INNOVARE JOURNAL OF ENGINEERING & TECHNOLOGY

Vol 10, 2022

ISSN - 2347-1573

Research Article

DESIGN AND IMPLEMENTATION OF A SMART HOME AUTOMATION SYSTEM

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Received: 23 November 2022, Revised and Accepted: 16 January 2023

ABSTRACT

Objective: Due to the rapid development of various technologies and communication devices, the use of the Internet of Things (IoT) for automation has become increasingly common in non-industrial environments. It has integrated well into our day-to-day activities, leading us toward the use of smart home technology. Smart home systems are intelligent system that provide control to home appliances and also security systems. There are limited numbers of intelligent systems that address multiple aspects of the home automation, such as appliances control, security bridge detection, and reducing energy consumption and cost simultaneously. Hence, this research developed a system that solves these problems with an intelligent home automation system.

Methods: The designed system was based on Arduino ATMEGA328P microcontroller, MQ2 sensor for gas detection, passive infrared (IR) sensor for motion detection, and flame sensor to detect fire outbreak. Arduino ATMEGA328P was used as a central controlling unit that controls the flow of system operations to achieved smart home automation system.

Results: The system sends audible alarms through a buzzer to draw the user's immediate attention. It also sends a warning message to the user's mobile phone through the global system for mobile communication module.

Conclusion: The system achieved a precision rate of 94.44% and provided a cost-effective platform for interconnecting a variety of devices and various sensors in a home through the IoT.

Keywords: ATMEGA328P microcontroller, GSM module, Sensors, Smart home, Internet of things.

 DOI: http://dx.doi.org/10.22159/ijet.2022v10i1.46883. Journal homepage: https://innovareacademics.in/journals/index.php/ijet

INTRODUCTION

The emergence of digital information technology has led to rapid changes in human lifestyles. Recently, there has been an increase in user interest in using smart home technology. The technology provides connection for multiple devices, offers home automation, surveillance, and many more using Internet of Things (IoT) [1,2]. The IoT-based technology allows for the integration of various devices and systems within the home, enabling them to work together seamlessly. This makes it easier for users to control and monitor multiple devices and systems from a single platform, such as a smartphone app [3]. It represents and reports the state of the connected devices in a user-friendly interface, then allowing the user to interact and control various devices with few buttons. These systems fully support the automation of household devices, maintaining, reducing energy usage, and improves comfort levels of the users [4]. The early intelligent home systems were implemented using Bluetooth technology, but the technology could only be accessed and controlled within a limited area. The IoT gets around this restriction and gives people a great way to control all of their home's devices anywhere in the world with their phones. WiMAX, Wireless LAN (Wi-Fi), ZigBee, and the Global System for Mobile Communication (GSM) are some of the various communication technologies used in today's home automation systems [5]. GSM technology is widely used cellular technologies due to the increase in the number of GSM subscribers and wide range coverage.

The use of smart home technology using IoT has been deployed in many areas to facilitates intelligent communication between things and users without necessary in contact to each other. Many times, the issue of forgetting to switch off gadget or electrical appliances has become so much in the society. Appliances might be ON while the owner is away to work or at work and finds it difficult to return home. Leaving home appliances turned on continuously, lead to energy waste, and also can lead to electrical hazards. This paper proposed a smart home system with low cost components; mobile phone, Arduino ATMEGA328P microcontroller, sensors, and GSM modules to monitor and control home appliances. It also provides security reports against fire hazards such as smoke and gas leakages no matter how far the users are from home.

The paper reviewed previously related existing systems needed for this research [6] proposed a smart home automated system with Raspberry Pi and computer vision technology. Raspberry Pi controls devices, video camera recording, and motion sensing, while computer vision techniques detect the presence of intruders. Raspberry sends an alert to its users through short message service (SMS) and other communication mechanisms when an invader enemy is detected [7] proposed a smart home system based on ZigBee Wi-Fi gateway and Sensors with actuators. It receives signals remotely through wireless network on a cubie board control unit, which operates through a designed graphics user interface and a gateway. The gateway provided connects for different protocols, resulting in the development of smart homes with various sensors and actuators. Because it uses a low-power communication protocol, ZigBee-based home automation systems can only communicate between appliances with limited memory [8] also proposed a low cost home automation system for three bedroom apartments using Raspberry Pi to controls home appliances. In all systems by [6-8], there is no provision for gas leakage handling in their designed systems.

