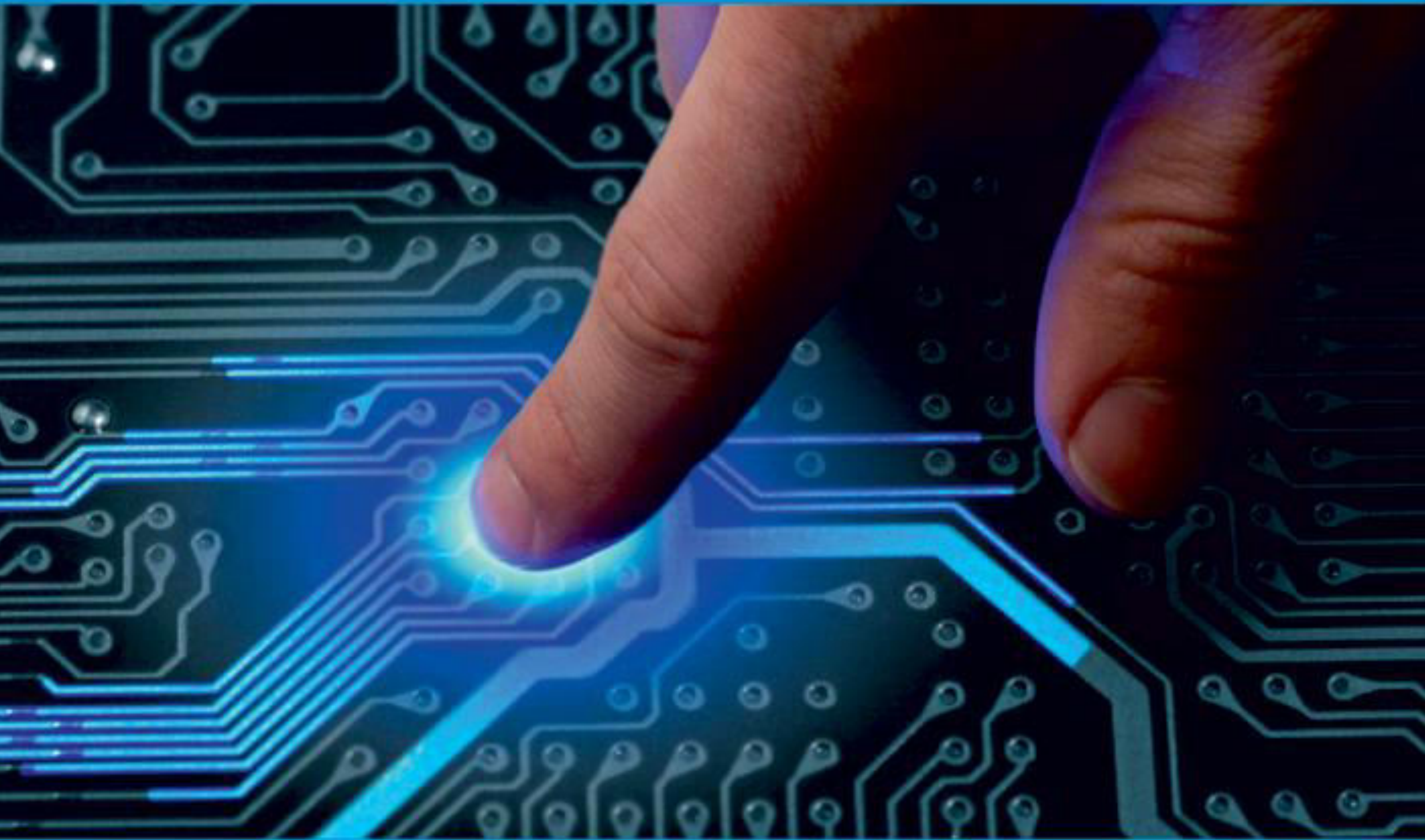
IJIRCCE

e-ISSN: 2320-9801 | p-ISSN: 2320-9798



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN COMPUTER & COMMUNICATION ENGINEERING

Volume 12, Issue 3, March 2024

INTERNATIONAL STANDARD SERIAL NUMBER INDIA

Impact Factor: 8.379

International Journal of Innovative Research in Computer and Communication Engineering

| e-ISSN: 2320-9801, p-ISSN: 2320-9798| www.ijircce.com | |Impact Factor: 8.379 | Monthly Peer Reviewed & Referred Journal |

|| Volume 12, Issue 3, March 2024 ||

| DOI: 10.15680/IJIRCCE.2024.1203100 |

Smart Emergency Response System Using Soil Communication for the Safety of Tunnel Workers

