Journal Of Harmonized Research (JOHR)

Journal Of Harmonized Research in Engineering
2(1), 2014, 153-161

ISSN 2347 – 7393

Original Research Article

MODELING OF ULTRASONIC SYSTEM

Apurva Y. Gandole*,Omkar S.Ghatpande*,Tushar R. Jadhav*

BE E&TC,V.I.I.T,Pune-48

Abstract
The Numerical simulations- i.e. the computershelp to solve the problems by simulating theoretical models- is part of new technology has emergedalong side pure theory and experiment during the last few decades. Computer simulations helps to perform the analysis and experiment thoroughly. This paper provides modeling and simulation of ultrasonic system for material characterization. The system includes the transmitter, transmitting transducer, receiver, receiving transducer, material for characterization.For simulation we have used PSPICE software. The lossy transmission line properties are calculated for 5MHz transducer. Thus the velocity and attenuation through different materials are studied.The experiment was successfully done and satisfactory results were obtained.

Index Terms—Simulation, Ultrasonic, Transducer.

Introduction

Simulation helps for faster and better study. The hardware needs to be built according to the results obtained from the simulation model. Many software applications are available for building the model according to the requirements and correcting the errors faced without loss of hardware or money. Thus we have used PSPICE software for our work and obtained the results accordingly. A hardware for this system is discussed in hardware design. Many systems are built on the pulse-echo system. But our system is a pulser-receiver system. Building the system step by step is important so that hardware flaws can be identified at that instance only.

For Correspondence:
aygandole99@gmail.com
Received on: XX-XX
Accepted after revision: XX-XX

II DESIGN APPROACH

Block Diagram and Description

The block diagram Ultrasonic system is shown in figure 1. The high frequency transmitter generates 5MHz frequency having pulse width 2 to 60 µs. The repetition rate of the pulses is 1 KHz. This high frequency pulse is fed to the ultrasonic transducer (Tx) having resonant frequency

5 MHz. The receiver-transducer (Rx), which is at the other end of the sample, converts the received ultrasonic pulse into an electrical signal. This signal is fed to an amplifier and then detected.

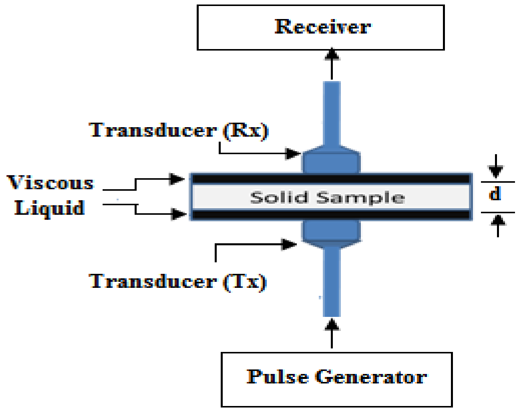


Fig.1 Block diagram of ultrasonic system

Pulser-Receiver system:

The transducer converts electrical energy into mechanical energy, and vice versa. The ultrasonic transmitter transmits the high frequency. The receiver transducer receives these ultrasound waves for analysis. These waves get attenuated as they pass through the material under test and require a definite time for the travel whichis used to calculate the velocity. Attenuation and velocity provide for material characterization.Ultrasonic transducer is made up of a piezoelectric element and non-piezoelectric layers for encapsulation which helps acoustic matching. Accordingly the hardware is built step by step to check the flaws. For simulation an analogy between lossy line and transducer is studied.

This lossy transmission line model is described by four lumped parameters,

- *R* is the resistance in both conductors per unit length in W /m
- *L* is the inductance in both conductors per unit length in H/m
- *G* is the conductance of the dielectric media per unit length in /m
- *C* is the capacitance between the conductors per unit length in F/m

Table 1. Physical properties of Transducers at25 ° C

S.No	Physical properties at 25°C	PZT-5A
1	Density (ρ) (kg/m^3)	7750 (b)
2	Mechanical Q (Q_m)	75 (b)
3	Sound velocity (c) (m/s)	4350 (b)
4	Permitivity with constant strain (ε^s) (C^2/Nm^2)	7.35 ×10^{-9} (b)
5	Piezoelectric stress constant (e^{33}) (C/m^2)	15.8 (b)
6	Acoustic Impedance (MRayl)	33.7 (b)
7	Piezoelectric Constant (10^{-12} C/N)	d_{33} = 374 (a) d_{15} = 584 (a)
8	Couping factor (K_{33})	0.66 (b)

To evaluate the model, the model parameters of PZT-5A transducers were calculated and given in table 2.

