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Development of Virtual Instrumentation for Biomaterial Characterization

A. V. Padole[1], **Y. B. Gandole**[2]

Research Student, Department of Electronics, Adarsha Science J. B. Arts and Birla Commerce, Amravati, India[1]

Department of Electronics, Adarsha Science J. B. Arts and Birla Commerce, Amravati, India[2]

Abstract: For the characterization of biomaterials the methodology used is the source of signal, Biomaterial sample and the response detector. The high frequency ultrasonic signal generator generates signals of high frequency suitable for biomaterial characterization. Ultrasonic signals are then made to fall on the biomaterial sample to be characterized. While passing through the sample, the ultrasonic signals are absorbed, reflected and scattered along different directions. The transmitted and reflected signals are sense and detect by sensor. The sensor produces proportional current in microamperes. This current will be applied to sensing circuit, which converts current into proportional amplified voltage with the help of an Op-Amp. An analog to digital converter (ADC) converts analog signal into digital signal and provide data to the computer. Driver software makes NI LabVIEW to interact with hardware. Data acquisition circuit interconnects the PC and driver software to which the data is input. The PC with LabVIEW platform is used to develop VI for biomaterial characterization.

Keywords: ADC, Attenuation, Biomaterial, NI LabVIEW, Ultrasonic velocity.

I. INTRODUCTION

The Virtual Instrumentation system using NI LabVIEW for the biomaterial characterization is carried out to improve accuracy, precision, reliability of ultrasonic velocity and attenuation measurement in solid biomaterials, as well as to fulfil the need of biomedical industry so as to enhance the patient's quality of life. The system developed is dedicated for the measurement of ultrasonic velocity and attenuation relative to evaluation of properties for the biomaterials Aluminium, Copper, 316L Stainless steel, Cast Iron and Titanium.

The ultrasonic NDT technique is a versatile tool for the characterization of material. The main objective of this NDT technique is to certify that the sample material being examined is fit for the intended service. Ultrasonic investigation in biomaterials relies mainly on the study of behaviour of wave propagation. Ultrasonic velocity and attenuation measurements can be computed in biomaterials by knowing the distance and time of flight.
The ultrasonic velocity is very useful for determining several important material parameters like porosity, residual stresses, texture and characterization of secondary phases in microstructure. In order to study the small and important variations, high- resolution technique for ultrasonic velocity measurements are necessary [1].

A. Ultrasonic attenuation and velocity in materials

Ultrasonic attenuation, velocity and their related parameters can be used to give insight into materials microstructures and associated physical properties. Behaviour of ultrasonic attenuation and velocity as a function of physical parameters related to different physical condition is used to characterize the material during the process as well as after production [2].
Velocity: Velocity of the wave is the distance travelled by the wave in one second. To measure the ultrasound velocity in the sample, the formula is:

$$\text{Velocity} = \text{Distance} / \text{Time}$$

Where 'T' is the time elapsed between registering echoes [3]. Some of the non-destructive testing techniques, which have been used to characterize material properties, are ultrasonic testing, radiometry, magnetic methods, eddy current testing, etc. Ultrasonic Testing is the most preferred NDT technique for characterization of material properties [4].
For the measurement of ultrasonic velocity and attenuation in materials a number of techniques are used. Some of the standard techniques used for the measurement of ultrasonic velocity are: pulse-echo technique, sing-around technique, diffraction technique and interferometer technique. The sing-around technique is more accurate for measurement of ultrasonic velocity. This can be described by Soitkar et.al. [5] and Beyer et al. [6]. The ultrasonic pulse-echo overlap technique is widely used for the ultrasonic velocity measurement, as it is accurate and versatile by Papadakies [7], Hellier et al. [8]. They also presented the circuits of pulse-echo-overlap technique.

Now a day's several new pulse techniques, with extremely high degree of precision have been developed for ultrasonic measurements. A solid-state variable frequency pulser-receiver system has been developed by Yawale et al. [9]. A solid-state pulser-receiver system for ultrasonic

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velocity measurement at fixed frequency using digital circuitry has been developed by Agnihotri et al. [10].

B. Biomaterials

The materials which are used for structural applications in the field of medicine are known as Biomaterials. These materials are successfully used to replace damaged parts in human or animal bodies. These materials are able to function by remaining in intimate contact with the living tissues, with a minimum adverse reaction to the body. Sometimes, a single material cannot fulfil the complete requirement of specific application; in that case, a combination of more than one material is used. In ancient times, metals were used for orthopaedic applications. Pure metals such as Silver, Gold and Copper were used for different medical applications. In view of requirements of suitable materials for medical applications, the alloys such as 316L Stainless Steel and Ti-6Al-4V have been developed for orthopaedic applications [11].

