Electronic Journal «Technical Acoustics»
http://www.ejta.org

2010, 5

S. Rajagopalan[1], S. J. Sharma[1], V. M. Ghodki[2]

[1]*Department of Electronics, Nagpur University Campus, Nagpur 440 033 (India),*
e-mails: rajagopalan@acousticsindia.com, sharmasat@gmail.com
[2]*Department of Electronics, J. B. Science College, Wardha 442 001 (India),*
e-mail: vilasghodki@rediffmail.com

Design of virtual sing-around system for precise ultrasonic velocity measurements

Received 27.02.2010, published 19.03.2010

A virtual sing-around system with operating frequency of 2 MHz has been developed in the laboratory using PCL 812 data acquisition card along with IBM compatible PC using. The necessary circuit elements such as wide band amplifier, detector, pulse shaper etc. were designed using indigenous components. Powerful and effective data acquisition software at the back end has been written in "C" programming language that controls pulse generation, detection, re-triggering and travel time measurement. User friendly and interactive GUI screen has been designed in Visual Basic at the front end to accomplish the data acquisition, parameter setting, file manipulation, control and synchronization of the other functions involved in the measurements. Standard external quartz crystal oscillator of 32 MHz has been used to measure the travel time. Improved accuracy in travel time measurements has been obtained.

Keywords: ultrasonic velocity, virtual instrumentation, virtual sing-around system, data acquisition card, GUI screen.

INTRODUCTION

Recently computers have virtually replaced almost all the measuring devices and control systems, due to the technological advancement, increased processing power, ergonomic window based software and growing list of available interfaces and drivers of the personal computers. Software has taken the complete control over the hardware. Such a software control of the instruments has given rise to entirely new field of instrumentation called the virtual instrumentation (V.I.) [1].

Virtual instrumentation is the modern, powerful and effective concept in electronics instrumentation. It is the software representation of traditional and exciting new measurement instruments on a computer. In other words, one can say that Virtual Instrumentation is a programming technique [2] to use a general-purpose computer along with suitable input/output hardware to mimic or simulate the characteristics and behavior of a real test/measurement/data logging instruments along with their dedicated controls and displays. All these features are accomplished readily with the added versatility that comes with the software.

To realize any Virtual Instrumentation we need a data acquisition card [3] or an ADC card along with other signal conditioners that is plugged into a PC. Under the suitable software data acquisition, process and display is achieved. In other words, the functions of data acquisition, analysis and display are performed by the computer software rather than by special hardware. But the actual data acquisition is performed by specially designed hardware. The outputs of these *virtual instruments* will be displayed on the screen in a manner that exactly copies the more familiar dedicated instruments, to emulate the output of a digital voltmeter, an oscilloscope or a spectrum analyzer etc.

The virtual instrumentation can be implemented in programming languages like C, C++, PASCAL, VB, VC etc. Graphic programming [4] involves the creation of a panel diagram, which contains the controls while the function diagram contains functions or icons corresponding to the controls and displays on the panel diagram. Each function is a Virtual Instrumentation or sub Virtual Instrumentation with terminals. These functions are wired through terminals so that the data flows from one function to the other. The Virtual Instruments are cost effective, flexible and customizable. The window based software menu and tool task bars allow the inexperienced user to easily carry out measurements. Measurements carried out using virtual instrumentation are very fast that they appear to be online. Measured data can be printed or stored as a file for further offline processing.

Ultrasonic measurement techniques can be grouped into pulsed and continuous wave. The pulse technique includes the time of flight, sing-around, variable path substitution and pulse superposition. The pulse techniques are applicable to the measurement of both phase and group velocities. Broadband pulses (short pulses) will yield group velocity whereas narrow band pulses (long pulses containing approximately 10–20 cycles or more) will yield the phase velocity for the frequency of radio frequency (r.f.) signal constituting the pulse. The continuous wave system employs the interferometric techniques, which involve either a fixed path length and a variable frequency or a fixed frequency and a variable path length. The continuous wave technique measures the phase velocity.

Among the pulse techniques, the sing-around technique is very popular and widely used due to its simplicity, better accuracy and reliability. Cedrone and Curran [5] first suggested principle of the technique. Forgacs [6] first attempted its high accuracy. Since then sing-around technique has undergone many modifications [7–16]. A frequency selectable sing around system was developed for high accuracy by Rajagopalan and Tiwari [17]. Apart from ultrasonic velocity measurements, sing-around technique has been used for the measurement of distance using optical fiber [18], concentration of the solution using Phase Locked Loop (PLL) [19] and differential velocity ratio [20]. A system using pulser-receiver involving integrated Fast Fourier transform has been developed by Joshi *et al* [21–22] for non-destructive characterization of materials.

In the present work, we have designed a precise virtual *sing-around system* using PCL 812 data acquisition card and off the shelf available electronic components for designing the necessary electronic circuits.

