DEVELOPMENT OF SMART ELECTRONIC SYSTEM TO IMPLEMENT SMART HOME

By

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Date Received: 31/12/2020 *Date Revised: 20/01/2021* *Date Accepted: 02/02/2021*

ABSTRACT

Smart homes and home automation are analogue terms used in reference to a wide range of solutions for controlling, monitoring of internal environmental parameters and automating various functions of the home. Deploying novel embedded technology, the smart system is designed, with AVR ATmega 32 microcontroller. The research is specifically focused on the development of a precise and stable system for monitoring and controlling the temperature, light intensity, humidity, human interference, etc. for home automation. The system provides controlling of cooler fan and heaters, measurement of light intensity and controlling of both internal and external lights of garden or strait light, measurement of humidity and domestic gas leakage detection system. A highly precise humidity sensor SY-HS-220, temperature sensor LM 35, LDR, MQ-6, and PIR are employed for this purpose. The signal conditioning circuit is wired with single power supply operated CMOS operational amplifier TLV 274. The firmware is designed in embedded C, using CodeVisionAVR, the Integrated Development Environment (IDE). The designed system is implemented to monitor and control the parameters and the results are interpreted in this paper.

Keywords: AVR ATmega32, Humidity Sensor, Temperature Sensor, MQ-6, PIR.

INTRODUCTION

Nowadays, the concept of smart home plays an innovative and important role in the planning of future models of housing. Regardless of the technology, smart homes present some very exciting opportunities to change the way we live and work, and to reduce energy consumption at the same time. A smart house or smart home is a home that incorporates advanced automation systems to provide the inhabitants with sophisticated monitoring and controlling the various functions. Smart homes use 'home automation' technologies to provide home owners with 'intelligent' feedback and information by monitoring many aspects of a home. Under smart home environment, numerous sensors such as motion detectors, gas leakage detectors, water leakage detector, smoke detectors, temperature controlling, monitoring and controlling of light inside and outside of the house, humidity controlling and monitoring, water level of tank controlling, some medical instrumentation like ECG, pulse oximeter, sugar measurement report send to doctor by using GSM or IoT etc. are deployed. The input from these sensors can be used to alert the owner of any unauthorized intrusion or control home appliances such as lightings. It is also an important factor to ensure the devices being used to operate in very low power consumption so that they would last longer. The system uses to revolutionize the standards of living which could give assurance for user to protect their homes from burglars, thieves and criminals (Cook et al., 2003; Davidoff et al., 2006; Gärtner, 2006; Jahnke et al., 2002; Kidd et al., 1999; Sripan et al., 2012). Therefore, to cater the needs of the smart home, advanced embedded technology is suitable. Moreover, recently, the field of VLSI design and development of embedded system is revolutionary and many technologists are employing this ubiquitous technique for sophisticated instrumentation employed for research and development purpose. It is need of the hour to develop most reliable and intelligent system for measurement of various physical parameters. Out of various parameters such as detection of human interference, temperature, light intensity, gas leakage etc. are considered for present development. Therefore, microcontroller based an embedded system is found to be most reliable, because these are developed using high performance microcontroller. On literature survey, it is found that many investigators have shown the interest in the use of microcontrollers for development of sophisticated instrumentation (Prasad et al., 1972). There are different high performances microcontroller from different vendors (Pawar et al., 2013). Moreover, recently the microcontrollers from AVR family, PIC family, ARM family, etc., of promising characteristics are readily available. In addition to this, the required on chip resources such as ADC, DAC, etc. are also available in these microcontrollers. In short a development of advanced microcontroller based embedded system is the novel field of development of instrumentation for Research and Development application (Patil et al., 2017a; Pawar et al., 2013). Therefore, it is proposed to undertake the project work development of an embedded system for realization of the smart home. The entire hardware is designed with AVR microcontroller and software is designed in the laboratory and results are presented in the paper.

On survey, it is found that the microcontroller based embedded system for sophisticated instrumentation shows tremendous application not only for the smart home applications but also for industrial, medical, office automation and also for need of different purposes (Bhimrao et al., 2013; Patil et al., 2016, 2017b; Pawar et al., 2014). Smart homes and home automation are interchangeable terms used in reference to a wide range of solutions for controlling, monitoring and automating functions in the home. Berg Insight had developed a smart home system, wherein specific App for smart home is developed for mobile phone by which a home is connected always to the mobile phone (Intille, 2006; Tamura et al., 1998). Any problem with the home will be immediately displayed on the mobile. Smart home systems can be grouped into six primary categories: Energy management and climate control systems, security and access control systems, lighting, window and appliance control systems, home appliances, audio-visual and entertainment systems, and healthcare and assisted living systems. Therefore, design of proper electronic system to control the house environmental condition is essential.