Dr. C. Bennila Thangammal[1], L.Lohith Kumar Reddy[2], Mohammed Suheb[3], K.Jayasathvik[4]

Professor, Department of Electronics and Communication Engineering, RMD Engineering College,

Kavaraipettai, India [1]

Department of Electronics and Communication Engineering, RMD Engineering College, Kavaraipettai, India[2,3,4]

ABSTRACT: Workers in tunnels face alarming safety concerns, with a significant risk of collapses resulting in fatalities. These incidents highlight the urgent need to enhance safety measures for tunnel workers. Communication breakdowns exacerbate the danger, especially when workers become trapped after a collapse, as seen in the recent Uttarkashi tunnel collapse where 41 workers were stranded. Motivated by this tragedy, we propose a solution: a communication system comprising Transmitter and Receiver units, both functioning as transceivers. The system incorporates LCDs for real-time status updates. The Transmitter unit, equipped with a keypad interfaced with Arduino Uno, allows workers to convey specific needs such as food, water, or medical assistance by selecting the corresponding key. In emergencies, an "emergency key" triggers the transmission of GPS coordinates (latitude and longitude) to the Receiver unit, facilitating swift rescue operations.

KEYWORDS: SOIL COMMUNICATION, IOT, GPS,KEYPAD

I. INTRODUCTION

The Advanced Soil Communication Module involves the development of specialized communication devices capable of transmitting and receiving signals through soil. This initiative includes exploring soil conductivity and integrating findings into the design for optimal signal propagation. Additionally, signal processing protocols are being designed and implemented to ensure reliable and real-time information exchange. These protocols will be optimized to address challenges related to soil composition and varying environmental conditions. Infrastructure development is another crucial aspect, aiming to create a robust infrastructure supporting communication through soil. This includes strategically deploying communication nodes within the tunnel network and integrating them with existing rescue operation systems to enhance overall efficacy. Real-time information exchange is a key focus, enabling trapped individuals to communicate with rescue teams for timely updates on the situation and coordination of rescue efforts. Furthermore, the Soil Communication System will enhance coordination among rescue teams by providing a reliable means of communication in challenging tunnel environments, thereby increasing efficiency in decision-making and resource allocation during rescue missions. Ultimately, the project aims to revolutionize emergency services in tunnel environments by offering a lifeline for individuals trapped underground, potentially saving lives in critical situations.

II. OBJECTIVES

The goal of implementing a Smart Emergency Response system utilizing soil communication technology is to improve communication with workers operating in tunnels and mines, particularly in emergency scenarios such as tunnel collapses. The integration of IoT (Internet of Things) facilitates data management in these environments. The "Soil Communication System for Tunnel Rescue Operations" project seeks to transform subterranean emergency response by creating specialized soil communication modules, signal processing protocols, and infrastructure. This innovative strategy enhances real-time communication, coordination, and overall effectiveness during tunnel rescue operations, offering a crucial lifeline for individuals trapped underground

III. LITERATURE SURVEY

In conventional long-distance communication, electromagnetic (EM) waves traverse through air, but when attempting communication through soil, EM waves face obstacles due to the varied compositions of soil like red or black cotton

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soil. This results in data loss due to high diffraction. Moreover, increased transmission distances lead to higher path loss and attenuation due to interior distance. In today's communication landscape, underground communication systems are essential for effective data transmission. To address these challenges, wireless underground sensor networks (WUSN) have been introduced. Magnetic induction (MI) is proposed as an alternative, utilizing magnetic induction coils as transceivers for efficient data transmission, overcoming the limitations of EM waves.

The practical advancement of Wireless Underground Sensor Networks (WUSN) holds promise for various applications, such as online infrastructure monitoring, earthquake warning systems, and agricultural automation. However, existing RF electromagnetic wireless systems struggle to transmit through soil due to significant signal path losses caused by absorption and scattering. Despite the modest data requirements for such applications, typically ranging from tens to hundreds of bps, RF systems are inadequate. Interestingly, animals like elephants, rodents, and insects utilize acoustic waves to communicate through soil, indicating the potential of soil as a communication medium and acoustic waves as carriers. This article demonstrates how soil can serve as a communication medium for wireless acoustic digital communication, achieving distances of up to 50 meters at data rates of 20 bps. By utilizing a physical model of the soil channel based on its identified characteristics, employing QPSK and OOK modulation, implementing sparse decision feedback equalization schemes, and utilizing well-coupled and matched acoustic sources, successful wireless digital communication was achieved in both laboratory and field experiments. This highlights the feasibility of transmitting application-specific data, ranging from binary sensor readings to low-resolution images, through this innovative approach.

