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

G.K.Singh[1], S.J.Sharma[2] and A. S. Lanje[3]

[1]*Deptt. of Electronics, A.N. College, Anandwan, Warora – 442907*

[2]*Deptt. of Electronics, RTM Nagpur University, Nagpur- 440033*

[3]*Deptt. of Electronics, Dr. Ambedkar College Chandrapur-442402*

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 Velocity Measurement:

The GUIS for velocity 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 Velocity Measurement. The temperature of sample is shown on this GUIS.

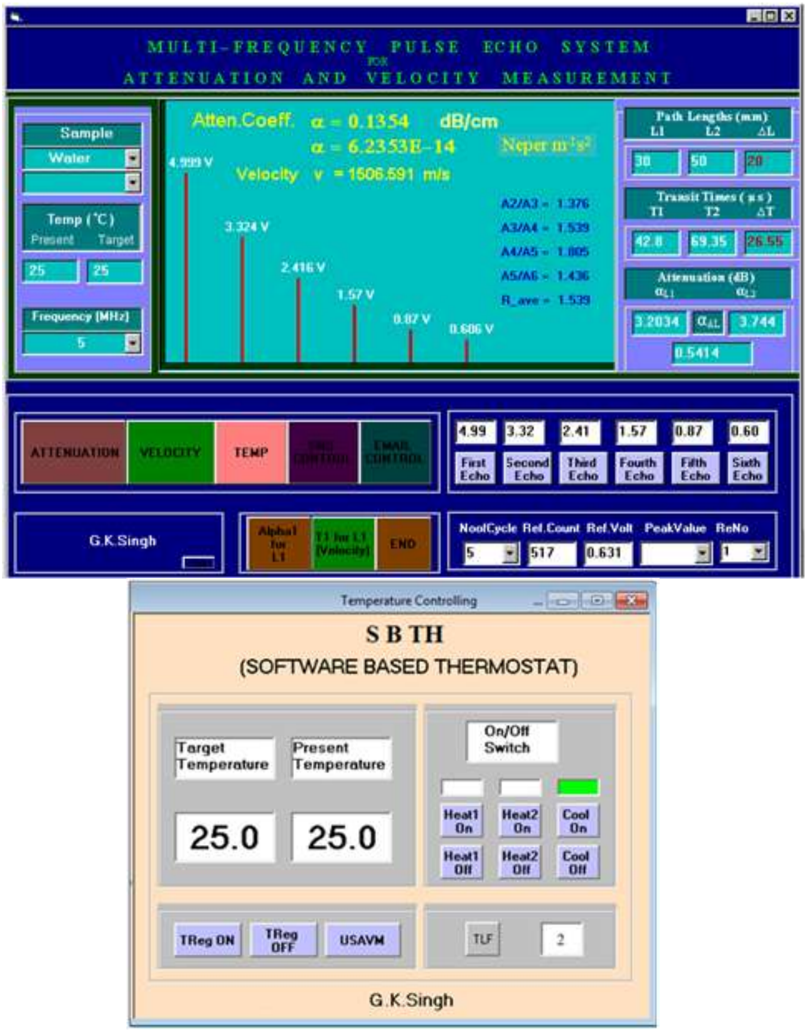

Fig.2: GUIS for Software Based Thermostat

C. Velocity Measurement:

The timing diagram is shown in Fig.3 and flowchart in Fig.4.Ultrasonic (US) velocity is found by measuring the time interval of the second echo by *Time Interval (TI)* Function, from the moment ultrasonic burst is sent by ultrasonic transducer in the liquid sample using.*Time Interval (TI)Function* sends command to generate ultrasonic burst as well as starts the timer counter to count 10MHz clock pulses.

The instant second echo is received, it stops the timer counter and reads its count value. Count reading of timer counter multiplied by 0.1 μs gives the time interval (t_{int}) of the second echo. Time interval of second echo divides by 2, i.e. $t_{int}/2$, gives the time interval between any two successive echoes with an accuracy of 0.1μs.

