HUMAN AND OBJECT DETECTION BEHIND WALLS

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Abstract

The development of a human and object detection system behind walls using an Arduino Nano and microwave sensors. The system leverages the principles of Doppler radar, where microwave signals are emitted by the sensor and reflected back from objects or humans. By analyzing the frequency shift in the reflected signals, the presence, movement, and distance of hidden objects or people can be detected. The Arduino Nano processes the signals in real time, filtering out noise and interpreting the data to distinguish between human and non-human objects based on movement patterns and signal strength. The project aims to create a compact, low-cost, and efficient detection system suitable for applications in surveillance, search-and-rescue operations, or security systems. With the use of microwave sensors, the system can detect motion through walls, making it an effective tool for environments where visual detection is not feasible. The project focuses on optimizing accuracy and minimizing false positives to improve the system's reliability in real-world scenarios. The system is designed to be portable and easy to implement, using the small form factor of the Arduino Nano. It

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offers real-time feedback through visual indicators, such as LEDs or a display, to alert users to detected motion. By optimizing the sensor's sensitivity and signal processing, the project ensures reliable detection of human movement and objects behind walls, with minimal interference or false readings. This solution provides an affordable and effective method for applications in security, emergency response, and other critical environments.

1 Introduction

The detection of humans and objects behind walls has become an essential area of research with applications in disaster response, military operations, building surveillance, and home security systems. Traditional technologies, such as optical cameras and infrared sensors, are limited by their inability to penetrate solid barriers. This challenge has spurred interest in advanced detection techniques utilizing radio frequency (RF) waves, ultrasonics, or Wi-Fi signals, which can pass through walls and other non-metallic obstacles. This project aims to design a system capable of identifying and locating objects or humans behind walls using non-invasive methods.By capturing reflected signals and analyzing them through signal processing and machine learning algorithms, the system can provide insights about the presence, movement, and even size of the target. The primary goal is to develop a portable, low-cost solution that maintains accuracy and reliability while addressing challenges like signal attenuation and noise. This mini-project serves as a foundation for future innovations in wall-penetration technology, bridging the gap between theoretical research and practical applications

2 Project Requirements

To implement human and object detection behind walls using a microwave sensor, the project requires a microwave sensor module such as HB100, RCWL-0516, or Xethru X4, along with

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a microcontroller like Arduino, ESP32, or Raspberry Pi for data processing. A power supply, such as a battery or adapter, is needed to operate the system. The experiment will involve placing different target objects, including metal, plastic, and a human subject, behind various wall materials such as plywood, drywall, or concrete. A laptop or PC will be used for data logging, signal processing, and visualization, utilizing software like Arduino IDE, Python, or MATLAB. The project will incorporate signal analysis techniques, such as Fast Fourier Transform (FFT), to differentiate between materials and detect human movement based on Doppler shifts. The goal is to assess signal variations to effectively distinguish between objects and human presence behind walls.

2.1 Hardware requirements

3 Microwave Sensor

Microwave sensor is used for detecting motion and presence behind walls. Microwave sensors operate by emitting electromagnetic waves (in the microwave range) and analyzing the reflected

signals from objects or individuals. Their ability to penetrate non-metallic materials like walls makes them ideal for such applications

Purpose of Using a Microwave Sensor in This Project:

4 Wall Penetration

Microwave signals can pass through materials like drywall, wood, and concrete (to some extent), enabling the detection of objects or humans behind walls.

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5 Motion Detection

These sensors detect motion by analyzing Doppler shifts caused by the movement of humans or objects, providing information about the presence and activity behind walls

6 Non-Invasive Operation

Unlike thermal imaging or direct optical systems, microwave sensors do not require a direct line of

sight and work without damaging walls or surfaces.

7 Range and Accuracy

Microwave sensors typically have a wider detection range and better sensitivity compared to ultrasonic

sensors, making them suitable for detecting humans or large objects at varying distances.

8 Classification of Objects

Variations in reflected microwave signals can be processed to classify objects based on size, material, or motion patterns.

9 Compact and Cost-Effective

Microwave sensors are lightweight, relatively inexpensive, and easy to integrate with other components like microcontrollers or signal processing units.

