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Contents

Volume 112
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Research Articles

SENSORDEVICES 2010:

The First International Conference on Sensor Device Technologies and Applications

July 18 - 25, 2010 - Venice, Italy

The inaugural event SENSORDEVICES 2010, The First International Conference on Sensor Device Technologies and Applications, initiates a series of events focusing on sensor devices themselves, the technology-capturing style of sensors, special technologies, signal control and interfaces, and particularly sensors-oriented applications. The evolution of the nano- and microtechnologies, nanomaterials, and the new business services make the sensor device industry and research on sensor-themselves very challenging.

Conference tracks

Sensor devices
Sensor device technologies
Sensors signal conditioning and interfacing circuits
Medical devices and sensors applications
Sensors domain-oriented devices, technologies, and applications
Sensor-based localization and tracking technologies

Important dates

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Notification: March 25, 2010
Registration: April 15, 2010
Camera ready: April 20, 2010

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July 18 - 25, 2010 - Venice, Italy

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Conference tracks

APASN Architectures, protocols and algorithms of sensor networks
MECSN Energy, management and control of sensor networks
RASQOFT Resource allocation, services, QoS and fault tolerance in sensor networks
PESMOSN Performance, simulation and modelling of sensor networks
SEMOSN Security and monitoring of sensor networks
SECSED Sensor circuits and sensor devices
RIWISN Radio issues in wireless sensor networks
SAPSN Software, applications and programming of sensor networks
DAIPSN Data allocation and information in sensor networks
DISN Deployments and implementations of sensor networks
UNWAT Under water sensors and systems
ENOPT Energy optimization in wireless sensor networks

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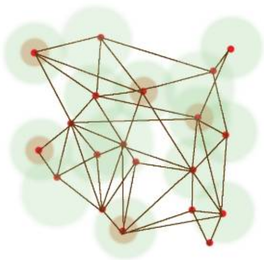

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Sensors & Transducers Journal, Vol. 112, Issue 1, January 2010, pp. 1-9

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Design of an Acoustic Displacement Transducer

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Abstract: Recently, several research works exploring the potential of utilizing acoustic waves for the measurement of many physical phenomena has been published. Propagation characteristics of standing acoustic waves at the boundary between two solid edges within a closed resonance tube are a function of displacement. The possibility of designing a waveguide acoustic transducer for linear displacement measurement was investigated. Signal conditioning and processing is carried out using LabVIEW VIs. Linear range of operation was found 10 cm. Results obtained show that such transducer may be integrated with other primary nonelectrical sensors in order to get an electrical read out, and to realize linear positional feedback control. *Copyright © 2010 IFSA.*

Keywords: Standing wave, Acoustic displacement transducer, LabVIEW VIs, Node and antinode

1. Introduction

Position as applied in measurement, invariably means position relative to some point, as the starting point of motion of an abject or any other convenient reference point. In order to locate position we normally make use of distance and direction (angle) information. Position on flat surfaces could be specified by using Cartesian or polar co–ordinates. For industrial purposes, positions are normally confined within a small space ranging from several millimeters to several centimeters [1]. Since position is related to distance, we shall investigate the possibility of utilizing the standing wave phenomenon for the measurement of linear displacement in small – scale range of movement.

The sensing of distance traveled , as distinct from distance, from a fixed reference point can make use of a variety of transducers such as potentiometric (resistive), capacitive and inductive transducers. Each of these transducers has its drawbacks and imperfections [2].

For example the range of movement is limited by the size of potentiometers; also, friction obstructs slider movement. One problem is associated with a wire-wound potentiometer. The wiper may while moving across winding, make contact with either one or two windings, thus resulting in a variable resolution. Although quite useful in some applications they have noticeable friction and need physical coupling with the object. Wiper friction and excitation voltage cause heating of potentiometer. Capacitive displacement sensors are employed directly to gauge displacement as building block in other transducers where displacements are produced by force, pressure and temperature. Capacitive transducers require extremely small forces to operate them and are useful for measurement of small displacements in millimeter or less. They have a good frequency response; hence they are useful for dynamic measurement. Principal disadvantages are nonlinearity behavior on account of edge effects and high output impedance on account of their small capacitance value; add to this, that the cable which connects the transducer to measuring point is a source of error. Moreover, the capacitance may be changed because of the presence of dust particles and moisture or because of temperature change.

