BRAC UNIVERSITY

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PROJECT REPORT

EEE 365 - Microprocessor

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Project Name: Overhead Projector Lamp Life Extender by Zero-Crossing Switching

Group No.: 9

Student ID	Student Name
17121073	A M Musa Shakib Khan
16110028	Romana Yesmin
16321021	Fariha Reza Khan

Abstract

This paper describes the implementation of Overhead Projector Lamp Life Extender by the technique of Zero Voltage Switching. The implementation has been performed using the AVR ATMega32 microcontroller in simulation using the Proteus Design Suite, with the microcontroller's program being written in CodeVision AVR Development Environment. The necessity of this project arises from the phenomenon of resistance of incandescent lamps decreasing in cold environments. This can cause them to draw very high currents when switched on and which in turn can reduce the life of the lamps. The implementation attempts to protect the lamp from this effect by using a comparator circuit to detect the zero voltage and current crossings of the AC power supply and then using a microcontroller to activate or deactivate the lamp at these points only. This mechanism would prevent current flow higher than what is required for safe operation of the lamp. After software simulation, the hardware implementation of the project was begun. Some errors were discovered due to the necessary differences between software circuit design and real life hardware set-up which have been also been discussed. Finally, alternative choices for isolation mechanisms have been briefly discussed before concluding the paper.

I. INTRODUCTION

An incandescent lamp consists of a filament of wire, which when current flows through it, is heated to temperature so high that causes it to glow and emit visible light. Filament wires are generally of metal and an extremely common material used is Tungsten. Figure 1 shows a typical tungsten filament lamp. In metals, the atoms lose valence electrons to become positive ions within a 'sea of electrons'. The bonding, known as the metallic bonding, between the positive ions and the electrons is what holds metal together. A metal is able to conduct electricity because when a potential difference is applied across its ends, the electrons begin to flow towards the positive terminals and current is nothing but the flow of charge.

Figure 1 Tungsten Filament Incandescent Lamp

This ability of a metal to conduct electricity varies with temperature. When a metal is heated, the positive ions begin to vibrate and obstruct the flow of electrons, reducing the rate and therefore the current. Conversely, with decreasing temperature, vibrations of the positive ions are much less and the metal's ability to conduct electricity increases. Figure 2 shows how the resistivity of Tungsten decreases with temperature:

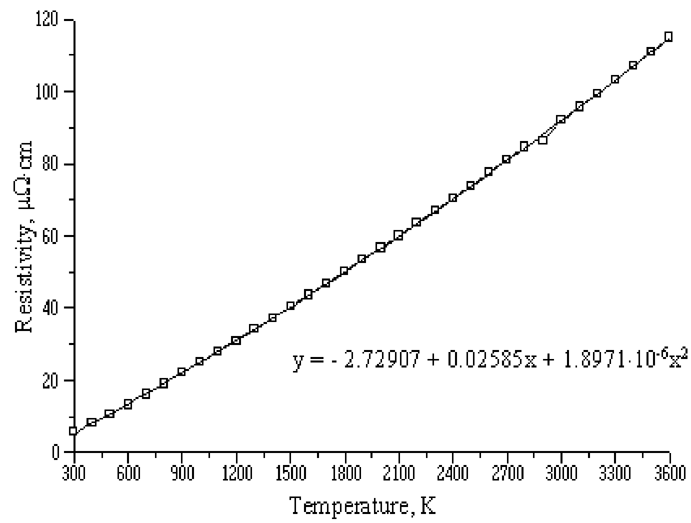


Figure 2 Resistivity of Tungsten against Temperature

This is precisely the circumstance for incandescent lamps in the lower temperatures of winter: the decrease in resistance (due to lesser vibration of positive ions) causes the filament lamp to suddenly blasted with a very high current, known as the ‘in-rush current’, from the AC power supply when just switched on as the filament wire was at the temperature of its cold surroundings. The in-rush current is much greater than the regular current that flows through the lamp. Light bulbs get extremely hot in general due to the current in them. The filament metal that it contains is brittle and when subjected to large current all of a sudden, can experience a great amount of vibration due to this burst of power and temperature. This excessive strain can reduce the lifetime of an incandescent lamp.

Extending the life of an incandescent lamp is clearly advantageous, economic and efficient for anyone wishing to thus derive more value from their expenses. Operating the lamp under optimum conditions is vital towards achieving this end. Therefore, the need comes to prevent the large ‘in-rush’ current in the filament lamp when switched on in a cold environment.

