Computer Controlled Lighting
Study And Trial: Home Christmas Light System

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ABSTRACT

A design project was conducted to learn the basics of a computer controlled lighting instance in which a strand of Christmas lights would be controlled through the parallel port of a standard desktop PC. Our project took into account the strengths of a Solid State Relay along with the use of low-voltage control mechanisms, such as the small amount of voltage drawn from a parallel port. This project seeks the better understanding of Computer Controlled Lighting. It is our hope that we can readily assess the benefits and drawbacks of using a Computer Controlled Lighting system in a small and contained environment and, in the process, extrapolate that data to a much larger scale in hypothetical terms.

Keywords

Computer Controlled Lighting, Solid State Relay, SSR, Christmas lights

INTRODUCTION

In 2001, 55% of Americans bought Christmas or other holiday decorations including lights totaling $6.4 billion.[1] These decorative lights are usually made up of 50 2.5V incandescent bulbs connected in series. Shunt wires are also in the bulbs in order to allow the rest of the lights to stay lit when one goes out. Larger strings of lights are made of groups of 50 lights placed in parallel with each receiving the same voltage.[2] Not all the lights are incandescent, though; some are LEDs, which can utilize fiber optic wires connected (as they are in some artificial Christmas trees.)[3] Christmas lights were not always this simple, however. These lights used to be made up of 120V incandescent lights in parallel which generated a much greater amount of heat.[4]

Incandescent light bulbs contain two metal contacts that lead from the base screw part to support wires that connect directly to the tungsten filament, supported by a glass mount. All of these components are contained within a glass bulb filled with argon. The light bulb emits light when electrons flow up one of the metal contacts to the filament, where they bounce around. This causes them to heat up and gain energy. When the electrons fall back to lower energy levels, they release the energy as photons or light.[5] Edison created this light bulb design, but Edward Johnson, an associate of Edison, created the idea of Christmas lights by putting 80 red, white, and blue incandescent bulbs on a tree in front of his house. The public then took notice of Christmas lights after President Cleveland in 1895 created the first electrically lit tree in the White House with over 100 lights. However, most people still did not use the lights because of the complicated wiring. Some people chose to use battery powered lights instead.

Christmas lights finally hit the mainstream when GE invented a pre-wired socket on the bulb, which eliminated the complicated wiring.[6] Modern lights can even blink by two different methods. One way is by use of a bi-metallic strip connected to the filament,t which bends and breaks the electricity flow when the filament gets hot. Then, once the filament eventually cools down since the lights are off, the bi-metallic strip bends backward. This allows the current to flow again, turning on the lights. Another way to make the lights blink is to use a controller box which consists of an integrated circuit and triacs. The integrated circuit sends enough current to turn on one of the triacs which in turn turns on a section of lights until the integrated circuit stops sending electricity to the triac.[7] This project also uses a triac to provide electricity to the lights but uses a solid state relay connected to a computer via the parallel port instead of an integrated circuit to control the lights.

1 http://retailindustry.about.com/library/bl/03q1/bl_um020303a.htm
2 http://home.howstuffworks.com/christmas-lights2.htm
3 http://en.wikipedia.org/wiki/Christmas_lights
4 http://home.howstuffworks.com/christmas-lights1.htm
5 http://home.howstuffworks.com/light-bulb.htm
6 http://www.oldchristmaslights.com/history.htm
7 http://home.howstuffworks.com/christmas-lights3.htm

BACKGROUND INFORMATION AND RELATED WORKS

Solid State Relays (SSR) are electrical devices that can conduct a load of current through one or more transistors or thyristors[8]. SSRs are made up of non-moving parts, making them more durable and reliable than relays using electromagnetism. SSRs tend to save space on printed circuit boards, as well as time in building and design. They also lead to better product life and performance[9]. The input and output switches of SSRs are triggered by low voltages.

