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Development of an Electronic Stick with Audio Sensory Perception for the Visually Impaired

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Abstract

The report details the use of ultrasonic transmitter and receiver for distance measurement which can be embedded in a stick thereby providing navigation assistance to the visually impaired. As the human ear's audible perception range is 20 Hz to 20 kHz, it is insensitive to ultrasonic waves, and hence the ultrasound waves can be used for applications in industries/vehicles without hindering human activity. The distance is measured using pulse echo method. The measurement unit uses a continuous signal in the transmission frequency range of ultrasonic transducers. The signal is transmitted by an ultrasonic transducer, reflected by an obstacle and received by another transducer where the signal is detected. The time delay of the transmitted and the received signal corresponds to the distance between the system and the obstacle so depending on this time value a beep frequency is generated which indicates the closeness of the obstacle to the system.

1. Introduction

The techniques of distance measurement using ultrasonic in air include continuous wave and pulse echo technique. In the pulse echo method, a burst of pulses is sent through the transmission medium and is reflected by an object kept at specified distance. The time taken for the pulse to propagate from transmitter to receiver is proportional to the distance of object. For contact less measurement of distance, the device has to rely on the target to reflect the pulse back to itself. The target needs to have a proper orientation that is it needs to be perpendicular to the direction of propagation of the pulses. The amplitude of the received signal gets significantly attenuated and is a function of nature of the medium and the distance between the transmitter and target. The pulse echo or time-of-flight method of range measurement is subject to high levels of signal attenuation when used in an air medium, thus limiting its distance range.

This report deals with development of an electronic stick using a microcontroller and ultrasonic transmitter and receiver. The controller is used for transmitting and receiving burst of pulses in ultrasonic frequency range. The time difference between transmission and reception gives the indication of the distance of the obstacle from the system. Depending on this time the frequency of beeps of the buzzer is modulated and this provides audio sensory perception to visually impaired.

The overall block diagram is shown in Fig. 1.

2. Design procedure

The circuit has been divided into two divisions.

(i) Digital section- micro controller AT89C2051.

(ii) Analog section –

(a) Transmitting side - Ultrasonic transducers, gain amplifier using TL084.

(b) Receiving side - Gain amplifier, comparator using TL084, voltage limiter.

(c) Buzzer/Headphone

(d) +15V and -15V power supply.

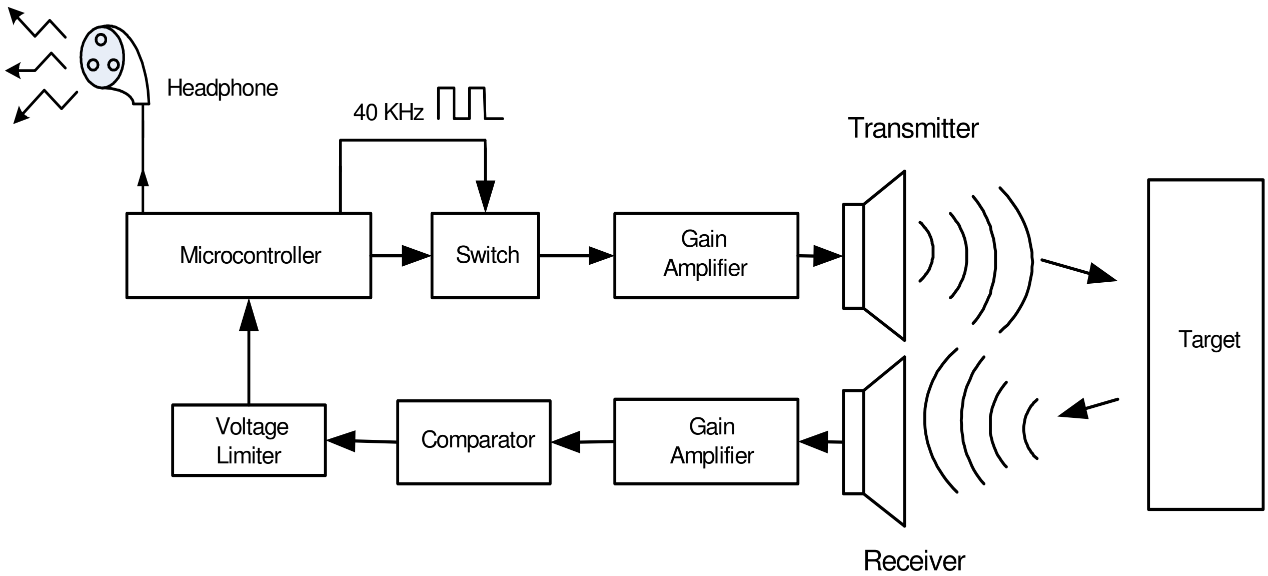

Fig. 1 Block Diagram of the distance measurement system

2.1 Transmitting unit

Microcontroller.

This system of distance measurement does not require large amount of memory, hence a 20 pin 8051 based microcontroller AT89C2051, is chosen as the controller with 12MHz clock. It performs the operation of giving 40KHz signal to the transmitter, computing the distance, compute the time of flight, and then depending on it changing the frequency of beep signal.