A micro-controller-based SMS alert system for intruder detection is designed in [9]. The system is designed around a PIC16F876A microcontroller programmed with a GSM module connected through MAX 232 integrated Circuit. The proximity sensor and vibration sensor provide information about intrusion to the design. The user's mobile number was entered into the system so that each sensor would receive a unique SMS notification of an intrusion. Some of the other GSM-based

systems include [5,9]. In [10], system is limited to detection of movement around the home environment while sending a message to authorized home user, informing the authorized home user of the intruder.

In [11], designed a low-cost home security system capable of detecting intruder movement and gas leakage is proposed. The Arduino Uno, Macro Quest MQ-7 (Gas Sensor), Passive IR (PIR) sensor, and HC-05 Bluetooth module made up the system. The PIR sensor detects any movement within its permissible range and sends a signal to the Arduino Uno board, which triggers the alarm. It also sends SMS to the user through the HC-05 Bluetooth module. This system can be easily used at home for security to prevent intruders and fires from spreading during a fire outbreak. However, there is limited range where the SMS can reach due to Bluetooth used [12] proposed a similar smart wireless home security and automation system. The system was designed and implemented using IoT. It used a Wi-Fi module that was linked to a microcontroller to receive notifications from the user's home from afar. Other researchers that have proposed a Wi-Fi-based automation systems include [13-16].

A friendly smart home system based on Arduino-microcontroller and android phone was proposed in [17]. The designed system has a Pi web server which manages overall network and database maintenance. In addition, in response to user input, it makes a request to the cloud and provides results through push notifications. The Arduino microcontroller was connected with PIR Motion Sensor, Light Sensor, Temperature and Humidity Sensor (DHT11), Magnetic Reed Sensor, Raindrop sensor (LM393), Soil Moisture Sensor, and Gas sensor (MQ5) to provide connectivity. A Pi actuator with a 12V relay array module functions as a switch capable of simultaneously sending and receiving messages. The system provides no human no interaction because the entire system is dependent on the sensors. When the sensors quit functioning, the system will as well stop giving response.

In [18], an intelligent home automation and security system is proposed. The system consists of microcontroller that controls the system and different sensors to detect many things. GSM module was used to send SMS while Wi-Fi Module was used to create network connection between devices. The camera captured image and recorded video. The user can also monitor the present condition of the home or office by using Facebook post of image and message status. A biometric fingerprint scanner, keypad, calling bell, and an electronic lock with password verification are included in the proposed system to ensure that unauthorized access to the system is prevented.

A home security system based on IoT is presented in [19]. The system made up of LPC1769 chip, a node module, and an APP module. The system contains an app to control the switch status of the LED Light of the Gusset plate as well as the ability to display temperature and humidity data received by the node board through a browser using a DHT11 sensor. The LPC1769 chip serves as the core component of the designed system, transferring data between the PC and the node board as well as between an app and the node board. The system allows users to remotely monitor the status of their home through IoT devices.

Our smart home system is design for various home appliances that need automation and as well security. The system incorporates the features such as gas leakages detection sensors, motion sensor, and buzzer into a single system design to control home appliances and provide security. This rest of the paper is organized as follows; the design of proposed system, implementation of the proposed system, while result and discussion were presented. Finally, the paper is concluded with future work.

System design

The hardware architecture of the developed smart home automation system consists of ATMEGA328P microcontroller, mobile phone, flame sensor, PIR sensor, relay module, gas sensor, and GSM modem. The block diagram of the proposed smart home system is given in Fig. 1. In the designed system, incoming message is sent from the phone user to the GSM modem as a text message through cellular network. The GSM modem then sends the commands in text mode to the Arduino Uno board designed around a ATMEGA328P microcontroller programmed to control home appliance while providing security through alarm. The other inputs to the designed system are from sensors and outgoing message from the system containing the home appliances status which is delivered to the mobile phone through GSM modem. This section discusses the design of major components within the smart home automation system.

