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Ultrasonic Based Distance Measurement System

Group No: 06

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Abstract

The report details the implementation of distance measurement system using the ultrasonic waves. 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. They are widely used as range meters and proximity detectors in industries also it can be used in parking assistance system. The distance can be measured using pulse echo and phase measurement method. Here the pulse echo method is used. 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.

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.

2. Design procedure

The circuit has been divided into two divisions.

(i) Digital section- micro controller and LCD display unit with 5volt power supply

(ii) Analog section –

(a) Transmitting side - Ultrasonic transducers**,** gain amplifier using uA741 CD4066 CMOS analog switch**.**

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

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

The overall block diagram is shown in Fig.1.

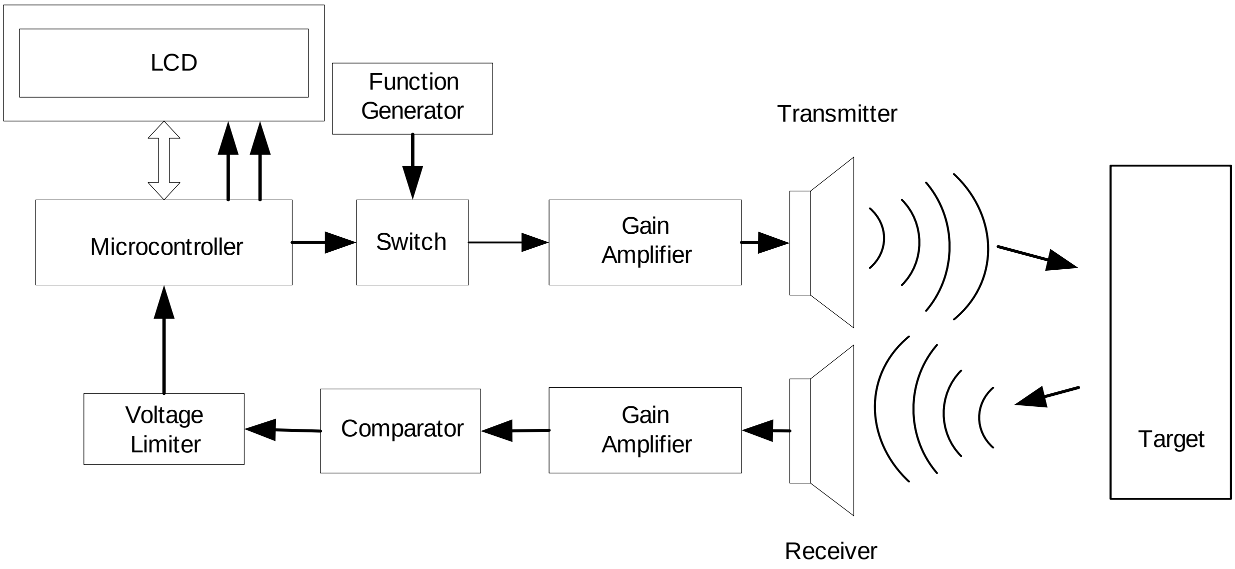


Fig. 1: Block Diagram

2.1 Transmitting unit

Switch

An analog switch CD4066 is used to allow the sine wave from function generator to the gain amplifier. The excitation to the Transmitter is given from the Function generator through the switch which can be digitally controlled. As the switch can pass only positive voltages, the 40kHz, 1Vp-p, sine wave from the function generator is given a DC shift of 0.5V.

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 the switching signal, computing the distance, converting the hex value to decimal and then to ASCII to be displayed in the LCD.

Gain Amplifier

As the 40 kHz sine wave cannot be passed through the analog switch 4066, a gain amplifier with level shifter is required. Both are integrated and built using µA741 opamp.

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 1000 in two stages with first being 100 and second being 10. The gain is set by taking into account the least magnitude (50mV) of the receiver output when sensing an object at distance of 2 metres.

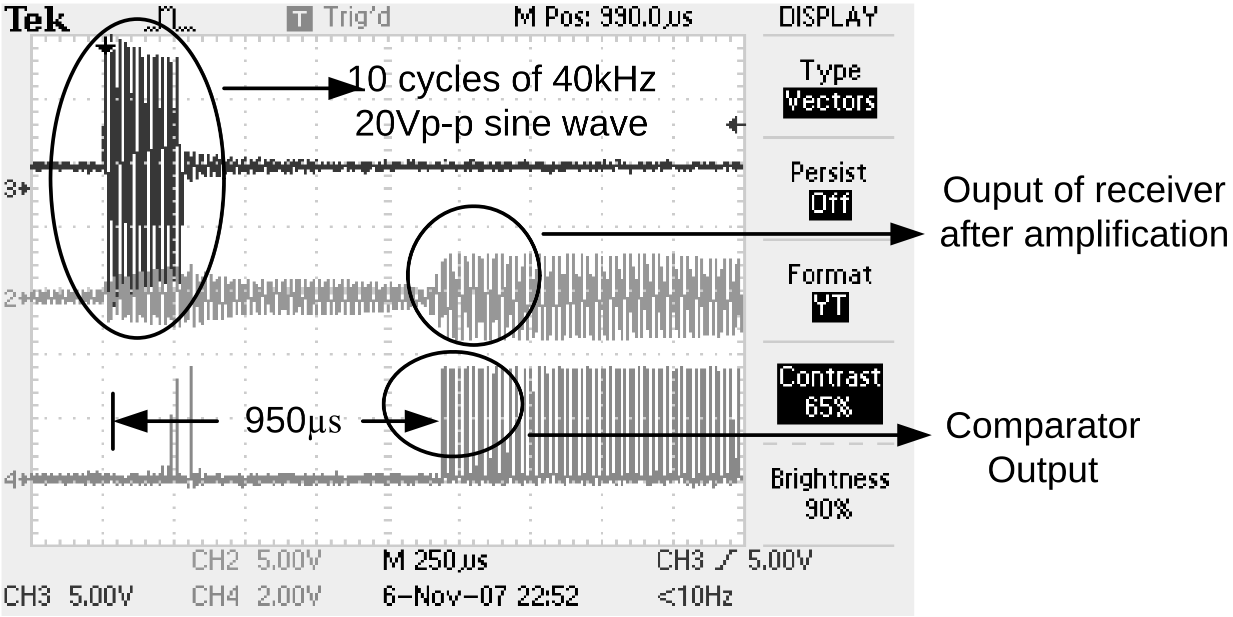
Comparator

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 fed to the microcontroller for counting the pulses.