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10 Arduino Nano

The Arduino Nano is a compact, breadboard-friendly microcontroller board designed for electronics projects. It is based on the ATmega328Pmicrocontroller (or ATmega168 in older versions) and is ideal for small-scale, embedded applications

11 OLED Display

An OLED (Organic Light Emitting Diode) display is a type of display technology where each pixel emits its own light, eliminating the need for a backlight. This results in sharp, high-contrast

images with low power consumption. It is widely used in small electronics projects for displaying text, graphics, and sensor data

12 IC7805

The 7805 IC is a popular linear voltage regulator from the 7805 series that provides a fixed 5V output. It is commonly used in electronics projects to step down and regulate higher DC voltage levels (e.g. 12V or 9V) to a stable 5V required for components like microcontrollers, sensors, and displays actuators, and a user-friendly interface. The system will be designed to sort waste into three primary

13 Dcj0202

The DCJ0202 is a digital-to-analog (D/A) converter, also known as a DAC. It is often used in embedded systems and electronics projects where there is a need to convert digital signals into analog output, such as for controlling audio, voltage, or signal generation

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13.1 Circuit Connections

This circuit diagram illustrates the setup for a moving objects and human detection system using a microwave sensor and Arduino Nano. The microwave sensor (e.g., RCWL-0516) is connected to the Arduino to detect motion by providing output signals based on reflected microwaves. The Arduino Nano processes these signals and communicates the results to an OLED display (128x64 I2C) for visual output. Power is managed using a 7805 voltage regulator to supply a stable 5V to the components, while decoupling capacitors (470 μF) ensure smooth voltage regulation. The system uses the Arduino's GPIO pins for interfacing the sensor and the OLED display, making it a compact and efficient design suitable for real-time motion and human presence detection.

