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# A LOW COST SOLID STATE PULSED SYSTEM FOR ULTRASONIC VELOCITY AND ABSORPTION MEASUREMENT

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An instrument is described to generate and detect pulsed ultrasonics. The instrument should be useful for ultrasonic measurements in gases for teaching laboratories and for research purpose because of its low cost and ease of construction.

The instrument is tested for ultrasonic wave velocity and absorption in air at frequency 40 kHz and at atmospheric pressure. The results are very much satisfactory.

## 1. Introduction

Ultrasonic generators are of two types. The first are those designed mainly for industrial flaw detection, produce a sharp voltage pulse of pulse width of few tens of nanoseconds. This type of technique was discussed by G. A. Forster [1]. The second are those designed mainly for research purpose where radio frequency pulse is used to ring the transducers of the same frequency. More advanced technique for measurement of ultrasonic attenuation was reviewed by Dignum [2]. He concentrated mainly on ultrahigh frequency range and the equipment he described is beyond the scope of many teaching laboratories. The sing-around technique for accurate measurements of ultrasonic velocity in liquids was discussed by Satyabala et al. [3] and V. S. Soitkar et al. [4].

Recently reverberation method for measurements of ultrasonic velocity and absorption in liquids was discussed by Satyabala et al. [5]. A system using non-resonant transducers for absorption measurement in $CO_2$ and air mixture was described by V. N. Bindal et al. [6].

So it is clear that more attempts have been made on ultrasonic measurements in liquid than in gases.

The commercial ultrasonic generator and detector would be the most satisfactory solution, but such an item of equipment would be excessively expensive.

In the present paper we described an instrument suitable to generate and detect pulsed ultrasonics at frequency 40KHz in gases. The major financial outlay is single trace oscilloscope with band width 5 MHz, which almost all laboratories possess. The circuit is implemented by using locally available integrated chips. Hence the equipment is useful for demonstration purposes at post-graduate level as well as for research purpose.

## 2. Acoustical architecture of the system

Quartz transducers having resonant frequency 40 ± 1 kHz and diameter 1 cm are used for ultrasonic velocity and absorption measurements. Sample container is made up of steel and has dimensions 30cm × 30cm × 30cm. The inner surfaces of the walls of container are kept rough to avoid multiple reflection of ultrasound. Sender transducer is rigidly fixed to one side of container and cables are taken out from small hole which is then closed with araldite. Receiver transducer is fixed on hollow movable steel rod to which scale is attached having least count of .01 cm. To avoid leakage at the time of movement of receiver transducer, rubber gaskets are used.

In the present case observations are made at room temperature (25° C) and at atmospheric pressure. The change in temperature of medium due to adiabatic compressions is negligible as pulsed system is used [7].

To measure and maintain pressure of gas in the container the elaborate gas handling system described by Thomas et al [8] may be used. The self explanatory block diagram of the system is shown in Fig. 1.

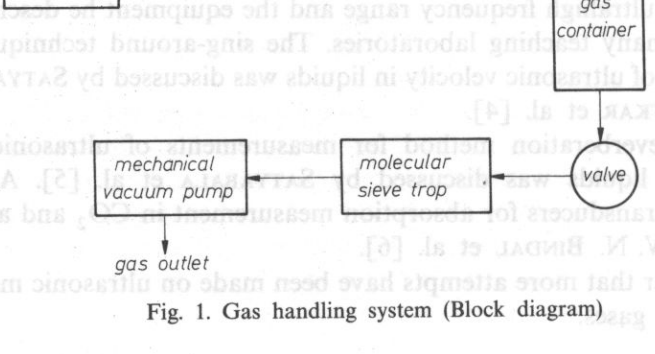

Fig. 1. Gas handling system (Block diagram)

## 3. Instrumentation

The schematic diagram of the instrument is shown in Fig. 2. The pulse generator generates sharp radio frequency (40 kHz) pulses of pulse width 0.012 ms to 0.86 ms with radio frequency pulse repetition rate of 156.25 Hz.

