# Water Aliasing

## Design Review

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**ECE 445**

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# 1. Introduction

## 1.1 Objective

An optical illusion is an illusion caused by the visual system and characterized by visually perceived images that differ from objective reality. The information gathered by the eye is processed in the brain to give a percept that does not tally with a physical measurement of the stimulus source. In the case of aliasing water, this illusion is achieved by means of a stroboscopic light. The concept involves altering the frequency of the vibrating water with respect to the frequency of the light. Today, these Gravity Defying Water products, at a small scale, are available in the market for as high as $500-$600 [1] and cost more money than we would like to spend for entertainment. Our goal is to bring this magic to households at a lower price, with the added benefits of physically controlling these water patterns. The overall aim is to provide an enjoyable experience of "waterbending".

## 1.2 Background

Our project is one born out of the want for aesthetic pleasure. Humans are creatures of habit and hence, our brain makes many assumptions about our surroundings without us actually consciously thinking about them. Our minds are trained from a very young age to understand and interpret things about the universe, one of which is gravity. When we see logic being outright defied without any rational explanation that our brain can come up with, we tend to be amazed and intrigued. Water aliasing is something that most people on this planet aren't aware of. Hence, the illusion of water rising or levitating instead of falling without the help of any device, like a suction or a pump, baffles the mind. It generates what is nowadays called the "wow factor". For a good water aliasing device, people pay hundreds of dollars out of their amazement of it. So far, the devices that exist on the market have little to no user interaction. We plan on changing this.

## 1.3 High Level Requirements

- The entire system must be compact and mostly waterproof, so that it is safe for operation.
- It should cost less than the commercial models available in the market today.
- It must be aesthetically pleasing to look at.
- It must be easily controllable by the user and glitch free.
- The water droplets produced must be clean and distinct i.e. well spaced for the human eye to register the illusion. [2]

# 2. Design

Our design works on a very simple principle: the frequency of the strobe light we build must match the frequency of the vibration of water for us to see floating droplets. Every time the light is on, an image of a different drop at the same position is visible. Similarly, if the frequencies of the light and that of the vibrating stream of water differ, we see the water moving up or down. In the case of water frequency being lower than the frequency of light, the next drop of water is slightly higher than the previous drop when light falls on it. The brain interprets this illusion as water "moving up". If the next drop appears lower, water is "moving down".

