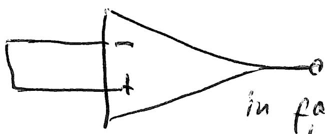
# Non-ideality of OpAmps

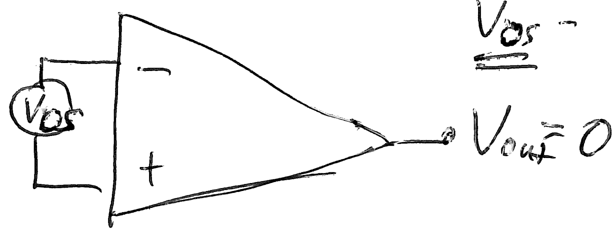
## Input voltage offset




$V_{out} \neq 0$ due to internal input voltage offset.

in fact it is often rails.

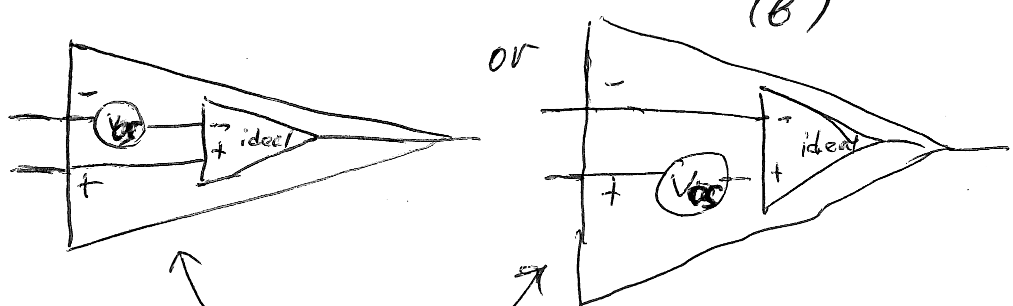
Voltage required to get $V_o = 0$ is called $V_{os}$ -




## Impact of $V_{io}$

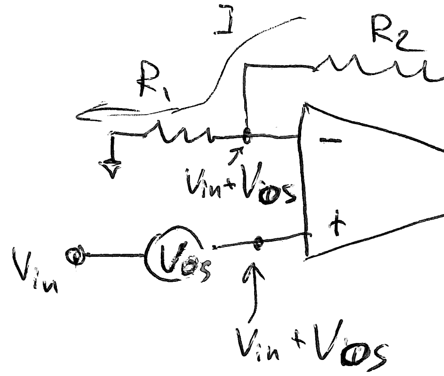
It is convenient to treat non-ideal OpAmp as ideal + some disturbance.

(a) or (b)




they are equivalent except the $V_{os}$ sign flip

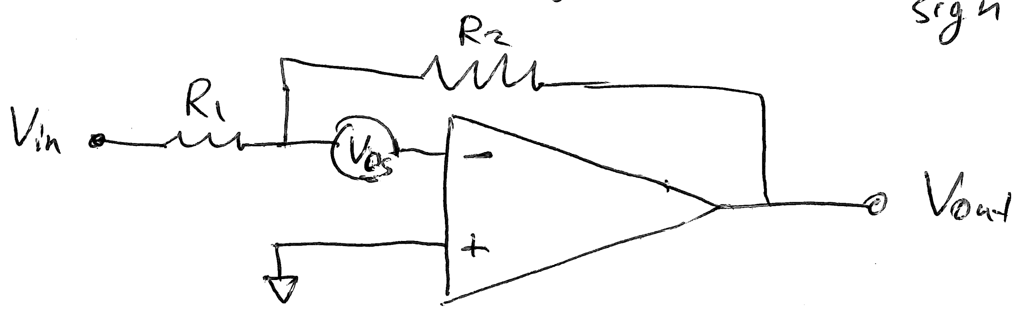
## Non-inverting Op-Amp




$$V_{out} = \overbrace{\underbrace{\frac{V_{in}+V_{os}}{R_1}}_{I} \cdot R_2}^{V_{R_2}} + (V_{in}+V_{os})$$

$$= \left(1+\frac{R_2}{R_1}\right)V_{in} + \underbrace{\left(1+\frac{R_2}{R_1}\right)V_{os}}_{\text{input offset contribution}}$$

HW 1 Show that model (a) is equivalent to (b), i.e. prove that $V_{io}$ contribution to the output is the same as above in the following model. Mind the (−) sign.