The project implemented attempts to address this need by increasing the current flow in the lamp gradually starting from the point when the AC voltage supply is of ‘0’ amplitude. As AC voltage amplitude increases from ‘0’, the current flow begins to increase too according to Ohm’s law. As the current begins to flow the temperature of the filament wire begins to increase progressively. Thus not only is a large in-rush current prevented but the sudden rise in temperature and the vibration that it brings to the filament lamp is controlled.

A point to be noted is that the maximum voltage of the AC power supply is not the issue that is to be avoided. If the lamp is turned on at zero voltage and it reaches full voltage during the AC cycle thereafter, the large current at the peak voltage is no longer a problem as the filament wire has already heated up and its resistance has therefore become high. The problem arises only when switching on at a cold temperature when the resistance is very low and starting at maximum voltage would result in the large in-rush current (larger than maximum current at maximum voltage during operating conditions at a different season of the year). Thus, the current that the project seeks to avoid is only the one during the first AC cycle because this is the highest current.

Another target of the project is to switch the lamp off at zero current. Disconnecting the circuit of the lamp at high values of current may cause sparks at the point of the circuit where it is broken. Because the lamp is (theoretically) a purely resistive load and there are no capacitive or inductive elements in its circuit, the current flowing in a resistive circuit is in phase with the voltage applied to it. This means the zero-crossing of the current is at the same time as the zero-crossing of the voltage cycle. This voltage-current phase relationship is useful in designing the project. Figure 3 depicts this scenario:

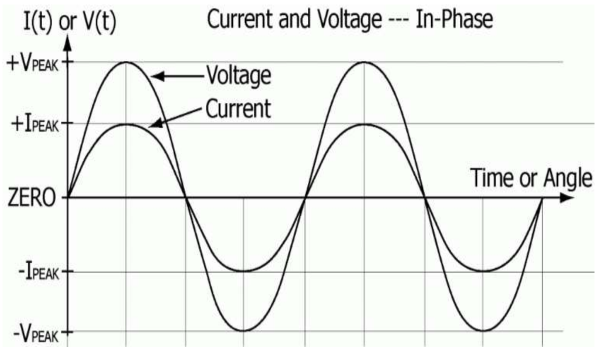


Figure 3 Current and Voltage Phase relationship in Resistive circuit

II. PROJECT DESIGN

The project implemented turns the lamp ON at zero voltage crossings and turns it OFF at zero current crossings of the AC cycle whenever the user toggles between the ON and OFF positions respectively of a switch. It has been implemented as a simulation in the Proteus Design Suite v8.6.