The main aim of this research is to investigate requirement of smart home and develop such system for dedicated application. Smart homes and home automation are analogue terms used in reference to a wide range of solutions for controlling, monitoring of internal environmental parameters and automating various functions of the home. The research is specifically focused on the development of a precise and stable system for monitoring and controlling of the temperature, light intensity, humidity, gas leakage detection, human interference etc. to realize home automation. However, the project work is of development of an embedded system for measurement of temperature and controlling of cooler fan and heaters, measurement of light intensity and controlling of both internal and external lights, measurement of humidity and domestic gas leakage detection system. The microcontroller AVR ATmega32 will be employed. Hardware of the system will be designed in our laboratory. A smart sensor such as LM35, LDR, SY-HS-220, MQ-6, and PIR will be employed. Analog part of the circuit will be properly designed. The data acquisition systems, display unit, relay driver unit will be designed using sophisticated components. The software required to synchronize the operation of the On-chip resources will be developed in Code Vision AVR. The designed system will be implemented for measurement and controlling the parameters and results will be interpreted.

1. Hardware

The present work emphasizes the design of microcontroller based embedded system for dedicated application. Therefore, it comprises both hardware and software. The hardware of the present system is designed about AVRAtmega32. Microcontroller is used for realizing smart home applications. The details regarding designing aspect of each part of hardware are described and classified thorough block diagram and circuit design.

2. Block Diagram

The entire system of the present hardware is depicted in Figure 1. As shown in Figure 1, the system consists of various stages of sensing, signal processing, microcontroller and the control unit as well.

3. Circuit Design

The circuit designed for this project is depicted in Figure 2. The circuit consists of following major sections.

- Microcontroller AVR ATmega32
- Transducer Interface section
- Temperature sensor LM 35
- Light dependent resistor (LDR)
- Humidity sensor module (SY-HS-220)
- LPG leakage sensor MQ-6
- Motion Detection Sensor PIR
- Signal conditioner section
- Display Unit
- Control unit (Relay and switching circuit)
- In System Program Unit (ISP)
- Power Supply unit

The details regarding designing of each of above stage is explained in the following points.

3.1 The AVR ATmega32 Microcontroller

There is need for high speed and low clock frequency operated microcontroller. This need is completed by the use of AVR microcontroller. It has wide range of micro-controller with large variant. However, the AVRAtmega32L, which fulfills the need of present embedded system, is used in this project.

3.2 Temperature Sensor LM35

The LM35 series are precision integrated circuit temperature sensors, whose output voltage is linearly proportional to the