3. 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 metres/second) in the following formula we can determine the distance between the transmitter and the target. Fig.2 shows the transmitted and received pulses.

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



Tek ⎍ T Trig'd M Pos: 990.0µs DISPLAY

Type Vectors

Persist Off

Format YT

Contrast 65%

Brightness 90%

CH2 5.00V M 250µs CH3 ⟋ 5.00V

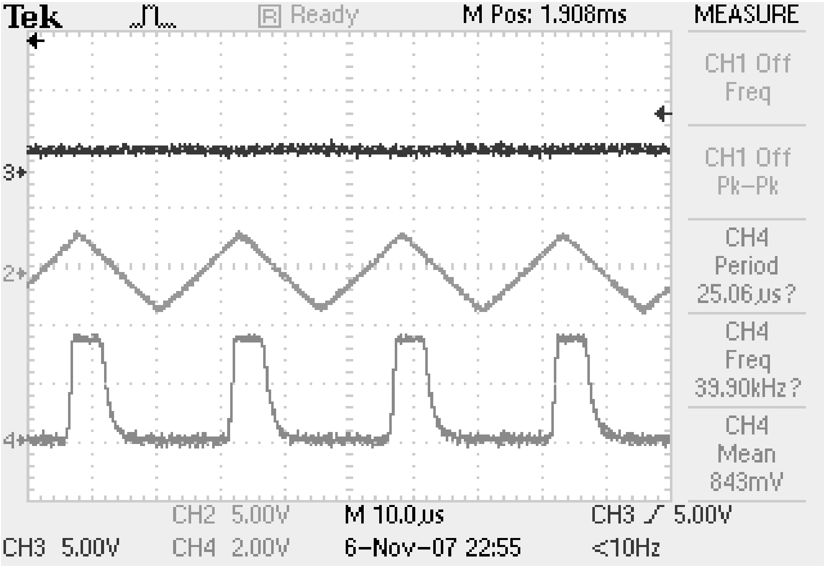
CH3 5.00V CH4 2.00V 6-Nov-07 22:52 <10Hz

$$\text{Time of flight} = 950\mu s$$

$$\text{Distance measured} = \frac{330}{950\mu s} = 0.347 \text{ metres}$$

Fig.2 Transmitted and Received Pulses

Microcontroller calculates the distance by the above formula. This distance is twice of the required distance. Hence it is reduced to half and this calculated distance is displayed on the LCD. The LCD is refreshed every 250 milliseconds.



Tek ⎍ R Ready M Pos: 1.908ms MEASURE

CH1 Off Freq

CH1 Off Pk–Pk

CH4 Period 25.06µs?

CH4 Freq 39.90kHz?

CH4 Mean 843mV

CH2 5.00V M 10.0µs CH3 ⟋ 5.00V

CH3 5.00V CH4 2.00V 6-Nov-07 22:55 <10Hz

Channel 3 : Output receiver amplifier
Channel 4 : Input pulses to the microcontroller.

Fig. 3 Signals in the receiver section

3.1 Firmware description

The microcontroller closes the switch for duration of 250 microseconds to allow 10 cycles of 40 kHz sine wave. The sine wave varying between 0-1V passes through the switch to the gain amplifier. The level shifter and gain amplifier gives a sine wave 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(a) & 4(b).