Table 2 Model parameters of Transducers

S.No.	Model parameters	PZT-5A
	Physical parameters	
1	Diameter (mm)	12.7
2	Cross sectional area (A) (m^2)	0.0001267
3	Center frequency (MHz)	5MHz
Equivalent lossy transmission line parameters(Mechanical section)		
4	C	53.8nF
5	R	411kΩ
6	L	981mH
7	G	0
8	Len	435µm
Electrical section parameter		
9	Static capacitance C_0	2.14nF
Controlled sources parameter		
10	Transmitting constant (h) (N/C)	2.15×10^9
11	Current source gain (F_2)	2.15×10^9
12	Dependant current source gain (F_1)	4.60
13	Voltage control voltage source gain (E_1)	1
14	R_1	1 KΩ
15	C_1	1F

The material under test is modeled using lossy transmission line. To verify the materials data was obtained from standard references; Lide(a) (1999), Kaye(b)*et al* (1995) , Stewart(c)*et al* (1930), Greenspan(d)*et al* (1959), Carl(e),Weast(f) (1981), Asay(g)*et al* (1967)are given in table3.

Table 3: Physical properties of sample materials at 25o C

Materials (Liquids)	Density ρ (Kg/m^3)	Sound velocity v (m/s)	Viscosity η (cP)	Acoustic Impedance Z (MRayl)	Reference			
					ρ	v	η	Z
Distilled water	1000	1497	0.890	1.494	f	d	e	f
Materials (Solid)	**Density ρ (Kg/m^3)**	**Sound velocity v, (m/s)**	**Young's modulus E, (10^9 N/m^2)**	**Acoustic Impedance Z, (MRayl)**	**Reference**			
					ρ	v	Y	Z
Teflon	2140	1390	0.5	2.97	a	g	a	a
Aluminium	2700	5100	69	17.33	a	c	a	a
Steel	7860	5874	200	46.00	b	c	b	b

Calculations of model parameters for some sample materials and intermediate layer are calculated. Model parameters of the some sample materials are calculated at 25 ^{o}C, which are given in table 4.

Table 4: Model parameters of somesolid sample materials at 25 ^{o}C.

Frequency		5 MHz			
Model parameters		C	L	R	G
S.No	Material	µF	mH	KΩ	
1	Distilled water	3.52	126.7	0.208	0
2	Teflon	1.88	271	326	0
3	Aluminium	0.071	342	1.74	0
4	Steel	0.029	988	57.3	0

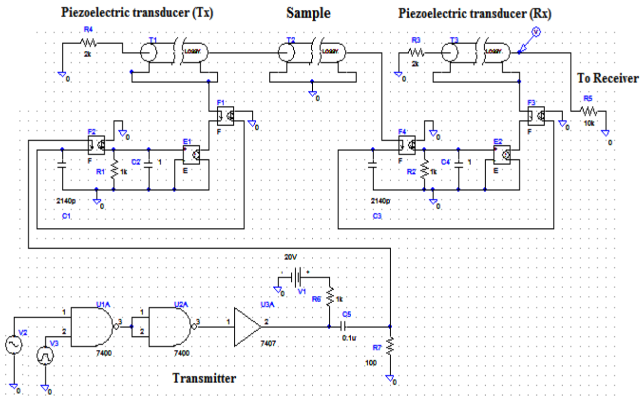
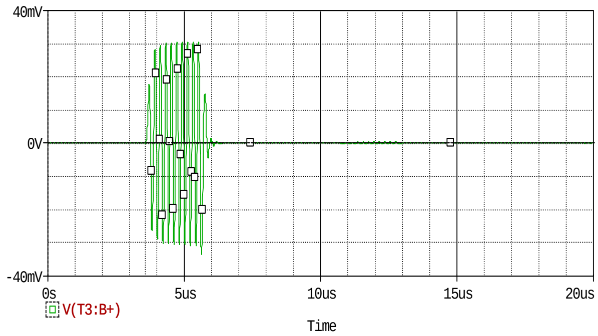