Amplifier

Ultrasonic transmitter requires +15V to -15V pulses of 40 KHz frequency range for operation. Therefore, the pulses generated by the microcontroller need to be amplified and then fed to the transmitter. TL084 is used to provide sufficient gain and the voltage levels required by the transmitter for its operation.

2.2 Receiver unit

Amplifier

The frequency of the received pulse is of 40 kHz which requires amplifiers working at high frequency. TL084 is used, as it has good high frequency gain characteristics. The gain of the amplifier is set to 100. This gain is set by taking into account the least magnitude (50mV) of the receiver output when sensing an object at distance of 2 metre.

Comparator

The output signal from the amplifier is passed through the comparator which compares with a reference threshold level to weed out the noises and false triggering. The signal is a series of square pulses as shown in Fig.1 with amplitude of ± 15 volts. This is passed through the voltage limiter (Zener regulator) to be converted into 0-5 volts pulses and is then fed to the microcontroller for counting the pulses.

3. Circuit Diagram:

The circuit schematic is included in the appendix.

3.1 Circuit Description

The time of flight method is used for finding the distance between the transmitter and the object. The transmitter sends out a burst of pulses and a receiver detects the reflected echo. The time delay between the corresponding edges of the transmitted and received pulses is measured by microcontroller; this gives the time of flight. Substituting the time delay and the velocity of ultrasound in air (330 m/s) in the following formula we can determine the distance between the transmiter and the target. Fig.2 shows the transmitted and received pulses.

$$\text{Distance} = \text{Velocity} \times \text{Elapsed time}$$

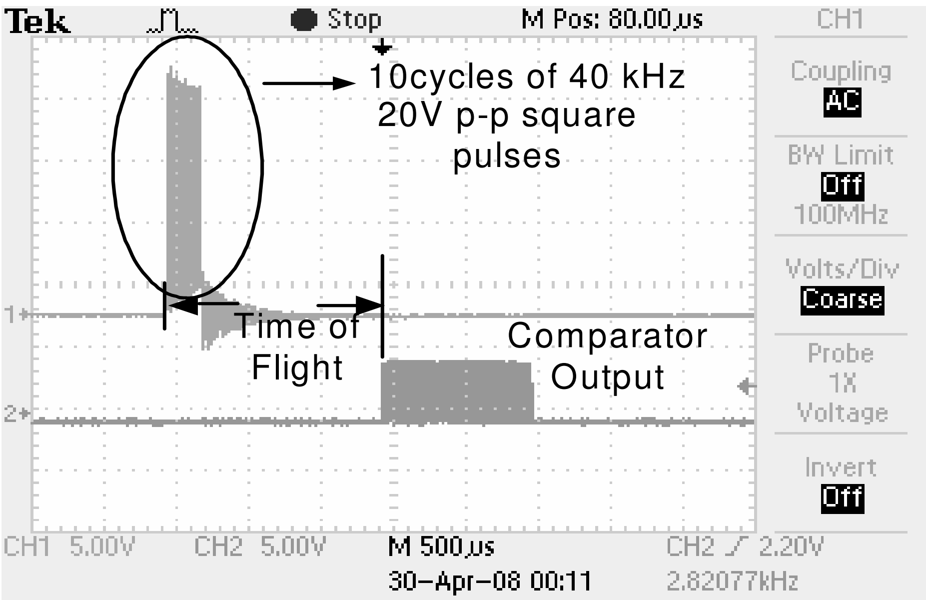

Fig. 2 Transmitted and Received Pulses

The microcontroller calculates the distance and the time of flight using above formula. This distance is twice of the required distance. Hence it is reduced to half and depending on this the beep frequency is evaluated and given to the headphone.

3.2 Firmware description

The microcontroller provides 10 cycles of 40 kHz pulses to the transmitter. The pulses varying between 0-5 V passes through the level shifter and gain amplifier which gives pulses with output varying between -10V and +10V. The transmitter sends out a burst of 10 pulses. As the transducers are directional they are positioned to face the target. Flow chart of the program is given in Fig. 4.

The microcontroller waits to receive the pulses for a maximum duration of 12 milliseconds. This is the time taken for the ultrasound waves to travel a maximum distance of 4 metres (time of flight gives twice the time taken to traverse a unit distance). If it doesn't receive the pulses within this time it is considered as absence of object or object out of range. Once the pulses are received the microcontroller counts 10 pulses with a time spacing of 25 microseconds only then the measurement is considered valid and the computation using the formula is implemented. Depending on the time of flight calculated by the microcontroller the beep frequency is varied, thus if the time of flight is more this means that obstacle is at considerable distance from the receiver, then the beep frequency will be low. If the time of flight is less it means that the obstacle is nearby and thus the beep frequency will be high.

The time of flight is stored in registers R0 and R1, this value is used to determine the number of pulses (stored in register R5) in 1 sec. Register R3 and R4 are used to generate burst of pulses, and the number of pulses in the burst is determined by register R2. The relations between these values are stored in the registers is as follows:

$$R5 = (R0 \times R1)/1000$$

$$R5(T_{on} + T_{off}) = 1 \text{ sec}$$

Ton and Toff are the on and off time period of the burst. Value of T_{on} is determined by value in register R2, R3, R4:

$$Ton = 2 \times R2 \times \text{ time delay generated by R3R4}$$

Thus values of T_{off} can be calculated from above formula. Therefore as the distance between the obstacle and receiver varies the time of flight of ultrasonic waves varies proportionally, this will change the values of register R0 and R1 and hence the number of pulses per second and T_{off} will vary.