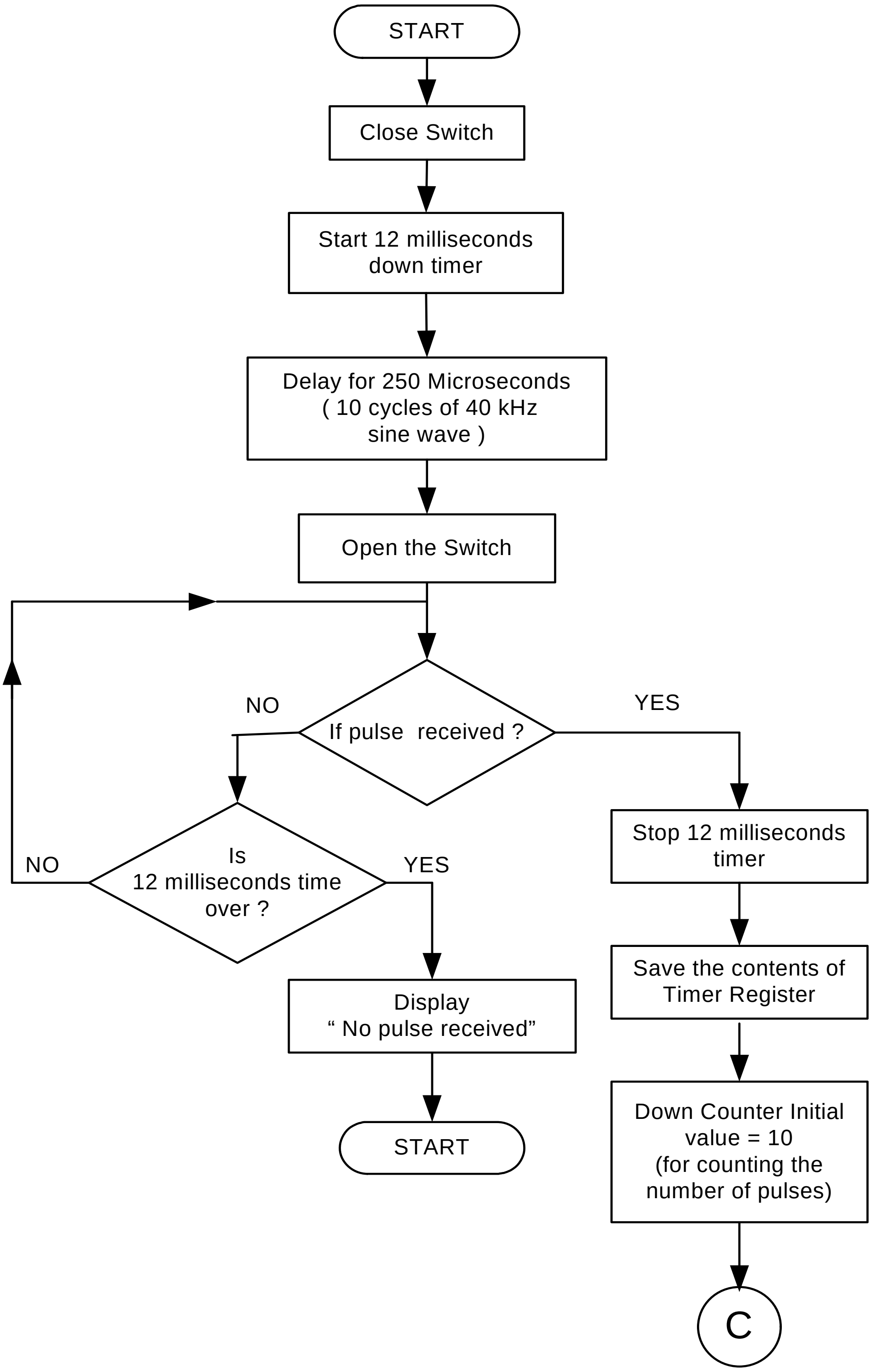

START
Close Switch
Start 12 milliseconds down timer
Delay for 250 Microseconds (10 cycles of 40 kHz sine wave)
Open the Switch
NO
If pulse received ?
YES
NO
Is 12 milliseconds time over ?
YES
Stop 12 milliseconds timer
Display " No pulse received"
Save the contents of Timer Register
START
Down Counter Initial value = 10 (for counting the number of pulses)
C

Fig.4(a) Flowchart of the Program

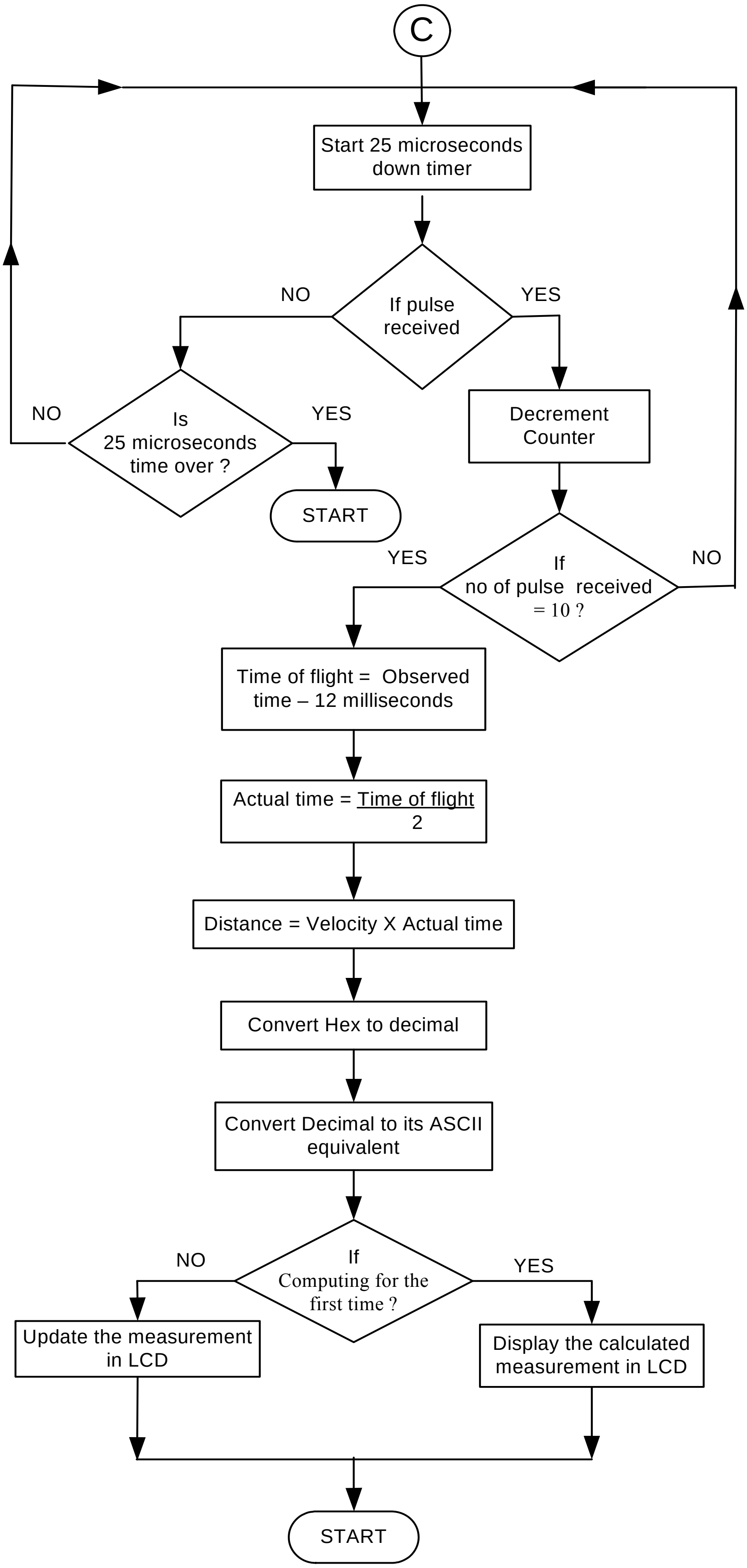

C
Start 25 microseconds down timer
If pulse received
NO
YES
Is 25 microseconds time over ?
NO
YES
START
Decrement Counter
If no of pulse received = 10 ?
YES
NO
Time of flight = Observed time – 12 milliseconds
Actual time = Time of flight / 2
Distance = Velocity X Actual time
Convert Hex to decimal
Convert Decimal to its ASCII equivalent
If Computing for the first time ?
NO
YES
Update the measurement in LCD
Display the calculated measurement in LCD
START

Fig.4(b) Flowchart of the Program.

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.

Necessary hex to decimal conversion and decimal to ASCII conversions are performed to display the output of the computation in the LCD. The appendix gives the detailed program with necessary comments for this application.

4. Conclusion

The microcontroller with LCD makes it user friendly and can be embedded in a single unit. 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.

5. 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.
- Can be used as parking assistance system in vehicles with high power ultrasonic transmitter.
- The 40 kHz signal can be generated using microcontroller itself which will reduce hardware.

