

Design of Microcontroller Based Multi-Frequency Ultrasonic Pulser Receiver

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ABSTRACT

Ultrasonic technique is widely accepted as a characterizing tool because of its non destructive nature. Great technical advancement in ultrasonic apparatuses over the last few years has permitted their increased use. In the present work, an attempt has been made to develop an ultrasonic pulser receiver for pulse echo technique which gives pulsed RF of desired frequency on selection from PC without shifting to another oscillator. A microcontroller (ATMega16) controlled oscillator generates required frequencies on receiving a command. A pulse repetition frequency (PRF) is generated by microcontroller in such a way to give fixed number of RF cycles for each selected frequency. The receiver section receives the echoes from the same transducer, rectifies and amplifies it and is projected to oscilloscope for further study. The designed multi frequency ultrasonic pulser receiver system has been tested in standard liquids for velocity measurements.

Keywords - ATMega16, multi frequency, PC Interface, pulse echo technique, ultrasonics

II.

I. Introduction

Ultrasonic technique is widely accepted because of its accuracy and non destructive nature; and finds its applications in medical imaging, detection, cleaning, diagnosis, physiotherapy, dentistry, surgical tools, radiology, industries, automobile industry, sonochemistry, spectroscopy, agriculture and even as weapons. NDT is perhaps better known in its more common applications for thickness gauging, flaw detection, and acoustic imaging, high frequency sound waves can also be used to discriminate and quantify some basic mechanical, structural, or compositional properties of solids and liquids. Commonly used ultrasonic testing method is pulse echo technique in which a sound wave is launched by exciting the transducer with a voltage spike or square wave. The sound wave travels through the test material, either reflecting off the far side to return to its point of origin (pulse/echo), or being received by the other transducer (through transmission). The received signal is then amplified, detected and analyzed. A variety of commercial instrumentation is available for this purpose, utilizing both analog and digital signal processing. The relevant measurement parameters will typically be one or more of the following: pulse-transmit time, attenuation, scattering, frequency content etc.

In a dedicated multi frequency setup, the frequency is selected by operating mechanical or solid state switches manually or through giving appropriate command using relays or solid state switches[1][2][3]. That means for each frequency there is a dedicated oscillator. This results in increase in size, weight and cost of the instrument.

In present work, an attempt has been made to design a multiple frequency pulser receiver module based on pulse echo technique, where an oscillator generates frequency as per our requirement. Hence, manual frequency selection has been completely replaced by automation. The complete design of pulser receiver has been developed using off the shelf available electronics components. The designed system is cost effective and smaller in size.

II. Experimental setup

Setup has a transmitter designed to generate RF tone burst of selected RF frequency [4][5], amplified and applied to a piezo electric transducer fitted at the bottom of the sample holder, whose other end has a glass reflector mounted to reflect the incident ultrasonic waves. The sample holder is a concentric cylindrical structure designed to hold the liquid sample in the inner cylinder with a provision for constant temperature maintenance. The reflected signal i.e. echoes are collected by the same transducer and processed by the receiver and then it is projected on a digital storage oscilloscope for study purpose. The device is interfaced to the serial port of the PC for control.

III. Working Principle

Fig. 1 shows the block diagram of the complete pulser receiver system. Pulsed RF is generated by the pulser section [6][7]. This section is interfaced to a PC where a command is issued to the pulser to set the desired frequency. The heart of this pulser is the microcontroller ATMega16 which accepts the

command from PC and redirects it to the oscillator in the form of another command. An oscillator generates the desired frequency whereas microcontroller generates the pulse repetition frequency (PRF), both of which are fed to an AND gate and then it is amplified and fed to a PZT transducer. This transducer is connected at bottom of a sample holder (cell) where the sample under consideration (liquid) is maintained at a specific temperature. The transducer vibrates to the tuned frequency given and thus the sound waves travel into the sample and gets reflected from the other end of the cell from a reflector plate. The received signal or echoes are collected by the same transducer. The receiver section, on receiving signals, filters, rectifies and amplifies it and fed to the oscilloscope.

