Dynamic Liquid Light Fountain (DLLF)

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ABSTRACT — **The Dynamic Liquid Light Fountain (DLLF) combines optical technology with laminar flow jets to display a lighted show. Driven by a servomotor and using Pulse Width Modulation (PWM), a cutting mechanism will randomly interrupt the laminar flow. LEDs will illuminate the water with light sequences chosen by remote control or by directly applying an audio signal which notifies the microcontroller to activate the Color Organ sequence. A passive infrared sensor, ambient light sensor, and low level indicator will signal the DLLF to operate only at pre-defined times. Finally, the DLLF utilizes the PIC16F887 microcontroller for complete system integration.**

Index Terms **— Light-emitting diodes, microcontrollers, optical communication, power supplies, pulse width modulation, servomotors.**

I. Introduction

Our group was motivated by a desire to enhance the appearance of the everyday home garden. Today people strive to have the outside of their homes reflect their personal tastes, and express their individuality. By bringing this project to fruition, we will increase the aesthetic appeal of the average home garden. This project also allows us to incorporate various aspects of electrical engineering while still preserving an individual and unique senior design project. The DLLF encompasses the specialties of analog and digital design, embedded systems, and fiber optic transmission. Because of our use of pumps, motors and laminar flow nozzles, we are also delving into the electromechanical field. The broad spectrum of topics covered by this project not only allows us to produce an aesthetic pleasing end result, but it also allows us to broaden our engineering knowledge in areas we may not have previously encountered.

II. Specifications and Requirements

In order to achieve our desired end result, we declared certain specifications and requirements for each aspect of the DLLF. A general block diagram showing the individual sections of our project is shown in Fig. 1 below with specifics described in detail throughout the remainder of the paper.

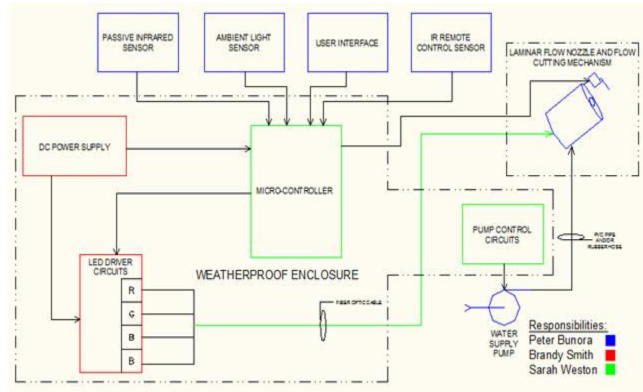

Fig. 1 Block diagram of project.

A. Nozzle and Flow Cutting Mechanism

We will design our stream of water to have a laminar flow; this is achieved when the fluid flows in parallel layers with little or no disturbance between them. When laminar flow is achieved, the water will have a smooth, almost glasslike appearance, which will allow for a transmission of light similar to fiber optic cable. Light from the LEDs will be diffused through the water and into the collection pool. The goal is to create a laminar stream that has a diameter of at least ¼” but no more than ½”. The stream must maintain its integrity throughout its entire length. Lastly, it must have an arc height of at least 2 ft. from the exit point of the nozzle and must also travel at least 4 ft. from this point.

A cutter mechanism will be mounted onto each nozzle and will be controlled by the microcontroller. The function of the cutter is to temporarily block or redirect the laminar stream of water while creating minimal disturbance to the stream. By blocking or redirecting the stream of water, it will provide the illusion that the water is “jumping” from one location to another. In order to provide the most intact stream of water, when the stream is blocked or unblocked, the cutter must rapidly move into and out of the stream. A slow moving cutter will cause major disruptions in either the leading edge of the stream when it is unblocked or in the trailing edge of the stream when it is blocked. Additional requirements of the cutter are that it must be able to complete its full travel in less than 0.15 seconds in either direction, and the actuating mechanism must operate utilizing a 5 VDC power source.

B. LEDs and Drivers

When operating in the dark, each stream of water will be illuminated by LEDs through fiber optic cables. LEDs have many benefits over other traditional lighting sources such as their compact size, lower energy and power consumption, and faster switching ability. A standard drive current for a high power red, green, or blue LED is 350mA, and each color will dissipate approximately 1 watt of power. We can also use a single 3 watt RGB LED which combines all 3 colors in one assembly.

