Continental J. Applied Sciences 7 (1): 1 - 6, 2012 ISSN: 1597 – 9928

http://www.wiloludjournal.com
Printed in Nigeria

COMPUTER-BASED ACOUSTIC DETECTOR FOR DETERMINING THE TYPE AND CONCENTRATION OF A SOLUTION

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ABSTRACT
The problem of determining the concentration and the type of solution is an important issue in food, medical and chemical industries. In this work a trial has been made to explore the possibility of designing an computer based acoustic detector for determining the type and concentration of solution. Experimentally, it was found that the produced acoustic signal (frequency) can be used as informative parameter related with the type and concentration of solution. Signal conditioning and processing was carried out using labVIEW (G Language) VIs.

KEYWORDS: standing wave, acoustic resonance, LabVIEW VI, concentration of a solution

INTRODUCTION
The problem of determining the concentration and type of a solution is still an important issue in solution miming and chemical processing (Patterson 1972). Since undesirable containment of solute in water may cause noticeable change in environmental parameters which play a great role in human life and industry. For example the solute content of in liquefied food product is an important parameter in determining the value, stability, quality, and processibility of the product. The measurement and control of the amount of solute present is an important concern for food processors.

Another example is the utilization of ionic liquids which are finding widespread use as solvents in several applications, including biphasic catalysis, liquid–liquid extraction, and organometallic synthesis (Dupont 2002, Dyson 2002 and Huddleston 1998).For those reasons, it is essential to have fast and efficient method of determining the type of solute in water.

Several techniques and methods are used, or have been investigated to determine the concentration of solution (Bradley 1994). Electrical property of solution is used to determine the concentration of solution. An example of measuring electrical property of solution is conductometry which is based on measuring the presence of free ions (conductivity) of electrolyte solutions (Lyubov 1992).

Infrared Spectrophotometers have been utilized to measure moisture content, particularly in milk. The infrared spectrum of a sample is recorded by passing a beam of infrared through the sample (Stuart 2004). Nuclear magnetic resonance is a technique which is used to measure solids/liquids ratio and hence the solids content (Basaran 1999).

Other techniques such as chromatography, mass and photo spectrometers provide reliable measurement of concentration of a solution with high accuracy (Daniel 2010). Nevertheless, these technologies are still fairly expensive.

Selection of the right technique depends on the field where the measurement of concentration o a solution is required, required accuracy, reliability of measurement, and the operating environment.

Ultrasound is also used for measuring the concentration of simple solutions. In this case the speed of sound is used to characterize the structure of material. The behavior of traveled sound wave usually depends on the type of media, i.e. it travels more rapidly through solids than liquids(McClements 1987). It was shown that the speed of sound in a fluid changes with concentration (solids content) of a given material and ultrasound was utilized to measure the concentration of solution with good precision (David 1969).

Acoustic Emission (AE) has been successfully applied in many fields of material sciences (Marec 2008) . For example AE is a very attractive non intrusive technique for monitoring crystallization processes (Nesrine 2007). Acoustic methods based on creating an acoustic standing wave within a waveguide are also used to measure the concentration of substance in liquids and gases (Shebel 2008). Computerized acoustic detectors (Shebel 2008, Tariq 2003) were developed to measure the concentration of gases and vapors, these detectors were a part of gas chromatograph.

Acoustic field was also combined with thermo effect to build a simple analyzer (Tariq, 2010) which was used to measure the concentration of water content in kerosene. The signal obtained by the means of this analyzer was presented as a “chromatogram”.

The literature review of existing measurement detectors or analyzers which are used to determine the concentration of a solution shows that this issue is still considered as one of the most common engineering activities.

This explains why research and development in this field is a viable continuous process. Determining the concentration and the type of a solution can be realized using different types of analyzers and detectors.

The work described in this paper presents the possibility of using an acoustic measurement in order to determine the concentration of a solution.

OVERVIEW OF THE COMPUTER-BASED ACOUSTIC DETECTOR

The block diagram of the Computer-Based Acoustic Detector (CBAD) is shown in Fig. 1.