By examining the acronym "SSR", one can gleam information about the basics of the device. In electronics a relay is an electronic switch that goes on or off depending on the power coming from another circuit. Solid state electronics are products that do not contain vacuum tubes[10]. This means that electrons flow through solid material (such as Germanium (Ge), Silicon (Si), and others) and not through open space. Solid state components last much longer than thermal components because they tend to have a stronger resistance to shock and mechanical ware[11]. By putting these terms together, one can clearly infer that an SSR is a device that is solid state and switches power.

There are three different types of SSRs, which are classified by their type of input. Reed-relay coupled SSRs have an input that is controlled by the input signal being sent though a coil of a reed relay. When the reed switch closes, the action triggers the thyristor into conduction, moving the SSR into action. Another type of SSR is the transformer-coupled SSR. An AC signal is sent through an aspect of the transformer. If the signal is DC based, it has to go through a DC/AC converter before it can be used by the primary transformer. Photo-coupled SSRs have a photosensitive diode or transistor used to distinguish between input and output. The photo-coupled SSR is activated when a control current supplies enough power to basically 'turn on the light'[9].

In our lighting system, the use of a photo-coupled SSR proved advantageous over the transformer-coupled units. It has the smallest and most inexpensive components. Furthermore, the switching times are faster than in the others. Additionally, the ability to control the voltages is under better control in a photo-coupled SSR[12].

Commonly, SSRs are designed to use either AC or DC power, put not both. The SSR used in the project contains a triac, which switches the input from DC to AC output. The most common type of SSR can handle 120 or 240 volts, but there are some AC-output SSRs that can switch 500 volts or more[12].

Since the SSR created in the project was photo coupled and took in DC current while outputting AC, optoisolators and triacs are employed. An optoisolator (also known as an optical isolator, optical-coupled isolator, or optocoupler) is an electrical device that is very small, is four pronged, and uses light to transmit signal. The device is usually used in solid state electronics because it does not have moving parts that are prone to breaking[13]. The device works by having one end that emits light and another end that detects light. Since the device is housed within a container, the only light read by the detector is the light that is within the system. A part of the emission from the system is optically coupled to the light and is sensed by the detector[14].

Another major component of the system is the triac (Fg 1). "Triac" is an abbreviation for "*tri*ode for *a*lternating *c*urrent". It is comprised of two thyristors joined in inverse parallel (that is, they are parallel with reverse polarity). Because of this setup, a switch that is able to push current in two separate directions depending on when it is triggered is created. The system is activated by a voltage against the electric gate. After it is triggered, current will continue to flow until the system drops below a certain voltage value. Furthermore, the system will be able to switch to the other side, making it practical for use AC circuits. Since very little amperage is needed to control the system, it allows strong control of high power with milliamperage. Typical uses of lower power triacs are light dimmers, speed control in electrical fans and motors, and in the small circuits of modern appliances[15].

8 http://galenet.galegroup.com/servlet/SciRC?ste=1&docNum=A61537251

9 http://galenet.galegroup.com/servlet/SciRC?ste=1&docNum=A146633838

10 http://en.wikipedia.org/wiki/Relay

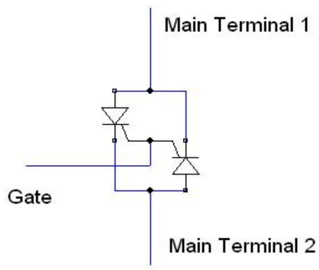
11 http://en.wikipedia.org/wiki/Solid_state_%28electronics%29

12 http://www.ssousa.com/pdf/an040.pdf

13 http://www.jaycar.com.au/images_uploaded/optocoup.pdf

14 http://en.wikipedia.org/wiki/Optocoupler

15 http://en.wikipedia.org/wiki/Triac



Fg. 1 Triac circuit

For the building of the circuit, our group needed an understanding of resistors. Resistors are devices that resist the flow of electrons in a circuit[16]. Usually, they are made of compressed carbon[17]. To use resistors correctly, one must be able to understand the logic behind them. According to Ohm's Law, voltage equals the current time the resistance (algebraically, V=IR). This means that particular voltages will require different resistances to produce the correct current. Ohm's Law takes into consideration the potential difference of a system. The conduction of current through a point in which the current drops when it hits another is known as the potential difference. The ohm, the measurement of resistance, is the ratio of one volt to one ampere.