13.2 Block Diagram

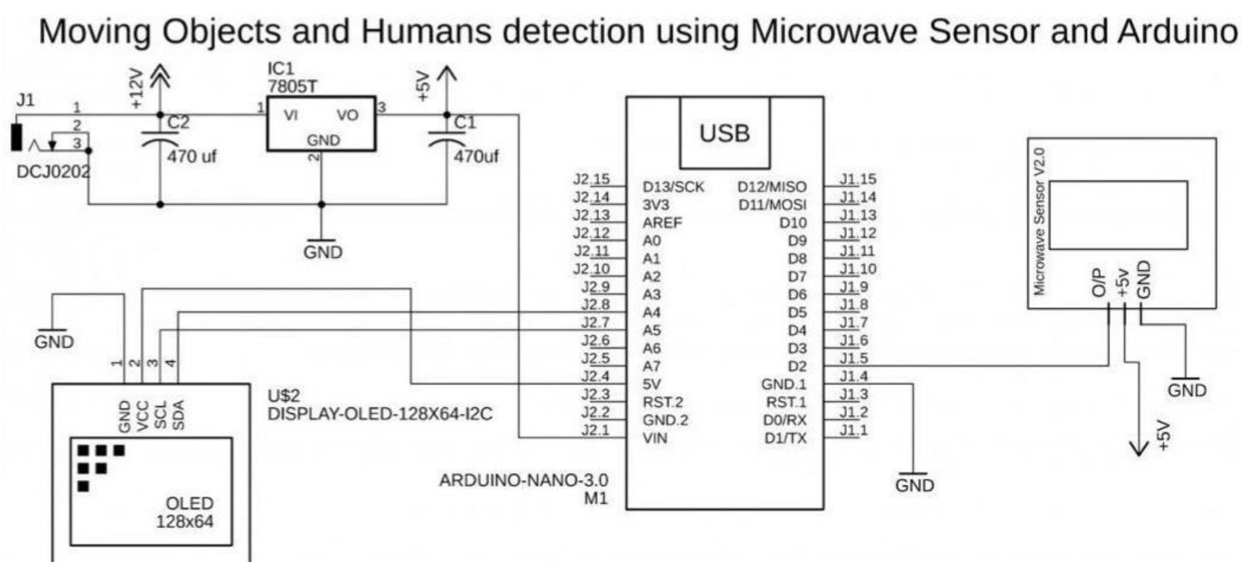

Figure 1: 1: Block Diagram Of Human And Object Detection Behind Walls

13.3 Program Code And Language Detail

```
#include <SPI.h>
```

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```
#include <MsTimer2.h> //Timer interrupt function library #include
<Adafruit_GFX.h>
#include <Adafruit_SSD1306.h>
#define SCREEN_WIDTH 128 // OLED display width, in pixels #define
SCREEN_HEIGHT 64
//
OLED display height, in pixels
// Declaration for an SSD1306 display connected to I2C (SDA, SCL pins) #define
OLED_RESET
1 // Reset pin # (or -1 if sharing Arduino reset pin) #define SCREEN_ADDRESS 0x3D
Adafruit_SSD1306 display(SCREEN_WIDTH, SCREEN_HEIGHT, &Wire,
OLED_RESET);
int pbIn = 0; // Define interrupt 0 that is digital pin 2 int ledOut = 13;
// Define the indicator LED pin digital pin 13 int number=0; //Interrupt times
volatile int state = LOW;
// Defines the indicator LED state, the default is not bright void setup()
{
Serial.begin(9600); pinMode(ledOut, OUTPUT);//
attachInterrupt(pbIn, stateChange, FALLING); // Set the interrupt function, interrupt
pin is digital pin
D2,
//interrupt service function is stateChange (),
//when the D2 power change from high to low , the trigger interrupt.
MsTimer2::set(3000, Handle); // Set the timer interrupt function, running once Handle()
function per
1000ms
MsTimer2::start();//Start timer interrupt function dispLay.begin(SSD1306_SWITCHCAPVCC,
```

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```
0x3C); display.clearDisplay();
display.display();
}
void loop()
{
display.setTextSize(2); display.setTextColor(WHITE); display.setCursor(0,5);
display.println("status: "); display.setTextSize(3); display.setTextColor(WHITE); dis-
play.setCursor(0,30); display.println(number); display.display(); display.clearDisplay(); de-
lay(10);
}
void stateChange() //Interrupt service function
{
number++; //Interrupted once, the number + 1
}
void Handle() //Timer service  function
{
number = 0;
}
```

The provided code is written in Arduino C/C++, designed to count the number of button presses using an interrupt and display the count on an OLED screen. It utilizes libraries like MsTimer2 for setting up a timer interrupt to reset the count every 3 seconds, and Adafruit_SSD1306 for controlling the OLED display. The program initializes hardware in the setup () function, continuously updates the display in loop (), and increments the count each time a button press (detected on pin D2) triggers the state Change () interrupt. After 3 seconds, the count is reset by the Handle () function, triggered by the timer interrupt.

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14 Results and Discussions

The experimental results demonstrated that the microwave sensor effectively detected human movement behind walls, with higher accuracy in thin walls like plywood compared to denser materials like concrete. The Doppler shift analysis showed clear frequency variations when a human moved behind the barrier, confirming the sensor's ability to detect motion. However, the signal strength decreased as wall thickness increased, leading to reduced detection efficiency.

Objects such as metal and plastic produced different reflection patterns, with metal causing stronger reflections due to its high conductivity, while plastic had minimal impact on the signal. The real-time data processing using Fast Fourier Transform (FFT) helped filter noise and improve accuracy in detecting movement patterns.

Despite successful detection of motion, distinguishing between stationary objects and humans posed a challenge, as stationary objects did not produce significant frequency shifts. To enhance object classification, machine learning techniques or additional sensor fusion (e.g., infrared or ultrasonic sensors) could be integrated. Additionally, environmental factors such as interference from nearby electronic devices slightly affected signal consistency, indicating the need for optimized sensor placement. Future improvements could involve using a lower-frequency microwave sensor for better wall penetration and implementing advanced algorithms to improve object differentiation. Overall, the project demonstrated the feasibility of detecting human presence behind walls but highlighted the need for further refinements to improve accuracy and classification efficiency.

14.1 Working efficiency

The working efficiency of this project depends on several factors, including the type of microwave sensor used, the material and thickness of the wall, and the effectiveness of signal processing techniques.

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Detection Accuracy: Microwave sensors can detect motion with high accuracy, but distinguishing between different objects (e.g., human vs. metal) may require advanced signal processing or machine learning.

Penetration Capability: Lower-frequency microwave signals (e.g., 2.4 GHz) penetrate walls better than higher frequencies, but signal attenuation increases with denser materials like concrete.

Environmental Factors: Interference from other electronic devices, wall composition, and object placement can affect detection efficiency.

Real-Time Processing: Using Fast Fourier Transform (FFT) and Doppler analysis improves efficiency in identifying motion but may require optimization for faster response times.