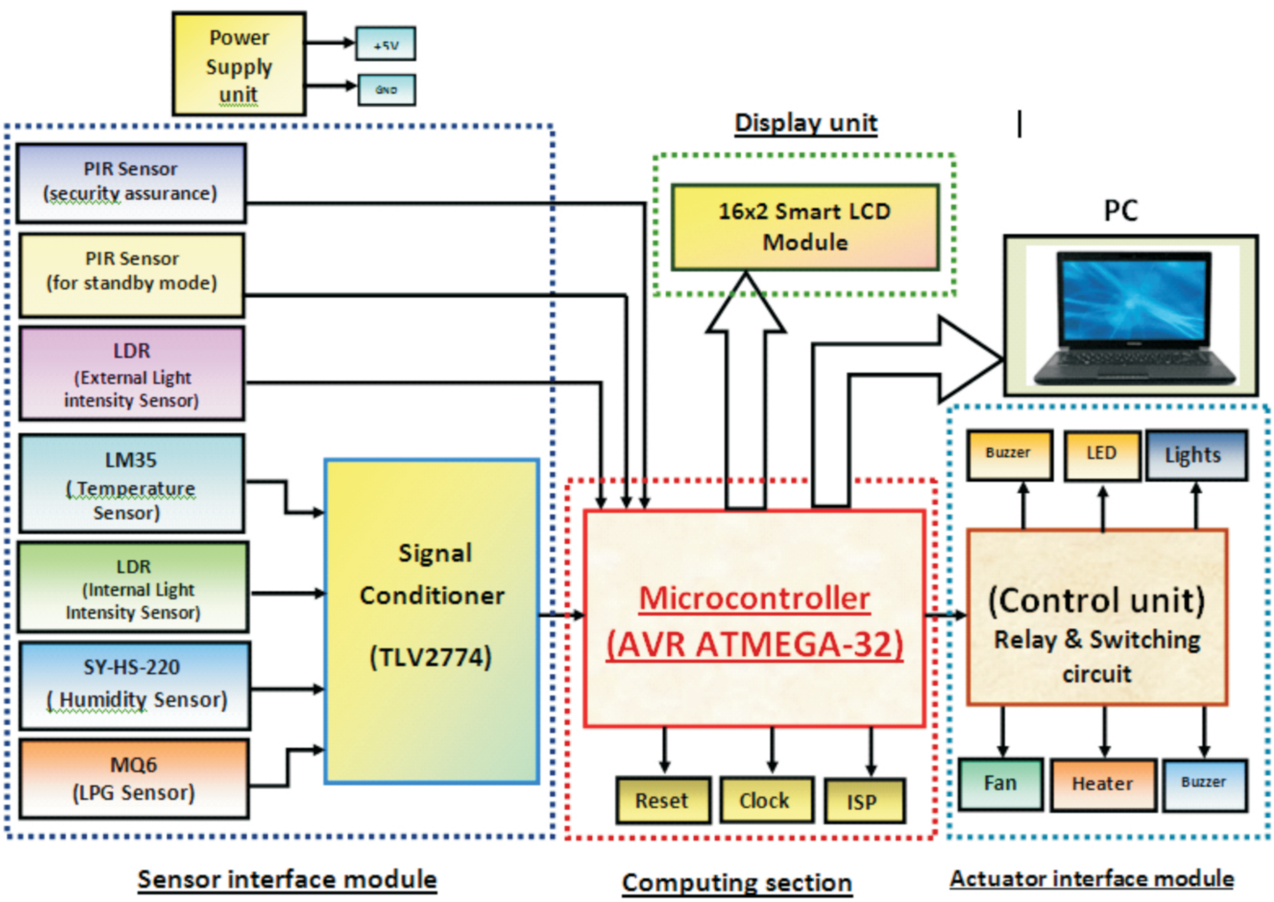

Figure 1. Hardware of the System

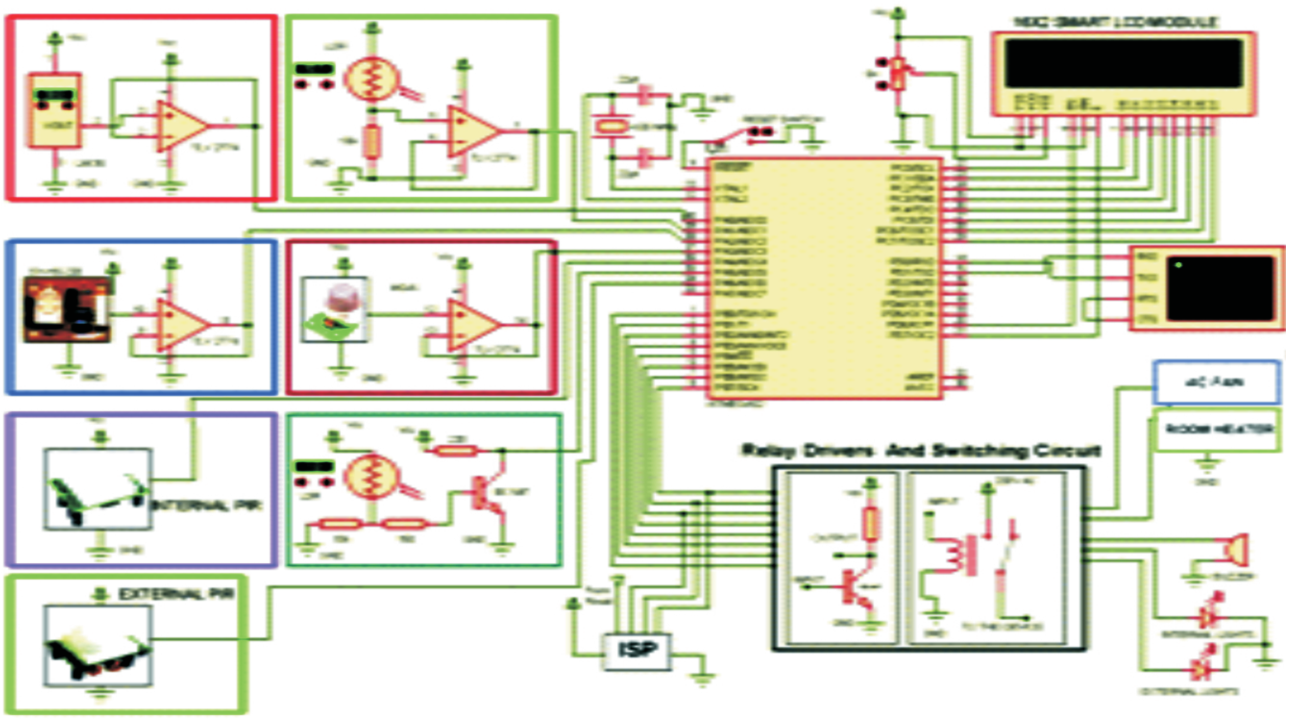

Figure 2. The Circuit Design

Celsius (Centigrade) temperature. The LM35 thus has an advantage over linear temperature sensors calibrated in degree Celsius, as the user is not required to subtract a large constant voltage from its output to obtain convenient Centigrade scaling. The LM35 does not require any external calibration or trimming to provide typical accuracies of ±1⁄4 °C at room temperature and ±3⁄4 °C over a full −55 to +150 °C temperature range. It exhibits good linearity over wide temperature range and provides temperature dependent emf with 10 mV/°C, temperature coefficient. Low cost is assured by trimming and calibration at the wafer level. The LM35's low output impedance, linear output, and precise inherent calibration make interfacing to readout or control circuitry easy.

