

The Circuit-level Design and Implementation of a Computer-Controlled Room with a Graphical Interface

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1 Abstract

Our research sought to simulate a computer-controlled environment on a smaller scale to assess the positive and negative aspects of an automated home. Through this technology, homeowners could lead a more efficient lifestyle. With the integration of computer and electrical engineering, we designed a system of computer-controlled appliances that react to various stimuli.

2 Introduction

With the computational power and speed of today's computers, nearly everything can be automated to eliminate the hassle of manual work. Switching the lights on and off is too difficult for most contemporary Americans. Therefore, we designed and built the components for a computer-controlled room to facilitate this process.

In the 1950s, the "home of the future" was inclined to rapid manufacturing. The vision of a futuristic home during this period consisted of a home that was easily transported, rapidly constructed, and

produced in large numbers; inside, the home would have built-in furniture and a small kitchen, and the entire structure would be made of plastic. Hence, "Living in the home of the future was like living in a Swiss army knife"[1]. However, a few decades later, the theory of a smart room has developed and the new vision of the "home of the future" is no different from the 1950s caricature, except that the innovative home would function through artificial intelligence.

An automated household or a Smart Room "is a physical space for living or working in, that is agent controlled and can bring computational power embedded within it to bear in a manner that helps users of the environment perform their daily tasks" [2] Automated rooms, in theory, are designed to sense what is occurring within its walls and respond by commanding lights, doors, etc in order to demonstrate intelligent behavior and help the inhabitants of the home. Javier Zamora, the general manager of Eneo Labs, an organization that is trying to create a smart home, explains that a smart home would be able to predict the inhabitants' routine and adapt consequently, Zamora also commented that smart houses have two focal constituents: an "information network,"

which was “like a human body's nervous system in that all devices inside the house would be connected to it; and a "brain," which coordinated what was inside the home and connected it to what went on outside.”[4] A smart room has an intelligent agent that is able to attain and apply knowledge about the environment and its residents in order to improve their lives.

Other applications of computer controlled electrical devices are not as complex but still just as popular. With a computer sequencing software, an elaborate electrical circuitry, and with brilliant craftsmanship, several advocates have managed to create stunning displays with computer controlled lights. Enthusiasts, like Mark Obermiller-a renowned celebrity for his computer controlled Christmas lights , have made it their hobby to create these amazing spectacles with lights and electrical control boxes that turn the lights on and off, and the software that run the control boxes and program the animated sequences. These small groups of hobbyists usually use Dasher, a software program that configures specific settings for the lights used in the display. The control hardware, used by these small groups, takes a computer's “low voltage digital signals and translates them to the standard electrical current powering the lights.” [9] This process can be computed by using digital input-output cards that are connected to solid state relays that in turn are connected to light circuits, or by implementing a control box to a computer’s parallel ports as well as to light circuits. [9] The use of automated devices on various levels whether it be the home or for entertainment, has proven that there is a market for computer controlled appliances.

3 Background Information

The technology exists to make smart and responsive rooms, sensors like

actuators, radio frequency identification (RFID) tags, personal software agents, voice and image recognition software, and robots [3] avail the configurations of an automated household, making it plausible for a house to be stimulated to help humans in their daily regiments. An RFID is a mechanical identification system that relies on storing and retrieving data using RFID tags. An RFID has two components-one is a circuit for storing and processing information, “modulating and demodulating a (RF) signal and perhaps other specialized functions.”[8] The second is an antenna that is used to receive and transmit signals. [8] - an RFID was used in our engineering design. With several inputs, this technology will revolutionize the idyllic and uncomplicated rendition of an average home.

Progress is being made in order to create these smart rooms. For example, researchers at Stanford University have created an iRoom, or “interactive room.” A prototype of the design includes an assortment of many microphones, wireless devices and cameras along with touch sensitive sensors along walls and other interactive displays. The researchers could move information immaculately from the applications implanted in the iRoom to their personal devices, which allows any user to control any application in the home. The researchers created a system for the iRoom called the Interactive Room Operating System, or IROS, an operating system that joins together distinct devices. The purpose of IROS is to “[take] the operating system idea to the space level, so people can coordinate their work in an environment with multiple devices,” says Terry Winograd, a computer science professor at Stanford. [3]

Projects like MavHome, the Gator Tech Smart House, the iDorm, the Georgia Tech Award Home, the Adaptive Home, and the Home Depot Smart Home.

A smart room, though uncommon, is not a concept that is completely unobtainable to average homeowners today. Products such as X10 controllers and IBM's Home Director allow individuals to automate their homes with little to no adjustments to the electrical wiring of the home.[10] In particular, X10 is a communications language that allows electrical devices to send digital information to each other through brief radio frequency bursts over a power line.[11] Thus when used in the home, X10 controllers allow compatible products to communicate through a structure's existing electrical wiring. Installation of X10 is relatively simple considering that it only requires a transmitter and receivers plugged into the household appliances and an outlet. Inexpensive and widely available, X10 is user-friendly and requires little work to set-up.

