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Designing of Embedded System for Realization of Smart Home

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ABSTRACT

Nowadays, the concept of Smart Homes has become pivotal in the design of future housing models focused on care. Irrespective of the technology involved, smart homes offer exciting possibilities to transform our living and working environments while also reducing energy consumption. A smart home, also known as a smart house, integrates advanced automation systems that allow residents to monitor and control various functions of the building efficiently. These homes employ 'home automation' technologies to deliver 'intelligent' feedback and information by overseeing multiple aspects of the household.

In a smart home setup, various sensors such as motion detectors, smoke detectors, water leakage detectors, gas leakage detectors, temperature controllers, light monitors, and humidity controllers are installed. The data from these sensors can alert the homeowner about any unauthorized intrusions and manage home appliances like lighting. It is crucial to ensure that these devices operate on very low power consumption to enhance their longevity. This system is designed to revolutionize living standards, providing users with the assurance of protecting their homes from burglars, thieves, and other criminal activities. Consequently, advanced embedded technology is well-suited to meet the needs of smart homes.

Keywords: Temperature sensor, Humidity sensor, LPG Sensor, LDR, Motion Sensor, Signal Conditioner, Microcontroller.

I. INTRODUCTION

The field of VLSI design and the development of embedded systems have seen revolutionary advancements, with many technologists leveraging this pervasive technique for sophisticated instrumentation in research and development. It is essential to develop highly reliable and intelligent systems for measuring various physical parameters. Key parameters for the current development include detecting human interference, temperature, light intensity and gas leakage. A microcontroller-based embedded system has proven to be highly reliable due to its foundation on high-performance microcontrollers.

A literature survey reveals significant interest in using microcontrollers for developing advanced instrumentation. There are various high-performance microcontrollers available from different vendors. While microcontrollers from the MCS51 family can be used for such system development, their limitations, such as current sinking and sourcing levels and on-chip RAM and flash ROM capacity, restrict their use in sophisticated embedded systems. However, microcontrollers from the AVR, PIC, and ARM families, which offer promising characteristics, are readily available and come with on-chip resources like ADC and DAC.

Developing advanced microcontroller-based embedded systems is an innovative area in instrumentation for R&D applications. Thus, the proposed project aims to develop an embedded system for realizing the concept of a smart home. This project focuses on creating a microcontroller-based embedded system for specific applications, such as measuring temperature and light intensity and detecting other critical parameters [1, 2], to support smart home functionality. This paper presents the features of an embedded system and its application spectrum, followed by a detailed study of the architectural aspects of the AVR microcontroller used in the design.

Hardware:

The research work is carried out for home automation deploying AVR microcontroller based embedded system for dedicated application. Therefore, it comprises both hardware & software. On survey, it is found that the microcontroller based embedded system for sophisticated instrumentation shows tremendous applications not only for the smart home, but also for industrial, medical, agriculture, office automation and also for different purposes [3]. 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 had developed a smart home system, wherein specific app is developed for mobile phone by which a home is always connected to the mobile phone [4, 5]. 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 [6-7]. Therefore, design of proper electronic system to control the house environmental condition is essential [8]. The deployment of HVAC is inevitable.

