Second Order Low Pass Filter

\[ j := \sqrt{-1} \quad f_{\text{crit}} := 10.28 \text{kHz} \quad f_3 := f_{\text{crit}} \]

\[ T(s) = \frac{V_o}{V_i} = K \cdot \frac{1}{\left( \frac{s}{\omega_o} \right)^2 + \frac{1}{Q} \cdot \frac{s}{\omega_o} + 1} \]

\[ K = 1 + \frac{R_4}{R_3} \]

\[ \omega_o = 2\pi f_0 = \frac{1}{\sqrt{R_1 R_2 C_1 C_2}} \]

Specifications

\[ Q := \frac{1}{\sqrt{2}} \quad \text{Butterworth Filter for which} \quad f_0 := f_3 \]

\[ K := 1 \quad R_4 := 0 \quad \text{short} \quad R_3 := \infty \quad \text{open} \quad \omega_o := 2\pi f_0 \]

\[ T(f) := K \cdot \frac{1}{\left( \frac{j \cdot f}{f_0} \right)^2 + \frac{1}{Q} \cdot \frac{j \cdot f}{f_0} + 1} \]

Special Case 2

Pick

\[ C_1 := 0.015\mu\text{F} \]

\[ C_2 := 1.5\text{nF} \]

\[ R_1 := \frac{1}{2Q\omega_0 C_2} \left( 1 + \sqrt{1 - 4Q^2 \cdot \frac{C_2}{C_1}} \right) = 13.826\text{k}\Omega \]

\[ R_2 := \frac{1}{2Q\omega_0 C_2} \left( 1 - \sqrt{1 - 4Q^2 \cdot \frac{C_2}{C_1}} \right) = 0.771\text{k}\Omega \]

\[ 20\log |T(f)| \]

\[ \begin{align*}
\text{arg} T(f) \left( \frac{180}{\pi} \right) \\
\end{align*} \]
Second Order LPF
Generalized Biquadratic Filter

\[ f_{\text{crit}} := 10.28 \text{kHz} \quad f_0 = \frac{1}{2\pi RC} \quad f_0 := f_{\text{crit}} \]

\[ \alpha = 0 \quad \gamma = 0 \quad \beta = \frac{1}{2} \]

**Specification 1 Bandpass**

\[ T(s) = K \cdot \frac{\frac{1}{Q} \frac{s}{\omega_0}}{\left(\frac{s}{\omega_0}\right)^2 + \frac{1}{Q} \frac{s}{\omega_0} + 1} \]

\[ T(f) = K \cdot \frac{j \frac{f}{f_0} \frac{1}{Q}}{\left(j \frac{f}{f_0}\right)^2 + \frac{1}{Q} \frac{j \cdot f}{f_0} + 1} \]
Specification 2 Second Order Notch Filter DC and High Freq Gain 1 Q of 2

\[ \alpha = \gamma = 1 \quad \beta = \frac{1}{2} \quad Q := 2 \]

\[ T(s) = K \frac{\left( \frac{s}{\omega_o} \right)^2 + 1}{\left( \frac{s}{\omega_o} \right)^2 + \frac{1}{Q} \frac{s}{\omega_o} + 1} \]

\[ T(f) := K \frac{\left( j \frac{f}{f_o} \right)^2 + 1}{\left( j \frac{f}{f_o} \right)^2 + \frac{1}{Q} j \frac{f}{f_o} + 1} \]
Specification 3 Second Order All Pass

\[ T(s) = K \frac{\left( \frac{s}{\omega_o} \right)^2 - \frac{1}{Q} \frac{s}{\omega_o} + 1}{\left( \frac{s}{\omega_o} \right)^2 + \frac{1}{Q} \frac{s}{\omega_o} + 1} \]

\[ T(f) = K \frac{\left( \frac{j \cdot f}{f_o} \right)^2 - \frac{1}{Q} \frac{j \cdot f}{f_o} + 1}{\left( \frac{j \cdot f}{f_o} \right)^2 + \frac{1}{Q} \frac{j \cdot f}{f_o} + 1} \]
Second Order AllPass Filter

\[ 20 \log |T(f)| \]

\[ \frac{180}{\pi} \arg(T(f)) \]
Experiment 8: Second Order Active Filters

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Time Completed</th>
<th>Date Completed</th>
<th>Verification (Must demonstrate circuit)</th>
<th>Points Possible</th>
<th>Points Received</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Low Pass</td>
<td></td>
<td></td>
<td></td>
<td>20</td>
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</tr>
<tr>
<td>2. High Pass</td>
<td></td>
<td></td>
<td></td>
<td>20</td>
<td></td>
</tr>
<tr>
<td><strong>3. Bandpass</strong></td>
<td></td>
<td></td>
<td></td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>4. Notch</td>
<td></td>
<td></td>
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<td>20</td>
<td></td>
</tr>
<tr>
<td>5. All-Pass</td>
<td></td>
<td></td>
<td></td>
<td>20</td>
<td></td>
</tr>
</tbody>
</table>

If you were born on or before June 30, your critical frequency is found from your birthday as Month.Day kHz. If you were born after June 30, your critical frequency is (Month.Day/2) kHz. Ex 1: If you were born on March 3, your critical frequency is 3.03 kHz. Ex 2: If you were born on December 18, your critical frequency is 6.09 kHz.

Enter your critical frequency below:

\[ f_{\text{crit}} \]

To be permitted to complete the experiment during the open lab hours, you must complete at least three procedures during your scheduled lab period or spend your entire scheduled lab session attempting to do so. A signature below by your lab instructor, Dr. Brewer, or Dr. Robinson permits you to attend the open lab hours to complete the experiment and receive full credit on the report. Without this signature, you may use the open lab to perform the experiment at a 50% penalty.

SIGNATURE: ___________________________________________  DATE: ___________________________________________
ECE 3043 Check-off Requirements for Experiment 8

Make sure you have made all required measurements before requesting a check-off. For all check-offs, you must demonstrate the circuit or measurement to a lab instructor. All screen captures must have a time/date stamp.

1 & 2. Low Pass and High Pass Filters
   ✓ Bode magnitude plot
   ✓ Table showing measured pass band gain and -3dB frequencies compared to design values

3 & 4. Bandpass and Notch Filters
   ✓ Bode magnitude plot
   ✓ Table showing measured center frequency and half power bandwidth

5. All Pass Filter
   ✓ Bode Phase Plot
   ✓ Measure frequency where phase shift is 180 degrees. Compare to $f_{\text{crit}}$. 