Correctly reading the pre-made resistors is crucial to creating any circuits because with a wrong resistance circuits could short and damage entire devices[9]. Resistors have four color bands on them and are read from left to right. The first two bands represent the first two digits of the resistance. The third represents the power of ten the number is multiplied. The last band represents the number the tolerance or variance level the resistor has. Because an overload of power can short a circuit, resistors are utilized to slow down the flow of electricity[17].

To place our project together, we needed the ability to solder parts together. Solder is a soft metal alloy that melts at low temperature. Therefore, it is very useful for fusing various harder metals together. Solder is used with flux, a substance that helps remove impurities from the metal so that electricity can be conveyed clearly[18].

16 http://en.wikipedia.org/wiki/Resistor

17 http://www.doctronics.co.uk/resistor.htm

18 http://en.wikipedia.org/wiki/Solder

EXPERIMENTAL / ENGINEERING DESIGN

To create a usable design, our team focused on four major landmarks when planning this project.

1. Secure usable parts that best serve our purpose;
2. Engineer a compact and practical design that can effectively control a small string of Christmas lights; and
3. Create an executable program that can manipulate a parallel port and allow operation of the lights (i.e., activating and deactivating the current flowing to them).

Secure Usable Parts

In order to find the most effective and practical parts, our group collaborated with Larry Liang and Blase Ur[19]. Liang supplied us with pre-etched circuit boards (PCB) and Ur was able to supply solder, soldering irons, and other necessary parts to make this design a success. (A list of parts can be found in Appendix A.)

Our group chose the parts, however, based on more than just Liang's advice. Liang advised us that the optoisolator (or optocoupler) allows electricity to be passed from an input into an output, but with certain controls. If too much or too little voltage is supplied to the optoisolator, it will not allow current to pass. This gives the user control over his or her lighting, and ensures that only a set range of voltages are accepted. This functions as a preventative measure against short-circuits.

The optoisolator was chosen based on two of its main advantages. The first is that optoisolators control current using a photo-sensitive diode; in other words, a small light. When this light is on, the current flows; when it turns off, the current stops[20]. The light only turns on when less than 15 milliamps (mA) of current pass through one side of the optoisolator. Optoisolators, however, control the flow with light only, and do not allow electricity to pass. Other relay mechanisms, such as electromechanical relays (EMR), have the potential to pass current and voltage, making them a poor choice for our design[21]. Therefore, our first advantage is that short-circuits are a much rarer occurrence.

The second advantage is that optoisolators can work on very different magnitudes. This means that one side of the optoisolator can handle very low voltages while the opposite side can handle very large voltages. Thus, a

19 Both Liang and Ur are juniors attending Rutgers and Harvard, respectively. Their aid was only in supply of parts and facilitation of our groups work.

20 http://www.jaycar.com.au/images_uploaded/optocoup.pdf

21 http://www.clare.com/home/pdfs.nsf/www/an-145.pdf/$file/an-145.pdf

small amount of power – in that case, the power coming from a parallel port – can control a large amount of lighting, such as thousands of Christmas lights. If a home user wanted to control his or her entire outdoor lighting system, all that user would need would be a low-voltage parallel port. Thanks to the fact that optoisolators do not allow the passage of current directly, but rather operate on light, this also prevents the high voltage from crossing into the low-voltage section and possibly harming the user's computer[22].

The 330ohm resistor is placed just before the optoisolator in order to make sure the voltage, the potential energy of the electricity, and the current (the rate of the electric flow) did not become too high in the case of a spike from the parallel port.[23] A spike in electricity from the parallel port could damage the optoisolator severely. The value of this resistor was determined using Ohm's Law by dividing the 5V source by 15mA, the maximum amount of current the optoisolator can handle. The result was 333.333 ohms. However, in practice, we used a 330ohm resistor, since this was the closest nominal resistor value – in other words, the closest value we could achieve with standard manufactured resistor sizes.