The biomaterials used in the performed experiment are given below,

a) Aluminium.
b) Copper.
c) 316L Stainless Steel
d) Cast Iron
e) Titanium.

C. Virtual Instrumentation

Virtual instrumentation uses mainstream computer technology combined with flexible software and high performance hardware technology to create powerful computer based instrumentation system. Virtual Instrumentation combines hardware and software with computer technology to create user defined instrumentation system. The objective in Virtual Instrumentation is to use a PC to mimic real instrument with their dedicated controls and displays with the added versatility that come with software. Virtual instrument is an effective and powerful combination of hardware and software. It combines processing power of PC with flexible software for numerous measurements. Engineers and scientist can create user defined systems to meet their exact application needs. The virtual instrumentation can be realized using software like LabVIEW, VB, JAVA etc and DAQ card as per the application. LabVIEW (Laboratory Virtual Instrument Engineering Workbench) is a graphical programming environment language to design virtual instrument [12].

Manual analog methods used for measurements are tedious and time consuming. Thus without computer automation the necessary measurements for material property evaluation would certainly be impractical where speed, accuracy and economy is required [13].
The ultrasonic velocity measurements using the present PC based system are found to be precise and consistent. The instruments that were used for ultrasonic measurements are replaced by Virtual Instrumentation [14]. A virtual design and testing procedure can save time and money [15]. Virtual sing around technique with improved accuracy have been designed by Ghodki etal [16], [17] & [18]. Virtual sing around technique with improved accuracy is controlled wirelessly using e-mail or using mobile phone by Singh etal [19].

D. NI LabVIEW 2010

LabVIEW is an integral part of Virtual Instrumentation because it provides an easy-to-use application development environment designed specifically for engineer and scientist. LabVIEW offers powerful features that make it easy to connect to wide verity of hardware and software. One of the most powerful features that LabVIEW offers is graphical programming language.

Laboratory Virtual Instrument Engineering Workbench (LabVIEW) is a graphical programming language written by National Instruments for the development of acquisition software that uses icons instead of lines of text to create programs. Its graphical nature makes it ideal for test and measurement, data acquisition, data analysis and instrument control applications. This results in significant result improvements over conventional programming languages. LabVIEW is an entirely graphical paradigm with the concepts of the block diagram and the front panel. LabVIEW, as a programming language, is a powerful tool that can be used to achieve our goals [20].

The LabVIEW is used for acquiring data and processing signals because- 1) It works faster with a Graphical approach. 2) It takes measurements from any sensor. 3) Get started immediately with open and run examples. 4) Measure in minutes with express functions. 5) Call advanced analysis libraries with one click. 6) Create a professional user interface in Seconds. 7) Log Data and Generate Reports in one easy step. 8) Distribute stand-alone applications. 9) Do more with a flexible, Scalable software platform. 10) Collaborate and develop with a worldwide community of engineers [21].

E. Basics of the system

In this system procedure is intended for 20 mm thick solid biomaterials. The surface is kept parallel to the direction of energy propagation and has been maintained parallel to at least 10°. Several possible modes of vibration can propagate in solids.

The ultrasonic testing system to be used in this work shall include the following apparatus.
1) Test Instrument: An ultrasonic instrument comprising a transmitter, receiver, data acquisition circuit to generate, receive, and display electrical signals related to ultrasonic waves. The equipment allows readings for the positions of 80mm & 180mm.
2) Search Unit: The search unit containing a transducer that generates and receives ultrasonic waves of an

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appropriate size, type and frequency, designed for tests by the contact method shall be used. Contact straight beam longitudinal mode shall be used for longitudinal velocity measurements. Here we make use of a 5MHz transducer.

3) Couplant: For longitudinal velocity measurements, the clean light-grade oil can be used as Couplant [22].

II. INSTRUMENTATION

A. Working Principle

The frequency generator circuit generates a signal of 5MHz frequency. This signal is fed to transmitting transducer which is at one end of the measuring cell. At the same time in microcontroller system, controller generates the trigger with specific time & amplitude, this trigger goes on vary with respect to time & amplitude till receiver will not receive the signal. The trigger time & amplitude will be variable for different sample. As soon as the signal is received by the receiving transducer at another end the system measures the peak amplitude of T_X & R_x signal. This process will be carried for multiple attempts. In single attempt, wave count is also measure with respect to transmission, reception and hence also wave drop. Finally controller measure transition time for the wave. All these data will be recorded in DAQ for future use and to transmit to PC.

