Local Positioning System using infrared and ultrasonic waves

Group No. D7

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Abstract

This project aims at building a local positioning system, using infrared and ultrasonic waves. The system has a set of four units mounted at the corners of the room and a mobile unit which is placed on the floor of the room. We aim at finding the co-ordinates of the mobile unit. The mobile unit consists of an ultrasonic receiver and an infrared transmitter. Each of the set of four units mounted on the wall consists of ultrasonic transmitter and an infrared receiver. Infrared waves transmitted by the mobile unit are used to trigger the corresponding unit mounted on the wall, and then the ultrasonic transmitter of the mounted unit sends an ultrasonic signal back to the mobile unit, which is used to calculate the distance. The mobile unit calculates the time taken to receive the ultrasonic signal and the time delay in the circuit, and calculates the distance accordingly.

1. Introduction

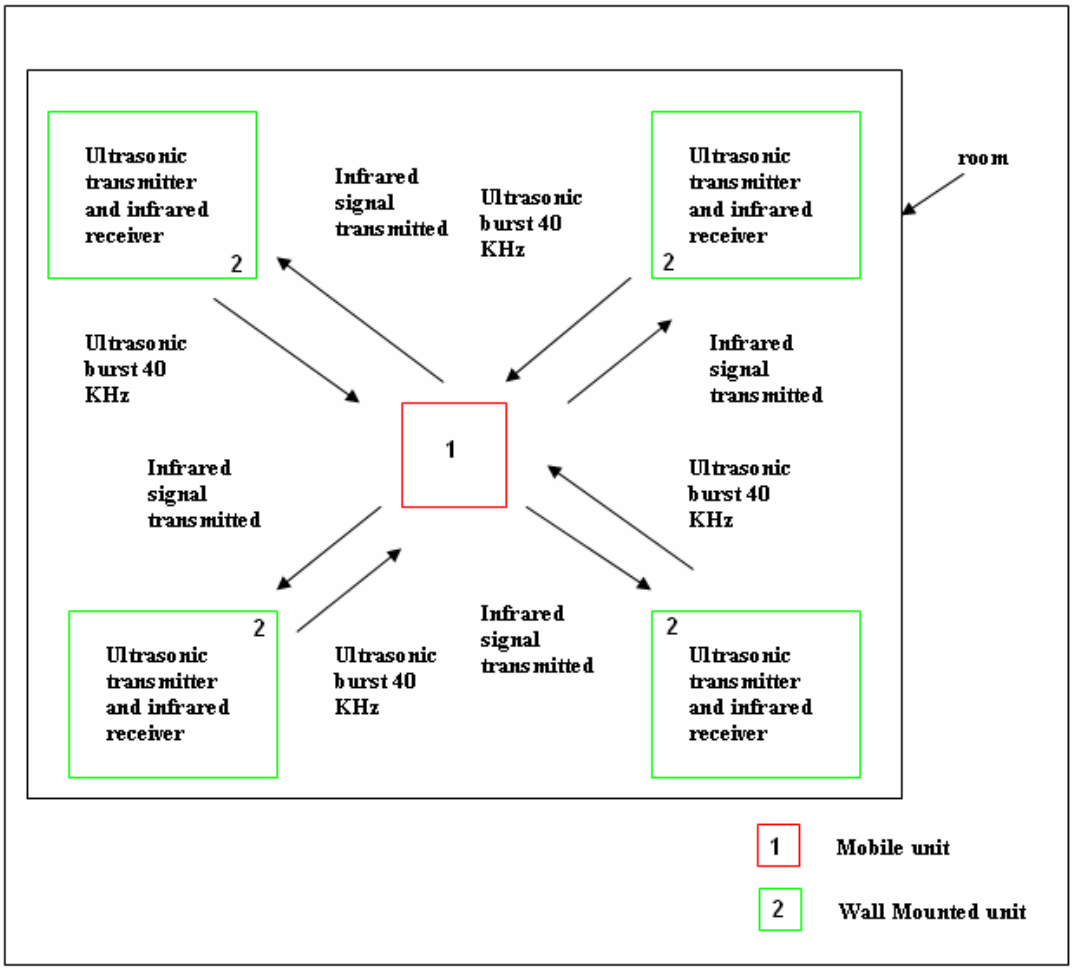

Fig 1: Local Positioning System

The above figure shows the setup of a local positioning system in a room. It consists of a mobile unit and four wall mounted units. The mobile unit sends an address over infrared wave in all directions and the wall mounted units receive this address and compares it with its specific address, if