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# Wireless Non-Line-Of-Sight Electronic Automation Using Sonar Based Gesture Detection For Human Machine Interaction

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**Abstract**

In a world where wireless is not just a technology but a trendsetter, imagine how lives would change if only one can control electronic appliances with just a flick of the finger or wave of a hand. The primary objective of the proposed idea is to wirelessly control home appliances with simple hand movements or gestures by overcoming the line of sight constraint. In this, a pair of RF transmitter and receiver coupled with ultrasonic detectors for gesture recognition is used. A control unit integrated with the receiver is used to actuate the electronic appliance depending on the gesture recorded. With the presented interface, users can control appliances like TV, fan, lightings, air conditioners and thermostats. This technology is devoid of privacy issues as in the case of cameras that use image processing and also proves to be much more cost efficient than existing system.

**Keywords:** Wireless Control, Ultrasonic Detector, Gesture Recognition, Non-Line-of-Sight, RF Transmitter, RF Receiver, Human Machine Interaction

## Introduction

Today, there is an abundant need for technology that is able to control other electronic appliances wirelessly under Non-Line of Sight (NLOS) conditions. This surge in need is especially to satisfy the needs of physically and visually disabled people. Such Human Computer Interaction can be based on simple gestures made by the hand and thus giving more operational ease and flexibility to the old and disabled [1]. In many ways a gesture based recognition system is far more intuitive, intelligent and robust than the conventional switches, touchscreens or remote control devices.

The works being carried out in this field can be classified broadly as: Inertial sensor based and other is vision based approach [2]. The vision based approach involves the use of cameras to capture the gestures from colours, position, orientations, shapes and motion features of hand or body [3]. The drawback with the vision based approach is it's over sensitivity to noise, cluttered backgrounds and unfavourable lighting conditions. Therefore, the inertial sensor based approach which makes use of position tracking of the hand is adopted [4]. Furthermore this approach is very sensitive and can be implemented with simple hardware and eliminates the need for complex computational algorithms.

**Comparison with existing systems**

While the concept of controlling wirelessly with mere gestures might sound baffling, there are quite a few feasible techniques being used already as an integral part of our life. The most rudimentary of the Human Machine Interaction (HMI) technology is the wired glove (Data Glove or Cyber Glove). The wired glove uses a combination of sensors like the magnetic tracking device or an inertial sensing device which measures the angle of rotation, bends and orientation. Simple gestures like the flipping of hand or bending of a finger can be interpreted using the data glove [5]. Due to its huge cost and not being completely wireless its usage was restricted, hence the product was not adopted widely.

The next prominent innovation is the depth-aware cameras, which use specialized time-of-flight (TOF) to create a depth image for gesture recognition [6][7]. This camera determines the distance between the camera and the object under test by using the time taken by a light signal from the moving object. This helps in creating a depth image which can be further analysed to predict the gesture. Furthermore, if two cameras are used then the relative property can be used to detect the direct motion, thus increasing the usability. The TOF cameras comprise of an illumination unit, optical sensors, image sensors, driver electronics and computational interface [8]. The need for high dynamic range of CMOS technology to avoid the interference effects of background lighting, then the interference due to operation of multiple TOF cameras simultaneously and presence of multiple reflections, make depth-aware TOF cameras less efficient [9].

Control-based HMI technology emerged during the end of last decade. The most popular example of one such device would be the Nintendo Wii Remote [10]. The primary requirement in this form of interaction with machine is a remote/wireless using which gestures can be performed that are later captured by software and interpreted accordingly. They use MEMS accelerometers, gyroscopes and other sensors to convert gestures into appropriate cursor movement [11]. Though this emerged as a huge success in the electronics consumer market, the constant need for a device to make the gestures makes it less flexible.

The various disadvantages posed by the existing systems described above can be overcome in the proposed idea of HMI using ultrasonic sensors which eliminate the need for any hand held device or the use of any cameras that depend on mammoth computational algorithms. In addition to them, the HMI through the technology discussed in this paper will be completely wireless and use minimal hardware to perform the most optimum functions, therefore making it much cost effective than existing models.

### Overview

Establishing a wireless NLOS connection for HMI using gesture control is the primary objective. Keeping that in view it should be ensured that in the particular case of home automation which is the primary focus here, the controller should be able to receive gesture commands from any part of the house without any interruption to its signal.

