International Journal of Engineering, Science and Mathematics
Vol. 10 Issue 06, June 2021,
ISSN: 2320-0294 Impact Factor: 6.765
Journal Homepage: http://www.ijmra.us, Email: editorijmie@gmail.com
Double-Blind Peer Reviewed Refereed Open Access International Journal - Included in the International Serial Directories Indexed & Listed at: Ulrich's Periodicals Directory ©, U.S.A., Open J-Gage as well as in Cabell's Directories of Publishing Opportunities, U.S.A

Design of Virtual Instrument for the Measurement of Ultrasonic Attenuation in Liquids and Liquid Mixtures

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Abstract:

The paper presents design of a Virtual Instrument (VI) for ultrasonic velocity measurements in liquids and liquid mixturesat frequencies from 1 to10 MHz. Hardware circuit designed in the laboratory with indigenous components is interfaced to PC using PCL-812 DAQ Card. Software is developed using Visual Basic. The liquid cell is designed in the laboratory and providesvariable distance between ultrasonic transducer and reflector that can be adjusted with an accuracy of ±0.01mm. This feature helps to carry out ultrasonic velocity and attenuation measurements in differential mode for increased accuracy. Ultrasonic transducers can be easily attached to liquid cell to carry out measurements at different frequencies.

Key words: Ultrasonic ; Virtual instrumentation; Attenuation;Velocity, DAQ.

1. Introduction:

Ultrasonic measurements have been put to use for a variety of applications for many decades. Initial rapid developments in instrumentation [1, 2] provoked by the technological advances since 1950 continue even today. Through the 1980's and continuing into the present, computers have provided scientists with smaller and more robust instruments with greater capabilities in the measurements of ultrasonic parameters [3]. The application of PC have made the researchers to exploit its capabilities to sense, detect, modify, manipulate and display the acquired data in user required form [4-5]. So the conventional instrumentation is being replaced by *Virtual Instrumentation* [6-7].

Numerous techniques and instruments have been designed by researchers to cope up with the requirements of higher accuracy. V.R.Vyagra has developed a PC based high resolution velocity measuring *virtual instrument*in pulse-echo setup [8]. P.K.Dube has developed *high resolution ultrasonic attenuation measurement setup* [9]. V.M.Ghodki have developed a *Sing Around Ultrasonic Virtual Instrumentation*forincreased precision of ultrasonic velocity measurement and making these measurements automated [10].

In the present work, a *Virtual Instrument (VI)*has been designed *for the measurements of ultrasonic velocity in liquids and liquid mixturesat frequencies from 1 to10 MHz.*

2. Experimentation:

A. Interfacing of Hardware to PC:

Hardware circuits are interfaced to PC using *PCL-812* data acquisition card [12]. It is a high performance, high speed, multi-function data acquisition card. The high end specifications of this full sized card and complete software support from third party vendors make it ideal for a wide range of applications in industrial and laboratory environments. These applications include data acquisition, process control, automatic testing and factory automation.

B. GUIS for Attenuation Measurement:

The GUIS for attenuation measurement is shown in Fig. 1. To find ultrasonic attenuation and velocity, the path length value (in mm), shown by digital vernier calliper fitted on the designed liquid cell, is entered in the *Path Length* text box. Now liquid sample is brought and maintained at desired temperature by starting SBTH. For this, *Temp button* is clicked which opens the GUIS of *SBTh* (Fig.2). The desired sample temperature value is entered in the text box of target sample temperature (TST) and *SBTh*is started by clicking *TReg (Temperature regulator)* button. After desired sample temperature is attained, the *Atte-Vel (Attenuation-velocity)* button is clicked that again opens the GUIS for Attenuation Measurement. The temperature of sample is shown on this GUIS.