B. System Block Diagram

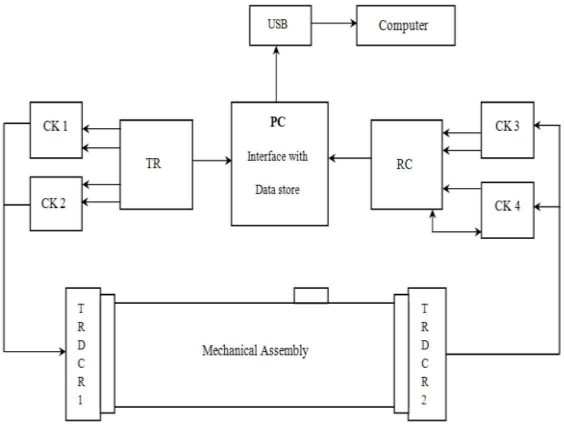


Fig. 1 System Block Diagram

C. Block Diagram Description

The block diagram of the system is shown in figure 1. The system consists of mechanical assembly embedded with a transducer pair. Receiver-transmitter circuits are also shown in support of two separate circuits each. Circuit 1 and circuit 3 are filter amplifier circuits while circuit 2 and circuit 4 are signal conditioner for the same. Receiver-Transmitter PCB's are interlinked to master PCB. Master controls all the triggering actions and also works for the data collections from the sub-circuits. Finally master interlinks the PC via USB driver as a part of data acquisition for virtual instrumentation for connectivity to LabVIEW.

III. CIRCUIT DIAGRAM

A. Schematic block diagram of a Microcontroller

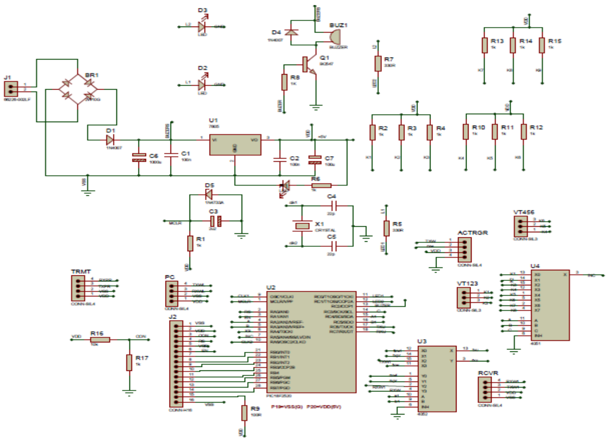


Fig. 2 Schematic block diagram of a Microcontroller

In the block diagram shown in Fig.2, TRMT and RCVR are the connections to the transmitter and receiver circuits respectively. ACTTRGR is the connection to active trigger for ultrasonic transducer while VT 123 and VT 456 are the voltage connections to monitor voltage parameters in the circuit. System interlinks to USB via PC connector. Other circuitry consists of oscillating and reset circuits for the microcontroller. Circuit consisting of IC U1 is the power regulator circuit for the master board.

B. Transmitter circuit

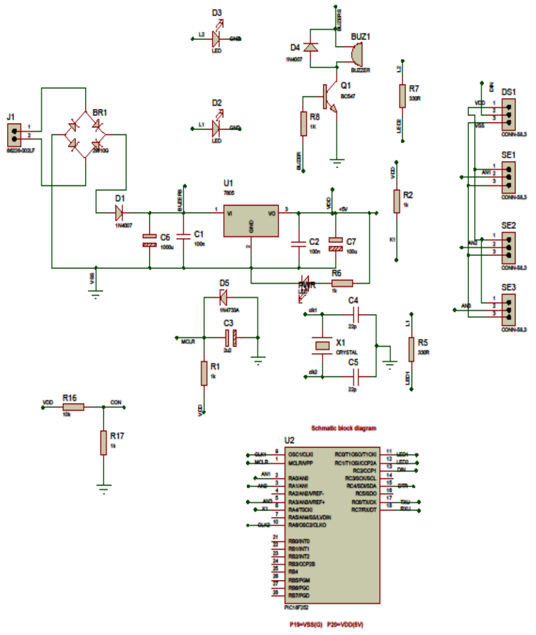


Fig. 3 Transmitter Circuit

Transmitter circuit receives the signal from signal generator circuit and measure parameter via SE1, SE2 and SE3. These parametric values are again re-transmitted to master circuit. Microcontroller IC does the function of data reading and monitoring.