Despite its benefits, however, X10 falls short of fulfilling the possibilities of a truly automated room. The use of a transmitter as opposed to a central computer to control electrical devices can lead to many problems and errors. For example, since X10 communicates through sending radio signals, interference between signals is likely to occur whereas an appliance following a computer program would not face such an issue. In addition, X10 does not have a sophisticated sensor system. Though X10 controllers enable time sensors, the system is not yet sophisticated enough to accommodate sound, touch, or infrared as a device stimulus.

In comparison to X10 controllers, IBM's Home Director is a home networking system that goes beyond simple appliances and connects the home's subsystems such as lighting, heating, air conditioning as well as security systems. [12] Home Director also links devices such as PCs and DVD players, but unlike X10, the system is limited when it

comes to simple appliances such as coffeemakers and the toaster. It is also a much more complicated installation process than that of X10 as it requires professional installation. Indeed, X10 and Home Director appear to present a similar product that operates on two different levels. While X10 is best for electrical devices belonging to a smaller scale, Home Director is specialized to coordinate the larger subsystems of the home. However, both are ineffective systems if a homeowner wishes to automate every electrical activity in the home. With our design, we hope to make complete automation of one's home a possibility.

Smart houses are a reality and they are the gateway to a future that was once only possible in imagination. In our research, we examined in detail the basic principles of a computer-controlled room with a specific focus on lighting activated by sensors; in particular, RFID tags. Furthermore, we explore its possible application to everyday life by assessing the results of our small-scale simulation.

4 Engineering Design

Diagrams (made in Blender v2.44, rendered in YafRay)

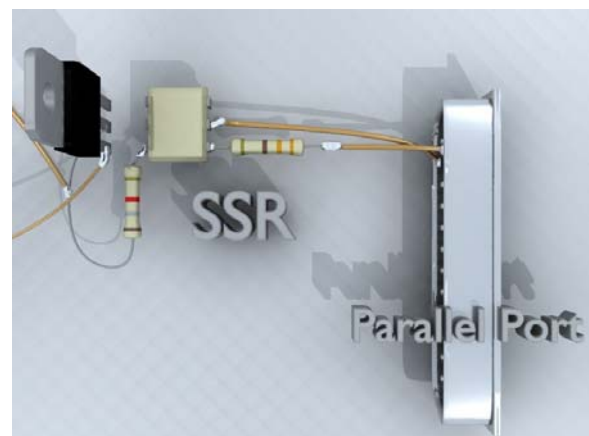


Figure #1, SSR

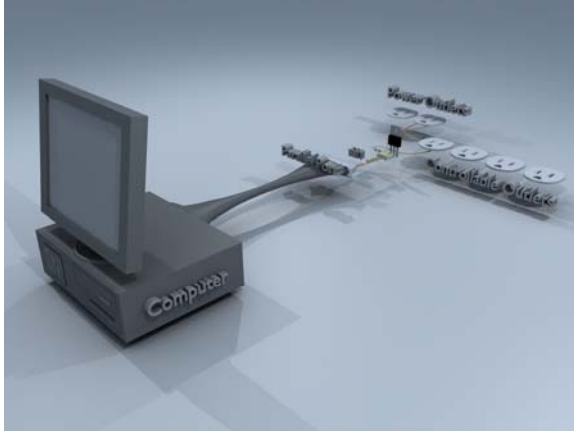


Figure #2, Electric circuit

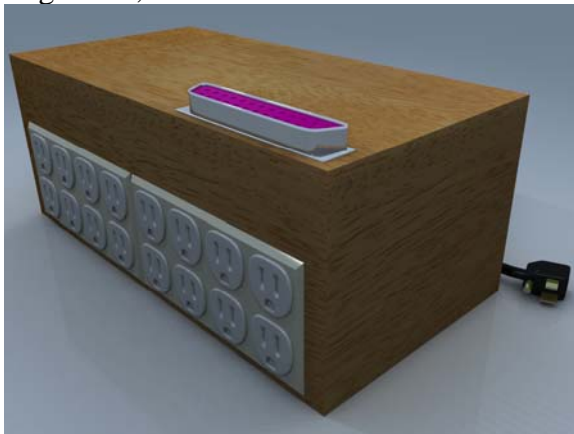


Figure #3, Main box

Working with basic electric components, our goal was to design a system that would control 8 different circuits (one for each output pin of the parallel port). Specifically, we needed to:

- Build Solid State Relays (SSRs) that connect to the parallel port of a computer and control lighting in an electric circuit.
- Construct a box of outlets that are controlled by the SSRs.
- Design a main box with openings for the outlets and parallel port.
- Develop software, with a graphical user interface, to control the SSRs, taking input from an RFID device and sending output to the parallel port. Unlike in the X10 system, the software will allow for

full appliance control and customizability.

