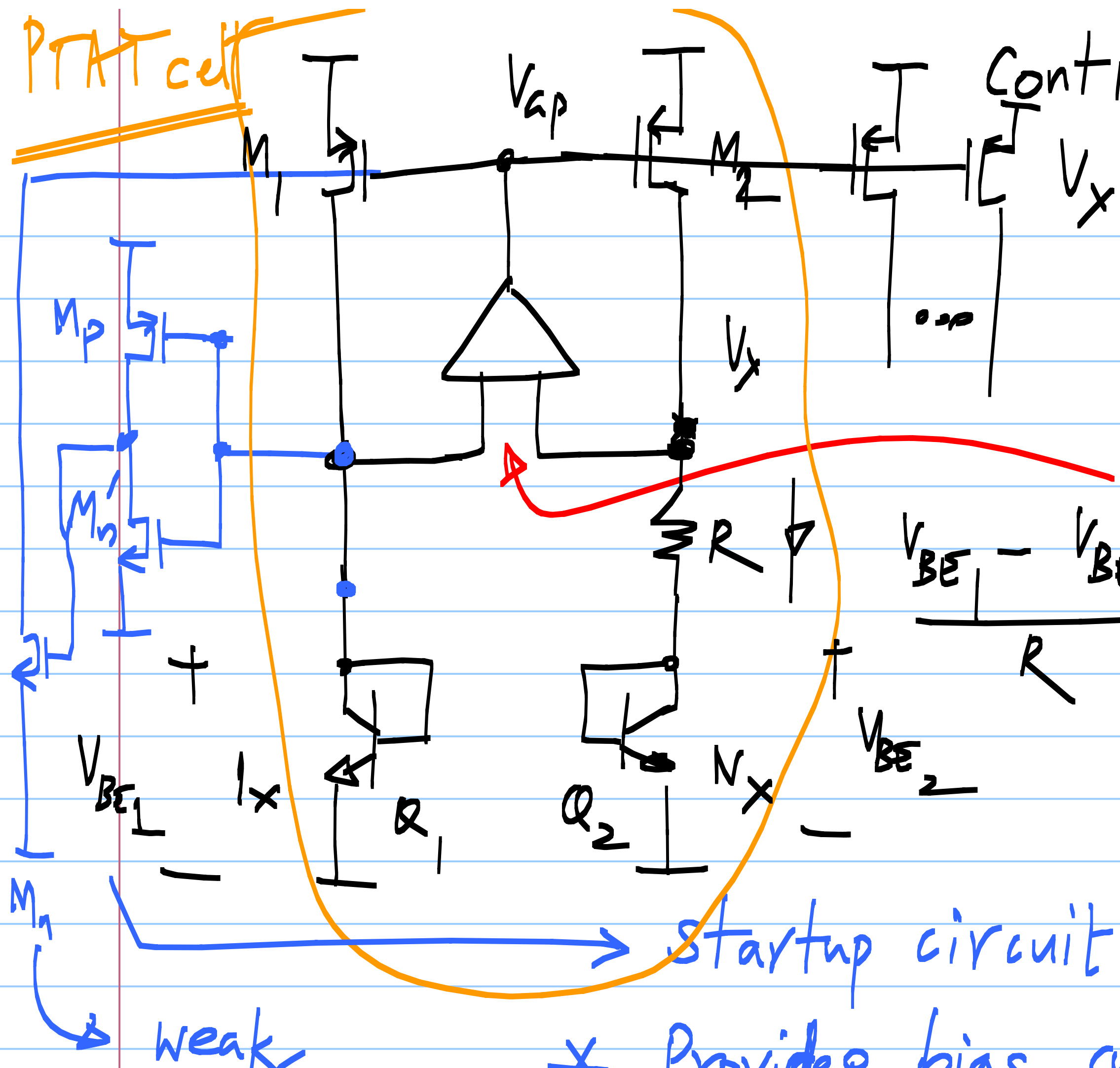
$V_{BE_1} - V_{BE_2}$ must appear across a resistor (must have zero TC)