The components that are used in building our system includes an ultrasonic sensor (HC SR04), 433 MHz transmitter and receiver module, Arduino Uno Kit, Encoder (HT12E), Decoder (HT12D) and Electronic relay switch. The ultrasonic sensor detects the motion of the hand which is encrypted by an indigenous algorithm in the Arduino kit. The encoder converts the parallel data from microcontroller to serial format and feeds it to the ASK transmitter. The receiver does the serial to parallel conversion using a decoder and drives the relays to control the required appliance.

## DESIGN

### Block Schematic Representation

The architecture of the system is described in Figure 1.The system receives the real time user gesture via two HC SR04 ultrasonic sensors. These sensors provide the time taken between the transmission of trigger signal and the reception of the echo signal.

The output of the sensors is provided to the Arduino UNO R3 compatible board which has a function written along with the code to generate the control bits, which estimates the distance based on the time duration given by the sensors. The Arduino board recognizes the user's gesture and generates a four bit control code accordingly as per the program burned on to the ATMega328P. This four bit control code is fed to HT12E encoder module.

The encoder considers the four control bits as the DATA along with an 8 bit address set by DIP switch. These bits are encoded into serial data which is fed to the 433MHz ASK transmitter. The RF 433 MHz transmitter sends this serial data to the 433 MHz ASK receiver, this serial data is given to the HT12D decoder which has the same address bit as that of the HT12E. The HT12D converts the serial data into four bit control code

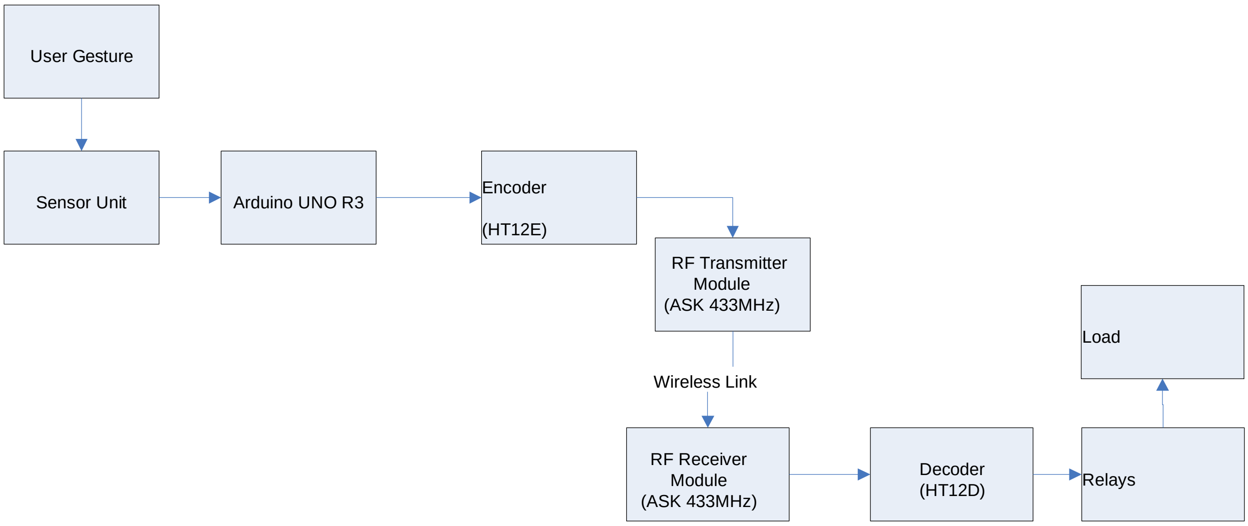


Fig 1. Block Schematic Representation

which is set by the Arduino board on the detector side. This 4 bit control code cannot be used to drive the 12V relays directly and hence they are fed through a relay driver ULN2003A.

## Design of Power Supply

The schematic in figure 2 shows the design of the power supply unit. The design is same for both the detector and control unit, the only difference being is the transformer used. For the detector the transformer used is 12-0-12V 1A unit whereas for control unit it is rated as 12-0-12V 750mA.

The AC voltage is stepped down by using the transformer. Since a center tapped transformer is used, two diodes are enough to rectify the AC output of the transformer to DC. Rectified output comprises of ripples, In order to reduce this a capacitor of about 1000µF with voltage rating of 24V is used.

