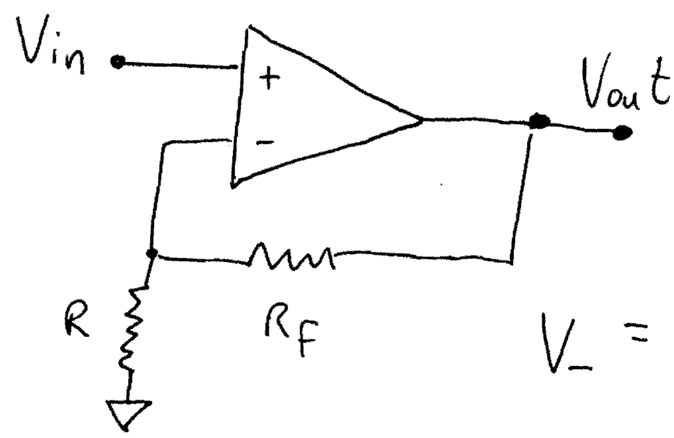
Non-Inverting Amplifier :

The name "non-inverting" is due to the amplified signal which is in phase with Vin.



$$V_{out} = G(V_+ - V_-)$$

$$V_+ = V_{in}$$

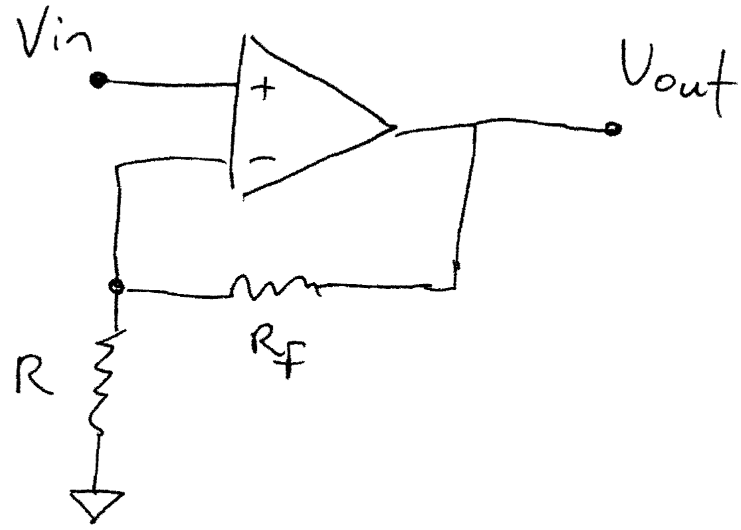
$$F = \left(\frac{R}{R+R_F}\right) \qquad V_- = \left(\frac{R}{R+R_F}\right) V_{out}$$

V_- = potential between V_- and ground, which is the same as V_R.

$$V_{out} = G(V_+ - V_-) = G(V_{in} - F\,V_{out})$$

$$V_{out}(1 + GF) = G\,V_{in}$$

$$\boxed{V_{out} = \left(\frac{G}{1+GF}\right) V_{in} \cong \frac{1}{F} V_{in}} \quad (\text{when } GF \gg 1)$$



$$V_{out} \cong \frac{1}{F} V_{in} = \left(\frac{R + R_F}{R} \right) V_{in}$$

$$\boxed{V_{out} \cong \left(1 + \frac{R_F}{R} \right) V_{in}}$$

Remember that this is the ideal case. Unless you trim the offsets there will be an offset potential $\underline{V_{off}}$ (~μV range minimum)

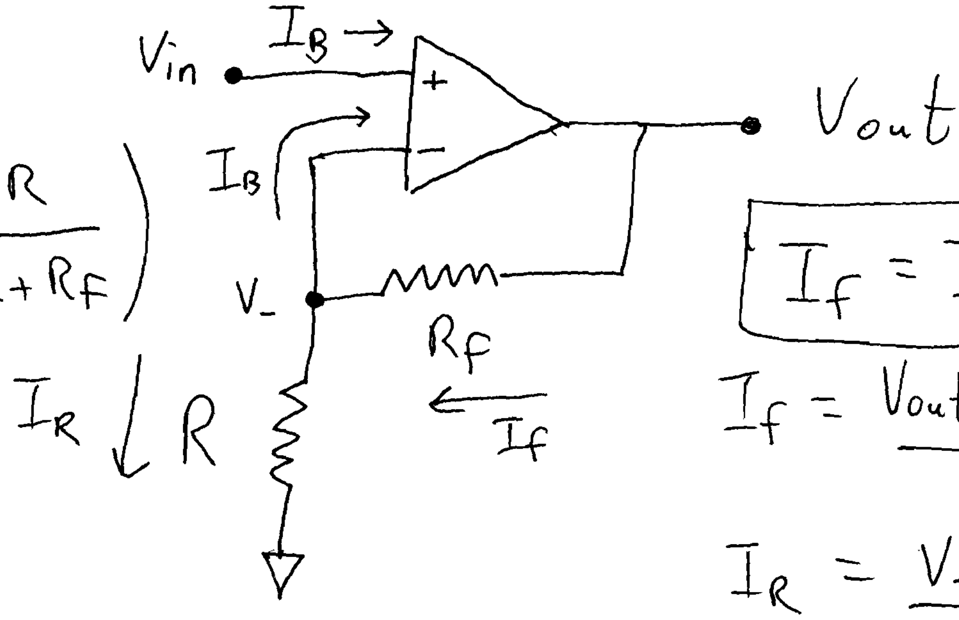
True signal : ... (almost)

$$\boxed{V_{out} \cong \left(1 + \frac{R_F}{R} \right) \left(V_{in} + V_{off} \right)}$$

Input Bias Current:

We already disussed the offset potential. There is another non-ideal behavior called Input Bias Current.