there is a match then that specific wall mounted unit sends an ultrasonic burst to the mobile unit. The mobile unit uses the timing of the infrared signal sent and the ultrasonic signal received to measure the total time delay, this delay is used to measure the distance between the mobile unit and the wall mounted unit.

The Block Diagram below shows signal transmission and detection between the mobile unit and any one of the wall mounted units.

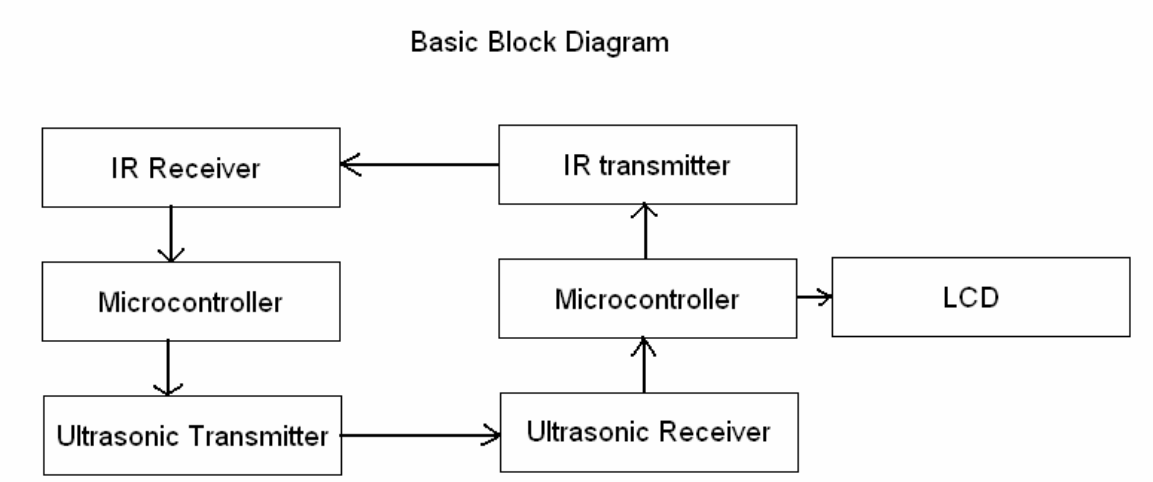

Fig 2: Basic Block Diagram

Infrared transmitter: The address code corresponding to anyone of wall mounted unit is transmitted over infrared waves. The infrared wave should be transmitted in all directions so as to not have any dark areas.

Infrared receiver: Each wall mounted unit has an infrared receiver, the output of which is connected to the microcontroller. The microcontroller detects whether or not the address code transmitted over the infrared wave matches with the code corresponding to that wall mounted unit. In case of a match, the microcontroller sends a trigger signal to the ultrasonic transmitter.

Ultrasonic transmitter: Sends an ultrasonic wave back to the mobile unit.

Ultrasonic receiver: Placed on the mobile unit, it receives the signal from the corresponding wall mounted unit and this reception is used to calculate the distance between the wall mounted unit and the mobile unit.