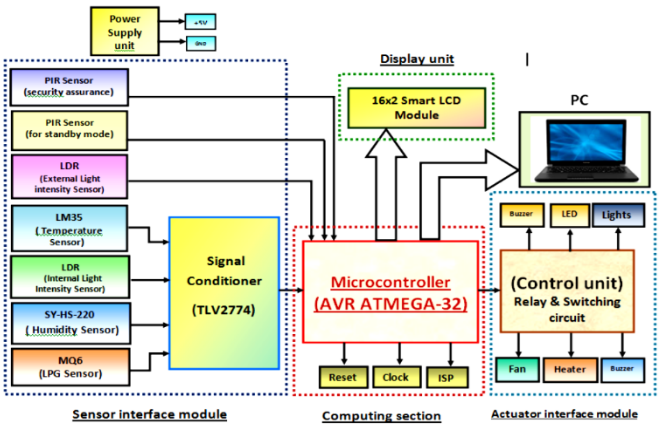

Figure 1: Block diagram of the system

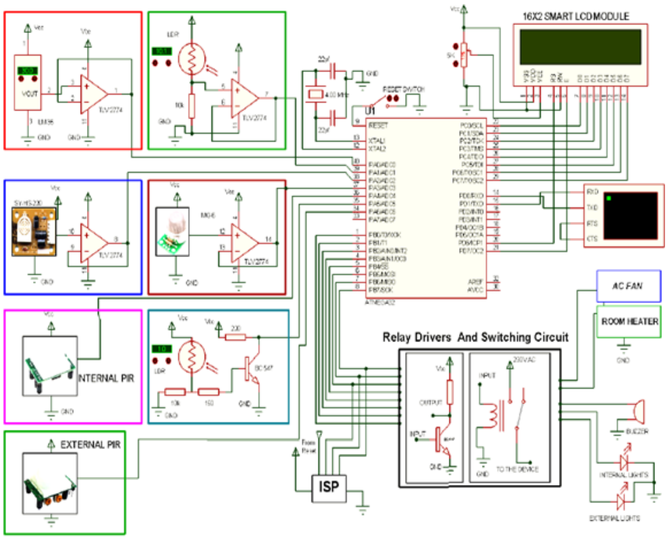

Figure 2 : Circuit Diagram of the system under investigation

The designing aspect of each part of hardware is classified as shown figure 2. The system consists of various stages of sensing, signal processing, microcontroller and the control unit as well. The provision of ISP is typically wired for this dedicated application.

Transducer Interface Section:

The transducer interface section comprises five distinct sensor units, each designed for specific monitoring purpose. The temperature sensor, LM35, accurately measures the ambient temperature, ensuring precise thermal readings. The Light Dependent Resistor (LDR) detects variations in light intensity, allowing the system to adjust based on the ambient lighting conditions [9]. The SY-HS-220 humidity sensor module monitors the relative humidity in the environment, providing crucial data for applications that require humidity control. The MQ-6 LPG leakage sensor plays a vital role in safety by detecting the presence of liquefied petroleum gas, alerting the system upon detection of gas leakage. Lastly, the Passive Infrared (PIR) motion detection sensor identifies movement by sensing infrared radiation from moving objects, enhancing security and automation functions. Together, these sensors enable comprehensive environmental monitoring and response.

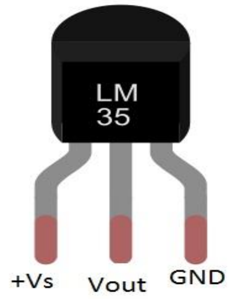

Figure 3: Temperature Sensor LM35

Temperature Sensor LM35:

The LM35 series consists of precision integrated-circuit temperature sensors with an output voltage that is linearly proportional to the temperature in Celsius. This feature eliminates the need for the user to subtract a large constant voltage to obtain readings in Celsius, unlike some other linear temperature sensors. The LM35 (figure 3) provides typical accuracies of ±1⁄4°C at room temperature and ±3⁄4°C across a wide temperature range of -55°C to +150°C without requiring any external calibration or adjustments. Cost efficiency is achieved through trimming and calibration at the wafer level [10]. The sensor's low output impedance, linear output, and precise inherent calibration facilitate easy interfacing with readout or control circuitry. It can operate with single or dual power supplies and, with a current draw of only 60μA, has very low self-heating, less than 0.1°C in still air. The standard LM35 operates over a temperature range of -55°C to +150°C, while the LM35C variant is designed for a range of -40°C to +110°C, offering enhanced accuracy at -10°C. The LM35 is available in hermetically sealed TO-46 transistor packages.

Light Dependent Resistor (LDR):

The Light Dependent Resisters (LDR) is used for sensing the light intensity of the room and control the electric bulb or lamps. The LDR (figure 4) is also known as a photo resistor while it is a device whose resistivity is a function of the incident electromagnetic radiation. Hence, they are light sensitive devices [11-12]. They are also called as photo conductors, photo conductive cells or simply photocells. They are made up of semiconductor materials having high resistance. The LDR is having wide spectral response, low cost and wide ambient temperature range.