Of course inductive transducers are utilized for displacement measurement also. There, the hysteresis effect, the existing nonlinearity between the output voltage and displacement and the electromagnetic interference are common issues which need to be addressed. Another important factor related to the above mentioned transducers is the need for comparatively complex electronic conditioning circuits which are used for the facilitation of accurate read out and transducer- computer interface [3].

Optical sensors are popular for measuring position and displacement. Their main disadvantages are absence of loading effects and relatively long operating distances. Optical incremental and absolute digital encoders are the most common optical transducers. Absolute encoders overcome some disadvantages of incremental type, but are more expensive. Generally optical encoders find use in relatively low reliability and low resolution applications [4]. Both types may suffer damage in harsh industrial environment [5].

Historically, the practical disadvantage of optical encoders have included pattern inaccuracies, concentricity errors between disc and shaft, susceptibility to electrical noise, vulnerability to shock and lose of data in power failure. One of major problems with optical encoders; ice crystal formation and resultant pattern damage when the shaft turns has not really been completely solved.

In the work [7] a new contact displacement transducer based on the phase shift of an acoustic wave is illustrated. This transducer was developed in order to obviate the need for accurate long core alignment of an LVDT transducer, which is used to control servomotor piston bump. The working range was 20 mm. This drawback of such a transducer is the complicated signal conditioning circuit, which included an oscillator, a digital divider, piezoelectric tweeter, capacitive receiver. BPF, phase adjuster, demodulator and a LPF.

Self oscillating acoustic displacement detector is designed for detecting very small displacement of an object with respect to a self oscillating piezoelectric crystal, by the means of acoustic interference at the crystal. Here the change in phase of reflected energy is utilized.

Building on the above, it becomes obvious that there is a wide range of engineering activities still needed to be done for the improvement of the existing industrial displacement transducers or for the development of new types based on new perspectives. In this work a theoretical and practical investigation of an acoustic displacement transducer (ADT) is carried out. Due to its enclosed structure such a transducer will not be affected by environment disturbances, and connects with the controlled process through computer interface easily. The introduction is followed by a representation of the (ADT) principle, the experimental investigation, and a series of discussion topics based on experiments.

2. Physical Background

When an object is forced into resonance vibrations at one of its natural frequencies, it vibrates in a manner such that a standing wave pattern is formed within the object. Standing wave patterns are created at specific frequencies of vibration known as harmonic frequencies, or simply harmonics. Each harmonic is associated with a standing wave pattern, and the harmonic frequencies are related to each other by simple whole number ratios.

At any frequency other than a harmonic frequency the resulting disturbance of the medium is irregular and unrepeatable. The vibrating object of the transducer is an air column enclosed inside a hollow glass, closed-end tube. A standing wave pattern shall be created within the tube when the vibrational frequency of the source causes reflected waves from one and of the tube to interfere with incident waves from the source in such a manner that specific point along the medium appear to be standing still. Air at the closed end of an air column is still and is free to undergo its back-and-forth longitudinal motion at the open end of an air column, and as such the standing wave patterns will have antinodes at the open ends and nods at the closed ends of air columns. A standing wave pattern for the fundamental frequency of a closed- end air column is shown in Fig. (1).

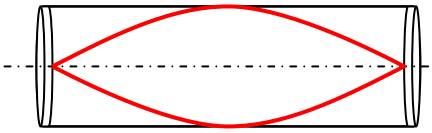


Fig. 1. 1^{st} harmonic for a closed-end air column.

The distance between adjacent antinodes on a standing wave pattern is equivalent to one-half of a wave-length, and the distance between an antinode and a node is equivalent to one-forth of a wave-length. Accordingly the length of the air column in Fig. (1) is equal to one-forth of the wave-length of the first harmonic.