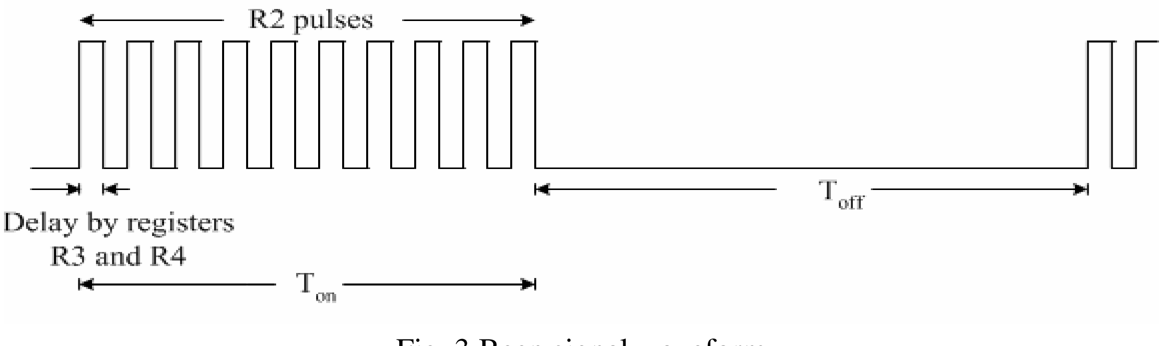

Fig. 3 Beep signal waveform

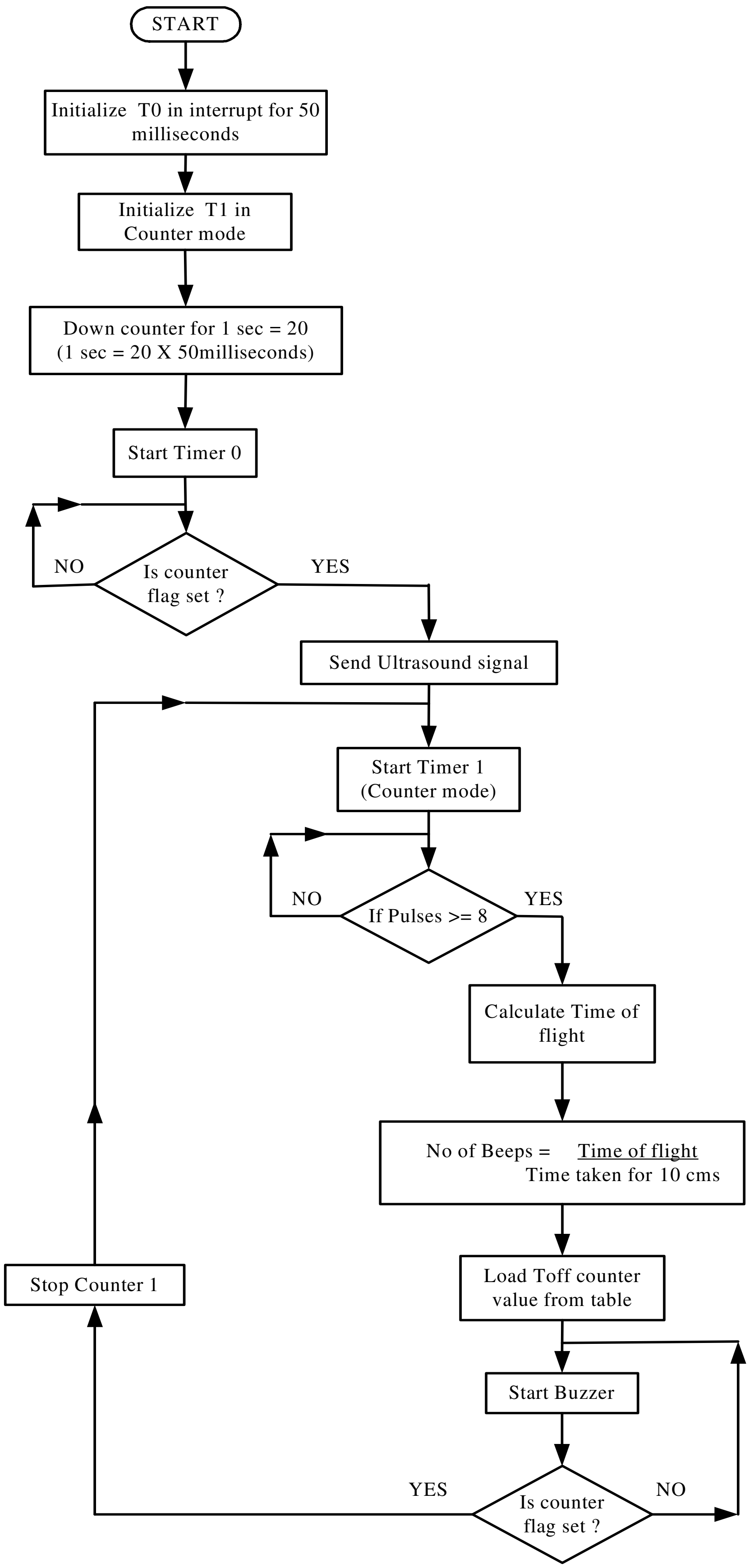

Fig. 4 Flowchart of the Program

4. Test Procedure and Results

This measurement system has been tested by transmitting the data serially to the PC using RS232. The data being transmitted consists of the distance between the obstacle and the system, time of flight, transmitter frequency, beeps frequency and the frequency of beeping. Some of the tested results are shown in figure 5.