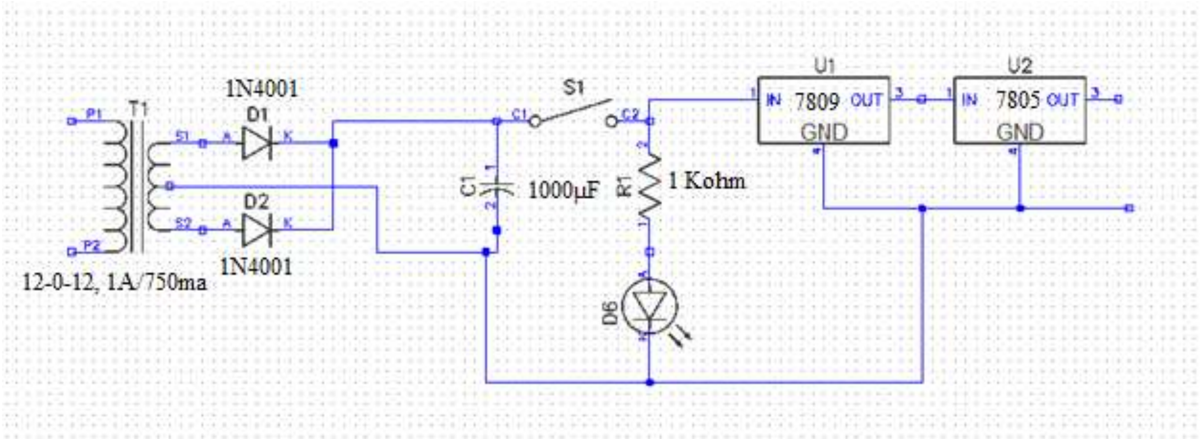


Fig 2. Regulated Power supply using IC 7809 and IC 7805

The filtered DC output is 12V, The Range of power supply to the Arduino UNO board should be 7-12 V thus the 12V DC is reduced and regulated by using a linear voltage regulator IC7809. The 9V regulated DC is supplied to the Arduino UNO, for rest of the circuitry the 5V regulated DC voltage is obtained by using IC 7805 [12][13].

**Design of Sensor Unit**

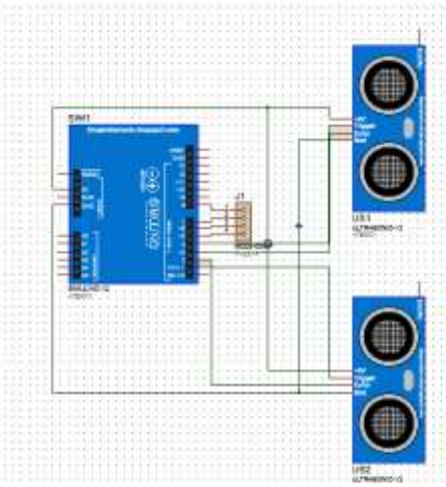

Fig 3. Interface of ultrasonic sensor HC SR04 with Arduino Uno.

An HC SR04 ultrasonic sensor is used to measure the distance to an object using SONAR like bats and dolphins. It has an operational rage between 2cm and 400cm, further it is not affected by sunlight or black materials [14].

The sensor comes in a compact package of dimensions 45mm x 20mm x 15mm with a power supply requirement of 5V DC. It also has a measuring angle of 30°. It is a four pin chip, with each chip assigned for Power supply (VCC), Trigger input for sensor (TRIG), Echo output of sensor (ECHO) and Ground (GND).The VCC pin along with the GND is used to provide the 5V supply to the sensor. The trigger pin is used to transmit a signal in ultrasonic frequency. The echo pin is used to receive the reflected signal from the obstacle.

To measure the distance, the TRIG pin must receive a pulse of high (5V) for 10µs, this initiates the sensor to send out an 8 cycle ultrasonic burst at 40 kHz frequency and wait for the reflected pulse. As soon as the reflected pulse is detected, the ECHO pin is set to high (5V) for a delay period. This delay is measured in microseconds and is used to calculate the distance between the transmitter and detector.The 5V and GND pins are taken from the Arduino board to provide 5V and GND to both the sensors.

For the same purpose two pins that are configured as the outputs are given to the trigger pins of the sensors. Suitable coding is written on the Arduino memory to produce a square pulse which would act as a trigger input. Two other pins of the Arduino are defined as the input and are connected with the echo pin of the sensors.