If the source sound wave is given as:

$$y_1 = A\sin(kx - \omega t) \tag{1}$$

And the reflected sound wave is:

$$y_1 = A\sin(kx + \omega t) \tag{2}$$

Both waves will combine in accordance with superposition principle and create standing wave (y), [6], where:

$$y_1 = 2A\sin(kx)\cos(\omega t) \tag{3}$$

A – Maximum amplitude

$k = \dfrac{2\pi}{\lambda}$, angular wave number, λ-wave length.

x- The positions of antinodes

The standing wave has an angular frequency (ω) and amplitude which is modulated by coordinate (x). i. e. every particle of the vibrating medium vibrates in simple harmonic motion with the same frequency. However, the amplitude of motion of a given particle depends on (x). This is in contrast with the situation involving a traveling sinusoidal wave, in which particles oscillate with both the same amplitude and frequency. Thus the device idea evolves around the principle of creating a standing wave in a closed medium which has amplitude that corresponds directly to the displacement (x). In turn this displacement is controlled by the position of a movable spindle.

The relationship between speed (V), frequency (f) and wave length (λ) of the sound wave is given by the following equation:

$$V = f \cdot \lambda \tag{4}$$

Important to note that even though the wave speed is calculated by using *f*, λ, the wave speed is not physically dependant on these quantities. It depends on the properties of the medium through which it moves. For a closed end column the relation between the column length (L) and the wave length for different harmonic standing waves is given below:

$\lambda_1 = \frac{2}{1} L$ For the first harmonic

$\lambda_2 = \frac{2}{2} L$ For the second harmonic

$\lambda_3 = \frac{2}{3} L$ For the third harmonic

$\lambda_n = \frac{2}{n} L$ For the (n) harmonic.

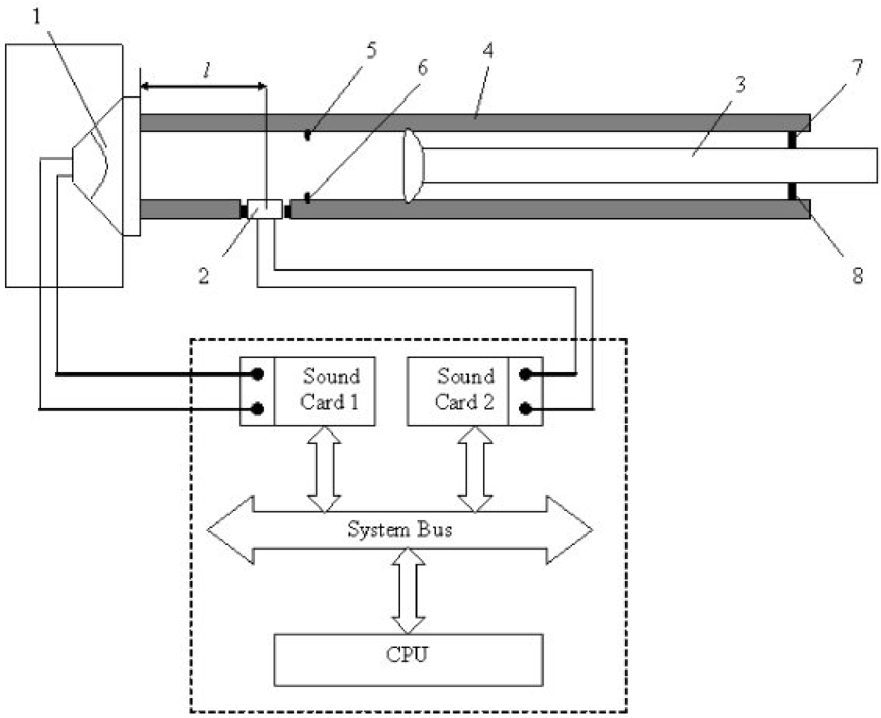
Taking the above relationships into consideration, equation No (4) can be written in the following form, [5]:

$$f_n = \frac{V}{\lambda n} = \frac{V * n}{2L} \tag{5}$$

The last equation shows that the variation of tube is length at fixed frequency and with constant speed of sound will result in many standing wave patterns within the tube which affect both pressure and molecular distribution.