6. 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] Mazidi, Muhammad Ali, 8051 Microcontroller and Embedded Systems, The (1st Edition) 1999, Prentice Hall

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

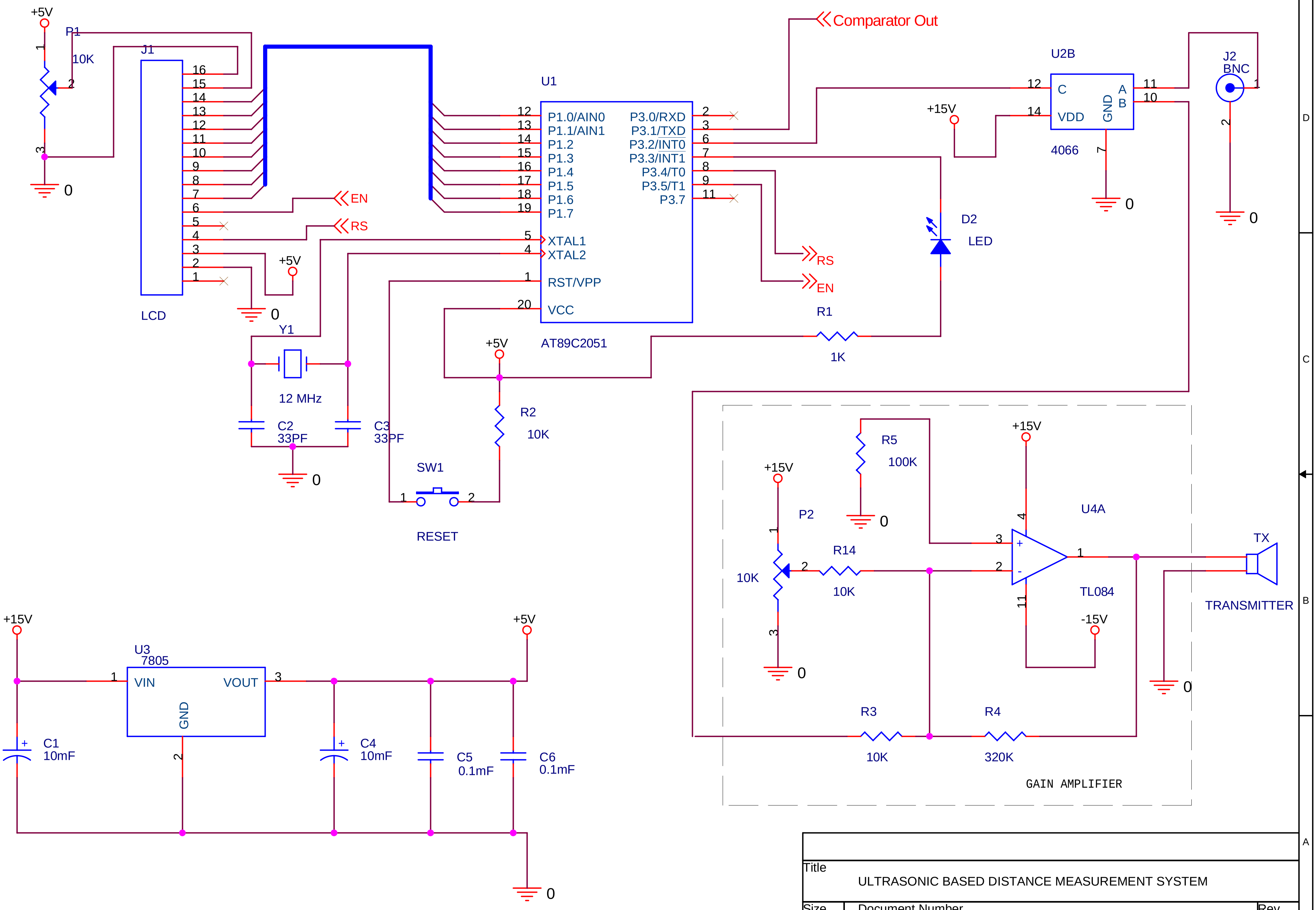
[3] “A high accuracy ultrasonic distance measurement system using binary frequency shift-keyed signal and phase detection” Huang et al review of scientific instruments volume73, number 10 october 2002.

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

APPENDIX

Bill Of Materials

Item	Quantity	Reference	Part
1	2	C4, C1	10mF
2	2	C3, C2	33pF
3	4	C5,C6,C8,C9	0.1mF
4	1	C7	1nF
5	1	D1	5Z1
6	1	D2	LED
7	1	J1	LCD
8	1	J2	BNC
9	12	P1,R2,P2,R3,P3,R6,R7, R9,R11,R12,R13,R14	10K
10	1	RX	RX-40F
11	1	R1	1K
12	1	R4	320K
13	2	R5,R10	100K
14	1	R8	1M
15	1	SW1	RESET
16	1	TX	TX-40F
17	1	U1	AT89C2051
18	1	U2	4066
19	1	U3	7805
20	2	U4,U7	TLO84
21	2	U5,U6	UA741
22	1	Y1	12MHz



