Inverting op amp with non-inverting positive reference voltage circuit

Design Goals

<table>
<thead>
<tr>
<th>Input</th>
<th>Output</th>
<th>Supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{\text{Min}}$</td>
<td>$V_{\text{Max}}$</td>
<td>$V_{\text{oMin}}$</td>
</tr>
<tr>
<td>–1V</td>
<td>2V</td>
<td>0.05V</td>
</tr>
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Design Description

This design uses an inverting amplifier with a non-inverting positive reference voltage to translate an input signal of –1V to 2V to an output voltage of 0.05V to 4.95V. This circuit can be used to translate a sensor output voltage with a positive slope and negative offset to a usable ADC input voltage range.

Design Notes

1. Use op amp linear output operating range. Usually specified under $A_{\text{OL}}$ test conditions.
2. Amplifier common mode voltage is equal to the reference voltage.
3. $V_{\text{ref}}$ can be created with a voltage divider.
4. Input impedance of the circuit is equal to $R_2$.
5. Choose low-value resistors to use in the feedback. It is recommended to use resistor values less than 100k$\Omega$. Using high-value resistors can degrade the phase margin of the amplifier and introduce additional noise in the circuit.
6. The cutoff frequency of the circuit is dependent on the gain bandwidth product (GBP) of the amplifier. Additional filtering can be accomplished by adding a capacitor in parallel to $R_1$. Adding a capacitor in parallel with $R_1$ will also improve stability of the circuit, if high-value resistors are used.
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Design Steps

\[ V_o = -V_i \times \left( \frac{R_1}{R_2} \right) + V_{\text{ref}} \times \left( 1 + \frac{R_1}{R_2} \right) \]

1. Calculate the gain of the input signal.

\[ G_{\text{input}} = \frac{R_1}{R_2} \]

\[ V_{o,\text{max}} - V_{o,\text{min}} = V_{i,\text{max}} - V_{i,\text{min}} - \frac{R_1}{R_2} \]

\[ -\frac{R_1}{R_2} = \frac{V_{o,\text{max}} - V_{o,\text{min}}}{V_{i,\text{max}} - V_{i,\text{min}}} = \frac{4.95V - 0.05V}{2V - 1V} = -1.633V \]

2. Select \( R_2 \) and calculate \( R_1 \).

\[ R_2 = 6.81 \ \text{k}\Omega \]

\[ R_1 = G_{\text{input}} \times R_2 = 1.633V \times 6.81 \ \text{k}\Omega = 11.123k\Omega \approx 11.1 \ \text{k}\Omega \text{ (Standard Value)} \]

3. Calculate the reference voltage.

\[ V_{o,\text{min}} = -V_{i,\text{max}} \times \left( \frac{R_1}{R_2} \right) + V_{\text{ref}} \times \left( 1 + \frac{R_1}{R_2} \right) \]

\[ 0.05V = -2V \times 11.11 \ \text{k}\Omega \times 6.81 \ \text{k}\Omega + V_{\text{ref}} \times 1 + 11.11 \ \text{k}\Omega \]

\[ V_{\text{ref}} = \frac{V_{o,\text{max}} + V_{i,\text{max}} \times \frac{R_1}{R_2}}{1 + \frac{R_1}{R_2}} \]

\[ = \frac{0.05V + 2V \times \frac{11.11 \ \text{k}\Omega}{6.81 \ \text{k}\Omega}}{1 + \frac{11.11 \ \text{k}\Omega}{6.81 \ \text{k}\Omega}} = 1.259V \]
Design References
See Analog Engineer's Circuit Cookbooks for TI's comprehensive circuit library.
See the circuit SPICE simulation file SBOC514.
See the Designing gain and offset in thirty seconds application report.

Design Featured Op Amp

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<td>$V_{inCM}$</td>
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<td>$V_{out}$</td>
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<td>$V_{os}$</td>
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<td>UGBW</td>
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<tr>
<td>SR</td>
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<td>#Channels</td>
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Design Alternate Op Amp

<table>
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<th>OPA376</th>
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Revision History

<table>
<thead>
<tr>
<th>Revision</th>
<th>Date</th>
<th>Change</th>
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<tbody>
<tr>
<td>A</td>
<td>February 2019</td>
<td>Downscale the title and changed title role to 'Amplifiers'. Added links to circuit cookbook landing page and SPICE simulation file.</td>
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