INTRODUCTION

Resonance method is one of the simple methods for measuring speed of sound in air. Since it requires simple equipment and the result from this method grees quite well with the theory[1], this method is suitable to be used as a sound laboratory exercise for students up to junior level. The auther built this similar set-up using Apple II computer for controlling the experiment ,and this set-up was used in second year physics laboratory. Basically, this report then just describes how to replace an Apple computer with an IBM Pc computer. Eventhough the computer in this experiment can be replaced by an oscillocope, but the author thinks that this experiment could be very useful for students at high school level, then the use of a computer instead of an oscilloscope would be essential since very few schools have oscilloscopes. It is realized that a plugged-in interfacing unit works faster than a separated interfacing unit, but the separated unit is much simpler to use and it is nearly foolproof to any body who knows nothing about hardware. The 8031 microcontroller is used as the central processor of the interfacing unit, it communicates with the main computer via RS232, which makes it safe and easy to use.

THEORY[2,3]

The speed of propagation of a longitudinal pulse in a fluid can be written as

$$V = B/\rho \quad (1)$$

Where **B** and ρ are adiabatic bulk modulus and density of fluid , respectively. For an ideal gas under going an adiabatic change

$$PV^{\gamma} = \text{constant} \quad (2)$$

Where γ is the ratio of heat capacity at constant pressure to heat capacity at constant volume, and **P** and **V** are pressure and volume, respectively.

By definition, $$B = -V(dP/dV) \quad (3)$$

From Eqs. (1),(2) and (3),

$$V = \sqrt{\gamma P/\rho} \quad (4)$$

For an ideal gas, $$P/\rho = RT/M \quad (5)$$

Where **R** is the universal gas constant, **M** the molecular mass, and **T** the kelvin temperature. The speed of longitudinal (sound) waves in an ideal gas is then given by

$$V = \sqrt{\gamma RT/M} \quad (6)$$

Even though Eq.(6) is for an ideal gas , by using the value of γ for air (= 1.40) the speed of sound in air calculated from Eq.(6) agrees with the measured speed within 0.3% [3]. For air, γ remains at the value of 1.40 over a wide temperature range (-80 ^{0}C to at least 150 ^{0}C)[2]

The speed of sound in air may also be measured approximately by resonance method[3]. In Fig.1, A and B are sources of sound waves with adjustable frequencies.

The sound intensity at an open end of the tube reaches a maximum when the air column resonates with the sound frequencies. This takes place when sound frequencies generated by the sources (A or B) equal the air column natural frequencies of vibration. These frequencies are :

for an open end tube

$$f_n = nV/2L \qquad ,n = 1,2,3 \qquad (7)$$

for closed end tube

$$f_n = nV/4L \qquad ,n = 1,3,5 \qquad (8)$$

where **V** is the speed of sound waves in the column, and **L** is the length of the column.

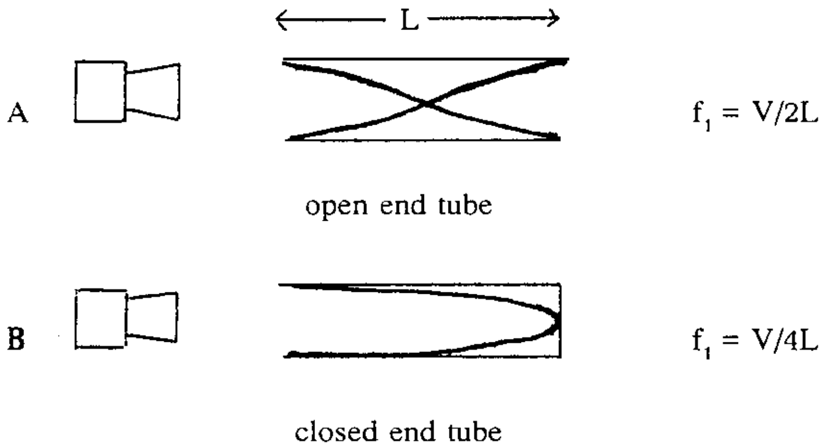

Figure 1 Block diagram of open and closed end tube methods, with A and B as sources of sound.