## 2.1 Block Diagram

**a)**

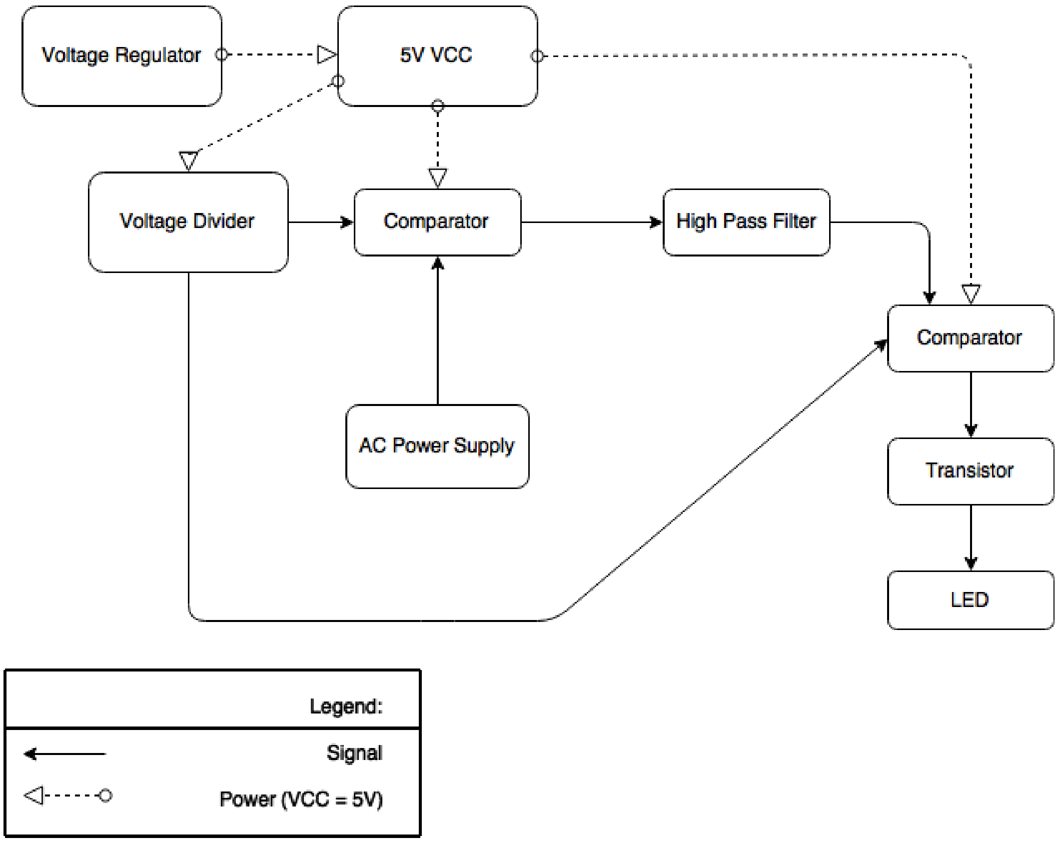


**Figure 1 a)** Block Diagram for Lighting Unit

**b)**

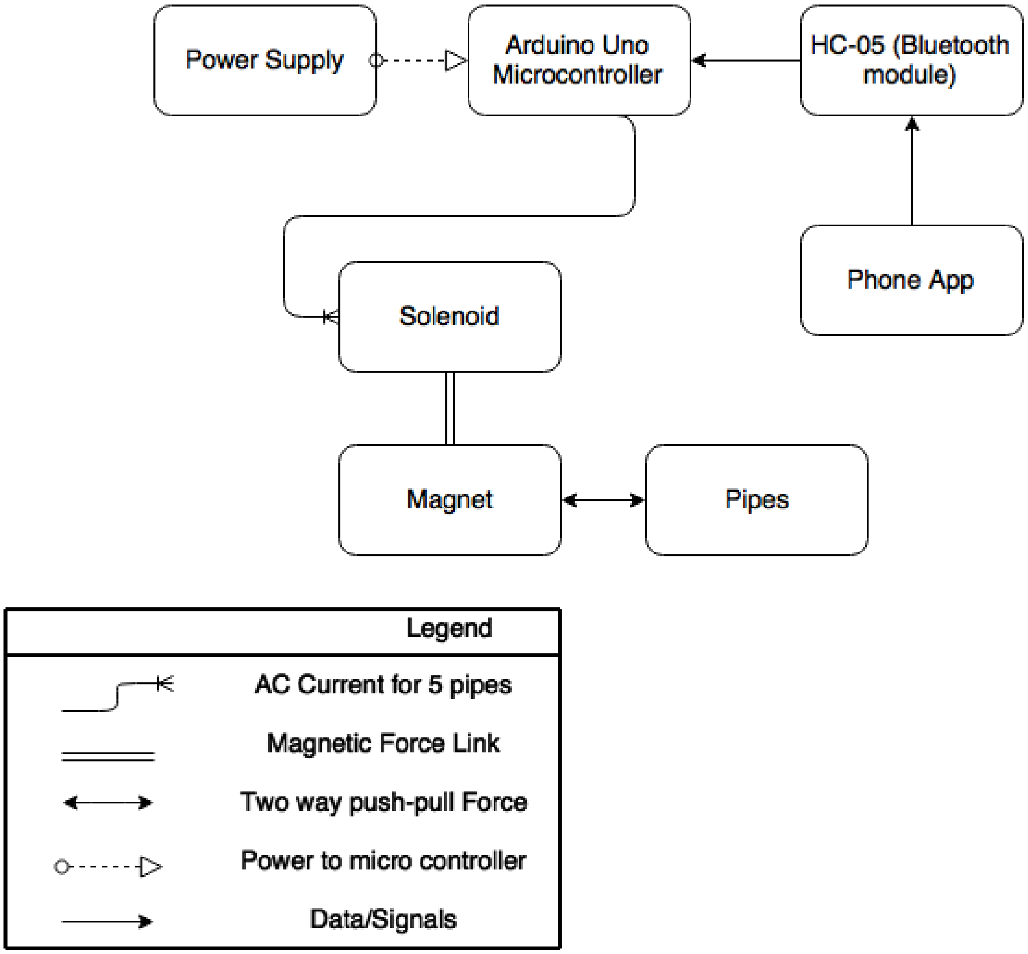


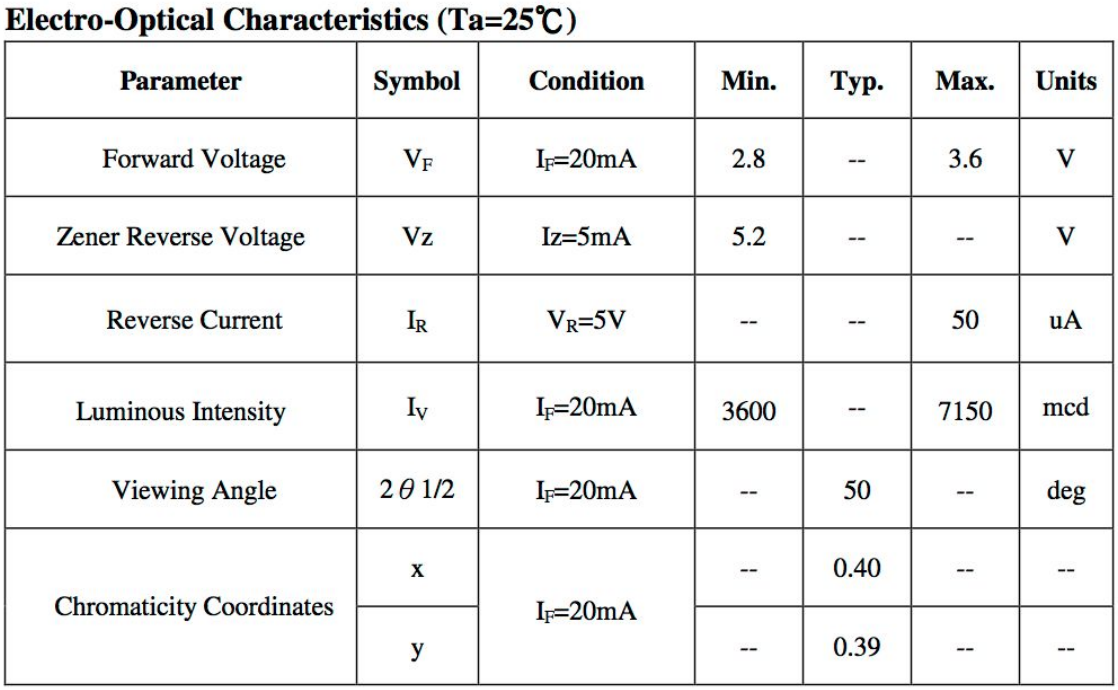
**Figure 1 b):** Block Diagram for our Water/User Interface Unit

## 2.2 Block Design

### 2.2.1 Lighting Unit

**LED**

For this part of the circuit, we plan to use Everlight Electronics Co Ltd. Part 334-15/X1C5-1QSA. These are white LEDs with a forward voltage of 3.2V. Since we are using these LEDs in a water based experiment, it is important to make sure that their Moisture Sensitivity Level (MSL) can allow exposure to moisture. The datasheet for this particular part has MSL = 1 (unlimited) which suits our purpose perfectly.