Wireless underground sensor networks (WUSNs) have become increasingly prevalent across various domains, necessitating a deep understanding of underground (UG) channel characteristics for robust system design. This paper presents a model of the UG channel impulse response, validated through extensive experiments conducted in both indoor and field testbed environments. Three types of soils were selected, spanning a range of sand and clay contents. Over 1,200 measurements were taken in a novel UG testbed, allowing for flexible soil moisture control to investigate its impact on channel characteristics. Time-domain features such as RMS delay spread, coherence bandwidth, and multipath power gain were analyzed, confirming the presence of direct, reflected, and lateral waves in the UG channel. The RMS delay spread follows a log-normal distribution, and coherence bandwidth varies between 650 kHz and 1.15 MHz for soil paths up to 1 m, decreasing to 418 kHz for distances exceeding 10 m. Soil moisture nonlinearly affects the RMS delay spread, suggesting opportunities for dynamic adaptation techniques based on soil moisture. A statistical channel model for wireless underground communication was developed, demonstrating good agreement with measurement data and paving the way for tailored solutions in data harvesting, UG sub-carrier communication, and UG beamforming. Additionally, a demo showcases a novel underground communication system and an online underground sensor network testbed, featuring an underground antenna designed to mitigate soil-related communication challenges. This system is connected to a testbed in Nebraska, equipped with soil moisture sensors and a mobile data harvesting unit with cellular communication capabilities, demonstrating real-time soil moisture data delivery from Nebraska to Korea.

IV. REQUISITES

The project utilizes an Arduino Uno microcontroller as the central processing unit, facilitating communication between the Transmitter and Receiver units. Inspired by a tragic incident in Uttarkashi, the Transmitter unit includes a keypad for workers to communicate specific needs via soil data communication. In emergencies, such as tunnel collapses, an emergency key initiates the transmission of GPS coordinates to the Receiver unit. Additionally, the Transmitter unit features an MQ-2 sensor to detect toxic gases, triggering alerts through a buzzer. The Receiver unit incorporates an ESP8266 controller, which updates received data in the IoT cloud. This system enhances communication and response capabilities in critical situations, enabling workers to convey vital information swiftly and efficiently. By leveraging technologies like GPS and IoT, the project aims to enhance rescue operations, particularly in challenging environments such as collapsed tunnels.

V. USAGE OF IOT IN THIS DOMAIN

This module serves as the central hub for storing and managing transmitted data. The ESP8266 controller embedded in the Receiver unit takes charge of updating received information in the IoT cloud. This integration enables real-time monitoring and coordination of rescue operations. Additionally, it streamlines data analysis and decision-making for emergency responders and authorities. Ultimately, the integration with the IoT cloud ensures uninterrupted

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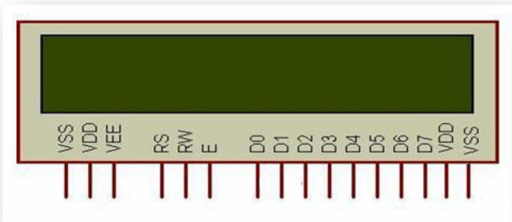
communication and improves the efficiency of rescue operations during critical situations. The IoT system stores data at regular intervals over time to maintain enhanced communication with workers inside the tunnels.

VI.ARDUINO UNO

Arduino is an open-source electronic platform renowned for its versatility in both hardware and software operations. In this system, Arduino is utilized to gather inputs from the tunnel. The keypad is connected to the Arduino, where the pressed keys serve as inputs, subsequently transmitted as outputs to the receiver side. Arduino Uno, specifically, is a microcontroller board built around the ATmega328P chip. It boasts 14 digital input/output pins, 6 of which support PWM outputs, along with 6 analog inputs. Equipped with a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header, and a reset button, Arduino Uno encompasses all essentials to support the microcontroller. Its user-friendly interface allows seamless tinkering without fear of irreparable damage; in the worst-case scenario, the chip can be replaced inexpensively, facilitating experimentation and innovation.