$$V_{BE_1} = V_t \ln\left(I_0/I_s\right)$$

$$V_{BE_2} = V_t \ln\left(I_0/NI_s\right)$$

$$V_{BE_1} - V_{BE_2} = V_t \cdot \ln(N)$$

Continuously vary V_{ap} until V_x becomes equal to V_{BE_1}

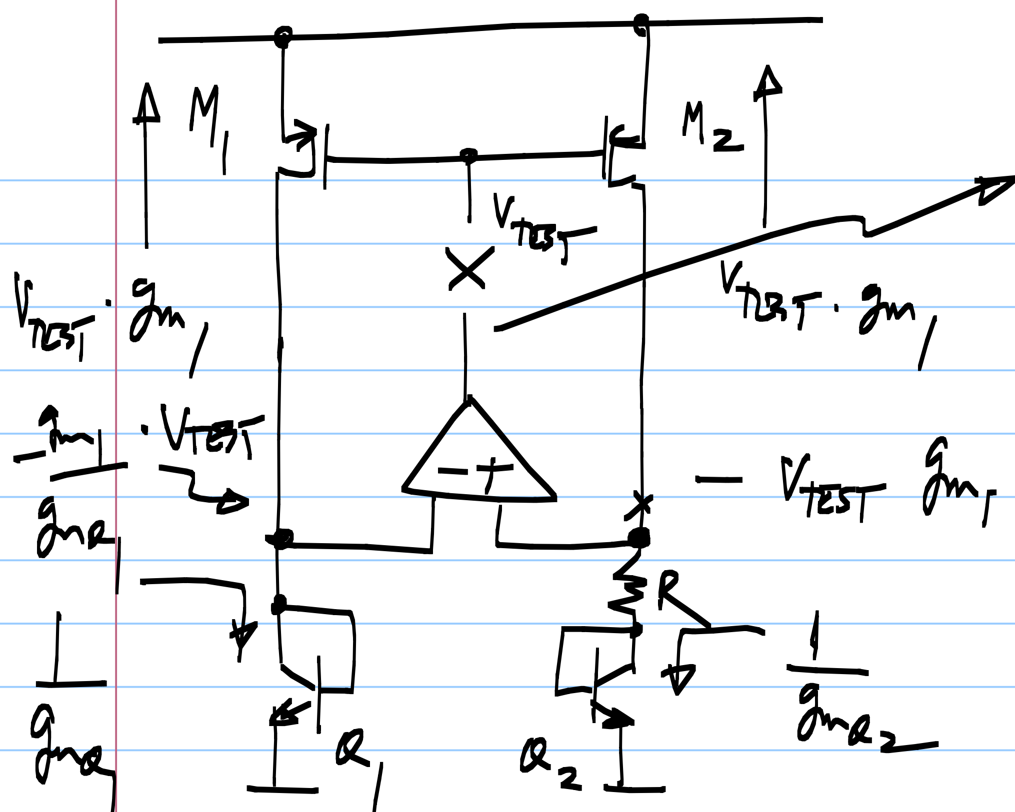


offset: small

$$\frac{V_{BE_1} - V_{BE_2}}{R} = \frac{V_t}{R} \ln(N)$$

Proportional to absolute temp. – PTAT

* Provides bias current at startup.
* Must carry negligible current after startup.