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************************************************************
 Development of Electronic Stick with Audio sensory Perception
           for the Visually impaired
(Debugging message for status of operation through Serial port)

 Distance     Time of      Ultrasonic    Beep          Frequency
 Measured     Flight       frequency     frequency     of Beeping
 (in cms)    (millisec)     (in kHz)     (Hz)          (Beeps/Sec)
************************************************************
  NO PULSE     RECEIVED !!!
  NO PULSE     RECEIVED !!!
  NO PULSE     RECEIVED !!!
  NO PULSE     RECEIVED !!!
  NO PULSE     RECEIVED !!!
  074 cms     02.263 ms     40 kHz     400 Hz          06 Beeps/s
  060 cms     01.829 ms     40 kHz     400 Hz          07 Beeps/s
  066 cms     02.009 ms     40 kHz     400 Hz          06 Beeps/s
  080 cms     02.439 ms     40 kHz     400 Hz          06 Beeps/s
  087 cms     02.657 ms     40 kHz     400 Hz          05 Beeps/s
  097 cms     02.961 ms     40 kHz     400 Hz          05 Beeps/s
  107 cms     03.247 ms     40 kHz     400 Hz          04 Beeps/s
  111 cms     03.369 ms     40 kHz     400 Hz          04 Beeps/s
```

Fig. 5 Test results

5. Conclusion

The microcontroller makes it user friendly and its functionality can be expanded by adding some more features like voice interface and determination of direction of the obstacle. The circuit has been implemented on bread board and tested for its functionality by varying the distance between the transducer and the target. The target surface needs to be perpendicular to the impinging ultrasound waves. The power level of the signal is too low for long range measurement so it cannot be used for distances beyond 2 metres.

6. Future work

- The range can be considerably increased by using high power drive circuit.
- Using temperature compensation, it can be used over wide temperature range.
- The resolution of the measurement can be improved by incorporating phase shift method along with time of flight method.
- Instead of using a stick this system can also be embedded in belt or shoes of impaired person, so that he can walk just like a normal person.
- Voice indication can be used in place of the buzzer, by which we can indicate the distance of the obstacle and the direction also.

7. Acknowledgement

We express our deep gratitude to Prof P. C. Pandey for his timely and valuable guidance for the successful completion of the project. We also like to thank the WEL lab RAs, TAs, and Staff for their continuous support. Doing this work was a really a lot of fun as we could get our hand on the practical applications of electronic principles, also it was a very good learning experience as a group.

References

[1] M. Mazidi, 8051 Microcontroller and Embedded Systems, (1st Edition) 1999, Prentice Hall

[2] K. J. Ayala, *8051 Microcontroller, Architecture, Programming & Applications*, Second Edition, Penram International Publishing (India), Mumbai, 1998.

[3] "A high accuracy ultrasonic distance measurement system using binary frequency shift-keyed signal and phase detection" Huang *et al.* review of scientific instruments volume73, number, October 10, 2002.

[4] Datasheets of all the components involved (AT89C2051, IC 4066, IC 7805, IC TL084, UA 741)

APPENDIX

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;*********************************************************************************************************
; Development of an Electronic Stick with Audio Sensory Perception for the
;                                Visually Impaired
;                                      BY
;                       DISHANT                 (07307022)
;                       KRITI KUMAR             (07322601)
;                       CHANDRAMOULI            (07307601)
;*********************************************************************************************************
; TYPE                  : LEVEL 3 BASIC 40 KHz SQUARE WAVE GENERATION PROGRAM
; FUNCTION              : GENERATES ULTRASOUND SIGNAL AND MODULATED THE BEEP ;
                   FREQUENCY BASED ON THE  DISTANCE BETWEEN THE
;                        TRANSDUCER AND THE OBJECT
; STATUS                : TESTED OK
; DATE                  : 5TH MAY 2008
; MICRCONTROLLER        : AT89C2051 , 12 MHz
; DESCRIPTION           : BUZZER - P1.2 AND SIGNAL - P1.7 CONNECTIONS AS DEFINED .
; TIMER 1 IS USED FOR COUNTING THE REFLECTED ECHO PULSES IN PIN P3.3.
; TIMER 0 IS CONFIGURED AS 16-BIT TIMER AND GENERATES A 50 MILLISEC INTR. THE
; ULTRASOUND SIGNAL IS GENERATED AT 40 kHz FROM PIN P1.7 EVERY 1 SECOND
;*********************************************************************************************************
          COUNTER         EQU       R6
          SIGNAL          EQU       P1.7
          BUZZER          EQU       P1.2

          UPDATE_FLG      EQU       2Dh
          TIMER_1_FLAG    EQU       2Eh
          TIMER_0_FLAG    EQU       2Fh

          T0_MSB          EQU       3Dh
          T0_LSB          EQU       3Eh
          NO_OF_BEEPS     EQU       3Fh

          FREQ_BP_MSB     EQU       40H
          FREQ_BP_LSB     EQU       41h
          TIME_COUNT      EQU       42h
          TOFF_COUNT      EQU       43h

          BUFFER          EQU       50h
          OFFSET          EQU       05h
          NO_OF_PULSES    EQU       0Ah

;         DATA MACRO
          NO_OF_CHARAC    EQU       60
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```
            DIST_PNTR       EQU     58
            TIME_PNTR       EQU     46
            ULTRA_PNTR      EQU     31
            BEEP_PNTR       EQU     22
            FREQ_PNTR       EQU     10