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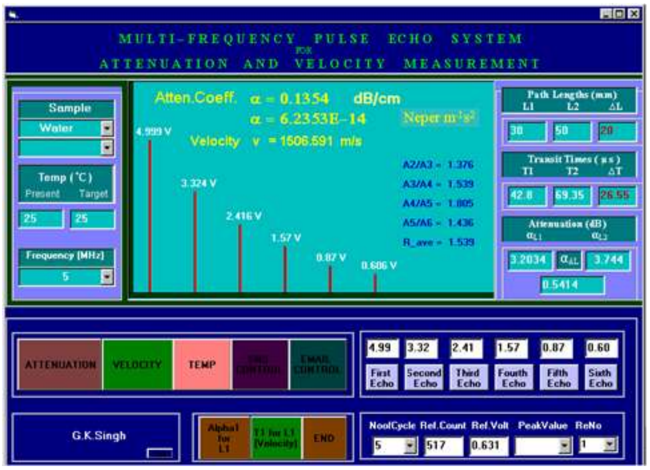

Fig.1: GUIS for Attenuation Measurement

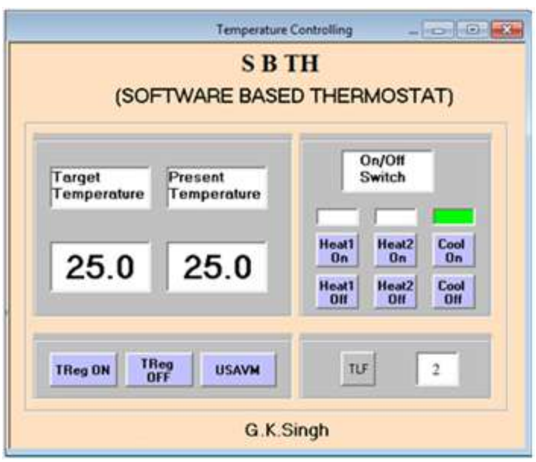

Fig.2: GUIS for Software Based Thermostat

C. Attenuation Measurement:

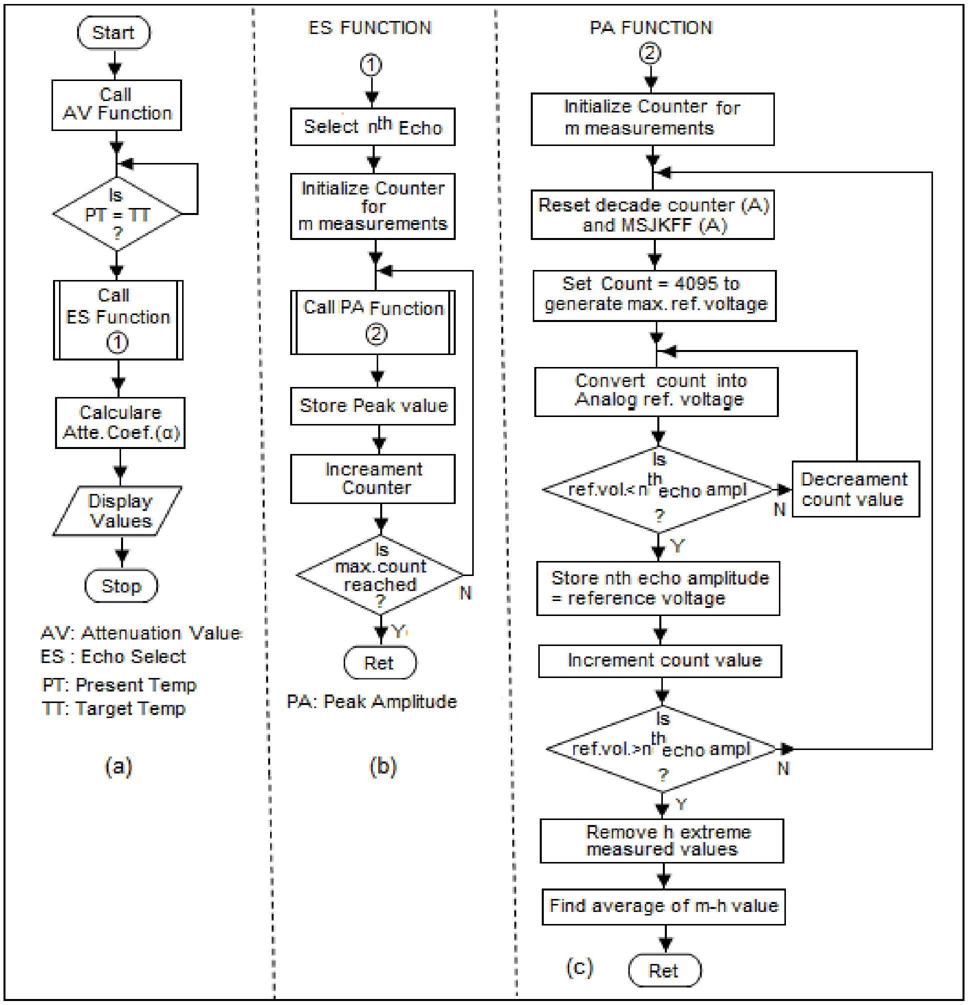

Fig.3: Flowchart for Attenuation Measurement

The logic and the sequence involved in attenuation measurements are shown in the flowcharts(Fig.3).The attenuation measurement starts with, an *Attenuation Value (AV)function* first reads the temperature value of liquid sample provided by *designed temperature controller* and verify, if its value is same as desired. If temperature of liquid sample differs from the desired value, *AV function* simply goes on reading and verifying liquid sample temperature continuously till its value equals as desired temperature value. When AV function finds that liquid sample temperature becomes equal to the desired temperature, it calls a function called*Echo Select (ES)* and transfers its control to it. *Echo Select(ES)* function selects n^{th} echo and calls a function called

Peak Amplitude(PA) to find amplitude of selected n^{th} echo. *PA function* repeats n^{th} echo amplitude measurement for desired number of timesand calls a function called *Filter* to remove some undesired extreme values. The two parameters of *PA function*, to make measurement desired number of times and to remove number of undesired extreme values, can be set by user through Graphical User Interface Screen (GUIS) of developed software. After getting some extreme values filtered out, *PA function* calculates average of remaining values that improves measurement accuracy.Like n^{th} echo amplitude measurement procedure, *PA function* measures amplitude of each echo when called by *ES function* and returns the measured value to *ES function*.Having all the echo amplitudes measured, *ES function* returns these measured values to *AV function*. *AV function* now finds the attenuation coefficient value by using equation (1) and displays attenuation coefficient value on GUIS.

