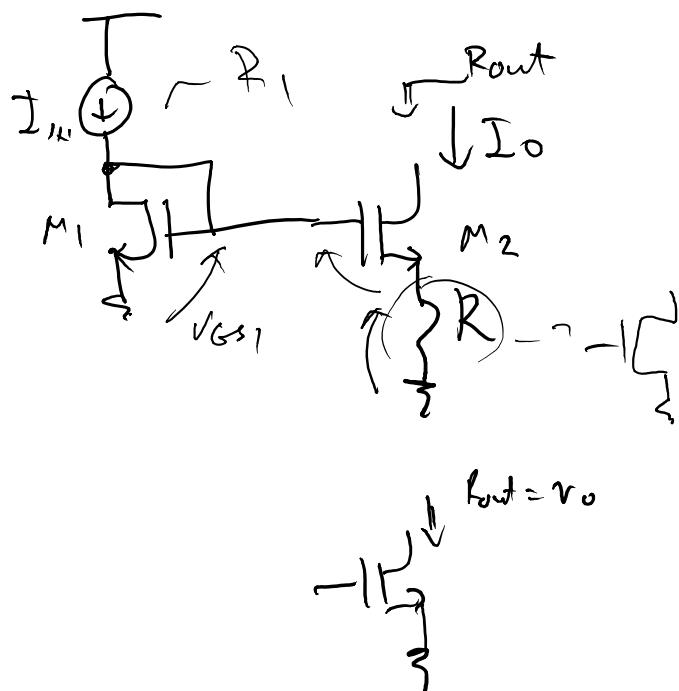
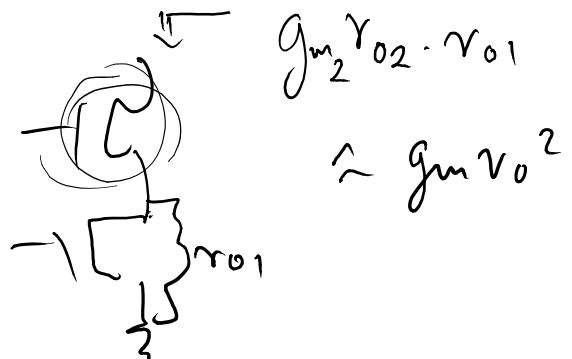


(10) Widlar Current Mirror



$$R_{out} = g_m v_{o2} \cdot R + v_{o2}$$



$$V_{GS1} = V_{GS2} + I_o R$$

ignore B.E.

$$I_o R = v_{ov1} - v_{ov2}$$

$$= \sqrt{\frac{2I_{IN}}{k'(\frac{w}{l})_1}} - \sqrt{\frac{2I_o}{k'(\frac{w}{l})_2}}$$

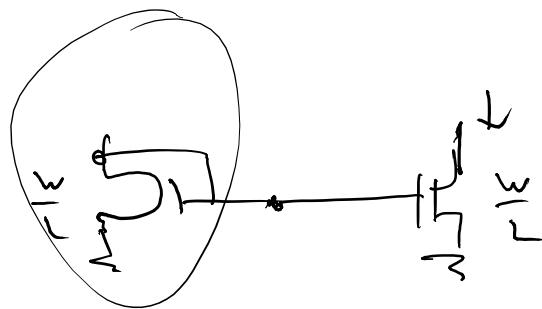
$$\sqrt{I_o} = -\frac{1}{2R} \sqrt{\frac{2}{k'(\frac{w}{l})_2}} + \frac{1}{2R} \sqrt{\frac{2}{k'(\frac{w}{l})_2} + 4RV_{ov1}}$$

Good for low $I_o \sim \mu A$

Practical issues:

① Matching of transistors

$$\frac{\Delta I_D}{I_D} = \frac{\Delta \left(\frac{W}{L}\right)}{\frac{W}{L}} - \frac{2\Delta V_{Th}}{V_{ov}}$$