Apparatus and experimental system

The equipment consists of three parts (see Fig.2). Part A consists of a signal generator, an audio amplifier, a loudspeaker, a glass tube and a condenser microphone. Part B is a signal amplifier, an analog to digital converter, an interfacing and 8031 units. Part C is a computer (an IBM pc compatible).

For Part A, any sine wave generator (few kiloherz) can be used as a signal generator.The audio amplifier is a 10 watt audi amplifier from Thai Amp (model TA 10). An 8 ohm, 6 inch Pioneer loundspeaker is used. A 4 c.m. in diameter and 67.2 c.m. long glass tube is used (longer tube is preferred since it will result in lower frequencies , then more modes can be shown for this ADC). A three pin condenser microphone is used.

Details of parts B and C are the same as in the report on " Development of computerized multichannel seimic equipment for field use ", except that only one channel is used in this case, Details of these two parts are shown in reference (4). It should be noted that an oscilloscope can be used instead of the computer. In that case, the signals that get amplified by the 084 should be fed into one of the channels of the oscilloscope, while the signals that just leave the signal generator should be fed into the other channel, this is then used as a referenced signal.

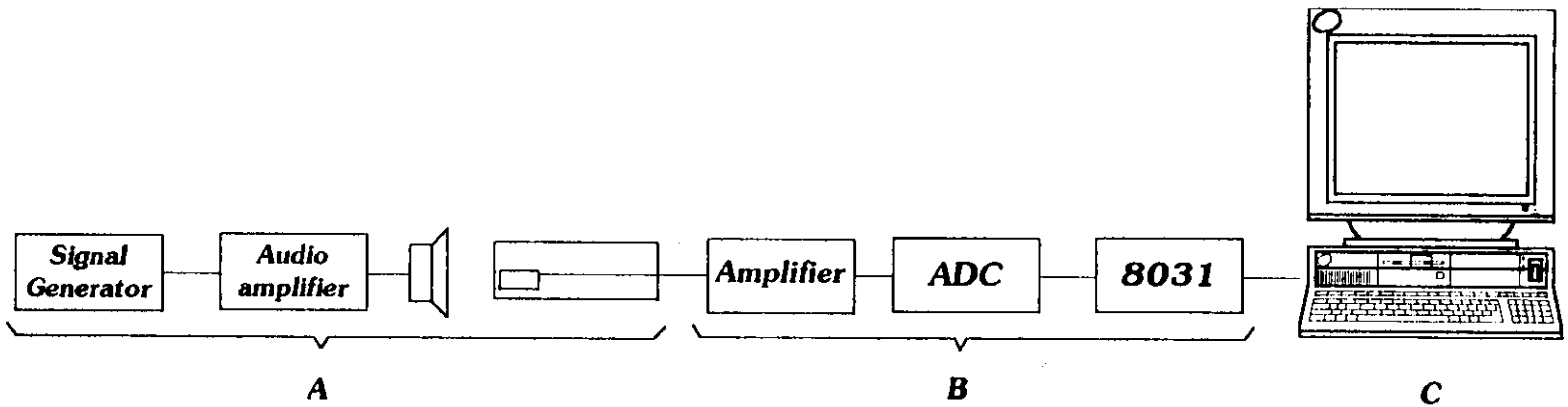

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FIG.2 Experimented setup

size	Document Number	rev.
A		02

Software

The software orogram that controls the euipment consists of two parts , one deals with the 8031 where the program is written in assembly language and burn onto the EPROM , the other part which is on the pc is written in C.

Fig. 3 shows the flowchart of 8031 program. The operator should first turns on the signal generator and the audio amplifier. After the designed frequencies are selected and the microphone is placed at a designed position (which can be any position in the tube, basically), the reset botton should be pushed. Once the reset botton on the equipment is pushed, the 8031 will be on the initialized stage, where time1 is set to mode 2, time0 to mode 1, and the 8031 then waits for a linking signal from the pc through RS232. On the pc side, when the " resonance" program is run , the pc will send a linking signal to 8031. Once the connection between the two is established, a delay time can then be chosen (between 100 microseconds to 64 milliseconds). and sent to 8031. Once the delay time is recieved, the 8031 is on the process of data acquisition. The sound waves inside the tube are picked up by the microphone , amplified and digitized and saved on the RAM. At the end of the data acquisition process, there will be 512 data points taken. The data are then sent to the pc. and then displayed on the screen right away. One can should to look at time or amplitude of the waves by choosing 'x-detail' or 'y-detail', respectively. If 'R' is chosen, the new set of data will be collected. Figures 3&4 show the flow charts of the 8031 program and the main program.