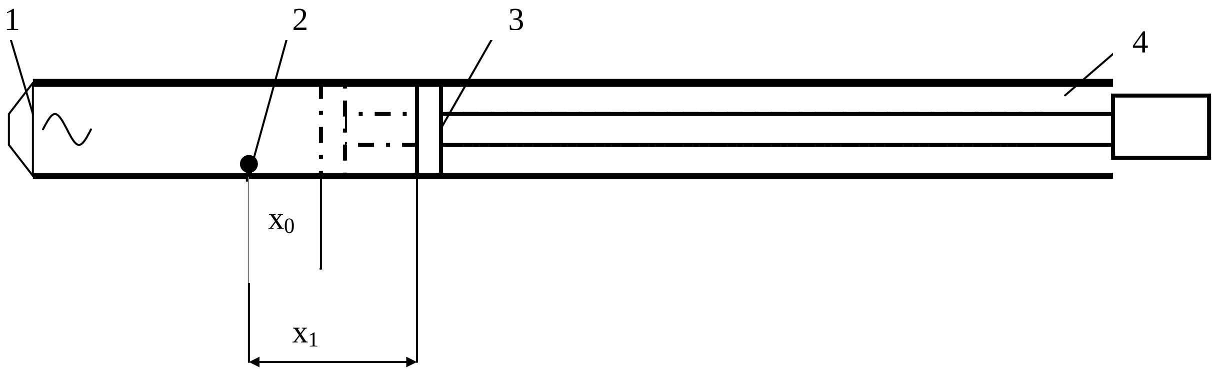
3. How does the Transducer Works?

Fig. (2) is used to describe the operation of the device. When the speaker starts generating the sound wave, the wave collides with the spindle and is reflected to travel in the opposite direction towards the speaker with the same amplitude and frequency before hitting the fixed end. In this situation there are two sound waves with the same amplitude and frequency traveling against each other in the same medium. This provides the condition for generating a standing wave. The microphone detects acoustic pressure amplitude at position (x_o) which equals (P_{AO}). When the spindle is moved to another position the conditions of forming a standing wave will change, creating a new pattern of standing wave and the microphone detects a new value of acoustic pressure amplitude (P_{A1}) at position (x_1). Similarly, different patterns of standing waves can be generated by manipulating the position of the spindle. At the beginning when the experiment started it was found that with one sound card the received signal was exactly the some as the transmitted one. This means that the software automatically simulates the data acquiring process and gives the results so that the acquired wave from the microphone is added to the transmitted wave. Thus there is a need for separating the speaker and the microphone by using one sound card for each device. Experiments show that the axial motion of the spindle along the tube is linearly related to the acoustic pressure amplitude within an interval of 10 cm approximately.



1- Loudspeaker; 2- Microphone; 3- Spindle;
4- Tube; 5,6,7,8 – Edges limiting axial motion.

a)



(b)

Fig. 2. Scheme of experimental setup of LADD (a); description model of experimental setup (b).

4. LabVIEW Virtual Instruments

The software task is to perform a wave generator – receiver role. This was realized by using the (G) language (LabVIEW) with the DAQ board type PCI-MIO-16E- 1. The VI consists of a front panel and block diagram shown in Fig. (3).

