A High End Building Automation and Online Video Surveillance Security System

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Abstract— This paper deals with the design and implementation of a building automation and security system which facilitates a healthy, flexible, comfortable and a secure environment to the residents. The design incorporates a SIRC (Sony Infrared Remote Control) protocol based infrared remote controller for the wireless operation and control of electrical appliances. Alternatively, the appliances are monitored and controlled via a laptop using a GUI (Graphical User Interface) application built in C#. Apart from automation, this paper also focuses on indoor security. Multiple PIR (Pyroelectric Infrared) sensors are placed within the area under surveillance to detect any intruder. A web camera used to record the video footage is mounted on the shaft of a servo motor to enable angular motion. Corresponding to which sensor has detected the motion; the ARM7 LPC2148 microcontroller provides appropriate PWM pulses to drive the servo motor, thus adjusting the position and orientation of the camera precisely. OpenCV libraries are used to record a video feed of 5 seconds at 30 frames per second (fps). Video frames are embedded with date and time stamp. The recorded video is compressed, saved to predefined directory (for backup) and also uploaded to specific remote location over the internet using Google drive for instant access. The entire security system is automatic and does not need any human intervention.

Keywords—Automation, OpenCV, Remote control, Security, SIRC, Web camera

I. INTRODUCTION

Automation and security systems are evolving to be one of the most effective modern age technologies. Building automation refers to the application of computer and information technology to control the appliances which may include centralized control of lighting, HVAC (Heating, Ventilation and Air Conditioning) appliances, security locks and other systems, to provide convenient, comfortable, energy efficient and secured environment. It can provide increased quality of life for the elderly and disabled. Security systems monitor certain critical zones to avoid unauthorized entry into the building or arena. Security alarms are utilized in industrial, residential, commercial, and military applications for protection against burglary, theft, property damage and personal protection against criminals. Security systems can be amalgamated with surveillance to monitor and track the unusual activities, and interface it to any access system.

During recent years, numerous wired as well as wireless systems were suggested for automation and security. In a Bluetooth based home automation system, each appliance is physically connected to a Bluetooth sub-controller and all the Bluetooth sub-controllers (multiple appliances) are hooked up to the central or primary controller [1]. The appliances communicate with their corresponding controller which sends signal wirelessly to the central controller. This design imposes heavy development cost. Mobile based home automation system uses Short Message Service (SMS) to control the home devices [2]. A message is sent to the server for controlling the appliances. Since it takes quite a bit of time to send any SMS to the home server, any instantaneous operation is not possible. Sensors and electrical appliances are connected to a control panel that can be controlled and monitored from all around the world using internet [3]. A web enabled system is made available and all the devices are operated via the internet. However, it is important to consider the propagation delay while sending/receiving commands to a system from any remote location. Also, the control panel is equipped with a 24 X 7 internet access for remote data transactions which is not quite possible for a low end automated system. Security systems based on wireless sensor network (WSN), MMS, Zigbee and GSM are capable to detect theft or any other abnormal household situation and send alarm message to the user [4-6]. However, it is essential to capture and save the information like video footage or picture regarding the intruder instead of just alerting the user via SMS. Security monitoring includes a GSM system which is enabled by a Zigbee module upon theft detection. SMS indicating theft is sent to the user when he is at remote places [7]. A dedicated smart phone is used as a security camera to monitor the location under surveillance. On receiving the SMS, user can make a video call and the smartphone camera will feed a live video and he can verify the status of his place. It is not quite feasible since the user may not have access to his cell phone and the intruder shall escape before the SMS is received or access to the live video feed is available. Also there is no provision to save the video footage. Motion detection application incorporates multiple web cameras attached to the computer. Whenever motion occurs in front of any camera, that particular frame is stored in a specific location [8]. But, system dedicating multiple web cameras will incur heavy development cost. Surveillance using motion sensor is implemented in which the PIR sensor is mounted on the ceiling. Images of the people coming under the surveillance area are captured and sent to authorize personnel via E-mail [9]. Since the area of surveillance is limited, the system holds not much importance when any mishap occurs outside the surveillance area. E-surveillance robot comprises PIR sensors for human detection and a web camera with rotary base to adjust the orientation. An HTML webpage is developed which enables the user to access the video feed and control the motion of the camera [10]. Human intervention is required to change the angular position of the web camera which is not quite optimum for automatic security system. Real time security systems must be highly efficient and should be automated to avoid any human intervention.

In this paper, a low power automated system is designed and developed which allows the user to control the appliances of a building wirelessly via an IR remote controller. The devices can also be operated using a computer. The security system is designed which is capable to detect the intruder, adjust the position of the web camera depending on his location, capture video feeds, compress, transmit it via internet and also save a backup file for future reference. All the process mentioned above are carried automatically without any human interference.

Hardware implementation includes:

- Remote Control to transmit IR data frame.
- IR Receiver to demodulate and decode the received data frame.
- Isolators to protect low power devices from high power networks.
- Triacs to operate the electrical appliances.
- Sensors to detect human motion.
- Web camera to capture video feeds.
- Servo motor to adjust the position of the web camera.

Software implementation includes:

- Algorithm to detect and identify received infrared data frame.
- Sending commands to operate the electrical appliances corresponding to the received data frame.
- Adjusting the orientation of the web camera w.r.t which sensor is triggered.
- Establishing serial communication medium between microcontroller and computer.
- C# script for web camera initialization, video capture, compression, storage and uploading to workgroup via internet.

This paper is organized as follows: Hardware architecture and design is discussed in section II followed by the software development in section III. Section IV deal with the results. Section V includes the conclusion.