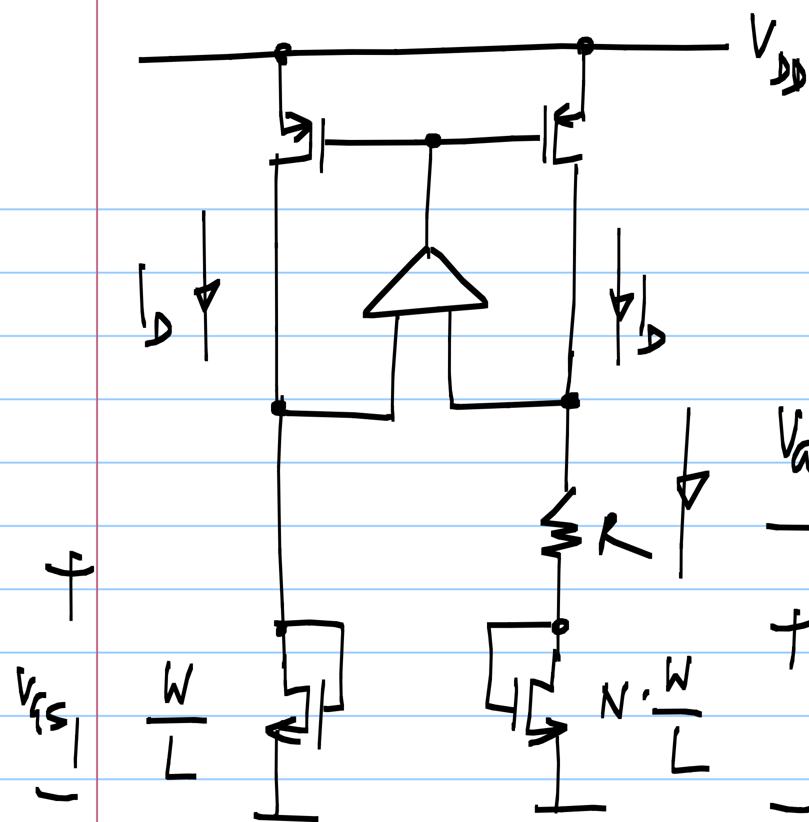


$$V_{TEST}\left(\frac{g_{m1}}{g_{mQ1}} - g_{m1}\left(\frac{1}{g_{mQ2}} + R\right)\right)\cdot A_o$$

$$-V_{TEST}\cdot A_o\, g_{m1}\cdot R$$

$$-V_{TEST}\, g_{m1}\left(\frac{1}{g_{mQ2}} + R\right)$$

$$g_{mQ2} = g_{mQ1} = \frac{I_c}{V_t}$$



$$V_{GS_1} = V_T + \sqrt{\frac{2 I_D}{\mu_n C_{ox} W/L}}$$

$$V_{GS_2} = V_T + \sqrt{\frac{2 \cdot I_D}{\mu_n C_{ox} N \cdot W/L}}$$

$$\frac{V_{GS_1} - V_{GS_2}}{R} = I_D$$

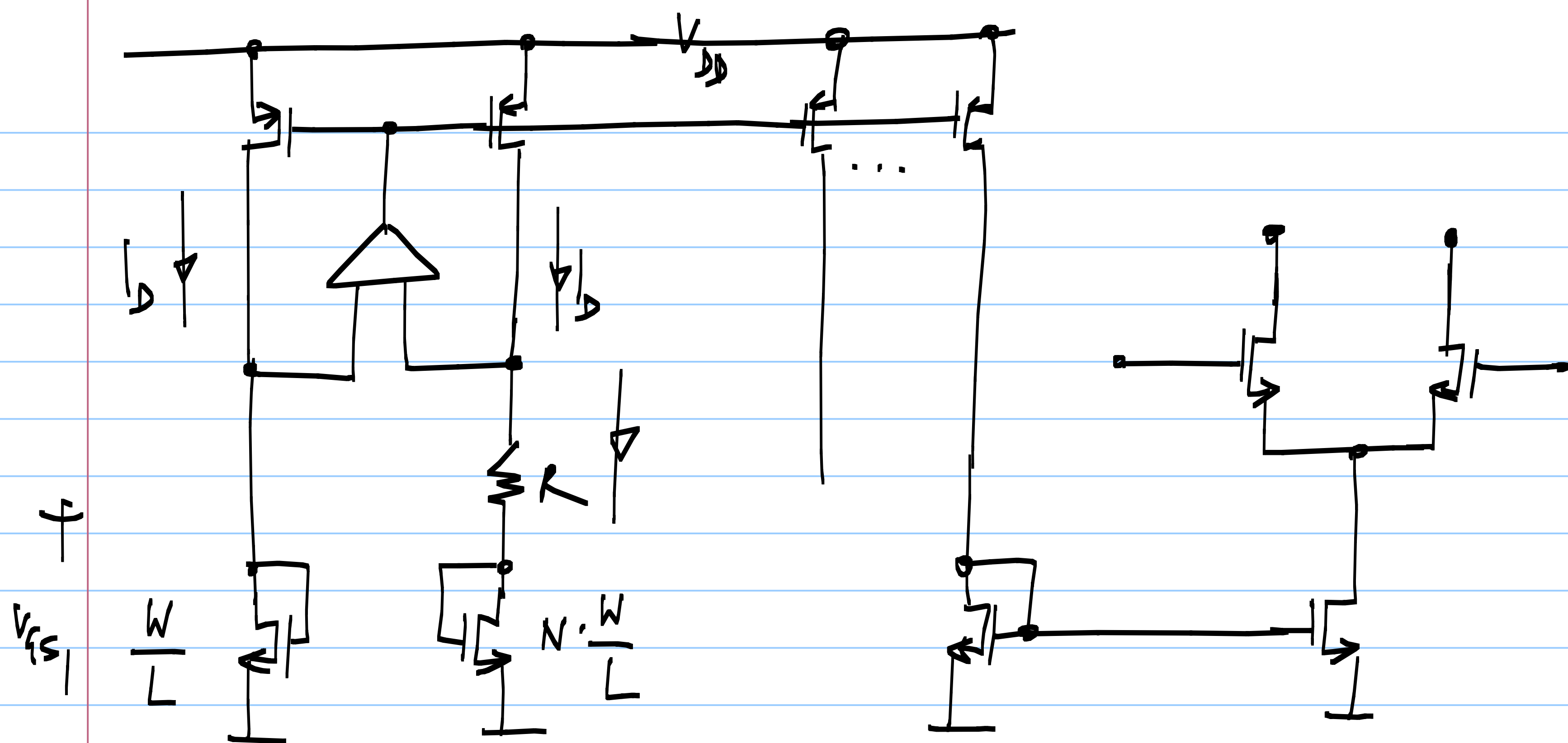
$$I_D = \sqrt{\frac{2 I_D}{\mu_n C_{ox} W/L}} \left(1 - \frac{1}{\sqrt{N}}\right) \cdot \frac{1}{R}$$