Fig.4 : Simulation Circuit

Analysis:

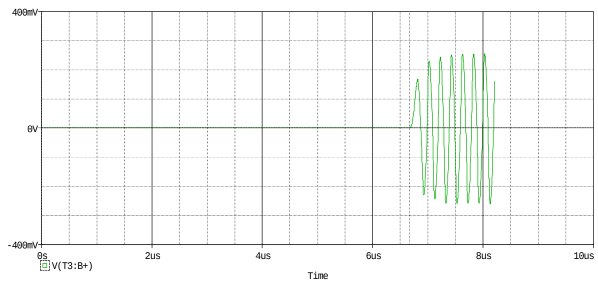
Time Domain : From the simulation we obtained the following output which gave us time as well as attenuation.



A1:(3.5689u,0.000) A2:(0.000,0.000) DIFF(A):(3.5689u,0.000)

Fig. 5 (a): Complete transient received by 5 MHz transducer at 25°C in Teflonat d=0.005m

As seen the values obtained match the reference values and hence the comparison is given in the table 5(a). This gives a green signal for development of hardware.

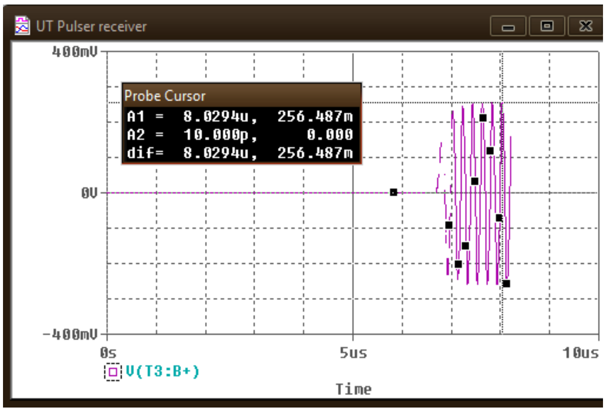


A1:(6.6781u, 250.272mV) A2:(0.000,0.000) DIFF(A):(6.6781u,, 250.272mV)

Fig. 5 (a): Complete transient received by 5 MHz transducer at 25°C in Distilled water at d=0.01m

Attenuation measurement:

Thus we developed the hardware step by step as shown in figure 7 and figure 9 and obtained the results



for the transmitter as shown in figure 8 and 10.

Figure 6 : probe screen for measurement of pulse height using probe cursor

Table 5(a): Comparison of ultrasonic velocities in liquid and solid samples at 25^{o}C.

S.No.	Sample	Simulated velocity (m/s)	Literature value (m/s)	Reference
1	Distilled water	1497.431	1497	Weast*et al* 1964
2	Aluminium	5143.999	5140	Podesta 2002
3	Steel	5870.105	5874	Kaye *et al* 1995
4	Teflon	1398.925	1400.31	*Yawal*et al *1995*
5	Copper	4750..470	4756	Kaye *et al* 1995

Table 5(b): Comparison of ultrasonic attenuation in liquids and solids samples at 25^{o}C.

S. No.	Materials	Attenuation at 25 ^{o}C (2MHz) $(\alpha/f^2) \times 10^{-15}$ (Np m^{-1} Hz^2)		Reference
		Simulated	Literature	
1	Distilled water	23.100	22	Weast 1964
Solid Samples		**Attenuation (dB/m)**		
		Simulated	**Literature**	
2	Aluminium	1.199	1.151	Kaye *et al* 1995
3	Steel	6.577	5.600	Kaye *et al* 1995
4	Teflon	0.0048	0.0039	Lide 1999