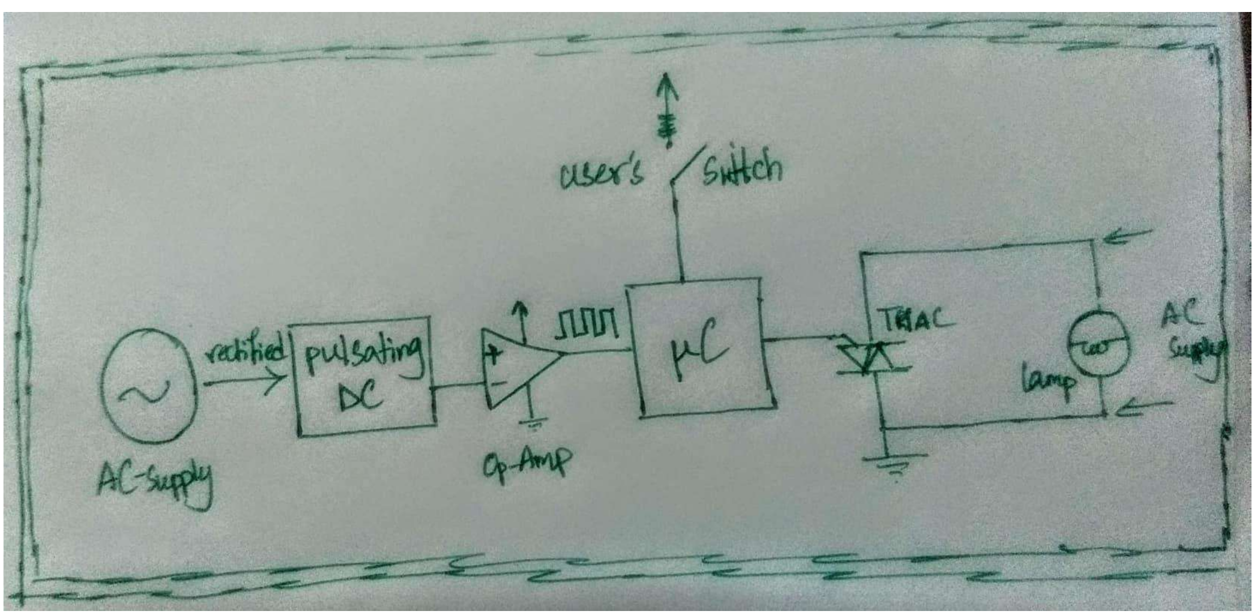


Figure 4 Initial Basic Circuit Design

The project is designed as follows: a comparator circuit is used that compares the voltage of the power supply to zero voltage level (or close to zero, for practical purposes) and outputs a square wave signal whenever this happens. This signal thus indicates the zero-crossing of the voltage and current of the power supply. It is then fed as input to a microcontroller. The pins receiving these signals are programmed to detect rising or falling edge of the square waveform. The user uses a switch to enable interrupts at these edges. When the switch is turned ON or OFF, two different interrupts are triggered respectively which cause the microcontroller to output ON and OFF signals. The output signals of the microcontroller activate/deactivate a TRIAC in the circuit of the lamp, which acts as a switch. Whenever activated, the TRIAC completes the circuit and current can flow in it and the lamp can light up. But this can only happen at the zero-crossings of the voltage at which points the microcontroller activates the TRIAC and thus lights the lamp. However, the Op-Amp signals of the microcontroller can only trigger interrupts when the user of the lamp presses a switch to turn it ON. When the switch is open, the Op-Amp outputs do not trigger interrupts for the microcontroller, even at zero-crossings. The list of items used for the implementation are:

ATMEGA32
BATTERY
BRIDGE
BUTTON
DIODE
LAMP
LED-RED
LMC6081A
RES
SWITCH
TRAN-2P2S
TRIAC
VSINE

Figure 5 shows the circuit implementation in the simulation software:

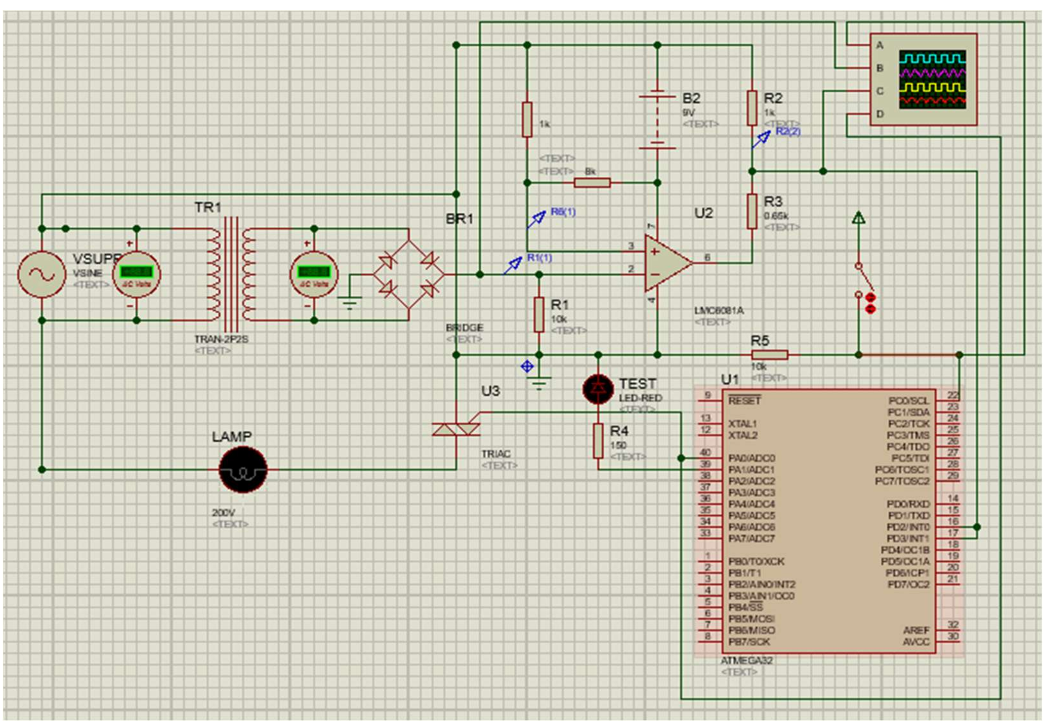


Figure 5 Proteus Circuit Design for Simulation

III. CIRCUIT DESCRIPTION

This section will explore into more depth of the circuit diagram above, that was taken from the simulation software. The AC voltage supply component has been set up using the parameters shown in figure to generate an output of 230V of AC voltage at 50Hz frequency.

