A hands-on approach to demonstrating active noise cancelling

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Abstract. As noise pollution has become an increasingly major factor in the quality of urban life, noise cancelling methods started to be a relevant option for everyday life. Starting from the first active noise cancelling headphones build for aircraft industry in order to facilitate communication between pilots, in the last decade, active noise cancelling products have become more and more relevant. Factories, military and lately, civil usage of active noise cancelling technology transformed this industry and made it widely available. The purpose of this paper is to demonstrate a practical way of active noise cancelling using LabVIEW. Two sound waves are guided through a cylindrical conduit and at a given position, by modifying the phase and amplitudes between the two signals, an amplitude close to zero is expected.

1. Introduction
As active noise cancelling has become a major part in today’s environment due to its high noise pollution, the need to cancel unwanted and disturbing noises has become a necessity [1]. The principle of active noise cancelling is relatively simple, an out of phase signal being needed to be applied on noise signal to cancel it [2]. The system proposed in this paper consists of a cylindrical conduit where two speakers, one placed on one end of the conduit and the other connected through a conduit couple at approximately 1 m distance of the conduit end are fed sound waves. The speaker placed at one end of the conduit is fed a sine wave which is considered as noise. The other speaker is fed a sine wave out of phase with respect to the first one in order to counter it, measuring the attenuation. The length of the conduit plays an important role in the overall result, as well as the phase between the two signals.

In order the quantify the results of such a system, a series of tests was done to be able to obtain the relation between frequency and phase of the two signals. For the speakers, a USB external sound card is used, with an audio amplifier (A232 module). Due to the limitations of sound card hardware and audio libraries of Windows and LabVIEW, the acquisition of the signal is done with a condenser microphone connected to LabVIEW through a USB acquisition board, USB-6218 to provide a fully usable set of data, with a high resolution, needed for the application in question. The USB-6212 can acquire data with 16-Bit and a maximum sampling frequency of 250 kHz.

Considering the practical approach of this paper, in order to simplify the overall system physical parameters, the speakers technical specifications and constructive differences of the same components were not considered.

2. Hardware and software structure of the proposed system
In this chapter, the hardware are software structures will be presented. The physical stand was built using widely available materials (PVC conduits) with good reflective properties for sound. The
speakers have the same physical properties in order to eliminate as much as possible the constructive differences between them, so to limit the alterations induced in the sound.

2.1. Hardware structure
The hardware structure consists of three conduits, two of them having approximately 1 m in length and the third one approximately 50 cm. The 50 cm conduit serves as a connection for the two conduits with an additional 45 degrees arm where the noise cancelling speaker is placed. The 30W speakers are connected to a dual channel audio amplifier powered at 12 V, with a signal to noise ratio of 100 dB and a crosstalk between the two channels of -130 dB for frequencies below 10 kHz. The audio amplifier is driven by an external sound card. The signal acquisition is done using an USB NI multifunctional I/O device, USB-6218 [3]. The microphone is connected to a preamplifier which amplifies the bare microphone signal in order to provide a usable signal for the USB-6218. In figure 1 a schematic of the system is presented.

![Figure 1. Block schematics of the proposed system.](image)

2.2. Software structure
Software structure of the proposed system consist of a LabVIEW program where the generation, acquisition and conditioning of the signals is done. The aim of the software program is to generate two sine waves for a given number of frequencies and to modify the phase of the noise counter signal in order to obtain an attenuation of the noise. At the end of the conduit, a condenser microphone is placed used to acquire the resulting signal and to calculate the attenuation for each frequency and phase difference between the two signals.

In order to obtain coherent results which are representative in comparison with other papers and applications, the attenuation for each frequency and phase it’s represented by the corresponding amplitude measured in [Vrms] (volts root mean square) for each set of measurements. For the ease of generation and measurements, the two sine waves are generated through a built-in function of LabVIEW. The parameters of the signal can be changed in order to obtain different scenarios for system testing. Using the front panel controls and indicators, a setup for testing can be scheduled [4].

The system testing consists of two tasks, one being the generation of signal with a parameter diversification and the second, the acquisition of data, in order to be able to measure the results in terms of attenuation for different phase shifts at different frequencies. The maximum phase increment between the two signals is 180 degrees. By changing the phase, a full attenuation is expected from theoretical point of view but considering the physical characteristics of the conduit, microphone, speakers, and drivers, such a result is hard to be achieved [5].
In figure 2, a block diagram of the software structure is presented.

![Software structure block diagram](image)

**Figure 2.** Software structure block diagram.

Following the schematic presented in figure 2, the LabVIEW program can be divided in two major blocks, as follows: generation and acquisition.

![LabVIEW program front panel during a test](image)

**Figure 3.** LabVIEW program front panel during a test.
Using the controllers place above the microphone graph, which can be seen in figure 3, the parameters used for signal acquisition can be set, as follows:

- Physical channels – the channels of USB-6218 where the microphone is connected.
- Sample mode – choses the sample mode for microphone (finite or continuous).
- Input terminal configuration – considering the physical circuitry, it can be changed accordingly in order to acquire relevant data.
- Sample rate – number of samples per second to be acquired.

The microphone acquired signal can be seen in raw format on the microphone graph and on the amplitudes graph and array, the amplitudes for each frequency are shown.

