ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 2, Issue 4, July 2013

Time Reversal Mirror in Ultrasound Imaging using High Speed Data Acquisition System FPGA (Vertex-5)

AISHWARYA B, DUSHYANTH
Student, Assistant Professor

Abstract*— Applications Time delay focusing in ultrasound is the process of adjusting the time delays of individual elements in an ultrasonic transducer. The time delays can be calculated a priori but in homogeneities in the insonifed medium and variations of the elements can lead to poor spatial focusing. Adaptive focusing is the process of dynamically changing the focusing properties of an ultrasound transducer to focus on a specific location. The time reversal process aims to solve this problem..Medical ultrasound Beam former designs are more challenging than those in other fields. Process block is implemented using FPGA because Modern Field Programmable Gate Arrays (FPGAs) are capable of performing complex discrete signal processing algorithms with clock rates up to 500MHz. This combined with FPGAs low expense, ease of use, and selected dedicated hardware makes them an ideal technology for a data acquisition system for ultrasound scanner.Using sampling frequency of 61.44MHz, the acquisition data rate of 5GBPS is obtained having a resolution of 12-bits. The aim of the project is cumulative addition of all signals in the receiving section, so that each signal is propagated with the delays and is tapped for further analysis. VHDL programming is carried out to achieve the above process.

***Index Terms*— Beamforming, FPGA, Data Acquisition, ADC, LVDS, Resolution, Process Block, Time reversal mirror.**

I. INTRODUCTION

Medicine is the applied science or practice of the diagnosis, treatment, and prevention of disease. It encompasses a variety of health care practices evolved to maintain and restore health by the prevention and treatment of illness in human beings.Imaging in ultrasonics is closely related to recent studies of time-reversal acoustics that have been experiencing a very rapid growth in interest and research activity [1]. Focusing a wave on a target through an inhomogeneous medium is an important problem to solve in acoustics. Analysis of array data from acoustic scattering in a random medium with a small number of isolated targets is performed in order to image and, thereby, localize the spatial position of each target. Because the host medium has random fluctuations in wave speed, the background medium is itself a source of scattered energy [2]. The basis behind ultrasound imaging is the reflection of ultrasound waves by abrupt changes in density. This is more commonly known as scattering. The ultrasound transducer transmits a pulse which is then reflected back after encountering a scatterer. The reflected wave is then detected by the ultrasound receiver. Scatterers can be of various size and types. For example, the interface between tissue and bone or a cluster of cancerous cells can both cause scattering. The transmitted beam is created by several transducers by methods such as time-delay beam-forming. This allows the transmitted waveform to constructively interfere at the specified location, thus focusing the energy from the transducer at this location. If there is a scatterer at this location, this will result a strong back-scattered response. Given a focal location, if the speed of sound in the medium is assumed to be constant, the propagation time of the wave from each transducer can be calculated. These propagation times can be used to determine the time delay required to focus on the given focal location. The problem with this approach is that the speed of sound is assumed to be constant. In homogeneities in the insonifed medium can influence the speed of the emitted wave thus decreasing the accuracy of focusing.

II. OPERATION OF ULTRASOUND TRANSDUCER (TIME REVERSAL)

The device that transmits and receives ultrasound is called a transducer and typically contains one or more piezoelectric elements. A piezoelectric material has the property that it contracts and expands when positive and negative voltages are applied. By applying a voltage alternating with the desired frequency, the piezoelectric elements transform electric energy into acoustic energy and emit ultrasound at the desired frequency [5].

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 2, Issue 4, July 2013

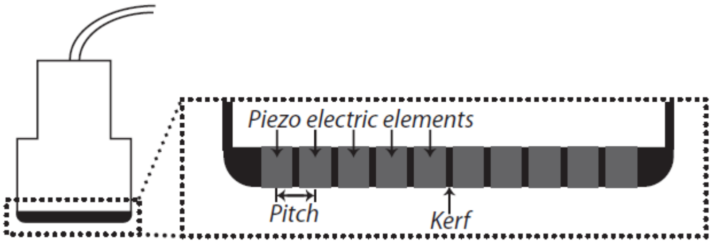

Fig 1: Illustration of a medical ultrasound transducer with piezoelectric elements.

