Analysis of Crossover Design in Custom-Built Stereo Speakers

Project Objectives:
- Determine if a higher order filter provides flatter speaker response
- Analyze the impact of additional corrective circuits on speaker response flatness

Selected Design
- HiVi B4N Woofer
- HiVi T20-8 Textile Dome Tweeter
- Ported Poplar Enclosure
- Crossover Options
  - 1st Order Butterworth Filter
  - 2nd Order Linkwitz-Riley Filter
  - Tweeter Attenuation Circuit
  - Zobel Woofer Impedance Compensator Circuit

Test Methods
- Oscilloscope Test
  - Woofer and tweeter removed from enclosure
  - Probe connected to driver wires
  - Crossover settings adjusted
  - Voltage measured at 20-20,000 Hz test tones
- Sound Level Meter Test
  - Speaker placed in anechoic chamber
  - Crossover settings adjusted
  - Sound output measured at 20-20,000 Hz test tones
- Listening Test
  - Musical selection analyzed with each crossover setting

Fabrication Methods
- Wood cut using table saw, miter saw, drill press, CNC mill
- Enclosures assembled using wood glue, clamps
- Crossover circuit boards assembled and soldered by hand

Results

<table>
<thead>
<tr>
<th>Filter Order</th>
<th>Attenuation</th>
<th>Zobel</th>
<th>Average Output (dB)</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Off</td>
<td>Off</td>
<td>73.4</td>
<td>6.0</td>
</tr>
<tr>
<td>2</td>
<td>Off</td>
<td>Off</td>
<td>71.1</td>
<td>5.2</td>
</tr>
<tr>
<td>2</td>
<td>On</td>
<td>Off</td>
<td>68.4</td>
<td>4.7</td>
</tr>
<tr>
<td>2</td>
<td>Off</td>
<td>On</td>
<td>70.7</td>
<td>4.5</td>
</tr>
<tr>
<td>2</td>
<td>On</td>
<td>On</td>
<td>67.5</td>
<td>3.1</td>
</tr>
</tbody>
</table>

Results (Cont.)
- There was a marginal improvement in flatness between 1st and 2nd order filters alone
- The second order filter with attenuation and impedance compensation provided the flattest response
- Tweeter attenuation and woofer impedance compensation were critically important for flat response
- More signal processing provided flatter response at the expense of sound output
- The tweeter required substantially less voltage than the woofer for the same sound output

Next Steps
- Explore woofer voltage peak in second order filter
- Finish speaker enclosures (sand and stain)
- Experiment with other types of filters and circuit elements
- Experiment with more speaker drivers (midranges, etc.)

Acknowledgements: Craig Severson, Josh DeLarm, ISU Boyd Lab Technicians, Dr. Hui Hu, Dr. Anupam Sharma, Jim Benson, Chris Schmidt