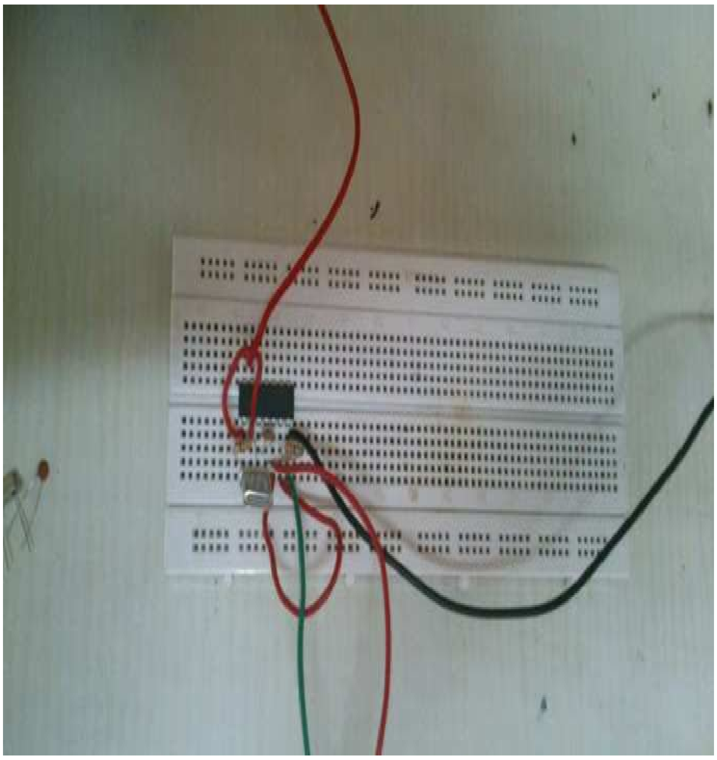


Fig.7: 5MHz crystal oscillator circuit

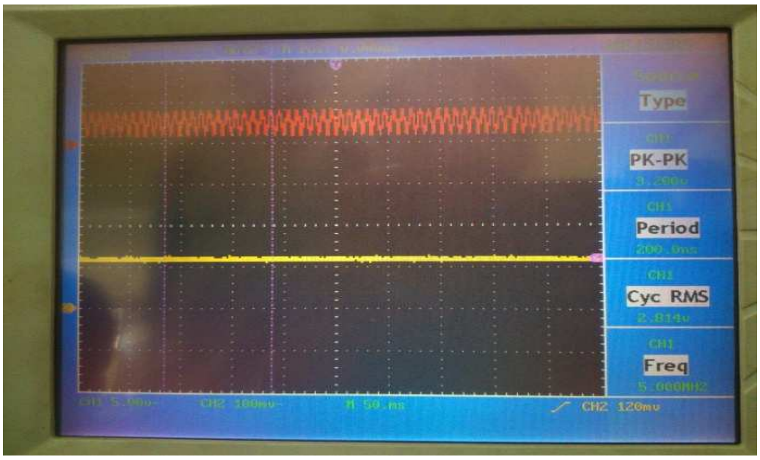


Fig. 8: 5MHz crystal oscillator circuit's output

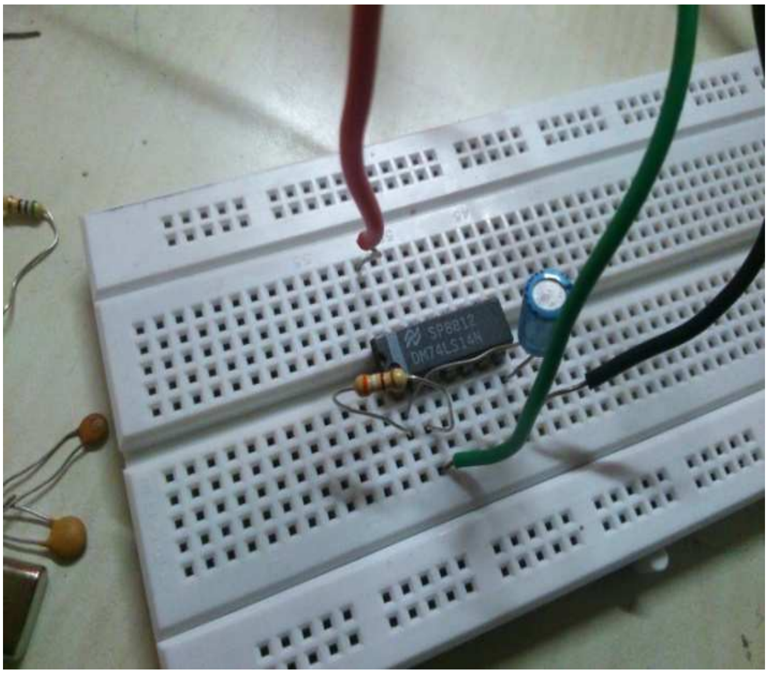


Fig.9: 1KHz oscillator circuit

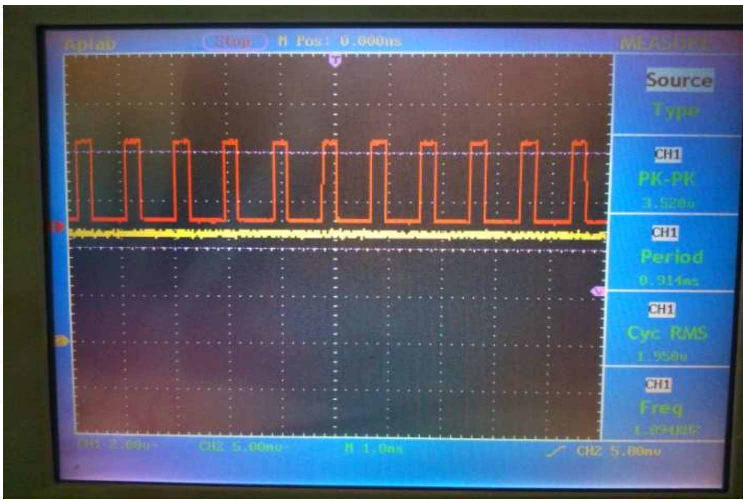


Fig.10:1KHz oscillator circuit's output

Conclusion:

The study of analogy between transducer and lossy line helped to build the simulation model for the transmitting transducer and the receiving transducer. This simulation helped us to verify the results obtained with the results of the references, thus allowing us to estimate the transmitter circuitry. Thus we built the primary transmitter hardware and got satisfactory results.

References:

- Asay J. R., Lamberson D. L. and Guenther A. H., *J. Appl. Phys.*, 40 (4), 1969, 1768-1783.
- Berlincourt D., Krueger H.A., and Near C. Important Properties of Morgan Electroceramics, Morgan Electroceramics, *Technical Pub.*, 2001, TP-226.
- Cheng D.K., Field and Wave Electromagnetics, 2nd ed. Reading, *MA*: *Addison-Wesley*, 1989, 96.