II. HARDWARE ARCHITECTURE AND DESIGN

The hardware design implemented in this paper can be divided into two major parts, automation and security. Automation includes the wireless control of electrical appliances. This design incorporates an infrared remote controller which is used to operate the devices. This model is capable to control the switching of lamps (ON/OFF), intensity control of electric bulbs and speed control of electric fans with 8 different levels of brightness and speed respectively. Along with wireless control, user can also operate and switch the devices via a computer using a GUI application. This paper also deals with the indoor security which is a major concern. Sensors capable of detecting human motion are used in this design. A web camera is mounted on the top of a servo motor which allows the camera to rotate. The GUI application is also capable to automatically record a live video footage, compress it, save a backup file and upload it to a work group or predefined remote location over the internet using Google drive. Figure 1 illustrates the block diagram of the Automation and Security System (ASS).

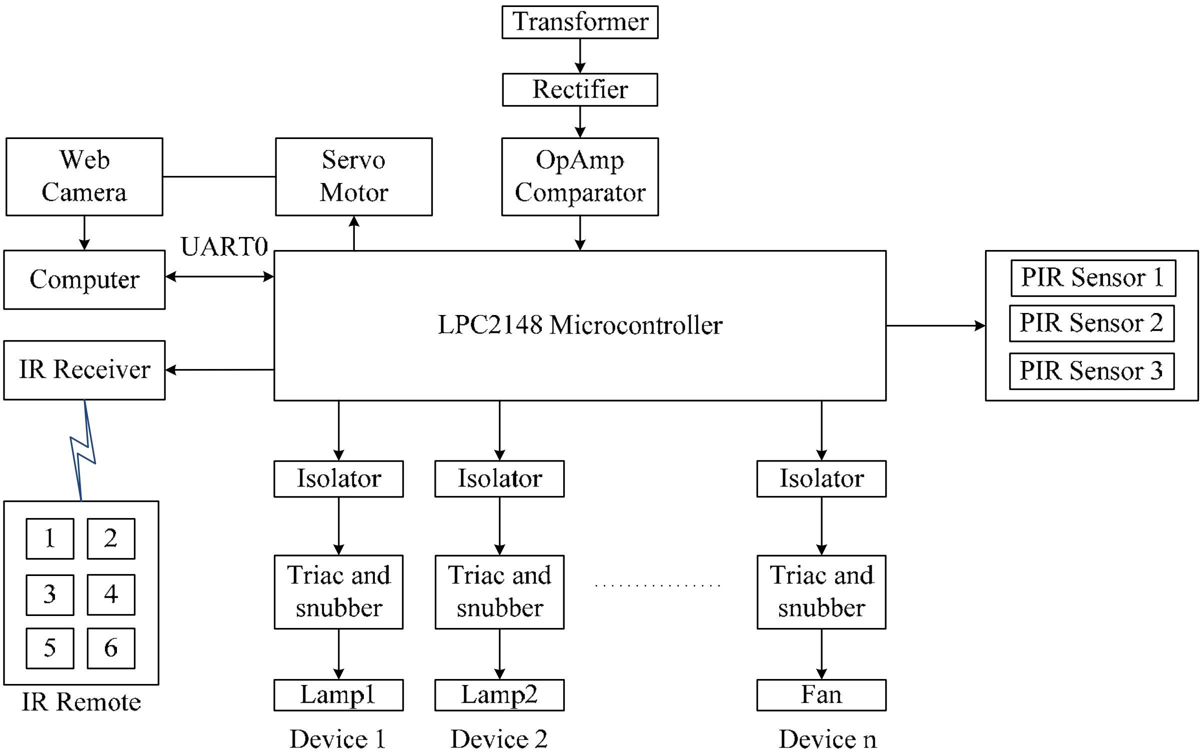

Figure 1: Building Automation and Security System Block Diagram

Philips RC5 and Sony SIRC protocol based remote controllers are widely used in wireless applications. In this design, a Sony SIRC Protocol compatible remote controller is used to switch the end devices. TSOP 1738 IR receiver connected to ARM7 LPC2148 microcontroller is used to demodulate and detect the transmitted data packet. Since the appliances are AC loads, Triacs (BT136) are used for power switching since they are capable to switch high voltages and currents over positive and negative half cycle of an AC signal. To eliminate EMI (Electromagnetic interference) and RFI (Radio frequency interference), a snubber circuit is designed to protect the triac. Electronic appliances and transmission lines are subjected to voltage surges induced by spikes, electrostatic discharge, sudden lightning etc. Hence, isolation is required to block such high voltage transients so that a surge in one part of the network will not disrupt the other parts. Opto-isolators (MOC3041) and (MOC3021) are incorporated in this design to provide sufficient isolation required between 5V circuit and the electrical appliances running at 230V as illustrated in figure 2.

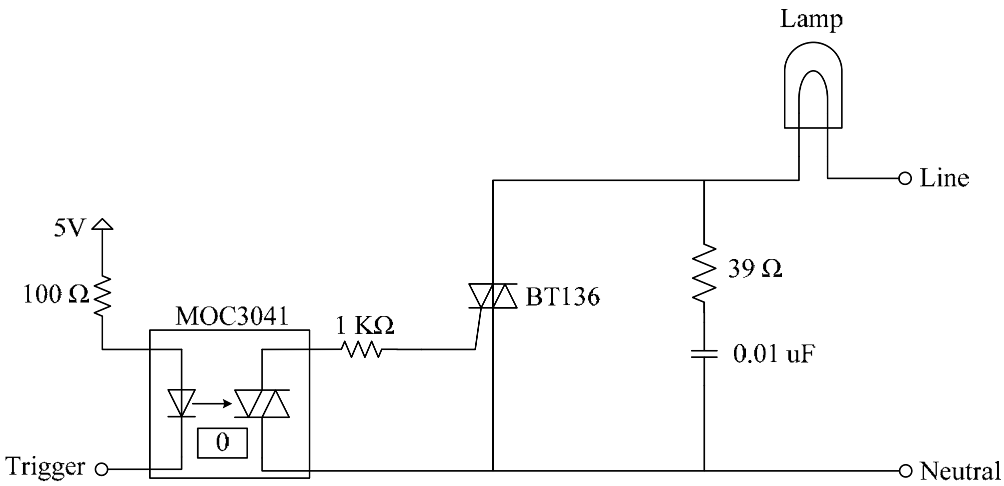

Figure 2: Isolation between 5V and 230V network

The devices are switched and controlled by providing gate pulses to the triacs. To serve this purpose, a comparator and signal conditioning circuit is designed which alerts the microcontroller at the beginning of every half cycle by sending an interrupt signal. A 230V/50Hz step down transformer is used which provides 12V DC after bridge rectification and filtering. An operational amplifier (LM324) is configured as a comparator as shown in figure 3, whose output is connected to the external interrupt pin (ExtInt0) of the microcontroller LPC2148. It will generate an interrupt every 10 milliseconds, thus indicating a zero crossover. With reference to this zero crossover, all the appliances are operated and controlled by providing appropriate gate pulses, corresponding to the commands received from the IR remote controller.