In order to power the LEDs, we must choose a driver that operates off a supply voltage of 5V. We also want to choose the correct value for our current limiting resistors in order to ensure that the maximum rated current of the LED is not exceeded. We will use a transistor, typically either a BJT or MOSFET, to act as a switch, completing the path from power to ground when signaled by the microcontroller. Each of the 6 LEDs (2 sets of RGB) will have a driver.

C. Color Organ

A color organ is a device that converts an audio signal into rhythmic light. Aside from the input circuitry, the color organ consists of writing code. However, for the circuitry, we must be sure our design can be powered from a 5V power supply and can be integrated with the chosen LEDs along with the rest of the components on our PCB. The color organ will convert an analog audio signal to digital by sampling the signal at a pre-defined rate, identify which frequency range the input signal belongs to (low, mid, high), and illuminate the appropriate LED.

D. System Control

The system control will be a microcontroller that will run off of 5 VDC and will have a minimum of 32 I/O pins, including at least 2 PWM I/O pins. The microcontroller must also be capable of using an external clock reference, which is needed for the infrared remote control. The chip shall also have sufficient memory to store 4 user programs. Furthermore, the system control must be capable of handling the following inputs:

- 6 for the automated program selection
- 1 manual cutter control
- 1 water level
- 1 IR remote control
- 1 day/night sensor
- 1 motion sensor
- 1 selecting manual control of LEDs
- 6 LED manual on/off
- 1 external oscillator (for IR remote control)
- 1 color organ

The microcontroller must provide outputs for the 6 LED drivers as well as 2 PWM outputs for the cutter arm. There will also be 1 output for the pump controls.

E. Pump and Pump Controls

The pump must provide enough flow and sufficient lift to the two flow nozzles to generate the desired laminar stream of the specified diameter, arc height and length. To accomplish this, the pump must have a discharge flow rate of at least 500 gph, a minimum of 25 ft. of lift, and must utilize a 120 VAC single phase power source.

The pump control circuitry will be responsible for protecting the pump from running dry, a condition that would significantly reduce the life of the pump. The normally closed relay will allow the pump to remain active while water levels are considered at a safe level. When the water level drops, a float switch will deactivate the normally closed circuit and turn off the pump. This circuit will also be responsible for ensuring the microcontroller does not run when there is no water output. This circuit is required to run off a 5 VDC power supply. The circuitry must turn off the pump when water levels fall below 6” to prevent the pump from running dry.

F. Environmental Controls

The first control we will implement is an ambient light sensor which will turn off our LEDs during daylight hours to conserve energy. The circuitry must allow the user to precisely adjust the sensitivity of the sensor. It must also run off the 5 VDC power supply.

Another control we will implement is a passive infrared sensor, or motion detector. When no motion has been sensed within a predetermined amount of time, the microcontroller will shut down the pump and LED drivers if they are in operation. The sensor must be able to detect motion within 10 ft. of the fountain, have a vertical detection field of ±22.5 º, have a horizontal detection field of ±45º, and the sensor circuitry must be able to operate utilizing a 5 VDC power source.

G. User Controls/Interface

For ease of use, we will implement an infrared remote control which will allow the user to dictate which LEDs are illuminated, when the cutter is operated, and when each system is off or on.

Next, the user interface will allow the user to manually operate the fountain, and it can also be used for troubleshooting purposes. The interface must have a means for the user to access the programming of the microcontroller to make alterations to the code. Furthermore, it must be able to reproduce all or most of the functions of the infrared remote control including the following items: rocker switches to control system and pump power, DIP switches to allow individual control of each LED color, DIP switches to select the preprogrammed fountain sequences, and momentary pushbuttons to actuate each of the nozzle cutters.

All of these items will be soldered onto a PCB which will be manufactured by 4PCB for a student price of $33 per 12” square board. We will use the free software they provide to build our schematic and ensure the proper footprints for the PCB are created. Once manufactured and received and after extensive testing of the board, we will solder each component to the PCB

H. Power Supply

To comply with all of our specifications and requirements, we must design a power supply that provides 120 VAC and 5 VDC. We can use a standard wall outlet and plug to achieve the AC voltage. To reach the desired DC voltage, we will design a circuit that coverts 120 VAC to 5 VDC using typical circuitry including a transformer, bridge rectifier, filtering capacitance, and voltage regulation. We will supply a current of 3.0 amps, with a maximum power of 15 watts.