DC Offset:	(Default)	Hide All
Amplitude:	300	Hide All
Frequency:	50Hz	Hide All
Time Delay:	0.005	Hide All
Damping Factor:	(Default)	Hide All

A transformer is used to step down this supply voltage to 12V to power the circuitry behind the implementation. The transformer parameters have been set as follows to make it perform the step-down operation:

Primary Inductance:	1H	Hide All
Secondary Inductance:	10mH	Hide All
Coupling Factor:	1.0	Hide All
Primary DC resistance:	1m	Hide All
Secondary DC resistance:	1m	Hide All

The 12V AC is then full-wave diode-bridge rectified such that it changes into a wave shape shown in figure. The waveform is now a pulsating DC signal, varying from 0V to peak continuously. The pulsating DC signal is displayed by the oscilloscope is shown in figure:

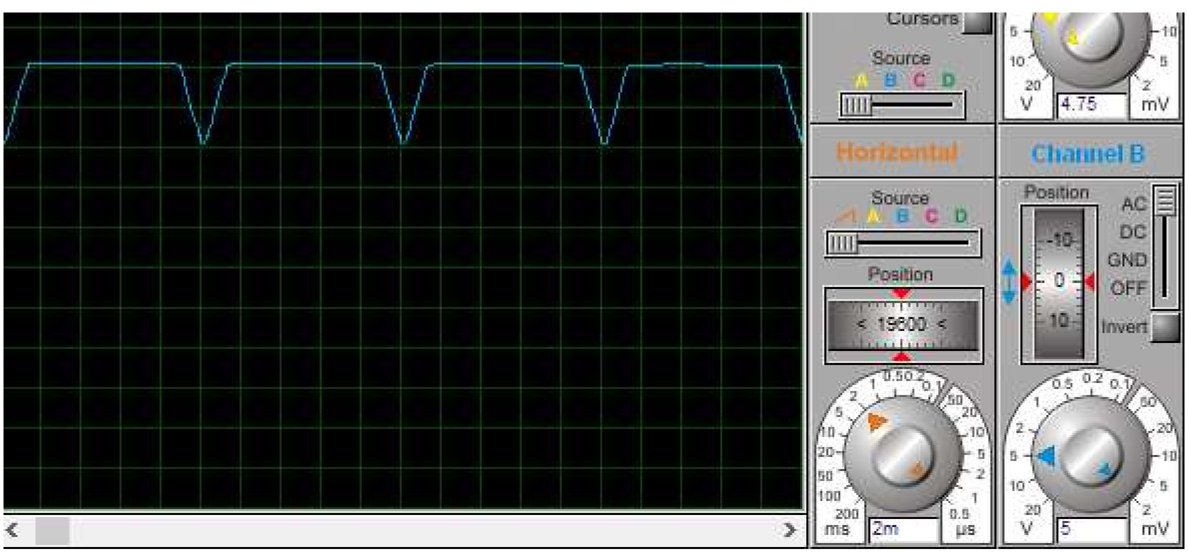


Figure 6 Rectified AC: Pulsating DC waveform

The Operational Amplifier (component LMC6081A), set up a 9V DC biasing voltage at pin 7 and grounded at pin 4 forms the comparator circuit. The pulsating DC signal is fed into pin 2 (negative) of the Op-Amp and pin 3 (positive) is connected to (ideally 0V) a voltage close to zero voltage: 1V. This compensation is made because the DC waveform does not go below 0V by definition and the comparator circuit may not detect the zero crossing. So for practical purposes, a voltage close to 0V is chosen instead, which it does cross. At this setting the comparator circuit is called an ‘Inverting Zero Crossing Detector’ (although to be precise, it is actually an inverting positive voltage (1V) level detector. Whenever, the pulsating DC waveform is of a level below 1V, the Op-Amp generates the biasing voltage (of pin 7) at pin 6 as the output. The result is a square wave signal at the Op-Amp output at the duration for which the pulsating DC waveform is less than 1V. The following figure displays this scenario as the oscilloscope output in Proteus. The blue waveform is that of the pulsating DC and the pink belongs to the output of the Op-Amp (although after being passed through the resistor to reduce its voltage level, but the square shape remains).