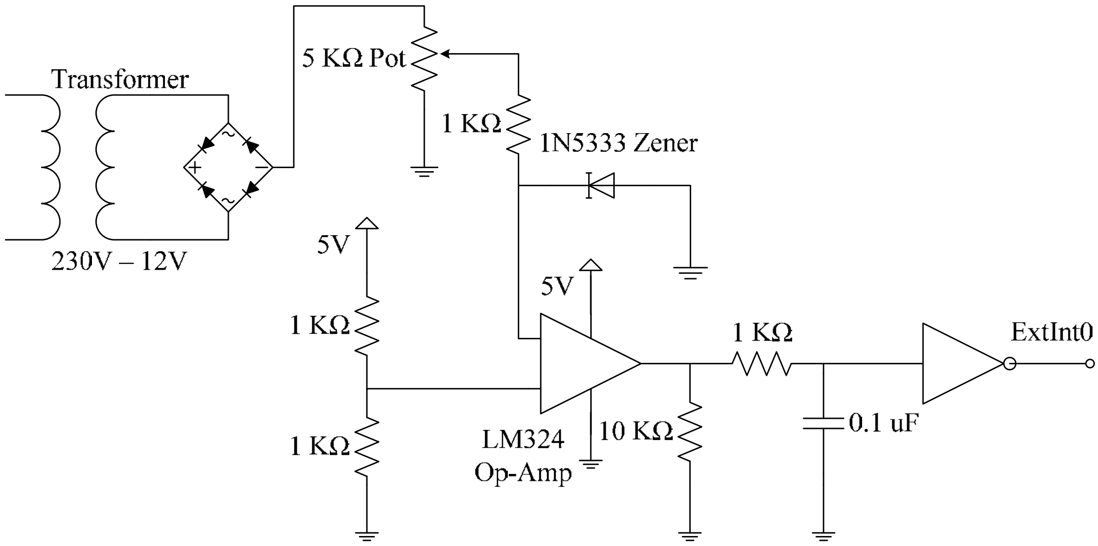

Figure 3: Comparator and signal conditioning for detection of zero crossovers

When any button from the remote controller is pressed, it transmits a data frame of 13 bits, modulated at 38 kHz frequency. It takes a maximum of 24 milliseconds for the transmitter to transmit one complete SIRC data frame. TSOP 1738 IR receiver with a range of 7-8 meters is used to detect the transmitted data packet. Individual port pin on the microcontroller is configured to control the corresponding end device.

Alternatively, the appliances can also be controlled and operated via the computer. Serial communication is established between microcontroller and the computer using UART0 of ARM7 LPC2148. A GUI application is developed using which the user can send commands via serial port to operate the appliances. Corresponding to the commands received, the gate pulses are provided to the triac thus controlling the devices. So this allows a dual mode operation of the devices using a remote controller as well as a computer.

In this system, PIR sensors are used to detect human motion. Three PIR sensors are used which are connected to the external interrupt pin of the microcontroller i.e. sensor 1, 2 and 3 are connected to ExtInt1, ExtInt2 and ExtInt3 pins respectively. These sensors are short ranged sensors (2 – 3 meters) but have the widest view (130 degrees) than other sensors, which makes it ideal for any indoor security system. The web camera used to record a video footage is firmly mounted on the top (shaft) of the servo motor. PWM channel 1 of the microcontroller is configured to drive the servo motor. PWM signal having pulse width between 0.55 ms – 2.40 ms is provided to achieve angular displacement between 0-180 degrees. Table 1 shows the PWM pulses generated to achieve a particular angular position of the servo motor thus adjusting the web camera.

Table 1: PWM VS Angular displacement for servo motor

Pulse width (ms)	**Angular position of servo motor (degrees)**
0.55	0
1.50	90
2.40	180

When any intruder breaks into the zone under surveillance, PIR sensor detects human motion and sends an interrupts signal to the microcontroller LPC2148. Corresponding to the interrupt, appropriate PWM pulses are provided to the servo motor, thus adjusting the angular orientation and direction of the web camera. Servo motor is used since precise position and angular control is required for accurate positioning of the web camera. Now, LPC2148 microcontroller issues activation signal to the GUI application via serial port. UART0 is at 9600 baud rate. The control is then transferred to the computer which initiates video streaming followed by compression, storage and sharing over the internet.

III. SOFTWARE DEVELOPMENT

Software development for this proposed design is a 2 stage process. Firstly it involves embedded C programming for the LPC2148 microcontroller and secondly it deals with GUI application development using C# and OpenCV. The TSOP1734 IR receiver is connected to LPC2148 microcontroller. Figure 4 illustrates an algorithm which is incorporated to decode the SIRC data frames by the LPC2148 microcontroller. When any button from the remote controller is pressed, it transmits a particular frame of data (12 bits + start bit). The frame consist a start bit which indicated that new data has arrived. The start bit is usually 2.4 ms wide. Start bit is followed by 12 data bits corresponding to individual button. Logic 1 is usually 1.8 ms wide pulse (low for 600 us and high for 1200 us) and logic 0 is 1.2 ms wide pulse (low for 600 us and high for 600 us). Figure 5 demonstrates the method of controlling appliances using remote controller. Individual buttons are allocated to all the devices. For ON/OFF switching, a single button is configured as a toggle switch while 2 buttons are allotted (increase and decrease) for intensity control (brightness of an electric lamp and speed of a fan). When any button is pressed, the SIRC frame is decoded and corresponding port pin is asserted thus providing a triggering pulse to the respective appliance.