14.2 Working Prototype

14.3 Conclusion and Future Work

In conclusion, this project demonstrates the use of Arduino microcontroller capabilities to count and display interrupt-driven events, such as button presses, on an OLED screen. By leveraging interrupt handling and timer interrupts, the system efficiently tracks user interactions and resets the count at regular intervals. The integration of the MsTimer2 library for timed resets and the Adafruit_SSD1306 library for display control highlights key concepts in embedded programming, such as hardware interfacing, real-time event handling, and periodic task execution. This project serves as a practical example of using interrupts and timers in embedded systems to create responsive, real-time applications

For future work, this project can be expanded in several ways: Multiple Button Inputs: Extend the system to handle multiple buttons or sensors, allowing for more complex interactions and counting events from different sources. Advanced Display Features: Enhance the OLED display with graphical elements like progress bars or icons, providing more

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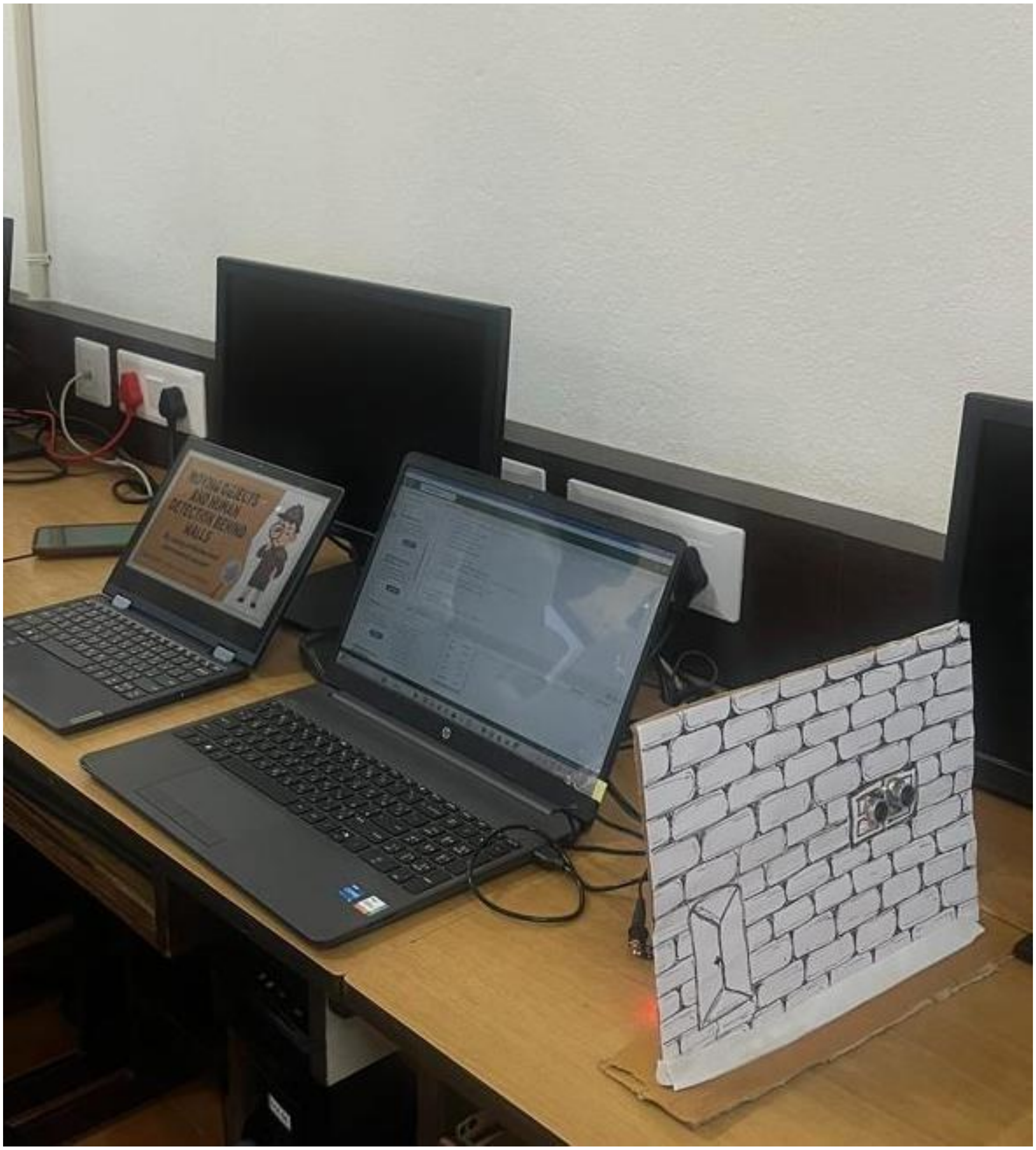