4.1 Solid State Relay

The heart of a computer-controlled room is a small circuit switch known as the Solid State Relay, or the SSR. The SSR uses a 5V DC control current to switch a much stronger current (120V AC) on and off. This is accomplished by using a TRIode for Alternating Current (a TRIAC) , an opto-isolator, and two resistors to control the flow of electricity over the circuit.

The TRIAC is a type of 3-pin transistor that cuts all current flow across the component until a voltage greater than the specific threshold for the TRIAC is applied to the gate pin. When voltage is applied to the gate, the circuit opens and the current is allowed to flow freely across the other two pins. In the circuit we developed, this device served as the gate mechanism for the wall current by alternatively restricting and opening the current to reach the outlet that the controlled appliance is plugged in to.

The opto-isolator is an 8-pin transistor that has complete electrical isolation from one side to the other. When certain voltages are applied to the pins on one side, a LED comes on, triggering a phototransistor to let current flow between the ports on the opposite side. In the SSR, the opto-isolator acts as an intermediary between the parallel port input and the TRIAC. When the parallel port sends voltage into the opto-isolator, the component allows voltage to reach the gate pin on the TRIAC, which consequently opens the circuit and allows wall current to flow.

The carbon-film resistors in the SSR are devices that lower the voltage across the sensitive opto-isolator to prevent it from being destroyed. Without these resistors, the LED in the opto-isolator would immediately be burned out, rendering the circuit useless.

Our group constructed 8 SSRs for this project. For each relay, the TRIAC, opto-isolator, and two resistors were laid out on a miniature circuit board. They were then soldered together at the appropriate pins, as demonstrated in Figure #1. Each SSR was connected to four pieces of stripped copper wire, two output and two input. One of the input wires was connected to a pin on the parallel port and carried a current to the opto-isolator. A 330-ohm resistor was used between the parallel port and the opto-isolator to decrease the voltage. To complete the circuit, a wire was connected to another pin on the opto-isolator, serving as a ground. The other end of the SSR, the TRIAC, was soldered to one input wire and one output wire. This formed a 120 volt AC circuit that was controlled by the opto-isolator.

4.2 Outlet Box

In a typical room, electric devices are plugged directly into the wall outlet. To control these devices with a computer, we wired the relays between the wall outlet and two outlet boxes. The entire circuit is demonstrated in Figure #2. Each outlet box consisted of four pairs of outlets screwed into a plastic encasement, as well as the wiring for the outlets. The boxes were powered by a two-pair outlet box similar to the larger “output” boxes. The “output” boxes were dimensioned 4 by 3.5 by 8 inches, and the “power” box had dimensions of 4 by 4 by 3 inches. Inside the “output” box, the outlets were wired in a series to a hot wire, conducting power from a wall outlet. Each relay was attached to one of the output pins on the parallel port and to one pair of outlets. The SSRs were then grounded to an external object to dissipate any electrical buildup that could destroy the opto-isolator or the TRIAC. As a further precaution, rubber tubing was used to shield the wire coming out of the parallel port, and

the rubber was shrunk with a heat gun. The SSRs were packed into 1 by 1 by 2 plastic project boxes, and all 8 project boxes were placed into a 6 by 6 by 4 plastic box, with an opening for the parallel port.

4.3 Main Box

Our last physical challenge was the construction of a container for the outlet boxes and SSR box. We chose wood as our building material due to its availability and low cost. To accommodate the three outlet boxes and SSR box, we chose main box dimensions of 19.5 by 9 by 9.5 inches. The plastic boxes were arranged inside the main box; the “output” boxes were stacked horizontally on the “front” of the main box. The “power” box and SSR box were placed so that the outlets powering the outlet boxes and the parallel port were on the “side” of the main box. This separation was made in hopes that users of the computer-controlled lighting system would not plug their appliances into the “power” box, which is meant solely to power the “output” boxes. Using power tools, a 2 by 4 piece of wood was cut into the proper dimensions. Figure #3 shows the completed main box.

4.4 Parallel Port Control Program

One of the key components of our computer-controlled room project is the software responsible for controlling the room itself. The program was written in C#, although any language which can acquire parallel port access would have been suitable. Although the room controlling software, RController, was written mainly as a proof-of-concept, it meets many of the criteria for a program deployed publicly for the same task.