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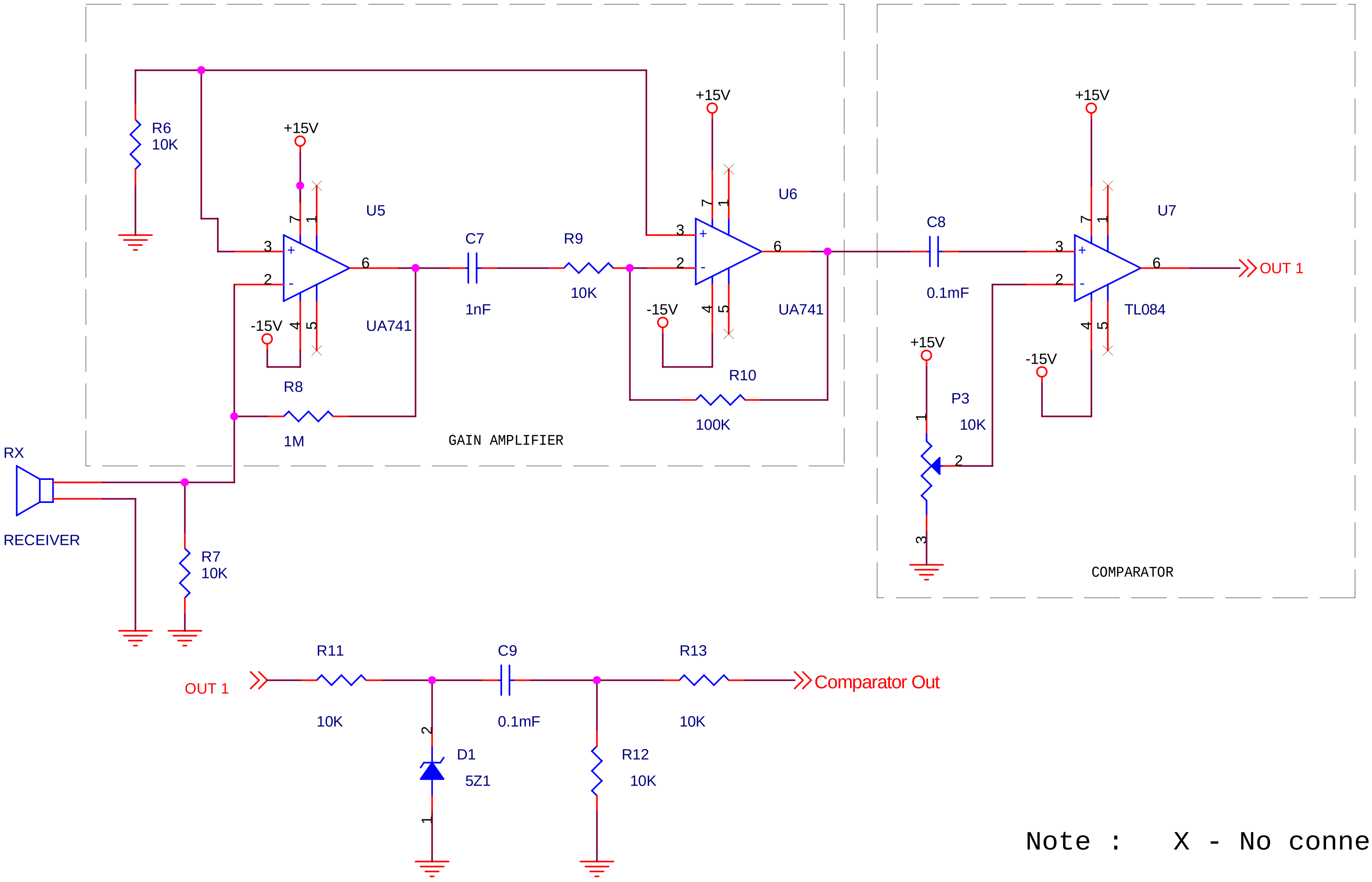
Size A	Document Number <Doc>	Rev 0.0
Date:	Sunday, November 18, 2007	Sheet 1 of 2



Note : X - No connection

Title ULTRASONIC BASED DISTANCE MEASUREMENT SYSTEM		
Size A	Document Number <Doc>	Rev 0.0
Date: Sunday, November 18, 2007	Sheet 2 of 2	

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;*******************************************************************************************************************************
;                    FiIRMWARE  FOR  DISTANCE MEASUREMENT USING ULTRASONIC TRANSDUCER
;                                                    BY
;                                   VIDYADHAR KAMBLE      (07307501)
;                                   DIPESH MAKWANA        (06323302)
;                                   C.CHANDRAMOULI        (07307601)
;*******************************************************************************************************************************
;TYPE                    :  LEVEL 3 - PROGRAM COMPLETED
;FUNCTION                :  OPENS AND CLOSES THE SWITCH FOR EVERY 250milliseconds AND CHECK FOR RECEIVING
;                        :  PULSES- COMPUTES DISTANCE FROM TIME OF FLIGHT, CONVERTS HEX  TO DECIMAL AND
;                        :  THEN TO ASCII TO DISPLAY IN LCD. DESCRIPTION FOR EACH SUBROUTINE INS GIVEN IN
;                        :   ITS HEADER
;STATUS                  :  TESTED OK
;DATE                    :  12th  NOVEMBER 2007
;MICROCONTROLLER         :  AT89C2051
;DESCRIPTION             :  GIVE THE LCD , LED CONNECTION, RCV-INPUT AS INDCTED IN THE DEFINE MACRO
;*******************************************************************************************************************************

                    RCV_INPUT           EQU          P3.1
                    SWITCH              EQU          P3.2
                    LED                 EQU          P3.3
                    RS                  EQU          P3.4
                    EN                  EQU          P3.5
                    FIRSTFLG            EQU          2Eh
                    TIMER_0_FLAG        EQU          2Fh
                    COUNTER             EQU          41h
                    FIRST_BYTE          EQU          42h
                    SECOND_BYTE         EQU          43h
                    THIRD_BYTE          EQU          44h
                    FOURTH_BYTE         EQU          45h
                    FIFTH_BYTE          EQU          46h
                    SIXTH_BYTE          EQU          47h
                    SEVEN_BYTE          EQU          48h
                    EIGTH_BYTE          EQU          49h
                    ROTA_CNTER_A        EQU          4Ah
                    ROTA_CNTER_B        EQU          4Bh
                    TIMER_1_FLAG        EQU          4Ch
                    DIG1                EQU          4Dh
                    DIG2                EQU          4Eh
                    DIG3                EQU          4Fh
                    BUFFER              EQU          50h
                    OFFSET              EQU          05h
                    NO_OF_PULSES        EQU          0Ah
                    LCD_DATA            EQU          P1

;*******************************************************************************************************
; 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
                           SETB    TIMER_0_FLAG
                           CLR     TR0
                           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

                SETB    TIMER_1_FLAG
                CLR     TR1
                RETI


;*************************************************************************************************************************************************************************
; THE MCU STARTS EXECUTING FRM THIS LOCATION WHEN THERE IS A SERIAL
; (RECEIVES) INTERRUPT
;*************************************************************************************************************************************************************************

                ORG     0023H                           ; SERIAL
                RETI


                ORG     0030H

;*********************************************************************************************************************************************
;               THE PROGRAM STARTS HERE
;*********************************************************************************************************************************************