C. Circuit Diagram of Receiver

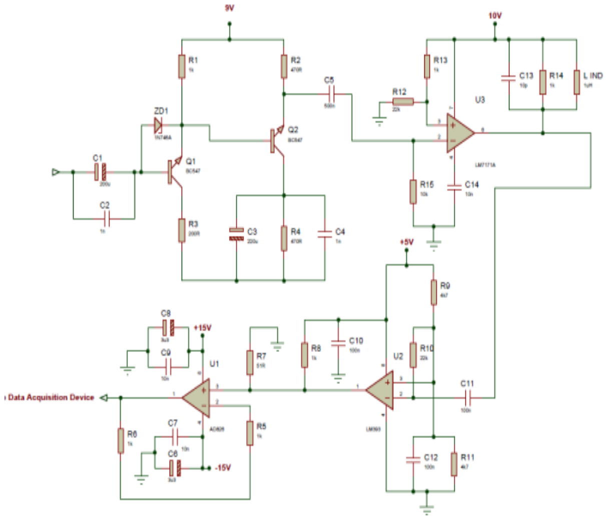


Fig. 4 Circuit diagram of receiver

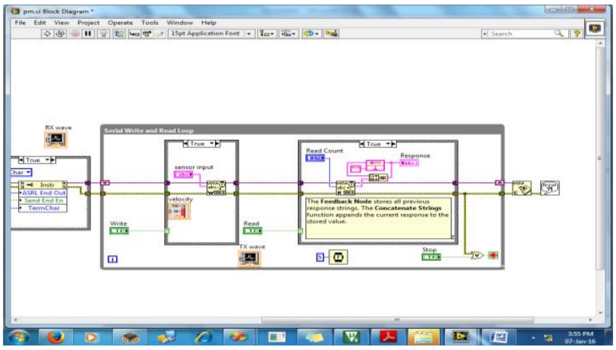
At the other end of biomaterial sample the receiver circuit receives, modulates and filters the received ultrasonic signal. First amplification of the signal is performed then two stage filters removes the unwanted transients and finally this signal will be send to data acquisition device.

IV. MEASUREMENT TECHNIQUE

For the measurement of ultrasonic velocity and attenuation, the transmitting transducer is firmly fixed at one end of the measuring cell while receiving transducer is fixed to movable end. The biomaterial sample is placed between two transducers. The ultrasonic velocity and attenuation measurements can be Computed and displayed on personal computer.

Fig. 5 Interfacing Hardware with Personal Computer

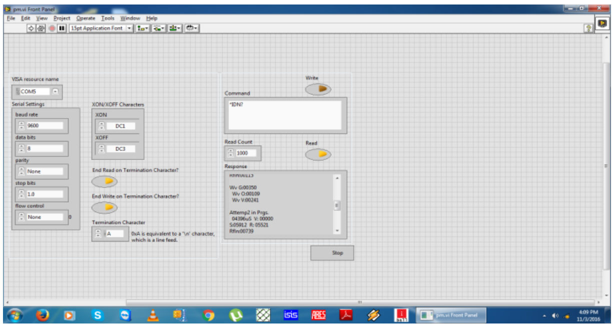
A. Block Diagram: The block diagram contains graphical programming code .



The Feedback Node stores all previous response strings. The Concatenate Strings function appends the current response to the stored value.

Fig. 6 Screenshot showing the block diagram of the project

B. Front Panel: All input and output status are available on front panel. They are as shown in following Fig. 7



0xA is equivalent to a '\n' character, which is a line feed.

Fig. 7 Screenshot showing the front panel of the virtual instrument

TABLE I - ULTRASONIC VELOCITY MEASUREMENTS AT 5 MHZ

Velocity									
Biomaterial Sample	d-180mm		d-80mm		Velocity (m/s)		Deviation		Average % Deviation
	Avg. Time	Velocity (m/s)	Avg. Time	Velocity (m/s)	Observed Avg.	Theoretical	Value	Percentage	
Aluminium	28.51	6312.84	12.65	6324.11	6318.47	6300.00	-18.47	-0.29	0.05
Copper	38.41	4685.87	17.12	4672.90	4679.39	4700.00	20.61	0.44	
316LSS	30.43	5915.86	13.62	5875.15	5895.51	5900.00	4.49	0.08	
Cast Iron	42.74	4211.18	19.12	4183.37	4197.28	4200.00	2.72	0.06	
Titanium	28.83	6243.50	12.82	6241.87	6242.68	6240.00	-2.68	-0.04	

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In the above table literature/ theoretical values are referred from reference [22].