3.3 Light Dependent Resistor (LDR)

The Light Dependent Resistors (LDR) are used for sensing the light intensity of the room and control the electric bulb or lamps. The LDR is also known as a photo resistor. It is a device whose resistivity is a function of the incident electromagnetic radiation. Hence, they are light sensitive devices. Circuit design for light dependent resistor is shown in Figure 3. A light dependent resistor works on the principle of photo conductivity. Photo conductivity is an optical phenomenon in which the materials conductivity (Hence resistivity) reduces when light is absorbed by the material. When light incident on the device is more, more current starts flowing and hence it is said that the resistance of the device decreases and increases in the dark.

3.4 The Humidity Sensor (SY-HS-220)

Humidity affects clothes, food, antic piece, metals, etc. Therefore, it is essential to precisely measure and control the humidity of the environment. It requires proper humidity sensor. There are number of humidity sensors based on

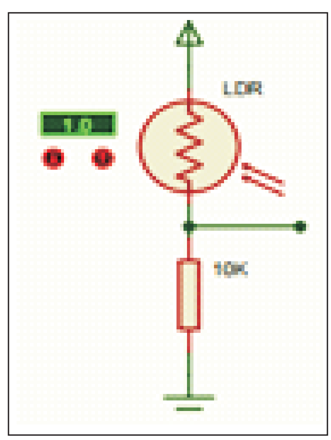

Figure 3. Circuit Design for LDR

different principles of operations, variations in the design, variations in the characteristics and availability of on chip intregrability. However, the humidity sensor SY-HS-220 has been opted for the system under present design as shown in Figure 4. The humidity sensor used in this system is highly precise and reliable. It provides DC voltage depending upon humidity of the surrounding in RH%. This work with +5 Volt power supply and the typical current consumption is less than 3 mA. The operating humidity range is 30% RH to 90% RH. The standard DC output voltage provided at 25 °C is 1980 mV. The accuracy is ± 5% RH at 25 °C. As shown in the Figure 5, it provides three pins recognized as B, W and R. The pin labeled W provides the DC output voltage, where as the pin labeled B is ground. The VCC of +5 V is applied at the pin R. The humidity dependent voltage is obtained and subjected for further processing.

3.5 LPG Leakage Sensor (MQ-6)

Sensitive material of MQ-6 gas sensor is SnO_2, which has lower conductivity in clean air. When the target combustible gas exit, the sensor's conductivity is more higher along with the gas concentration rising. Sensor composed by micro Al_2O_3 ceramic tube, Tin dioxide (SnO_2) sensitive layer, measuring electrode and heater are fixed into a crust made by plastic and stainless steel net. The heater provides necessary work conditions for work of sensitive components. The enveloped MQ-6 have 6 pin, 4 of them are used to fetch signals, and other 2 are used for providing heating current as shown in Figure 5. MQ-6 gas sensor has high sensitity to Propane, Butane and LPG, and also respond to Natural gas. The sensor could be used to

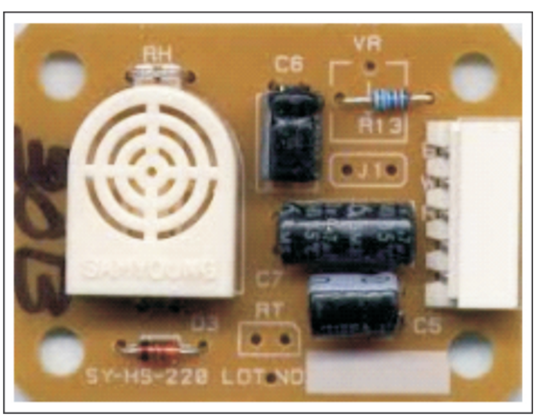

Figure 4. SY-HS-220 Humidity Sensor

Figure 5. MQ-6 LPG Gas Sensor

detect different combustible gas, especially Methane, due to its low cost and suitability for different application. LPG leakage sensor MQ-6 is used for detection of leakage of domestic gas and a buzzer is actuated for indication of leakage.

3.6 PIR Sensor

The PIR sensors shown in Figure 6 allows to sense motion, almost always used to detect whether a living body, animal in particular undergoes any kind of movement. They are small, inexpensive, low-power, easy to use and don't wear out. For that reason they are commonly found in appliances and gadgets used in homes or business campuses. They are often referred to as PIR, "Passive Infrared", "Pyroelectric", or "IR motion" sensors. PIRs are basically made of a pyroelectric sensor as in Figure 6, which can detect levels of infrared radiation. Here two PIR

Figure 6. The PIR Sensors

sensors are used for the project work. One for security purpose and other for implementing of standby mode for smart home.

4. The Smart LCD

The electronic system, has to be designed for smart home. Therefore, measurement of physical parameters in house, always needs a proper alphanumeric display to represent the parameters in real engineering unit. For this purpose, the Hitachi make intelligent LCD has been employed.