$$F = \left(\frac{R}{R+R_F}\right)$$



$$\boxed{I_f = I_R + I_B}$$

$$I_f = \frac{V_{out} - V_-}{R_F}$$

$$I_R = \frac{V_-}{R}$$

$I_f = I_R + I_B$ implies $\dfrac{V_{out} - V_-}{R_F} = \dfrac{V_-}{R} + I_B$

$$\rightarrow \quad V_{out} = I_B R_F + V_- \underbrace{\left(1 + \frac{R_F}{R}\right)}_{= \frac{1}{F}}$$

Now calculate

$$V_{out} = G(V_+ - V_-)$$

$$V_{out} = G\left(V_{in} - F V_{out} + F I_B R_F\right)$$

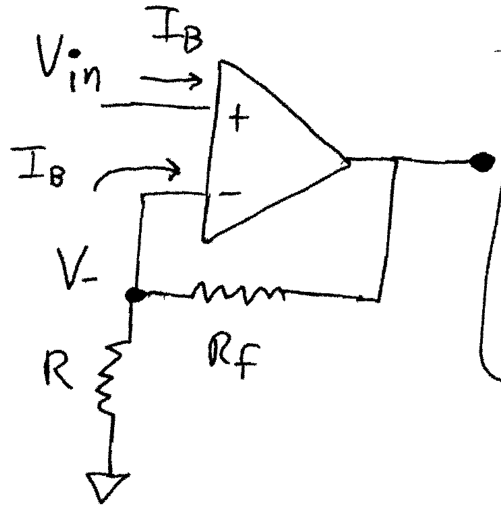
$$V_{out}\left(1 + GF\right) = G\left(V_{in} + F I_B R_F\right)$$

$$V_{out} \cong \frac{1}{F}\left(V_{in} + F I_B R_F\right)$$

(when $GF \gg 1$)

$$\boxed{V_{out} = \frac{1}{F} V_{in} + \underbrace{I_B R_F}_{I_B \text{ correction}}}$$

Real Total Picture:



"offset potential"

$$\boxed{V_{out} = \left(1 + \frac{R_F}{R}\right)\left(V_{in} + V_{off}\right) + I_B R_F}$$

"I_B contribution"

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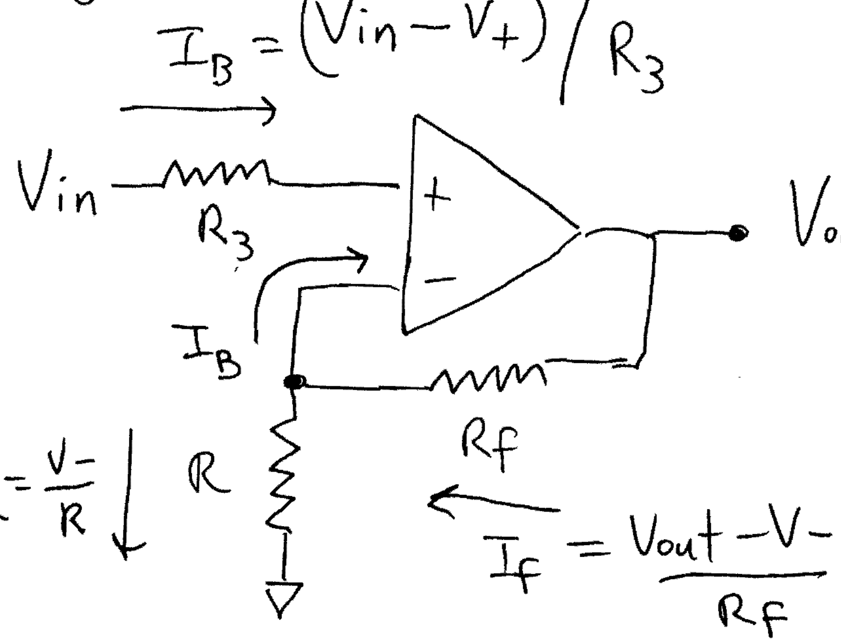
Correction For I_B:

Recall to fix V_{off} we use a potentiometer. How do you fix the I_B correction?



$V_{out} = \left(1 + \frac{R_f}{R}\right) V_{in} + \underbrace{I_B R_f}_{}$

want to get rid of this...

Solution: $\boxed{R_3 = R_f \,||\, R = \frac{R R_f}{R + R_f}}$

Proof: $I_B = \frac{(V_{in} - V_+)}{R_3}$,

therefore $V_{in} = I_B R_3 + V_+$

$$V_{in} = I_B R_3 + V_+ = \frac{I_B R_F}{\left(1 + \frac{R_F}{R}\right)} + V_+$$

$$F = \frac{R}{R + R_F} \; ; \; \frac{1}{F} = \left(1 + \frac{R_F}{R}\right)$$

(1) $$\boxed{V_+ = V_{in} + F I_B R_F}$$

Use $I_B + I_R = I_F$

$$I_B + \frac{V_-}{R} = \frac{V_{out} - V_-}{R_F}$$

(2) $$\Rightarrow \boxed{V_- = F V_{out} - I_B R_F F}$$

Combine (1) and (2)

and compute $V_{out} = G(V_+ - V_-)$

$$V_{out} = G(V_+ - V_-) = G\left[V_{in} - F I_B R_f - (F V_{out} - I_B R_f F)\right]$$

$$V_{out} = G\left[V_{in} - F V_{out}\right]$$

$$V_{out} \cong \frac{1}{F} V_{in}$$

or

$$\boxed{V_{out} = \left(1 + \frac{R_f}{R}\right) V_{in}}$$

when

$$\boxed{R_3 = R_f \| R = \frac{R_f R}{R_f + R}}$$