Multi Control Chandelier Operations Using XBee for Home Automation

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***Abstract*— Home automation systems aim to control all home activities and functionalities. Control can be done through a remote control that sends command signals wirelessly by means of infrared radiation, Bluetooth connectivity, or any other RF technology as well as via internet or GSM communication. The controlled target devices usually include domestic appliances, security and safety systems, HVAC systems, home theater, lights, and many other home tasks. In this study, we design, program, and implement a light chandelier with multiple functionalities. The operational modalities comprise manual and remote on/off, different working timers, daylight, romance option, light dimming, party style, on/off luminosity turning, password keys, and motion detection. The chandelier remote control uses XBee transceivers that fulfill secure commands and prevent any interference between similar systems. The remote control realization is based on PIC 16F877A microcontroller and supported by an LCD to display notifications.**

Keywords—home automation; chandelier control; microprocessor; light dimming; circuit design; hardware implementation; XBee

I. INTRODUCTION

The domain of home automation [1-6] is becoming increasingly interesting, useful, and demanded by households and companies to be practically implemented and conceived. Home systems have numerous advantages since they are comfortable, intelligent, efficient, and can improve the quality of life. Moreover, they are low-power consumption, cost saving, secure, flexible and scalable. The user control interface is friendly designed and can be a simple remote control or a software application downloaded on a tablet, i-device, smart phone or computer. There are several technologies of communication that realize the interaction between the user interface and the home control board such as infrared radiation, Bluetooth connectivity, and any other RF signals for short and medium distances. For far distances, the GSM communication system and the Internet are prevalent for numerous applications. Concerning the target controlled devices, the domestic appliances and the common house functionalities such as lights, doors, windows, curtains, and HVAC (Heating, Ventilation, and Air Conditioning) are the most popular. Besides, smart homes include security and safety systems [7] such as detectors of gas, smoke, fire, intruder, camera surveillance and alarm system. Moreover, various home modalities can be inserted such as the luxury home theater for music and movies, plant irrigation as well as pet feeder and containment system.

The basic operations intended for lights and lamps in most home automation systems are the remote on/off switching and dimming modes. These operations are done mostly using on-wall manual control. The garden, hall, and corridor lights are controlled by a motion detector sensor that turns on the lights when motion is detected. Indeed, lighting systems based on occupancy sensor and dimming modes are widely offered by lightings manufacturers especially for hotels, restaurants, conference halls, and galleries. However, few home systems use daylight sensor for power saving purpose. In general, the department lights are commanded to turn off when the illumination during the day has clear appearance and visible sight. The programmed lights, simulation scenarios, sparkling and flashing lights are popular in disco places and dancing scenes.

In this work, we are interested in the operation modes of home lights, especially the chandelier. The chandelier is known as a decorative ceiling mounted light. It is often ornate, decorated by different levels of arrays of crystal prisms that illuminate marvelously the room with refracted lights. The chandeliers are initially introduced in the religion places and palaces to reflect the art of luxury, but nowadays, they are used at homes, particularly in living rooms. We aim to control, using wireless remote control, the multiple operations being achieved on lights, with additional features that have not yet been implemented. Our proposed design system is aimed to be applied to an existing chandelier where the standard manual control is realized using two separate switching points. Two groups or cluster sets of eight lamps in the chandelier are assumed, where each group of lamps can be lighted alone or the two sets can be illuminated together. The hardware prototype is conceived using two partitions: the handheld remote control and the control board supported to the chandelier. The remote includes an LCD to display warnings, ten command modality buttons labeled PWD, On/Off, Lamp1, Lamp2, Romance, Dimming, Daylight, Motion, Party, and Timer as well as four auxiliary buttons labeled from 1 to 4. The XBee transceivers [8-9] are connected to both remote and control board. The control board is connected to infrared motion detector, light sensor, Triac switching elements, and

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other electronic components. The strength of our design is the incorporation of the light functionalities into an overall system. The control is achieved remotely using XBee that prevents any interference between similar systems. The On/Off button increases the battery life time while the PWD is a sophisticated option to prevent children and prohibited users from accessing the chandelier system.

