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Design and Implementation of Home Automation System Based on Raspberry Pi

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Abstract

This paper presents the design of a centrally controlled Home Automation System based on Raspberry Pi (as a mini-computer) and Arduino UNO (as a microcontroller). The Raspberry Pi acts as a master device that monitors the overall function of the system and the Arduino UNO functions as a slave device that is connected to sensors and some electrical and electronic home appliances to control the appliances based on the data received from the sensors. To establish communication between the devices, the Inter-Integrated Circuit (I^2C) communication is used to control the appliances of more than one room, such that for each additional room to be automated, an Arduino UNO can be added on the I^2C bus for expansion. Each Arduino UNO on the bus has a unique slave address that is used by the Raspberry Pi to send data back and forth to the Raspberry Pi. This system was designed and implemented successfully to control electrical devices throughout the room/house automatically.

1. Introduction

Automation is a technique, method or system of operating or controlling a process by electronic devices with reducing as much human involvement as possible. The fundamental of constituting an automation system for an office or home is increasing day by day with numerous benefits. Enthusiasts, industrialists and researchers are working to build efficient and affordable automatic systems that monitor and control varieties of appliances like lights, fans, HVACs, etc. based on requirements [1]. Automation makes not only an efficient but also an economical use of our daily needs like water, electricity, etc. and it helps reduce wastages [2]. The Internet of Things (IoT) grants both people and things the opportunity to stay connected at any time, any place, with anyone, ideally using any network and (or) service. Automation is just another important application of IoT technologies. It is the monitoring of energy consumption in power plants and controlling of environments in buildings, schools, offices etc., by using different types of sensors and actuators that control lights, temperature, humidity and dampness [3, 4] .

Many home devices now have Wifi technology and can interact with other home devices, smartphone applications or home computers. An alarming point in question is that these devices cannot communicate with each other directly. In doing so, they may require an additional device and an individual application on the smartphone or computer to be controlled [5, 6]. A much better approach is to centralize these devices into one system that controls them all. For instance, one can control the air-conditioning system, lights, microwave, wall sockets, gates and door locks through a web interface or an application on the smartphone or computer, giving the end-user more control of their home, like setting up conditions for when the lights turn on/off. With this all said, home automation can simplify manual operations by reducing human interaction to its minimum [7, 8]. But to acquire or install such a system costs a lot of money, which is the key factor why home automation has not received much demand and attention, and on top of that, the complexity of installation and configuration. Thus, it is essential to make it as cost-effective and easy to configure as possible, compelling people to install it in their homes, offices and schools [9, 10].

One home automation application that is recently trending is the ability to control household appliances based on sensor data using a smartphone application or through the internet (web application). [11] proposed the design and implementation of a home automation system that focuses on the use of ordinary electrical appliances for remote control using Raspberry Pi and relay circuits and does not use expensive IP-based devices which provides control over the appliances via both the local network and remote access. [2] propelled home mechanization framework that utilizes an android application to control and screen the home apparatuses using Internet of Things (IoT) and Raspberry Pi 4 interfaced with numerous sensors that may evaluate temperature and steaminess, light and energy to turn on/off remotely by means of mobile application and web-server [12, 13, 14].

This paper aims to develop a prototype of such product capable of turning on/off light based on a light-dependent resistor (LDR) that measures the light intensity and turning on/off fan based on a passive infrared (PIR) sensor that detects motion, with an emphasis on low cost and open-source configurability. The end goal beyond this paper would be a product that would hopefully enable people to connect many other home devices through wireless connectivity.

1.2 Background

The home automation system design uses Raspberry Pi 2 Model B, Arduino UNO microcontroller, PIR sensor, LDR sensor, LCD screen and relay module. Moreover, the Raspberry Pi 2 Model B uses the Raspbian operating system based on Debian Linux to control and optimize the Raspberry Pi hardware as shown in Figure 1 [15].

Figure 1: Raspberry Pi [15]

The Arduino UNO R3 in Figure 2 is an open-hardware technology coupled with a programming language and an Integrated Development Environment (IDE) based on open-source wiring software. While the Raspberry Pi is a fully functional Linux computer, the Arduino is only a microcontroller [15, 16, 17].