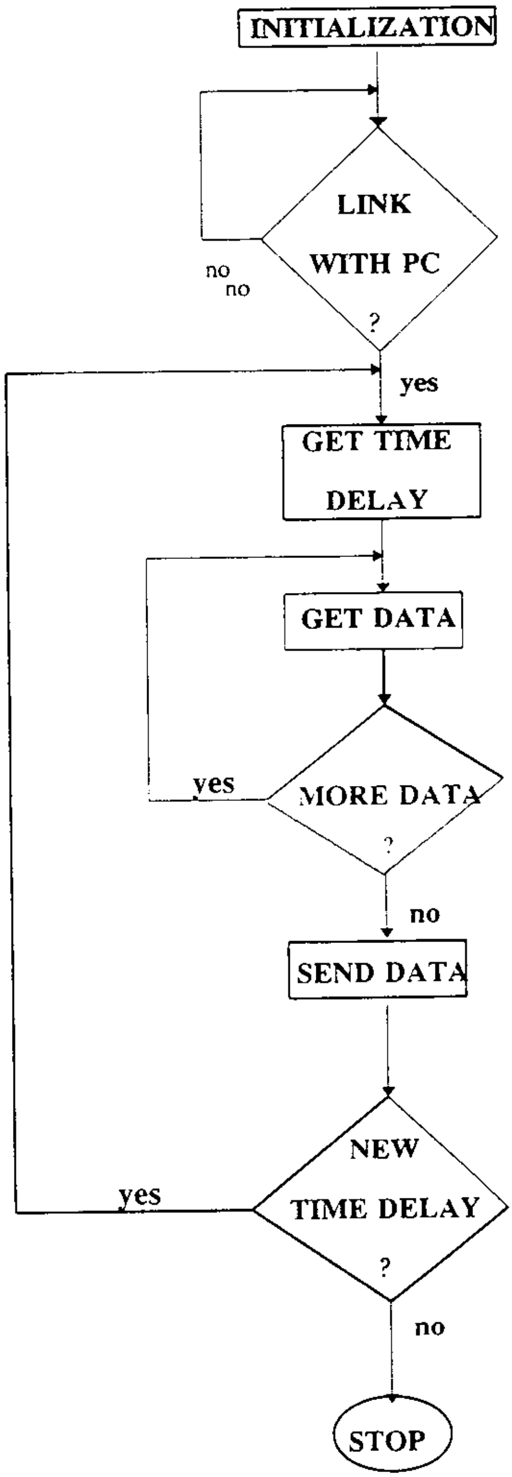
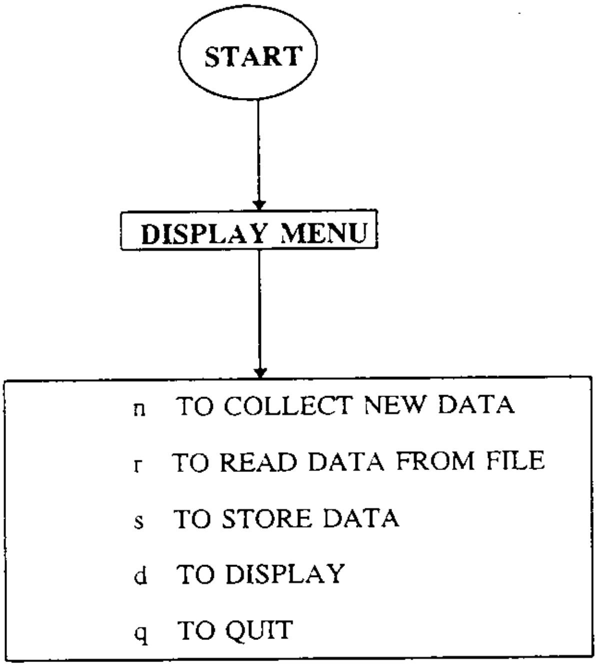
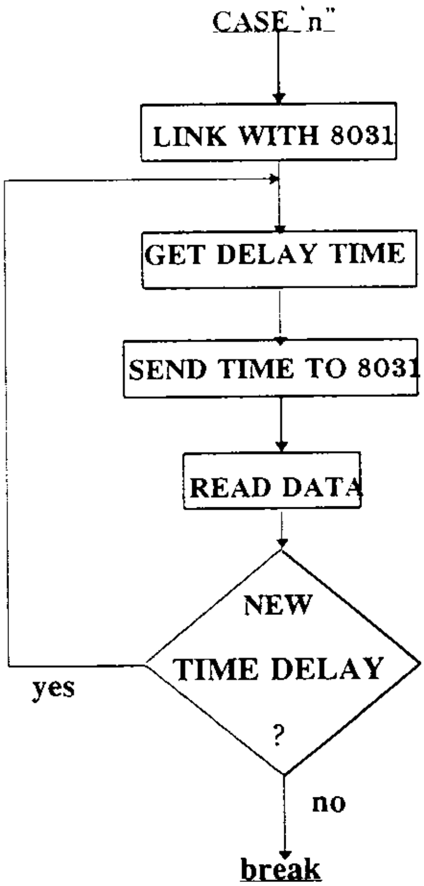