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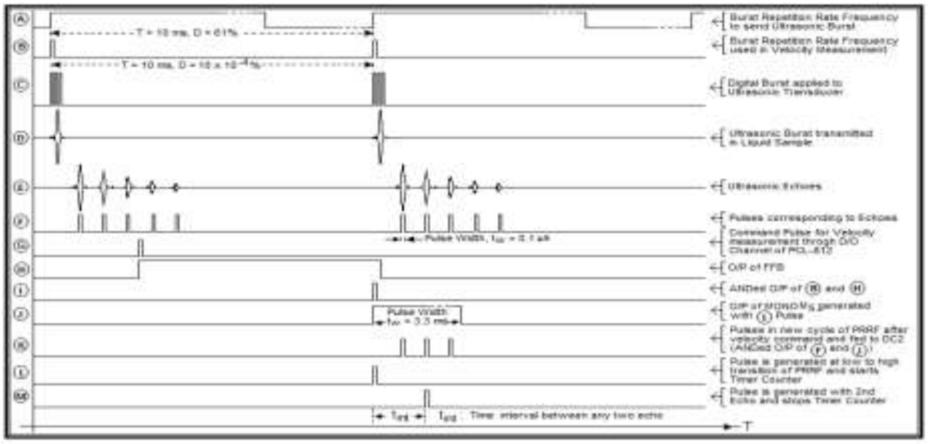
Thus, after finding time interval between two successive echoes, the *ultrasonic velocity*, in liquid sample, is calculated using the formula:

$$V = \frac{2d}{t_{int}} \qquad (1)$$

where, V : Ultrasonic velocity
2d: Path length that ultrasonic echoes travels
t_{int} : Time interval between two successive echoes



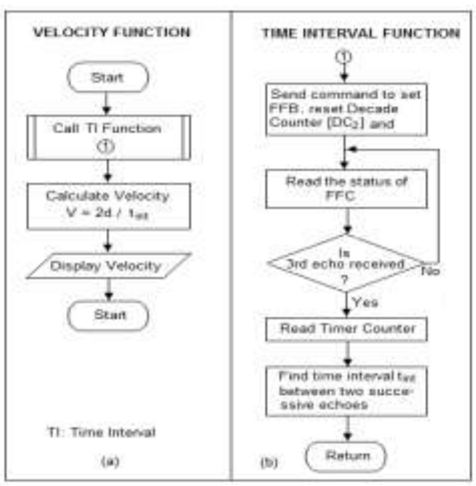


Fig.4: Flowchart for Ultrasonic Velocity Measurement

3. Result and Discussion:

Ultrasonic velocities are measured in distilled water, methanol, ethanol, acetone, acetonitrile and cyclohexane at frequencies of 2 and 5 MHz in the temperature range of 20 to 40 °C. Measured values are given in tables 1, 2 and 3 respectively. Variations of velocities with respect to temperatures are shown in Fig.5, 6, 7, 8, 9 and 10.

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Table 1: Measuredultrasonic velocities in Distilled Water and Methanol at 2 and 5 MHz frequencies in the temperature range from 20 to 40 ^{0}C

Sample	**Freqn.**	**Temp.**	**Path lengths**			**Transit Time**			**Measured velocity**	**Litt. value**
	f (MHz)	**T (^{0}C)**	**L_1 (mm)**	**L_2 (mm)**	**ΔL (mm)**	**T1 (μs)**	**T2 (μs)**	**ΔT (μs)**	**V (m/s)**	
Distilled Water (H_2O)	2	20	30	50	20	42.45	69.45	27.00	1481.481±6.207	1482.343
	5					43.25	70.22	26.97	1483.129±6.220	[13]
	2	25	30	50	20	42.05	68.80	26.75	1495.327±6.317	1496.687
	5					42.80	69.55	26.75	1495.327±6.317	[13]
	2	30	30	50	20	41.65	68.15	26.50	1509.434±6.430	1509.127
	5					42.20	68.70	26.50	1509.434±6.430	[13]
	2	35	30	50	20	41.35	67.70	26.35	1518.027±6.499	1519.808
	5					41.30	67.65	26.35	1518.026±6.499	[13]
	2	40	30	50	20	41.23	67.40	26.17	1528.468±6.583	1528.863
	5					41.00	67.15	26.15	1529.637±6.592	[13]
Methanol (CH_4O)	2	20	30	45	15	53.25	79.05	25.80	1162.791±5.265	1120.000
	5					53.85	79.73	25.88	1159.012±5.235	[14]
	2	25	30	45	15	54.00	80.20	26.20	1145.038±5.118	1103.250
	5					54.55	80.66	26.11	1149.070±5.150	[15]
	2	30	30	45	15	54.75	81.35	26.60	1127.820±4.975	1089.360
	5					55.35	81.95	26.59	1128.350±4.979	[15]
	2	35	30	45	15	54.45	82.35	26.90	1115.242±4.874	1061.920
	5					56.15	83.11	26.96	1112.657±4.854	[15]
	2	40	30	45	15	56.15	83.40	27.25	1100.917±4.759	1055.780
	5					56.95	84.32	27.37	1095.891±4.721	[15]