5. Control Unit

As per the objectives of the project work, the monitoring and controlling of various environmental parameters inside and outside the house and also to ensure alarming because of any intruder, the system is designed. Along with the measurement, the controlling of typical parameters is also essential. As depicted in the schematic of the hardware, a specific unit has been designed to ensure controlling action called as a Control Unit. The control unit of the system comprises the actuators which are software controlled. The circuit diagram for control unit is shown in Figure 2. The control unit is designed for following purpose.

- To control temperature of the in house environment.
- To control ON-OFF of internal lamps automatically.
- To control the operation of the street light.
- To ensure safety and security by alarm indication.

The control unit is developed by employing relay and switching circuits for controlling the AC home appliances and DC components such as buzzers, LEDs, etc. Control unit consist of two parts Relay drivers and Switching circuits.

6. Circuit Operation

The present system is developed for detection as well as controlling of home environment. Particularly monitoring and controlling of temperature, light intensity and humidity, gas leakage detection, external light control and theft detection. LM 35, LDR and SY-HS-220 sensor is deployed for this purpose of sensing of temperature, light intensity and humidity respectively. The temperature sensor senses the temperature of in house environment and converts it into DC voltage. Then signal is given to operational amplifier. The output of first operational amplifier TLV2774 is given to the microcontroller pin 40. Microcontroller read the analog voltage and digitalizes the same with use of on-chip ADC of the 10 bit resolution. System is calibrated for temperature (in $^{\circ}$C) using standard digital thermometer DM-97. Moreover, set point for cooler fan is fixed at 31 $^{\circ}$C and if the room temperature exceeds that temperature then the fan is automatically ON and remains OFF if it is below the set point. Similarly, set point for heater is fixed at 27 $^{\circ}$C and if the room temperature decrease below this set point. The heater is automatically ON condition if temperature fall 23 ^{0}C and remains ON if it is above the set point 28 $^{\circ}$C. The relay driver circuit is connected to pin number 1 and 2 of AVR microcontroller to control the fan and heater respectively. Another important parameter is light intensity control for smart home. Present development is the model for realization of the smart home. Therefore, the LED bulbs are controlled by employing a LDR as a light intensity sensor in the house. The output voltage from LDR is given to second operational amplifier of TLV2774 and given to the second channel of AVR microcontroller pin 39. This is used to amplify the analog signal from LDR. On chip ADC of AVR ATmega32 converts this analog signal to digital and this digital signal is processed according to the software embedded into the microcontroller. Further, system is calibrated for light intensity in LUX unit using a standard LUX meter. A set point is fixed at 50 LUX and if light intensity decreases below the set point value, automatically LED bulbs are made ON otherwise they remain in OFF condition. By using such techniques internal light intensity can be controlled as well as electricity can be also conserved. Third important parameter is the humidity of internal environment of the smart home. Humidity sensor SY-HS-220 is used for measurement of humidity of internal environment. Analog output voltage of the humidity sensor is given to the third operational amplifier of TLV2774 and given to the third channel of ADC at pin number 38 of AVR ATmega 32. The smart LCD module 16x2 is deployed for displaying the temperature, light intensity and humidity of internal environment of the home. Safety is also an important aspect of Smart home, so to ensure safety in terms of LPG explosion, LPG leakage detection is implemented in the home. MQ-6 LPG leakage detection sensor is used for this purpose. Output analog voltage of MQ-6 varies with respect to the LPG gas sensed by it. This analog voltage is given to the fourth operational amplifier of TLV2774, and particular output of TLV2774 is given to the fourth channel of on-chip ADC of AVR microcontroller at pin 37. The gain of all four amplifiers is unity. When LPG leakage sensor senses LPG leakage, automatically buzzer at pin number 6 of microcontroller starts sounding to indicate the leakage. Due to such indication, user of the smart home is made alert to avoid the accidents. Protection of home from thieves and burglars is rather more important aspect in a smart home system. PIR sensor module is used as a human interception sensor for security assurance purpose. Digital output signal of PIR sensor module is given to pin 37 of the microcontroller. A buzzer alert which is connected at pin 8 of the microcontroller is made when the PIR sensor senses any person in its sensing range. LDR is used for detecting day and night condition. Digital output of LDR is given to pin number 35 of the microcontroller. Street lights, garden lights are controlled according to the detected condition. Energy consumption is a growing concept in the present era. Considering the need of energy consumption, a standby mode is implemented for the system. A PIR sensor is deployed for this purpose. If the sensor senses any human presence in the room then the system is ON and all functions are carried out normally and if human presence is not detected by the sensor then the system goes in standby mode within 10 seconds and all the home appliances are automatically made off to save the energy. Street light or garden lights control is also done by the system to ensure the control over external appliances. The read data serially to PC facility is also provided. Here, the software performs the job of the data processing and set point values.