III. Design and Implementation

Because this project is our own creation there are no restrictions to the items that we may include. One of the first decisions we made before research began was which voltages we would like to use. For diversity of component availability we chose to use a 5 VDC power supply. By choosing this value, we had a large amount of parts to choose from. After determining the voltages, we divided the research responsibilities among the group members; we then spent the next few weeks researching any options that we thought would benefit the overall outcome of the fountain. Based off the research we conducted, we began our design which is described in more detail in next section.

A. Nozzle and Flow Cutting Mechanism

The factors involved in choosing a nozzle and cutting mechanism are the overall size of the mechanism, speed as it moves to block the water stream, voltage and power requirements of the actuator, the control circuitry to activate the mechanism, its ability to withstand the environmental factors it will be exposed to, and cost. After taking each of these factors into account, we had the following methods of actuation as viable solutions: linear solenoids, stepper motors, servo motors and rotary solenoids.

Based on our research it appears that, in order to maintain a single voltage power supply scheme and to keep costs down, the use of servo motors is our best option. The servo motors are generally small in size, high speed servos are readily available, most servo motors run on a 5 VDC supply voltage, and the control circuitry can be designed with or without using one of the pulse width modulated outputs from the microcontroller. Basic servo motors used in radio controlled hobby designs are inherently designed to withstand the environmental factors that that our project will subject them to. The only prohibitive factor against the use of the servo motors is the cost as compared to some of the other actuator choices. After much consideration, we selected a HITEC HS-56HB servo. This servo has a 0.12 second/60º speed rating and 13.88 oz-inch torque specifications.

The nozzle will be constructed from the following readily-available supplies: 24” x 4” diameter SCH40 PVC pipe, 24” x 25’ vinyl screening, 12” x 36” x ¼” acrylic sheet, 18” x ¼” diameter stainless steel tubing, 4 packages of standard non-bending drinking straws, silicone sealant, 24” x ¼” diameter threaded rod, ½” NPT water hose fitting, ¾” x ¼” plastic cord grip fitting with locking nut, and (8) ¼” nuts, washers and lock washers. A diagram of the laminar flow nozzle is shown in Fig. 2 below.

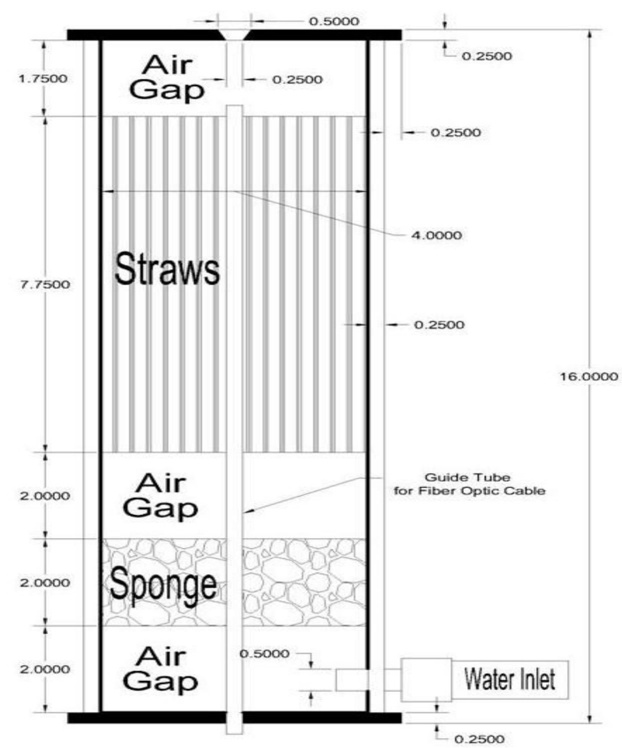

Fig. 2 Laminar Flow Nozzle.

B. LEDs and Drivers

The DLLF includes design for LED lighting when the fountain is operating in the dark. When LEDs are switched on, or are in forward mode, electrons and holes can recombine which results in a release of light. To provide enough light to travel through our laminar stream of water, we decided to use a RGB, 3watt LED which has the following specifications: reverse voltage: 5.0V; DC forward voltage: 3.2V; DC forward current: 350mA; and viewing angle: 120̊. The LED is shown in Fig. 4 below.

