

# Chapter 10

## Active Noise Control for Hearing Screening Test: Simulation and Experiment

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### **ABSTRACT**

*A hearing screening test is a method to determine human ear disorders and conventional audiometers and audiologists are required to perform the test. However, this procedure is difficult to implement, especially in a remote site such as a factory or a school due to the ambient noise that may cause test inaccuracy. In this work, the application of active noise control (ANC) is proposed to reduce the ambient noise using a personal computer in a hearing screening test. The ANC algorithm was simulated in MATLAB software and implemented using a computer with data acquisition modules and LabVIEW software. Results show that anti-noise was successfully generated in the electrical domain but no reduction was observed in the acoustic domain. ANC is a deterministic application that requires a real-time operating system to respond to the input with precisely timed output. To have an effective ANC system, the processing time has to be less than 0.125 ms at 8 KHz sampling rate.*

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## **INTRODUCTION**

Acoustic noises always influence and disturb people who are working nearby to its source. The problem becomes obvious with increased number of industrial equipments such as engines, blowers, fans, transformers and compressors that are in use (Robert & Joseph, 1993; Thayer & Sataloff, 2006). Passive techniques using enclosures, barriers and silencers are commonly used to attenuate the unwanted noise. However, passive methods are costly, bulky and not effective to reduce the lower frequency noises which come from the industrial equipments (Colin, 2001).

The limitation of the passive techniques motivated the researchers to investigate the possibility of active techniques to reduce low frequency noise less than 500 or 1000 Hz. Active noise control (ANC) (Elliott & Nelson, 1993) which consists of feed-forward and feed-back system is a promising technique in noise reduction by using a DSP controller, microphones and loudspeakers. The ANC systems are effective when the unwanted noise is periodic. However, it is not effective when the system influenced with random noises (white noise).

One possible application of the ANC technique is the hearing screening test. Pure tone audiometer is a device used to perform the hearing screening test by sending pure tones to each ear by using a headphone (American Speech-Language-Hearing Association, 1997; Brad, 1998; Daniel, 2005; Lewis & Douglas, 1994; William, 2007). The stimuli sent to the ear are varied in intensities and frequencies. By recording the subject's responses, we are able to classify them into pass or fail group (Reilly, Wingfield, Troiani, & Grossman, 2007). When a subject failed the test, he may then be referred to an audiologist for in-depth evaluation. Normally, hearing screening test is conducted in a quiet room where the ambient noise, when using 20 dB hearing level (HL) to screen the ear, should not exceed 46 dB sound pressure level (SPL) at 1000 Hz, 54 dB SPL at 2000 Hz and 57 dB SPL

at 4000 Hz (ANSI S3.1 (R2003), 1999). In order to perform the test under normal working environment, the headphone has to be incorporated with noise reduction features.

In hearing screening test application, the feed-forward ANC system is preferable compared to the feedback system. In the feedback system, the stimuli are considered as noises and will be attenuated by the anti-noise which is produced by the headphone. As a result, the stimuli that reached the subject's ear have different intensity from the sent stimuli. Feed-forward ANC system will only attenuate noise which is correlated to the reference signal. Since the stimuli are not correlated with the noise, they are not cancelled by the ANC system (Yong-Kim, Liang, See-Chiat, & Woon-Seng, 2005).

In this paper, the feasibility of the PC-based ANC system is evaluated using LabVIEW and the problems encountered during the test are reported. The use of a high clock speed personal computer is proposed to implement the filtered-x LMS algorithm which may be suitable for screening application without the attendance of an expert. The use of DSP chips for ANC implementation has been widely reported (Lorenzo & Paolo, 2007). However, such implementation may not be easily made interactive for usage by non-experts.

## **EXPERIMENTS**

### **A. Filtered-x LMS Algorithm**

LMS algorithm is a commonly used algorithm in ANC application (Collier, Kaliski, & Ray, 2003; Brammer, 1996; Pan, Brammer, & Crabtree, 2007; Ray, Collier, & Kaliski, 2002; Pan, Brammer, Goubran, Ryan, & Zera, 1994; Pan, Brammer, & Pan, 1998) but it is constrained by the time of convergence. In order to reduce the noise acoustically, the anti-noise has to be generated as soon as the noise reaches the ear. Filtered-x LMS (FxLMS) algorithm as proposed in (Widrow &

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