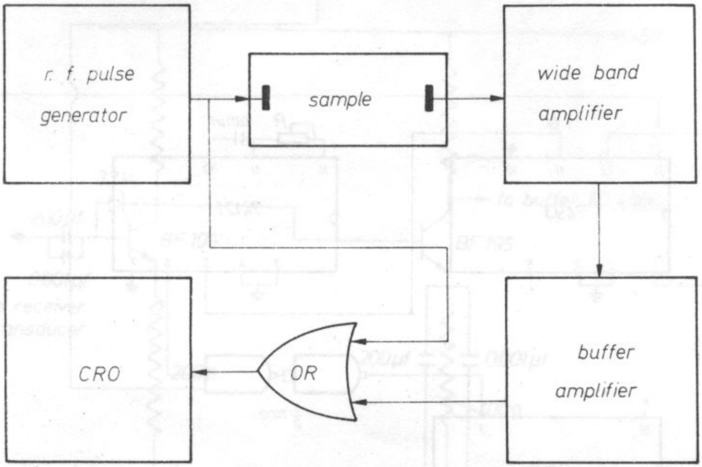

Fig. 2. Block diagram

This radio frequency pulse is placed across sender transducer (whose resonance frequency is the same as that of radio frequency pulse) causing it to ring and send ultrasonic pulse through sample. At the other end of sample the receiver transducer converts ultrasonic pulse into *rf* pulse. This pulse is directly displayed on CRO for absorption measurement. For velocity measurement sender pulse and amplified received pulse through buffer, is connected to OR gate and displayed on CRO screen to measure time delay.

### *3.1. Pulse generator*

A radio frequency pulse generator circuit is shown in Fig. 3 and its wave forms are sketched in Fig. 4 (not to scale). The *rf* generator is designed to generate 40 kHz frequency using two NAND gates of IC 7400 (wave form a). This 40 kHz frequency is divided by two IC 7493 (four bit binary counter). Each IC 7493 divides frequency by 16. So resulting frequency is 156.25 Hz (wave form b). The width of pulse of frequency 156.25 Hz is controlled by monostable multivibrator IC 74121 which produces variation in width from 0.012 ms to 0.86 ms (wave form c). The wave forms a and c are given to AND gate (implemented by using IC 7400) which generates radio frequency pulse of frequency 40 kHz and of sharp width (width can be changed by changing R). This radio frequency pulse is given to buffer IC 4050 with pull up of + 7V which gives 7V peak to peak pulse for ultrasonic generation and is applied to sender transducer.