        START:
                LCALL   INIT_INTR
                SETB    LED                     ; TURN ON LED
                LCALL   DISPLAY_LCD
        BEGIN:
                CLR     A
                MOV     TH1,#0D0h
                MOV     TL1,#0A6h
                CLR     TIMER_1_FLAG
                SETB    TR1                     ; START TIMER
                SETB    SWITCH                  ; CLOSE THE SWITCH
                LCALL   DELAY_250MICRO_SEC      ; KEEP THE SWITCH CLOSED FOR 250 MICRO SEC
                CLR     SWITCH                  ; OPEN THE SWITCH
                CPL     LED                     ; TURN ON LED
                MOV     R7,#NO_OF_PULSES
         BACK:
                JB      TIMER_1_FLAG,BEGINA     ; CHECK IF MAXIMUM TIME OF 12 MILLI SECONDS IS OVER
                JNB     RCV_INPUT,BACK          ; WAIT FOR THE RECIVING PULSE
                CLR     TR1                     ; STOP DISTANCE MEASUREMENT TIMER
                DEC     R7
        BACKB:
                MOV     TH0,#0FFh
                MOV     TL0,#0E5h               ; CONFIGURE DOWN COUNTER FOR 25 MICRO SEC
                SETB    TR0                     ; START COUNT DOWN TIMER
                CLR     TIMER_0_FLAG
        BACKA:
                JB     TIMER_0_FLAG,BEGIN       ; CHECK IF 25 MICRO SECONDS IS OVER OR NOT
                JNB     RCV_INPUT,BACKA         ; WAIT FOR THE RECIVING PULSE
                CLR     TR0
                DJNZ    R7,BACKB
                LCALL   PROCESS
                JB      FIRSTFLG,UPDATE
                LCALL   DISPLAY_LCD2             ; DISPLAY THE TME IN HEX
                SETB    FIRSTFLG
                SJMP    CONTINUE
```

```
             UPDATE:
                        LCALL   UPDATE_DATA
          CONTINUE:
                        LCALL   DELAY_1_SEC             ; WAIT FOR ONE SECOND
                        SJMP    BEGIN
            BEGINA:
                        LCALL   NO_PULSE_RCVD
                        CLR     FIRSTFLG
                        LJMP    BEGIN

;**************************************************************************************************
;               THE PROGRAM ENDS HERE
;**************************************************************************************************
        PROCESS:
                        MOV     R0,TH1
                        MOV     R1,TL1
                        MOV     R2,#0D0h
                        MOV     R3,#0A6h
                        LCALL   SUBTRACT
                        LCALL   DIVI
                        MOV     R2,#01h
                        MOV     R3,#4Ah
                        LCALL   MUL_16BIT
                        MOV     A,R5
                        MOV     DIG3,A
                        MOV     A,R6
                        MOV     DIG2,A
                        MOV     A,R7
                        MOV     DIG1,A
                        LCALL   HEX2DEC
                        LCALL   CONV_2_ASCII       ; CONVERT THE CONTENTS OF THE TIMER TO ASCII
                        RET

;**************************************************************************************************
;               INTITIALIZATION ROUTINE
;**************************************************************************************************

INIT_INTR:
                        MOV     IE,#8Ah
                        MOV     TMOD,#11h       ; TIMER 0  IN 16 BIT TIMER MODE , TIMER 1  IN 16 BIT TIMER MODE
                        CLR     A
                        MOV     TH0,A
                        MOV     TL0,A
                        CLR     TR0
                        CLR     TR1
                        MOV     P1,#00H
                        MOV     P3,#02H
                        CLR     FIRSTFLG
                        RET

;**********************************************************************************************************************
;               DSIPLAY THE DISTANCE
;**********************************************************************************************************************

        DISPLAY_LCD2:
                        LCALL   CLEAR_LCD
                        MOV     DPTR,#LINE3
                        LCALL   LINE1_DATA
                        MOV     DPTR,#LINE4
                        MOV     COUNTER,#10h
                        MOV     R1,#BUFFER
                 LOOP3:
                        CLR     A
                        MOVC    A,@A+DPTR
                        MOV     @R1,A
                        INC     DPTR
                        INC     R1
                        DJNZ    COUNTER,LOOP3
                        LCALL   LOAD_DATA
                        LCALL   DATA_FRM_BUFFER
                        RET
```

```
;**********************************************************************************************************************
;                          DSIPLAY NO PULSE RECEIVED
;**********************************************************************************************************************

NO_PULSE_RCVD:
                                        LCALL   CLEAR_LCD
                                        MOV     DPTR,#NOPULSE
                                        LCALL   LINE1_DATA
                                        MOV     DPTR,#NOPULSEA
                                        LCALL   LINE2_DATA
                                        RET
;**********************************************************************************************************************
;   LCD TEST    - THIS ROUTINE IS USED FOR TESTING THE LCD. THE FUNCTIONS
;    FOLLOWING THE ROUTINE ARE SUBROUTINES USED IN THE LED TESTING ROUTINES
;**********************************************************************************************************************

DISPLAY_LCD:
                                        LCALL   LCD_INIT
                                        LCALL   CLEAR_LCD
                                        MOV             DPTR,#LINE1
                                        LCALL   LINE1_DATA
                                        MOV             DPTR,#LINE2
                                        LCALL   LINE2_DATA
                                        RET

;**********************************************************************************************************************
;                PRINTING THE LINE 1 DATA
;**********************************************************************************************************************

 LINE1_DATA:
                                        MOV     COUNTER,#10h
   ALL_DATA:
                                        CLR     A
                                        MOVC    A,@A+DPTR
                                        INC     DPTR
                                        LCALL   DATAWRT
                                        DJNZ    COUNTER,ALL_DATA
                                        RET

;**********************************************************************************************************************
;                PRINTING THE LINE 2 DATA
;**********************************************************************************************************************

LINE2_DATA:
                                        MOV     A,#0C0h                         ; LINE 2 STARTS FROM C0h
                                        LCALL   COMNWRT
                                        MOV     COUNTER,#10h
             AL_DATA:
                                        CLR     A
                                        MOVC    A,@A+DPTR
                                        INC     DPTR
                                        LCALL   DATAWRT
                                        DJNZ    COUNTER,AL_DATA
                                        RET

;**********************************************************************************************************************
; WRITING THE DATA FROM THE BUFFER TO THE LCD'S SECOND LINE
;**********************************************************************************************************************

DATA_FRM_BUFFER:
                                        MOV     A,#0C0h                         ; LINE 2 STARTS FROM C0h
                                        LCALL   COMNWRT
                                        MOV     COUNTER,#10h
                                        MOV     R0,#BUFFER
              DATA_BUF:
                                        MOV     A,@R0
                                        LCALL   DATAWRT
                                        INC     R0
                                        DJNZ    COUNTER,DATA_BUF
                                        RET
```

```
;*****************************************************************************************************************************
; LOAD THE DATA FROM THE TIMER TO THE BUFFER
;*****************************************************************************************************************************