II. HARDWARE COMPONENTS

The hardware system is conceived by means of handheld remote control and control board. The resident commands the chandelier by selecting the desired mode and pressing the appropriate button. To cancel a given selected mode, the user should press again the related mode button. A notification LED turns on in the background of the button when the selected mode is activated and turns off when the mode is deactivated. Moreover, a notification message is simultaneously shown on the LCD screen. The user remote and chandelier board are both mounted PIC 16F877A microcontrollers [10-11]. The XBee transceivers on both sides of the two partitions achieve the total communication between them and fulfill both the command orders and the status information to be properly transmitted.

A. PIC 16F877A microcontroller

The PIC 16F877A [10-11], a family of Harvard architecture microcontrollers made by Microchip, is an integrated circuit (IC) consisting of a simple central processing unit (CPU), clock, timers, and five input/output ports for general purpose, labeled from A to E. The data transfer through these ports can be configured in input or output direction according to the content value of the corresponding TRIS register. The PIC is also supported by different types of memory such as RAM, ROM, and EEPROM where the 256-bytes program memory map consists of 4 banks. To shift from one bank to another, the two selection bits RP0 and RP1 of the STATUS register should be configured properly. The PIC 16F877A has various advantageous features: the instructions set are restricted to 35 instructions, low power consumption, wide operating voltage ranges (2 V to 5.5 V), and input clock operation up to 20 MHz.

The most important characteristic of the PIC is the Universal Synchronous Asynchronous Receiver Transmitter (USART) module which allows it to communicate with a wide range of devices. It involves sending or receiving 8-bit packets of data serially. In particular, the transmitter (TX) and receiver (RX) pins achieve full duplex communication, in either asynchronous or synchronous mode, with an appropriate transmission speed baud rate.

B. XBee Tranceiver module

XBee [8-9, 12], from Digi International, is a family of compatible radio modules based on the IEEE 802.15.4 standard designed for point-to-point and star communications. The XBee module is presented in several versions that own similar pin outs but are different in the power output, antenna style, operating frequency and networking abilities. The XBee transceivers afford very reliable, cost effective, and simple communication between the microcontrollers and are supported by sleep mode for extended battery life. The 1 mW XBee adopted in this work operates at 2.4 GH and has at least a range of 30 meters.

C. Light Sensor

The light sensor [13] is employed to detect the intensity of ambient light. It is based on the principle of photoelectric semiconductor, where its resistivity changes according to light intensity falling on its face. The Arduino light sensor module is compatible with the microcontroller and can be used to realize light measurement, light control and effect. These photocell sensors are small, inexpensive, low-power and easy to use.

D. Motion sensor

The digital infrared motion sensor [13] is commonly used for many different appliances. It is powered up and after 1-2 seconds it gets a snapshot of the still room. Then, the sensor looks for any source of energy as human or pet and makes a comparison. If anything moves or any recent change is revealed, the alarm pin will trigger. In fact, the sensor checks for infrared heat within its detecting angle (110 degrees) and its detecting distance-range (7 meters).

III. REMOTE CONTROL MODALITIES

The final prototype of the user handheld remote (Fig.1) allows to control from distance several modalities of the chandelier. It is supported by an LCD screen to show the functionality currently activated, connected to the XBee transceiver to interact with the chandelier board, and mounted by 10 principal buttons associated to the system modes (PWD, On/Off, Lamp1, Lamp2, Romance, Dimming, Daylight, Motion, Party, and Timer) and 4 auxiliary buttons labeled 1 to 4.

Fig. 1. Handheld remote control associated to the chandelier

The role, objective, and the running procedure of the implemented modes are detailed below.

- The On/Off button permits to turn on the remote when the user aims to use it. When he or she ends by choosing the desired modalities, the remote will shut down. This option increases the battery life of the remote and maintains it in a good performance for a long period. Consequently, it reduces the electronic components failure and protects them against insufficiency.