$$I_D = \frac{2}{\mu_n C_{ox} \frac{W}{L}} \frac{1}{R^2} \left(1 - \frac{1}{\sqrt{N}}\right)^2$$

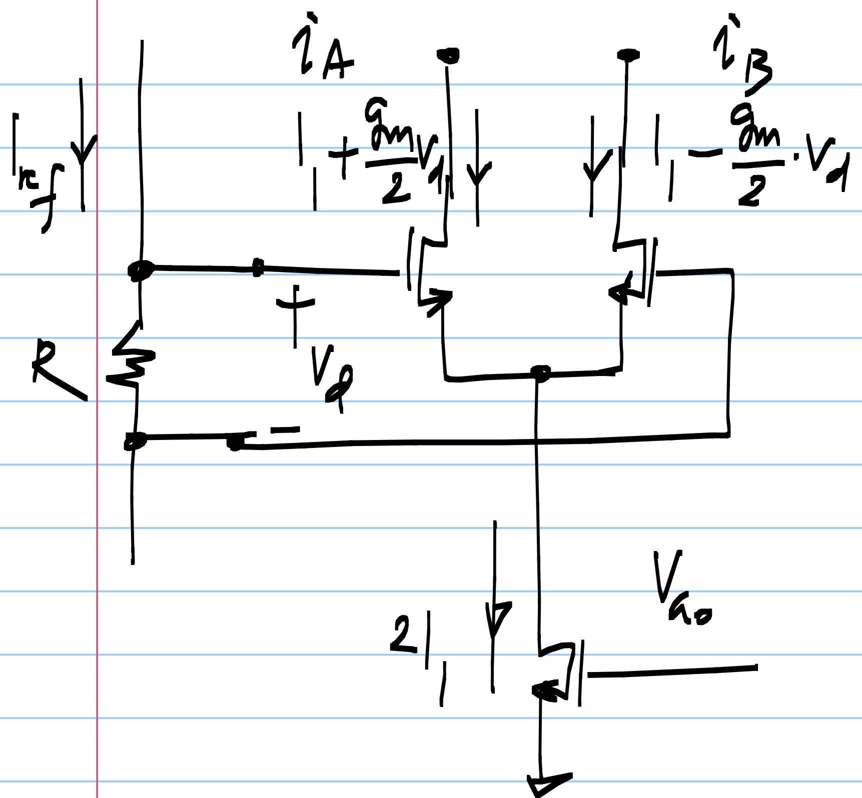
nMOS transistor biased at I_D:

$$g_{m1} = \sqrt{2 I_D \cdot \mu_n C_{ox} \frac{W_1}{L_1}} = 2 \sqrt{\frac{W_1/L_1}{W/L} \cdot \frac{1}{R}\left(1 - \frac{1}{\sqrt{N}}\right)}$$

$$\sqrt{I_D} = \sqrt{\frac{2}{\mu_n C_{ox} \frac{W}{L}}} \frac{1}{R}\left(1 - \frac{1}{\sqrt{N}}\right)$$