IV. Circuit Description

Figure 1 shows block diagram of ultrasonic pulser receiver. Transmitter consists of a frequency generator section, power amplification and output section (Fig. 2). The whole module is controlled by a microcontroller whereas the module itself is controlled by a PC.

In the present work, Atmel's ATmega16 an 8-bit and 40-pin AVR microcontroller is used. The MCU is operated on a 16MHz clock derived from a piezoelectric crystal oscillator of 16 MHz. This microcontroller is interfaced with a PC on the virtual com port using USB to TTL UART converter.

The oscillator consists of DS1077 which is a processor-controlled or standalone solid state oscillator chip. It is an 8 pin, 2-wire serial interface chip capable of generating frequency from 8.1 kHz to 133MHz. This chip does not require any external components for its operation. The desired frequency is selected by issuing a command word to the chip on a 2-wire serial interface. The output of this oscillator is a square wave form.

Output of the oscillator is refined using a Schmitt trigger which enables the square wave to drive the next stage. The square wave output is synchronized with the PRF through the interrupt pin of the microcontroller, which results in generation of pulsed RF with the help of an AND gate.

This tone burst, thus generated needs further amplification to drive the transducer load. A non-inverting buffer/driver with open collector high voltage output chip (SN7407) is used for this purpose. The power delivered by this stage is governed by the open-collector resistor and voltage applied to the open collector (Maximum 30V). The output is amplified enough to drive the transducer.

Fig.3 shows the block diagram of receiver which consists of passive filters, which is then pre-

amplified and amplified using op-amp LM7171. It is then rectified using a peak detector diode, and amplified again. The resultant received waveform can be seen on oscilloscope. Figure 4 and 5 shows the circuit diagram of transmitter and receiver respectively. Figure 6 shows the implemented system of pulser and receiver along with sample holder and DSO. Figure 7 and 8 shows the tone burst frequencies of 2 MHz and 5 MHz respectively as measured by DSO. Figure 9 and 10 shows the transmitted pulse and echo pattern received using double distilled water at 5 MHz and 2 MHz respectively.

V. Result

The circuit gives stable output of RF burst for a long duration without undergoing any frequency variation. Double distilled water and Ethanol (absolute for analysis) is considered for testing. The system successfully transmitted the signal, received and amplified and thus measured on a digital storage oscilloscope. In the present work, 2MHz and 5MHz frequencies are tested successfully on above mentioned samples. The observed velocities are plotted in a graph. Figure 11 shows the ultrasonic velocity measurements carried out using 2MHz tone burst on double distilled water and Ethanol and Figure 12 shows the ultrasonic velocity measurements carried out using 5MHz tone burst on double distilled water and Ethanol.

VI. Conclusion

The designed multi frequency ultrasonic pulser receiver is tested successfully using double distilled water and Ethanol with 2MHz and 5MHz frequencies. The transmitter successfully generates frequencies from 1 MHz to 10 MHz without changing any component (except transducer) or without using a manual switch. Repeatability and stability is observed in the functioning of the transmitter over a period of time. PRF can also be changed without changing a single component. The observed velocities at different temperatures are compared with literature values. Errors in measurement can further be minimized by using digital storage oscilloscope having higher resolution or a dedicated system. Intension of this experiment is to use locally available components. For more power requirement this buffer/driver can be replaced with high speed transistor or MOSFET without disturbing the setup. Such a design is useful for the development of light weight hand held ultrasonic devices. Other parameter such as attenuation can also be measured using the same setup.