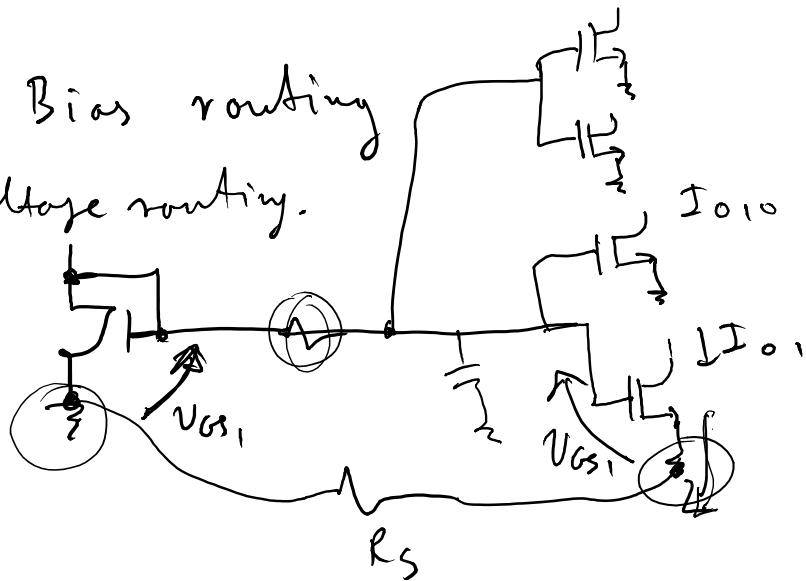


$$\Delta \left(\frac{W}{L}\right) = \left(\frac{W}{L}\right)_1 - \left(\frac{W}{L}\right)_2$$

$$\frac{W}{L} = \frac{\left(\frac{W}{L}\right)_1 + \left(\frac{W}{L}\right)_2}{2}$$

② Bias routing

a) Voltage routing.



$$\Delta V_{Th} = V_{Th1} - V_{Th2}$$

$$V_{Th} = \frac{V_{Th1} + V_{Th2}}{2}$$

$$V_{ov} = V_{GS} - V_{Th}$$

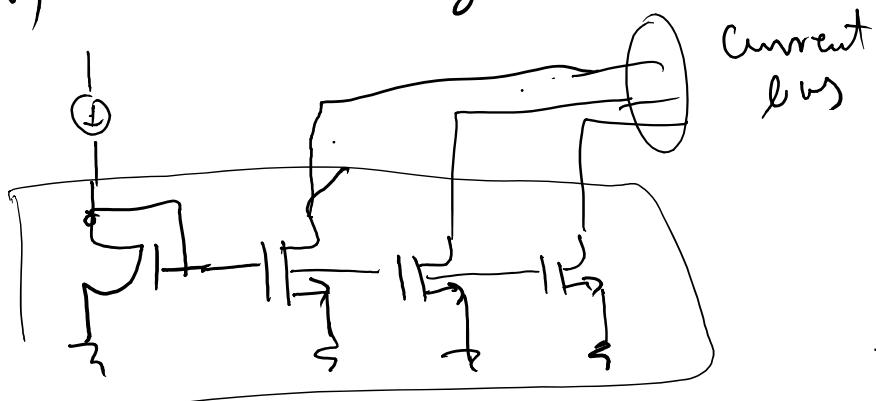
Advantages: less dense

Disadv: - variations due

to R_s

- \rightarrow mismatch

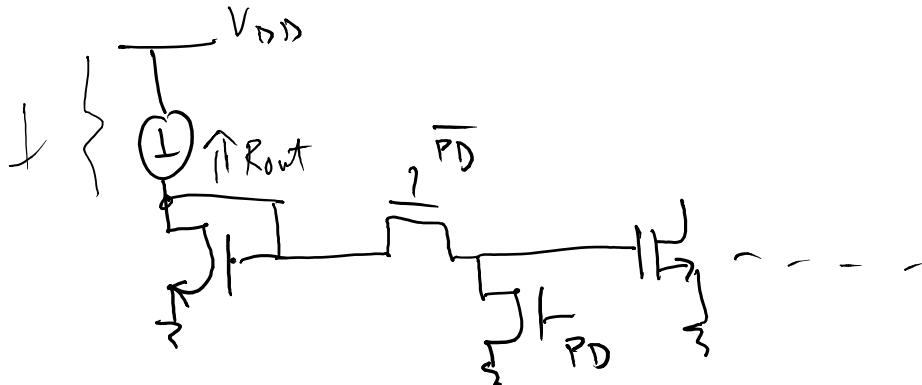
b) Current routing:



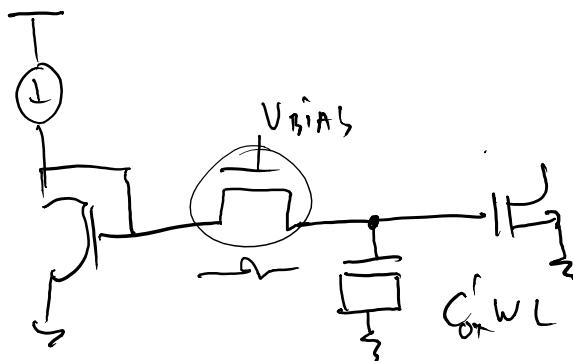
Advantages: - matching
- no supply R

Disadv: - lots of wires

route currents globally
route voltages locally



② Supply filtering:

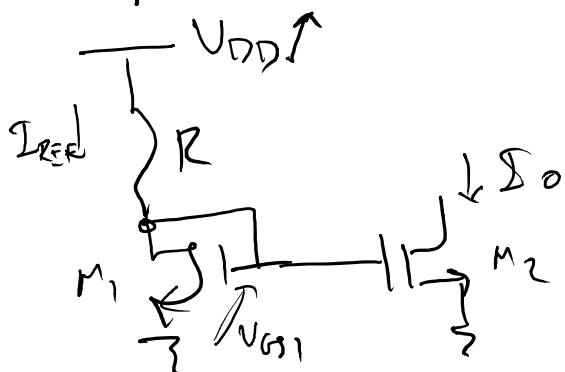


References:

- a) Supply independence
- b) Temperature independence

a) Supply independent biasing.

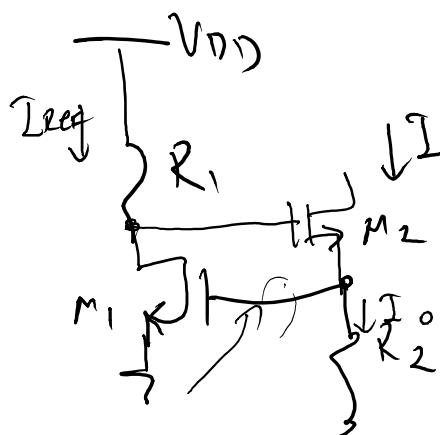
Example how not to do it



$$I_{REF} = \frac{V_{DD} - V_{GS1}}{R}$$

$$V_{GS1} = V_{th} + \sqrt{\frac{2I_{REF}}{k'(\frac{w}{l})}}$$

$$I_o = I_{REF} \sim \frac{V_{DD}}{R} - \sqrt{e^{-\frac{V_{GS1}}{V_{DD}}}}$$



$$I_o = \frac{V_{GS1}}{R_2}$$

$$I_{REF} = \frac{V_{DD} - V_{GS2} - V_{GS1}}{R_1}$$

$$V_{GS1} = \sqrt{\frac{2I_{REF}}{k'(\frac{w}{l})}}$$

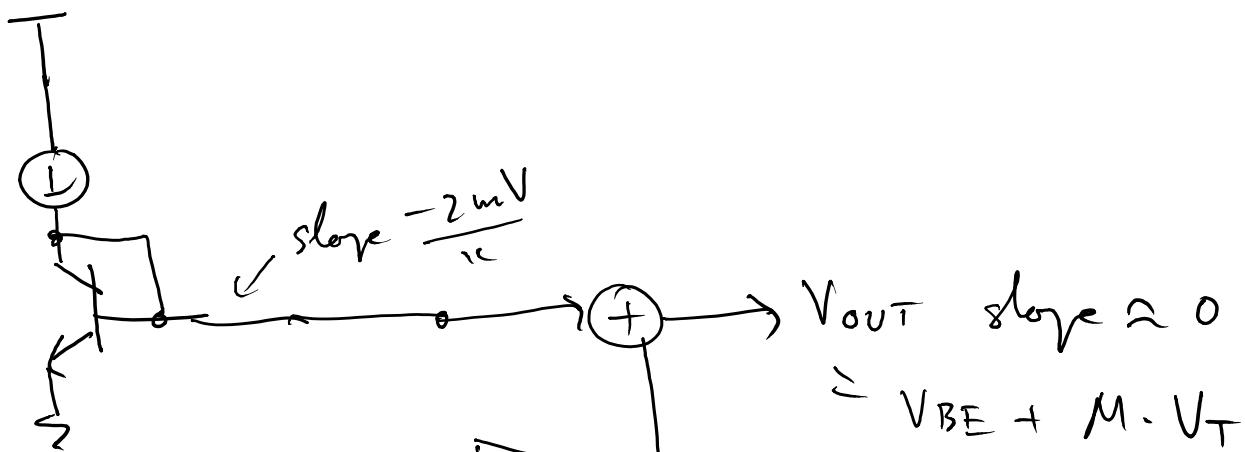
$$I_o \sim V_{GS1} \sim \sqrt{I_{REF}} \sim \sqrt{V_{DD}}$$