**Electro-Optical Characteristics (Ta=25℃)**

| Parameter | Symbol | Condition | Min. | Typ. | Max. | Units |
|---|---|---|---|---|---|---|
| Forward Voltage | $V_F$ | $I_F$=20mA | 2.8 | -- | 3.6 | V |
| Zener Reverse Voltage | Vz | Iz=5mA | 5.2 | -- | -- | V |
| Reverse Current | $I_R$ | $V_R$=5V | -- | -- | 50 | uA |
| Luminous Intensity | $I_V$ | $I_F$=20mA | 3600 | -- | 7150 | mcd |
| Viewing Angle | $2\theta 1/2$ | $I_F$=20mA | -- | 50 | -- | deg |
| Chromaticity Coordinates | x | $I_F$=20mA | -- | 0.40 | -- | -- |
|  | y |  | -- | 0.39 | -- | -- |

**Table 2.1.1:** Electro-Optical Characteristics of LED

The luminous Intensity for this LED varies between 3600 mcd and 7150 mcd. To determine how many LEDs to use in our circuit, we compare its intensity with a common incandescent light bulb. The actual output of a normal light bulb is about 24 lumens. To convert millicandela to lumens we use Equation (1):

$$\Phi v = Iv * \Omega \tag{1}$$

- $\Phi_v$ is the luminous flux, in measured in Lumens (lm),
- $I_v$ is the luminous intensity, measured in Candela (cd), and
- $\Omega$ is the solid angle of the beam is measured in Steradian (sr).

And Conversion from beam angle to solid angle (sterians) is done with this formula:

$$\Omega = 2\pi\,[1 - cos(\theta\pi/360)] \tag{2}$$

where:

- $\theta$ is the the beam angle measured in degrees (50 degrees).

Thus, the luminous flux for each LED lies between 2.119 lm and 4.209 lm.

We would like our brightness to be at its maximum, so we aim to achieve the higher limit. This means 6 LEDs can provide as much light as 1 light bulb. Due to this fact, we will use 20 LEDs.

**Blocking Capacitor**

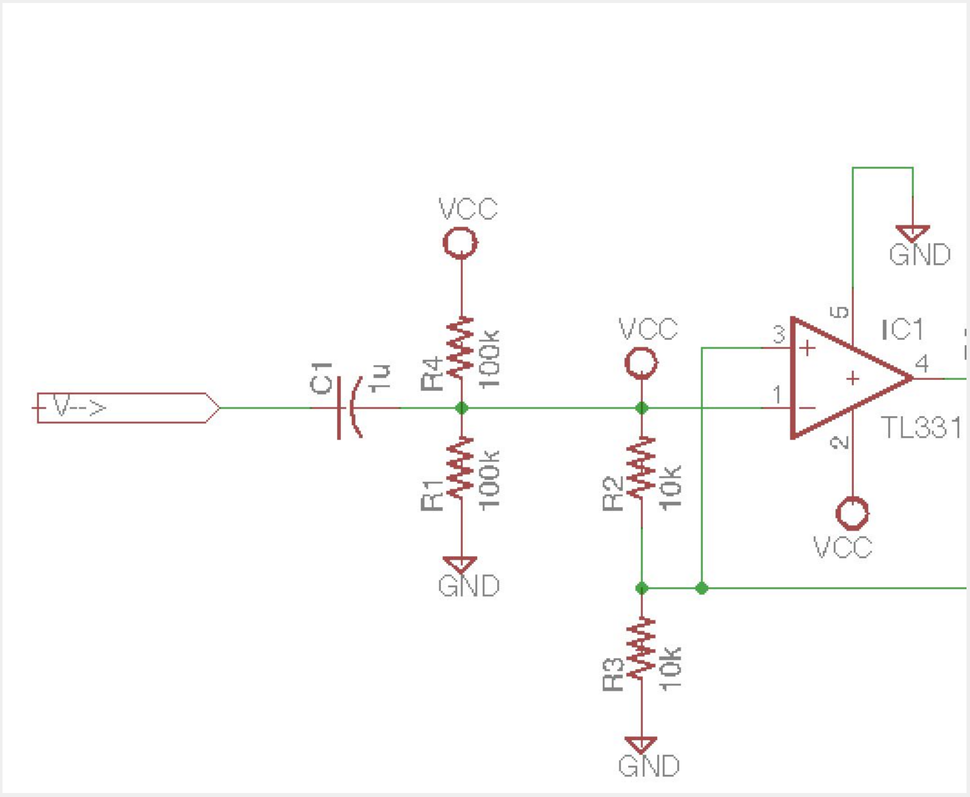


**Figure 2: Schematic for Lighting unit showing comparator inputs**

Our sinusoidal input waveform has some DC component which we need to get rid of in order to reduce noise from our power supply. We use the concept of coupling capacitors for this purpose. We know that the amount of charge that develops across the plates of a capacitor with a given voltage across its terminals is governed by the formula:

$$Q = C \times V \text{ (Charge = Capacitance x voltage)} \tag{3}$$

In the case of a DC voltage, the rate of change of voltage is 0. So the current (time derivative of charge) flowing through the capacitor in such a case is zero, which is essentially blocking the DC component of the wave.