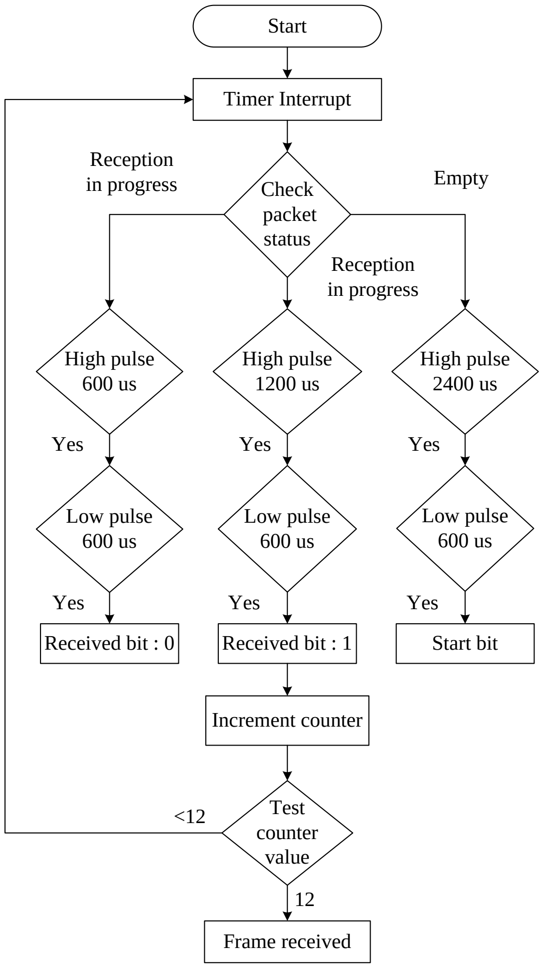

Figure 4: SIRC frame decoding algorithm

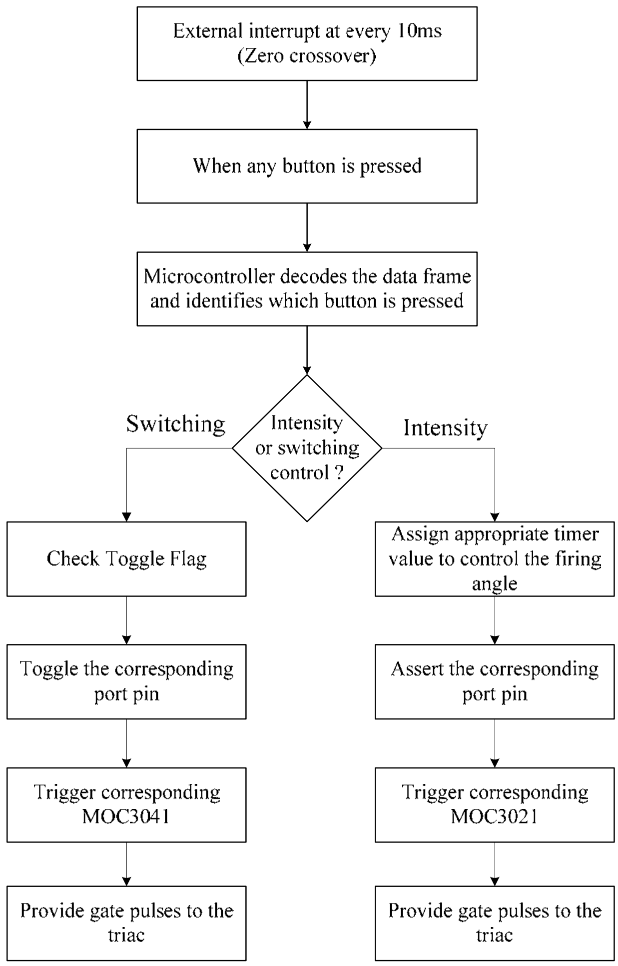

Figure 5: Wireless operation of electrical appliances

Microcontroller is interrupted at duration of every 10ms, denoting the beginning of a new half cycle. It is at the beginning of the half cycle, when the gate pulses are provided to triac for ON/OFF switching. For intensity control, timers are configured to fire the gate of triac at a particular angle depending on the button pressed. For example: when the button allocated for increasing the intensity is pressed, the triac is fired at a particular angle. As the button is pressed continuously, the firing angle reduces to 0 degree thus delivering more power to the load. Same concept holds true to reduce the intensity. At 0 degrees, the intensity is highest, and will reduce to zero at 180 degrees. Alternatively, all the devices are controlled via the computer.