Some transducers (fig 4) use only a single element to transmit ultrasound. However, most transducers contain an array of small elements since this provides the greatest flexibility in controlling the radiation pattern. Since each element is small, they emit spherical sound waves. By controlling the amplitude and delay of the signal for each element, the interference pattern created from all the spherical waves can be controlled. Typically the radiation pattern is formed into a narrow, focused and steered beam of sound. The ideal transducer for ultrasonic imaging would have characteristic acoustic impedance perfectly matched to that of the (human) body, have high efficiency as a transmitter and high sensitivity as a receiver, a wide dynamic range and a wide frequency response for pulse operation. Fig 3.8 shows echo transmission inside human body. PZT has much higher characteristic impedance than that of water but it can be made to perform quite well by the judicious use of matching layers consisting of materials with intermediate characteristic impedances. Even better performance can be obtained by embedding small particles or shaped structures of PZT in a plastic to form a composite material: this has lower characteristic impedance than that of PZT alone, although it has similar ferroelectric properties. Here we are using Linear Array Type of transducer shown in Fig 5, with the help Mux and Demux the operation takes place (128 element transducer).

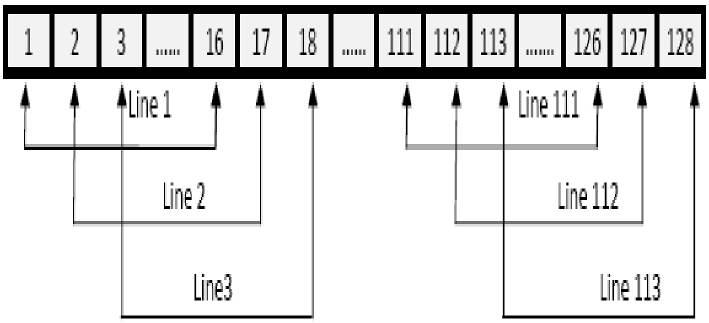

Fig 2: Linear array elements

- ***Applications***

The beauty of time reversal signal processing is that one need not know any details of the channel. The step of sending a wave through the channel effectively measures it, and the retransmission step uses this data to focus the wave. Thus one doesn't have to solve the wave equation to optimize the system; one only needs to know that the medium is reciprocal. Time reversal is therefore suited to applications with inhomogeneous media. An attractive aspect of time reversal signal processing is the fact that it makes use of multipath propagation. Many wireless communication systems must compensate and correct for multipath effects. Time reversal techniques use multipath to their advantage by using the energy from all paths. Fink imagines a cryptographic application based on the ergodic cavity configuration. The key would be composed of the locations of two transducers. One plays the message, the other records waves after they have bounced throughout the cavity; this recording will look like noise. When the recorded message is time reversed and played back, there is only one location to launch the waves from in order for them to focus. Given that the playback location is correct, only one other location will exhibit the focused message wave; all other locations should look noisy.

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 2, Issue 4, July 2013

III. ACQUISITION OF DATA

FPGA Vertex-5 contains DSP blocks as shown in fig 1. Through ADC with LVDS 12-bit data is received by FPGA ,those data will be in serial form which it is converted to parallel data and sent to the process block for all channels. The operation takes place parallel as shown in above block diagram. The data rate of each channel is 737.28MSPS, the electrical signals will reach back at different interval of time, first signal may travel fast then second, third and fourth and other four signals are replication of first four signals. Delays are added up according to the signals such that all signals can reach at a time. Process block is built as shown in fig 2, shift registers are used in which the phase shift takes place. According to different focal points the operations of multiplication is achieved with the help of complex multiplier generated by IP CORE's from Xilinx ISE tool, phase shifting generates cosine and sine values and multiplied with the constant cosine and sine values according to different focal points. Adder adds up all the values of different samples in a cycle, this process takes place in all 8 channels process block. Adder helps to add all of the outputs of the process block which generates a single beam. It will be repeated for 121 beams per frame and 3025 beams for 25 frames. Output will be 16-bit after the data acquisition; these values are stored in SRAM. The Challenging work in this project is that 3025 beams should be obtained at the sampling frequency of 61.44MHZ at a faster speed, signal frequency of 7.68MHZ. The constant values of Cosine and Sine are generated by MATLAB and applied to below equation 1.

$$Sin\,(\omega t + \phi) = Sin\,(\omega t) * Cos\,(\phi) + Cos\,(\omega t) * Sin\,(\phi) \quad (1)$$

Considerations of beams and data rate of the channels,

a) Beams per second = Beams per frame * Frames per second = *121 * 25 = 3025*
b) Data rates (8 channel) = No. of channels * No. of bits of ADC * Sampling frequency
   = *8 * 12 * 61.44 = 5 Gbps*

c) Distance travelled by the Signal from Channel to Focal point
   Distance= ((Focal point) ^2+ ((length of all crystals/2) - pitch) ^2) ^ (1/2) (2)
   Where pitch =0.3*10^-3
d) Time taken by the signal to travel that distance
   Time=Distance/Velocity (3)
   Where velocity= 1540 m/s
e) Delay in reception of the signal in respective channel
   Delay=Time (Const) -Time of particular signal (4)