Figure 4: Light Dependent Resistor (LDR)

Humidity Sensor (SY-HS-220):

To measure humidity of the environment, humidity sensor SY-HS-220 has been opted for the system under design. On close inspection of figure 5, it is found that, the board consists of humidity sensor along with signal conditioning stages [13]. The humidity sensor is of capacitive type, comprising on-chip signal conditioner. However, it is mounted on the PCB, which also consists of other stages employed to make sensor rather smarter. The humidity sensor is highly precise and reliable. It can be a smart sensor, which provides DC voltage depending upon humidity of the surrounding in %RH. It works 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 250C is 1980 mV and the accuracy is 5%RH at 250C. As shown in the figure 5, it provides three pins recognized as B, W and R. The pin labelled W provides the DC output voltage, whereas the pin labelled B is ground. The VCC of +5V is applied at the pin R. This board is mounted in such a way that it can probe in to desired environment. The output from humidity sensor is obtained and applied to the system for further processing.

LPG Sensor (MQ-6):

The Sensitive material of MQ-6 gas sensor is SnO_2, which has lower conductivity in clean air. When the target combustible gas exist, the sensor's conductivity is 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. As shown in figure 6, the enveloped MQ-6 has 6 pins, 4 of them are used to fetch signals, and other 2 are used for providing heating current. MQ-6 gas sensor has high sensitivity to Propane, Butane and LPG, also response to Natural gas. The sensor could be used to detect different combustible gases, especially Methane; it is with low cost and suitable for different applications [14].

Motion Sensor (PIR):

The PIR sensors allow to sense the 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 (figure 7), which can detect levels of infrared radiation. The sensor in a motion detector is actually split in two halves. The reason for that is the users are looking to detect motion (change) not average IR levels. The two halves are wired up so that they cancel each other out. If one half sees more or less IR radiation than the other, the output will swing high or low. Along with the pyroelectric sensor, the unit has supporting circuitry. It seems that most small hobbyist sensors use the BISS0001 ("Micro Power PIR Motion Detector IC") undoubtedly a very inexpensive chip. This chip takes the output of the sensor and does some minor processing on it to emit a digital output pulse from the analog PIR sensors. These sensors are more complicated than many of the other sensors like photocells, FSRs and tilt switches because there are multiple variables that affect the sensors input and output. The PIR sensor itself has two slots in it; each slot is made of a special material that is sensitive to IR. The lens used here is not really doing much and so it is seen that the two slots can 'see' out past some distance (basically the sensitivity of the sensor). When the sensor is idle, both slots detect the same amount of IR, the ambient amount radiated from the room or walls or outdoors. When a warm body like a human or animal passes by, it first intercepts one half of the PIR sensor, which causes a positive differential change between the two halves. When the warm body leaves the sensing area, the reverse happens, whereby the sensor generates a negative differential change. These change pulses are what is detected. Here two PIR sensors are used for the project work, one for security purpose and other for implementing of standby mode for smart home.

Signal Conditioner (TLV2774):

The TLV2774 CMOS operational amplifier is used to develop the signal conditioning stages required to facilitate the transducer interface module of the hardware designed for realization of the smart home. The TLV2774 CMOS operational amplifier family combines high slew rate and bandwidth, rail-to-rail output swing, high output drive, and excellent dc precision. The device provides 10.5V/μs of slew rate and 5.1MHz of bandwidth while only consuming 1mA of supply current per channel. These amplifiers have a 360mV input offset voltage and a 2pA input bias current for measurement, medical, and industrial applications. The temperature range (–40°C to 125°C), making it useful for automotive systems. These devices operate from a 2.5V to 5.5V single supply voltage and are characterized at 2.7V and 5V. The single supply operation and low power consumption make these devices a good solution for portable applications.

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 microcontroller with large variant. However, the AVR ATmega32 is the microcontroller which fulfils the need of present embedded system. The AVR core combines a rich instruction set with 32 general purpose working registers. All 32 registers are directly connected to the Arithmetic Logic Unit (ALU), allowing two independent registers to be accessed in one single instruction executed in one clock cycle. The resulting architecture is more code efficient while achieving throughputs up to ten times faster than conventional CISC microcontrollers. The AVR ATmega32 provides the 32K bytes of In-System Programmable Flash with Read-While-Write capabilities, 1024 bytes of EEPROM, 1K byte of SRAM, 23 general purpose I/O lines, 32 general purpose working registers, three flexible Timer/Counters with compare modes, internal and external interrupts, a serial programmable USART, on chip parallel programming, a byte oriented Two-wire Serial Interface, a 8-channel ADC with 10-bit accuracy, a programmable Watchdog Timer with Internal Oscillator, an SPI serial port, and six software selectable power saving modes. The Idle mode stops the CPU while allowing the SRAM; Timer/Counters, SPI port, and interrupt system to continue functioning. The Power-down mode saves the register contents but freezes the Oscillator, disabling all other chip functions until the next Interrupt or Hardware Reset. In Power-save mode, the asynchronous timer continues to run, allowing the user to maintain a timer base while the rest of the device is sleeping. The ADC Noise Reduction mode stops the CPU and all I/O modules except asynchronous timer and ADC, to minimize switching noise during ADC conversions. In Standby mode, the crystal/resonator Oscillator is running while the rest of the device is sleeping. This allows very fast start-up combined with low-power consumption. The device is manufactured using Atmel's high density non-volatile memory technology. The Flash Program memory can be reprogrammed In-System through an SPI serial interface, by a conventional non-volatile memory programmer, or by an On-chip boot program running on the AVR core. By combining an 8-bit RISC CPU with In-System Self- Programmable Flash on a monolithic chip, the Atmel AVR ATmega32L is a powerful microcontroller that provides a highly flexible and cost-effective solution to many embedded control applications.