V_{DD}
I_D
I_D
R
V_{GS1}
$\frac{W}{L}$
$N \cdot \frac{W}{L}$



$$i_A = I_1 + \frac{g_m}{2} \cdot V_d = I_1 + \frac{g_m}{2} I_{ref} R$$

$$i_B = I_1 - \frac{g_m}{2} V_d = I_1 - \frac{g_m}{2} I_{ref} R$$

$$V_d = I_{ref} \cdot R$$

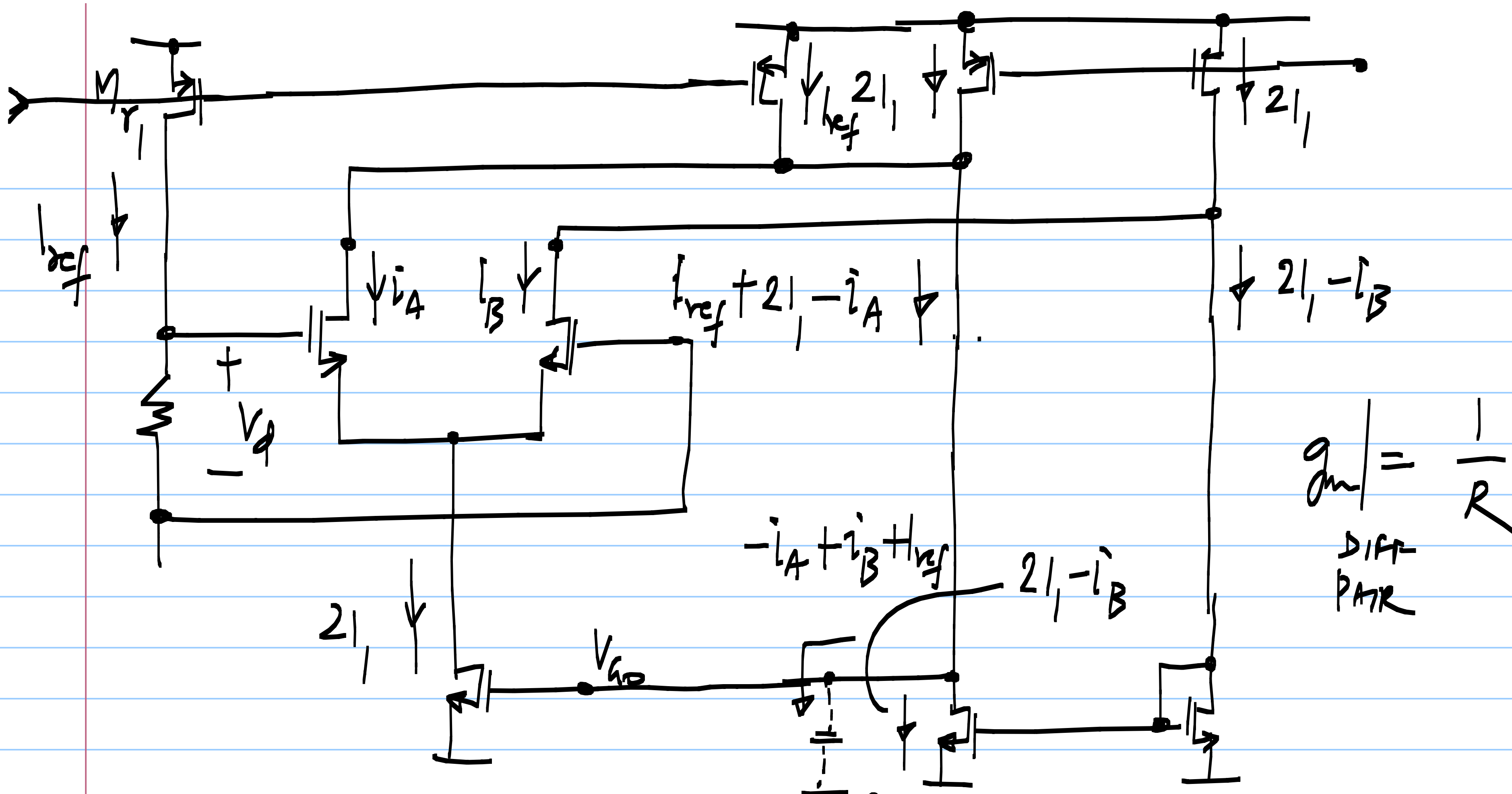
R → constant with temp.

