self - independent biasing.
Current Source (cont.)

lect#8&9
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→ end.

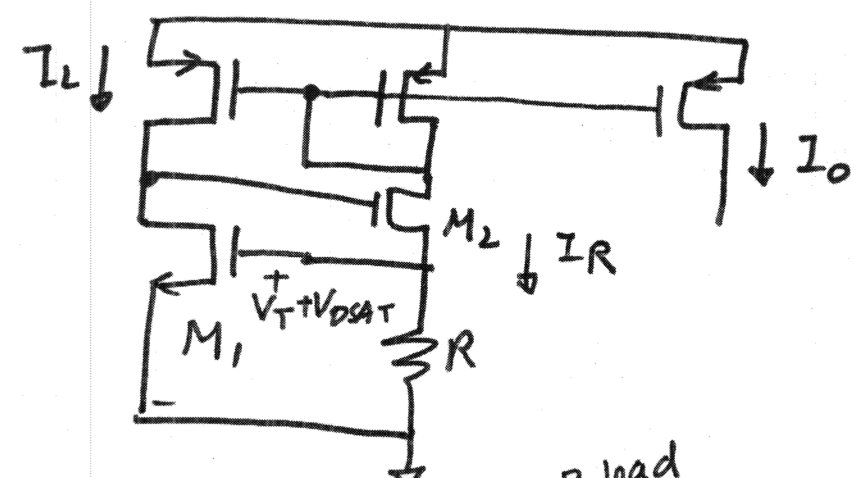
What you can use as REFERENCE current?

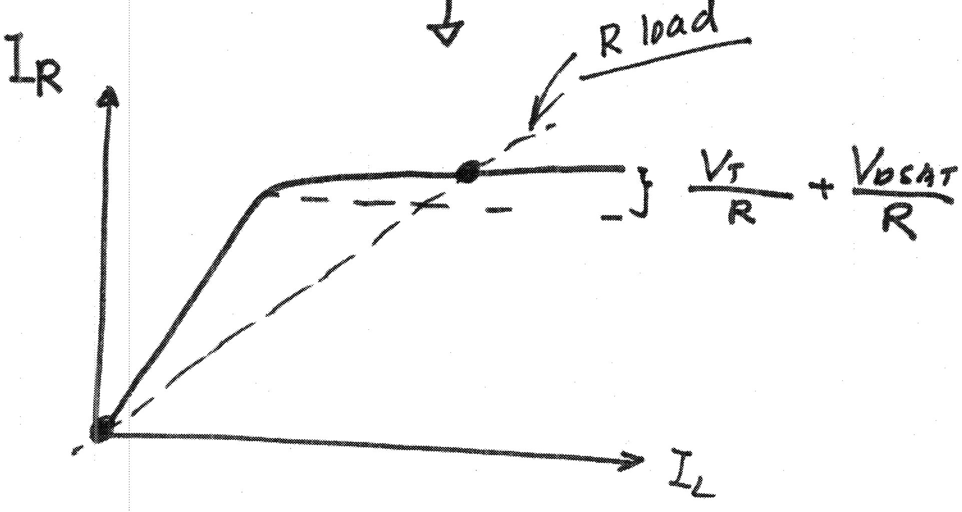
Problems: I_{REF} ↑ 10%
V_{dd} ↑ 10%

We want to find sensitivity:

$$\frac{\partial I_{REF}}{\partial V_{DD}} \longrightarrow \text{more often.} \quad \frac{\partial I_{REF}/I_{REF}}{\partial V_{DD}}.$$

How to design a good reference current?





$$V_{GS_1} = I_R \cdot R = V_{DSAT} + V_{T_1}$$

$$= \sqrt{\frac{2 I_{DS_1}}{\underbrace{\mu C_{ox}}_{k'} \left(\frac{W}{L}\right)_1}} + V_{T_1}$$