A GUI application developed using C# uses serial communication to communicate with the microcontroller. For this purpose, UART0 of LPC2148 is configured to operate at 9600 bits/second baud rate. Initially when the microcontroller is powered up, serial communication link is established with the computer. The GUI application includes a serial communication module that communicates with the COM port to which the microcontroller is connected. Upon reset, the microcontroller transmits a byte of data serially to the .NET application which sends back an acknowledgement byte. Thus handshaking is established between both the modules. To operate any appliance, the application issues fixed commands to the microcontroller. Corresponding to the received command, microcontroller asserts the respective output line which triggers the MOC which provides gate pulses to the triac. The PIR sensors are connected to the external interrupt pin of the microcontroller. When any motion is detected by the sensor, it enables its output line thus interrupting the LPC2148 microcontroller. Corresponding to which sensor has triggered; PWM channel 1 is configured to generate a PWM signal to drive the servo motor. Figure 6 represents the interrupt processing methodology that has been adapted and incorporated in the security system design. When any external interrupt (PIR) occurs, the microcontroller vectors to the interrupt service routine (ISR) and that particular interrupt is disabled. Appropriate pulse width modulated signal is provided to the servo motor to adjust the orientation of the web camera (mounted on the servo motor). A byte of data is sent serially by LPC2148 to the GUI application, thus enabling the web camera and initiating the video capture to record a video of 5 seconds. The GUI application also imports OpenCV libraries as a back-end support for web camera operation and image processing. Figure 7 shows the flowchart of events that occurs when the windows application receives activation command from the microcontroller. The camera is activated only if it receives the activation command and is idle during the rest of the time. Once an activation signal is received, web camera is powered up, the concerned OpenCV libraries are invoked and the camera drivers are connected .After the drivers are connected, the application starts recording a video of 5 seconds at 30 frames per second (fps). The video is compressed using MPEG-4 compressor thus reducing the storage capacity (Table 2). Once compressed, the video feed is saved automatically in the predefined database. The application is developed in such a manner that a directory is created in the DDMMYYYY format and the video is saved in the created directory with filename format HHMMSS.avi corresponding to system date and time. Also the video feed has an embedded time stamp using which the user can check the date and `time of the video footage for verification. Once the video has been saved, the application sends a byte of data serially to microcontroller as an acknowledgement. The video is uploaded to remote location via internet using Google drive. Now the video feed can be accessed by the work group globally.

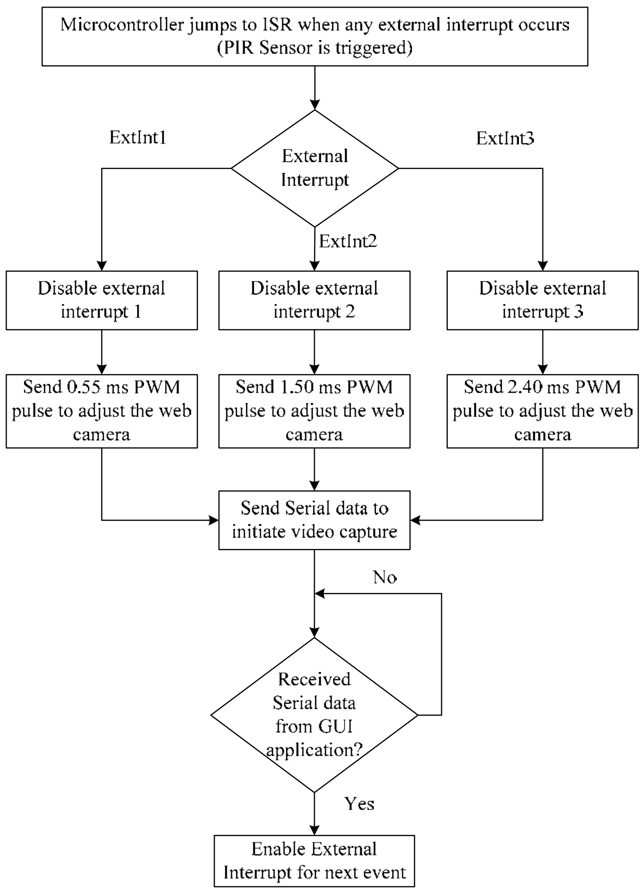

Figure 6: Security System Processing Methodology

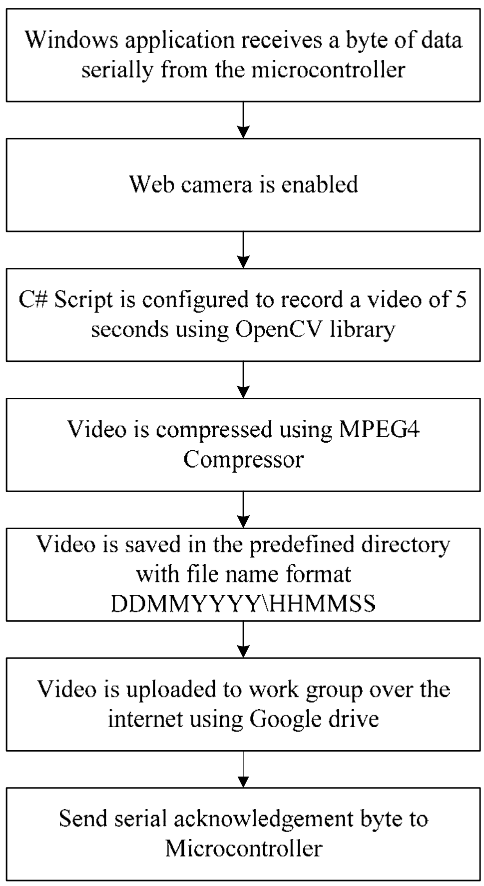

Figure 7: Video footage processing in C#

Table 2: Comparison of Video compressors

Compressor	Size before compression	Size after compression
Full frames	25 MB	25 MB
MJPG	25 MB	4 MB
MPEG-4	25 MB	1 MB

The C# application developed for automation and security system solely works on serial communication protocol. Figure 8 shows the serial data flow diagram established between microcontroller and computer. Initially after reset, a two-way handshaking process takes place which ensures successful serial connectivity between the GUI application and LPC2148 microcontroller. Control commands are issues by the GUI application to the microcontroller to operate the electrical appliances. Corresponding to the incoming data, microcontroller controls corresponding device. Similarly, when PIR Sensor is triggered, microcontroller issues serial commands to the application which in turns control the video recording, storing and uploading process.

