Non-ideality of OpAmps

Input voltage offset

\[ V_{os} \neq 0 \quad \text{due to internal input voltage offset.} \]

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) \hspace{1cm} \text{or} \hspace{1cm} (b)

\[ \text{they are equivalent except the } V_{os} \text{ sign flip} \]
Non-inverting Op-Amp

\[
\text{Vout} = \frac{\text{Vin} + \text{Vos}}{R_1} \cdot R_2 + (\text{Vin} + \text{Vos})
\]

\[
= \left( 1 + \frac{R_2}{R_1} \right) \text{Vin} + \left( 1 + \frac{R_2}{R_1} \right) \text{Vos}
\]

HW 1: Show that model (a) is equivalent to (b), i.e., prove that Vio contribution to the output is the same as above. In the following model, mind the (−) sign.

Some spec. sheet values

LM 741    \( V_{os} = 2 \div 6 \text{mV} \)
OP 27     \( V_{os} = 30 \div 100 \text{µV} \)

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

\[ V_{out} = -\frac{R_2}{R_1} V_{in} + V_{os} \left(\frac{R_1 + R_2}{R_1}\right) \]

So we need to provide compensating voltage

\[ V_{os} \left(1 + \frac{R_2}{R_1}\right) = \frac{R_2}{R_{comp}} V_{comp} \]
Input Bias current

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

\[ I_B \text{ is defined as } I_B = \frac{I_{B-} + I_{B+}}{2} \]

input bias current.

For simplicity, it is often assumed or modeled that

\[ I_{B+} = I_{B-} = I_{IB} \]

By the way, direction of \( I_{IB} \) could be any: in or out.
Inverting of Amp and $I_{1B}$

We will use principle of superposition:

$V_{out} = \text{Sum of } V_{in} \text{ contribution } + \frac{R_2}{R_1} V_{in}$

and $I_{1B}$ contribution.

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

Bias current contribution

Is it a big deal?

<table>
<thead>
<tr>
<th>Op Amp</th>
<th>$I_{1B}$</th>
<th>$V_{out}$ for $I_{1B}$</th>
<th>$V_{out}$ for $R_2 = 1$ MΩ</th>
</tr>
</thead>
<tbody>
<tr>
<td>LT1741</td>
<td>80 ÷ 500 nA</td>
<td>80 ÷ 500 μV</td>
<td>80 ÷ 500 mV (\rightarrow) wow!</td>
</tr>
<tr>
<td>OP27</td>
<td>15 ÷ 80 nA</td>
<td>15 ÷ 80 μV</td>
<td>15 ÷ 80 mV</td>
</tr>
</tbody>
</table>
How to cure non zero $I_{IB}$ problem?

$$V_{+} = R_{comp} I_{IB}$$
looks like offset voltage problem

$$\Rightarrow V_{comp} = (R_{comp} \cdot I_{IB}) \left(1 + \frac{R_{2}}{R_{1}}\right)$$

$\Rightarrow$ We want $V_{comp} + V_{out_{IB}} = 0$

$$R_{comp} \left(\frac{R_{1} + R_{2}}{R_{1}}\right) - R_{2} = 0$$

$$\Rightarrow R_{comp} = \frac{R_{2}R_{1}}{R_{1} + R_{2}} = R_{21/1}$$

Notice that similar case can be shown for non-inverting opamp but one should remember about source impedance of input voltage.
Input offset current

Usually \( I_{1B-} = I_{1B+} \)

\[ I_{10} = I_{1B-} - I_{1B+} \]

<table>
<thead>
<tr>
<th>Op Amp</th>
<th>( I_{10} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>LM341</td>
<td>( 20 \div 200 \text{mA} )</td>
</tr>
<tr>
<td>OP27</td>
<td>( 12 \div 45 \text{mA} )</td>
</tr>
</tbody>
</table>

HW2

Show the contribution of \( I_{10} \) to the non-compensated for \( I_{1B} \) inverting op amp output voltage.

HW3

Do the same but for \( I_{1B} \) compensated inverting op amp.

Hint: Use superposition principle