          LOAD_DATA:
                              MOV     A,#OFFSET
                              MOV     R0,#BUFFER
                              ADD     A,R0
                              MOV     R0,A
                              MOV     A,SECOND_BYTE
                              MOV     @R0,A
                              INC     R0
                              MOV     A,THIRD_BYTE
                              MOV     @R0,A
                              INC     R0
                              MOV     A,FOURTH_BYTE
                              MOV     @R0,A
                              INC     R0
                              MOV     A,#'.'
                              MOV     @R0,A
                              INC     R0
                              MOV     A,FIFTH_BYTE
                              MOV     @R0,A
                              INC     R0
                              MOV     A,SIXTH_BYTE
                              MOV     @R0,A
                              INC     R0
                              MOV     A,SEVEN_BYTE
                              MOV     @R0,A
                              INC     R0
                              RET

;********************************************************
;                       CONVERT TO ASCII
;********************************************************

CONV_2_ASCII:
                              MOV     A,R0
                              ANL     A,#0Fh
                              MOV     DPTR,#ASCII
                              MOVC    A,@A+DPTR
                              MOV     FIRST_BYTE,A

                              MOV     A,R1
                              ANL     A,#0Fh
                              MOV     DPTR,#ASCII
                              MOVC    A,@A+DPTR
                              MOV     SECOND_BYTE,A

                              MOV     A,R2
                              ANL     A,#0Fh
                              MOV     DPTR,#ASCII
                              MOVC    A,@A+DPTR
                              MOV     THIRD_BYTE,A

                              MOV     A,R3
                              ANL     A,#0Fh
                              MOV     DPTR,#ASCII
                              MOVC    A,@A+DPTR
                              MOV     FOURTH_BYTE,A

                              MOV     A,R4
                              ANL     A,#0Fh
                              MOV     DPTR,#ASCII
                              MOVC    A,@A+DPTR
                              MOV     FIFTH_BYTE,A