$$\alpha = \frac{20}{2l} log_{10} \frac{\frac{A_1}{A_2}+\frac{A_2}{A_3}+ --- +\frac{A_{n-1}}{A_n}}{n-1} \frac{dB}{cm} \qquad (1)$$

where,

α : attenuation coefficient, dB/cm

A_1, A_2, A_3, --------, A_{n-1}, and A_n are amplitudes of n echoes, and

$2l$: the path length that ultrasonic waves travel in the liquid sample.

Attenuation coefficient (α) is also displayed on the GUIS in Neper $meter^{-1}s^2$.

3. Result and Discussion:

Ultrasonic attenuations are measured in distilled water, methanol, ethanol, acetone, acetonitrile, and cyclohexane at frequencies 2 and 5 MHz at 25 ^{0}C temperature. Measured values are given in table-1. Attenuation values are found to be well in agreement with literature values.

Table 1: Measuredultrasonic attenuations in distilled water, methanol, ethanol, acetone, acetonitrile and cyclohexane at 2 and 5 MHz frequencies at 25 ^{0}C

Sample	**Freq.**	**Path lengths**			**Total attenuation**			**Attenuation Coefficient**		**Litt. Value**
	f (MHz)	L_1 (mm)	L_2 (mm)	ΔL (mm)	Atten. for L_1, α_{L1} (dB)	Atten. for L_2, α_{L2} (dB)	Atten. Diff. Δα (dB)	$\alpha = \frac{\Delta\alpha}{\Delta L}$ (dB/cm)	α/f^2 (10^{-15} $Nm^{-1}s^2$)	
Distilled Water	2	30	40	10	3.0092	3.0312	0.0220	0.0110	27.50	25 [18]
	5		50	20	3.2034	3.3974	0.1940	0.0485	22.35	
Methanol	2	30	45	15	3.1571	3.1913	0.0342	0.0114	32.81	32 [18]
	5				3.2758	3.5284	0.2526	0.0842	38.79	
Ethanol	2	30	40	10	3.2676	3.3010	0.0334	0.0167	48.07	51 [18]
	5	35	45	20	3.9492	4.3916	0.4424	0.1106	50.93	
Acetone	2	30	50	20	3.3384	3.4196	0.0812	0.0203	58.43	35 [18]
	5	20	30	10	2.232	2.6616	0.4296	0.1074	49.46	
Acetonitril	2	30	45	15	3.2109	3.2793	0.0684	0.0228	65.62	
	5	30	50	20	3.5659	4.0131	0.4472	0.1118	51.49	
Cyclohexane	2	20	40	20	6.4218	6.6550	0.2332	0.0583	167.85	
	5				6.9114	8.3466	1.4352	0.3588	165.25	

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