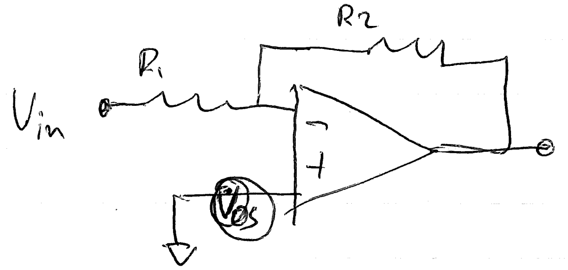

Some spec. sheet values

| | | |
|---|---|---|
| LM741 | $V_{os}$ = | $2 \div 6\,mV$ |
| OP 27 | $V_{os}$ = | $30 \div 100\,\mu V$ |

Moreover $V_{os}$ has temperature dependence and drifts with time.

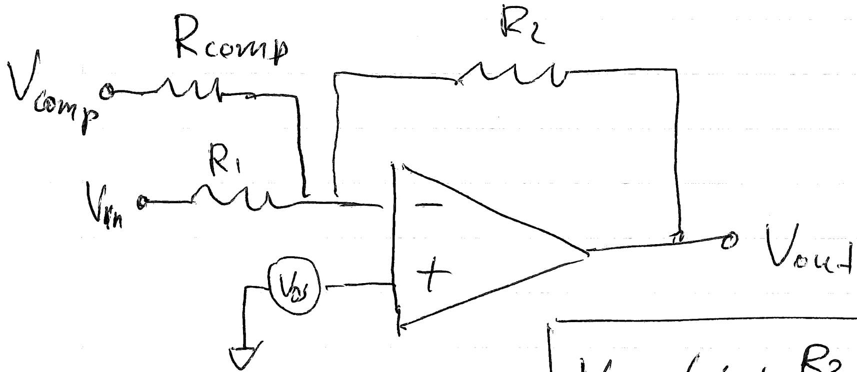
# How to compensate Input offset voltage?

by adding compensating voltage via adder circuit for example




$$V_{out} = -\frac{R_2}{R_1}V_{in} + V_{os}\frac{(R_1+R_2)}{R_1}$$

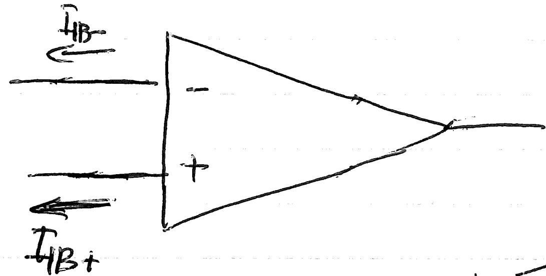
So we need to provide compensating voltage




$$\boxed{V_{os}\left(1+\frac{R_2}{R_1}\right) = \frac{R_2}{R_{comp}}V_{comp}}$$

# Input Bias current

Unlike an ideal OpAmp story, the Inputs of this op-amp might feed or source current




$I_B$ is defined as

$$I_{IB} = \frac{I_{IB-} + I_{IB+}}{2}$$

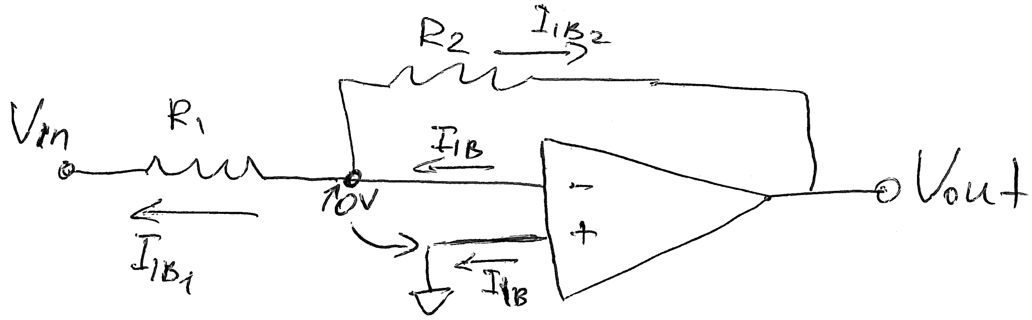
input bias current.

For simplicity it is often assumed or modeled that

$$I_{IB+} = I_{IB-} = I_{IB}$$

By the way direction of $I_{IB}$ could be any : in or out

# Inverting opAmp and $I_{IB}$

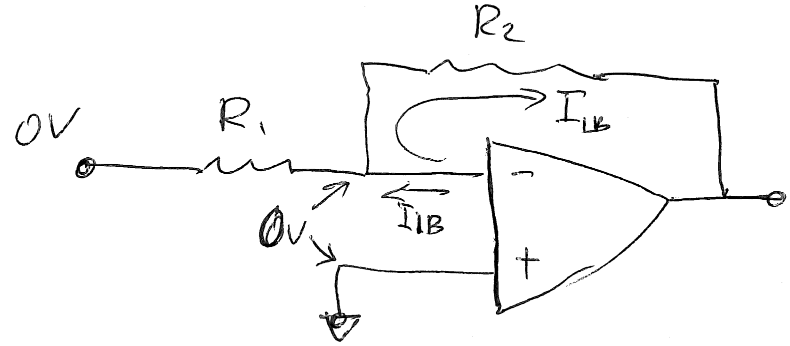



We will use principle of superposition

$V_{out}$ = Sum of $V_{in}$ contrib $= -\frac{R_2}{R_1} V_{in}$
and $I_{IB}$ contribution.