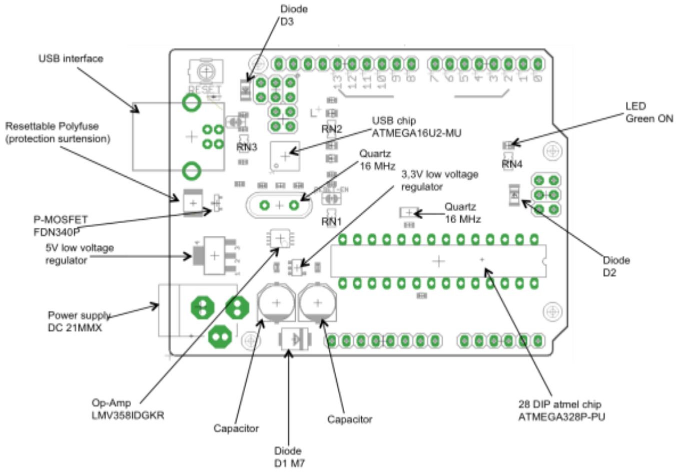

Figure 2: Arduino UNO R3

Figure 3 shows the ATMega328 Microcontroller Chip. It is imperative to think of the microcontroller chip itself as the brain of the board [18].

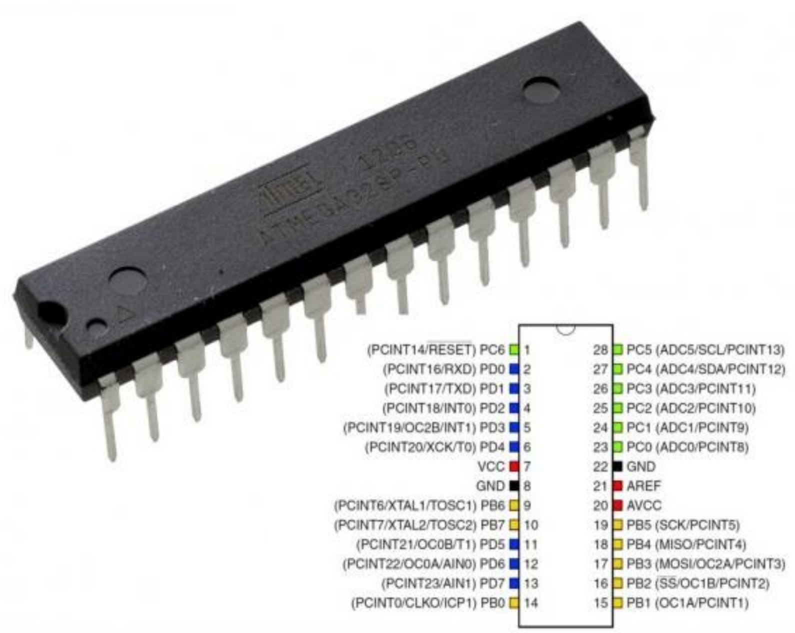

Figure 3: ATMega328 Microcontroller

The Relay Module used in this paper is a 5V-10A 2-channel relay module that is connected to the output pins of the Arduino UNO and then connects the fan and lamp/bulb to the relay to control the voltage of the devices as shown in Figure 4.