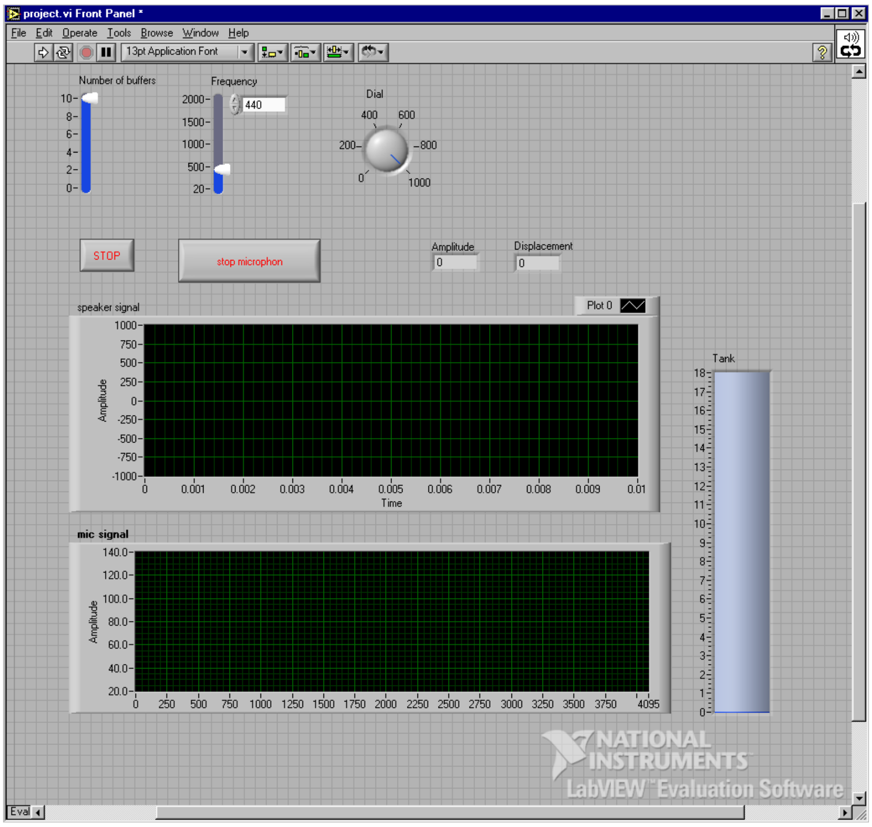


Fig. 3. VI's front panel.

The front panel is a user interface which includes the controls and indicators. It includes the following:

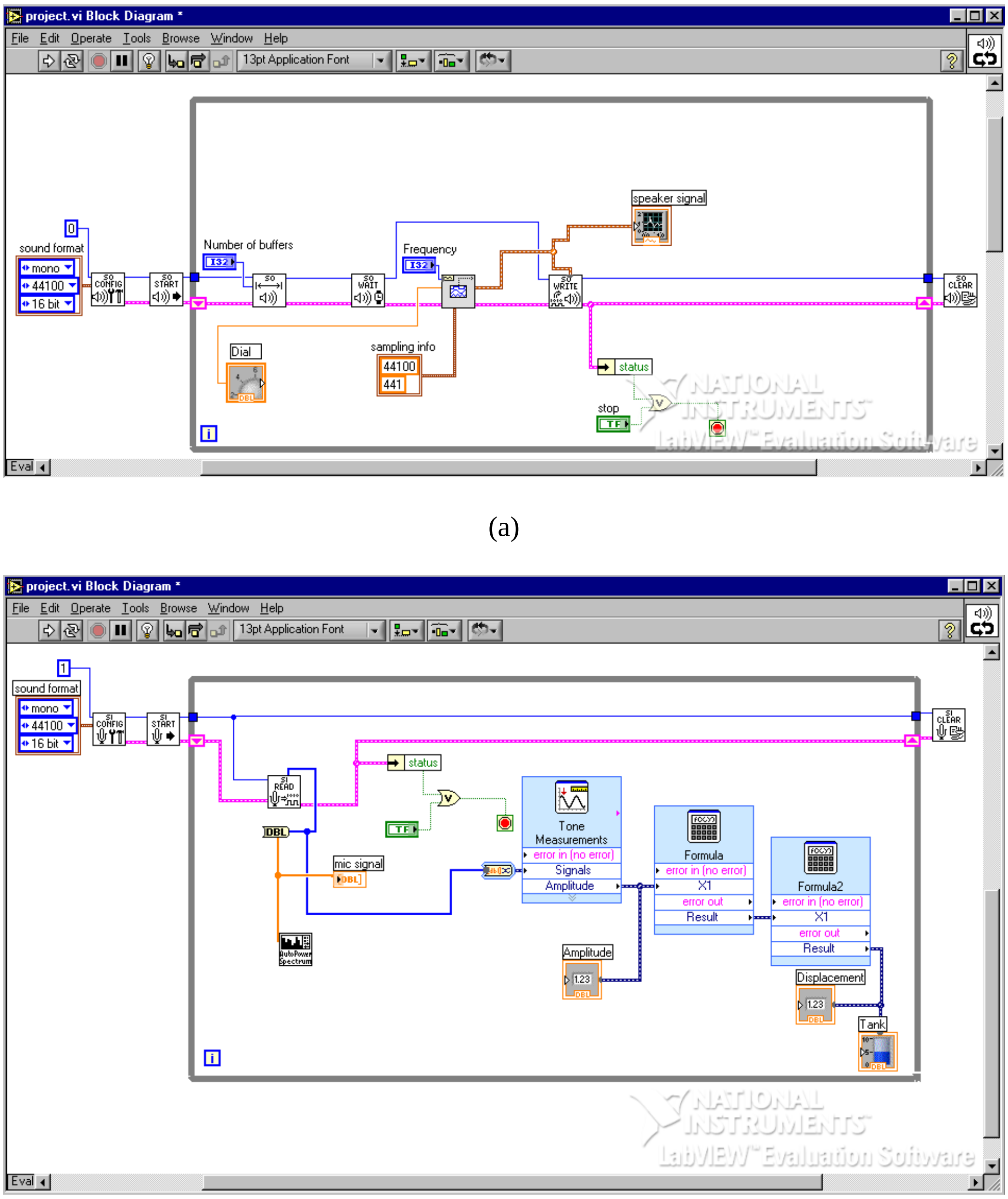
- **Number of buffers control**. Using more buffers ensures eliminating gaps and the generation of continuous sound wave.
- **Frequency control**, which allows the user to select the frequency of the generated sound wave (440 Hz).
- **Dial knob**, which determines the amplitude entered to the basic function generator.
- **Stop button**- Stops the sound wave generator (Speaker)
- **Stop mic button –** Stops the microphone
- **Amplitude –** A numerical indicator for the received wave amplitude
- **Displacement –** numerical indicator for linear displacement.