RController was designed to allow the end user of this product to configure when changes in the state of attached

devices would occur. This program supports both time and RFID “sensors.” The decision to unify the factors which control the room under the class of sensors was made to facilitate setup and allow for changes to be quickly made. RController is assigned events and which changes to invoke upon this event. Events are prioritized to create complex chains of actions. For example, an event/change pair such as “the toaster is on between 7:00 and 9:00am when George is present” can be created.

RController is capable of using any number of parallel ports to control individual devices. These devices can be named and referred to by name once created. Control is done by means of sensors. All sensors implement a common interface, allowing for the addition of future sensors easily. Current sensors include both an RFID interface, and a time module. Through chains of events, complex events can be created to control individual devices with multiple criteria. A priority-based system was used to allow for complex events.

RController is written so as to allow for easy future expansion. The modular design of the program makes the addition of new sensors easy. Control by new ports can be accomplished by modifying the port controller to allow for additional non-parallel port addresses. The program can be readily modified to include any conventional port, although changes in the hardware would need to take place for the system to be compatible with additional ports.

The main library controlling the communications between the computer and the devices, such as the lamps, is a native DLL named InpOut32. This allows the user to specify where the port is, which pins are connected to which devices, and whether or not the devices are active. The user interface (UI) will handle the rest, including setting the state of the port and registering the devices. Each device is given a unique

name which can be specified by either the user or the computer; the UI will make sure that every parameter of each device is available so that no conflicts arise. The Phidgets library is also implemented in the program. This library provides functions for controlling the USB RFID device used for input in this project.

Results

At the conclusion of this project, our group had spent an estimated \$400 dollars on materials. Furthermore, through mistakes in building the design, many materials were wasted and parts of our final project were damaged such as parallel port pins and Solid State Relays. However, the design worked despite the various shortcomings.

Our project proves the effectiveness of the Solid State Relay as a circuit controller device; it is possible to use a low, DC current from a computer to toggle a high AC current on and off using an SSR. A Solid State Relay was used as opposed to an electromechanical relay due to the break in signal caused by the opto-isolator; this allows for fast, reliable switching capability.

Furthermore, we have ascertained that the parallel port is in fact the optimum computer port to use for controlling appliances. The parallel port sends low, harmless signals of 5 volts to the opto-isolator of the Solid State Relay; this means there is a low risk of injury. Also, the parallel port has 8 output pins and is easy to control with inpout32.dll, a freeware parallel port driver.

The use of RFID as a sensor also proved to be successful. This is an indication that RFIDs could be practically utilized as a sensory tool in computer-controlled lighting and also automated homes.

On a software level, a program written in any high level language can be

used to read input from the USB RFID and output to the parallel port with inport32.dll.

In comparison to existing home automation systems, our current design is still crude, and without refinement, it is an impractical alternative to a system such as X10. However, our designs show advantages over the X10 system in that devices would be powered by a central computer as well as have more sensory abilities, thus allowing more sophisticated options for user preferences.

Future Work

Upon completion of the project, it became clear that a system of computer-controlled outlets is relatively simple to design and implement. These outlets can be used to control lighting in a room, as well as any other electric appliances. It is probable that computer-controlled rooms will develop into computer-controlled houses, or “smart” houses and become omnipresent in the near future. A “smart” house will implement a similar design to the one we created, except every wall outlet will be an integral part of the system. Also, the entirety of the house will be controlled by one central computer. The parallel port is become less common; therefore, “smart” houses will likely use another interface, such as USB or Wifi. Computer-controlled devices can extend past the home; cars, planes, and factory robots are already controlled, to a certain extent, by computers. In years to come, the extent of computer control will almost certainly increase, making life simpler for everybody.

Yet, the priority of a smart home should not focus only on providing a domestic bliss but on other humanitarian causes. One of the most promising uses of a smart home is to help elderly people to live in a secure and independent environment. There has been an increment of individuals

who are physically impaired due to aging. In 1985, five and a half million disabled elders were living at home. But it is estimated that by 2030, seventy million Americans will be over the age of 65 [5] and over ten million of the elderly will be living at home with disabilities [6]. Even with these statistics, surveys indicate that most elders want to remain in their homes as they grow old despite their disabilities which may compromise their safety. The development of a smart room for seniors “can tremendously impact and facilitate the desire of adults to age in place” [7].

Conclusion

During the course of this project, our group learned the intricate aspects of electrical and computer engineering. Through the construction of solid-state relays and circuit boxes, we experienced first-hand the challenges that electric engineers face. Furthermore, our group designed a program that worked in conjunction with the electric circuit. This close relationship demonstrates the intertwined nature of electrical and computer engineering.

The results of our work have led us to believe that our simulation of a computer-controlled room is possible to implement in a real-life setting. The project has proven that the materials are cost effective and readily available, thus making the “smart home” a practical design. With advancements in technology, it is possible to expand on this design by centralizing the system that controls lighting in a house.

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