VII. LCD (Liquid Crystal Display)

An LCD screen, or Liquid Crystal Display, is a versatile electronic display module widely utilized across various applications. Among its variations, the 16x2 LCD display stands out as a fundamental module commonly integrated into devices and circuits. Compared to alternatives like seven segments and other multi-segment LEDs, LCDs offer several advantages. They are cost-effective, easily programmable, and do not have limitations on displaying special or custom characters, unlike seven segments. Additionally, LCDs support animations and other visual effects. The "16x2" designation indicates that the LCD can display 16 characters per line, with 2 such lines available. Each character is represented by a 5x7 pixel matrix on the display. The LCD contains two registers: the Command register and the Data register. The Command register stores instructions given to the LCD, such as initializing it, clearing the screen, setting cursor position, and controlling display functions. Meanwhile, the Data register stores the ASCII values of the characters to be displayed on the LCD.
The LCD is used to display the status of the message that is pressed by the worker in the keypad.This is placed at both ends that is at both receiver and transmitter.



VIII.KEYPAD

Keyboards are structured at their most basic level in a matrix formation of rows and columns. The CPU accesses both rows and columns through ports, enabling the connection of an 8*8 matrix of keys to a microprocessor using two 8-bit ports. When a key is pressed, a connection is established between a row and column; otherwise, there is no connection between them. IBM PC keyboards employ a single microcontroller, which integrates a microprocessor, RAM, EPROM, and multiple ports onto a single chip, to handle both software and hardware interfacing of the keyboard. In such systems, the programs stored in the EPROM of the microcontroller are responsible for continuously scanning the keys, identifying activated keys, and transmitting this information to the motherboard.

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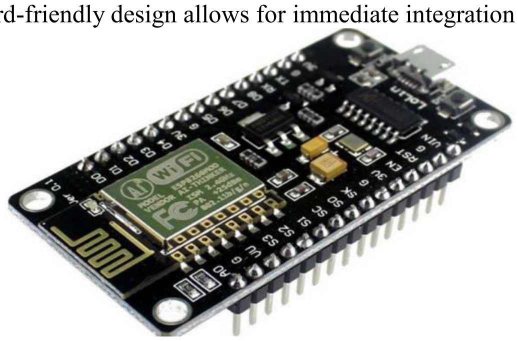
The diagram depicts a 4*4 matrix linked to two ports, with the rows linked to an output port and the columns to an input port. In the absence of any key press, reading the input port will result in all columns registering 1s, as they are connected to a high voltage (Vcc). However, when all rows are grounded and a key is pressed, one of the columns will register a 0 due to the path to ground provided by the pressed key. It falls upon the microcontroller's responsibility to continuously scan the keyboard, detecting and identifying any pressed keys.

IX.ESP-12E BASED NODEMCU

The ESP8266, developed by Espressif Systems, serves as a microcontroller offering a self-contained Wi-Fi networking solution. It acts as a bridge between existing microcontrollers and Wi-Fi, while also supporting self-contained applications. Equipped with a built-in USB connector and a diverse array of pin-outs, this module facilitates easy connectivity and programming. Using a micro USB cable, NodeMCU devkit can be seamlessly connected to a laptop for flashing, similar to the Arduino. Additionally, its breadboard-friendly design allows for immediate integration into prototyping setups.



The ESP-12E Wi-Fi module, developed by the Ai-thinker Team, features the core processor ESP8266 encapsulated in a compact size. It incorporates the Tensilica L106, an industry-leading ultra-low power 32-bit MCU microcontroller, supporting 16-bit short mode and clock speeds of 80 MHz and 160 MHz. The module includes integrated Wi-Fi MAC/BB/RF/PA/LNA and an onboard antenna. It adheres to the standard IEEE802.11 b/g/n agreement and offers a complete TCP/IP protocol stack. Users can easily integrate the module into existing devices for networking purposes or use it to build separate network controllers. ESP8266 is designed as a high integration wireless SOC, catering to the needs of space and power-constrained mobile platform designers. It offers unparalleled capability to embed Wi-Fi functionalities within other systems or operate as a standalone application, boasting the lowest cost and minimal space requirement.