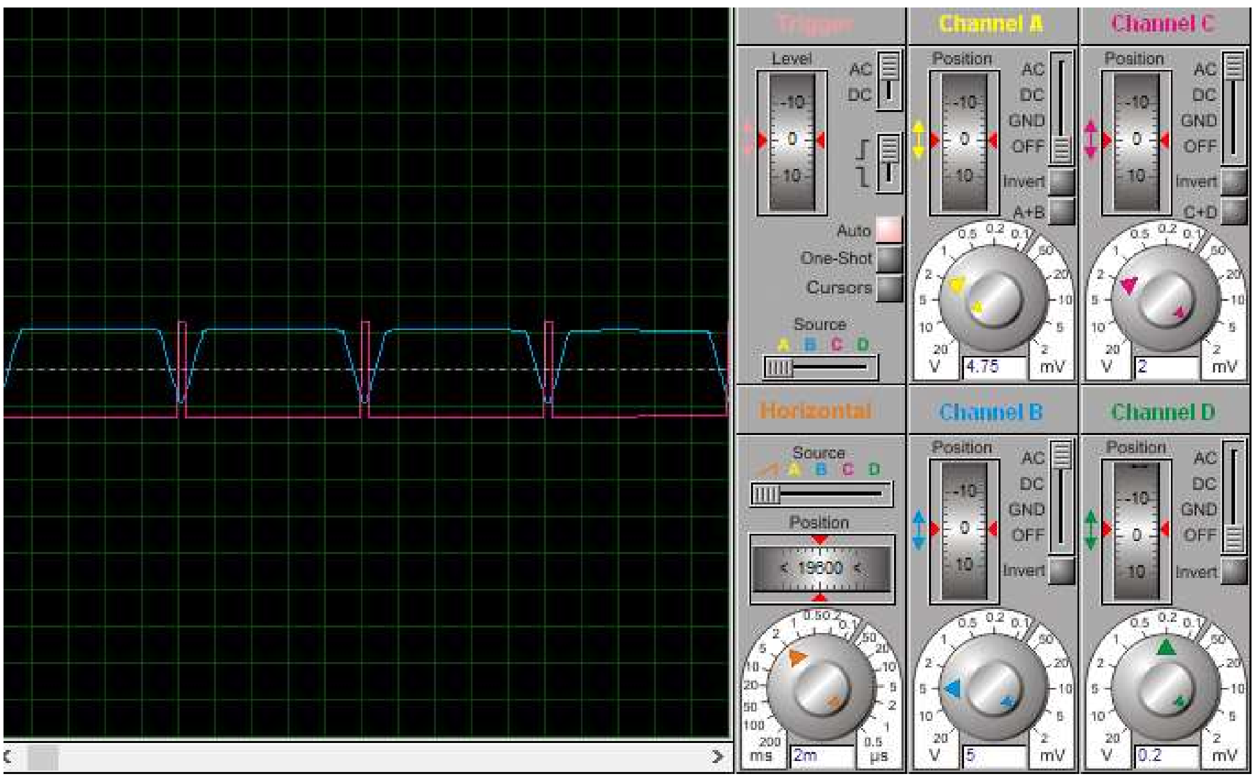


Figure 7 Pulsating DC (blue) and Op-Amp output (pink)

The peak value of the square wave output of the Op-Amp is reduced to 5V using a voltage division by resistance before being fed as interrupt inputs into the microcontroller.

The interrupt inputs are fed into pins PD2 (INT0) and PD3 (INT1) of the microcontroller. The microcontroller has been programmed to detect any change at these pins using the MCUSR register. This means, whenever there is a rising edge or falling edge at these pins, they will be detected. However, another condition has been placed by the project design before interrupts are actually triggered. The interrupts are enabled by the user’s switch which is connected using an external pull-up resistor network to PC0 pin. It is this switch that essentially turns the lamp ON and OFF, because this is what enables the interrupts. At this point, three cases arise which determine how the lamp is to be controlled.

Case 1: The lamp is already OFF and the switch is just closed. The microcontroller will then begin to respond to rising or falling edges at PD2 (INT0) which will trigger interrupt0. The routine of this interrupt activates the gate of the TRIAC so that the lamp may turn ON.