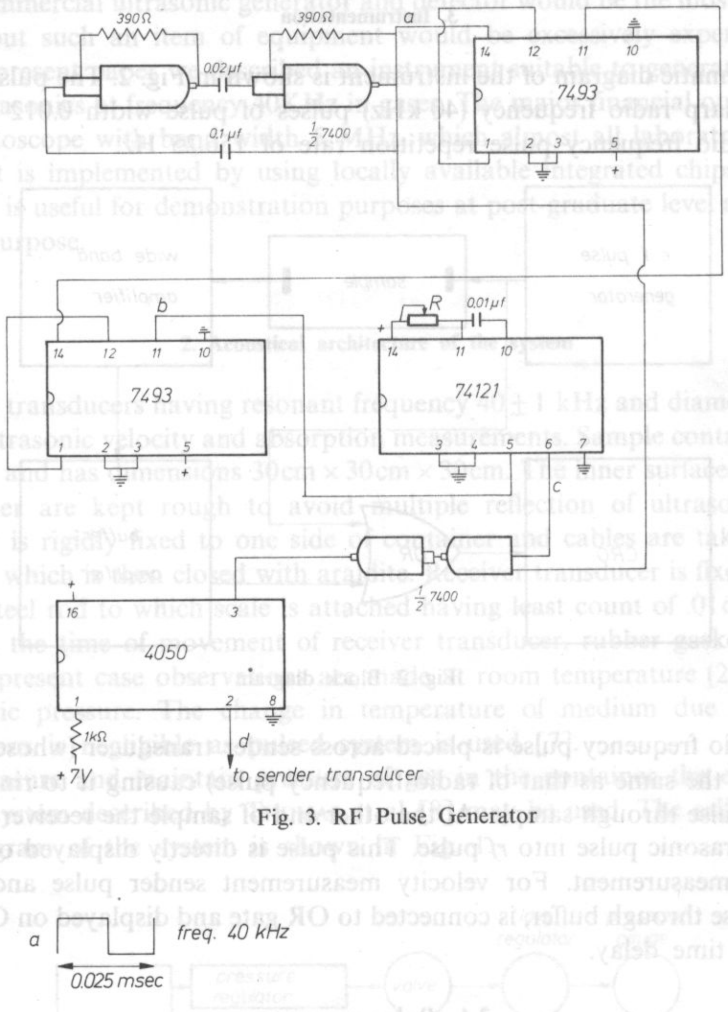

Fig. 3. RF Pulse Generator

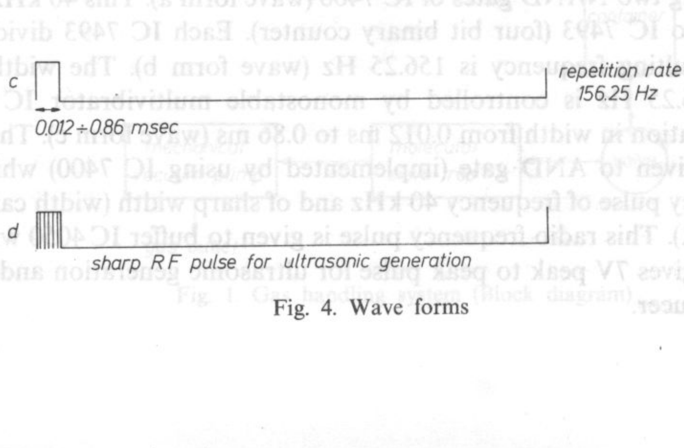

Fig. 4. Wave forms

### 3.2. *Amplifier*

Amplifier is designed to amplify received *rf* pulse using transistors BF 195 (Fig. 5). The emitter resistance of transistor $Q_1$ is unby-passed to increase input resistance and band width and to reduce distortion and noise.

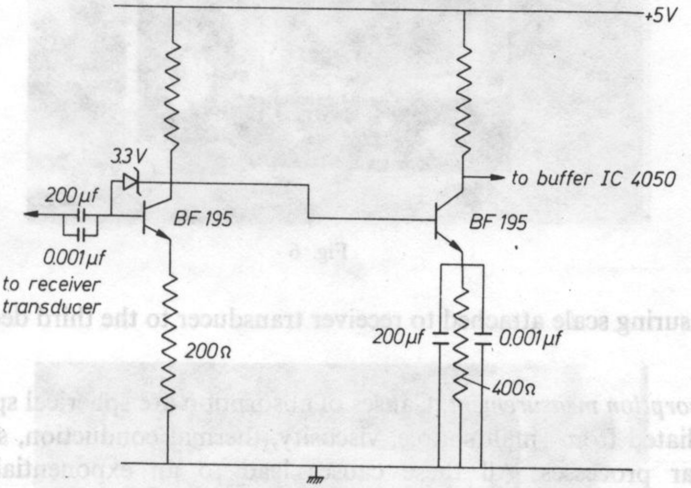

Fig. 5. Amplifier

The Zener diode 3.3 V is connected between base and collector of $Q_1$ to give proper d.c. bias and stabilise $V_{CE}$. The output of first amplifier stage is directly coupled to second transistor $Q_2$. The second stage is by-passed in order to increase voltage gain amplifier. The output of amplifier is given to buffer IC 4050 with pull-up of + 7V.