X.Gas sensor (MQ-2)

To create a simple electro circuit, the MQ-2 gas sensor's sensitive material, SnO_2, reacts by changing conductivity when exposed to combustible gases like LPG, propane, hydrogen, methane, and others. As the gas concentration increases, the sensor's conductivity rises accordingly. The circuit comprises the MQ-2 gas sensor, which detects flammable gases and

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smoke. Powering the smoke sensor with 5 volts, it outputs voltage proportional to the detected smoke level. A potentiometer adjusts sensitivity, while the sensor provides analog resistive output based on smoke concentration. Additionally, the circuit includes a heater powered by VCC and GND, affecting resistance across the pin depending on smoke presence. Increased smoke reduces resistance, raising voltage between the sensor and load resistor.

X.GLOBAL POSITIONING SYSTEM

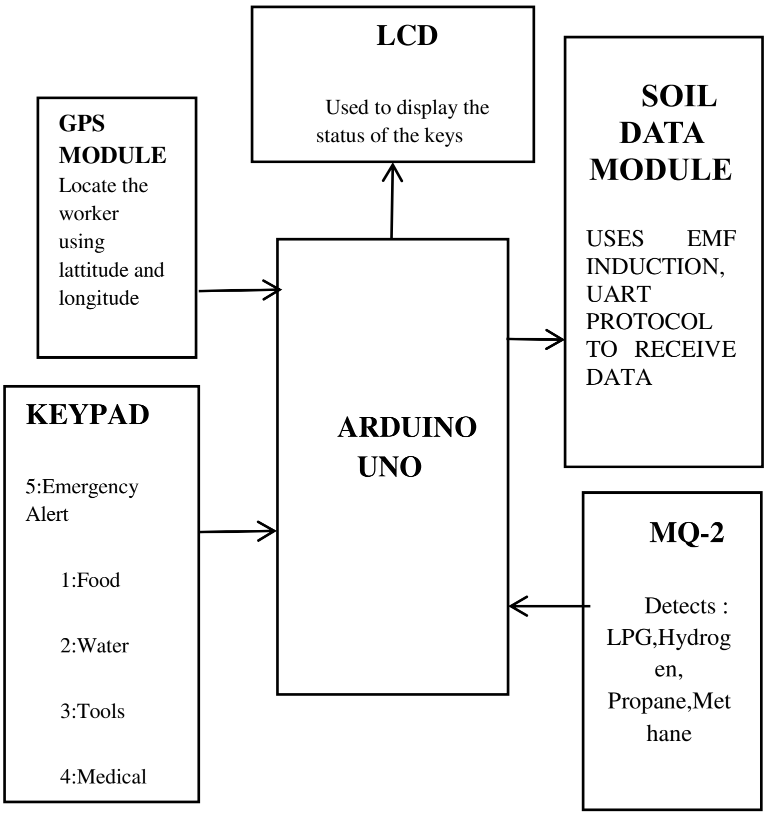
The Global Positioning System (GPS) is a satellite navigation system that offers location and time information in all weather conditions worldwide. It is extensively utilized for navigation in various vehicles such as planes, ships, cars, and trucks. The system plays a vital role for both military and civilian users globally, providing continuous real-time, three-dimensional positioning, navigation, and timing capabilities. Consisting of at least 24 satellites, GPS operates 24 hours a day without subscription fees or setup charges. Initially developed by the U.S. Department of Defense (USDOD) for military purposes, the system became available for civilian use in the 1980s.

XI.WORKING MODEL

The Arduino board is linked with a keypad, gas sensor, and GPS, which serve as input sources for the Arduino. The outputs from the Arduino are connected to both an LCD and a soil data module. The LCD screen is utilized to showcase the status of the keys pressed by the worker on the keypad. Meanwhile, the soil data module utilizes UART protocol and electromagnetic induction for transmitting messages

BLOCKDIAGRAM OF THE TRANSMITTER

This module acts as the interface for tunnel workers, featuring an Arduino Uno microcontroller and a keypad. Each key on the keypad corresponds to specific information, enabling workers to convey their needs or signal emergencies. The Arduino Uno processes the selected data and transmits it via soil data communication. Furthermore, the Transmitter unit is equipped with an MQ-2 sensor to detect toxic gases, enhancing worker safety. In emergency situations, such as the detection of toxic gases or pressing the emergency key, the module transmits GPS coordinates along with the selected data to the Receiver unit.