$$i_A - i_B = g_m R \cdot I_{ref}$$

If $i_A - i_B = I_{ref} \Rightarrow g_m R = 1$

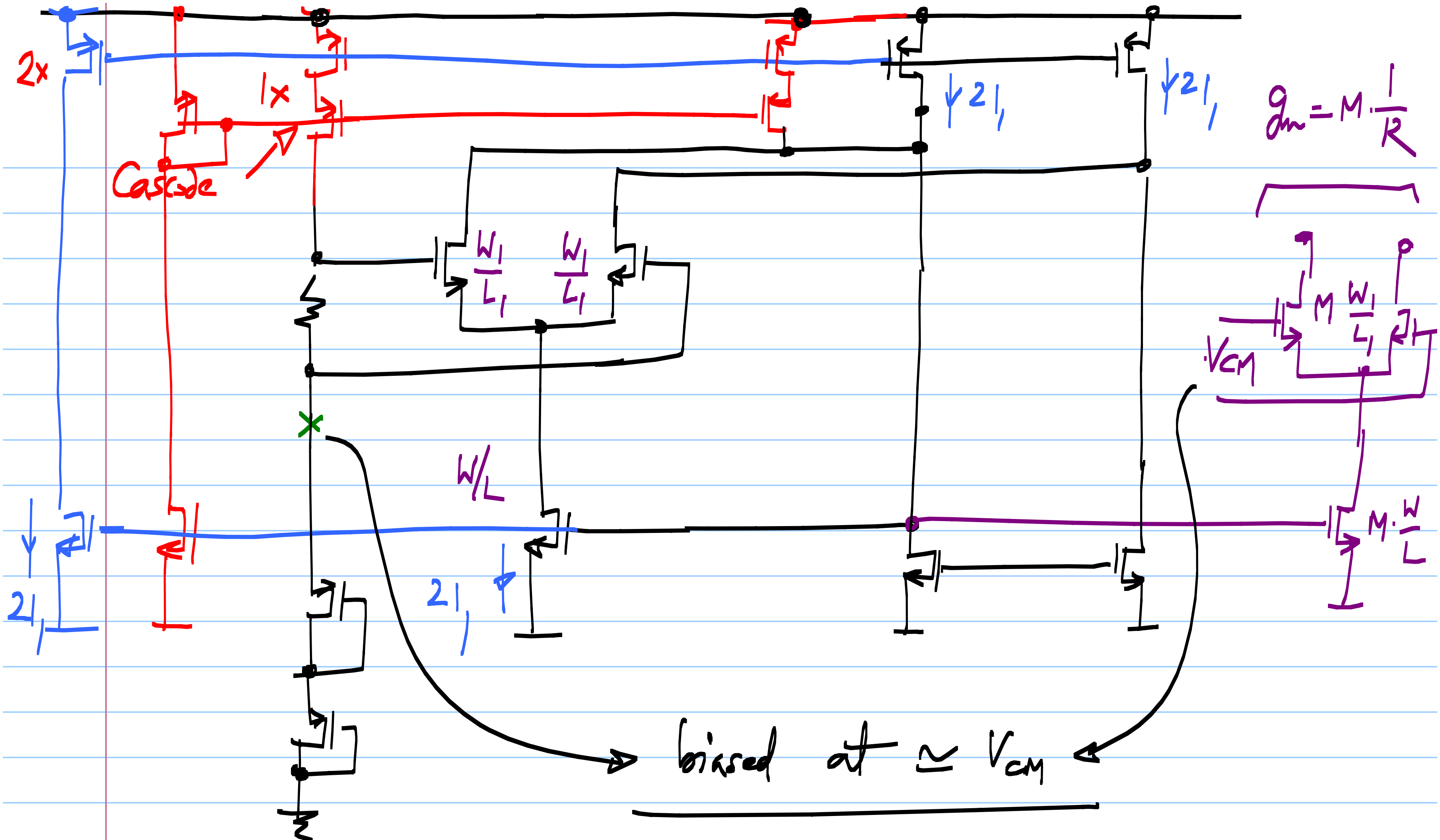
$$g_m = \frac{1}{R}$$

* Vary g_m ($\Rightarrow$ vary $2I_1 \Rightarrow$ vary V_{ao}) until $i_A - i_B$ equals I_{ref}



If $i_A - i_B > I_{REF}$, reduce g_m (reduce V_{Ao})

$[i_A - i_B - I_{REF} > 0]$


2x
1x
Cascode
W1/L1
W1/L1
2I1
2I1
gm = M·1/R
M W1/L1
VCM
W/L
2I1
M·W/L
2I1
biased at ≃ VCM