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Table 2: Measuredultrasonic velocities in Ethanol and Acetone at 2 and 5 MHz frequencies in the temperature range from 20 to 40 ^{0}C

Sample	Freqn.	Temp.	Path lengths			Transit Time			Velocity	Litt. value
	f (MHz)	T (^{0}C)	L_1 (mm)	L_2 (mm)	ΔL (mm)	T1 (µs)	T2 (µs)	ΔT (µs)	V (m/s)	(m/s)
Ethanol (C_2H_6O)	2	20	41.3	51.3	10	72.05	88.65	16.60	1204.819±8.419	1160.300 [16]
	5		35.0	45.0		67.62	84.15	16.63	1202.646±8.391	
	2	25	41.3	51.3	10	73.10	89.95	16.85	1186.944±8.190	1143.100 [16]
	5		35.0	45.0		68.75	88.95	17.20	1162.791±7.884	
	2	30	41.3	51.3	10	74.15	91.30	17.15	1166.181±7.927	1126.200 [16]
	5		35.0	45.0		67.75	87.30	17.55	1139.601±7.597	
	2	35	41.3	51.3	10	75.15	92.65	17.50	1142.857±7.636	1109.400 [16]
	5		35.0	45.0		70.65	88.40	17.75	1126.761±7.439	
	2	40	41.3	51.3	10	76.15	94.20	18.05	1108.034±7.213	1092.700 [16]
	5		35.0	45.0		71.75	89.80	18.05	1108.033±7.213	
Acetone (C_3H_6O)	2	20	41.3	51.3	10	70.65	87.20	16.55	1208.460±8.467	1192.000 [17]
	5		20.0	30.0		41.25	58.05	16.8	1190.476±8.235	
	2	25	41.3	51.3	10	72.20	88.85	16.65	1201.201±8.372	1170.000 [18]
	5		20.0	30.0		42.00	59.05	17.05	1173.021±8.013	
	2	30	41.3	51.3	10	73.50	90.65	17.15	1166.181±7.927	1148.000 [19]
	5		20.0	30.0		42.58	60.00	17.15	1166.181±7.927	
	2	35	41.3	51.3	10	74.80	92.35	17.55	1139.601±7.597	1123.000 [17]
	5		20.0	30.0		43.85	61.35	17.50	1142.857±7.636	
	2	40	41.3	51.3	10	75.97	94.15	18.08	1106.195±6.890	1101.000 [19]
	5		20.0	30.0		44.55	63.00	18.45	1084.011±6.928	

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Table 3: Measuredultrasonic velocities in Acetonitrile and Cyclohexane at 2 and 5 MHz frequencies in the temperature range from 20 to 40 ^{0}C.