- Kinsler L.E., Frey A.R., Coppens A.B. and Sanders J.V., Fundamentals of Acoustics, 3rd ed. New York: Wiley, 1982, 212.
- Kino G.S., Acoustic Waves: Devices, Imaging, and Analog Signal Processing. Englewood cliffs, N.J: *Prentice-Hall*, 1988. 601.
- Kaye G.W.C.andLaby T.H., Tables of Physical and Chemical constants, 16th ed. Harlow, UK: *Longman Group Ltd*., 1995, 93-233.
- Leach W.M., *IEEE Trans. Ultrason, Ferroelect., Freq. Contr*., 41, 1994, 60-66.
- LideDavid R., CRC Handbook of Chemistry and Physics, Ed. 80th edition, *CRC press*, *BocqRaton*, *FL*, 1999, 2496.
- Stewart G.W. and Lindsay R.B., Acoustics, *D Van Nostrand, New York,* 1930, 327
- MurawskiKrzysztof , Analytical and Numerical Methods for Wave Propagation in Fluid Media, *World Scientific Pub. Co. Pte.Ltd*., 2002, 2.
- PodestaMichael De, Understanding the Properties of Matter, 2nd ed. *Taylor and Francis Inc. New York*, 2002, 194.
- Tront J.G., Pspice for Basic Circuit Analysis, *McGraw-Hill Professional* ,2004, 1
- Weast Robert C., CRC Handbook of chemistry and Physics, Ed. 62nd edition, *CRC press*, *BocqRaton*, *FL*, 1981. E349-E351
- Yawale S.P. and Pakade S.V., Ind. *J. Pure Appl. Phys*., 33, 1995, 638-642.