2. Infrared Transmitter

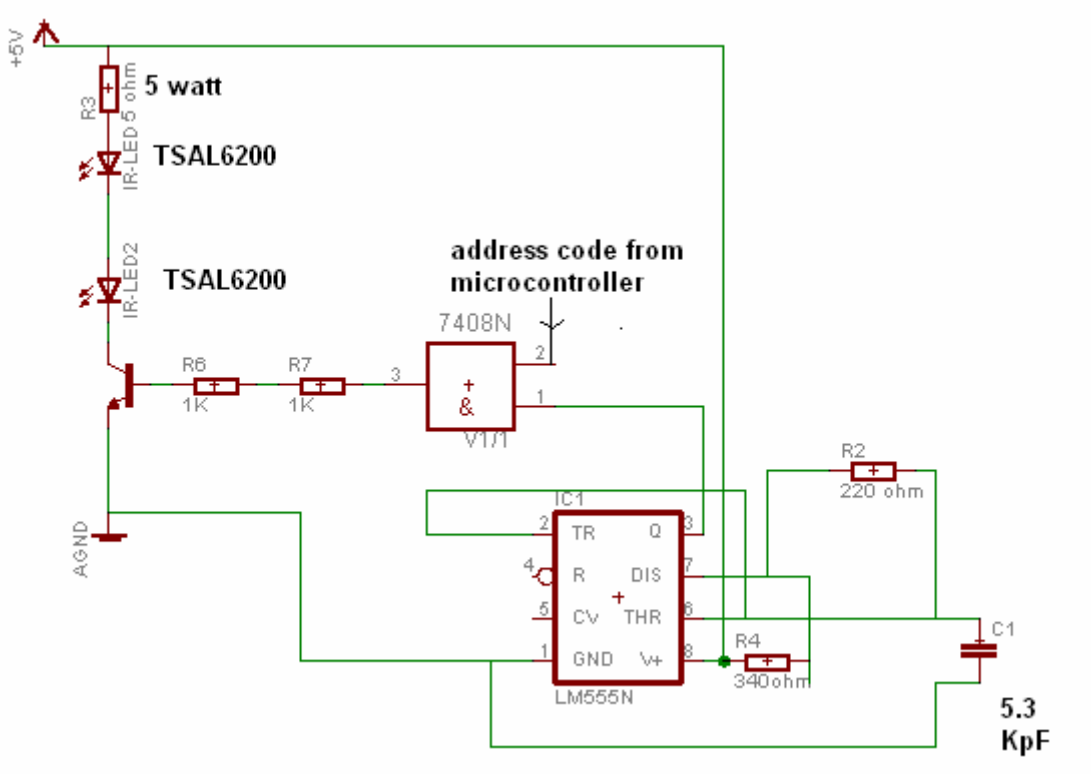

Fig 3: Infrared Transmitter

The infrared signal generated by the infrared led is modulated by 56 KHz square wave produced by a 555 timer. The reason for the modulation of the infrared signal is to remove the detection of stray infrared signals produced by nearby external sources. The 56 KHz signal from the 555 timer is ANDed (using 7408) with the address code generated by the microcontroller. This is done so to transmit the address code over the infrared wave.

4. Infrared receiver

The infrared receiver that we used is TSOP 1356 which detects infrared waves modulated at 56KHz only. This detector gives a high output voltage (+ 5 volts) when no infrared wave is detected and gives a low output voltage (0 volts) when an infrared wave is detected. Hence we invert the output of this receiver before feeding it to the microcontroller of the wall mounted unit, which uses this signal to decide whether or not to send the ultrasonic signal. The circuit for the infrared receiver is given below.