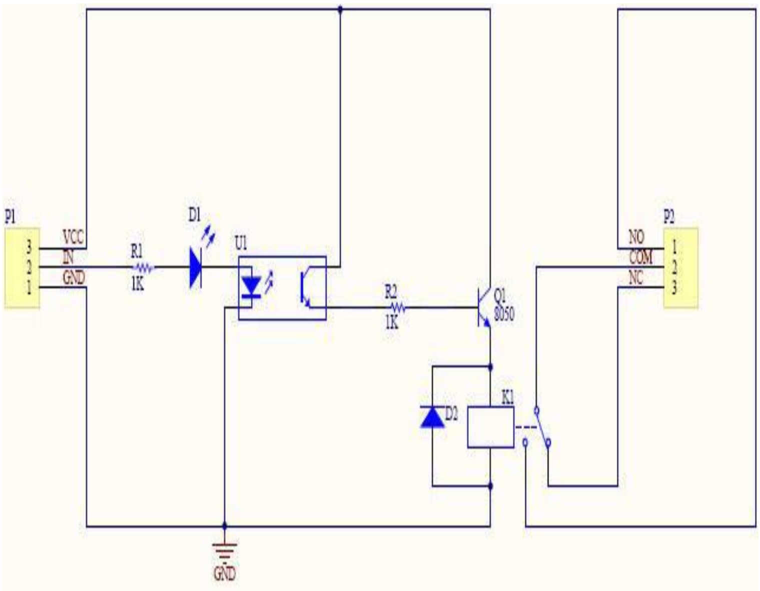

Figure 4: Relay Module

Passive Infrared (PIR) Sensor in Figure 5 is a pyroelectric device that detects motion by measuring changes in the infrared (heat) levels emitted by surrounding objects [19, 20].

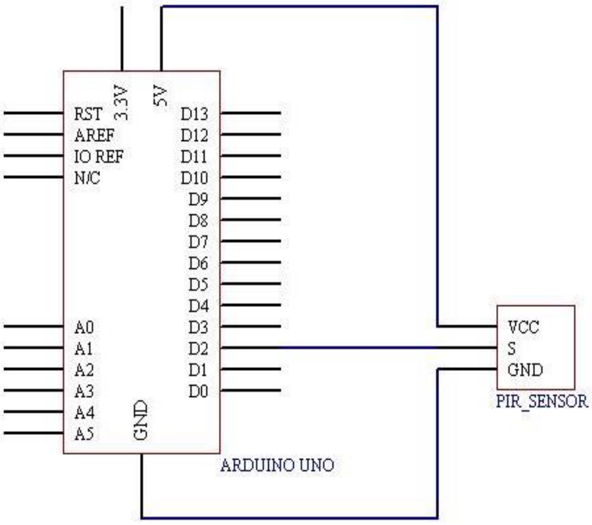

Figure 5: Passive Infrared (PIR).

2. Methodology

These steps include both hardware implementation and software programming as follows:

1. Establishing communication between the Raspberry Pi and the Arduino UNO. Also creating a simple and reliable home automation system using Arduino UNO as a microcontroller that will act as the intermediary between the Raspberry Pi and home devices.

2. The Arduino UNO board will be programmed in such a way that it controls the home appliances based on the values of sensors attached to its input pins.

2.1 Design and Implementation

The system is designed using Raspberry Pi 2 Model B, Arduino UNO microcontroller, PIR sensor, LDR sensor, LCD screen, relay module, portable fan and a bedside lamp. As illustrated in the block diagram in Figure 6, the Raspberry Pi 2 Model B and the Arduino UNO R3 microcontroller communicate via the I^2C communication platform, where the SDA, SCL and GND pins of both devices are interconnected and the LCD screen is connected to the Raspberry Pi 2 Model B via the HDMI cable. The Arduino UNO R3 on the other hand connects to the PIR sensor, LDR sensor and the relay module, where the PIR and LDR sensors send signals back to the Arduino UNO regarding their state and the Arduino uses these signals to control the relay state, which in turn determines the state of the portable fan and bedside lamp connected to it whether they should be switched ‘ON’ or ‘OFF’.