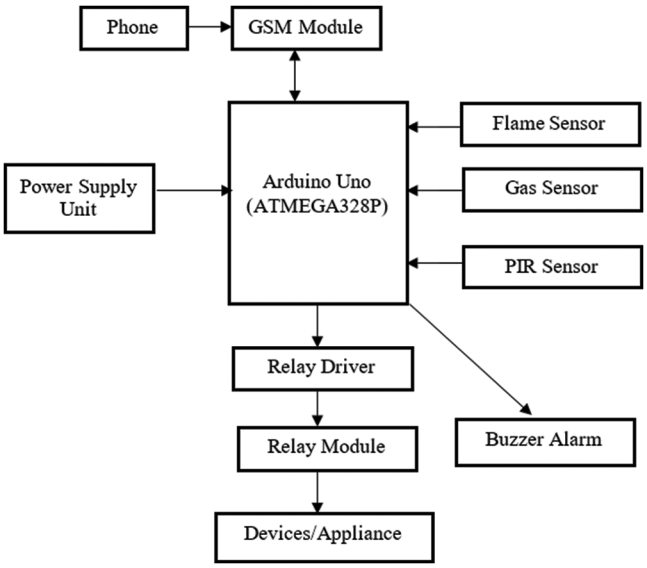

Fig. 1: Block diagram of the developed system

ATMEGA328P

ATmega328P board developed by Arduino was used as a microcontroller to the system. The board is equipped with sets of 14 digital input/output pins, six analog input/output pins and other ports and jacks that can be interfaced to various expansion boards (shields). It is programmable with the Arduino integrated development environment (IDE) through a Type B USB cable. It can be powered by a USB cable with 5V or by an external 9-volt battery. In this design, a 5V/12V 1.5A power adapter was used, it supplies required power to ATMEGA328P microcontroller and other components. The power adapter converts a 220/240V AC into 5V and 12V DC. The adapter provides two DC outputs, 5V and 12V. The ATMEGA328P microcontroller controls operations of all the components used in the system.

GSM SIM 900 module

SIM900 GSM/GPRS module is a miniature GSM modem, which can be integrated into a great number of IoT projects. The module is used to make/receive phone calls, send text messages (SMS), connecting to internet through GPRS and TCP/IP. The module operating voltage is in the range of 3.2V–4.8V. The SIM800L GSM chip's data pins have all been separated into 0.1'' pitch headers. This comprises the pins needed for hardware serial port communication with a microcontroller. The module enables Auto-Baud detection and baud rates between 1200 bps and 115200 bps.

In this design, the module was supplied with about 4.3V and 2A which is enough power module effectively. The baud rate was set to 19200 bps and phone number was added by sending AT commands from FTDI programmer on Arduino IDE.

Module receiver serial pin was connected to digital pin 8 on the ATMEGA328P microcontroller, the transmitter serial pin was also connected to digital pin on ATMEGA328P microcontroller and both components were grounded as shown in Fig. 2.

MQ2 gas sensor

MQ2 sensor is a gas detector that detects the presence or leakage of gases in an area. It has very high sensitivity and fast response time. In

