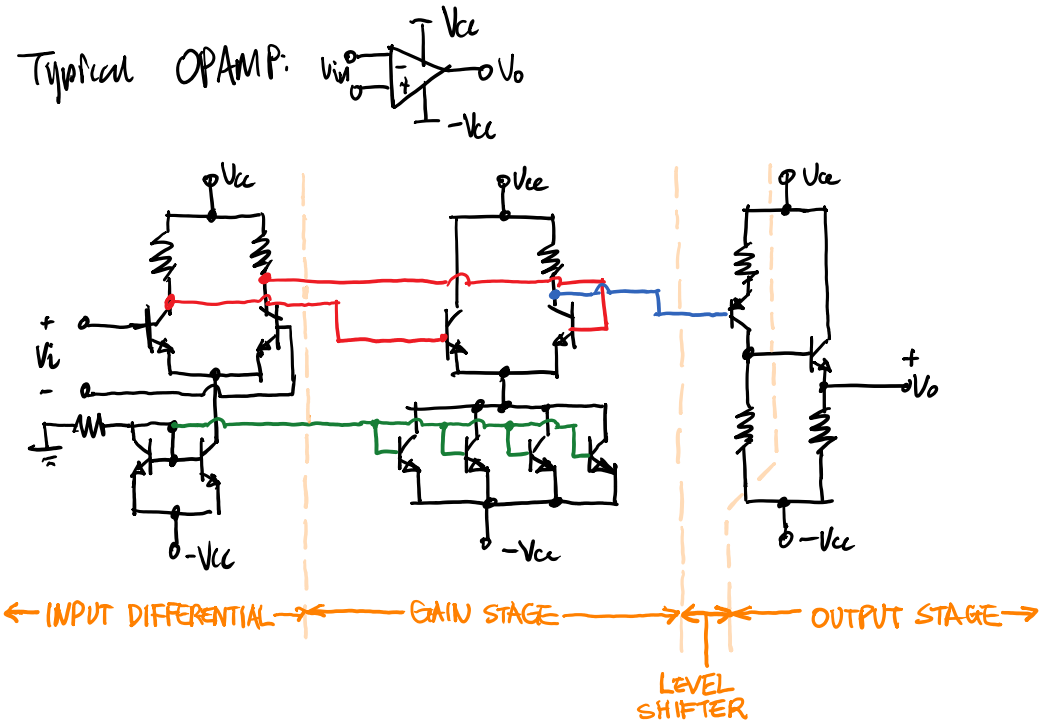
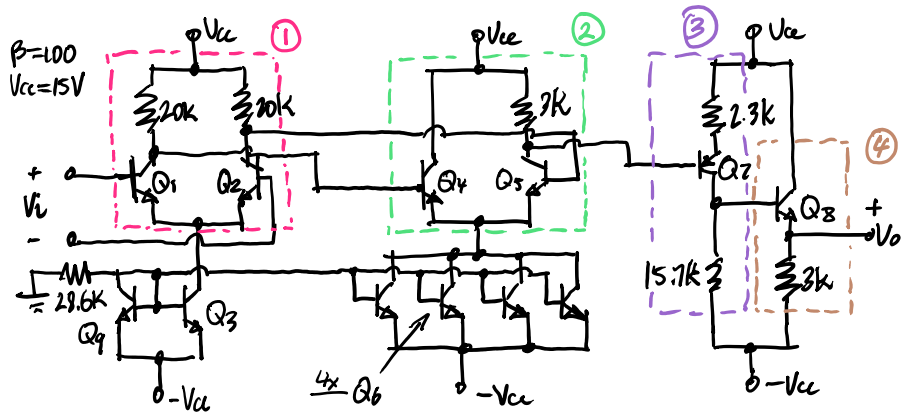
OPAMP

November 6, 2017 3:33 PM

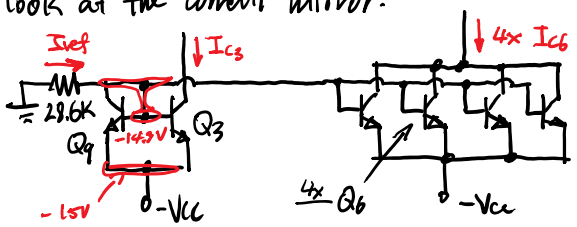
Typical OPAMP:



Analyzing OPAMP:



First, look at the current mirror:



$I_{ref} = \frac{14.3V}{28.6k} = 0.5mA$

$I_{C3} = I_o = I_{ref} \cdot \frac{1}{1+\frac{N}{\beta}}$ ← N = 6 transistors in this current mirror; β = 100

$\approx 0.5mA$

Next, consider the differential amplifiers:

Q1 and Q2: $I_{E1} = I_{E2} \approx I_{C1} = I_E = \frac{1}{2} I_{C1} = 0.25mA$.

$g_{m1} = g_{m2} = \frac{0.25mA}{} = 0.010\,\mho$

Q1 and Q2: $I_{E1}=I_{E2}\approx I_{C1}=I_e=\frac{1}{2}I_{C1}=0.25mA$.