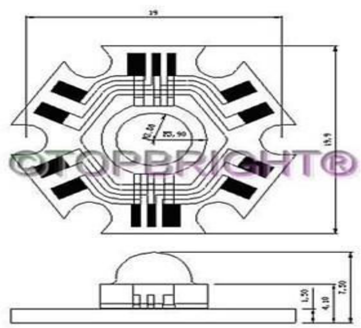

Fig. 3 LED dimensions (in mm).

In order to power the LEDs we must choose a driver that operates off a supply voltage of 5V. We also want to choose the correct value for our resistors in order to ensure that the proper forward voltage is reached. We will use a BJT or MOSFET to act as a switch, completing the path from power to ground when signaled by the microcontroller. For example, using (1), we can calculate the correct resistor values for both the green and blue colors which share a forward voltage of 3.2V.

$$R = \frac{V_s - V_f}{I_f} \quad (1)$$

This gives us an equivalent resistance of 5Ω or two 10Ω resistors in parallel. Using this information, we designed a simple LED driver as shown in Fig. 4. Note that we will have 6 drivers, 3 for each RGB LED with 1 LED illuminating each laminar stream of water.

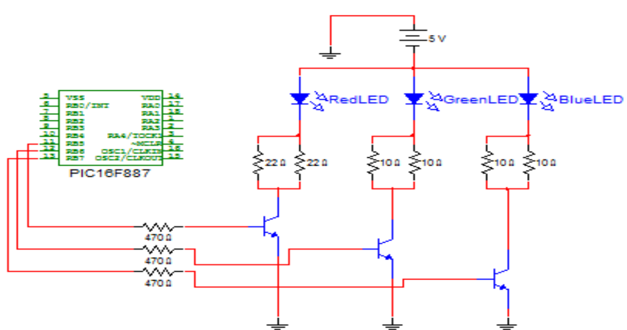

Fig. 4 LED driver for one RGB LED.

C. Color Organ

The main operation of a color organ begins with an input signal. After the input signal, we will add an in-series capacitor to couple in the input. This way, only the AC signal is transmitted and the DC signal is blocked. Next, this signal is sent to a dual operational amplifier for isolation and amplification. First, there is an isolation amplifier to provide an electrical safety barrier while providing electrical isolation. If an isolation amplifier were omitted from the design, excessive noise could be present and sometimes instrument destruction will occur. Then, we need amplification of the signal before it can be applied to the microcontroller. One such amplifier that we will use is the LM1458 dual operational amplifier by National Semiconductor. These two amplifiers share power supply leads and a common bias network; otherwise they operate completely independent of one another. Once the signal has left the isolation amplifier, it enters the amplification stage. We will need a 50kΩ potentiometer for gain control in the feedback loop of our gain pot. From here, the output is analyzed by the microcontroller which will receive the analog input signal, convert it to digital, manipulate it so that it falls into one of three categories (low band, mid band, high band), and then send an output signal to the corresponding I/O pin to light up a particular LED. This circuitry is shown in Fig. 5 below.

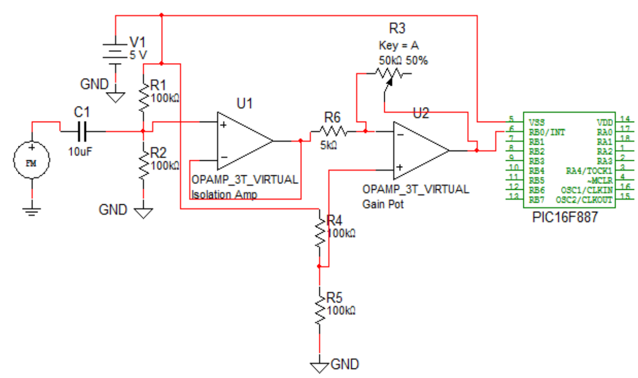

Fig. 5 Color organ circuitry.

Once our color organ is in full operation, the user will be able to connect music to the DLLF and see the colors "dance" to the music.

D. System Control

In researching the system control, we concentrated on ease of use and cost. Because of the simplicity of tasks required by the system control, we narrowed down our research to include only microcontrollers. Upon suggestion from our advisor, we decided to look at Atmel, Motorola, and Microchip microcontrollers. We decided not to use Atmel because of the slightly higher prices and inconvenient web site. We are familiar with Motorola 68HC11 from our previous classes but are unable to use it because it only has 26 I/O pins and we need at least 30. Thus, this leaves us with Microchip which offers 8-bit, 16-bit and 32-bit microcontrollers. For this project we only need an 8-bit microcontroller which narrows the search to PIC10, 12, 16, or 18. After further consideration, the midrange architecture, or PIC16 family, appears to be the most beneficial to our application.