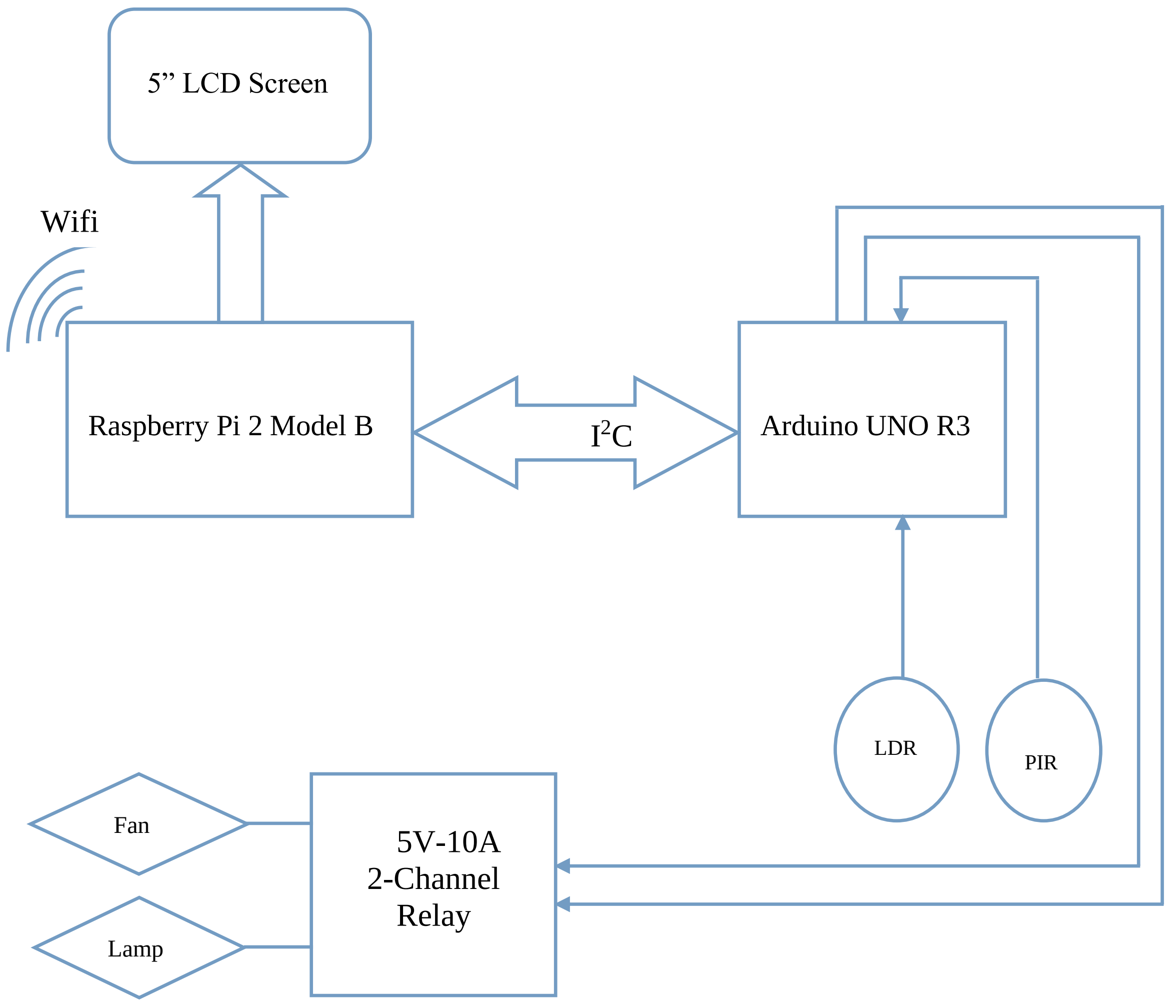

Figure 6: Overall Home Automation System Diagram

The device design comprises a couple of hardware components and a range of system testing at various implementation stages. Figure 7 show the Raspberry Pi 2 Model B Pinout Allocation and figure 8 shows the Arduino UNO R3 Pinout Allocation.