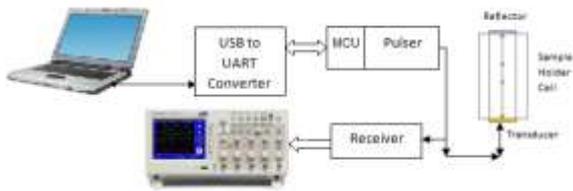


Fig: 1 ultrasonic pulser receiver system

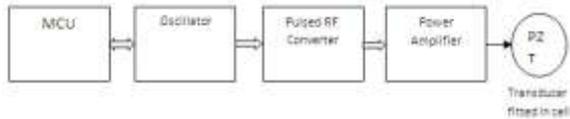


Fig: 2 block diagram of ultrasonic pulser

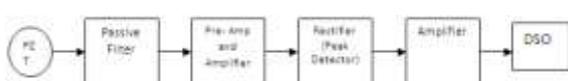


Fig: 3 block diagram of ultrasonic receiver

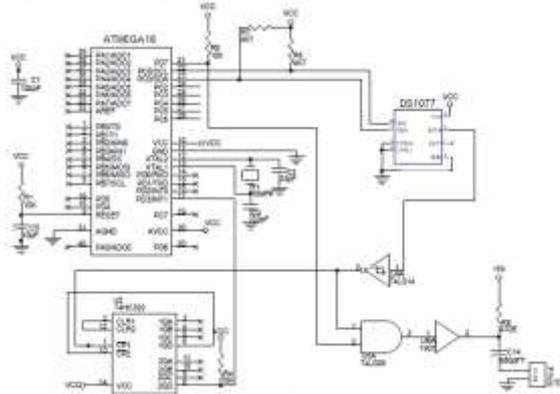


Fig: 4 circuit diagram of ultrasonic pulser

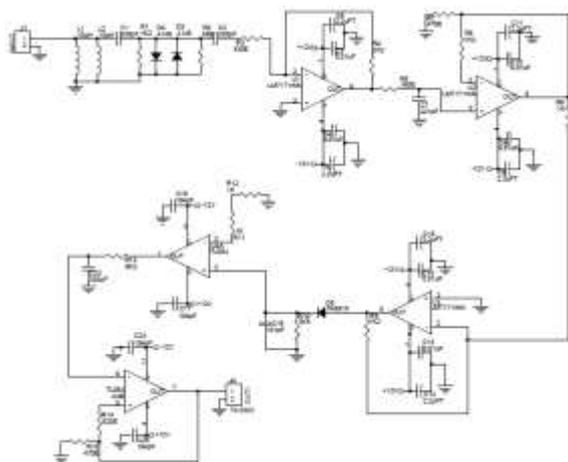


Fig: 5 circuit diagram of ultrasonic receiver



Fig: 6 Designed System

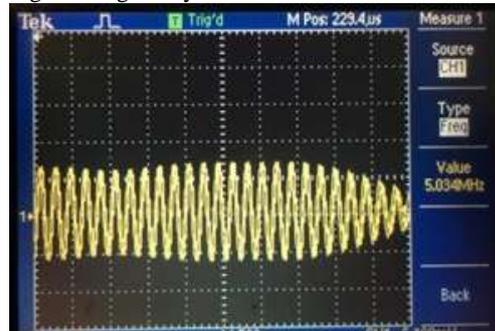


Fig: 7 rf burst (5 MHz)

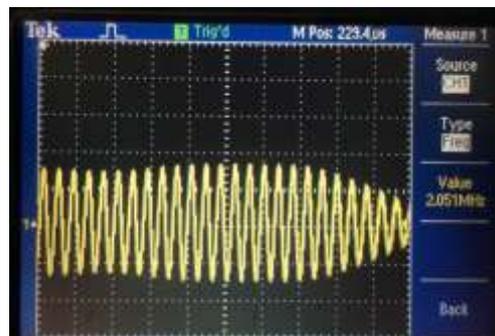


Fig: 8 rf burst (2MHz)

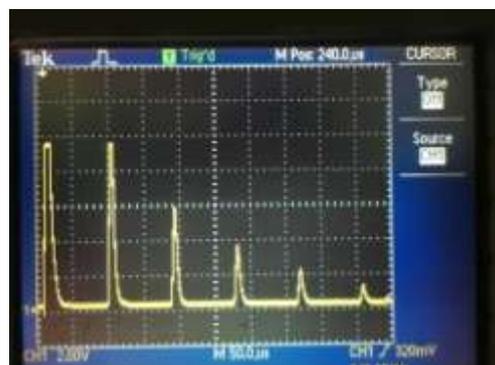


Fig: 9 echoes obtained (tx: 5 MHz)