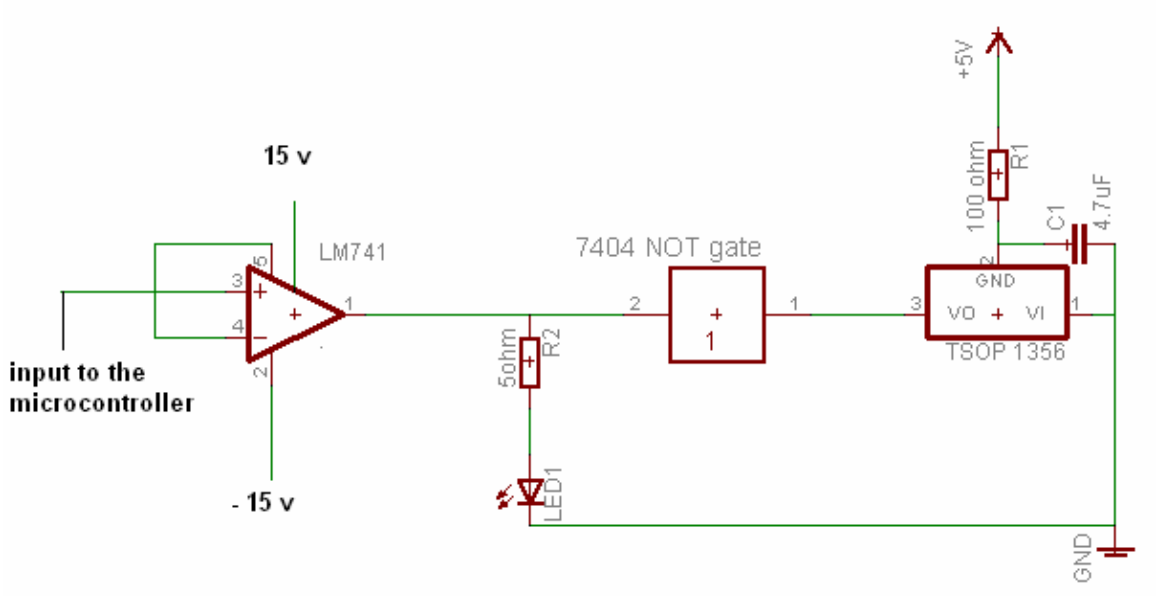

Fig 4: Infrared Receiver

5. Ultrasonic Transmitter

The ultrasonic signal is transmitted at 40 KHz since the signal to noise ratio is large at 40 KHz.
A LM555 timer is used to generate a 40 KHz square wave. During experiments it was observed that the gain of the ultrasonic receiver remains same even when the ultrasonic transmitter is excited with a square wave, triangular wave or a sine wave.
During experiments the ultrasonic transmitter was getting excited by 40 KHz harmonics. To remove this we have used a capacitor 330nF in parallel with the ultrasonic transmitter (and across the output of 555 timer) so as to pass 40 KHz signal and to remove higher harmonics. The ultrasonic transmitter circuit is given below

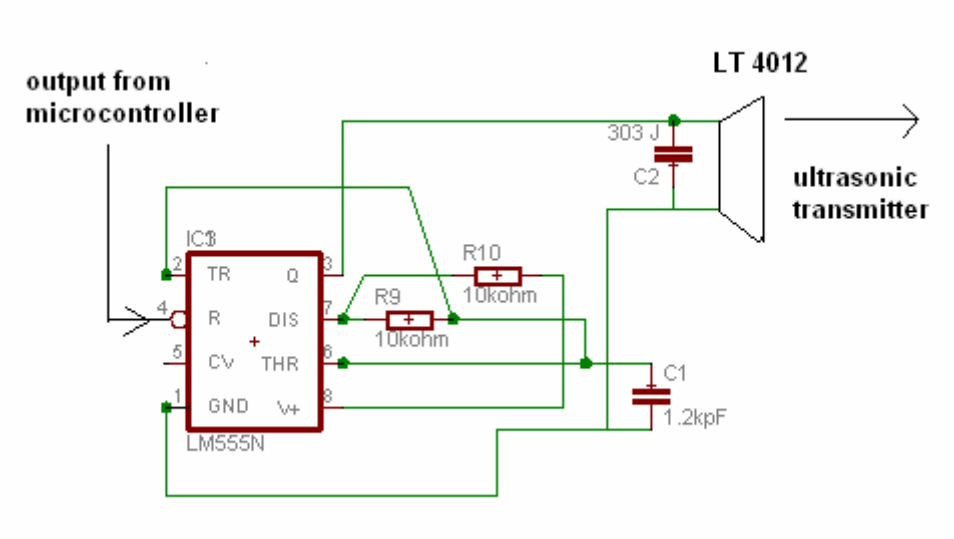

Fig 5: Ultrasonic Transmitter

6. Ultrasonic receiver

The ultrasonic receiver receives the ultrasonic signal only at 40 KHz. This received signal is very feeble (80mv peak to peak); hence it needs to be amplified by a high frequency amplifier.

