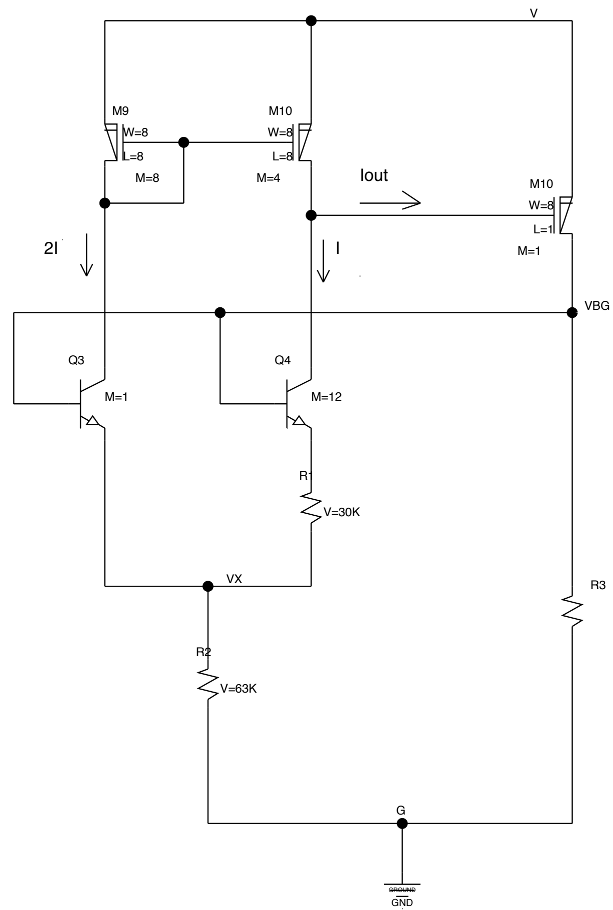
Vbg and mos current mirror sensitivity calculation



VBGcore

Vbg and mos current mirror sensitivity calculation:

$g_{m(Q3)} = \frac{2 \cdot I}{V_T}$, where Vt=26mV at room temperature.

$$I = \frac{V_T \cdot \ln(24)}{R_1} = \frac{26mV \cdot \ln(24)}{30k} = 2.75uA$$

$g_{m(Q4)} = \frac{I/V_T}{1 + \frac{I \cdot R_1}{V_T}} = \frac{I/V_T}{1 + \frac{2.75uA \cdot 30k}{26mV}} = \frac{I/V_T}{1+3.17} \cong \frac{I/V_T}{4}$, so the ratio of Gm between Q3 and Q4 is:

$$\frac{g_{m(Q3)}}{g_{m(Q4)}} = \frac{\frac{2I}{V_T}}{\frac{1}{4} \cdot \frac{I}{V_T}} = 8$$

A small voltage variation of Vbg will roughly equal to a small voltage variation on node Vx, therefore the total current through R2 changes by:

$$\Delta I_{R2} = \frac{\Delta V_X}{R_2} \cong \frac{\Delta V_{BG}}{R_2} = \Delta I_{C(Q3)} + \Delta I_{C(Q4)},$$

Since Gm(Q3) is 8 times of Gm(Q4), so the 8/9 parts of the ΔI_{R2} current flow through Q3, and 1/9 parts of the ΔI_{R2} current flow through Q4. The M9 to M10 is a 2:1 mirror, therefore the output current is:

$\Delta I_{OUT} = (\frac{4}{9}\Delta I_{R2} - \frac{1}{9}\Delta I_{R2}) = \frac{1}{3}\Delta I_{R2} = \frac{1}{3} \cdot \frac{\Delta V_{BG}}{R_2}$, So the trans-conductance of VBG to Iout is:

$$G_{m(V_{BG})} = \frac{\Delta I_{OUT}}{\Delta V_{BG}} = \frac{1}{3R_2}$$

The M10 PMOS device is running 2.75uA current and it's 4 squares (W=L=8um, M=4), so the current density is roughly 2.75/4=0.6875uA per square. For the typical 0.35um technology this means that (Vgs-Vt)/2=75mV approximately, which means that the pmos Gm is about 1/3 the Gm of a PNP running the same bias current. Also, remember that $I_{R2} = 3I = 8.25uA = \frac{V_X}{R_2}$, so, $V_X = 8.25uA \times 63k = 519.75mV$, the trans-conductance of M10 is:

$$G_{m(M10)} = \frac{I}{\frac{(V_{gs} - V_{t(pmos)})}{2}} = \frac{1}{3R_2} \cdot \frac{V_X}{75mV} = \frac{1}{3R_2} \cdot \frac{519.75mV}{75mV} = \frac{6.93}{3R_2} \cong \frac{7}{3R_2}$$

, so the ratio of the trans-conductance of M10 to VBG is as follows:

$$\frac{G_{m(M10)}}{G_{m(V_{BG})}} = \frac{\frac{7}{3R_2}}{\frac{1}{3R_2}} = 7$$

This means that **1mV mis-match of M9 and M10 mirror causes 7mV changes in VBG voltage.**

The typical Vt mismatch in the 0.35um technology is roughly 15mVum to 30mVum, so the M10, M9 mirror mismatch is:

$$\Delta V_{t(M10,M9)} = \frac{(15 \sim 30)mV \cdot \mu m}{\sqrt{8 \times 8 \times 4}\mu m} = 1 \sim 2mV$$

So, the Bandgap voltage will change by 7~14mV. This voltage should be considered in the design of bandgap voltage trimming range. More important is that the Vt mismatch will cause a T.C. in the bandgap voltage over temperature.