1. PRINCIPLE OF SING-AROUND TECHNIQUE

A pulse generator sends out a short instant pulse of r.f. carrier frequency which is fed to transmitting transducer, T_x , (Figure 1) at one end of the sonic course in the medium under consideration. After traversing the medium, the acoustic pulse is reconverted to an electronic pulse by a receiving transducer, T_r, at the other end of the sonic course where it is amplified, detected and used to re-trigger another input pulse so that a continuous succession is generated. This loop runs continuously. A count of pulses generated in an accurately measured interval of time allows the determination of the average time delay experienced by a single pulse in circulating around in the closed loop. From this average time, circuit delay and the accurately known path length of the sonic course, the ultrasonic velocity in the medium is calculated.

This average time delay is made up of two components; the desired acoustic delay due to the medium and the delay caused by the electronic circuits and the crystal transducers. Since the electronic delay cannot be ignored, it has to be accurately determined and accounted for. In the present work, electronic circuit delay has been found for 32 MHz crystals of 1.131 μs.

Figure 1. Block diagram of PC based sing-around system

2. HARDWARE DESIGN AND SOFTWARE

Figure 1 shows the block diagram of a PC based sing-around technique. It consists of IBM compatible PC with ISA or PCI slots, ADC card, RF Amplifier, sample holder with matched piezoelectric transducers, receiver amplifier and pulse shaper circuit. The multifunction ADC card can be any ISA or PCI slot based. A small pulse of 5 μs is generated using a "C" program. The pulse width can be changed as per the need of the system under study. This pulse is ANDED with a 2 MHz source so as to get radio frequency carrier pulse of 2 MHz. This is amplified to 24 V peak to peak using transistor BD115 and is used to drive the transmitting transducer, T_x. The ultrasonic waves generated travel through a sample and are then received by receiving transducer, T_r. The received pulse consists of the direct received pulse and the echoes. This pulse is amplified by the receiver amplifier and shaped to generate pulse of 5 Volts for each echo.

The software written in "C" language controls the operations of the electronic circuits of the sing-around system. 2 MHz signal of 5 μs from the PCL 812 ADC card itself is generated under the software control. This pulse is amplified to 24 Volt (peak to peak) using transistor BD115 and fed to the transmitting transducer, T_x, travels through the sample. This pulse is then received at the receiving transducer, T_r. This pulse is then amplified and detected using external pulse shaper circuit; and is used to re-trigger the transmitting transducer. The loop runs continuously. In the present work, it can be made to run for the desired number of times selected from the front panel menu to go in the sing around mode. A counter with 32 MHz (Figure 2) external standard gated pulse are used to count the number of pulses, that are proportional to travel time in the specimen under study, described in our earlier work [23].

A powerful and effective Visual Basic Windows98 based *data acquire, control, display & signal processing* software package has been developed in our laboratory [24]. The graphical user interface screen has been developed in Visual Basic [25–27], which form the front control panel (Figure 3). This software package enables the operator to select appropriate parameters such as frequency, pulse width and travel time measurement (using 32 MHz crystal) to carry out ultrasonic velocity measurements at room temperature, with an additional feature of database generation of the measurements carried out on various samples in one cycle or for whole day at room temperature. This database could be accessed in the excel sheet for plotting the graph and further analysis.

Figure 2. Block diagram for using 32 MHz source for precise measurement of ultrasonic velocity

Figure 3. Screen shot of the designed Virtual Instrumentation

3. RESULTS

The virtual sing-around system developed in the laboratory has been tested for the ultrasonic velocity measurements in different standard liquids. It has been found that the ultrasonic velocity measurements carried out using the above system matches well with those reported in the literature [28]. Exhaustive statistical analysis has been done on the large amount of data collected on distilled water and the other standard liquids, at different temperatures. It has been found that the satisfaction criteria of our measurements are of the order of 99%. Table 1 shows the results of our measurements carried out in various liquids at different temperatures.

Liquid	Temperature in °C	Measured Velocity(m/s)	Velocity from literature (m/s)
Dist. Water	25.00	1495.8830	1496.6870 [28]
	25.90	1499.0335	1499.0630 [28]
	26.00	1500.0487	1499.3230 [28]
	26.60	1500.6010	1500.8680 [28]
	27.40	1502.8900	1502.8870 [28]
Benzene	25.00	1298.7563	1298.8200 [15]
	25.10	1298.4643	
	26.00	1294.2867	
	27.40	1288.9041	
	27.80	1283.1267	
Toluene	24.50	1306.7727	
	25.00	1304.2011	1304.0700 [15]
	25.20	1302.0568	
	26.90	1301.8234	
	27.90	1291.5767	
Chlorobenzene	25.00	1276.1242	1276.3200 [17]
	25.60	1275.3562	
	26.60	1273.1429	

4. CONCLUSION

The ultrasonic velocity measurements using the present virtual sing-around system is found to be accurate and consistent. The system can be used for precise ultrasonic velocity measurements in liquids, gels and solids; and can be performed at different temperatures and frequencies. In the present work, a 32 MHz standard frequency source was used for travel time measurements. Attempts are being made to use other frequency sources for better time measurements. New systems in nano-colloids/nanoparticle gels are being taken up for further study. Most of the functions and controls are user selectable from GUI screen or the front panel menu to match needs of the system under study in the sing-around mode.