                              MOV     A,R5
                              ANL     A,#0Fh
                              MOV     DPTR,#ASCII
                              MOVC    A,@A+DPTR
                              MOV     SIXTH_BYTE,A
```

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                        MOV     A,R6
                        ANL     A,#0Fh
                        MOV     DPTR,#ASCII
                        MOVC    A,@A+DPTR
                        MOV     SEVEN_BYTE,A

                        MOV     A,R7
                        ANL     A,#0Fh
                        MOV     DPTR,#ASCII
                        MOVC    A,@A+DPTR
                        MOV     EIGTH_BYTE,A
                        RET

;***************************************************************
;          INITIALIZATION ROUTINE FOR LCD
;***************************************************************
UPDATE_DATA:
                        MOV     A,#0C5h                 ; LINE 2 STARTS FROM C0h
                        LCALL   COMNWRT
                        MOV     A,SECOND_BYTE
                        LCALL   DATAWRT
                        MOV     A,THIRD_BYTE
                        LCALL   DATAWRT
                        MOV     A,FOURTH_BYTE
                        LCALL   DATAWRT
                        MOV     A,#'.'
                        LCALL   DATAWRT
                        MOV     A,FIFTH_BYTE
                        LCALL   DATAWRT
                        MOV     A,SIXTH_BYTE
                        LCALL   DATAWRT
                        MOV     A,SEVEN_BYTE
                        LCALL   DATAWRT
                        RET

;***************************************************************
;          INITIALIZATION ROUTINE FOR LCD
;***************************************************************

        LCD_INIT:
                        MOV     A,#38H
                        LCALL   COMNWRT
                        MOV     A,#0EH
                        LCALL   COMNWRT
                        MOV     A,#06H
                        LCALL   COMNWRT
                        RET

;***************************************************************
;           CLEARING THE LCD
;***************************************************************

        CLEAR_LCD:
                        CLR     RS
                        MOV     A,#01h
                        LCALL   ROTATE
                        MOV     LCD_DATA,A
                        SETB    EN
                        CLR     EN
                        LCALL   DELAY_25MS
                        RET

;***************************************************************
;  ROUTINE TO SEND DATA
;***************************************************************

        DATAWRT:
                        SETB    RS
                        LCALL   ROTATE
                        MOV     LCD_DATA,A
                        SETB    EN
                        CLR     EN
                        LCALL   DELAY_25MS
                        RET

;************************************************************
;  ROUTINE TO SEND COMMAND
;************************************************************

            COMNWRT:
                        CLR     RS
                        LCALL   ROTATE
                        MOV     LCD_DATA,A
                        SETB    EN
                        CLR     EN
                        LCALL   DELAY_25MS
                        RET

;************************************************************
;  ROUTINE TO ROTATE THE BITS
;************************************************************

            ROTATE:
                        MOV     ROTA_CNTER_A,A
                        MOV     A,ROTA_CNTER_A
                        MOV     C,ACC.7
                        MOV     A,ROTA_CNTER_B
                        MOV     ACC.0,C
                        MOV     ROTA_CNTER_B,A

                        MOV     A,ROTA_CNTER_A
                        MOV     C,ACC.6
                        MOV     A,ROTA_CNTER_B
                        MOV     ACC.1,C
                        MOV     ROTA_CNTER_B,A

                        MOV     A,ROTA_CNTER_A
                        MOV     C,ACC.5
                        MOV     A,ROTA_CNTER_B
                        MOV     ACC.2,C
                        MOV     ROTA_CNTER_B,A

                        MOV     A,ROTA_CNTER_A
                        MOV     C,ACC.4
                        MOV     A,ROTA_CNTER_B
                        MOV     ACC.3,C
                        MOV     ROTA_CNTER_B,A

                        MOV     A,ROTA_CNTER_A
                        MOV     C,ACC.3
                        MOV     A,ROTA_CNTER_B
                        MOV     ACC.4,C
                        MOV     ROTA_CNTER_B,A

                        MOV     A,ROTA_CNTER_A
                        MOV     C,ACC.2
                        MOV     A,ROTA_CNTER_B
                        MOV     ACC.5,C
                        MOV     ROTA_CNTER_B,A

                        MOV     A,ROTA_CNTER_A
                        MOV     C,ACC.1
                        MOV     A,ROTA_CNTER_B
                        MOV     ACC.6,C
                        MOV     ROTA_CNTER_B,A

                        MOV     A,ROTA_CNTER_A
                        MOV     C,ACC.0
                        MOV     A,ROTA_CNTER_B
                        MOV     ACC.7,C
                        MOV     ROTA_CNTER_B,A
                        RET
```

```
;*******************************************************
;                   SUBROUTINE FOR 1 SECOND DELAY
;*******************************************************

 DELAY_1_SEC:
                              MOV             R0,#10
          LOOP:
                              MOV             TH0,#3Ch
                              MOV             TL0,#0AFh
                              CLR             TIMER_0_FLAG
                              SETB    TR0
                              JNB             TIMER_0_FLAG,$
                              DJNZ    R0,LOOP
                              RET

;*******************************************************
;         SUBROUTINE FOR 2.5 MILLISECOND SECOND
;*******************************************************

DELAY_250MICRO_SEC:
                              MOV             TH0,#0FFh
                              MOV             TL0,#05h
                              CLR             TIMER_0_FLAG
                              SETB    TR0
                              JNB             TIMER_0_FLAG,$
                              RET

;*************************************************************
;         A DELAY OF 25 milliseconds
;*************************************************************

DELAY_25MS:
                              MOV     TH0,#1Eh
                              MOV     TL0,#57h
                              CLR     TIMER_0_FLAG
                              SETB    TR0
                              JNB     TIMER_0_FLAG,$
                              RET

;*******************************************************
;                   R2 R3 -
;                   R0 R1
;                   --------
;                   R0 R1
;*******************************************************

         SUBTRACT:
                              CLR     C
                              MOV     A,R1
                              SUBB    A,R3
                              MOV     R1,A
                              MOV     A,R0
                              SUBB    A,R2
                              MOV     R0,A
                              RET

;*********************************************************************************
;MSB->      R0 R1    DIVIDEND
;                R2    DIVISOR
;MSB->      R0 R1    RESULT
;*********************************************************************************
         DIVI:
                              CLR     C
                              MOV     A,R0
                              RRC     A
                              MOV     R0,A
                              MOV     A,R1
                              RR      A
                              MOV     ACC.7,C
                              MOV     R1,A
                              RET
```

```
;**************************************************************************************
;MSB->          R0 R1   MULTIPLICAND
;              R2 R3   MULTIPLIER
;MSB->  R4 R5 R6 R7   RESULT
;**************************************************************************************

MUL_16BIT:
                        CLR     A
                        MOV     R4,A
                        MOV     R5,A
                        MOV     R6,A
                        MOV     R7,A
                        CLR     C
                        MOV     A,R1
                        MOV     B,R3
                        MUL     AB
                        MOV     R7,A
                        MOV     R6,B

                        MOV     A,R0
                        MOV     B,R3
                        MUL     AB
                        ADD     A,R6
                        MOV     R6,A

                        MOV     A,B
                        ADDC    A,R5
                        MOV     R5,A

                        MOV     A,R1
                        MOV     B,R2
                        MUL     AB
                        ADD     A,R6
                        MOV     R6,A
                        MOV     A,B
                        ADDC    A,R5
                        MOV     R5,A

                        MOV     A,R0
                        MOV     B,R2
                        MUL     AB
                        ADDC    A,R5
                        MOV     R5,A

                        MOV     A,B
                        ADDC    A,R4
                        MOV     R4,A
                        RET




;**************************************************************************************
;               HEX TO DECIMAL CONVERSION ROUTINE
;                       DIG3            ;MSB
;                       DIG2
;                       DIG1            ;LSB
;               R0 R1 R2 R3 R4 R5 R6 R7   RESULT
;**************************************************************************************

HEX2DEC:
                MOV     R0,#00H         ; R7
                MOV     R1,#00H         ; R6
                MOV     R2,#00H         ; R5
                MOV     R3,#00H         ; R0
                MOV     R4,#00H         ; R1
                MOV    R5,#00H          ; R2
                MOV    R6,#00H          ; R3
                MOV    R7,#00H          ; R4
        FIRSTA:
                CLR     C
                MOV     A,DIG1
                SUBB    A,#0AH
                MOV     DIG1,A
                JC              OUT
        OUTB:
                INC     R6
                CJNE    R6,#0AH,FIRS
                MOV     R6,#00H
                INC     R5
                CJNE    R5,#0AH,FIRT
                MOV     R5,#00H
                INC     R4
                CJNE    R4,#0AH,FIRU
                MOV     R4,#00H
                INC     R3
                CJNE    R3,#0AH,FIRA
                MOV     R3,#00H
                INC     R2
                CJNE    R2,#0AH,FIRB
                MOV     R2,#00H
                INC     R1
                CJNE    R1,#0AH,FIRC
                MOV     R1,#00H
                INC     R0
                JMP     FIRST

        FIRST:
                LJMP    FIRSTA

        FIRS:
                JC      FIRST
                INC     R5
                CJNE    R5,#0AH,FIRT
                MOV     A,R6
                SUBB    A,#09H
                MOV     R6,A
                JMP     FIRST
        FIRT:
                JC      FIRST
                INC     R4
                CJNE    R4,#0AH,FIRU
                MOV     A,R5
                SUBB    A,#09H
                MOV     R5,A
                LJMP    FIRST
        FIRU:
                JC      FIRST
                INC     R3
                MOV     A,R4
                SUBB    A,#09H
                MOV     R4,A
                LJMP    FIRST

         FIRA:
                JC      FIRST
                INC     R2
                MOV     A,R3
                SUBB    A,#09H
                MOV     R3,A
                LJMP    FIRST

        FIRB:
                JC      FIRST
                INC     R1
                MOV     A,R2
                SUBB    A,#09H
                MOV     R2,A
                LJMP    FIRST

    FIRC:
                JC      FIRST
                INC     R0
                MOV     A,R1
                SUBB    A,#09H
                MOV     R1,A
                LJMP    FIRST

        OUTBA:
                LJMP    OUTB

         OUT:
                CLR     C
                MOV     A,DIG2
                SUBB    A,#01H
                MOV     DIG2,A
                JNC     OUTB

                CLR     C
                MOV     A,DIG3
                SUBB    A,#01H
                MOV     DIG3,A
                JNC     OUTBA

                MOV     A,DIG1
                ADD     A,#0AH
                MOV     R7,A
                RET

LINE1:          DB      ' Hi ALL   !!!!  '

LINE2:          DB      ' HAVE A GOOD DAY'

LINE3:          DB      ' Dist Measured  '

LINE4:          DB      '      .   cms    '

NOPULSE:        DB      '  NO PULSE      '

NOPULSEA:       DB      '  RECEIVED !!!  '

ASCII:          DB      '0123456789ABCDEF'

                   END
```