7. Software Development

Accordingly, the system is designed using both hardware and software equally important for embedded system. Development of software, oftenly called as "firmware" is rather tedious job. While developing software, microcontroller has to play with the physical world (Pawar et al., 2013; Ladgaonkar, 2011). Various types of analog signals from sensors and data acquisition system must be displayed on display unit, wherein either computer monitor or LCD is used. While designing software one should convert these data automatically into engineering units. However, this tedious job can be accomplished with use of proper IDE. The Code Vision AVR IDE is used for development of software for present system. The software for present embedded system is developed in embedded C and described. The main flowchart of the software is described in Figure 7 and 8. The measure of the parameters of house, and analog data of temperature sensor LM35 is given to channel 1 of ADC, analog data of LDR is given to channel 2, analog data of humidity sensor SY-HS-220 is given to channel 3, where as analog data of LPG leakage detection sensor MQ-6 is given to channel 4 of ADC. The digital data from other sensors is also processed in the main function of the software. Therefore, in the beginning temperature data is processed followed by the light intensity data and humidity data and similarly

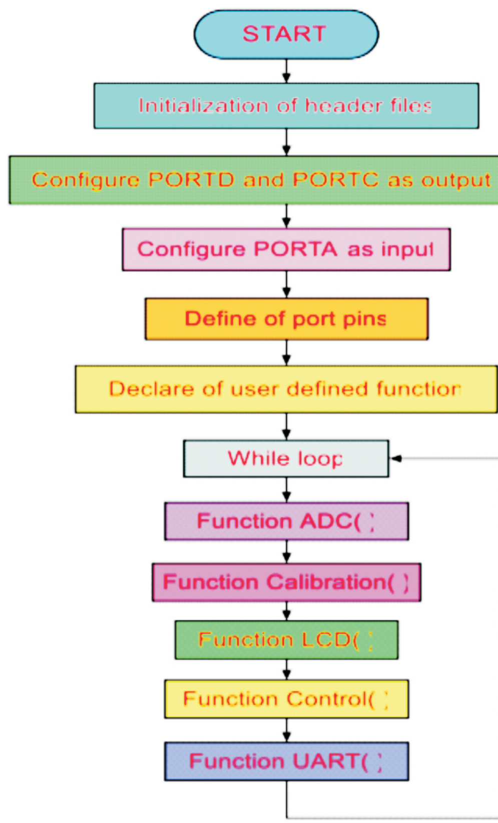

Figure 7. Main Program Flowchart

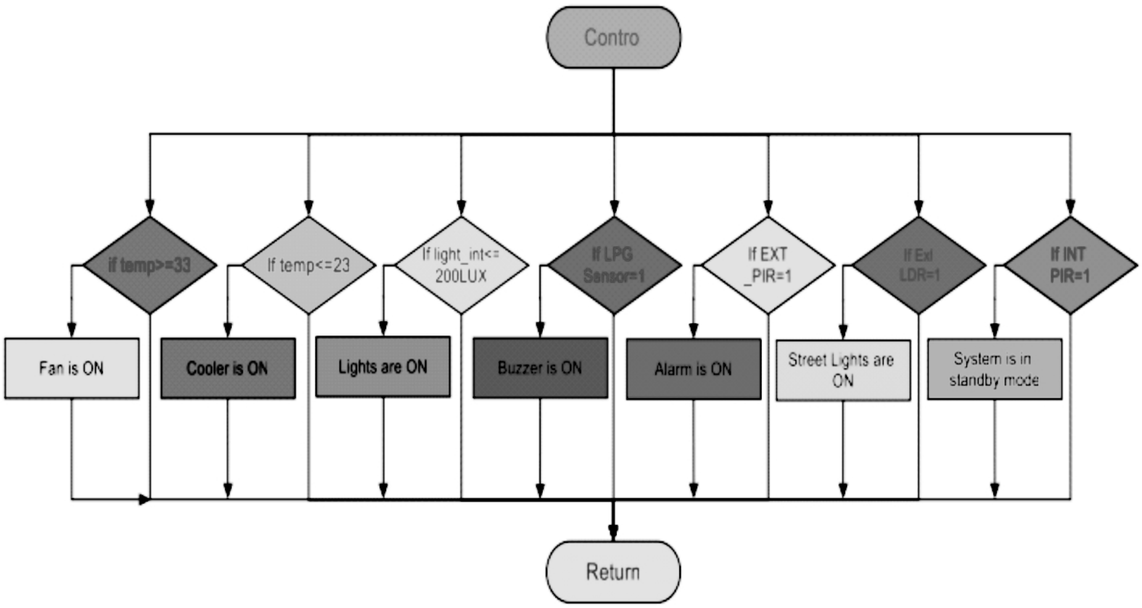

Figure 8. Flowchart of Control Function

the data from other sensor is processed. Readings of temperature, light intensity and humidity are displayed simultaneously on 16x2 LCD display while the analog as well as digital data from other sensors is processed so as to actuate the relays and switching circuits for their respective applications. At the same time microcontroller checks the upper limit and lower limit of temperature and light intensity also control the relay driver circuit using PORT B.