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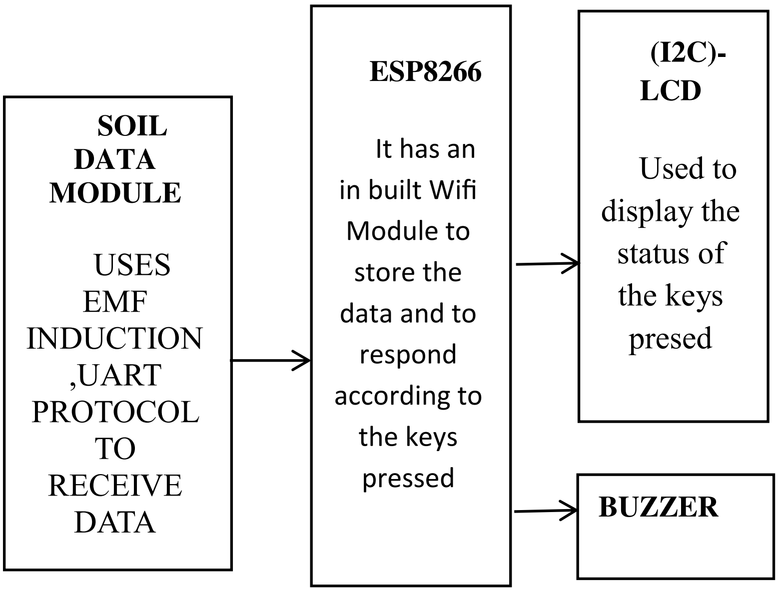
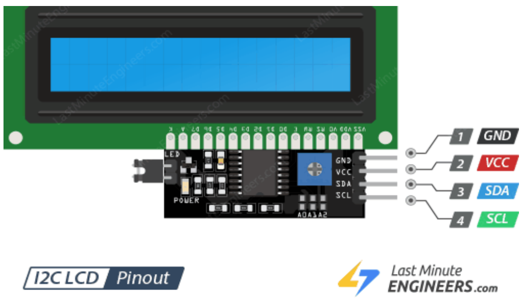
BLOCK DIAGRAM OF RECEIVER

The Receiver unit functions as the recipient and processor of data transmitted from the Transmitter unit. It includes an ESP8266 controller that communicates with the Arduino Uno of the Transmitter unit. Upon receiving data, the ESP8266 updates the information in the IoT cloud. Additionally, the Receiver unit features a buzzer to deliver immediate alerts during emergencies, activated by the detection of toxic gases or the activation of the emergency key.



CONNECTIONS ACCORDING TO BLOCK DIAGRAMS



GND is a ground pin. Connect it to the ground of the Arduino.
VCC supplies power to the module and LCD. Connect it to the Arduino's 5V output or an external 5V power supply.
SDA is the I2C data pin. Connect it to the Arduino's I2C data pin.
SCL is the I2C clock pin. Connect it to the Arduino's I2C clock pin.
Hooking up an Arduino Uno to an I2C LCD display
Connecting an I2C LCD is much easier than connecting a standard LCD. You only need to connect 4 pins instead of 12. Start by connecting the VCC pin to the 5V output on the Arduino and GND to ground.Now we are left with the pins which are used for I2C communication. Note that each Arduino board has different I2C pins that must be connected accordingly. On Arduino boards with the R3 layout, the SDA (data line) and SCL (clock line) are on the pin headers close to the AREF pin. They are also known as A5 (SCL) and A4 (SDA).

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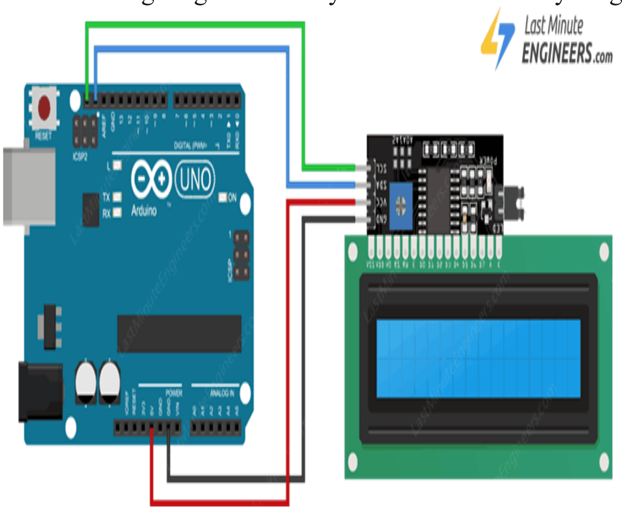
If you are using a different Arduino board, please refer to the table below.