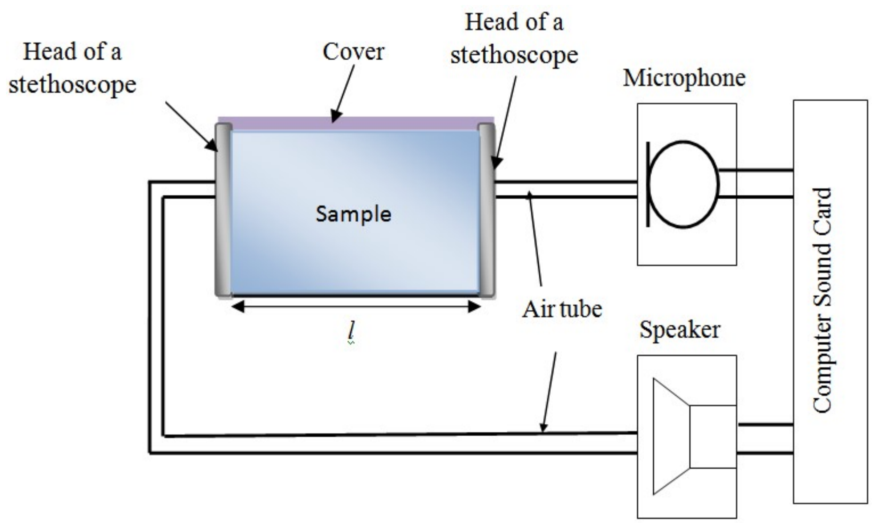

Figure 1. The block diagram of the Computer-Based Acoustic Detector

The detector consists of two head of a stethoscope type 3M Littmann, a microphone type HCM4530, a speaker type TM-2A, air tubes , a container, sound card type creative CT4810 and PC with LabVIEW software.

The principle of operation of the developed detector for determining a type of solution and the concentration of that solution is based on acoustic resonance when a standing wave is created in a chamber filled by a solution. The basic principle of the CBAD is that speed of sound is varied depending on the type of media filled in the chamber, which is also related to the frequency of the acoustic standing wave, when the distance between the two heads of stethoscope is constant. The standing wave may be created using the principle of acoustic resonance, which is characterized by the use of a speaker- microphone combination (Mohammad 2007).

Mathematical model

In section 2 we have mentioned that speed varies depending on the medium through which the sound wave passes. If the solution is an aqueous solution of NaCl or KCl, the speed of sound is given by the relation (Thomas, 2007):

$$V = \sqrt{\frac{E}{\rho}} \qquad (1)$$

Where:

V- Speed of sound [m/s]

E- Bulk Modulus

ρ- Density of media

In works (Shebel 2007 and Lawrence 2000) , it was shown that for aqueous solution, the speed of sound in a solution can be written as

$$C = \sqrt{\frac{\breve{E}}{\breve{\rho}}} \qquad (2)$$

Where

$\bar{E} = E_{water} + E_{solute}$

$\breve{\rho} = \rho_{water} + \rho_{solute}$

The frequency of free resonance when a standing wave is generated within a chamber is given as

$$f = \frac{C}{2L} \qquad (3)$$

L = The distance between two heads of stethoscope.

From formula 2 and 3 we can find

$$f = \frac{\sqrt{\frac{\bar{E}}{\breve{\rho}}}}{2L} = \frac{\sqrt{\breve{E}}}{2L} \cdot \sqrt{\frac{1}{\breve{\rho}}} \qquad (4)$$

Which can be simplified as

$$f = \frac{\sqrt{\breve{E}}}{2L} \cdot \sqrt{\frac{1}{\breve{\rho}}} = K\sqrt{\frac{1}{\breve{\rho}}} \qquad (5)$$

As given in relation 5, it was shown that the frequency is a function of density .

SIGNAL CONDITIONING AND PROCESSING

To measure frequency the signal from the microphone is entered to the MIC input of sound card of PC. Then, the entered signal is measured using computer software. The signal acquisition and processing were realized using LabVIEW software (Tariq, 2010 and Riccardo 2011). Implementing such experimental arrangement, one can measure, store, and log data to computer and make use of measured variable for further display and control purposes. The sound card was configured to generate a free resonance. The output the microphone is fed to the sound card where it is amplified and fed back to the speaker. Figure 2 shows the block diagram of LabVIEW program which was used to measure the frequency of the microphone input.