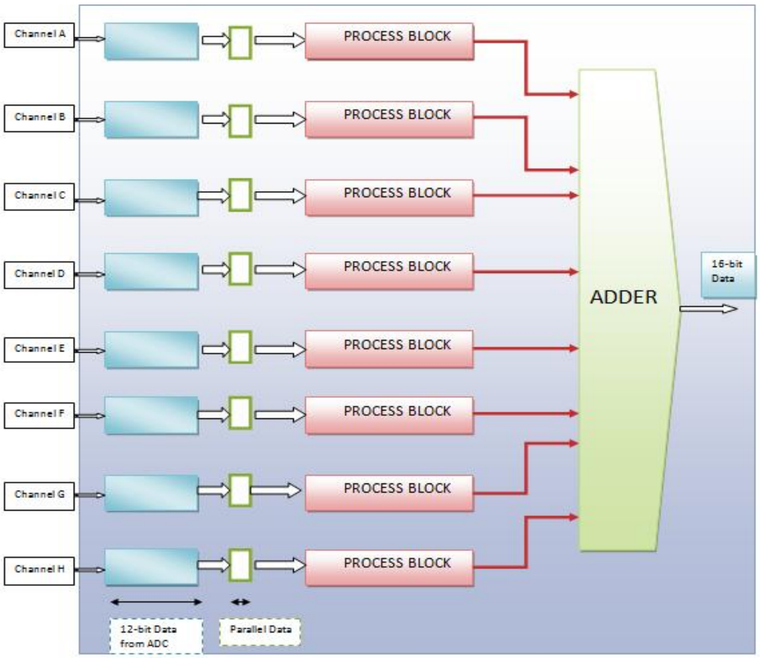

Fig 3: DSP Blocks inside FPGA (Vertex-5)

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 2, Issue 4, July 2013

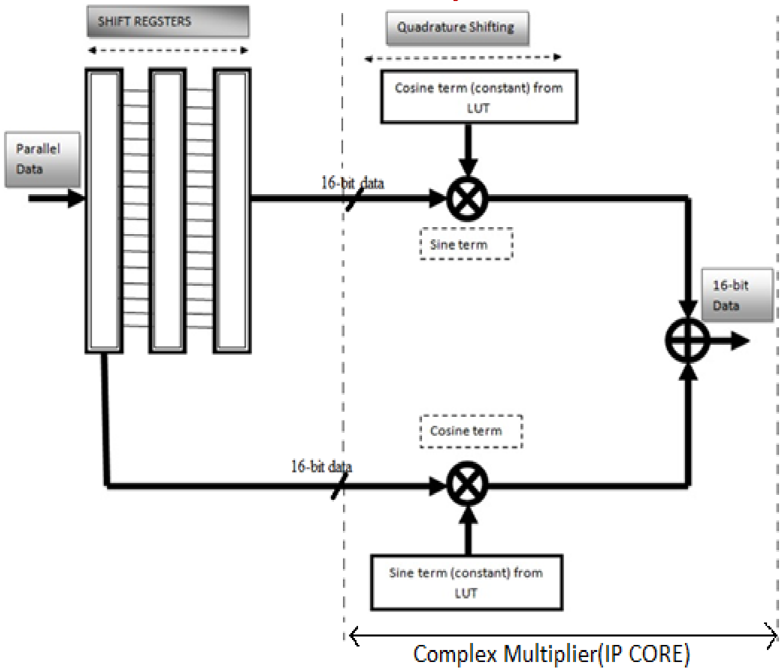

Fig 4: Process Block

To know the distance travelled by signal, particular Focal point, length of all crystals and pitch should be found. By knowing distance and velocity of human body, time can be calculated. Later delay in reception of the signal is calculated. These above process achieved by MATLAB for all the signals equation 2, 3, 4 are calculated.

IV. RESULTS AND DISCUSSIONS

The 12-bit input to all 8 channels is given, According to particular focal points the process block outputs are generated in terms of hex-values.

Process block: The inputs to a process block of 350mhz clock , when reset is 1 then the operation takesplace. If data present is equal to 1, then according to focal points pb_data_out is generated for all 8 channels. As IP Core multiplier is a part of process block sine_term and cosine_term will be multiplied as the above simulation results indicates the operations held by process block.