$$I = C \times dV/dt \text{ (Current = Capacitance * rate of change in voltage)} \tag{4}$$

This sinusoidal signal has to be centred around 2.5 V to meet the input voltage requirement of the comparator we wish to use. Therefore, we run this signal through a voltage divider circuit (Eq. 5 through 7) having VCC = 5V and two 10Kohm resistors in parallel.

$$Vcc * \frac{R_4}{R_4 + R_1} \tag{5}$$

$$= 5 * \frac{10K}{10K + 10K} \tag{6}$$

$$= 2.5\text{V} \tag{7}$$

**Comparator**

Our comparator of choice is the LM2903M. It has an operating supply voltage of 2V - 36V and can now be used since we have the signal offset by 2.5V. It has a very wide temperature tolerance: -40C to 85C.

The signal riding on 2.5 V can be compared to a fixed reference voltage of 2.5 V to output a uniform square wave with a peak-to-peak voltage of 5V. We set our $V_{ref}$ with another voltage divider circuit as mentioned above. We now consider a non-inverting single supply comparator which has its -VEE pin grounded.

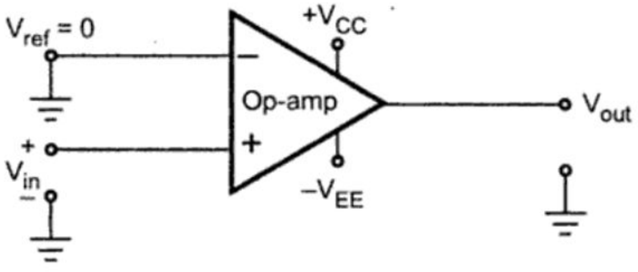


**Figure 3**: A basic non inverting comparator[3]

We provide this comparator a VCC of 5V. Our 2.5V sinusoid is an input to the Vin+ port, while the Vref, also of 2.5V is passed into the Vin- port. The transfer characteristics and schematic of this type of comparator is shown below in Figure 4:

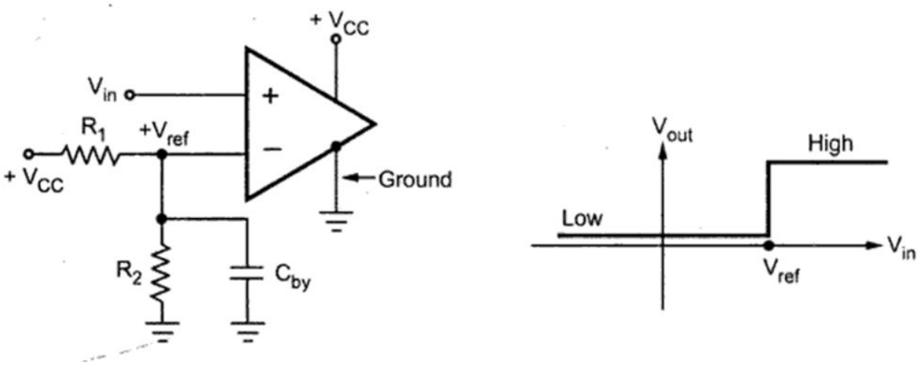


**Figure 4:** Single Supply Comparator and its transfer characteristics[3]

The two output values of a comparator are +Vsat and -Vsat. If Vin is greater than Vref, the output is +Vsat, which is almost equal to VCC = 5V in our case. If Vin drops below Vref, the output goes to -Vsat. However, since -VEE is grounded, this lower level value is almost zero and we get a square wave with an amplitude approximately equal to our VCC input. This is depicted in the waveforms below:

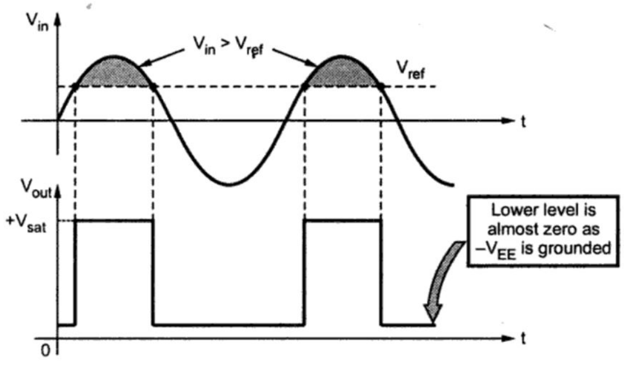


**Figure 5:** Waveform of single supply comparator[3]

At this stage in our circuit schematic we have produced a square wave of the same frequency as our input sinusoidal AC waveform. Our next step is to reduce the width of these waves to create a pulse like behavior which we can use to strobe our LEDs.

## High Pass Filter

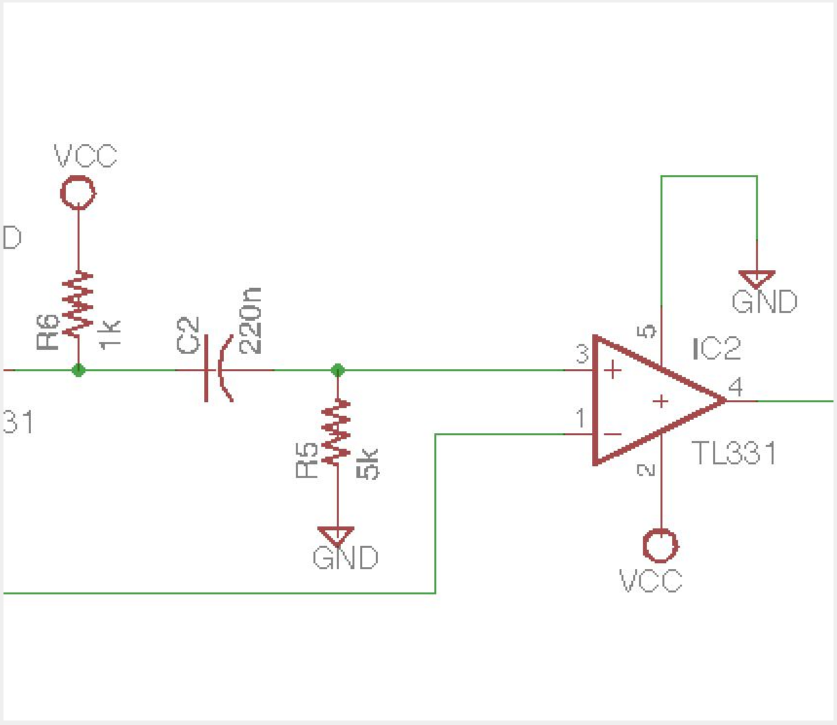
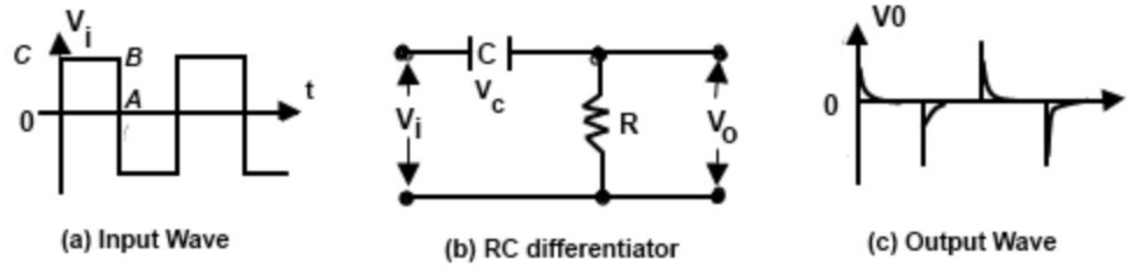


**Figure 6:** Schematic for Lighting Unit showing high pass filter and second comparator

In a high pass filter, we use a series RC circuit. In such a circuit, the output is taken across the resistor. At very high frequencies, the capacitor acts as a short circuit and all the input appears at the output. On the other hand, at DC or zero frequency, capacitor has infinite resistance and behaves as an open circuit. The circuit is designed in such a way that the output is proportional to the derivative of the input. In the case of our input square wave, the amplitude changes abruptly at the edges and hence the output displays a corresponding narrow pulse like behaviour. However, during the constant portion of the wave, the output is mostly zero, since the derivative here is zero.