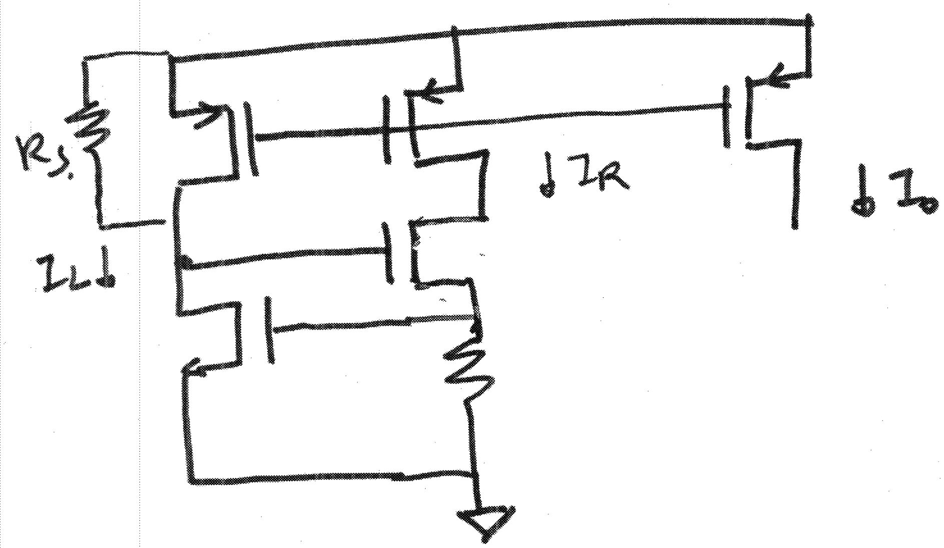
V_{DSAT} & I_{DS_1} we don't want this!

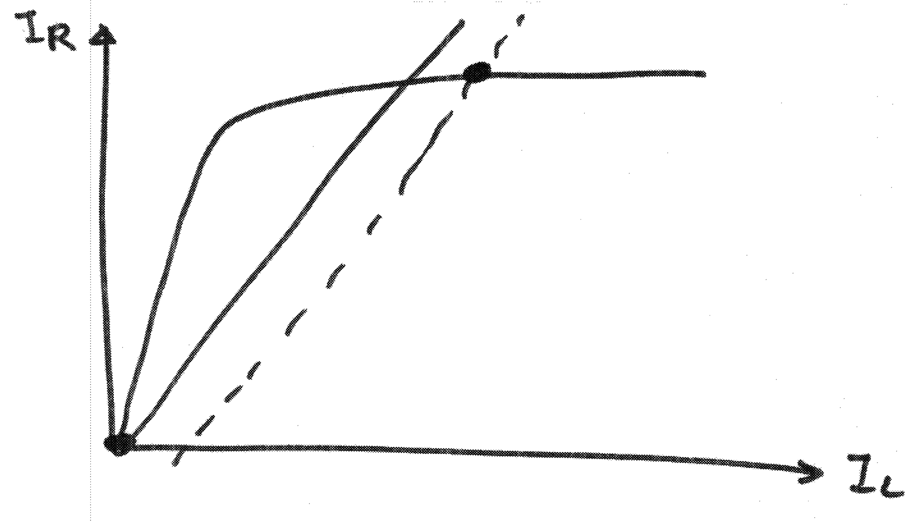
$V_{GS_1} \approx V_{T_1}$

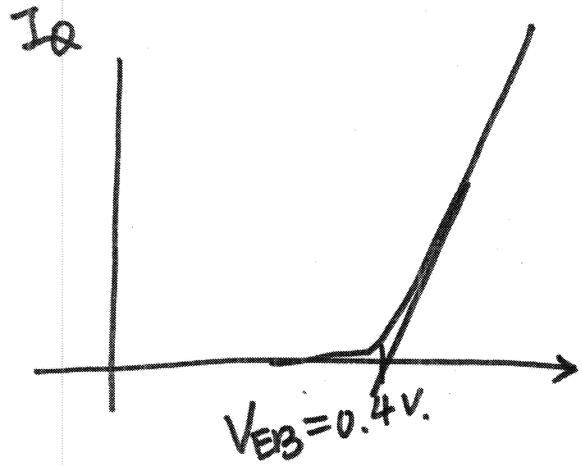
so how to do it?

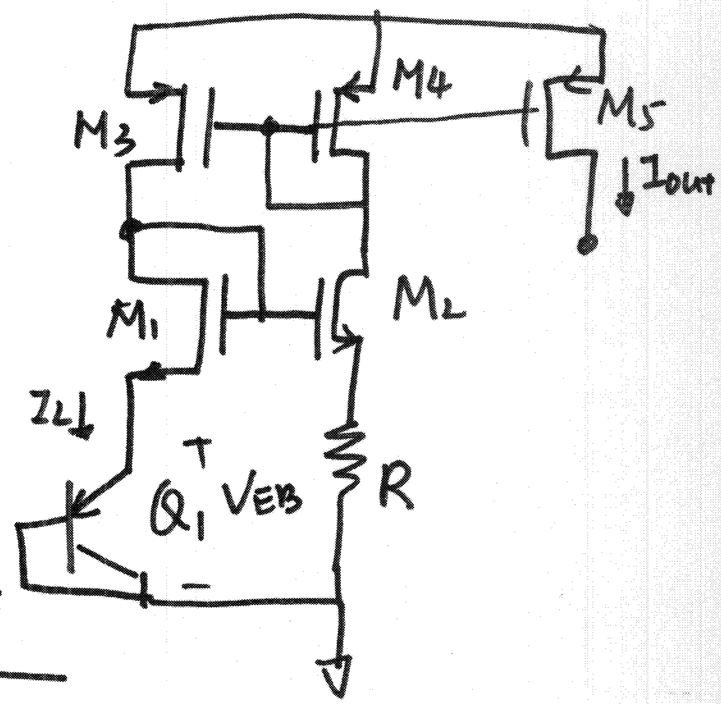
$\left(\frac{W}{L}\right)\uparrow \gg 1.$