- The PWD button specifies the remote by a password of 6 digits formed by the combination of the 4 numbers (1 to 4) stated as auxiliary buttons. The default password is set to 122334. When the remote is turned on, a message is displayed on the LCD asks the user to enter the password. If the pass code combination is valid, the remote is ready to be used. Otherwise, the user is asked to try another code. The pass code is stored on the EEPROM of the microcontroller and it can be modified by the user. When the remote is in ready status, the user presses the PWD button and types a new six-digit combination. The new combination is then recorded in the memory. The numbers of the possible combination codes are $4^6 = 4096$ codes. We think it is fairly enough since the reason for setting a password is preventing children and unauthorized users from controlling the chandelier.
- Lamp1 and Lamp2 illuminate respectively the 2 groups of lamps of the chandelier. Each group is constituted of 8 electric bulbs. It is important to note that the manual switching, assuming realized from two separate points, is still functioning. In fact, if the user turns on manually a group of bulbs, a message on the remote LCD is displayed to inform the user about the new status. The lighted lamps could be turned off manually form the same point, from the other local point, or remotely from the device. Furthermore, if the remote button is employed to light the chandelier, all three above mentioned possibilities could be adopted to turn it off. This mutual control between manual and remote is not straightforward and requires electrical connections and programming.
- Romance and dimming modes achieve respectively 50% and 20% of the maximum luminosity that could be radiated by the chandelier. The Romance mode is suitable for romance dinner, in intimate sitting that requires special audience, or in prolonged night séance with the family and friends where the chatting and the conversation become pleasant and charming at dimming lights. In addition, in winter when it is dark, the sky is leaden with overcast that blocks the radiation from the sun, and the murk fog encloses the ambiance with dusky view. In this case, it is convenient to choose the dimming mode as a compromise between the unnecessary full floodlight and the power-consumption saving criteria. The romance and dimming modes are performed using the pulse width modulation (PWM) technique [14]. Its main concept resides in sending a sequence of digital pulses rather than applying an analog voltage of varying amplitude. The average power supplied to the load depends on the duty cycle that corresponds to the proportion of the On-time to the period of the pulsed generated signal.
- The daylight mode also calls the PWM to achieve 50%, 70%, and 85% of the maximum chandelier light. However, in contrast to the romance and dimming modes where the selection of luminosity level is done by the user, the daylight is determined according to the output signal of the light sensor. Indeed, the light sensor generates an analog signal that varies in correlation with the ambient luminosity and brilliance. This effect is appropriate in gloomy dark winter days and in the evening. The analog to digital converter mechanism [15] recognizes the level of darkness and is sensitive to changing daylight availability. Consequently, it turns on the chandelier with the corresponding level of lighting. The daylight harvesting decreases energy consumption by an average of 24% annually [16] and thus reduces operations cost. While work efficiency decreases at lower lighting levels, glare or excess lights have adverse health effects as headache, stress, and increased blood pressure.
- In motion mode, the chandelier is turned on when the infrared motion detector detects a motion in the room. In fact, this occupancy sensor reads the changes in heat such as pattern treated by a moving person. A break in the pattern caused by any motion in the area triggers the control. This preference is adequate in the nights when the resident crosses the room or when an intruder or housebreaker enters the dwelling and thus lighting the room could warn and alert the inhabitant.
- The party mode is a specialized mode dedicated for parties, celebrations, anniversaries, and dancing shows. The 2 groups of bulbs are turning on and off, the lights are dimmed, shifted, rotated, and flashed in a harmonic scene and splendid shining as emulation to the melodic disco. The connection between the chandelier board and its lamps permits to act on each bulb individually, which leads to display various fantastic light shows.
- Finally, the timer mode used for different purposes offers 3 periods of timing before the chandelier lights are shut down. The shortest period is suggested to be around 5 minutes, the moderate is 30 minutes, and the longest period is specified for 2 hours. After selecting the timer mode, the user should consecutively press one of the three auxiliary modes 1, 2, or 3 for the three variant timers.

At the end, we should note that the number of groups of lamps can be extended to 3 or 4 while the number of electric bulbs per group can be determined according to the resident specification or depending on the chandelier size and shape as well as the dimension of the room.

IV. CHANDELIER CONTROL BOARD

The chandelier control board is implemented using PIC 16F877A microcontroller that is connected to XBee transceiver, light sensor, motion sensor, and 16 switching blocks based on Triac power electronic element associated to the 16 bulbs. The XBee transceiver receives the different command orders from the handheld remote and sends the chandelier status. The infrared light sensor and the motion detector sensor are compatible with the microcontroller and can be directly connected to it. The motion detector output signal is digital and can be easily processed according to high or low voltage level, whereas the infrared light senor output signal is analog and thus an analog to digital converter should

be applied in order to treat the signal and measure the light luminosity level.