$g_{m1}=g_{m2}=\frac{0.25mA}{25mV}=0.010\mho$

$r_{\pi1}=r_{\pi2}=\frac{100}{0.010\mho}=10k$

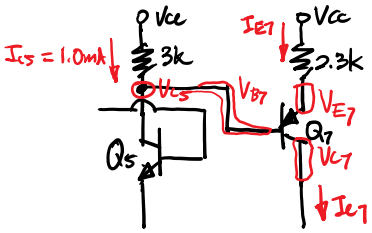
$I_{C6}\approx 0.5mA$

Q4 and Q5: $I_{E4}=I_{E5}\approx I_{C4}=I_{C5}=\frac{1}{2}(4\times I_{C6})=1.0mA$

$g_{m4}=g_{m5}=\frac{2mA}{25mV}=0.040\mho$

$r_{\pi4}=r_{\pi5}=\frac{100}{0.040\mho}=2.5k$

Now look at the PNP transistor:



$V_{C5}=V_{B7}=15V-(1mA)(3k)=12V$

PNP: $V_{E7}=V_{B7}+0.7V=12.7V$

$I_{E7}=\frac{15V-12.7V}{2.3k}=1.0mA$

$I_{C7}\approx 1.0mA$

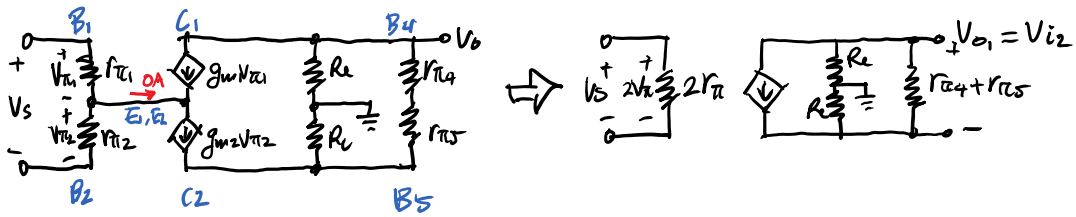
$g_{m7}=\frac{1.0mA}{25mV}=0.040\mho$

$r_{\pi7}=\frac{100}{0.040\mho}=2.5k$

Input resistance of PNP: $R_{i7}=r_{\pi7}+\beta R_{E7}=230k$

Input resistance of Q8: $R_{i8}=(1+\beta)R_{E8}+r_{\pi8}\approx(1+\beta)R_{E8}=303k$

Midband of input differential amplifier ①



$V_{o1}=V_{i2}=-g_{m1}V_{\pi1}\left((2R_c)\,/\!/\,(r_{\pi4}+r_{\pi5})\right)$

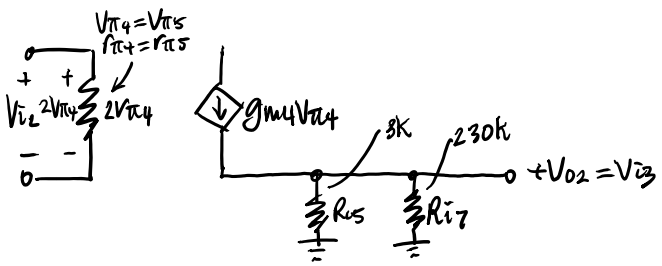
$=-(0.01)V_{\pi1}\left((2\cdot 20k)\,/\!/\,(5k)\right)$

$=-44.4V_\pi$

$V_{\pi1}=\frac{1}{2}V_s$

$A_{m1}=\frac{V_{o1}}{V_s}=\boxed{-22.2}$

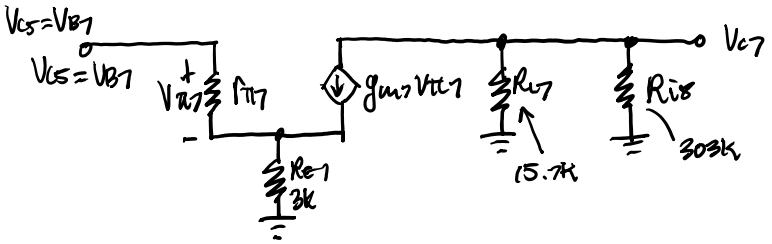
Midband of Intermediate diff. amp. ②



$V_{o2}=V_{i3}=g_{m4}V_{\pi4}\left(R_{c5}\,/\!/\,R_{i7}\right)$

$$V_{o2} = V_{i3} = g_{m4} V_{\pi 4} (R_{C5} \parallel R_{i7})$$
$$= 118.5 V_{\pi 4}$$
$$V_{\pi 4} = \tfrac{1}{2} V_{i2}$$
$$A_{m2} = \frac{V_{o2}}{V_{i2}} = \boxed{59.2}$$

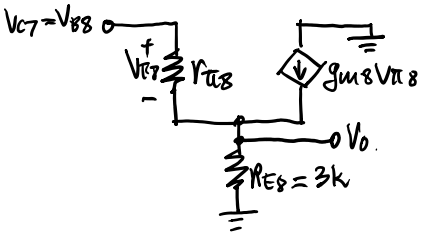
Midband of the PNP ③



$$V_{c7} = -g_{m7} V_{\pi 7} (R_{C7} \parallel R_{i8})$$
$$= -597 V_{\pi 7}$$

$$V_{\pi 7} = \frac{r_{\pi 7}}{r_{\pi 7} + (1+\beta) R_{E7}} \cdot V_{B7}$$
$$= 0.011 V_{B7}$$
$$A_{m3} = \frac{V_{c7}}{V_{B7}} = \boxed{-6.4}$$

Midband of output stage ④



$$V_o = (1 + g_{m8} V_{\pi 8}) \cdot 3k$$
$$V_{\pi 8} = \frac{r_{\pi 8}}{r_{\pi 8} + (1+\beta)(3k)} \cdot V_{B8}$$
$$A_{m4} = \frac{V_o}{V_{B8}} \approx \boxed{1}$$

Total Gain: $A_m = A_{m1} A_{m2} A_{m3} A_{m4} = \boxed{8411}$