Band pass filtered inverting attenuator circuit

Design Goals

<table>
<thead>
<tr>
<th>Input</th>
<th>Output</th>
<th>Supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{i,\text{min}}$</td>
<td>$V_{i,\text{max}}$</td>
<td>$V_{o,\text{min}}$</td>
</tr>
<tr>
<td>100mV_{pp}</td>
<td>50V_{pp}</td>
<td>1mV_{pp}</td>
</tr>
</tbody>
</table>

Design Description

This tunable band-pass attenuator reduces signal level by –40dB over the frequency range from 10Hz to 100kHz. It also allows for independent control of the DC output level. For this design, the pole frequencies were selected outside the pass band to minimize attenuation within the specified bandwidth range.

Design Notes

1. If a DC voltage is applied to $V_{\text{ref}}$ be sure to check common mode limitations.
2. Keep $R_3$ as small as possible to avoid loading issues while maintaining stability.
3. Keep the frequency of the second pole in the low-pass filter ($f_{p2}$) at least twice the frequency of the first low-pass filter pole ($f_{p1}$).
**Design Steps**

1. Set the passband gain.
   
   \[
   \text{Gain} = - \frac{R_2}{R_1} = - 0.01 \frac{\mu V}{V} (-40\text{dB})
   \]
   
   \[
   R_1 = 100k\Omega
   \]
   
   \[
   R_2 = 0.01 \times R_1 = 1 \text{ k}\Omega
   \]

2. Set high-pass filter pole frequency \(f_{p1}\) below \(f_h\).
   
   \[
   f_i = 10\text{Hz}, \quad f_{p1} = 2.5\text{ Hz}
   \]

3. Set low-pass filter pole frequency \(f_{p2}\) and \(f_{p3}\) above \(f_h\).
   
   \[
   f_h = 100\text{kHz}
   \]
   
   \[
   f_{p2} = 150\text{kHz}
   \]
   
   \[
   f_{p3} \geq 2 \times f_{p2} = 300\text{kHz}
   \]

4. Calculate \(C_1\) to set the location of \(f_{p1}\).
   
   \[
   C_1 = \frac{1}{2\pi \times R_1 \times f_{p1}} = \frac{1}{2\pi \times 100k\Omega \times 2.5\text{Hz}} = 0.636 \mu F \approx 1 \mu F \text{ (Standard Value)}
   \]

5. Select components to set \(f_{p2}\) and \(f_{p3}\).
   
   \[
   R_3 = 8.2\Omega \text{ (provides stability for cap loads up to 100nF)}
   \]
   
   \[
   C_2 = \frac{1}{2\pi \times (R_3 + R_3) \times f_{p2}} = \frac{1}{2\pi \times 1008.2\Omega \times 150\text{kHz}} = 1052\text{pF} \approx 1200\text{pF} \text{ (Standard Value)}
   \]
   
   \[
   C_3 = \frac{1}{2\pi \times R_3 \times f_{p3}} = \frac{1}{2\pi \times 8.2\Omega \times 300\text{kHz}} = 64.7 \text{nF} \approx 68\text{nF} \text{ (Standard Value)}
   \]
Design Simulations

DC Simulation Results

The amplifier will pass DC voltages applied to the noninverting pin up to the common mode limitations of the op amp (±13V in this design)

AC Simulation Results

![Gain vs Frequency Graph]

Frequency (Hz)

Gain (dB)

-60.00
-55.00
-50.00
-45.00
-40.00

1 10 100 1k 10k 100k 1MEG

fl = 10Hz
Gain = -40.11dB

fh = 100kHz
Gain = -40.5dB

Transient Simulation Results

![Waveform Graph]

Vi

0.00
-25.00
-249.86m

Vo

0.00
-248.95m

Time (s)

0.00 1.00m 2.00m 3.00m
Design References
See Analog Engineer's Circuit Cookbooks for TI's comprehensive circuit library.
See circuit SPICE simulation file SBOC503.

Design Featured Op Amp

<table>
<thead>
<tr>
<th>OPA1612</th>
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<tbody>
<tr>
<td>$V_{ss}$</td>
<td>4.5V to 36V</td>
</tr>
<tr>
<td>$V_{inCM}$</td>
<td>$V_{ss}+2V$ to $V_{cc}-2V$</td>
</tr>
<tr>
<td>$V_{out}$</td>
<td>$V_{ss}+0.2V$ to $V_{cc}-0.2V$</td>
</tr>
<tr>
<td>$V_{os}$</td>
<td>100µV</td>
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<tr>
<td>$I_{q}$</td>
<td>3.6mA/Ch</td>
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<tr>
<td>$I_{b}$</td>
<td>60nA</td>
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<tr>
<td>UGBW</td>
<td>40MHz</td>
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<tr>
<td>SR</td>
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www.ti.com/product/opa1612

Design Alternate Op Amp

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<tbody>
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<td>$V_{ss}$</td>
<td>4.5V to 36V</td>
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<tr>
<td>$V_{inCM}$</td>
<td>$V_{ss}-100mV$ to $V_{cc}-2V$</td>
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<tr>
<td>$V_{out}$</td>
<td>Rail-to-rail</td>
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<tr>
<td>$V_{os}$</td>
<td>200µV</td>
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<tr>
<td>$I_{q}$</td>
<td>1.6mA/Ch</td>
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<tr>
<td>$I_{b}$</td>
<td>8pA</td>
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<tr>
<td>UGBW</td>
<td>10MHz</td>
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<tr>
<td>SR</td>
<td>10V/µs</td>
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<tr>
<td>#Channels</td>
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www.ti.com/product/opa172

Revision History

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<tr>
<th>Revision</th>
<th>Date</th>
<th>Change</th>
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<tbody>
<tr>
<td>A</td>
<td>January 2019</td>
<td>Downscale the title and changed title role to 'Amplifiers'. Added link to circuit cookbook landing page.</td>
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