The shape of the output waveform of an RC high-pass filter depends on the value of the circuit time constant T, which is a product of the resistance and capacitance. To get the pulse like waveform we desire for our strobing circuit, we need to have a very short time constant.



(a) Input Wave

(b) RC differentiator

(c) Output Wave

**Figure 7:** Differentiating Circuit showing square input and corresponding output[4]

To achieve good differentiation, we must satisfy the following two conditions:

- Time constant RC of the circuit should be smaller than the time period of the input signal
- The value of a capacitive reactance, $X_c$, should be ten or more times larger than R at the operating frequency.

The time period of the input signal is 1/60 Hz = 0.01667s. The capacitive reactance, $X_c$, is the internal impedance of the capacitor which restricts the current flow through it as it charges or discharges. It is given by equation 8 below:

$$X_c = 1 / (2 * \pi * f * C) \tag{8}$$

This gives us two constraints for our time constant:

$$1 / (2 * \pi * 60 * C) > 10R \tag{9}$$

$$\mathrm{RC} < 0.01667\mathrm{s} \tag{10}$$

This puts our time constant in the range 0.000265s < RC < 0.01667s.

We estimate our RC value to be one order of magnitude greater than its lower limit and one order of magnitude less than our upper limit ~ 0.001s.

We choose our R value to be 5000 ohms and C to be 220 nF. Certain tradeoff considerations we had to make:

- Resistors of larger values are far easier and cheaper to find compared to capacitors of a higher value.
- Capacitors with relatively large values of capacitance are often far from ideal at high frequencies

The output voltage decays exponentially from the input voltage with this time constant.

$$V_{out} = V_{in}{}^{-1/RC} \tag{11}$$

This output pulse form, with an amplitude starting at 5V, is then passed through a comparator again, this time compared to a Vref of 2.5 V. Same as the previous comparator stage, we will find that there will be a 5V narrow pulse output corresponding to the decaying region where Vout is greater than 2.5V. The region where the exponential decay is below the Vref level, we get a zero output.

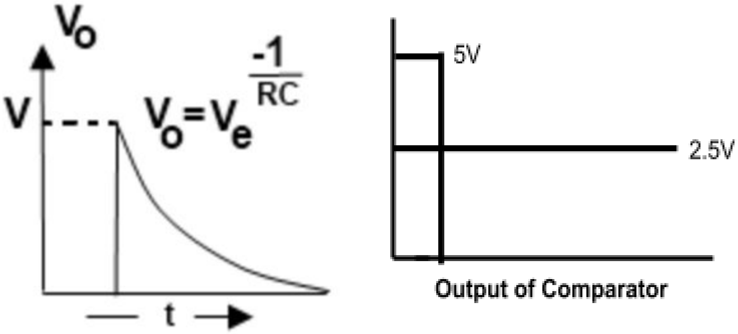


**Figure 8:** Output of High Pass Filter[4] and Second Comparator

## Transistor

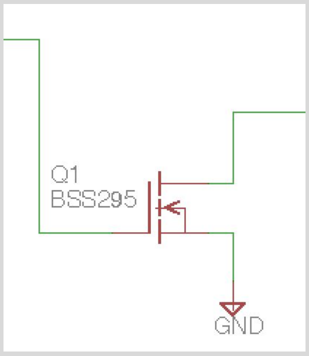


**Figure 9:** Schematic for NMOS transistor

The last stage we will need to implement in this strobing circuit is the transistor. We will use a N-MOSFET to use as a switch. When there is no applying voltage between the Gate-Source , the Drain-Source resistance is very high, which is almost like a open circuit, so no current may flow through the Drain-Source. The LEDs in our circuit will be off in this case. When Gate-Source potential difference is applied, the Drain-Source resistance is reduced, and there will be current flowing through Drain-Source, which is now a closed circuit. The LEDs turn on.