Figure 2: 2 : Working Prototype Of Human And Object Detection Behind Walls

dynamic feedback to the user. Data Logging: Introduce data storage options (e.g., SD card or EEPROM) to log button press counts over time, allowing for tracking of usage or event frequency. Wireless Communication: Add wireless capabilities (e.g., using Wi-Fi or Bluetooth) to transmit the count or event data to another device, such as a smartphone or computer for remote monitoring. Debouncing: Implement a software debounce mechanism

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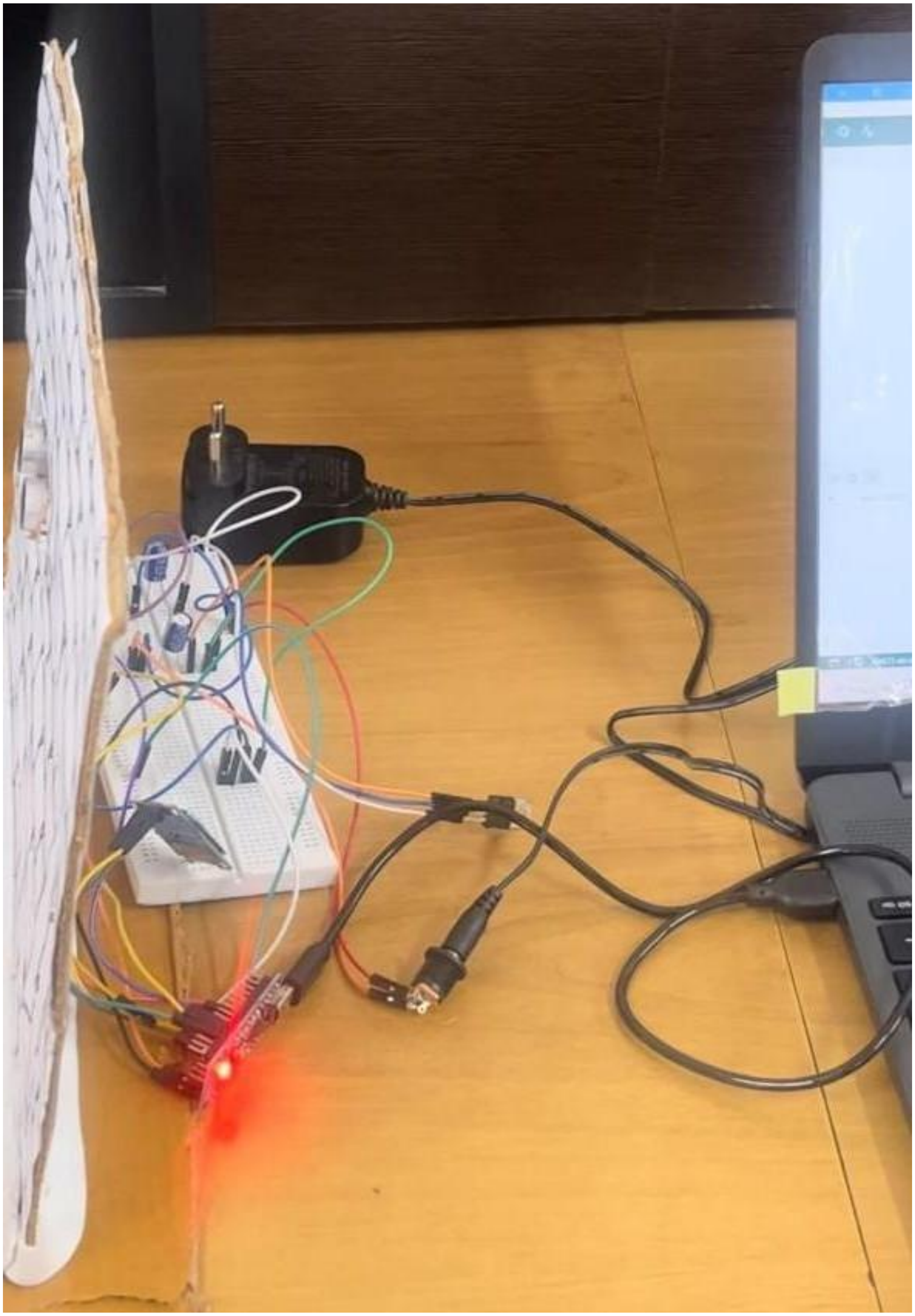

Figure 3: 3: Circuit Connection Of Human And Object Detection Behind Wall

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for more reliable button presses, avoiding multiple counts from a single press due to mechanical bounce. Advanced Timer Functionality: Include customizable timer intervals for reset actions, enabling more flexible control over the counting period

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