Fig: 10 echoes obtained (tx: 2MHz)

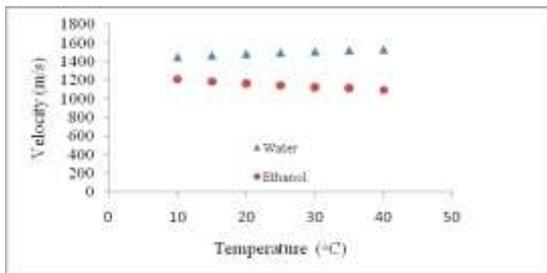


Fig: 11 ultrasonic velocity measurements in water and ethanol mixture at 2MHz

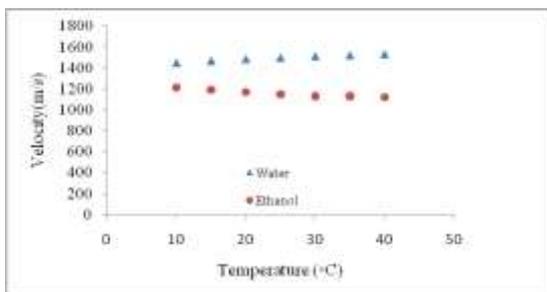


Fig: 12 ultrasonic velocity measurements in water and ethanol mixture at 5MHz

REFERENCES

- [1] V. R. Vyaghra, *Ultrasonic Signal Processing For Characterization of Matter*, doctoral diss., Department of Electronics and Computer Science, RTM Nagpur University, Nagpur, M.S., India, 2006.
- [2] V. M. Pendsey, *Development of PC Based Pulse Technique For Ultrasonic Measurements*, doctoral diss., Department of Electronics and Computer Science, RTM Nagpur University, Nagpur, M.S., India, 2011.
- [3] G. K. Singh, S. J. Sharma and S. Rajagopalan, Design of Multi Frequency Ultrasonic Pulse Echo System, *Journal of Applied Physics*, 2(4), 2012, 35-39.
- [4] Ke-Nung Huang and Yu-Pei Huang, Multiple Frequency Ultrasonic Distance Measurement Using Direct Digital Frequency Synthesizers,

Sensors and Actuators A: Journal, 149, 2009, 42-50.

- [5] Wen-Yuan Tsai, Hsin-Chieh Chen, Teh-Lu Liao, High Accuracy Ultrasonic Air Temperature Measurement Using Multi Frequency Continuous Wave, *Sensors and Actuators A: Journal*, 132, 2006, 526-532.
- [6] S. A. Jaffar, K. Malakondiah and Y.B. Gandole, Design and Development of Computer Based Ultrasonic Velocity Measurements in Liquids, *International Journal of Power System Analysis*, 1(2), 2012, 38-44.
- [7] G. K. Singh, S. J. Sharma and S. Rajagopalan, Measurement of Ultrasonic Velocity in Liquids Using Wireless Technology: SMS, *Journal. of Applied Physics*, 1(3), 2012, 20-22.
- [8] M. Lenz, M. Bock, E. Kühnicke, J. Pal and A. Cramer, Measurement of The Sound Velocity in Fluids Using Signals from Scattering Particles, *Ultrasonics*, 52, 2012, 117-124.
- [9] M. K.-K. Figueiredo, R. P.B. Costa-Felix, L. E. Maggi, A. V. Alvarenga and G. A. Romeiro, Biofuel Ethanol Adulteration Detection Using an Ultrasonic Measurement Method, *Fuel*, 91, 2012, 209-212.
- [10] B. Liu and A.B. Koc, Ultrasonic Determination of Water Concentration in Ethanol Fuel Using Artificial Neural Networks, *American Society of Agricultural and Biological Engineers*, 55(5), 2012, 1865-1872.
- [11] P. Subramanyam Naidu and K. Ravindra Prasad, Ultrasonic Velocity and Allied Parameters in Solutions of Cypermethrin with Xylene and Ethanol, *Indian Journal of Pure and Applied Physics*, 42, 2004, 512-517.