            DIST_ADDR       EQU     50h
            TIME_ADDR       EQU     53h
            ULTRA_ADDR      EQU     58h
            BEEP_ADDR       EQU     5ah
            FREQ_ADDR       EQU     5dh
;************************************************************************************************************
; THE MCU STARTS EXECUTING FROM THIS LOCATION AFTER POWER UP
;************************************************************************************************************
                ORG     0000H
                SJMP    START
;************************************************************************************************************
; THE MCU STARTS EXECUTING FRM THIS LOCATION WHEN THERE IS AN EXTERNAL
; INTERRUPT (INT0)
;************************************************************************************************************
                ORG     0003H           ; INT0
                RETI
;************************************************************************************************************
; THE MCU STARTS EXECUTING FRM THIS LOCATION WHEN THERE IS A TIMER 0
; INTERRUPT (TIMER0)
;*******************************************************************************************************
                ORG     000BH           ; TIMER0
                LCALL   TIMER_0_ISR
                RETI
;************************************************************************************************************
; THE MCU STARTS EXECUTING FRM THIS LOCATION WHEN THERE IS AN EXTERNAL
; INTERRUPT (INT1)
;************************************************************************************************************
                ORG     0013H           ; INT1
                RETI

;************************************************************************************************************
; THE MCU STARTS EXECUTING FRM THIS LOCATION WHEN THERE IS A TIMER 0
; INTERRUPT (TIMER0)
;************************************************************************************************************

                ORG     001BH           ; TIMER1
                LCALL   TIMER_1_ISR
                RETI
```

```
;*************************************************************************************************************
; THE MCU STARTS EXECUTING FRM THIS LOCATION WHEN THERE IS A SERIAL
; (RECEIVES) INTERRUPT
;*************************************************************************************************************
                ORG     0023H                           ; SERIAL
                RETI

                ORG     0027H
;*************************************************************************************************************
;               THE PROGRAM STARTS HERE
;*************************************************************************************************************

        START:
                MOV             SP,#30h
                LCALL   INIT_INTR
CHECK_AGAIN:
                CLR             C
                JNB             TIMER_0_FLAG,$
                MOV             A,TL1
                CJNE            A,#08h,TIME1A
                MOV             TL1,#00h        ; RESET THE COUNTER 1 TO 0
                SJMP            CONTN
        TIME1A:
                JC              CHECK_AGAIN
        CONTN:
                CLR             TR1
                MOV             T0_MSB,TH0
                MOV             T0_LSB,TL0
                MOV             R0,TH0
                MOV             R1,TL0
                MOV             R2,#3Ch
                MOV             R3,#0AFh
                LCALL           SUBTRACT
                MOV             R5,#02h
                MOV             R4,#47h
                LCALL           DIVI
                MOV             A,R3
                MOV             NO_OF_BEEPS,A
                MOV             DPTR,#TABLE
                MOVC            A,@A+DPTR
                MOV             TOFF_COUNT,A
                CLR             C
                MOV             A,#12
                MOV             B,NO_OF_BEEPS
```

```
                SUBB        A,B
                MOV         NO_OF_BEEPS,A
                CLR         TIMER_0_FLAG
      AGBN:
                LCALL       TON_DELAY      ; USING R3,R4,R5
                JB          TIMER_0_FLAG,AGNO
                CLR         BUZZER
                LCALL       TOFF_DELAY
                JNB         TIMER_0_FLAG,AGBN
      AGNO:
                SJMP        CHECK_AGAIN

;********************************************************************************************************
;                 INTITIALIZATION OF TIMER
;********************************************************************************************************

INIT_INTR:
                MOV         IE,#02h
                MOV         TMOD,#51h      ; TIMER 0  IN 16 BIT
                                           ; TIMER MODE , TIMER 1  as counter
                CLR         A
                MOV         TH0,#3Ch
                MOV         TL0,#0AFh
                SETB        TR0
                MOV         TH1,#00h
                MOV         TL1,#00h
                CLR         TR1
                MOV         TIME_COUNT,#20
                SETB        TIMER_0_FLAG
                SETB        IE.7
                RET
;********************************************************************************
;                 TIMER 0 INTERRUPT SERVICE ROUTINE
;********************************************************************************

TIMER_0_ISR:
                PUSH   0
                PUSH   1
                PUSH   2
                PUSH   3
                PUSH   4
                PUSH   5
