Active Noise Cancellation (ANC) Headsets using fixed analog & adaptive neural controllers

Muhammad Nazmul Islam
Department of Electrical & Computer Engineering,
University of New Hampshire, Durham, NH

Introduction
ANC can implement either feedforward controller, feedback controller or adaptive neural network controller to reduce noise.

Three questions posed at the outset of the study were:

1. Among the feedforward controller and feedback controller, which one works better in ANC Headsets?
2. How does the designed headset in this project perform with respect to practical headsets?
3. How does the Cerebellar Model Arithmetic Computer (CMAC) neural controller perform comparing with the fixed analog controllers?

Why Noise Cancellation?
According to the National Institute of Health, approximately 28 million people in the United States are affected by noise⁴. Sixty percent of soldiers who return from Iraq or Afghanistan suffer from noise-induced hearing loss.

Why ANC?
1. Passive headsets fail to reduce noise in the low frequency range (20 Hz – 4 kHz).
2. ANC mixes out-of-phase noise, commonly known as anti-noise, with original noise to reduce it.

Feedforward Controller & Feedback Controller
Feedforward controller changes the magnitude of the picked up noise whereas, feedback controller changes both magnitude and phase. This helps the canceller to achieve a higher noise reduction range.

The bode plots shown above were obtained in the lab. Feedforward circuit does not provide the controllability to vary the noise cancellation range of the headset. By changing gain, the user can only vary the amount of noise cancellation. On the contrary, feedback circuit can implement phase controller (namely lag & lead controller) which can alter the noise cancellation range and the amount of noise reduction in an ANC headset.

Adaptability of CMAC Controller
If the noise source (engine of a jet plane or a machine in an industry) changes its frequency, CMAC still adapts its parameters very quickly to reach steady state with low transient time.

Feedforward Controller
Feedback Controller

Comparison with Commercial Headsets
The above figure shows that my Headset outperforms Bose Headset from 800 Hz to 1650 Hz.

Table. Comparison between Commercial Headsets & My Designed Headset

<table>
<thead>
<tr>
<th>Headset Brand</th>
<th>Maximum Noise Cancellation</th>
<th>Noise Cancellation Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sennheiser PX150</td>
<td>15 dB</td>
<td>1000 Hz</td>
</tr>
<tr>
<td>ANC Headphones</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Noisebuster Noise Cancelling Headphones</td>
<td>20 dB</td>
<td>800 Hz</td>
</tr>
<tr>
<td>Bose Noise Cancelling Headphones</td>
<td>21.5 dB</td>
<td>1200 Hz</td>
</tr>
<tr>
<td>Noisebuster FX NC Headphones</td>
<td>20 dB</td>
<td>1200 Hz</td>
</tr>
<tr>
<td>My Designed ANC Headset</td>
<td>11 dB</td>
<td>1650 Hz</td>
</tr>
</tbody>
</table>

Conclusion
- Feedback controller is better than the feedforward controller.
- My designed circuit provided wider noise cancellation range than the commercially available headsets.
- CMAC controller adapts its parameters very quickly to cancel single tone noises of all frequencies in its region of convergence.

Background
Why Noise Cancellation?

Why ANC?

References
4. Sixty percent of soldiers who return from Iraq or Afghanistan suffer from noise-induced hearing loss.

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Correspondence concerning this poster should be e-mailed to:
Muhammad Nazmul Islam
mnp3@unh.edu