ACKNOWLEDGEMENT

The authors are grateful to Dr. V. R. Vyaghra for useful discussions during the work, to Dr. M. N. Ghoshal and Dr. K. N. Sathianathan for their interest in the work. Two authors (S. J. Sharma and V. M. Ghodki) would like to thank University Grants Commission, New Delhi for the financial assistance provided to carry out the work.

REFERENCES

1. http://www.national.com – National Instrumentations Web site, 2009
2. http://www.Advantech.com.
3. http://www.usUltratek.com.
4. http://www.ni.com.
5. N. P. Cedrone and D. R. Curran. Electronic pulse method for measuring the velocity of sound in liquids and solids. J. Acoust. Soc. Am. 26(6), 963-966 (1954).
6. R. L. Forgacs. Improvement in the sing around technique for ultrasonic velocity measurement. J. Acoust. Soc. Am. 32, 1697-1700 (1960).
7. M. Greenspan and C. E. Tschiegg. Sing around ultrasonic velocimeter for liquids. Rev. Sci. Instr. 28, 897–901 (1957).
8. A. Myers, L. Mackinnon and F. E. Hoare. Modification to standard pulse technique for ultrasonic velocity measurement. J. Acoust. Soc. Am. 31, 161-164 (1959).
9. R. Garnsey, R. J. Boe, R. Mahoney and T. A. Litovitz. Determination of electrolyte apparent Molal compressibility at infinite dilution using a high precision ultrasonic velocimeter. J. Chem. Phys. 50 (12), 5222-5225 (1969).
10. S. P. Satyabala, M. Rao and M. Suryanarayana. A sing around ultrasonic velocity meter using Integrated circuit. Acoust. Lett. 2, 29 (1978).
11. Y. K. Yogurtcu, E. F. Lambson, A. J. Miller, and G. A. Saunders. An apparatus for high precision measurement of ultrasonic wave velocity. Ultrasonics 18, 155–159 (1980).
12. V. S. Soitkar, K. P. Sunnapwar and G. N. Navaneeth. A solid state pulse sing-around system for ultrasonic velocity measurement. Ind. J. Pure Appl. Phys. 19, 555–559, (1981).
13. B. Woodward and M. N. Salman. Programmable ultrasonic velocimeter. Acoustics letters 6(8), 110–114 (1983).
14. P. K. Agnihotri, C. S. Adgaonkar and C. Y. Bedre. A low cost solid state pulsed system for ultrasonic velocity and absorption. Archives of Acoustics, 12(3- 4), 301–309 (1987).

15. S. Ernst, W. Marczak, R. Manikowski, E. Zorebski and M. Zorebski. Speed of ultrasonic in liquids measured at a constant acoustic path length: comparison ad discussion of errors. Acoust. Letters, 15(7), 123–130 (1992).
16. S. P. Yawale and S. V. Pakade. Solid state variable frequency pulser-receiver system for ultrasonic measurement. Ind. J. Pure and Appl. Phys., 33, 638–642 (1995).
17. S. A. Tiwari, S. Rajagopalan and V. Amritha. A frequency selectable sing around for measurement of ultrasonic velocity. Acoustics Letters, 14(7), 135–140 (1991).
18. Kentaro Nakamura, Takahiro Okada and Sadayuki Ueha. Measuring optical path length of a plastic optical fiber using the sing around method and its sensor applications. Opt. A: Pure Appl. Opt. 3(5), L17–L19 (September 2001).
19. Kiyoshi Ikeda. Ultrasonic measurement of concentration in solutions by phase –locked loop method. Jpn. J. Appl. Phys., 36(5B), 3180–3183 (1997).
20. S. Mitaku and A. Saknishi. Differential ultrasonic velocimeter for measurement of dilute suspension. Rev. Sci. Instrum. 48(6), 647-649 (1977).
21. P. D. Motiwala, A. A. Agashe, S. R. More, V. M. Joshi, and S. K. Kataria. PCI bus based high speed digitizer for capture and analysis of ultrasonic signals. Proc. of the International conference and Exhibition on Ultrasonics (ICEU 99) held at New Delhi Dec.1999.
22. V. M. Joshi, S. R. More, P. D. Motiwala, A. A. Agashe, S. K. Lalwani, T. S. Krishnan and S. K. Kataria. Development of PCI bus based add-on cards for waveform analysis and video image capture. BARC News Lett. No. 196, May 2000.
23. S. Rajagopalan, S. J. Sharma, V. M. Ghodki. Low cost virtual instrumentation using PC printer port for ultrasonic velocity measurement. Electronic Journal of Technical Acoustic, www.ejta.org, 12, 2007.
24. Designing the User Interface: Ben Shneiderman, Addison Wesley Longman Inc. pp. 156–183 (2000).
25. Mastering VB6: Evansgelos Petroutos, BPB Publication, New Delhi (1998).
26. VB6 in 24 Hours: Greg Perry and Hettihew, Tech Media, New Delhi (1998).
27. VB6 Complete: Sybax, BPB Publication, New Delhi (1999).
28. V. A. Del Gross and C. W. Mader. Speed of sound in pure water. J. Acoust. Soc. Am. 52 (7), part2, 1442–1446 (1972).