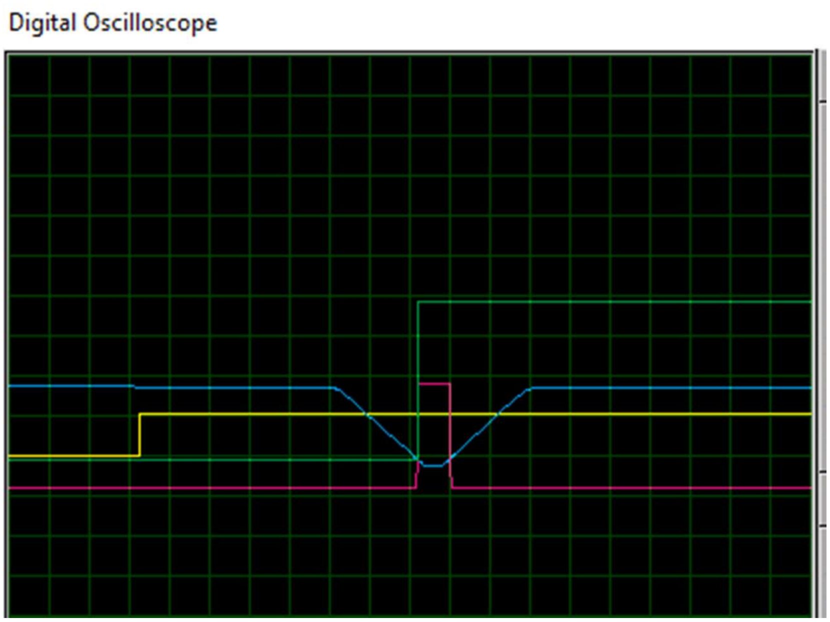
Case 2: The lamp is already ON and the switch is just opened. The microcontroller will again begin to respond to rising or falling edges at PD3 (INT1) which will trigger interrupt1. The routine of this interrupt deactivates the gate of the TRIAC so that the lamp may turn OFF.

Case3: Any other combination of the states of the lamp, the user's switch and the Op-Amp output peaks and t will be ignored by the program and the TRIAC will remain at its then present state.

Thus to control the lamp, 3 states must be monitored:

1) Zero-Crossing signals from the Op-Amp
2) User's switch
3) Lamp state

The following oscilloscope capture depicts the results of the implementation:



Blue: Pulsating DC (after rectifying AC power)

Pink: Zero-Crossing Indicator Pulse from Op-Amp

Yellow: User turning ON switch pulse

Green: Lamp turns ON at zero-crossing edge

IV. THE PROGRAM

```
/*

  The following program basically uses two ISRs to turn lamp ON and OFF at zero-crossings. Note that, because the load of AC circuit is purely resistive

  (load = lamp) current and voltage across the lamp are in phase. Therefore, zero-crossings of voltage = zero-crossings of current. Whenever there is a

  zero-crossing, the uC is interrupted to go to ISRs. One ISR turns lamp ON and the other turns lamp OFF.

*/

#include <mega32.h>

#include <delay.h>

#define button PINC.0

#define lamp PORTA.0

#define test PORTA.1


int power_state = 0; //if power_state=0, it means LAMP is OFF and if power=1, LAMP is ON


interrupt [EXT_INT0] void ext_int0_isr(void)

{

   lamp = 1;

   test = 1;

   power_state = 1; //power is now ON

   delay_ms(500);

}


interrupt [EXT_INT1] void ext_int1_isr(void)

{

    lamp = 0;

    test = 0;

    power_state = 0; //power is now OFF

    delay_ms(500);

}


void main(void)
```

```
{
  DDRA= 0xFF;
  PORTA= 0x00;
  DDRC= 0x00;
  DDRD= 0x00;

  MCUCR=(0<<ISC11) | (1<<ISC10) | (0<<ISC01) | (1<<ISC00);
  #asm("sei")

  while (1)
   {
   if ((button==1)&(power_state==0)){      //to turn power ON
     GICR = (1<<INT0) | (0<<INT1) ;        //respond to zero-crossing signals at int0
   }
   else if ((button==0)&(power_state==1)){ //to turn power OFF
     GICR = (0<<INT0) | (1<<INT1) ;        //respond to zero-crossing signals at int1
   }
   else
     GICR = (0<<INT0) | (0<<INT1) ;
   }
}
```