The second resistor, which measures 180 ohms in resistance, is placed between the triac port, MT2, and pin 6 of the optoisolator in order to prevent electricity from flowing from port 4 of the optoisolator through the gate back into pin 6 of the optoisolator. This prevention occurs because the path of least resistance is down the AC neutral wire for the electricity rather than back into pin 6 as a result of the 180ohm resistor. Otherwise, the optoisolator would most likely be damaged.

AC hot is not connected directly to the solid state resistor in order to prevent any injuries to the group during an electricity surge. This is because electricity leaves from the wall to the extension cord on the AC hot wire. Two AC neutral wires are connected instead because electricity returns on the AC neutral wire to the wall. The AC hot wire is then simply connected to the outlet in order to isolate it.

Finally, overall, the group used a solid state relay to turn the light on or off by closing or opening the entire circuit respectively. Solid state relays work by having an optoisolator receive the electricity, convert it to light with an LED, convert the light back to electricity, and finally send the electricity to a triac, which allows the electricity to continue only if the voltage and current values are correct. An electromechanical relay could also have been used. Electromechanical relays work by having two pieces of iron with one wrapped with a coil that when electricity passes over causes the iron to become magnetized. This then attracts the other piece of iron which is on a pivot causing a connection to occur or a closed circuit.[24] However, we used a solid state relay rather than an electromechanical relay, because solid state relays have no moving parts and use zero-crossover switching. Zero-crossover switching causes the triac to keep the circuit closed even after the LED is off until the AC current drops to a certain level. This causes electromechanical relays to be larger, operate more slowly, last less time, be more dangerous, and have corrosion problems.[25] Therefore, a solid state relay was obviously more practical for our design.

Engineer a Practical Design

After learning about circuits in general and studying the actual schematic, the group began making the actual design. First, after gathering all the necessary materials, the group soldered two wires to two of the data pins, pins 2-9, and the other wire to one of the ground pins, which are pins 18-25 on the parallel port.[26] The group soldered the wires by cutting a two foot long strand, stripping both ends of the wire, heating the soldering iron up, putting a small amount of solder on the soldering iron, adding the solder onto one end of the wire from the iron, putting the wire into the correct pin, and finally putting the soldering iron onto the wire where the solder is for a few seconds. Then, we repeated this process for the other two wires. Next, we checked to make sure this parallel cable worked by plugging it into the computer, hooking the other end of one of the data wires and the ground wire into a multimeter, and using a program named lpt.exe in Windows XP to send current down the parallel cable to make sure the multimeter registered a voltage.

Then the group started to create the outlet part by cutting the female part of an extension cable off with wire cutters. We then separated the two wires with a knife, stripped both of the wires, inserted the wires into the punched hole of the box for the outlet, and twisted the ends of the wires, making the ends form a hook. Then the group attached the AC hot wire, or the wire from the smaller prong, to the screw next to the smaller prong on the top outlet, and the AC neutral wire, or the wire from the larger prong, to the screw next to the larger prong on the top outlet. Then, after securing the

22 http://www.analog.com/Analog_Root/static/pdf/dataConverters/faqs/iCoupler_faq.pdf

23 http://hyperphysics.phy-astr.gsu.edu/hbase/electric/ohmlaw.html#c1

24 http://ourworld.cs.com/gknott5413/elect129.htm

25 http://www.allaboutcircuits.com/vol_4/chpt_5/5.html

26 http://www.epanorama.net/circuits/parallel_output.html

outlet to the protective box, the group cut the AC neutral wire and stripped both ends. Next, the group cut another wire, stripped both ends, twisted one end, curled this same end, and finally secured this wire to the bottom AC neutral screw. Then, in order to isolate the two AC neutral screws, we used the soldering iron to superheat the connecting piece of metal and the pliers to break off the piece. In order to connect the two AC hot screws, we then cut, stripped, twisted into a hook, and secured a small wire between the two screws.