Sample	**Freqn.**	**Temp.**	**Path lengths**			**Transit Time**			**Velocity**	**Litt. value**
	f (MHz)	**T (^{0}C)**	**L_1 (mm)**	**L_2 (mm)**	**ΔL (mm)**	**T1 (µs)**	**T2 (µs)**	**ΔT (µs)**	**V (m/s)**	**(m/s)**
Acetonitrile (C_2H_3N)	2	20	41.5	51.5	10	65.55	80.85	15.30	1307.190±9.796	1305.000
	5		30.0	50.0	20	53.55	84.00	30.45	1313.629±4.927	[17]
	2	25	41.5	51.5	10	66.80	82.32	15.52	1288.659±9.538	1290.000
	5		30.0	50.0	20	54.30	85.25	30.95	1292.407±4.808	[17]
	2	30	41.5	51.5	10	67.85	83.59	15.74	1270.648±9.293	1264.000
	5		30.0	50.0	20	55.15	86.55	31.40	1273.885±4.681	[17]
	2	35	41.5	51.5	10	68.75	84.75	16.00	1250.000±9.014	1245.000
	5		30.0	50.0	20	55.80	87.95	32.15	1244.160±4.480	[17]
	2	40	41.5	51.5	10	69.85	86.10	16.25	1230.769±8.758	1224.000
	2		30.0	50.0	20	56.95	89.40	32.45	1232.666±4.403	[17]
Cyclohexane (C_6H_{12})	2	20	20.0	40.0	20	38.12	69.45	31.33	1276.732±4.701	1278.450
	5					38.15	69.45	31.30	1277.955±4.709	[17]
	2	25	20.0	40.0	20	38.40	70.35	31.95	1251.956±4.532	1253.390
	5					38.44	70.40	31.96	1251.564±4.529	[17]
	2	30	20.0	40.0	20	39.19	71.75	32.56	1228.501±4.375	1228.720
	5					39.20	71.80	32.60	1226.994±4.365	[17]
	2	35	20.0	40.0	20	39.91	73.15	33.24	1203.369±4.211	1204.380
	5					39.90	73.15	33.25	1203.008±4.209	[17]
	2	40	20.0	40.0	20	41.12	75.05	33.93	1178.898±4.054	1180.240
	5					41.10	75.05	33.93	1178.898±4.054	[17]

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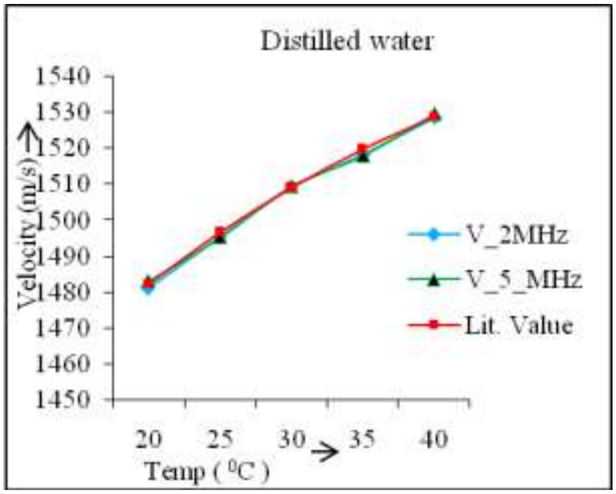