Suitable coding is provided to calculate the distance from the time duration given by the sensors [15].

Time = Width of the Echo Pulse in µs.

Distance in centimetres = Time/58.

Range = (High Level Time x 340 $ms^{-1}$)/2

Where 340$ms^{-1}$ is the velocity of sound.

**Design of Transmitter Circuit**

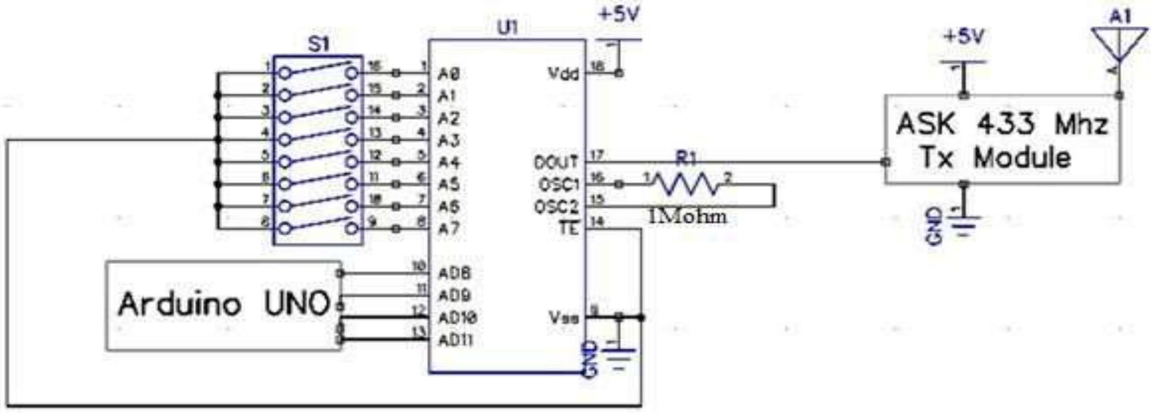


Fig 4. Interface of 433 MHz ASK Transmitter and HT12E Encoder with Arduino Uno.

To establish communication between the transmitter unit and detector unit we use RF modules which establish communication link at 433MHz. The transmitter circuit shown above obtains the control code from the Arduino board encodes it into a serial data which is then provided to the ASK 433 MHz transmitter module.^^
Four pins of the Arduino board are configured as output. These four pins are programmed in such a way so as to provide various control codes for various user gestures. The encoder HT12E is provided with a 5V bias. The pins 1-8 acts as address bit which is preset by using DIP switch (For multiple receiver few address bits are made programmable). To activate the IC, TE pin is made low. Pins 15 and16 are connected to a 1MOhm resistor thereby activating the internal oscillator. The Data OUT pin is connected to the ASK 433 MHz Transmitter module.

**Design of Receiver Circuit**

The receiver circuit schematic in Figure 5 shows biasing of HT12D decoder IC with the same address as that of the transmitter circuit set by the DIP switch. ASK receiver module obtains the serial data sent by the transmitter module. The serial data is decoded into four bit control code which is then sent to the relay board. The internal oscillator is activated by connecting a resistor between pins 15 and 16. VT pin is connected to the ground. The serial data from the ASK receiver module is connected to Data IN of the decoder IC.

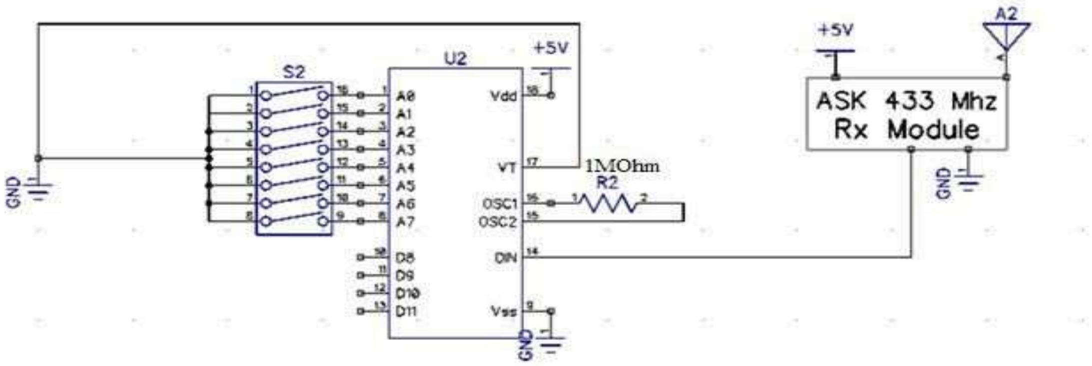


Fig 5. Interface of 433 Mhz ASK Receiver and HT12D Decoder with Arduino Uno.