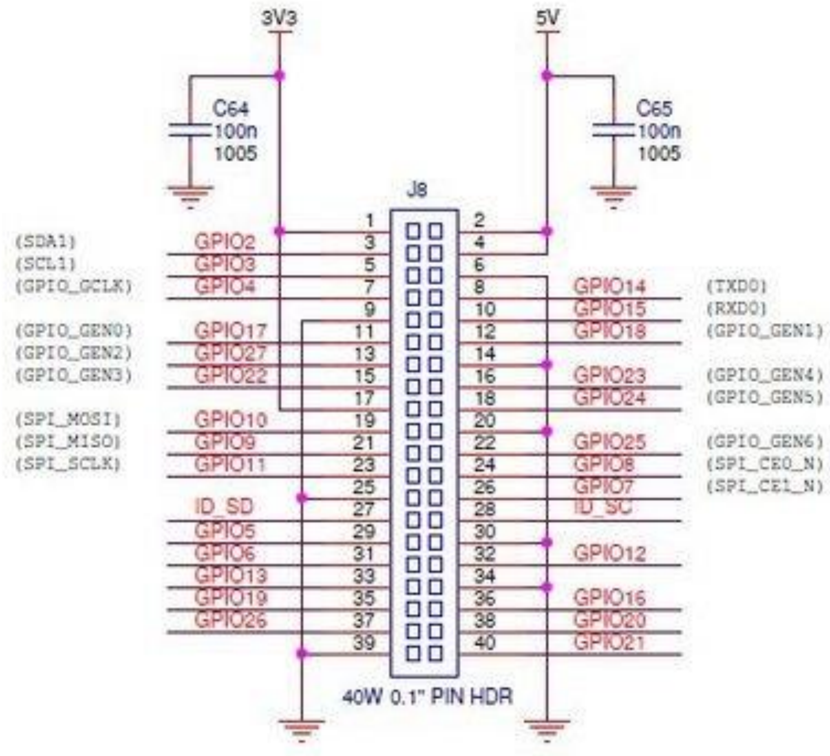

Figure 7: Raspberry Pi 2 Model B Pinout Allocation

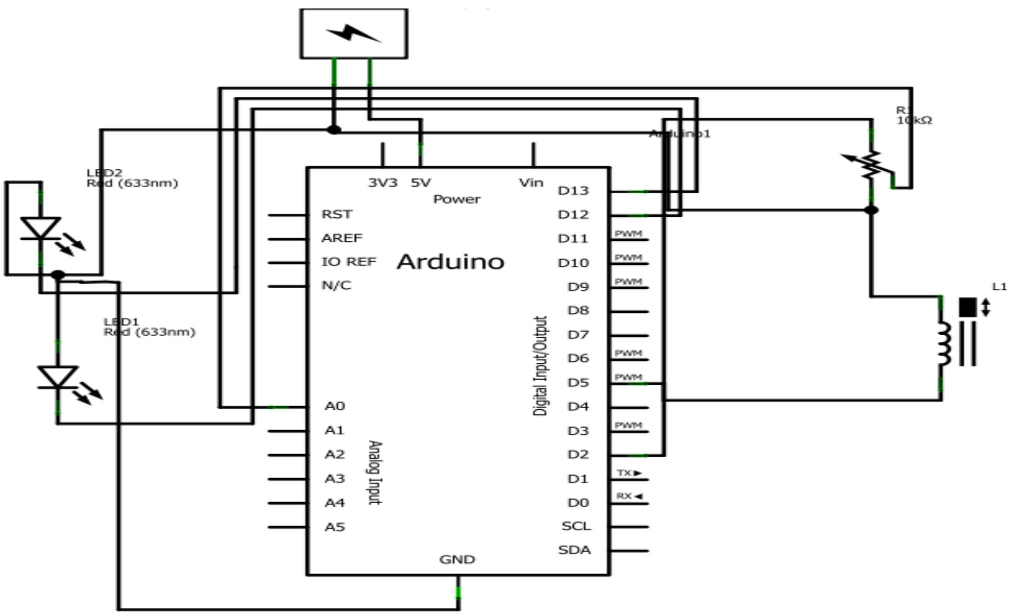

Figure 8: Arduino UNO R3 Pinout Allocation

2.2 Power Supply

The power adaptors of the Raspberry Pi and the LCD screen are connected to a 10A-250V~ mains extension wire to power up the Raspberry Pi and the LCD screen. The Raspberry Pi in turn powers up the Arduino UNO board via a USB cable as shown in Figure 9.