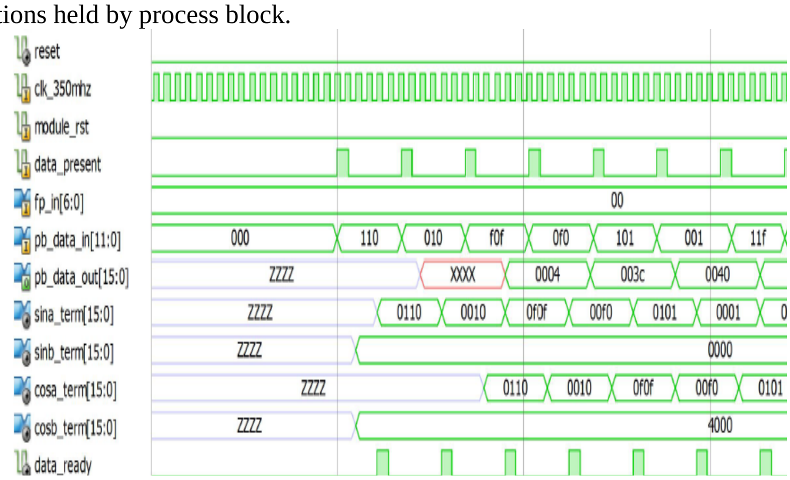

Fig 5: Complex multiplier output of a process block

Operation: The sina_term is 0110 and cosb_term is 4000, both terms are multiplied. Again sinb_term is 0000 and cosa_term is 0110 are multiplied and added to get the output of multiplier. If the focal point is 1.99cm and the process block input is 010, by using equation 1 values are calculated.

ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 2, Issue 4, July 2013

TABLE I: Comparison of different parameters

Parameters	Existing	Proposed
Data Rate/sec	1GB to 2GB	5GB
FPGA Series	Cyclone II & other lower series	Vertex-5
Hardware required	more	Comparatively less
Clock frequency	250MHZ	500MHZ
Cost	$4000	$1081.92

From the above table 1, it's clear that 5GBPS data rate is achieved with FPGA Vertex-5 series having clock frequency of 500 MHz. Usually the main parameter for any implementation of particular application, Cost is the main parameter which in this project around 70% is reduced compared to existing.

V. CONCLUSION

The beam former design is an excellent example of scalable approach of design. Cumulative addition of all signals in the receiving section is achieved with time reversal mirror. According to preliminary estimate-indigenously designed ultrasound beam former will cost at least 60% less than off the shelf products. FPGA Vertex-5 is particularly used for higher speed of higher sampling rate. Data Acquisition of Ultrasound Beam former is achieved by DSP Blocks using FPGA by programming.

ACKNOWLEDGEMENT

The satisfaction and euphoria that accompanies the successful completion of any task would be incomplete without the mention of the people who made it possible. Hard work, perseverance, undeterred missionary zeal, encouraging guidance and advice, which served as a beacon of light, crowned my efforts with success. Words cannot express the gratitude I owe my guide **Mr. Karthigeyan S**, Senior Project Manager, L & T, Mysore for giving me an opportunity to do my thesis work at L&T and providing me all the necessary facilities.

REFERENCES

[1] M. Fink, C. Prada, and F. Wu, in Proc. IEEE Ultrason Symp. 1989, edited by B. R. McAvoy (1989), vol. 2, pp. 681- 686.

[2] James G. Berryman.Statistically stable ultrasonic imaging in random media. University of California, Lawrence Livermore National Laboratory, P.O.Box 808 L-200, Livermore, CA 94551-9900, USA.

[3] D. Kouam´e, J.M. Gr´egoire, L. Pourcelot, J.M Girault, M. Lethiecq and F. Ossant, "Ultrasound Imaging: Signal Acquisition", New Advanced Processing For Biomedical And Industrial Applications, LUSSI, FRE 2448.

[4] Kai E. Thomenius, "Recent Trends in Beam formation in Medical Ultrasound", 2005 IEEE Ultrasonic Symposium.

[5] Christopher M,Fabian, Kailash N Ballu, John A, Hossack,Travis N, Blalock and William F. Walker, "Development of a Parallel Acquisition System for Ultrasound Research", University of Virginia, Charlottesville, VA 22903.

[6] J. Weber, M. Chin, LBNL, Berkeley, CA, U.S.A, "Continuous Bunch-By-Bunch 16-Bit Data Acquisition Using Ddr2 Sdram Connected To An FPGA", Proceedings of BIW10.

[7] David Quin, "The Advantages of Using FPGAs in High Speed, High Density Data Acquisition Systems", White paper. March 18, 2013.

[8] K. Kirk Shung and Jesse T. Yen, Development of a Real-Time, "High-Frequency Ultrasound Digital Beam former for High-Frequency Linear Array Transducers", IEEE transactions on ultrasonic, ferroelectrics and frequency control, vol.53, no.2, February 2006.