Next, the group began putting the solid state relay together according to the schematic. The group attached two 330ohm resistors by bending the wire part up to the actual resistor and inserting the wire part into the correct holes with the traces of the PCB facing downward. Then the group attached the 2 optoisolators to the pin with the dot above it, connected to the trace that leads directly to the 330ohm resistors. The group next attached two 180ohm resistors to the trace that leads directly to pin 6 of the optoisolator in the same way as the 2 330ohm resistors. Then the group added the triac by connecting the gate pin to the trace that directly leads to pin 4 of the optoisolator. Finally, the group soldered all of these components making sure that none of the solder on different pins touched each other, and then cut all of the extra part of the pins.

Then, the group cut, stripped, and soldered wires to the individual outputs of each triac, the shared output of the triacs, each of the 330ohm resistors, and the ground hole. After this, we connected the wire from the ground hole to the wire from one of the ground pins on the parallel port. The group individually soldered the two wires from the data pins of the parallel port to each of the 330ohm resistors. Then we individually soldered the wires of the individual outputs of the triacs to the two wires connected to the AC neutral screws. Finally, the group soldered the wire from the shared output of the triacs to the AC neutral wire connected directly to the plug.

Write the Code

We utilized C++ coding on a Windows XP platform in order to control our lighting system. Our code used the Inpout32.dll driver, which was available as freeware online. We combined this DLL (Dynamic Link Library) file with our own command methods in order to control pins 3 and 7 on the parallel port. By alternating on and off, we were able to control the lights attached.

Inpout32.dll is a library file that acts as a driver. This driver literally 'drives' our program, because it translates our code into instructions that are readable by the parallel port. In the Windows XP operating system, User and Administrator level accounts do not have access directly to the parallel port, so the Inpout32.dll provides a mask that gives our program access to the port directly.

Using this direct access and a pre-programmed set of commands, our computer was able to manipulate our Christmas lights through the parallel port. With more time, it would be possible to create a graphical user interface (GUI) that would allow even the most inexperienced of users control over lights.

RESULTS

Upon the completion and preliminary testing of our design, we found that, with no more than the click of a button, a user could operate a standard 110-volt home outlet. This ease of use proved our belief that computer -controlled lighting can be effectively controlled by someone with little experience, thus making it available to a wide base of the consumer market.

Overall, the design of small control boxes can manipulate the power flow easily. We were able to make a small string of Christmas lights flash on and off, using a Windows executable coded in C++. When we work our code into a customizable design, an easy to use interface could be applied for the common user.

The results of this trial point to one conclusion: that computer-controlled lighting is effective and can be applied to multiple circumstances. Although our study was small – a string of Christmas lights – the optoisolator can control much larger sources of power, making it a great tool for controlling many lighting systems. Our team now strongly believes that this type of computer automation is an efficient and powerful system for controlling the common home owner's lighting.

FUTURE WORK

Seeing a small-scale design in action, our group came to the following conclusions:

- Computer Controlled Lighting is indeed a powerful and innovative tool;
- Home use is a possibility.

The most notable and simplistic question to answer was that Computer Controlled Lighting was a strong technology that could be applied to practical situations. In the case of the home Christmas lighting system, the use we made of the SSR and PC program helped us identify that an average user could, in fact, operate their home light system from the comfort of a computer. We noted that the control mechanism is safe and effective for what it is designed to do. The optoisolator allows for the control of voltage without actually passing voltage – a safe and secure mechanism for home use.

The optoisolator also lends itself to the expansion of the home lighting system far beyond a modest strand of Christmas lights. Because of the fact that optoisolators can control large amounts of voltage with very small amounts of voltage, a user could effectively light their entire home and not worry about how a surge of electricity might affect the computer they have hooked up to the system. The optoisolator, we have found, is a tool worthy of its placement in this trial.