**Design of Relay Board**

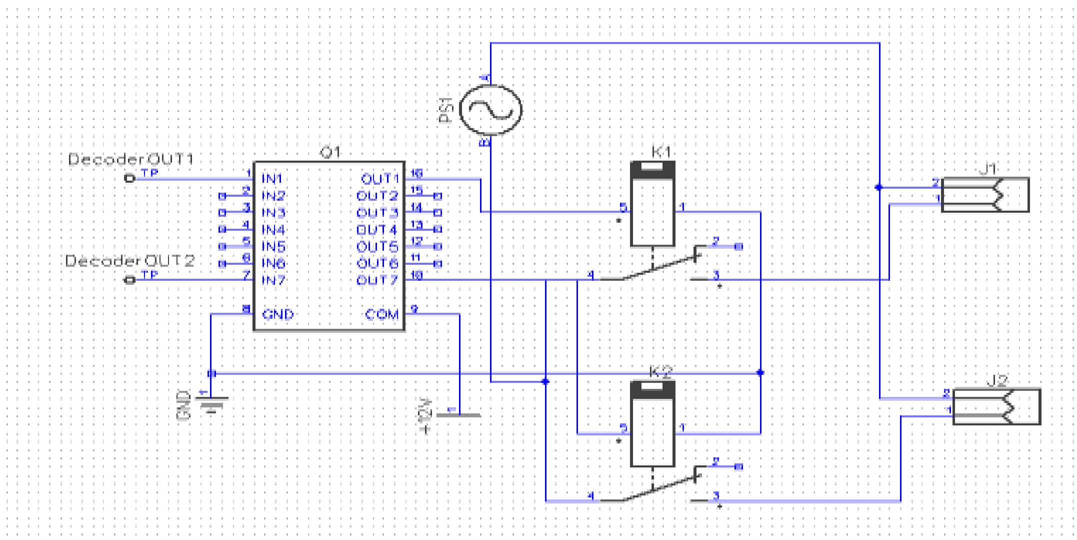


Fig 6.Layout of Typical Relay and Relay Driver ULN2003A.

ULN2003A requires 12V DC voltage and thus the supply is taken directly from the input pin of IC7809.
The Load is connected to N-O (Normally Open) pin of the relays. The central pin of the relay is supplied with 230V AC which is given by directly connecting the phase line from the input of the transformer. The Neutral line is given as common to both the load sockets [16].

**Software Design**

The Prototype of the system is designed in such a way that based on the user's hand on four different zones, four different codes of control are generated by the Arduino board. However these four zones can be used more efficiently and more gestures can be programmed.

Addition of another sensor increases the number of gestures that can be used to operate the appliances connected to the system. Mapping of gestures to a control code is the next step, each gesture should control the appliance is a different manner. The Table 1 illustrates the control

**Table 1: Software Control**

| Gesture | Appliance 1 | Appliance 2 | Control Code |
|---|---|---|---|
| Up | ON | ON | 1111 |
| Down | OFF | OFF | 0000 |
| Left | ON | OFF | 1010 |
| Right | OFF | ON | 0101 |

The flowchart in figure 7 explains the sample algorithm which is used to demonstrate the capability of the system to detect four gestures of the user and to generate four control codes exclusively for each gesture.