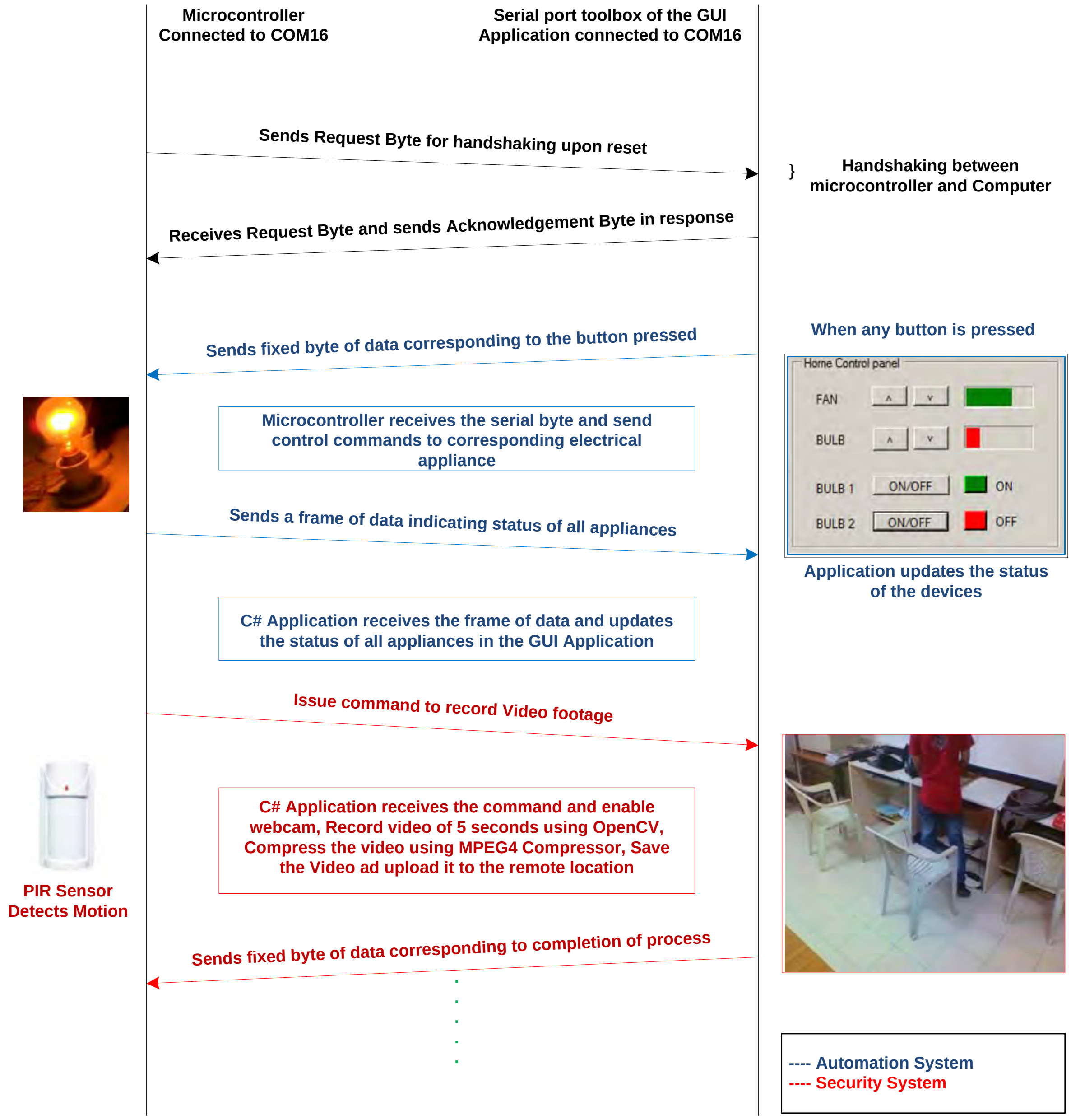

Figure 8: Data flow diagram of serial communication established between microcontroller LPC2148 and GUI Application

IV. RESULTS

Figure 9 shows the waveform which represents the output of the comparator and signal conditioning circuit. Op-Amp output is a square wave which interrupts the microcontroller regularly at an interval of 10 ms indicating the beginning of a new half cycle (zero crossovers). When any button on the remote controller is pressed, the IR transmitter inside the remote controller transmits a data frame of 13 bits. Figure 10 (a) to 10 (c) shows the waveform of a typical SIRC data frame (Start bit, logic one, logic zero) received by the microcontroller after demodulation and decoding. The entire data frame arrives within 21.5 – 24 milliseconds. Table 3 depicts the variants in SIRC frame and bit timings.

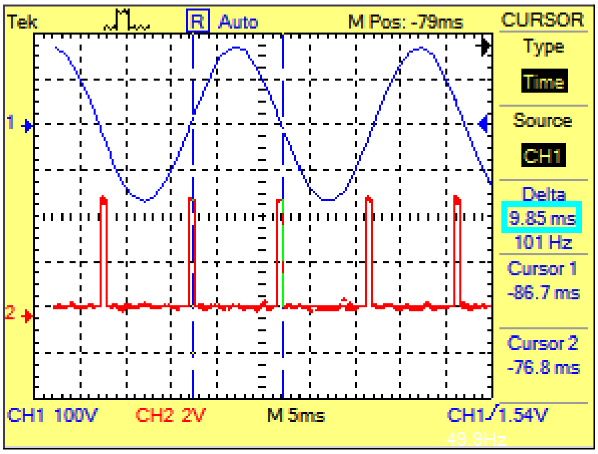

Figure 9: Comparator output

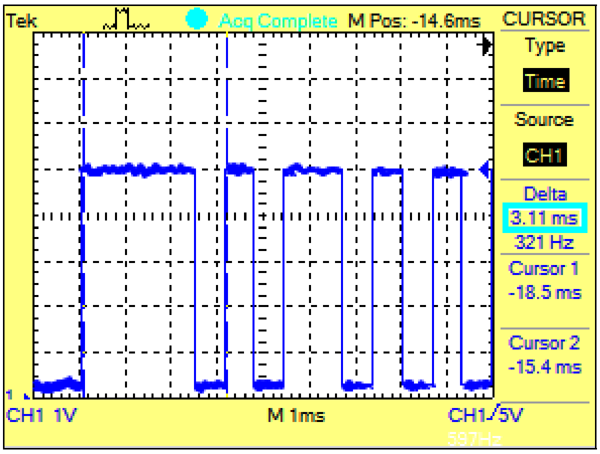

Figure 10 (a): SIRC data frame – Start bit (3.11ms wide)