The idea that large amounts of power can be controlled by very small, safe amounts of power has led to the suggestion that entire cities can be run in this manner. In Cantt, India, the city is planning to place their streetlight system, which consists of over 5,000 individual lights, on a computer-controlled lighting system. The computer would monitor when heavy volumes of cars pass by, and adjust the light accordingly. Also, depending on the weather that day or the season of the year, the system will adapt itself to fit the situation. Computer-controlled lighting can be applied much further than the adornment of a holiday party-house or church nativity scene. It can be used for government power regulation purposes or business interests. As in the situation with Cantt, the power costs will be cut by near 45 percent[27].

On the more business-oriented end of the spectrum, the company X10 manufactures and sells kits for home use that enable consumers to wire their personal lighting systems. In one press release, X10 hints at how their products can be used to control appliances such as lights, sprinklers and fountains[28]. This idea of computers more or less controlling an average person's everyday life brings our consumer-driven society into a new age: The Age of Automation.

The Age of Automation

One day soon, the average person's desktop PC will be able to control his or her home with a few simple commands in a tactfully designed and easy to use interface. Our trial with the effectiveness of Computer Controlled Lighting has shown that this age is advancing on us rapidly, brought to the average end-user by companies such as X10 and government agencies similar to those in Cantt, India. If these ideas work, we can expect to see more and more of companies like X10 on the rise. In the overall view of things, the world will take one more giant step to being accessible from anywhere, as a greater percentage of people take advantage of computer control to do common tasks such as watering their grass while on vacation. Computer-controlled lighting technology opens the doorway for bigger and better things. In this age, the Age of Automation, people can expect to see very big things, all accessible from their own personal computers.

CONCLUSION

The Computer-Controlled Lighting Project combined the software and hardware parts of electrical and computer engineering. The hardware part consisted of first learning about Ohm's Law, V=IR, which sets a relationship between voltage, V, current, I, and resistance, R and says that in a closed circuit the sum of the voltage drops must equal zero. Then the group learned about parallel circuits, voltage stays constant, and series circuits, current stays constant. Next was node voltage which was used to solve for certain voltage, current, or resistor values based on Kirchoff's Current and Voltage Laws. Kirchoff's Current Law states that the sum of currents at any node must be zero while his Voltage Law says that sum of voltages must equal zero at any node. The group then continued with learning about the actual schematic for the solid state relay that would be created. The solid state relay consists of the parallel port as the source of electricity, resistors 1 and 2 to protect the optoisolator, an optoisolator to separate the computer from the outlet by using LED's, and a triac to send the power from the optoisolator to the AC neutral on the outlet. The solid state relay is connected in between the AC neutral wires in order to control it by opening or closing the circuit. The current will flow from the wall outlet to the AC hot on the plug to the outlet with the light to the AC neutral to the solid state relay outputs and finally back into the wall outlet from AC neutral. AC hot is the smaller prong of the plug where the electricity enters while AC neutral is the larger prong where the electricity returns back into the wall. The computer controls the light by opening or closing the circuit by sending no electricity or electricity from the parallel port. The software part of the project is the computer program written in C++ and running on Windows XP. This program controls whether or not electricity is sent along the one data and one control ports of the parallel port that are connected to the solid state relay. The Computer-Controlled Lighting Project shows how electrical and computer engineers must balance not only one or the other, but both their hardware and software knowledge in order to accomplish their objectives.

27 http://cities.expressindia.com/fullstory.php?newsid=185074

28 http://www.marketwire.com/mw/release_html_b1?release_id=74173

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CITATIONS

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APPENDICES

Appendix A

The parts used for this trial were as follows:

- (2) Optoisolator (Model MOC3031 605Q)
- (2) TRIAC (Model NTE 5638 92M)
- (2) 180 Ohm Resistors
- (2) 330 Ohm Resistors
- Pre-Etched Circuit Board (PCB)
- 14 Gage Multi-Strand wire
- 20 Gage Multi-Strand wire
- 20 Gage Single-Strand wire
- Electrical Box
- 110-volt Outlet
- Plastic box for completed PCB
- Parallel Port (25-pin)