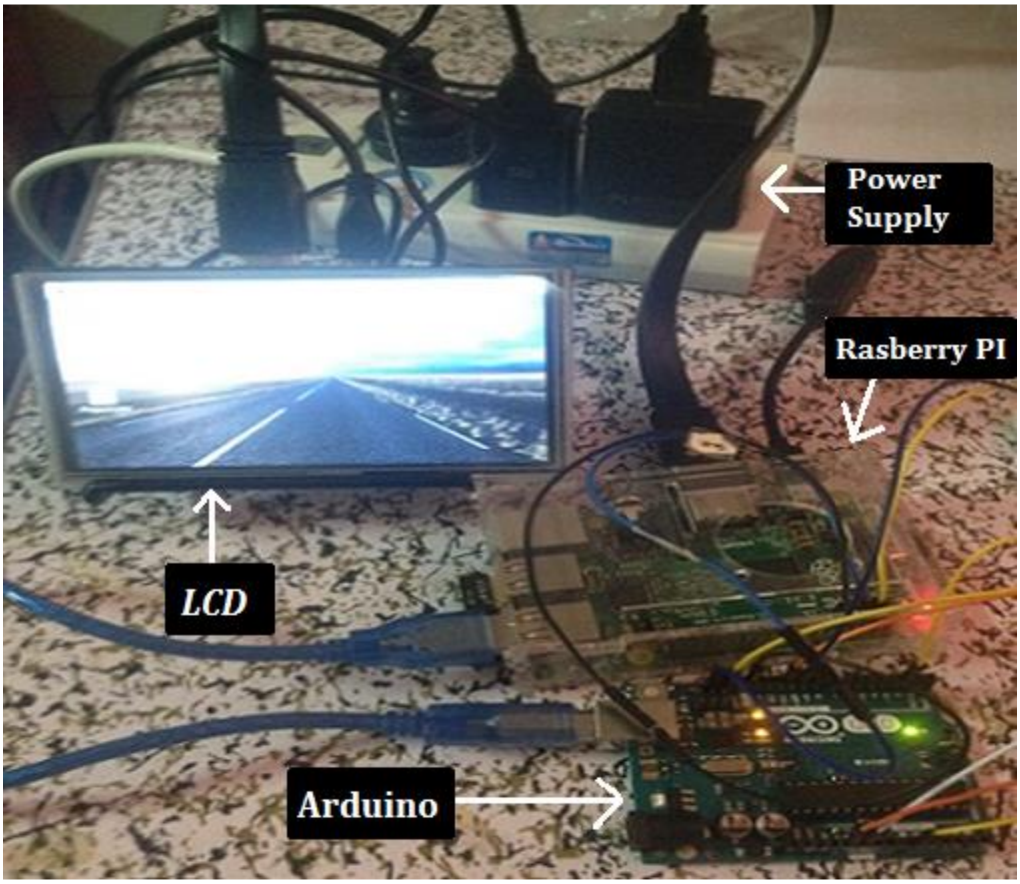

Figure 9: Power Supply

2.3 I²C Communication between Raspberry Pi and Arduino UNO

There are many ways of communication between Raspberry Pi and Arduino UNO, like using a USB cable or serial connection, but I²C communication is chosen because it does not use the serial or USB ports on the Raspberry Pi, rather it is a two-wire protocol that allows up to 128 Arduino slave devices to be connected to the Raspberry Pi via a single bus, linking them directly without the need for a Logic Level Converter. Given the fact that the USB ports on the Raspberry Pi are limited, this is a big advantage. The SDA (Serial Data Line) and SCL (Serial Clock Line) pins are the reserved I²C communication pins on both the Raspberry Pi and the Arduino UNO R3 (refer to devices pinout diagrams above). To connect the Raspberry Pi and Arduino via I²C communication, we simply connect Raspberry Pi's SDA pin to Arduino's SDA pin, Raspberry Pi's SCL pin to Arduino's SCL pin and Raspberry Pi's GND pin to Arduino's GND pin as shown in Figure 10.