The middle controls are used to control the sound generation, as follows:

- Sound device id – user input to select the sound card device id.
- Sound format – contains information about the number of samples, number of channels and resolution of generated signal.
- Signal – powers off and on signal writing to sound card.
- Volume – sets output volume for sound card.
- Frequency increment – value used to increment frequency after a 180 degree phase shift is done.
- Min. frequency – value used for starting frequency. The frequency increments adds to this value.
- Number of frequency increments – number of frequency increments done in a full program. It adds the frequency increment to the last frequency.
- Phase increment – increment of phase in range of 0-180 degrees.
- Phase reset selectors – used to reset phase either on signal or noise cancel wave.
- Current frequency – indicator which shows the current loop frequency.
- Current phase – indicator which shows the current loop phase.

3. Practical implementation and system testing

Following the schematic presented figure 1, the physical system was built in order to conduct a series of tests. In figure 3, the conduit with attached speakers can be seen. The back of the speakers is covered with an insulation material in order to minimize the sound leakage.

![Figure 4. Conduit, USB-6218 and LabVIEW program.](image)

To be able to attach the microphone to the conduit, a custom support system was designed using 3D CAD (Computer Aided Design) techniques in order to provide a fully functional mechanical system which can slide around the diameter of the conduit. The need of measuring in different points around the conduit diameter comes as a result of conduit dimension. A large difference of amplitudes between different points of conduit diameter indicate that the sound waves are not mixed properly. In this case, the length of the conduit should be increased in order to be able to obtain an overall constant
amplitude on conduit diameter. The test measurement samples provided coherent results in multiple points around conduit diameter, so the microphone was placed in the centre of the conduit for this experiment. For conduit support, due to its large dimensions, a series of custom stands were designed in order to match the conduit outer diameter. Beside the support function, they also isolate the conduit from outer excitations, providing a smaller contact area to the conduit. In figure 5, the slide and grip system and a conduit support can be seen.

![Figure 5. Conduit support and microphone grip and slide system.](image)

The system testing started with a “calibration” measurement. The noise producing speaker was turned on at a given amplitude and the output was measured at the end of the conduit. The measured amplitude values will be later compared with the values measured with the noise cancel speaker turned on at different amplitudes and phases. For this experiment, four frequencies were chosen, 100 Hz, 400 Hz, 700 Hz and 1 kHz. The frequency range was chosen considering the audio amplifier characteristics. As noted from the beginning of the paper, the best results for crosstalk are obtained at frequencies below 10 kHz. The results for noise speaker amplitudes can be seen in figure 6.

![Figure 6. Noise amplitude at different frequencies and phases.](image)
As expected, the measurement provides steady values for different frequencies with noise speaker only. Next, the noise cancel speaker is turned on at half the amplitude of the noise speaker. The results are presented in amplitude and percentual comparison in order to have a better representation of the attenuation and amplification of signal at different phases.

Figure 7. Measured noise amplitude in [Vrms] and attenuation in [%] at different frequencies with ½ noise cancel amplitude.

Figure 7 shows two graphics where the amplitude and the attenuation in percent are represented when the noise cancel speaker is turned on at ½ of noise amplitude. Looking at the graphs, the highest attenuation is obtained at 400 Hz and 1 kHz with a phase difference of 120 and 180 degrees in respect to the noise wave. The worst result is obtained at 700 Hz frequency for a phase difference between the two signals of 60 degrees. As it can be seen on the right graph, the amplification of noise is increased with almost 30 % compared with 0 degrees phase.

Figure 8. Measured noise amplitude in [Vrms] and attenuation [%] at different frequencies with equal noise cancel amplitude.

In figure 8, the noise cancel amplitude is equal with noise amplitude. The attenuation is higher for the same frequencies of 500 Hz and 1 kHz at 120 and 180 degrees phase shift between the noise wave and the noise cancel wave. The 700 Hz frequency curve follows the same trajectory, but with higher ups and downs due to increased amplitudes. A big difference between the two measurements can be seen on 100 Hz frequency curve. If in the first measurement it follows a trajectory similar to the other frequency curves, in the second measurement when the noise cancel amplitude is increased to a value equal to the noise, the trajectory changes its behaviour, having ups and downs with big peak-to-peak differences. This may be a consequence of the conduit entering in its resonance zone, amplifying even more the sound waves at different phases.

4. Conclusions and future development

The paper proposes a practical way to demonstrate active noise cancelling principle using an easy to build system for testing which uses common materials and objects which can be easily procured. The software side of the system was done in LabVIEW and for the microphone signal acquisition a USB-6218 acquisition board was used to provide a high quality acquired signal in order to obtain relevant
measurements. The results were satisfactory considering the premises, the active noise cancelling principle being demonstrated. Both attenuation and amplification of final sound wave were obtained, considering the phase shift between the two sound waves.

Using the above system, the link between frequency, amplitude and phase can be seen in active noise cancelling applications. The curves shown in figure 7 and figure 8 represent the behaviour of two sound waves with different parameters in a conduit. Future development aims to consider all the functional and constructive parameters of the system and also to perform the testing in an anechoic chamber to have a better control on the environmental noise pollution. Regarding signal processing, a change of the USB-6218 DAQ with a myRIO board is considered, which can execute real time applications. In this case, the noise should be converted to an arbitrary signal which must be countered using a new software structure along with myRIO board.

5. References
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