The signal received is passed through a voltage follower, and then is amplified by using LF 356 high frequency operational amplifier. LM 741 is not used here for amplification because its open loop gain is not very high at 40 KHz. A resistor matching with the impedance of the ultrasonic receiver is put across the receiver, as voltage follower has high input impedance.

The LF 356 amplifiers are connected in non-inverting configuration. A High pass circuit (RC circuit) is used after the operational amplifiers so as to remove DC offset voltage at the output. The amplified AC signal is then passed through a diode for rectification and then is passed through a RC circuit for converting the signal to DC. This DC signal is fed into the LM 339 comparator which gives a positive high voltage (+15v) if the input signal is greater than the threshold voltage(1.1v), and gives a negative low voltage (-15v) if the input signal is less than the threshold voltage. The threshold voltage is set so to remove the amplified noise caught by the ultrasonic receiver.

This output voltage is then converted to 5v for high signal and 0v for low signal, so that it could be fed as an input to the microcontroller. This is done by passing the signal through a voltage follower (impedance matching) and then through a diode (so that negative low voltage of the comparator does not pass) followed by a voltage divider. The Voltage divider is used so that the output of the voltage divider is 5V when the output of the comparator is 15 volts.

The detailed circuit is given below.

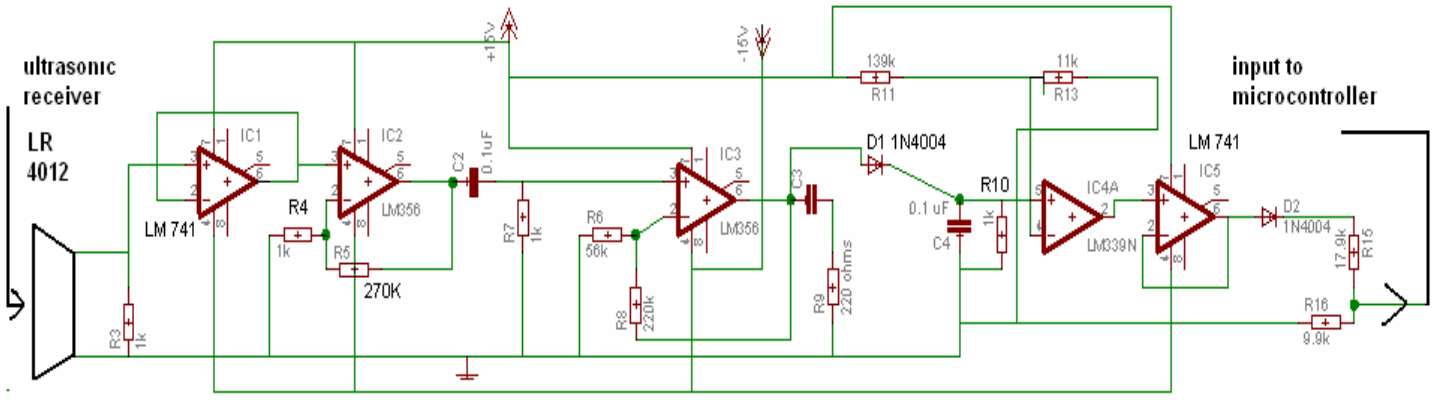

Fig 6: Ultrasonic receiver

6 Microcontrollers

6.1 Microcontroller on the mobile unit

This microcontroller is used to send an address code corresponding to a particular mounted wall unit over infrared wave. The output port pin at which this code is sent is connected to the input of the AND gate whose other input is the 56 KHz infrared wave modulating signal from LM555 timer.

Then the microcontroller starts a counter as soon as the code is transmitted. The output of the ultrasonic receiver module (on the mobile unit) is connected to an input port of the microcontroller. The microcontroller stops the counter as soon as it detects logic one at this input port. The time taken in the counter is calculated and is used to measure the distance of between the central mobile station and that particular mounted wall unit.