V. HARDWARE IMPLEMENTATION:

After completing the simulation in Proteus, the hardware implementation was begun. Initially the setup was exactly like that of simulation, but this led to some major points were noted which will be discussed below:

i) AC circuit loops do not have any connection to ground. While the simulation in Proteus required the AC neutral wire to be connected to ground for it to work (it is NOT clear why), hardware implementation should definitely not include such a connection. Because no isolation mechanism was used in the initial hardware design, this connection dangerously resulted in AC power entering the low power DC circuitry, damaging several components including the microcontroller itself, some resistors and wires. Another error of hardware connection that was discovered is the connection of the negative terminal of the DC battery to the AC neutral (assuming erroneously that it is grounded). The errors have been marked in red below:

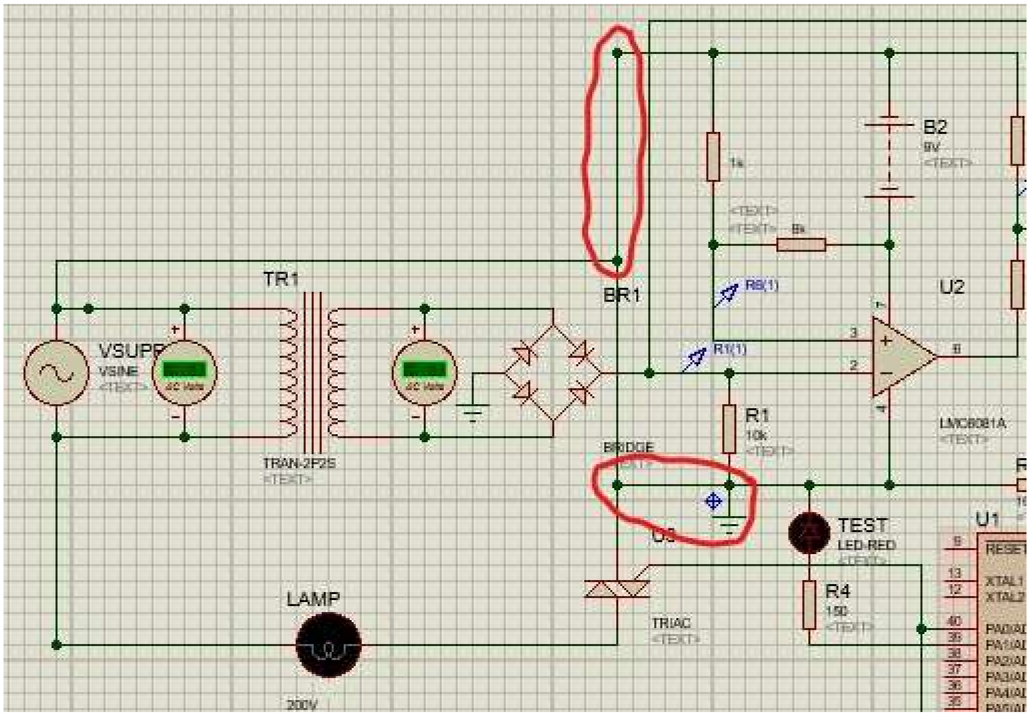


Figure 8 Errors in hardware implementation (circled red)

ii) As a safety measure, it is very important to use an isolation mechanism such as an Optoisolator in this design. The optoisolator should be placed between the TRIAC and the microcontroller.

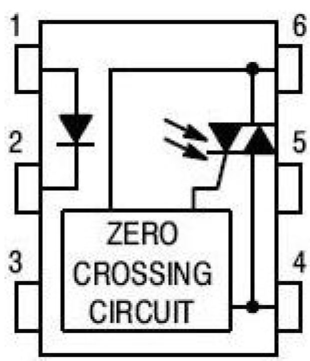


Figure 9 Internal Circuitry of MOC3041 Optoisolator

iii) It may be safe to try observing whether the TEST LED performs properly as the switch is turned ON and OFF. The lamp may be tested after the LED is found to work correctly since the microcontroller provides them both with the same output and so they should work similarly.