                CLR         TR0
                MOV         R7,TIME_COUNT
```

```
                DJNZ        R7,TIM0
                SETB        TIMER_0_FLAG
                MOV         TIME_COUNT,#20
                MOV         TH0,#03Ch
                MOV         TL0,#0AFh
                MOV         TH1,#00h
                MOV         TL1,#00h
                SETB        TR0
                LCALL       SEND_ULTRASOUND
                POP   5
                POP   4
                POP   3
                POP   2
                POP   1
                POP   0
                RET

        TIM0:
                MOV         TIME_COUNT,R7
                MOV         TH0,#03Ch
                MOV         TL0,#0AFh
                SETB        TR0
                POP   5
                POP   4
                POP   3
                POP   2
                POP   1
                POP   0
                RET

;**********************************************************************************
;               TIMER 1 INTERRUPT SERVICE ROUTINE
;**********************************************************************************
TIMER_1_ISR:
                RET
;******************************************************************************************
;       ROUTINE TO SEND ULTRASONIC SOUND WAVES
;       GENERATE 10 CYCLES OF 40kHz SQUARE WAVE THROUGH P1.7
;******************************************************************************************
SEND_ULTRASOUND:
                MOV         COUNTER,#10 ;ULTRASOUND IS BEING
                                        ;TRANSMITTED
        SEND_AGAIN:
                SETB        SIGNAL
```

```
                MOV         R7,#05h
                DJNZ        R7,$
                NOP
                CLR         SIGNAL
                MOV         R7,#04h
                DJNZ        R7,$
                DJNZ        COUNTER,SEND_AGAIN
                SETB        TR1
                RET
;*****************************************************************************************
;                TON AND TOFF Calculation
;*****************************************************************************************
TON_DELAY:
                MOV         R3,#0Ah  ; NO OF CYCLES OF 400Hz SQUARE WAVE
        TONA:
                SETB        BUZZER
                MOV         R4,#0D0h
        AGNTIN:
                NOP
                JB          TIMER_0_FLAG,TONB
                DJNZ        R4,AGNTIN
                CLR         BUZZER
                MOV         R4,#0D0h
        AGNTIO:
                NOP
                JB          TIMER_0_FLAG,TONB
                DJNZ        R4,AGNTIO
                DJNZ        R3,TONA
        TONB:
                RET
;*****************************************************************************************
;                TON AND TOFF Calculation
;*****************************************************************************************
TOFF_DELAY:
                MOV         R4,TOFF_COUNT
         TOFF_ONE:
                MOV         R0,#0Ah
        AGNTIP:
                MOV         R1,#249
                JB          TIMER_0_FLAG,TONC
                DJNZ        R1,$
                DJNZ        R0,AGNTIP
                DJNZ        R4,TOFF_ONE
        TONC:
```

```
                RET
;****************************************************************************************
;           R0 R1 -
;           R2 R3
;           --------
;           R0 R1
;****************************************************************************************
      SUBTRACT:
                CLR         C
                MOV         A,R1
                SUBB        A,R3
                MOV         R1,A
                MOV         A,R0
                SUBB        A,R2
                MOV         R0,A
                RET

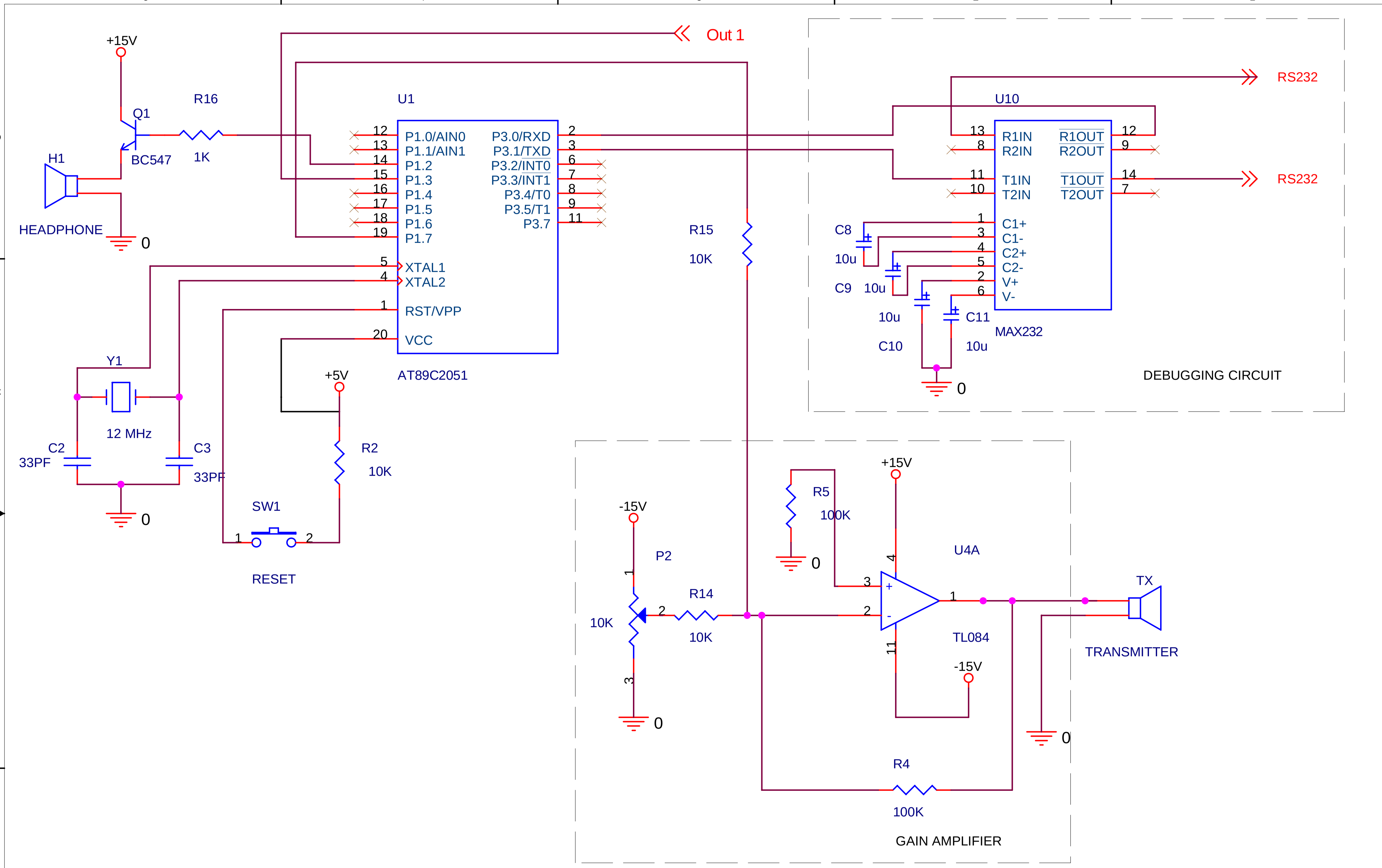
;****************************************************************************************
;           16-BIT DIVISION ROUTINE
;****************************************************************************************
      DIVI:
                CLR         A
                CLR         C
                MOV         A,R1                    ;R0 R1
                ADD         A,R0                    ;--------  = R2 R3
                JZ          MOVE_OUTH               ;R5 R4
                MOV         A,R4
                ADD         A,R4
                JZ          MOVE_OUTH
                CLR         A
                CLR         C
                MOV         R2,A
                MOV         R3,A
           NUST:
                MOV         A,R1
                SUBB        A,R4                    ;     DIVISOR
                MOV         R1,A                    ;
                JC          MUSTH
           DIVIAB:
                MOV         A,R0
                SUBB        A,R5                    ;     DIVISOR
                MOV         R0,A                    ;
                JC          ETH
                LCALL       INTRE
```

```
            LJMP        NUST
        MUSTH:
            CLR         C
            MOV         A,R0
            SUBB        A,#01h
            MOV         R0,A
            JC          OUWA
            SJMP        DIVIAB

        INTRE:
            CLR         C
            CJNE        R3,#0FFH,BREJ
            MOV         R3,#00H
            INC         R2
            LJMP        ETH
        BREJ:
            CLR         C
            INC         R3
        ETH:
            RET

MOVE_OUTH:
            MOV         R2,#00H
            MOV         R3,#00H
        OUWA:
            RET

TABLE:  DB  10,12,14,16,18,22,28,34,44,60,94,192
            END
```