Fig.3 Flow chart of 8031 program


START
DISPLAY MENU
n TO COLLECT NEW DATA
r TO READ DATA FROM FILE
s TO STORE DATA
d TO DISPLAY
q TO QUIT


CASE "n"
LINK WITH 8031
GET DELAY TIME
SEND TIME TO 8031
READ DATA
NEW TIME DELAY ?
yes
no
break

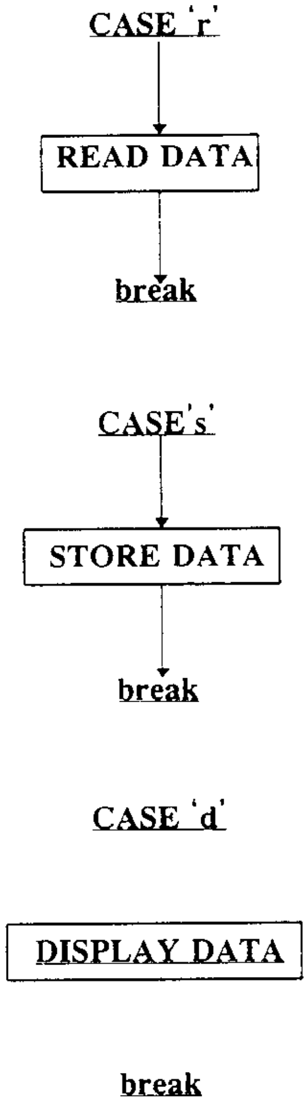


Fig.4 Flow chart of main program

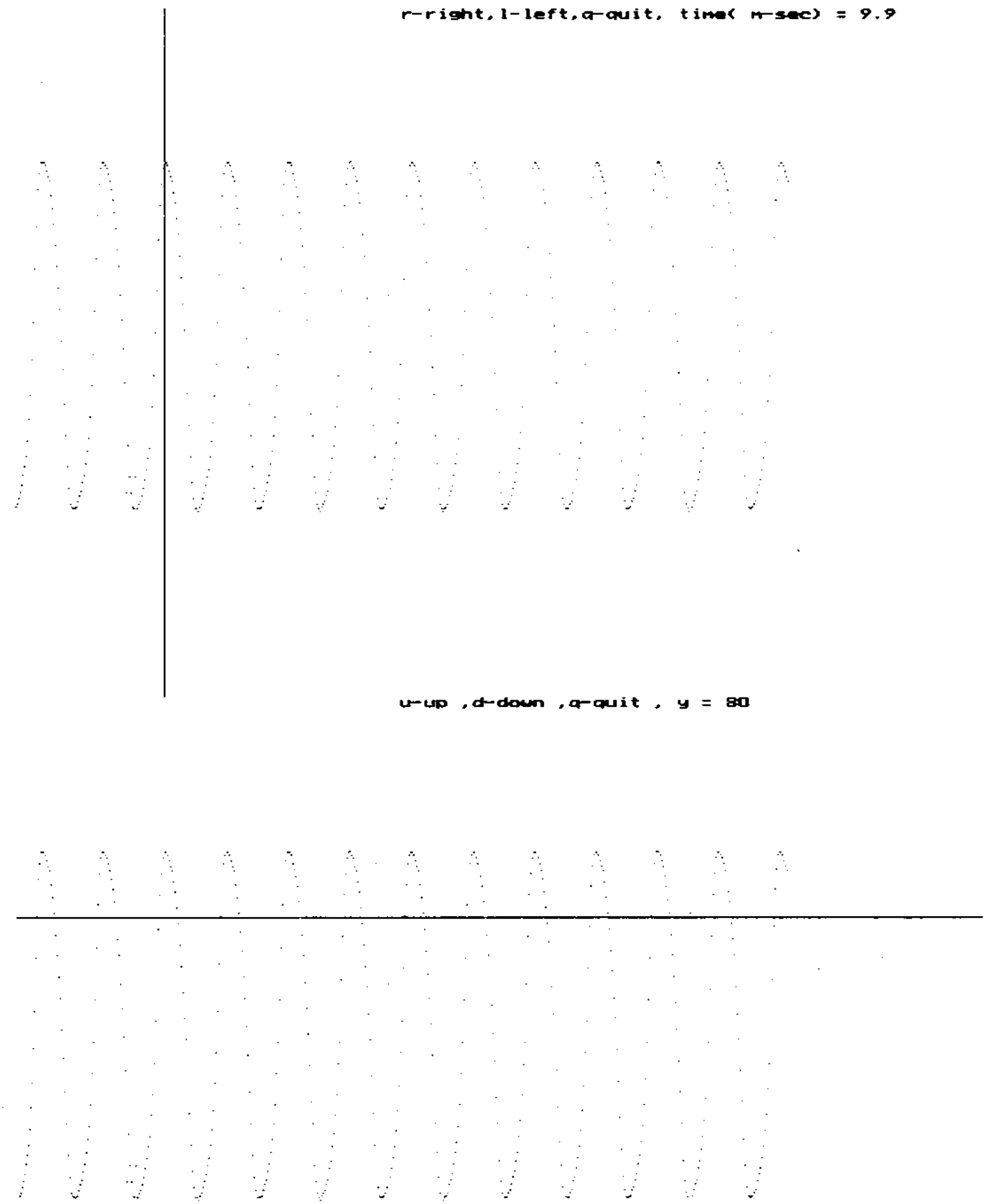


Figure 5 Typical display of data showing vertical and horizontal marks

RESULTS

A circular glass tube ,with an inner diameter of 2 c.m. and 67.2 c.m. long , was uased. A time delay of 100 microseconds was used through out the experiment.

Fig. 5 shows a typical output with vertical or horizontal lines for measuring times or amplitudes, respectively. Table 1 and 2 show the results of open and closed end tubes, respectively.

Table 1 Speeds of sound measured by resonance method (open end tube).
Air temperature is 28.5 ^{0}C.

$V_{(theoretical)}$ = 34898.9 cm/sec , L = 67.2 c.m.

frequency (Hz)	speed of sound (c.m./sec)	error
f1 = 245.9	33049.0	5.3%
f2 = 495	33264.0	4.7%
f3 = 735	32928.0	5.6%

Table 2 Speeds of sound measured by resonance method (closed end tube)
Air temperature is 28.5 ^{0}C

$V_{(theoretical)}$ = 34898.9 c.m./sec. , L = 67.2 c.m.

frequency (Hz)	speed of sound (c.m./sec)	error
f1 = 122	32780.5	6.1%
f3 = 370	33152.0	5.0%
f5 = 625	33600.0	3.7%

DISCUSSION

Much of error is presumed to arise from measurement of frequencies, which is limited by the lowest delay time of the ADC (for 0804 chip, the limit is 100 microseconds). The end effect, the approximate position of the antinode, also gives rise to the error. At some frequencies, one can measure amplitudes against distance in the tube, and that one complete wavelength (or more, for some cases or longer tubes) can be obtained. With this measurement, the end effect can be removed, and this should give a better results. With longer tubes, one can get more than one wavelengths in the tube, and that gives a better averaged wavelength, which will then give a better result.

ACKNOWLEDGEMENT

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