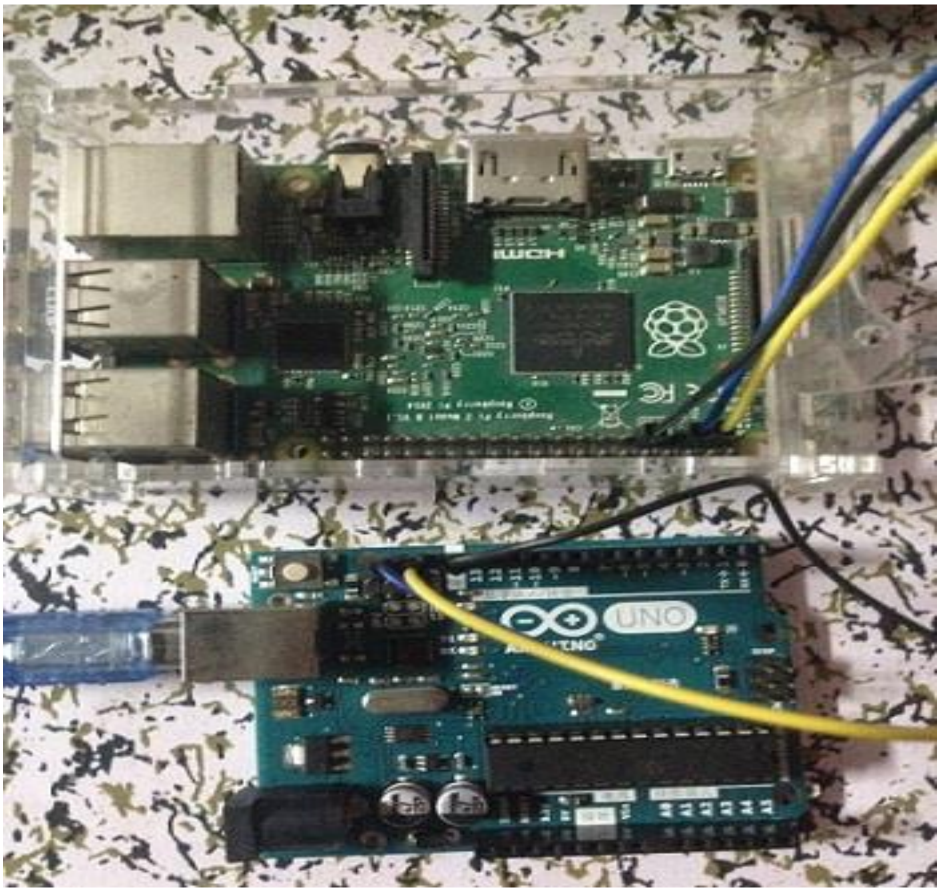

Figure 10: I^2C communication between Raspberry Pi and Arduino

With Raspberry Pi using I^2C communication, we have the advantage to connect single or multiple Arduino boards to it. It would be really useful to have additional input and output pins by combining the Raspberry Pi and Arduino UNO because the Raspberry Pi has only 8 GPIO pins.

3. Result and Discussion

The complete home automation system based on Raspberry Pi and Arduino microcontroller, designed to control home appliances based on sensor data was successfully implemented. Figure 11 shows the overall designed system schematic. The control of lighting in a room was done with other appliances in the room. The designed home automation system was tested several times and endorsed to control any home appliance used in the system, be it the lighting system, air conditioning system, heating system, home entertainment system, and many more home appliances. The proposed design works similarly to a research by Maragatham et al using the Raspberry Pi 4 interfaced with numerous sensors to allow two-way communication between appliances to evaluate temperature and steaminess, light, energy [2]. But this is only possible as long as the maximum power and current rating of the appliance that is to be controlled do not exceed that of the relay used to connect the appliance to the microcontroller.