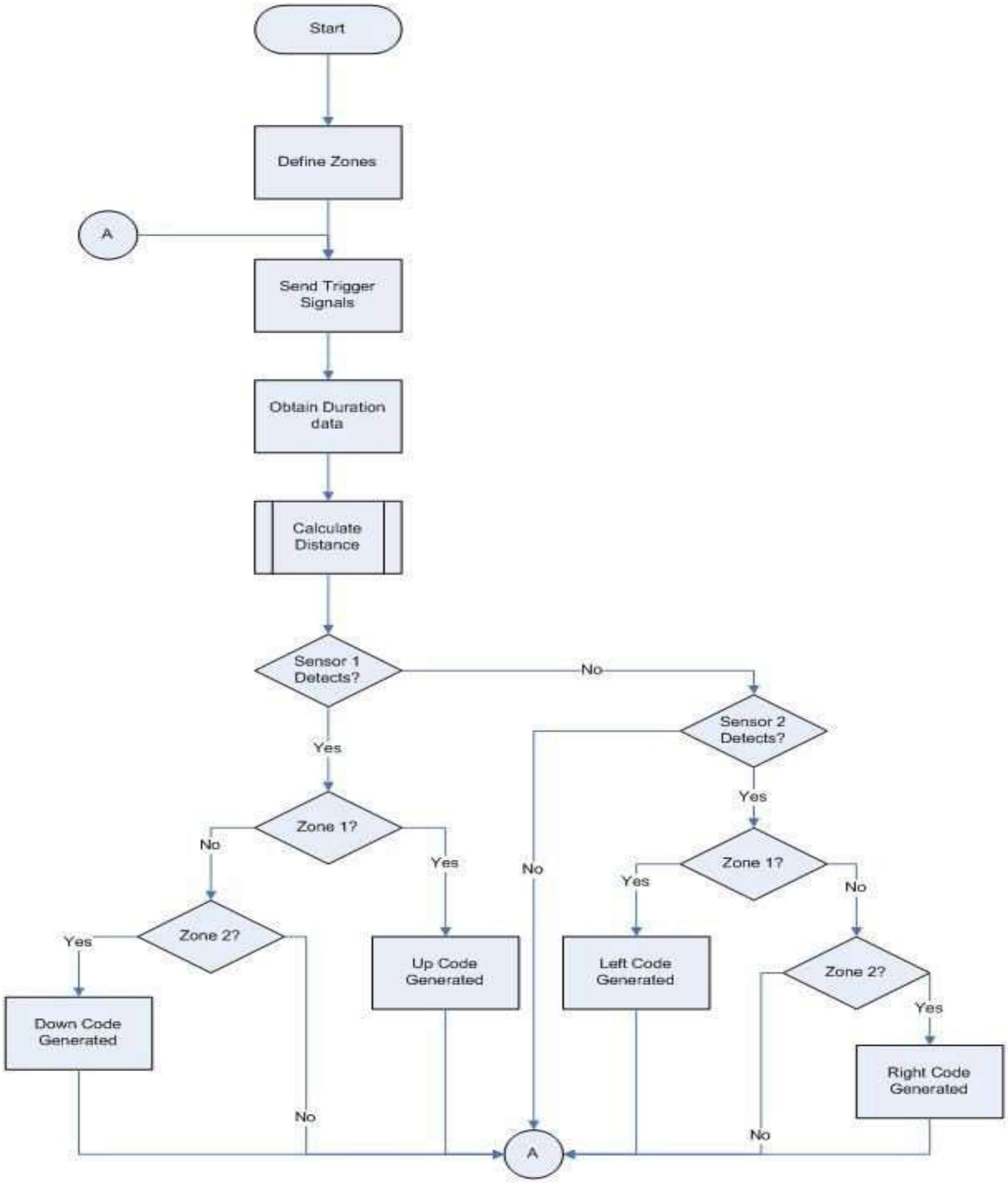


Fig 7.Flowchart for Software Process.

## Working Implementation

The ultrasonic sensors used, take into consideration the time delay to calculate the distance of the object. To get the desired results in the proposed project, two ultrasonic sensors are used to capture four different gestures.

The coding is done in such a way that the range of the ultrasonic sensor is divided into two regions. The range 0-25cm is the first region and the range 25-50cm is the second region with 50cm being the maximum boundary of the region covered by the sensor. If

the hand of the user is in the first region of sensor 1 then both the lines should be switched OFF. If the hand is in the second region then both the lines are switched ON. If the hand is in the region one of sensor 2 then one line should be switched ON and the other should switched OFF. Whereas if the hand is in the region two of sensor 2 then the previously ON line should be switched OFF and the OFF line should be switched ON.
Considering the required pattern of function, the Arduino is programmed. As per the input received by the Arduino board from the ECHO pins, the corresponding control bits are generated and the appliance is controlled wirelessly.

## Conclusion

The proposed idea of controlling a remote appliance wirelessly under Non-Line of Sight condition was successfully accomplished with supportive proof. The designed system is robust and will work effectively with clear distinctions between various gestures. Therefore the developed prototype is a novel way of controlling appliances without the need for any tangible media in between the user and device.

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