8. Calibration of the System

The system is subjected to the process of calibration. The process of regression is adopted for calibration of the engineering units. In present system, the parameters such as temperature, humidity, light intensity, and leakages of LPG gas etc. are emphasized. Therefore, the system is calibrated to the respective units and discussed through following points.

8.1 Experimental Setup for Calibration of the System for Temperature

The system under investigation interact with the physical world, read the signal and process into real units. Hence, it is essential to calibrate the system to temperature scale, light intensity scale and humidity scale. Therefore, the system is standardized, in the beginning, and then implemented for which it has been designed.

The experimental arrangement for temperature measurement is shown in Figure 9. As shown in the Figure 9, DM-97, a standard temperature measurement device is used for calibration purpose. Temperature sensor LM35 of the system and a thermocouple sensor of DM -97 is placed in the controlled environment. The temperature from 25 ^{0}C to 95 ^{0}C and temperature (t), dependent emf (VT) shown by the system and displayed by DM-97 are recorded. The temperature dependent emf VT is plotted against applied temperature (t) and depicted in Figure 6. From Figure 10, it is found that, the system exhibit linear relationship with the

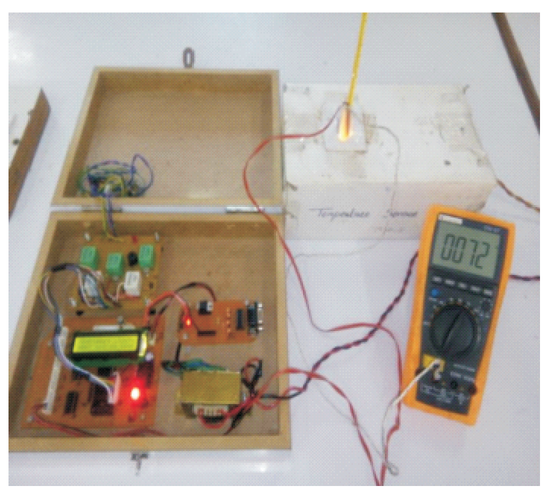

Figure 9. Calibration of System for Temperature

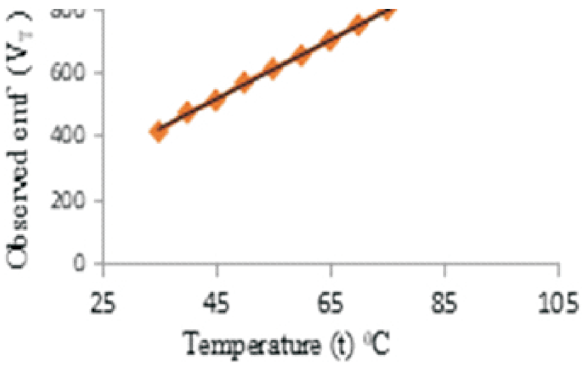

Figure 10. Graph of Observed emf (V_T) Against Applied Temperature (t)

process value (t). On standard regression process, the empirical relation obtained is

$$VT = 8.187x + 33.05 \qquad (1)$$

The offset of about 33.05 mV is observed, which may be due to analog component. However, the offset is compensated while employing the relation in embedded software which produced output in real unit, the degree Celsius.

8.2 Experimental Setup for Calibration of the System for Humidity in % RH

Similarly, the system is also extended to obtain humidity in relative units. For calibration, in the beginning a humidity dependent voltage is measured for entire range from room temperature conditions to the condensation of water. The voltages are measured up to saturation point. Experimental setup is shown in Figure 11. For calibration, the humidity chamber, model Gayatri Scientific Ltd. from Mumbai has been used. The humidity from 30 RH% to 90 RH% with accuracy of 1 RH% is applied. The temperature range from 25 °C to 95 °C can be controlled. The temperature as well as humidity of the chamber is controlled by using PID techniques. Keeping temperature constant, the humidity applied to sensor is varied between 30 RH% to 90 RH%. The system shows readings on its display in millivolt with respect to the applied humidity. The data regarding emf is collected and used for calibration. The emf observed is plotted against humidity in %RH. The graph of emf against humidity in RH% is shown in Figure 12. Using least square fitting process of data analyzed and fitted to the straight line. The expression resulted from curve fitting

Figure 11. Experimental Setup Calibration of System for Humidity

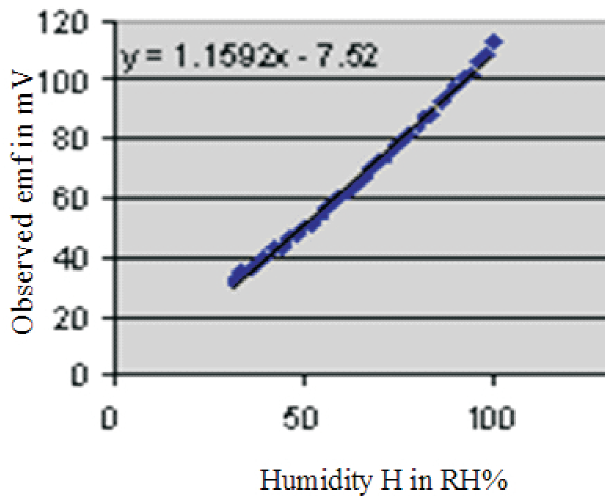

Figure 12. Graph of Observed emf (mV) Against Applied Humidity in RH%

procedure is,

$$Humidity\ RH\% = (VRH + 7.52)/1.16 \qquad (2)$$

This expression is used for further calculation. The expression is solved during firmware execution. The system is precisely calibrated and it shows accurate reading of humidity in RH%.