The PIC16 microcontroller requires software to program the chip. Also, in order to communicate with the chip, we need some type of interface between the programmer and the chip. We chose to look for a development board that would allow for easy program upload and decided to purchase from Futurlec. This development board comes with all the necessary equipment for programming the PIC. Choosing this option allows us to begin program development and testing before the PCB is complete. In addition, PIC microcontrollers can be programmed using either assembly or C compilers.

Software for this project will be developed using MPLAB, the free development software provided by Microchip. Because of the availability of open source code on the internet, we will be developing the code in a block fashion using assembly language.

The first block of program to be developed will be the cutter control. The code must be able to drive the servos of the cutter in 2 directions to open and close the nozzle. We will use 2 of the 4 PWM I/O pins, RD5 and RD6, in order to control the cutters. By varying the pulse widths we will be able to vary the amount of time the cutter is open and the amount of time the cutter is closed.

Next, we will develop the LED driver block. This will consist of the development of 6 separate programs that will turn off and on the LEDs in order to color the water from the nozzle. The chosen LED program will run in a continuous loop until a new program is chosen by the user.

Once the first 2 blocks of software are developed, we will combine them to run together so the cutter and LEDs are running at the same time. Then we will write the code for monitoring the peripherals. The signal for the passive IR and the ambient light sensors will be AND-ed together and the microcontroller will only execute a user chosen program if the output from the AND gate is a 1. This will ensure that programs are running only when the user can see the DLLF in its best visual display.

The program will also require an interrupt to be acknowledged if the AND-ed output from the IR sensor and ambient light sensor goes low for longer than 5 minutes. This will be monitored and timed using a clock. If at any point during the 5 min. countdown the AND-ed output goes high, the timer will restart its countdown. The final block of code that we will write will allow the user to activate the color organ by attaching an audio input to the microcontroller.

E. Pump and Pump Controls

After researching multiple types of pumps including direct lift, displacement, velocity, buoyancy and gravity, we selected a TEMCO centrifugal, single phase, 110 VAC, ½ hp pump for our project. We chose this pump because of its excellent lift and flow rate capabilities as well as its ability to run on single phase 120 VAC and its smaller cost.

The pump control circuitry is responsible for protecting the pump from running dry, a condition that will significantly reduce the life of the pump. The circuit will contain a relay that operates in a normally closed position. The normally closed relay will allow the pump to remain active while water levels are considered safe. When the water level drops, a float switch will deactivate the normally closed circuit and turn off the pump. This circuit will also be responsible for ensuring that the microcontroller does not run when there is no water output. This circuit is required to run off the 5 VDC power supply and must turn off the pump when water levels fall below 6” to prevent the pump from running dry.

The schematic shown in Fig. 6 will be used for the pump control circuitry.

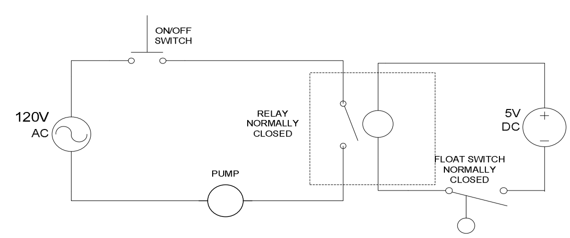

Fig. 6 Diagram showing pump control.

The left hand side of the circuit controls whether the pump is on or off. If the water level falls below 6” the float switch will open, which in turn will open the relay, signaling the pump to turn off.

F. Environmental Controls

First, we will implement the ambient light sensor so that the optical portion of the DLLF only operates at night. We have decided to use a phototransistor coupled with an operational amplifier as the basis of our day/night circuitry due to its faster response time, lack of memory, and its versatility to more easily interface with TTL level components. There are two varieties of phototransistor circuits, binary/logic and analog. For the purposes of our project, a binary/logic circuit will provide the input to the microcontroller. This circuit is shown in Fig. 7 below.