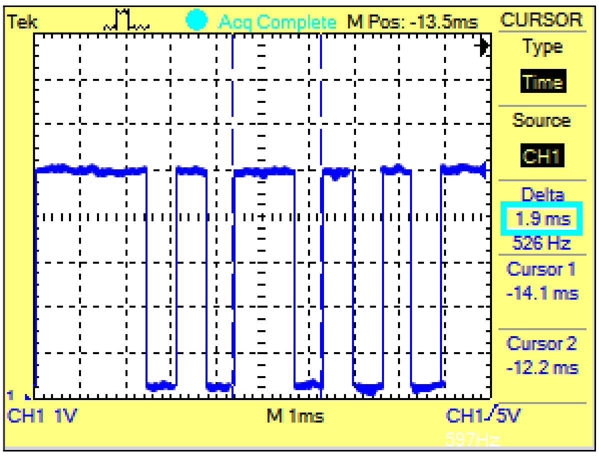

Figure 10 (b): SIRC data frame – Logic one (1.90ms wide)

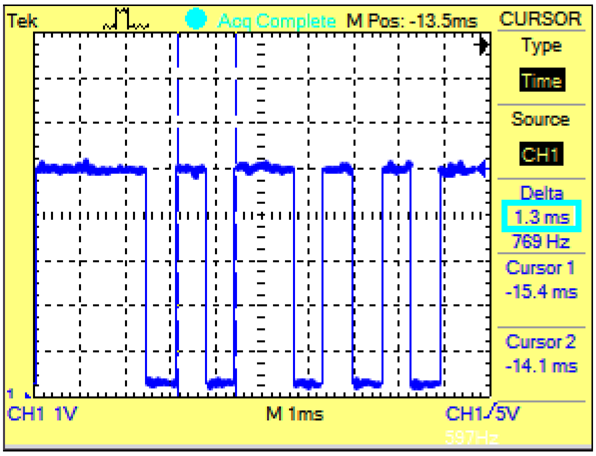

Figure 10 (c): SIRC data frame – Logic zero (1.30 ms wide)

Table 3: Typical SIRC timings

Entity	Minimum time (ms)	Average time (ms)	Maximum time (ms)
SIRC frame	21.5	22.00	24.00
Start bit	2.85	3.00	3.20
Logic 0	1.05	1.20	1.40
Logic 1	1.70	1.80	1.95

After detecting that which button has been pressed, the triac is fired at a particular phase angle. Power delivered to the load can be controlled by altering the firing angle. For intensity control, firing at 0 degrees refer to maximum power delivery to the load and it gradually reduces to minimum as firing angle reaches 180 degree. Figure 11, 12 and 13 indicates the power delivered to the load when triac is fired at 100 degrees, the result of intensity control of an electric lamp and the experimental setup of the security system incorporated in the design.