8.3 Experimental Setup for Calibration of the System for Light Intensity in LUX

As per the objective, system is designed for smart home applications along with controlling internal lights in the home to provide sufficient amount of light intensity, the system should be calibrated for displaying light intensity in LUX. For calibration, the system with light intensity sensor along with the LUX meter is placed in open sunlight during day time so the sun rays directly fall on both the sensors as shown in Figure 13. Readings on displays of both the system and the LUX meter can be recorded. The system shows readings in millivolt while the LUX meter shows readings in LUX units. Readings shown by the system are recorded for respective readings shown by the LUX meter. A graph is plotted to obtain a curve for analog voltage (in millivolt) against the light intensity (in LUX). By using least square fitting process an Equation is obtained for the curve as,

$$LI = 70847v - 11398 \qquad (3)$$

Equation (3) is used in the software to display the values of light intensity in LUX unit.

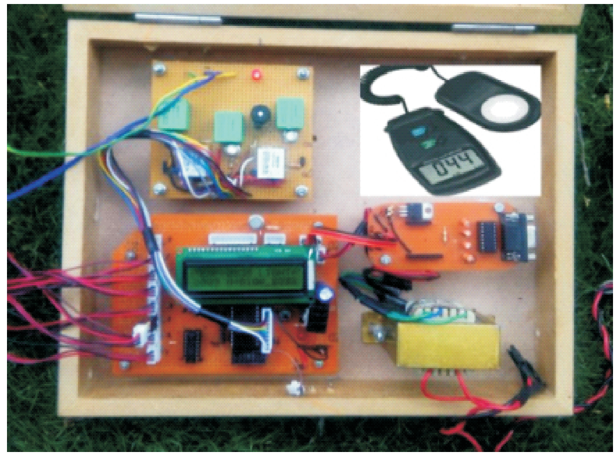

Figure 13. Experimental Setup for Calibration of System for Light Intensity

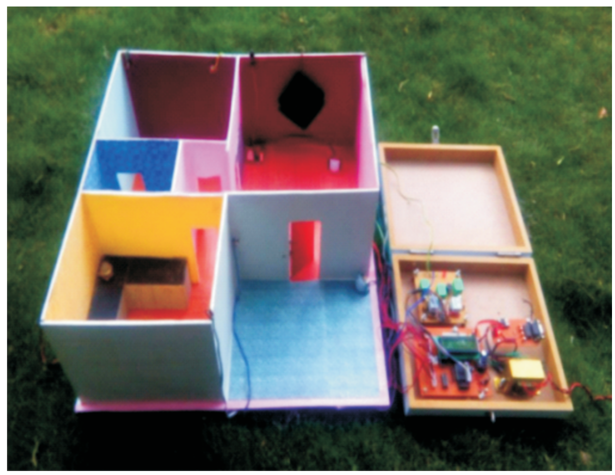

Figure 14. Photograph of Realization of Smart Home

9. Implementation of the System

An embedded system is designed for smart home applications. Hence it includes monitoring of humidity as well as controlling of internal environmental parameters such as temperature and light intensity and also the system detects domestic gas leakage, controls external lights and detects human presence in the home. It is implemented for the purpose it has been designed. To realize the themes of the Smart Home, in the beginning a model of home is constructed and photograph of the model of the Home is depicted in Figure 14. The street light system, LPG cylinder and other kitchen wares are symbolically presented in the model. The street light assembly is installed in the area in front of the entrance of the home. The Entrance is also made smart with installation of the PIR sensor to detect the movement of the intruder if any. It is installed at the place, from which the area covered is wide. The LPG gas sensor is installed in the kitchen to detect the leakages of the LPG gas. Other monitoring and controlling part of the system are typical locations within the smart home. All sensing and controlling operations are enabled simultaneously, smartness of the home is realized by observing values of various parameters on the display unit. After successful verification of system implemented in real home, the realization of smart home has been done.

Conclusion

It can be concluded that, the system is successfully monitoring, control temperature and light intensity using ON/OFF control loop. Also the system monitors the humidity, detects domestic gas leakage, controls external lights and human presence inside the house as well as outside the house. The system is calibrated and standardized with the operating values. It depicts preciseness and reliability in the performance. From observations it can be concluded that, present system realizes the concept of Smart Home.

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