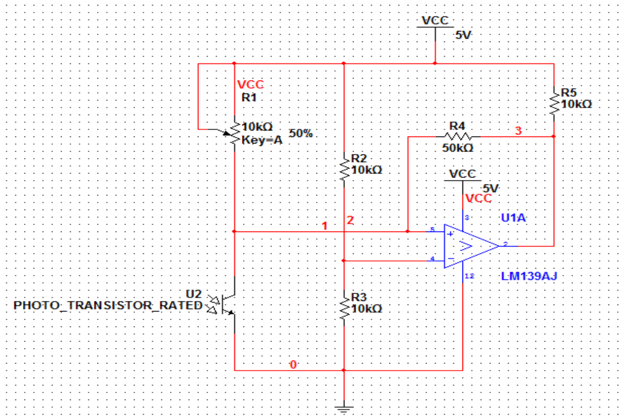

Fig. 7 Ambient light sensing circuitry.

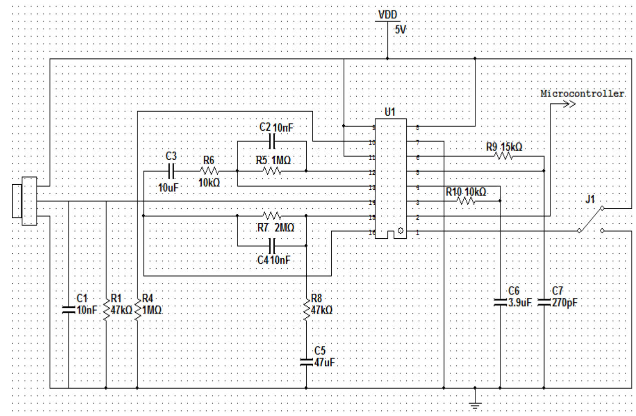

Fig. 8 Passive IR motion sensing circuit.

U1A is an operational amplifier configured as a comparator. Potentiometer R1 is used to set the light detection level. A low resistance value (i.e. a few thousand ohms) sets a high detection level for the light to exceed before any switching can occur, making the circuit less sensitive. If a larger potentiometer is used, i.e. 100 KΩ, a low light detection level would be set, making the circuit more sensitive. Resistors R2 and R3 set up a voltage divider network which generates the reference voltage (V_{ref}) for the operational amplifier. Resistor R5 is a pull up resistor for the open collector output of the comparator. Resistor R4 is used for hysteresis. With the use of hysteresis, there is a dead band between light levels that switch between “0” and “1”; this will prevent unnecessary switching if the light level is near the detection level. The smaller the value of R4 the larger the dead band between switching.

As light strikes the phototransistor (U2), it begins to conduct; the more light that strikes U2, the more it conducts. As the conduction of U2 increases, the voltage at the non-inverting terminal (V^+) of U1A decreases. Once V^+ is below the value of V_{ref} the output of U1A switches to a logic “0” voltage level. As the light intensity striking U2 decreases, the amount of conduction of U2 decreases. This will cause V^+ to increase, and once V^+ is greater than V_{ref}, the output of U1A will switch to logic “1” voltage level.

Another control we will implement is a passive infrared sensor, or motion detector. The design of the circuitry for our passive infrared motion sensor is based on the circuit provided as an application example in the datasheet for the BISS0001 motion sensor decoder. With a few modifications, this circuit will work with our project. Fig. 8 shows the circuit we will implement.

Since we want the fountain to remain active for 15 min. after motion is detected a value of 900 sec. will be used for T_X. The value for R_{10} is assumed to be 10 KΩ and the value of C_6 is calculated using (2)

$$C_6 \cong \frac{T_X}{(24576 * R_{10})}. \quad (2)$$

Since our calculated value of 3.662 isn’t a standard capacitor value, a capacitor with a value of 3.9 µF will be used. This value, which is slightly larger than the calculated value, will provide a high output for approximately 16 min.

To provide a 0.1 millisecond inhibit time between triggers (T_I) we can use (3)

$$T_I \cong 24 * R_9 * C_7. \quad (3)$$

A resistor value of 15 KΩ is used for R_9 and we can calculate the value of capacitor C_7 using (4)

$$C_7 \cong T_I/(24 * R_9). \quad (4)$$

Since our calculated value of 3.662 isn’t a standard capacitor value, a capacitor with a value of 270 pF will be used. This value which is slightly smaller than the calculated value will provide a trigger inhibit time of approximately 0.0972 milliseconds.