### 3.3. *Measurement techniques*

*3.3.1. Velocity measurement.* For velocity measurement sender pulse from buffer and received pulse from amplifier followed by buffer (IC 4050) is given to OR gate and displayed on CRO (Fig. 6). (Pulse on left is sender pulse and on right received pulse). The single beam CRO is sufficient to display both pulses simultaneously because pulse repetition rate of pulse generator is very large as compared to the time required for ultrasonic pulse to travel through sample. As both the transducers are inside the container, the exact distance measurement between the two is not possible. Therefore change in distance $\Delta x$ with corresponding change in time $\Delta t$ is measured and velocity is found out by relation $v = \Delta x / \Delta t$. Readings are reported in Table 1. Mean value of ultrasonic velocity at 25°C in air at atmospheric pressure is found out to be 333.31 m/s. Literature value [9] is 331.46 m/s at 0°C. The accuracy in velocity measurement is 0.69%. The accuracy can be further increased by improving least

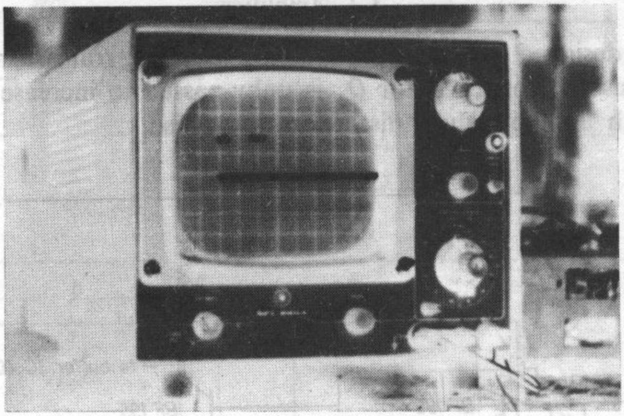

Fig. 6

count of measuring scale attached to receiver transducer to the third decimal place of centimetre.

*3.3.2. Absorption measurement.* Causes of absorption are spherical spread of beam of sound radiated from small source, viscosity, thermal conduction, scattering and intermolecular processes. All these causes lead to an exponential decrease in amplitude with distance.

For absorption measurement the received pulse is displayed on CRO screen directly (Fig. 2). Fig 8 shows five time expansion of received pulse. Pulse height

**Table 1.** Ultrasonic velocity in air (frequency 40 kHz and at atmospheric pressure.)

| | $\Delta x$ [m] | $\Delta t[\mu s]$ | $v = \dfrac{\Delta x}{\Delta t}$ |
|---|---|---|---|
| 1) | .0123 | 37 | 332.43 |
| 2) | .0224 | 67 | 334.32 |
| 3) | .0323 | 97 | 332.98 |
| 4) | .0291 | 87 | 334.48 |
| 5) | .0127 | 38 | 334.21 |
| 6) | .0332 | 100 | 332.00 |
| 7) | .0283 | 85 | 332.94 |
| 8) | .0314 | 94 | 334.04 |
| 9) | .0253 | 76 | 332.89 |
| 10) | .0243 | 73 | 332.87 |

Mean ultrasonic velocity in air at 25°C is found out to be 333.31 m/s.