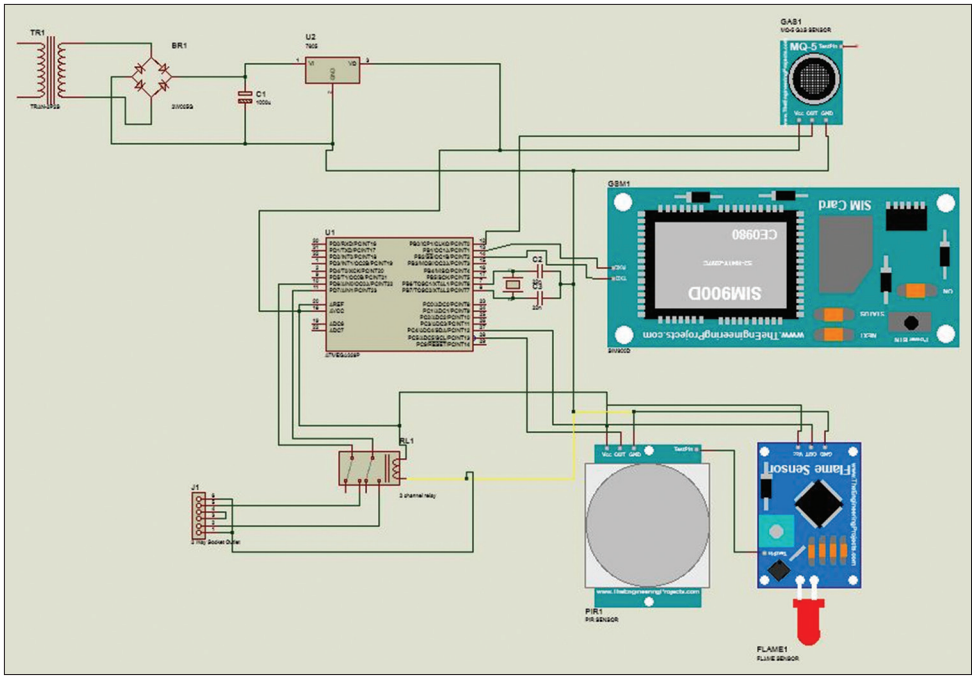

Fig. 2: Circuit diagram of the proposed smart home system

this proposed design, MQ2 sensor was used to detect methane, butane, liquefied petroleum gas, and smoke released into the environment at the time of the gas leak anywhere from 200 to 10,000 ppm. The sensor has six pins; three pins of the gas sensor were connected to +Vcc at one side. On the other side, one terminal is pulled to the ground through a 470 kΩ resistor to reduce flow of current, and the middle pin is connected to the ground. The remaining pin is the output pin of the sensor. It works on 5V DC and draws around 800 mW. The output interfacing of MQ2 device with Arduino is shown in Fig. 2.

PIR sensor

A PIR sensor is a type of electrical sensor used in motion detection applications. It detects and measures IR radiations emitted by any object inside its range of view. In this paper, PIR sensor was used to detect intruders who go near home environment in absent of house owner. The module has only three pins; Vcc pin, which is a +5V input, a ground pin and the digital output pin. The +5 V from Arduino is connected to Vcc of PIR sensor module and PIR sensor GND is connected to ground of Arduino while the output pin is connected to digital eight pin on Arduino. The connections between the components are shown in Fig. 2. The output values produced either a HIGH or a LOW mode. When there is no object inside the PIR sensor's range, it outputs a LOW value or 0 V. When an object is detected inside the range of the PIR sensor, it immediately produces a HIGH value or +5 V at the output.

Flame sensor

A flame sensor was used in this designed to detect and respond to the presence of a flame or fire. When a fire is detected the digital output pin (D_0) on the microcontroller used gives 0 V which low (LOW) and when the is no fire the output pin gives 5 V (HIGH). In this proposed system, the flame sensor used is based on YG1006 sensor which is a high speed and high sensitive NPN silicon phototransistor. It detects IR light with a wavelength ranging from 700 nm to 1000 nm and its detection angle is about 60°. The working voltage of the sensor is between 3.3V and 5 V DC, with a digital output. Logic high on the output indicates presence of flame or fire. Logic low on output indicates absence of flame or fire. Fig. 2 represents the connection of the flame sensor to other components used.

Relay

Relay is use to control electrical circuit by open or close when contacts in another circuit. A relaycontact is normally open (NO) when there is an