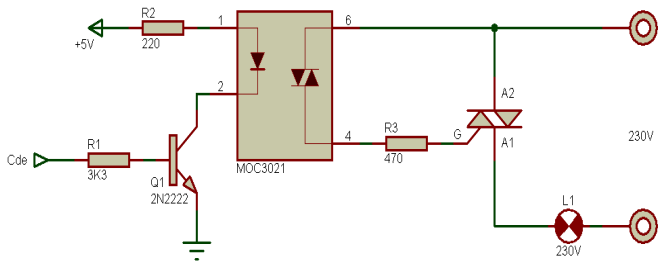

Fig. 2. Handheld remote control associated to the chandelier

The 16 switches corresponding to the 16 electric bulbs of the chandelier are realized, each, by three main components (Fig. 2): a transistor, an optocoupler element, and a Triac. The microcontroller activates the transistor by sending the switching command. Next, the transistor triggers the optocoupler component by producing a current in its gate. Finally, the optocoupler, in turn, commands the Triac to drive voltage. The analysis of this circuit switching shows that the optocoupler separate optically between the microcontroller and the power circuit since it can support high voltage and drive high currents in contrast to the transistor that endures low current flow and is directed by the 5 V signal issued from the microcontroller.

V. Conclusion and Perspectives

Nowadays, the concept of smart homes has become very popular, especially with the advanced technological devices, the spread use of smart phones and i-devices, and the unruly desires to own comfort system and live in luxury. Of course, the home automation system encloses all the house activities, appliances, and systems but the lighting systems remain in the first place. However, the majorities of studies in this domain innovate approaches and techniques to command the dwelling from distance using RF communication, GSM system, and the internet profiting from the extremely increase in the technologies advance and the development in communication and computer software. Instead, we find that the home lighting control is still poor and restricted to few operations such as on/off switching and dimming. Other modalities as daylights, occupancy and disco control are well presented by lightings manufacturers but are not employed for residents. Thus, this study performed all the lighting operation modalities in addition to other features as password code, On/Off option, and remotely control without interference. The chandelier is intentionally selected since it is the most complicated lighting appliance.

The chandelier is controlled using handheld remote where the XBee transceivers, implemented at both sides, achieve an easy and secure communication without interference problems. The design prototype is conceived with ten modalities: on/off for saving power, PWD to keep away the children and the unauthorized users, Lamp1 and Lamp2 to switch on and off the 2 group of lights in combination with manual mode, romance and dimming to faint the light, daylight to light on the chandelier when it becomes dark, party to inspire the scene of celebration as well as various timers and occupancy functionality. The integrated overall chandelier system is designed, all the preference modalities are programmed and tested using Proteus software, and the apparatus is implemented using hardware components. The running code is tested and the equipment prototype is inspected and validated.

Despite the fact that the proposed chandelier is structured of 2 groups each of 8 bulbs, the number of groups and the number of bulbs in each group can be easily modified to meet the resident specifications, the room extension, chandelier size, and the space volume to be illuminated. Furthermore, if the place requires two or more chandeliers, it is possible to control many chandeliers using one single remote control. In fact, the XBee unit connected to the remote will be configured in coordinator mode while the other XBees connected to the chandeliers board are assigned in router status.

It is to be noticed that using newest environmental LED lights rather than standard incandescent electric bulbs could reduce power consumption to 10%. Moreover, these LEDs have life time mush longer and are presented by different colors according to applied voltage. This variable color control allows the simulation activities by merging sparkling color lights for entertainment, party, and other special scenes.

Finally, many additional features could be introduced in the chandelier system according to user specifications. The first issue concerns the failure of the LED attached to the remote that alerts the user when a bulb, or more, is burned. This feature allows the user to make continuous and complete maintenance, in particular, when the number of electric bulbs becomes large and the room requires more than one chandelier. The second feature is the use of smart meter device that records the period of operations, determines the electric power consumed, and computes the bill amount to be paid. It is a manageable addition, efficient and cost disposal where it can be supported by powerful scheduling program and timing reports. The third characteristic involves a DC motor that rotates the chandelier arms in the special events providing comfort ambiance for relaxation to get rid of tension and anxiety. Besides, many chandeliers have bulky volume and massive weight due to the metallic components, decorative chains, and reflective crystal prisms. This special kind requires the use of safety weighting test that alert users when the maximum lifting weight is exceeded. Finally, a circuit breaker will be convenient to protect the chandelier against high voltage tension and high current flow.

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