Placing switch J1 in the position indicated in Fig. 8 will place 5 VDC on pin 1, which makes the decoder circuit retriggerable. The output, pin 2, will be connected directly to the microcontroller to enable or disable fountain operations.

G. User Controls/Interface

The user interface consists of both primary and secondary systems. The primary user interface is a programmable universal infrared remote control. We chose the Philips Pronto TS1000 for its versatility and due to the fact that we can get one for free. The Pronto has a 3.8" diagonal touch screen. The touch screen has a resolution of 240 x 320 pixels with four color grey scale. It has 1 MB of non-volatile flash memory, 512k SRAM, a serial interface, infrared code learning and an infrared operating range of approximately 33 ft. There are 7 programmable access buttons and a built in light sensor that automatically turns on the backlight in low-light environments. Through the use of the Pronto Edit graphical editing software, we can create any type of control panel or menu driven system we desire. This remote allows the user to create macros and timers to send control sequences to the microcontroller.

The secondary portion of the user interface consists of various electromechanical switches including DIP and rocker switches. Using appropriately sized rocker switches, we allow the user to turn ON and OFF the entire system by removing the 120 VAC that feeds both the 5 VDC power supply, including all of the electronic circuitry from the microprocessor to the low water level sensing circuitry, and the centrifugal water pump. Another rocker switch will de-energize the 120 VAC power to the centrifugal pump without de-energizing the 5 VDC systems. A third rocker switch will be used to de-energize the 5 VDC power supply while allowing the centrifugal pump to continue to operate. This switching combination allows the user to de-energize all or part of the system for various user needs and troubleshooting.

DIP switches make up the bulk of the secondary user interface. While we could have purchased one continuous block of switches, we chose to break the DIP switches into smaller blocks to aid the user in identifying the appropriate switch. By using blocks of 6, we can separate the 6 preprogrammed selector switches from the 6 individual LED ON/OFF input switches. With switches being relatively small and close together it is sometimes difficult to actuate the correct switch in a long block of DIP switches; this design choice should alleviate this problem. The final block of 6 DIP switches will be used to select manual or automatic operation and provide spare switch positions for future system expansion.

Two momentary pushbuttons round out the last of the switch portion of the user interface. When the system is placed in manual mode, the pushbuttons will provide the user with the means to control the individual nozzle cutter mechanisms. By using non-locking momentary pushbuttons, we ensure that the nozzle cutting mechanisms cannot be unintentionally blocked and require a constant user input to block the laminar stream.

H. Power Supply

We researched both linear and switched mode power supplies. After studying the topology of each, we decided that the simpler linear power supply would satisfy our project requirements. The main disadvantages of a linear power supply are its decreased efficiency and higher heat generation. Thus, they are typically larger in size when compared to a switched-mode power supply.

The first component of our power supply is a transformer which must convert 120 VAC down to a smaller AC voltage level before being rectified. Thus, we chose a transformer from Radio Shack with an AC output of 12.6 VAC and a 3A current output.

After transforming the AC voltage to 12.6 V, we need to rectify it using a full-wave bridge rectifier. This can be done either through an IC chip or using 4 power rectifiers. Next, we need to add a capacitive filter to smooth out the ripple in the voltage which will improve the output voltage waveform. To do this, we must choose a large capacitor using (5)

$$dv = \frac{I}{C} dc \qquad (5)$$

with typical values in the thousands of microfarads. With dc=0.008 for 60Hz power lines, dv will be approximately 4.3V if we were to use a capacitor with a value of 4,700μF. Since our secondary voltage will be 12.6V, the peak voltage will be (1.41) * (12.6) or 17.8V. If we subtract 2V from our bridge rectifier and 4.3V for the ripple voltage we just calculated, theoretically we will have 11.5V going into the DC voltage regulator. When choosing a regulator, we must be sure that these calculations are performed.