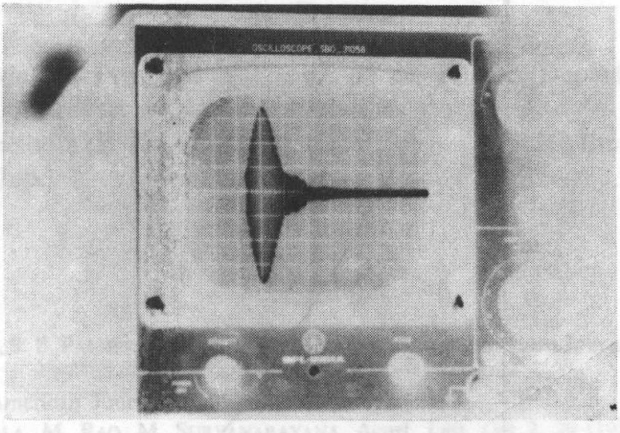

Fig. 7

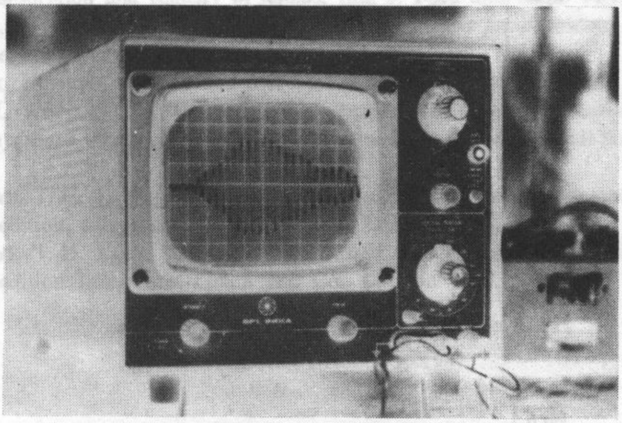

Fig. 8

Fig. 9 measured by changing the distance between transducers. The graph of pulse height vs distance is exponential as expected (Fig. 9). The graph of log e (pulse height) vs distance is shown in Fig. 10. Slope of this straight line is absorption coefficient $\alpha$ in neper/cm and when expressed in dB/cm the value is 8.686 $\alpha$ dB/cm. The attenuation of sound in air is abnormal for frequency variation and also depends greatly on moisture content [10].

In present case the value of $\alpha$ from graph is found out to be $8.53 \times 10^{-3}$ neper/cm (or .074 dB/cm) at 40 kHz.

Literature value [10] of $\alpha$ for sound waves in air at relative humidity of 40% is $2.26 \times 10^{-3}$ neper/cm at 50 kHz.

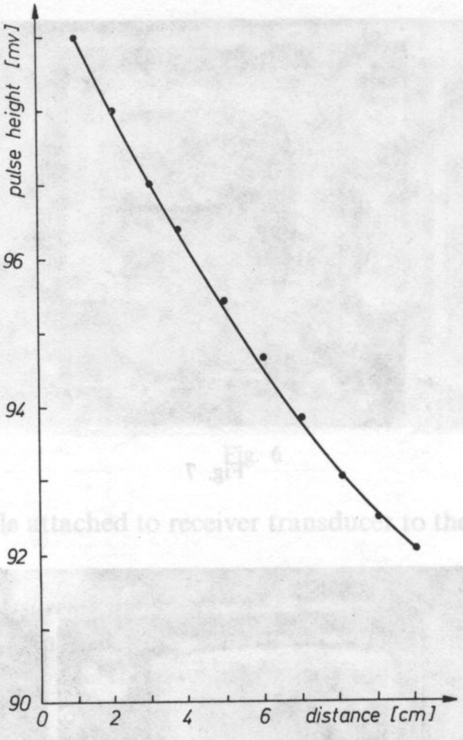

Fig. 9. Graph of pulse height (h) vs distance

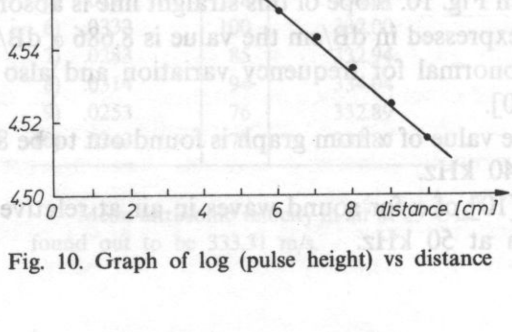

Fig. 10. Graph of log (pulse height) vs distance

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