Software:

The aim of this research is to create an embedded system utilizing the AVR ATmega32 microcontroller to implement the Smart Home concept. Developing the software, commonly known as "firmware," is a complex and meticulous task. When programming microcontrollers, it is essential to interact with the physical environment. The CodeVisionAVR Integrated Development Environment (IDE) is specifically designed for developing embedded software for AVR microcontrollers. The developed software successfully measures temperature and light intensity and controls household devices such as fans and electric bulbs using the AVR Atmega32, along with various other smart home applications.

Realization of Smart Home:

The smart home concept is innovative and rapidly advancing across the globe. Embedded technology plays a crucial role in this evolution, earning a prominent place in the field of instrumentation [15-16]. Its key feature is the use of microcontrollers or VLSI devices to enhance the intelligence of smart instruments, making them highly portable and applicable. Leveraging this technology, an embedded system based on the AVR ATmega32 microcontroller has been developed to monitor temperature and light intensity, as well as control these parameters in a room. This system exemplifies automation in smart homes, providing comprehensive monitoring and control of various physical parameters.

The design ensures precise measurement and regulation of internal environmental factors such as temperature and light intensity. It also includes features like humidity monitoring, domestic gas leakage detection, control of external lighting, and detection of human presence within the home. The system operates as intended, offering a practical implementation of smart home automation.

As illustrated in figure 9, the system is installed in various sections of the home. The street light assembly is positioned in front of the entrance, enhancing security and convenience. A PIR sensor is installed at the entrance to detect any intruder movements, covering a wide area for better surveillance. An LPG gas sensor is placed in the kitchen to promptly detect any gas leakage. Other components of the system are strategically located throughout the smart home to optimize monitoring and control functions. All sensing and control operations run simultaneously, and the home's smartness is realized through the display unit, which shows the values of various monitored parameters.

Calibration:

The process of regression is adopted for calibration to the engineering units. In present system, the parameters such as temperature, humidity, light intensity, and leakages of LPG gas etc. are emphasized. Based on AVR ATmega32 microcontroller a smart system is designed for home application. First objective of the system is to display temperature in 0c and control the temperature of the home so the system should be calibrated for temperature in 0C. Temperature sensor LM35 of the system and a standard thermocouple sensor of DM-97 are placed in the controlled environment. The system displays readings sensed by LM35 for the temperature values are match with the readings of DM-97 thermocouple.

For controlling internal lights in the home to provide sufficient amount of light intensity, the Light Dependent Resistor is deployed so the system should be calibrated for displaying light intensity in LUX.

The LPG gas leakage is detected in the home by deploying LPG sensor MQ6. The LPG gas leakage detects gas concentrations anywhere from 200 to 10000ppm. If no LPG gas leakage is detected, the system will continue to detect the gas level through the LPG gas sensor until it detects an LPG gas leakage.

PIR sensors are most commonly used in motion-based detection, such as in-home security systems.

Result:

The proposed research work is carried out to realise the smart home automation system. The system is developed around advanced microcontroller and smart sensors are utilised for high accuracy. As discussed earlier the system is calibrated with standard unit and ready to use. The developed system is installed in the home prototype for validation. On investigation of the system it is found that the system works with high accuracy with synchronization of other peripherals. The future extension of the system is to make it capable for self-powered using solar and battery. Moreover the monitored parameters can be communicated through the internet using IOT.

Conclusion:

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

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