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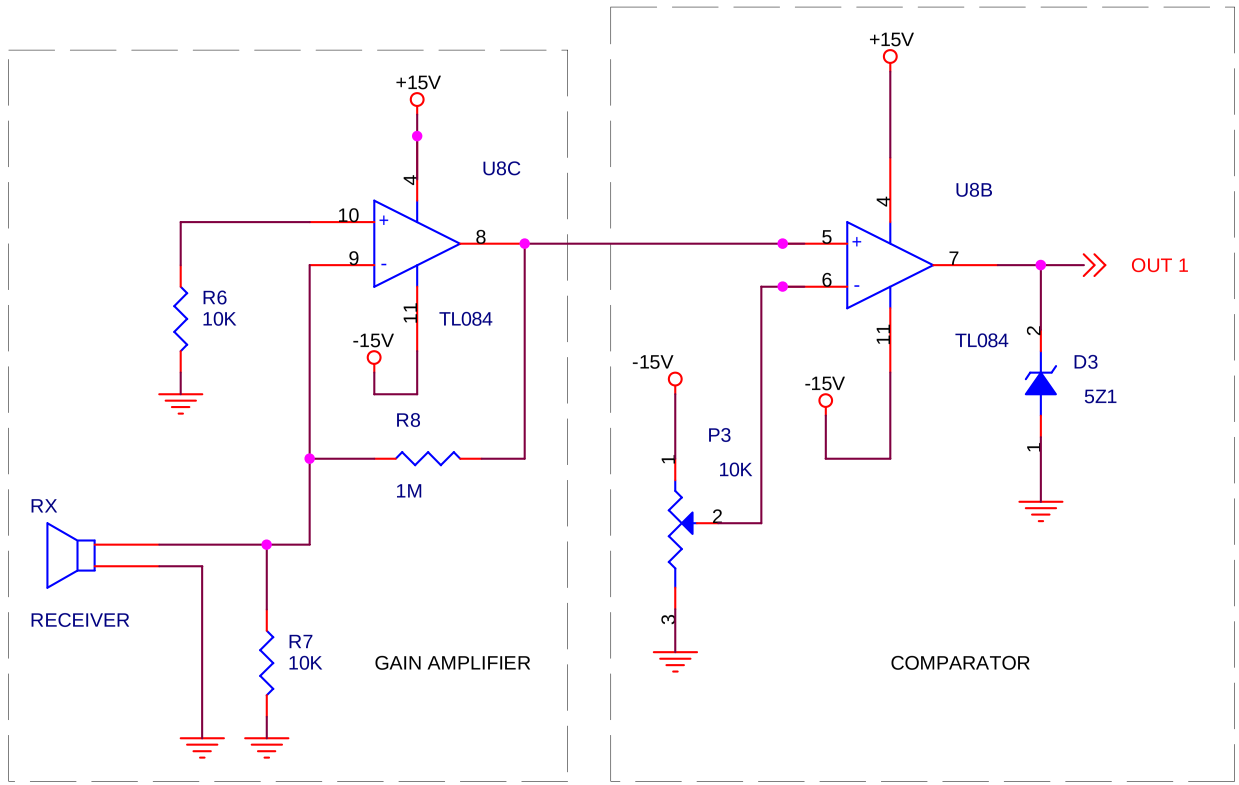