Fig. 5: Temperature dependence of velocity in distilled water

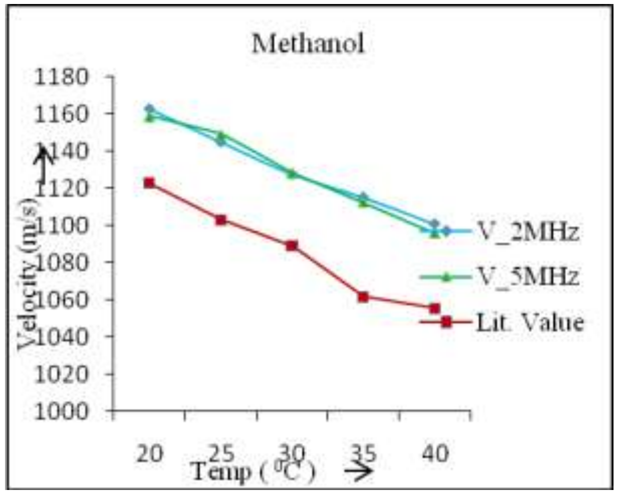


Fig. 6: Temperature dependence of velocities in methanol

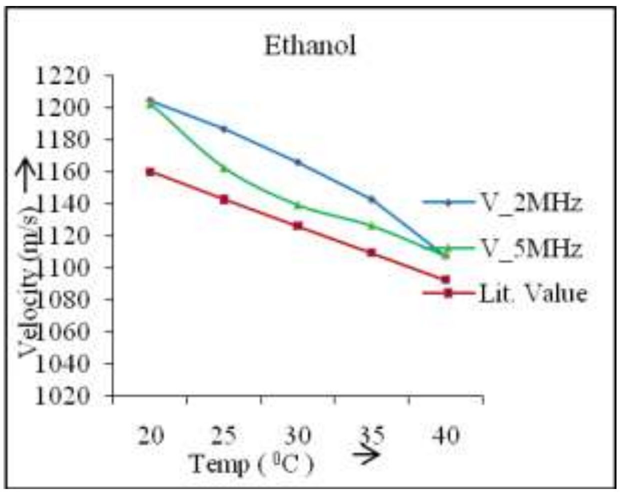


Fig. 7: Temperature dependence of velocities in ethanol

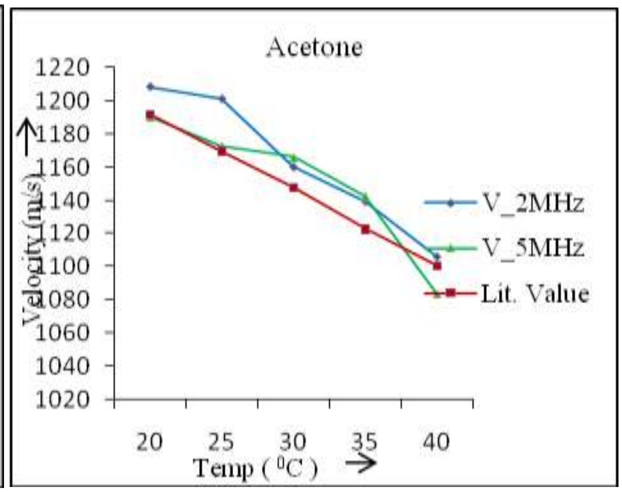
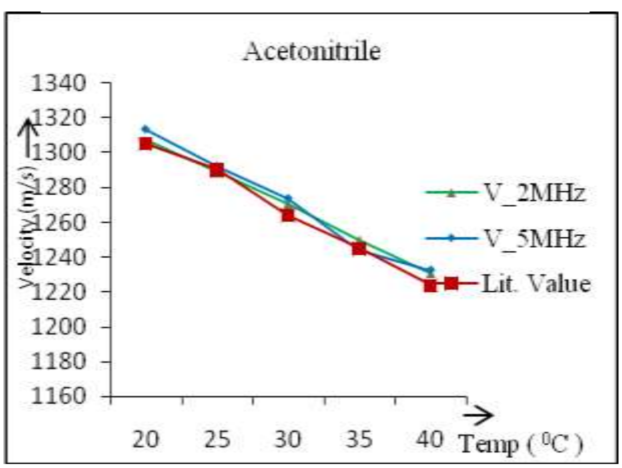
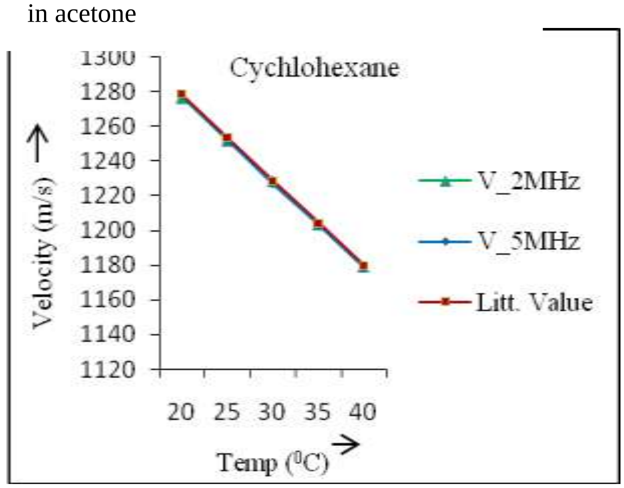


Fig. 8: Temperature dependence of velocities in acetone





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