	SCL	SDA
Arduino Uno	A5	A4
Arduino Nano	A5	A4
Arduino Mega	21	20
Leonardo/Micro	3	2

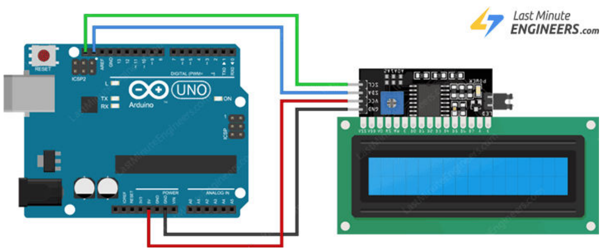
The following diagram shows you how to wire everything up.



Adjusting The LCD Contrast

After wiring up the LCD you'll need to adjust the contrast of the display. On the I2C module you will find a potentiometer that you can rotate with a small screwdriver.

Plug in the Arduino's USB connector to power the LCD. You will see the backlight lit up. Now as you turn the knob on the potentiometer, you will start to see the first row of rectangles. If that happens, Congratulations! Your LCD is working fine.



Once this is done, we can start programming the LCD.

Library Installation

To drive an I2C LCD you must first install a library called LiquidCrystal_I2C. This library is an enhanced version of the LiquidCrystal library that comes with your Arduino IDE. To install the library navigate to Sketch > Include Libraries > Manage Libraries… Wait for Library Manager to download the library index and update the list of installed libraries. Filter your search by typing 'liquidcrystal'. There should be some entries. Look for the LiquidCrystal I2C library by Frank de Brabander. Click o n that entry, and then select Install.

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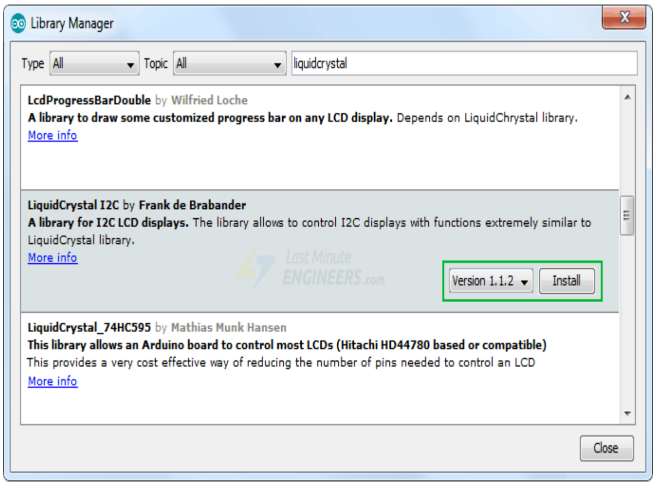

Determining the I2C Address
The I2C address of your LCD depends on the manufacturer, as mentioned earlier. If your LCD has a Texas Instruments' PCF8574 chip, its default I2C address is $0x27_{Hex}$. If your LCD has NXP Semiconductors' PCF8574 chip, its default I2C address is $0x3F_{Hex}$.
So your LCD probably has I2C address $0x27_{Hex}$ or $0x3F_{Hex}$. However it is recommended that you find out the actual I2C address of the LCD before using it. Luckily there's an easy way to do this, thanks to the Nick Gammon.
Nick wrote a simple I2C scanner sketch that scans your I2C bus and returns the address of each I2C device it finds.
Load this sketch into your Arduino and then open your Serial Monitor. You will see the I2C address of your I2C LCD display.