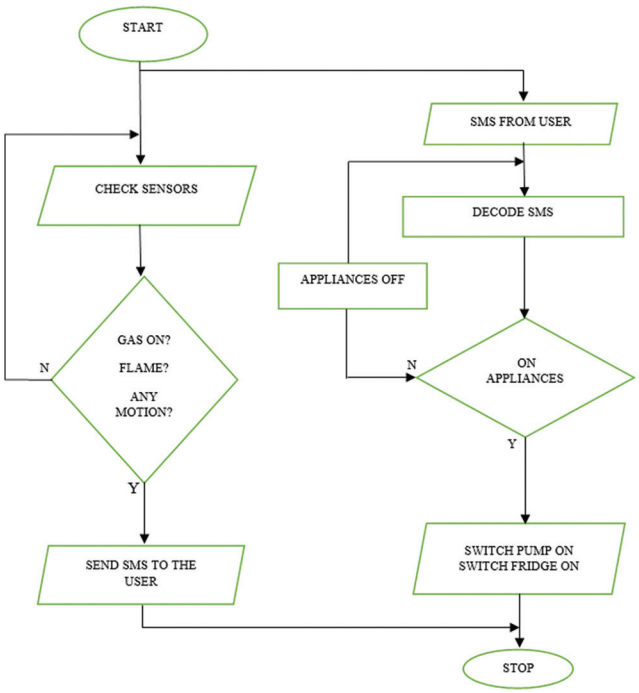

Fig. 3: Flowchart of the proposed smart home system

open contact (relay is not energized) while the contact is normally closed (NC) when there is a closed contact (relay is energized). The model of the relay used in this design is SRD-05VDC-SL-C. It runs on 5V obtained from Arduino (ATMEGA328P). The relay was used to switch smaller currents in a control circuit with a small voltage to get activated received from the ATMEGA328P. Once it is activated, it pulls the contact to make the high voltage circuit. The relay module has six pins in total, three on one side and three on the other. There are three pins on the bottom side: signal, 5V, and ground. These pins were wired into the Arduino. On the other side, the output pins of the 5V relay are NC, C (Common), and NO. The designed system used NO principle of operation of relay to ensure the flow of

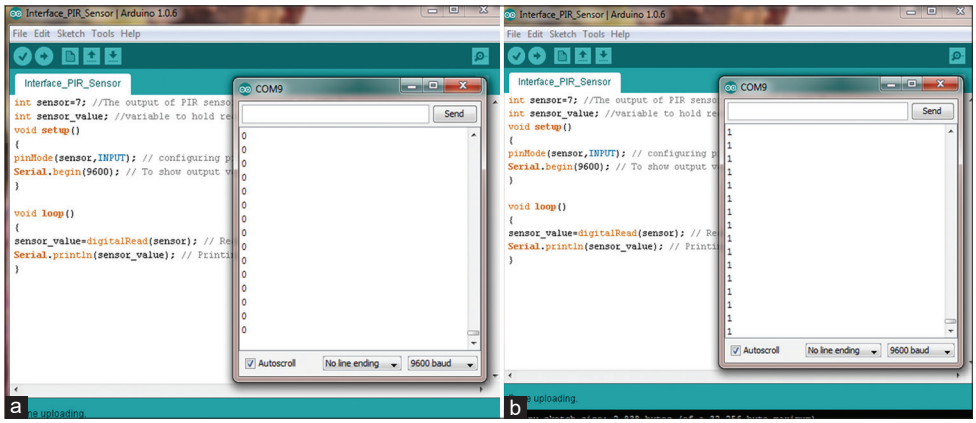

Fig. 4: (a) Simulation of PIR sensor from Arduino IDE when there is no motion inside the range (b) Simulation of PIR sensor from Arduino IDE when motion detected

Fig. 5: Interfaced system with relay

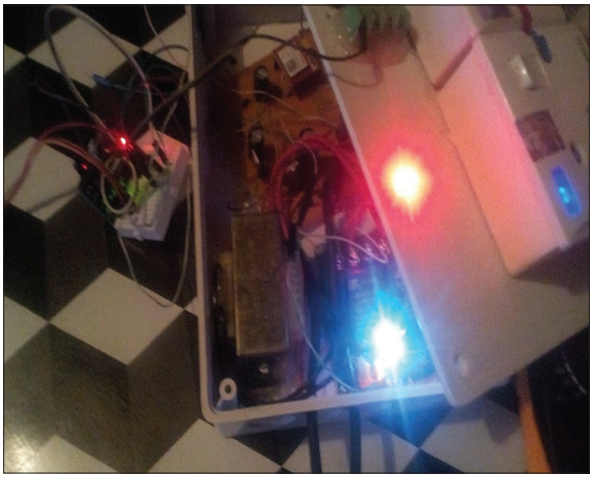

Fig. 6: Interfaced system with relay in OFF mode in ON mode

current only when it is activated. The relay 5V and ground was connected to Arduino 5V and ground pins to achieved 5V operating voltage of relay module. The signal pin of the relay module was connected with the digital pin 9 and 10 of the Arduino to trigger the relay output. Fig. 2 shows interfacing of relay module and relay driver with ATmega328P.