β JTs: $I_o \sim \ln(V_{DD})$

b) Temperature independence :

study $\frac{dV_{BE}}{dT} = -2 \frac{mV}{K}$

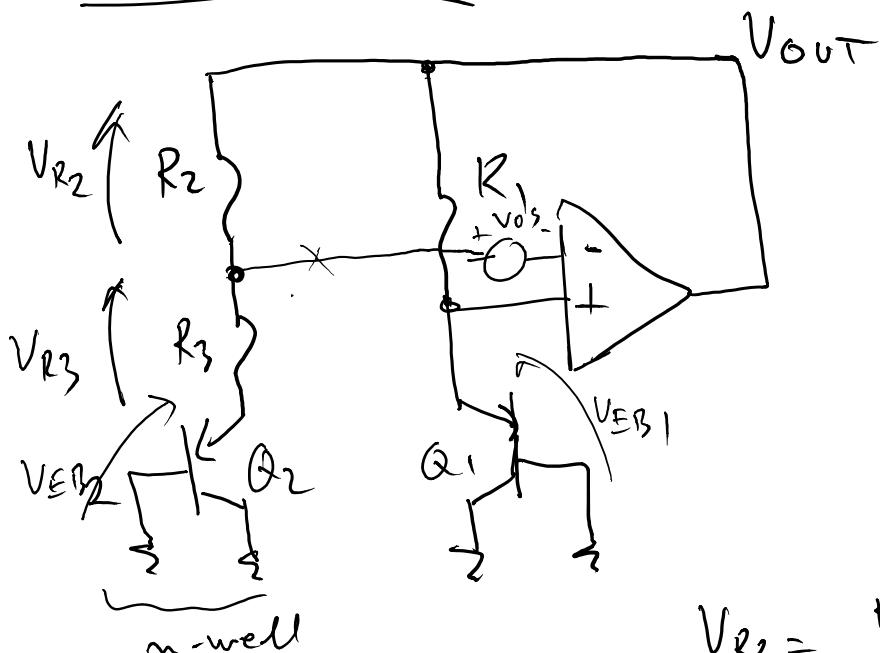
$$\frac{dV_T}{dT} = \frac{k}{q} = +0.086 \frac{mV}{K}$$



$$\frac{dV_{out}}{dT} = \frac{dV_{BE}}{dT} + M \frac{dV_T}{dT}$$

$$M = 23$$

In CMOS:



$$\Delta V_{EB} = V_{EB1} - V_{EB2}$$

$$= V_T \ln \frac{I_1}{I_{S1}} - V_T \ln \frac{I_2}{I_{S2}}$$

$$= \underbrace{(V_T) \ln \left(\frac{I_1}{I_2} \cdot \frac{I_{S2}}{I_{S1}} \right)}_{\text{gain}}$$

$$V_{R2} = \frac{R_2}{R_3} V_{R3} = \frac{R_2}{R_3} (V_{EB1} + V_{OS} - V_{EB2})$$

$$V_{R2} = \frac{R_2}{R_3} (\Delta V_{EB} + V_{OS})$$

$$V_{OUT} = V_{EB2} + V_{R2} + V_{R3} = V_{EB2} + \left(1 + \frac{R_2}{R_3} \right) \cdot (\Delta V_{EB} + V_{OS})$$

$$I_1 > I_2 \quad I_1 \approx 10 I_2 \quad (\text{tweak } R_{R3} \text{ & } R_1) \quad \underline{\underline{m}} \quad \underline{\underline{V_T \ln(\)}}$$

$$I_{S2} > I_{S1} \Rightarrow A_2 > A_1 \quad A_2 \approx 10 A_1$$

$$V_T \ln 100 = 120 \text{ mV} \Rightarrow \left(1 + \frac{R_2}{R_3} \right) \approx (5 - 6) \times$$