First notice $V_+ = 0$ there is no voltage drop on hook up wire.

## Bias current contribution

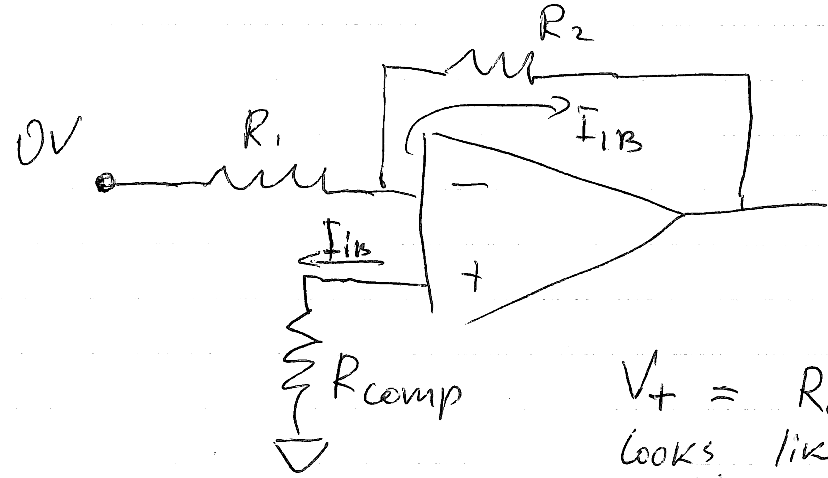



$$\boxed{V_{out_{IB}} = -R_2 I_{IB}}$$

Is it a big deal?

| OpAmp | $I_{IB}$ | $V_{out_{IB}}$ for $1k\Omega$ $R_2$ | $V_{out_{IB}}$ for $R_2 = 1M\Omega$ |
|---|---|---|---|
| LM741 | $80 \div 500$ nA | $80 - 500\,\mu V$ | $80 - 500$ mV ← wow! |
| OP27 | $15 \div 80$ nA | $15 \div 80\,\mu V$ | $15 \div 80$ mV |

# How to cure non zero $I_{IB}$ problem?




$V_+ = R_{comp} I_{iB}$

Looks like offset voltage problem

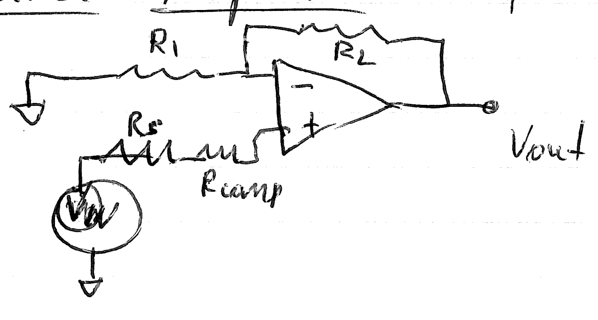
$$\Rightarrow \quad V_{comp} = (R_{comp} \cdot I_{IB})\left(1 + \frac{R_2}{R_1}\right)$$

We want $V_{comp} + V_{out_{iB}} = 0$

$$R_{comp}\left(\frac{R_1 + R_2}{R_1}\right) - R_2 = 0$$

$$\Rightarrow \boxed{R_{comp} = \frac{R_2 R_1}{R_1 + R_2} = R_2 // 1}$$

Notice that similar case can be shown for Non-Inverting op Amp but one should <u>remember</u> about <u>source</u> <u>impedance</u> of input voltage



## Input offset current

Usually $I_{IB-} \neq I_{IB+}$

$\rightarrow I_{IO} = I_{IB-} - I_{IB+}$

| Op Amp | $I_{IO}$ |
|---|---|
| LM741 | $20 \div 200nA$ |
| OP27 | $12 \div 75nA$ |

**HW2**

Show the contribution of $I_{IO}$ to the non compensated for $I_{IB}$ inverting OpAmp output voltage.

**HW3**

Do the same but for $I_{IB}$ compensated inverting Op Amp.

Hint: Use superposition principle