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

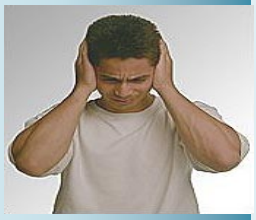
ANC can implement either feedforward controller, feedback controller or adaptive neural network controller to reduce noise.

Three questions posed at the outset of the study were:

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

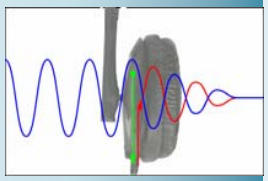
Background

Why Noise Cancellation?



- According to the National Institute of Health, approximately 28 million people in the United States are affected by noise[3].
- Sixty percent of soldiers who return from Iraq or Afghanistan suffer from noise-induced hearing loss.

Why ANC?



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

Feedforward Controller & Feedback Controller

Feedforward Controller

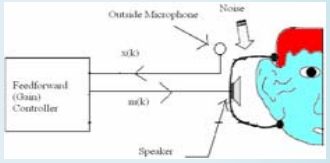


Fig. Block Diagram of a Feedforward Controller

Feedback Controller

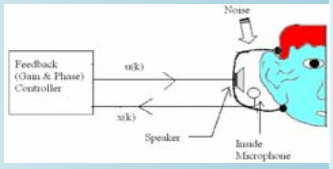


Fig. Block Diagram of a Feedback Controller

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.

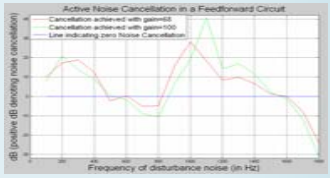


Fig. Noise Cancellation in a Feedforward Circuit

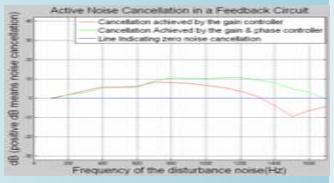


Fig. Noise Cancellation in a Feedback Circuit

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.

The controllability of noise cancellation range makes the feedback controller suitable for ANC headsets.

Comparison with Commercial Headsets

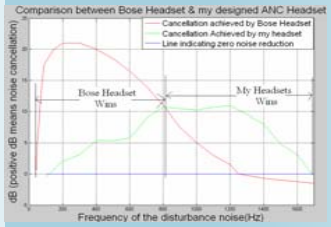


Fig. Comparison Between Bose Headset & My Headset[1]

The above figure shows that my Headset outperforms Bose Headset from 800 Hz to 1650 Hz.

Headset Brand	Maximum Noise Cancellation	Noise Cancellation Range
Senheiser PXC 250 ANC Headphone[2]	15 dB	1000 Hz
Noisebuster Noise Cancelling Headphone[2]	20 dB	800 Hz
Bose Noise Cancelling Headphone[1]	21.5 dB	1250 Hz
Noisebuster FX NC Headphones	20 dB	1200 Hz
My designed ANC Headset	11 dB	*1650 Hz*

Table. Comparison between Commercial Headsets & My Designed Headset

The table on the top right shows that **my headset provides wider noise cancellation range than the commercially available headsets.**

CMAC Controller

CMAC controller adapts its parameters to achieve noise cancellation.

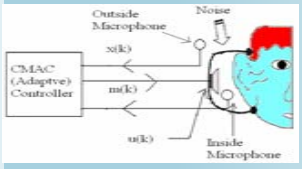


Fig. Block Diagram of a CMAC Controller

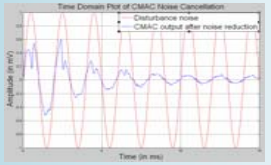
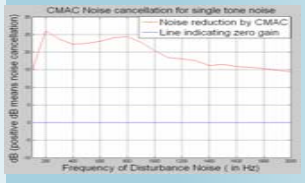


Fig. Time Domain Plot of ANC in CMAC

The top right figure shows that the CMAC controller gradually tunes its parameters to reduce noise by 93% within 15 ms.



. **Fig. Noise Cancellation in a CMAC Circuit**

The bode plot on the left was obtained in simulation. It shows that CMAC reduces single tone disturbance noise by 15-25 dB from 100 Hz to 2 kHz. **Unlike fixed controllers, CMAC reduces noise in its entire region of convergence.**

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.

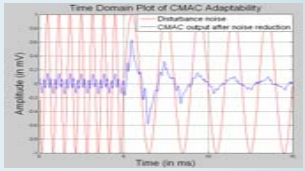


Fig. Time Domain Plot of CMAC Adaptability

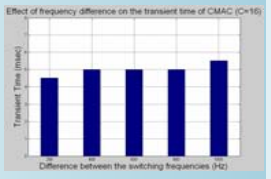


Fig. Effect of frequency difference on the transient time of CMAC

Both figures shown above were obtained in simulation. In the top left figure, when the input frequency was changed from 1.5 kHz to 500 Hz, CMAC adapted its parameters to cancel 90% noise within 6 ms. The top right figure shows that the transient time of CMAC lies between 4.5 – 5.5 ms when the difference between the two source frequencies lie between 200 Hz – 1000 Hz. This proves that **CMAC adapts its parameters very quickly.**

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.**

References

1. Bose, Amar, "Headphoning," US Patent No. 4,455,675, 6/19/84
2. Noise Cancelling Headphones, Retrieved April 05, 2008 from http://www.21st-century-goods.com/page/21st/CTGY/ANC
3. Noise and Hearing Loss. NIH Consensus Statement Online (1990, Jan 22-24). 8(1): 1-24. Retrieved October 1, 2007 from http://consensus.nih.gov/1990/1990NoiseHearingLoss076html.htm

Acknowledgments

1. Dr Gordon Kraft, for his supervision and continued support during the project.
2. Undergraduate Research Opportunities Program of UNH, for their grant in the form of Summer Undergraduate Research Fellowship & Undergraduate Research Award.

Correspondence concerning this poster should be e-mailed to:

Muhammad Nazmul Islam
mnp3@unh.edu