System implementation

Proteus software, version 8.1, was used to simulate the interconnection of the circuit components before transferring the stimulated output into development board. Fig. 2 shows circuit diagram of the simulated interconnection of the ATmega328P microcontroller, PIR sensor, flame sensor, MQ2 sensor and GSM modem, and other miscellaneous components in the Proteus environment. Fig. 3 presents the flowchart of the proposed system.

The software implementation was done using Arduino IDE to write the set of instructions to control the device after which is was compiled and uploaded into the ATmega328P microcontroller. Fig. 4a shows the output of PIR sensor in Arduino serial monitor when there is no motion inside range with value of Zero (0) and Fig. 4b shows the output of PIR sensor in Arduino serial monitor when there is motion detected in range with value of One (1).

On detection of object, the sensor sends signal to the microcontroller which triggers the alarm system to sound repeatedly in an alternating manner through the buzzer. The mobile phone was used as a transmitting medium through which the user sends a code that contains commands and instructions to the second mobile station which is based on a specific area where our control system is located, through GSM network. The received code was sent in AT-command to the GSM module through an SMS. The GSM module converts commands into digital signals and sends it to the microcontroller that is connected to it. The ATMEGA328P then processes the code and performs the necessary operations. The ULN2003 is used to power the relay circuits that switch the various appliances connected to the interface. The gas detector sensor D_0 pin is connected to the analog pin A_1 of the ATMEGA328P microcontroller chip, while the Vcc pin of the sensor is connected to the 5dv supply from the power unit, and also the GND pin is connected to the common ground of the DC power supply.

The PIR sensor was test for motion detection and on detection, an alarm system will be triggered with a repetitive tone that runs 5 times before it stops. The gas detection sensor also on detection of gas leakage sends a signal to the ATMEGA328P which triggers the alarm systems. This tone gives an alternation between two tones that's goes on 5 s after each other and repeatedly for 4 consecutive times. Likewise, the flame sensor also on detection of fire sends a signal to the ATMEGA328P which triggers the alarm systems. This tone gives an alternation between three tones that's goes on 5 s after each other and repeatedly for 3 consecutive times. The interfacing and connection of the proposed system were done using circuit diagram in Fig. 2 and the result of the interfacing is presented in Fig. 5 and Fig. 6.

After all connection and interfacing were made with the microcontroller, the system was package and tested again. A command was sent from a mobile phone to the inserted sim card in the device to switch ON and OFF the sockets using "SOCKETON" to switch ON the relay module attached to the water pump socket rated 15 amps and also "REFON to switch ON the relay module attached to the 13-amp socket to control other home appliances. The complete proposed system is shown in Fig. 7.

Fig. 7: Complete proposed smart home system

Table 1: Performance of the core features of the proposed smart home system

Core feature	Total number of attempts	No of good functional performance	Precision (%)
GSM module	15	14	93.33
PIR sensor	15	13	86.67
Gas sensor	15	13	86.67
Flame sensor	15	15	100
Alarm	15	15	100
Home appliance	15	15	100
		Average	94.44

RESULTS AND DISCUSSION

The designed smart home automation system allows the user to control home appliances from anywhere in the world using GMS module. Text messages were used as a communication channel between the main module and core features which controls and monitors home appliances as well provide security against intruders. All the implemented features of this proposed smart home system are functionally working. The core features of the proposed system consist of GSM module, PIR sensor, gas sensor, flame sensor, and home appliance. The proposed home smart automation system is practically implemented and thus the results are obtained. The performance of each core feature was tested for user functionality after 15 triers as shown in Table 1. The proposed smart home system achieved average precision of 94.44% on all the core features. Precision metric equation is given as:

$$\text{Precision} = \frac{\text{No of good functional performance}}{\text{Total number of attempts}} \quad (1)$$

CONCLUSION

In this research, IoT-based smart home and security system have been designed and implemented using GSM and ATMEGA328p microcontroller. The system provides a low cost home automation system with different sensors incorporated. PIR sensor was used to detect human presence, MQ2 sensor was used to detect gas leakage, and Flame sensor was used to detect presence of fire. The outputs of the sensing devices send SMS through GSM modules and sound is generated by the alarm system that is attached. The system also reduces energy consumption by controlling home appliances. The system had a precision of 94.44%, but in the future work, more sensors could be added to the system to achieve better performance. By incorporating computer vision techniques, too, false alarms caused using PIR sensors to detect intruders could be reduced.

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