The hardware implementation is still in process:

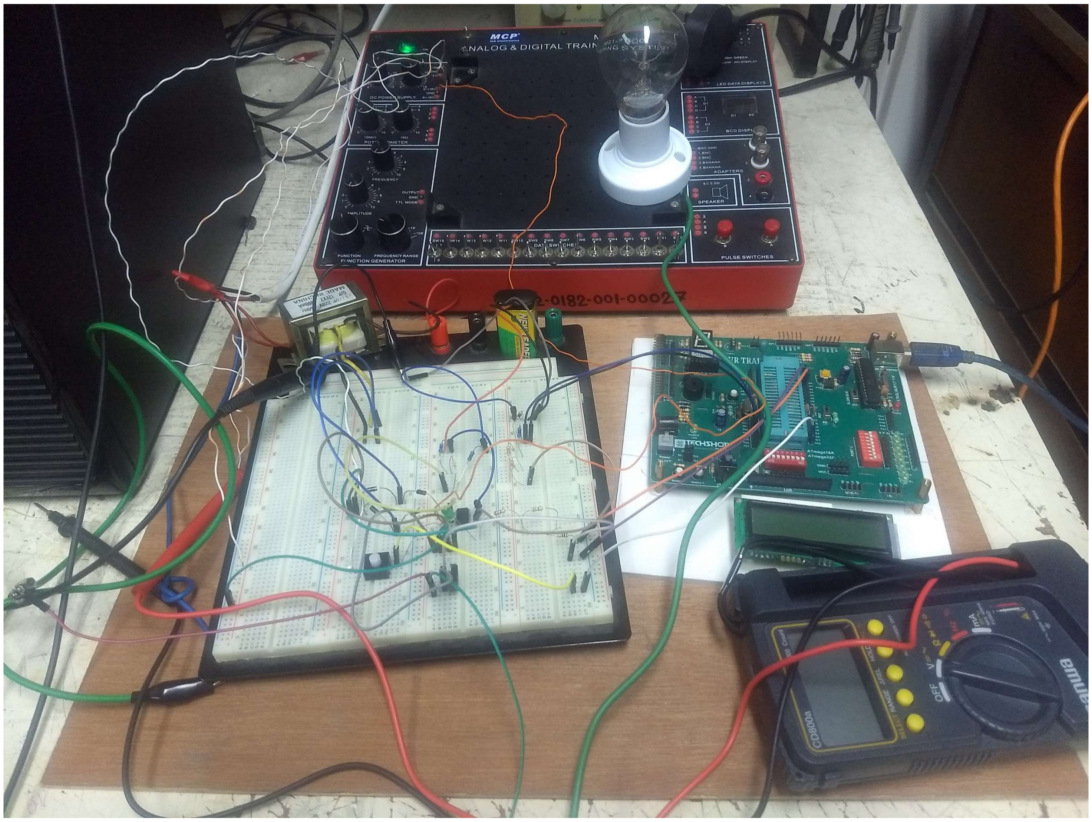


Figure 10 Hardware Implementation in progress

VI. ALTERNATIVE DESIGN CONSIDERATIONS:

The comparator circuit is a quick and effective means of generating square wave signals for zero-voltage crossing of the AC signal and therefore does not seem to be alternatives to this part of the design. It should be noted however, that the Op-Amp was comparing the pulsating DC waveform with the 1V level, generating the peak of the square wave signal whenever the pulsating DC was less than it. Hence, for greater accuracy, the comparison could be made with a value even closer to 0V. However, for practical purposes, this would require very precise electronic components, such as a more expensive and accurate Operational Amplifier than what is available at the typical university laboratory.

The electronic component that was used to control the switching of the lamp in its AC circuit is the TRIAC. In order to isolate the low power microcontroller circuit from the high power AC circuit of the lamp, there may be a choice between two options:

i) An optocoupler as an interface between the microcontroller and the TRIAC

ii) A relay

In order to select between them, an important criterion could be observing which of the two choices result in faster and thus more accurate zero-crossing switching of the lamp.

CONCLUSION:

This project implemented an Overhead Projector Lamp Life Extender by the technique of Zero Voltage Switching by using the AVR ATMega32 microcontroller and a TRIAC. In order to do this, the design used a comparator circuit to output signals whenever the AC supply reached near 0V, indicating a zero-crossing, and then used these signals to switch ON or OFF the lamp to be protected whenever the user closed or opened an external switch respectively. While the simulation seemed to show correct switching of the lamp during zero-crossing, hardware implementation required isolation of DC circuitry from AC circuitry.

REFERENCES:

https://www.researchgate.net/figure/Tungsten-resistivity-dependence-on-temperature-99_fig46_266497853