XI.OUTPUTS

THE ABOVE FIGURE SHOWS THE SETUP OF THE PROJECT

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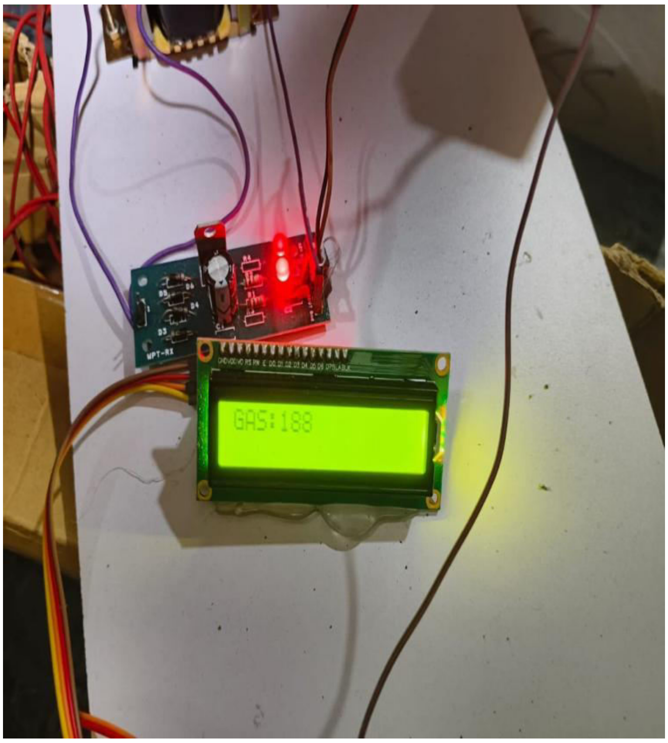
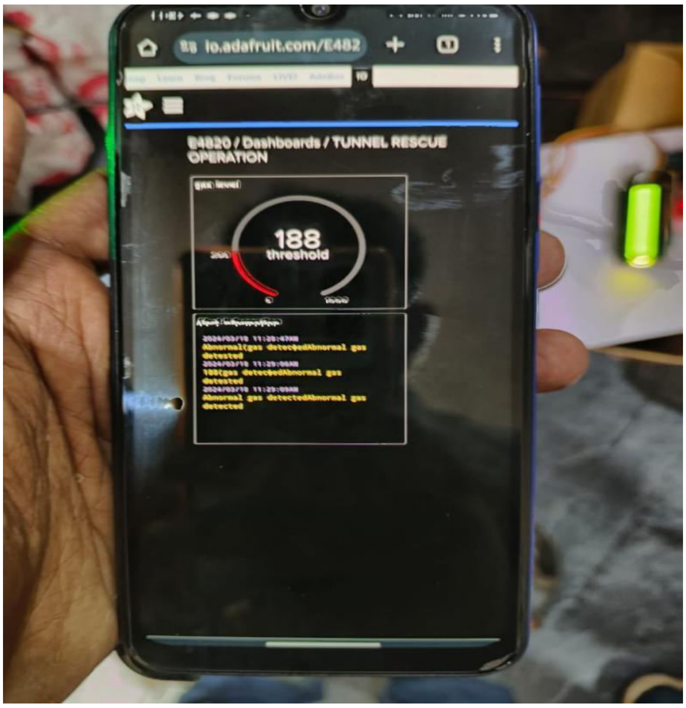


THE DISPLAY SHOWING THE ABNORMAL GAS INDICATION
(<200 IS CONSIDERED AS ABNORMAL GAS)



THE SAME OUTPUT IS SHOWN IN THE MOBILE PHONE(WEBSITE CAN ALSO BE VIEWED IN DESKTOP OR LAPTOP)

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XIII.CONCLUSION AND FUTURE WORKS

In summary, the "Soil Communication System for Tunnel Rescue Operations" presents an innovative solution to the communication challenges encountered in underground emergencies. By utilizing advanced soil communication modules, this project introduces a fresh approach to establishing reliable networks in tunnel scenarios where traditional methods are inadequate. Through the integration of signal processing protocols and a robust infrastructure, seamless communication is facilitated between trapped individuals and rescue teams, greatly enhancing coordination and the effectiveness of rescue missions. This groundbreaking technology not only addresses the immediate needs of those in distress but also revolutionizes the operational procedures of emergency services in tunnel environments. The project's interdisciplinary approach, drawing on expertise in soil science, communication technology, and emergency response systems, highlights its potential to save lives and improve overall efficiency. The Soil Communication System serves as a vital resource for individuals trapped underground, providing essential updates, timely assistance, and improved outcomes in critical situations, representing a significant advancement in tunnel rescue operations.

Future enhancements could involve incorporating advanced communication technologies such as LoRa or satellite communication for increased range and reliability in remote or hazardous environments. Integration of machine learning algorithms could enable predictive analysis of potential hazards, enhancing preemptive safety measures. Implementing drones equipped with cameras and sensors could provide real-time aerial surveillance, aiding in search and rescue operations. Furthermore, the addition of automated robotic systems capable of navigating through tunnels could improve response times and reduce risks to human rescuers. Overall, these advancements would further enhance communication, safety, and efficiency in emergency scenarios like tunnel collapses.

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