6.2 Microcontroller on the wall mounted unit

The output of the infrared signal receiver is given as input to the microcontroller. The microcontroller matches the address code sent over the infrared wave with its signature address code, if a match is found then its sets the output to the ultrasonic transmitter as logic one, otherwise sets it as zero. This output is connected to pin 4 of the LM555 timer in the ultrasonic transmitter circuit, and is used to gate the ultrasonic signal. Only when the pin 4 of the 555 timer is high, a 40 KHz square wave is generated to drive the ultrasonic transmitter.

6.3 Software description

There are 2 micro controllers (AT89c2051)

1. **Transmitter**: which sends code and the calculates distance
2. **Receiver**: which receives the code checks it and sends back an ultrasonic burst

Here we are using Serial Port (baud rate=1.2Kb/s) for transmitting the code as IR signal and normal I/O is employed for ultrasonic transmission. Looping is done for continuous measurements.

Algorithm

1. Transmitter:

Start: Initializes all the required registers/ports
Serial port mode1/Timer1 mode2 (TH1=E6h)
P3.1 (serial port transmitter) to Infrared transmitter
P3.2 to Ultrasonic receiver (initialized=1)

Restart: Initializing Timer0 registers to 0 (counting time in microseconds)
Sends code (99h here) and waits for serial transmitter to send its data
Waits for a falling edge at P3.2 OR Timer0 Interrupt (waited for 65535 µsec)
If Timer interrupts then go back to 'Restart'
If P3.2=1 (burst yet not received) loop to itself

Calculations: Distance = (calculated time - pre-fed delay) * speed of ultrasonic in air
Where speed = 343µm/µsec at room temperature
Divide by 1000 to get result in mm
Distance converted into BCD for display

Display: LCD display code
Delay of 10secs and go back to restart for next calculations

2. Receiver

Start: Initializing the ports/registers
P3.0 (serial port receiver) to Infrared receiver
P3.3 to Ultrasonic transmitter (initialized=1)

Restart: Wait for receiver to receive code

If not the code corresponding to that particular receiver goto ‘Restart’

Else clear P3.3 (for 2 msec)

Goto ‘Restart’

The total numbers of power sources used in the circuit were as follows:

Mobile unit

One DC supply 15 volts {for LM741, LM356, LM339}

One DC supply -15 volts {for LM741, LM356, LM339}

One DC supply 5 volts {for AT89C2051, 7408, LM555}

Wall mounted unit

One DC supply 15 volts {for LM741}

One DC supply -15 volts {for LM741}

One DC supply 5 volts {for AT89C2051, TSOP1356, 7404, LM 555}

COMPONENTS USED:

1. LM 555 Timer
2. TSOP 1356 IR Receiver
3. TSAL 6200 IR Transmitter
4. LM 339 Voltage Comparator
5. Ultrasonic Transmitter LT 4012
6. Ultrasonic receiver LR 4012
7. Microcontroller

7 Conclusions

1. The infrared signal is transmitted and received at a distance of 17m.
2. Half power beam width of infrared LED *TSAL 6200*: ±17 degrees.
3. The ultrasonic signal is transmitted and successfully detected at a distance of 9m.
4. Ultrasonic transmitter LT4012 and receiver LR4012 have a half power beam width of ±45 degrees.
5. The code to find the time delay for a single loop and infinite loop has been tested separately and is working. Time delay of the signal sent and received between the mobile unit and the wall mounted unit has been measured in one dimension, but has an error of about 5%. Time delay of the signal sent and received has been demonstrated to be increasing with increasing distance.
6. The PCB for the whole circuit has been fabricated and soldered. The hardware part i.e. ultrasonic transmitter, ultrasonic receiver, infrared transmitter and infrared receiver circuits are working.

8 Future work

The circuit can be used to measure distances in one dimension. By making the infrared signal omni directional (i.e. by putting infrared LEDs along the circumference of a circle pointing radially outwards) we can use the same circuit for measuring distances in two dimensions. This can be used to find the co-ordinates of the mobile unit with respect to the wall mounted units.

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