The block diagrams are shown in Fig. (4). The VIS block diagrams consist of a generator block diagram and a receiver block diagram. They include the following main components:

- **SO config VI**, it configures a sound output device. The device number is (0) and is associated with the PC speaker.
- **SO start VI**, **SO set number of buffers VI**, **SO wait VI, basic function generator VI**, **SO write VI**, **SO clear VI** and a **while loop**.

The receiver block diagram includes:

- **SI config. VI**, which configures a sound device for sound input operation. The device number is (1) which is associated with the microphone.
- **SI start VI**, **SI read VI**, **Tone measurement VI**.



(a)

(b)

Fig. 4. . Generator block diagram (a); receiver block diagram (b).

The last finds the single tone with the highest amplitude and returns the amplitudes value on its output terminal.

- **Formula VI. It receives a numeric value and applies it in a mathematical formula set by the** user, and returns a new value on its output terminal. The acquired amplitude value is fed to this VI, then it is applied in the formula D= f (A) in order to get the value of the displacement (D) at the output terminal, which feeds the displacement numeric indicator and the tank indicator. The block diagram includes a **SI clear VI** and a **while loop VI** also.

5. Experimental Results

Experiment results are given in Table (1).

Table 1. Experiment results.

Displacement (mm)	Amplitude (mV)
0	61
5	101
10	148
15	195
20	236
25	276
30	318
35	357
40	402
45	437
50	477
55	510
60	552
65	586
70	625
75	657
80	685
85	716
90	742
95	765
100	788

To represent the data, the method of data regression is used by utilizing Matlab curve Fitting Toolbox. Equation (3) with an additional phase term $y = a_1 \sin(b_1 x + c_1)$ is used to fit the regression model of the transducer. Curve fitting is shown in Fig. (5).