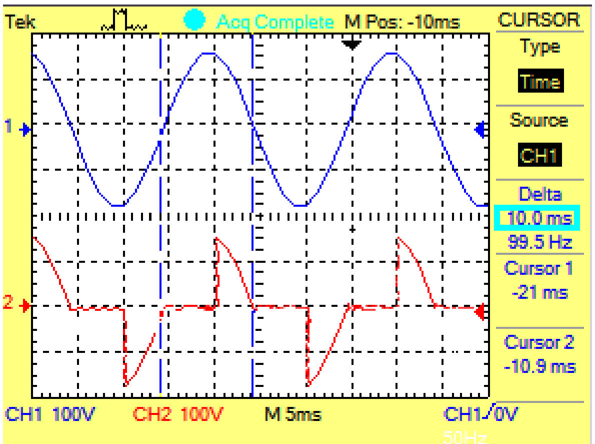

Figure 11: Power delivered to the load at 100 degrees firing angle

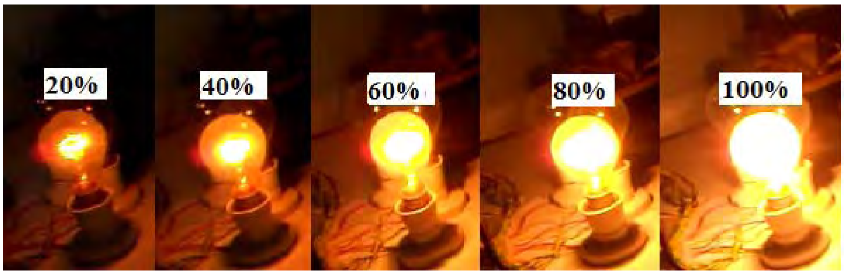

Figure 12: Intensity control of an electric lamp

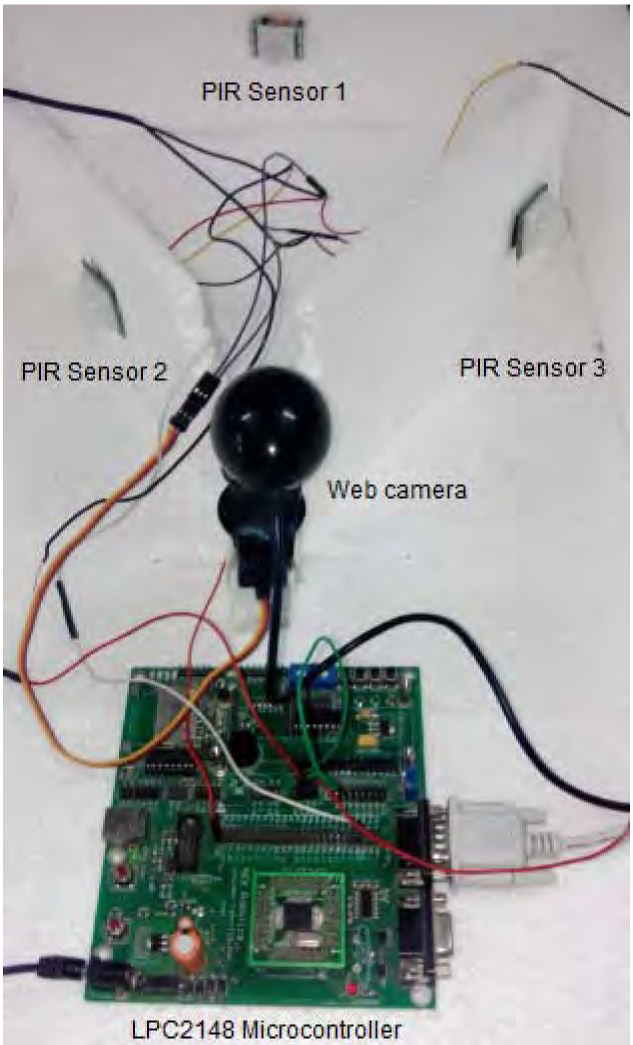

Figure 13: Experimental setup of Security System

Figure 14 depicts the Graphical user interface developed using C# for Automation and Security System. This design incorporates the establishment of a serial communication link between the computer's serial port and UART0 of LPC2148 microcontroller. Once both the devices are serially connected, data transfer is initiated and corresponding respective events are executed. This application is capable to detect all available COM ports, can connect to any selected COM port, and set the baud rate (Kbps) for data transfer between microcontroller and computer. Exception handling is efficiently used to deny access to system ports and ensure that a connection is established before any party is trying to transfer the data byte. Window buttons are used to control the end devices. When any button is pressed, a fixed data byte is sent to the microcontroller LPC2148 via serial port. Microcontroller receives the serial data and corresponding to it, it will provide the trigger pulses to the opto-isolator thus providing gate pulses to the Triac. The GUI application receives an activation command serially from the microcontroller, when any intruder is detected (PIR sensor is triggered). Once the activation command is received, web camera is enabled the video recording is initiated. Once the video is recorded, it is uploaded to the predefined workgroup using Google drive. The uncompressed video clip of 5 seconds occupies approximately 25 MB of storage. Here, the video file is compressed using MPEG4 video compressors and the same video now occupies merely 1 MB of disk capacity. One more concept incorporated in this design is the frame rate multiplication strategy. Using this strategy, it was possible to capture a video of 15 seconds, and the playback frame rate was increased by a multiplication factor of 3. The result was a 5 second video occupying 1 MB but has 3 times more frames than the former video thus having footage of 15 seconds. In order to overcome the bugs that automatically rename the system folders and files, the video feed that is recorded is embedded with live system date and time stamp. It takes around 3-4 minutes to upload the uncompressed video over the internet using a 512 kbps modem, while the compressed version reaches the destination within 1 minute.

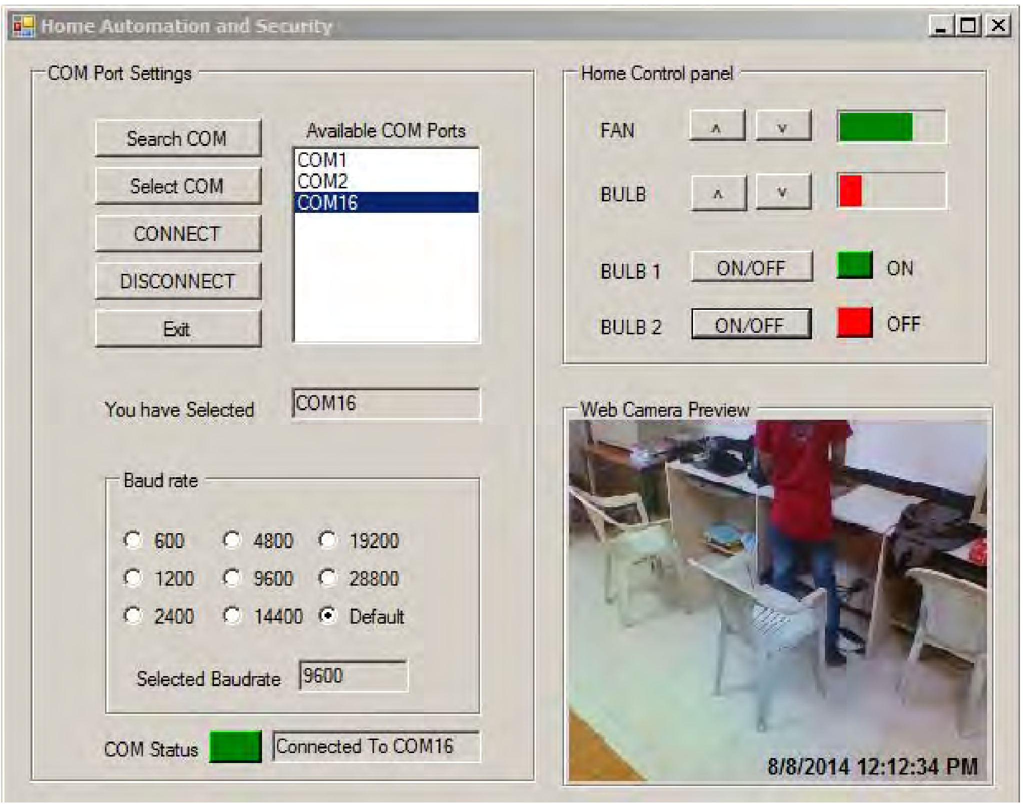

Figure 14: Building automation and security system GUI application

V. CONCLUSION

The building automation system implemented in this design is a smart, energy efficient and cost effective solution for the wireless operation of electrical appliances. It is comfortable for the user to control the devices via a wireless remote control as well as a computer. It increases the quality of living for the elderly and disabled. The same design can be incorporated to control the appliances of an entire building. All the operations in this design involve interrupt based processing which reduces the overall system delay significantly. As far as the household security is concerned, this design is an efficient method to detect any theft. The methodology used for recording and online transfer of video is far more sophisticated. As far as the efficiency is concerned, replacing a single sensor with an array of sensors can give better results. Including image processing with the proposed security system will be more effective and prove to be an efficient solution for indoor security.

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