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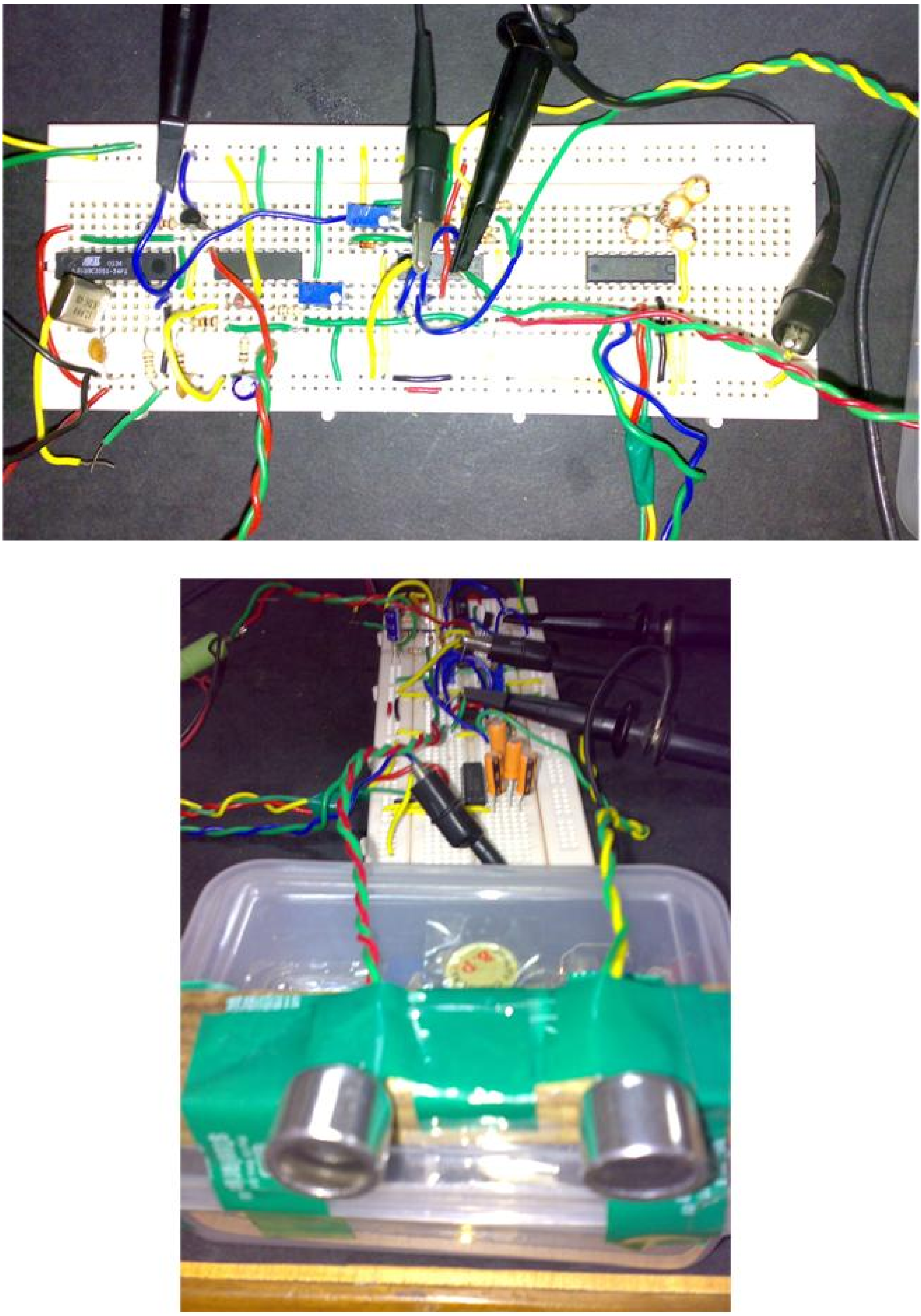

Fig 1. Photograph of the setup