Next, we looked at several voltage regulators. Since our maximum load current is approximately 2.5A, we must choose a regulator with a slightly higher output current. After researching numerous voltage regulators including the LP3872ES-5.0 from National Semiconductor and the MIC29300-5.0WU from Micrel, Inc., we decided on the LM350K from STMicroelectronics. We chose this regulator because of its built-in overload protection which activates at 30W of power dissipation, improved ripple rejection, and better stability compared to the elementary voltage regulator. The input/output voltage differential can be calculated using (6)

$$3V \leq (V_{in} - V_{out}) \leq 35V. \qquad (6)$$

Since, from our previous calculations, $V_{in} = 11.5V$ and $V_{out} = 5V$, our voltage differential is 6.5V which is in the range specified by the data sheet of the voltage regulator. After initially reviewing the specifications for the LM350K, we thought we would need additional capacitors and diodes for device protection. However, after carefully reading the datasheet, we noticed that this is only recommended if the output voltage of the regulator is above 25V and has high values of output capacitance. For our application, this is not necessary. However, since this is an adjustable output voltage regulator, we must set the output voltage to our desired 5V. To do this, we must use a current set resistor with the output voltage equal to (7)

$$V_o = 1.25V(1 + \frac{R_2}{R_1})\ . \qquad (7)$$

Setting R_2 as a potentiometer with a value of 5kΩ and R_1 as 240Ω, the output can be easily adjusted to 5V. The final addition to the voltage regulator is an output capacitor. Even though the LM350K is suitable for use without one, a 1μF output capacitor swamps the ringing effect and ensures stability. Combining all of these components results in our linear power supply circuit which is shown in Fig. 9 below.

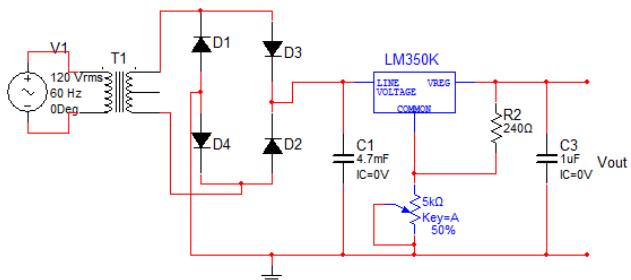

Fig. 9 120 VAC to 5 VDC linear power supply.

The final aspect of the power supply we must consider is heat generated from the voltage regulator. A large heat sink will be required since we will be generating approximately 12 watts of power. However, choosing a heat sink is not as simple as one might think. In order to calculate the size of the heat sink, we must find the thermal resistance required between the junction and the ambient air, *qja*, using (8)

$$qja = \frac{(T_j - T_a)}{P} \qquad (8)$$

where T_j is the maximum junction temperature (℃); T_a is the maximum ambient temperature (℃); and P is the maximum power dissipated (W). The maximum junction temperature and power dissipated are found in the data sheet of the voltage regulator and the maximum ambient temperature is measured at the motherboard. Thus, our *qja* = 2.8337℃/W. Next we must find the thermal resistance, *qcs*, of the material we will place between the regulator and the heat sink, which in our case is 0.1 ℃/W. Finally, we must find the thermal resistance between the semiconductor junction and its case, *qjc,* by using (9)

$$qjc = \frac{(T_j - T_c)}{P}\ . \qquad (9)$$

Here, T_c is the maximum case temperature in℃ which is given in the data sheet as 110℃. Thus, *qjc* = 0.5 ℃/W. Finally, after we've determined the required resistance for the entire assembly and the resistances of the thermal material and regulator, the heat-sink thermal resistance, *qsa*, can be solved by (10)

$$qsa = qja - qjc - qcs. \qquad (10)$$

After solving for *qsa*, our heat-sink must have a thermal resistance ≤ 2.23℃/W.

IV. Conclusion

After spending a considerable amount of time researching and simulating the various aspects of our project, we are confident that the Dynamic Liquid Light Fountain will be a success. Throughout the implementation process of this project, the entire team has had the opportunity to apply electrical theory and real-life applications which will be crucial to a successful career. We have enjoyed the opportunity to work together as a team and come to realize the importance of successful teamwork when designing and building a technical project. We sincerely appreciate all of the help received from the faculty.

V. Group Members

Peter Bunora is a senior BSEE student who will be graduating in May 2010. He currently works in the power generation industry and plans to pursue his master's degree following graduation.

Brandy Smith is a senior BSEE student who will be graduating in May 2010. She enjoys spending time with her 2 year old daughter, Mica, and husband, Jacob. Her goal is to begin a career in the electric utility industry.

Sarah Weston is a senior BSEE student who will be graduating in May 2010. She is currently employed as an electrical engineering intern at FLIR Government Systems. After graduation, Sarah would like to attend school part time to pursue a master's degree in Electro Optics.