V. RESULT AND DISCUSSIONS

The system is checked by measuring the ultrasonic velocity and attenuation, in different biomaterial samples at 5 MHz frequency. The distance between transmitting transducer and receiving transducer is kept 80mm and 180mm. Table 1: shows the comparison between the theoretical / literature values and experimentally observed values of ultrasonic velocity in the biomaterial samples.

A. Graphs: The fallowing graphs are drawn from observations obtained.

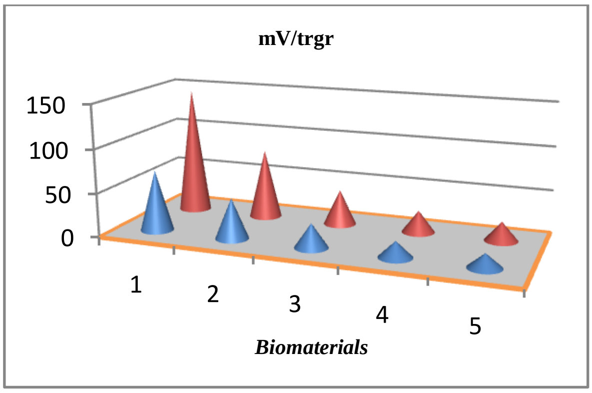

Fig. 8 The graph shows triggering amplitude

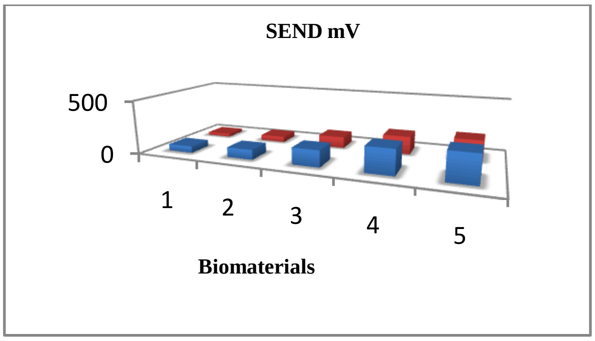

Fig. 9 The graph shows average send signal amplitude

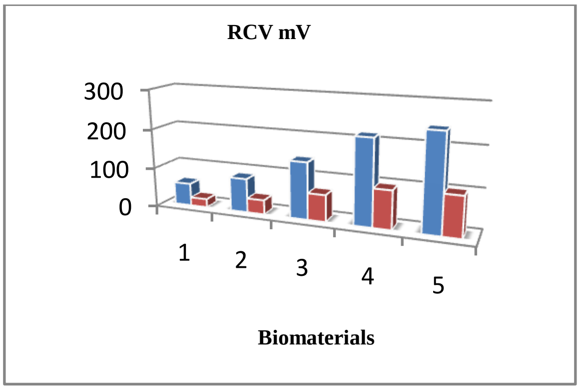

Fig. 10 The graph shows an average received signal amplitude

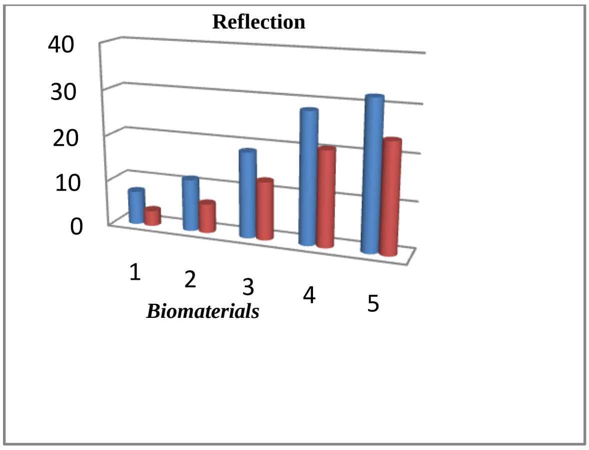

Fig. 11 The graph shows reflection of the signals

VI. CONCLUSION

Ultrasonic velocity and attenuation measurements are useful for determining several important biomaterial properties. From the table 1, it is observed that, the experimental values of ultrasonic velocity and attenuation at 5MHz frequency are in good agreement with the literature values. Moreover it shows very small deviation in the observed values, which indicates the accuracy, precision and reliability of the system. Thus it is conclude that the developed Virtual Instrumentation system shows good performance and can be used as a reliable system for biomaterial characterization.

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