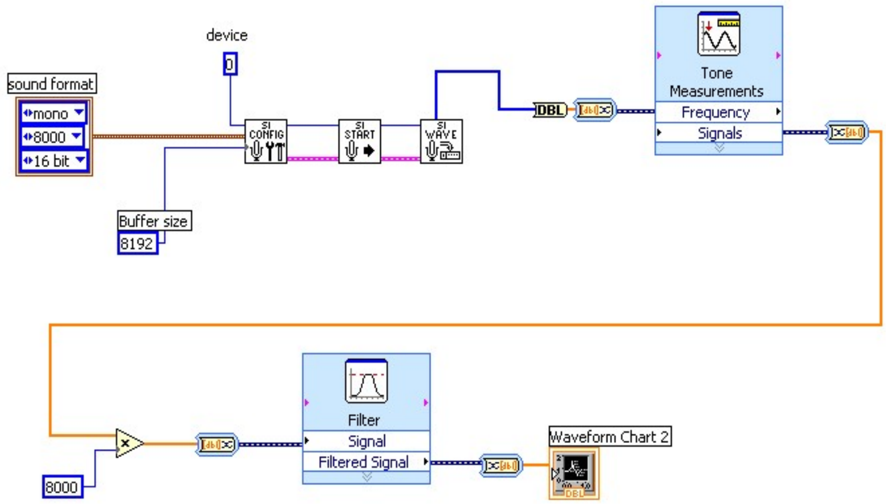

Figure 3. Block diagram of LabVIEW program

As shown above the elements and their functions are as follows:

a) SI configures VI:

Configures a sound device for sound input operation, the device is selected through the device number terminal, the selected number is 1 which is associated with the microphone in the LabVIEW, also the sound format terminal is fed by a constant controller.

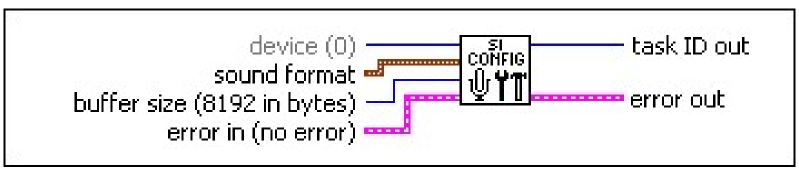

Figure 4. SI configure VI

b) SI start VI:

Prompts the sound input device to begin accumulating incoming data.

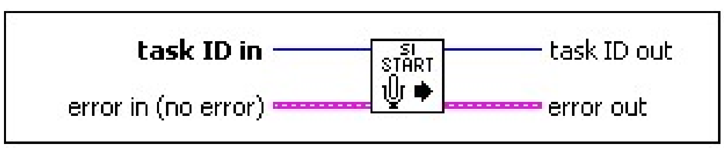

Figure 5. SI start VI

c) SI read VI:

Reads data from the sound input device, if data has arrived in the device buffer, it returns the data after buffering. Otherwise, it waits until data arrives .the microphone signal wave graph is fed from the output of this VI.

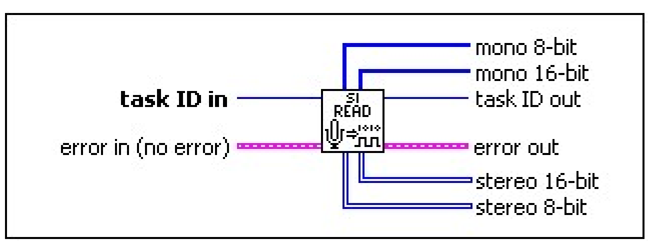

Figure 6. SI read VI

d) Tone measurement VI:
Finds the single tone with the frequency and returns the value in its output terminal. The frequency numeric indicator in the front panel is fed from the output terminal of this VI.

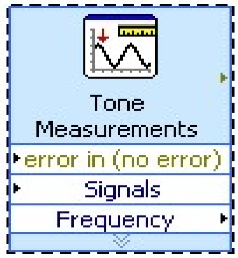

Figure 7. Tone measurement VI

EXPERIMENTAL RESULTS
Aqueous solutions of sodium chloride and potassium chloride were used as samples under test. The resonance frequency of each medium as a function of concentration was determined and it compared favorably with the literature (DelGRosso, 1994). Additionally, the frequency of sound was determined for aqueous solutions of sodium chloride or potassium chloride over the applicable concentration range.

Table 1. Experimental results

Density of solution [g/ 100ml]	Frequency , [Hz]	
	KCl	NaCl
1	2300	2680
2	2352	2700
3	2380	2780
4	2410	2830
5	2430	2848
6	2475	2890
7	2510	2920
8	2540	2958
9	2590	3010
10	2890	3045

CONCLUSIONS
- A simple computerized measurement system can be developed to determine the type and concentration of solution.
- As a future work, it is possible to design an acoustic analyzer for determining the type and consternation of solution.

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