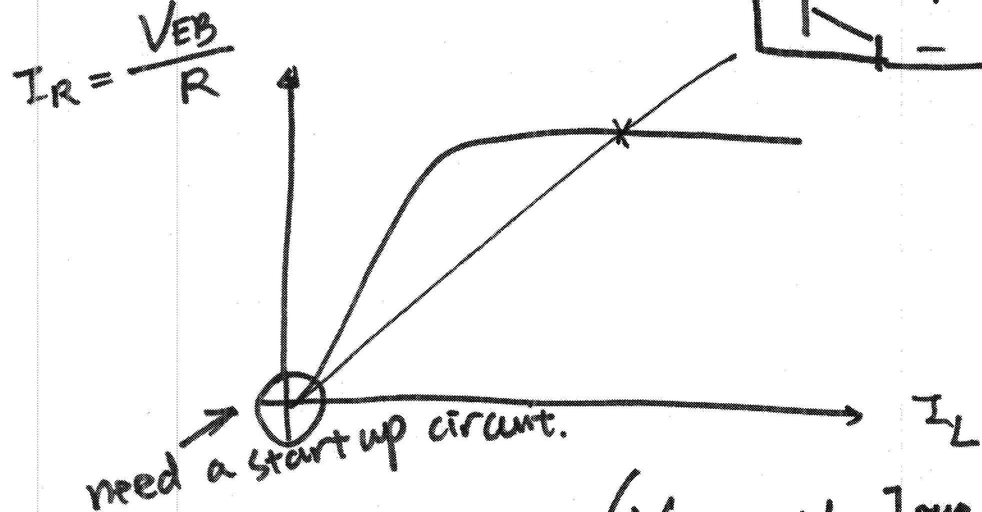
V_t - Referenced self-Biased Circuit











$$I_{out} = \frac{V_{EB}}{R} = \frac{\left(V_{thermal} \ln \frac{I_{out}}{I_s}\right)}{R}$$

$\frac{\Delta I}{I}$ = parts per million / °C = ppm/°C

↳ $\frac{\Delta I}{I}$ normalized sensitivity

if 1 mA current source, parts per million = 1 mA / 1 million
= 1 nA

if 20°C, 1 μA current source

changs 50°C to 70°C,

if you have 100 ppm/°C as normalized sensitivity

50°C × 100 ppm/°C = 5000 ppm

$$\frac{\Delta I}{I} = 5000\ ppm \Rightarrow \Delta I = \frac{5\times10^3}{10^6} * I = 0.5\%\, I$$

0.5% · 1 μA.

$$\frac{1}{I_{out}}\frac{\partial I_{out}}{\partial T} = ?$$

$$I_{out} = \frac{V_{EB}}{R}$$

$$\frac{\partial I_{out}}{\partial T} = \frac{1}{R}\frac{\partial V_{EB}}{\partial T} - \frac{V_{EB}}{R^2}\frac{\partial R}{\partial T}$$

$$TC = \frac{1}{V_{EB}}\frac{\partial V_{EB}}{\partial T} - \frac{1}{R}\frac{\partial R}{\partial T}$$

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$I_S \propto AE$ $\quad I_{EC} = I_S e^{V_{EB}/V_{therm}}$

similar to

$I_S \propto \frac{W}{L}$

$I_{S_2} = n I_{S_1}$

$I_{out} R + V_{EB_2} = V_{EB_1}$

$I_{out} \cdot R + V_{therm} \cdot \ln\left(\frac{I_{out}}{n I_{S_1}}\right) = V_{therm} \cdot \ln\left(\frac{I_{out}}{I_{S_1}}\right)$

$I_{out} = \frac{V_{therm}}{R} \ln(n)$

$\Rightarrow R I_{out} = V_{thermal} \cdot \ln(n)$

what is TC of this ?

$V_{thermal} = KT.$