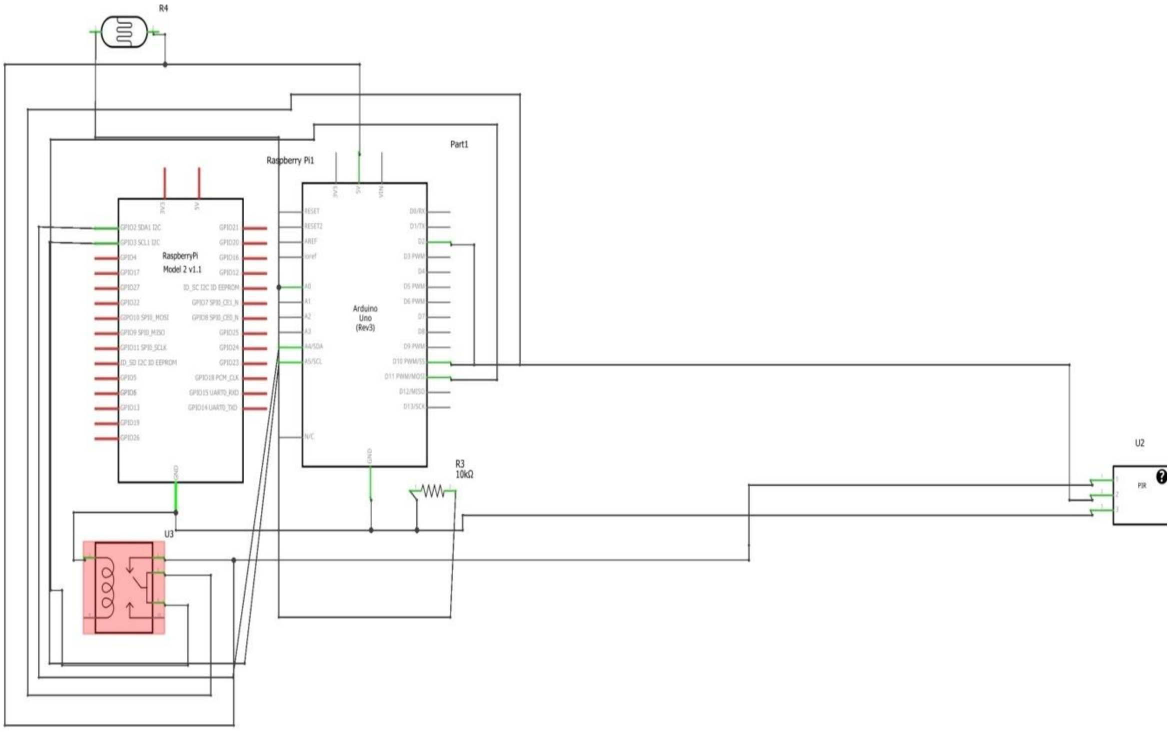

Figure 11: Overall Home Automation System Schematic

This home automation system design can also be implemented via the internet using a web interface, without much change to the design, and yet still be able to control a variety of home appliances remotely. Similar research was also conducted by Ashraf et al that proposed a system using Raspberry Pi to control appliances via both local network and remote access [11]. This same framework can also be extended to utilize an android application to control and screen the home appliances using Raspberry Pi 4 interfaced with numerous sensors that will evaluate temperature, steaminess, light and energy statuses and turn them on/off remotely using a mobile application and web-server as proposed by Javale et al [13]. One of the challenges related to Raspberry Pi's GPIO interface is that it uses a weak CMOS 3V interface. The GPIO pins are exposed to static electricity damage and the I/O pins are 2 to 16mA, which makes them weak. Additionally, GPIO power must be budgeted from the total spare current capacity of 50mA. Using adapter boards overcomes these problems but adds significantly to the cost. This then provides a fertile area for coming up with cheap and effective solutions. A couple of GPIO pins like GPIO pins 2 (SDA) on P1-03 and GPIO 3 (SCL) on P1-05 have a 1.8$k\Omega$ pull-up resistor. This should be considered if you use these for something other than I^2C.

4. Conclusion

The designed home automation system, built from low-cost electronic components like the Raspberry Pi and Arduino was successfully implemented and can be used to individually control various home appliances ranging from lamps, fans, TV sets to the HVAC system and even the entire home lighting system. The electronic hardware components required are so portable and flexible that they can be packaged into a small unnoticeable container and positioned in an unnoticeable location in homes. This design can also be implemented via the internet using a web interface, without much change to the design and yet still be able to control a variety of home appliances remotely. Hence, the complete system design is flexible and reliable.

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