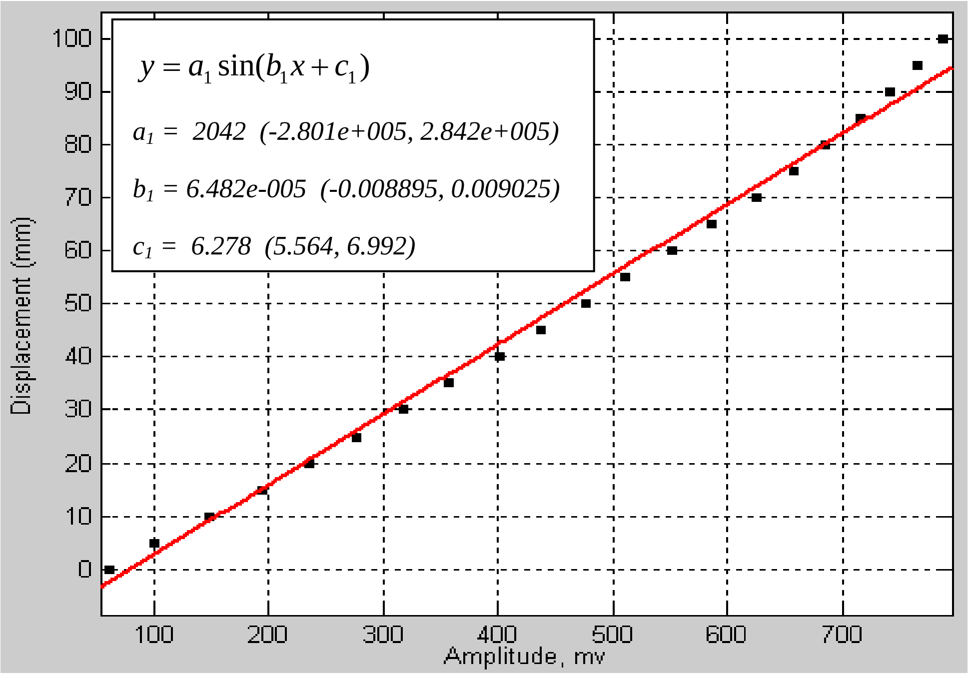


Fig. 5. Choosing $y = a_1 \sin(b_1 x + c_1)$ to fit the regression model of the transducer.

Concerning the transducer relative error by using the experimental results and regression model, maximum relative error (to F.S.D) was found equal to 1 %. It is important to note that environmental influences as temperature, humidity or vibration may have a minimum negligible effect on transducer performance. That is because the transducer tube may be made by of any isolating material with any wall thickness.

Moreover the tube could be externally isolated to any required degree. Limited friction of the plunger movement is mainly related to the moving object and has no influence on transducer components. Concerning signal processing, it takes place within the computer and is not affected by external noise.

Conclusions

- By utilizing the acoustic standing wave characteristics an acoustic displacement transducer was designed and tested successfully.
- The designed transducer is efficient, in expensive, and multipurpose. It could be integrated with other primary non electrical sensors and order to get an electrical read out and to realize computer data logging and automatic positional control.
- The Application of the acoustic displacement transducer as a position feed back of a pneumatic or hydraulic cylinder rod is an additional advantage. In this case the transducer is not embedded within the cylinder, but externally tied through a yoke to the cylinder rod.

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Guide for Contributors

Aims and Scope

Sensors & Transducers Journal (ISSN 1726-5479) provides an advanced forum for the science and technology of physical, chemical sensors and biosensors. It publishes state-of-the-art reviews, regular research and application specific papers, short notes, letters to Editor and sensors related books reviews as well as academic, practical and commercial information of interest to its readership. Because it is an open access, peer review international journal, papers rapidly published in *Sensors & Transducers Journal* will receive a very high publicity. The journal is published monthly as twelve issues per annual by International Frequency Association (IFSA). In additional, some special sponsored and conference issues published annually. *Sensors & Transducers Journal* is indexed and abstracted very quickly by Chemical Abstracts, IndexCopernicus Journals Master List, Open J-Gate, Google Scholar, etc.

Topics Covered

Contributions are invited on all aspects of research, development and application of the science and technology of sensors, transducers and sensor instrumentations. Topics include, but are not restricted to:

- Physical, chemical and biosensors;
- Digital, frequency, period, duty-cycle, time interval, PWM, pulse number output sensors and transducers;
- Theory, principles, effects, design, standardization and modeling;
- Smart sensors and systems;
- Sensor instrumentation;
- Virtual instruments;
- Sensors interfaces, buses and networks;
- Signal processing;
- Frequency (period, duty-cycle)-to-digital converters, ADC;
- Technologies and materials;
- Nanosensors;
- Microsystems;
- Applications.

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