The output pulse from our comparator is applied to the gate of our chosen transistor and will be able to control our entire LED array by switching it on and off according to the pulse we have systematically created.

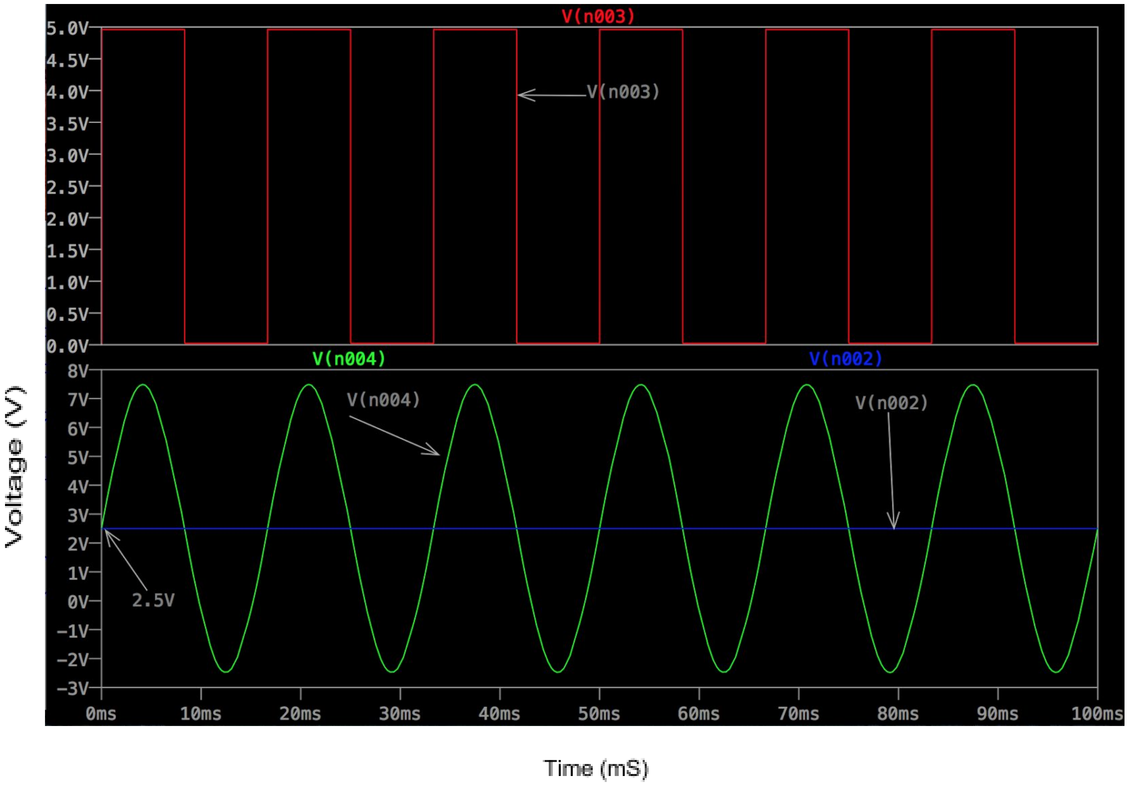
**Regulator**

We may use a regulator in our design to keep a constant output voltage to avoid unwanted high voltage. We will input a battery voltage of 12V to the regulator and obtain a fixed output of 5V to provide as VCC for all the aforementioned components.

**Simulations for Comparator**

To test our idea for using the comparator to convert a sinusoidal waveform into a square wave, we simulated that part of our circuit to observe the output waveform.

As we can see from figure 10, we have a jump from -Vsat at 0 V to +Vsat at 5V. We see ideal behavior in the jump however in practical cases the jump may not be so smooth. This is expected since it will take some time to switch from one voltage level to another. In order to make this response as close to the ideal response as possible, we must reduce this transition time.

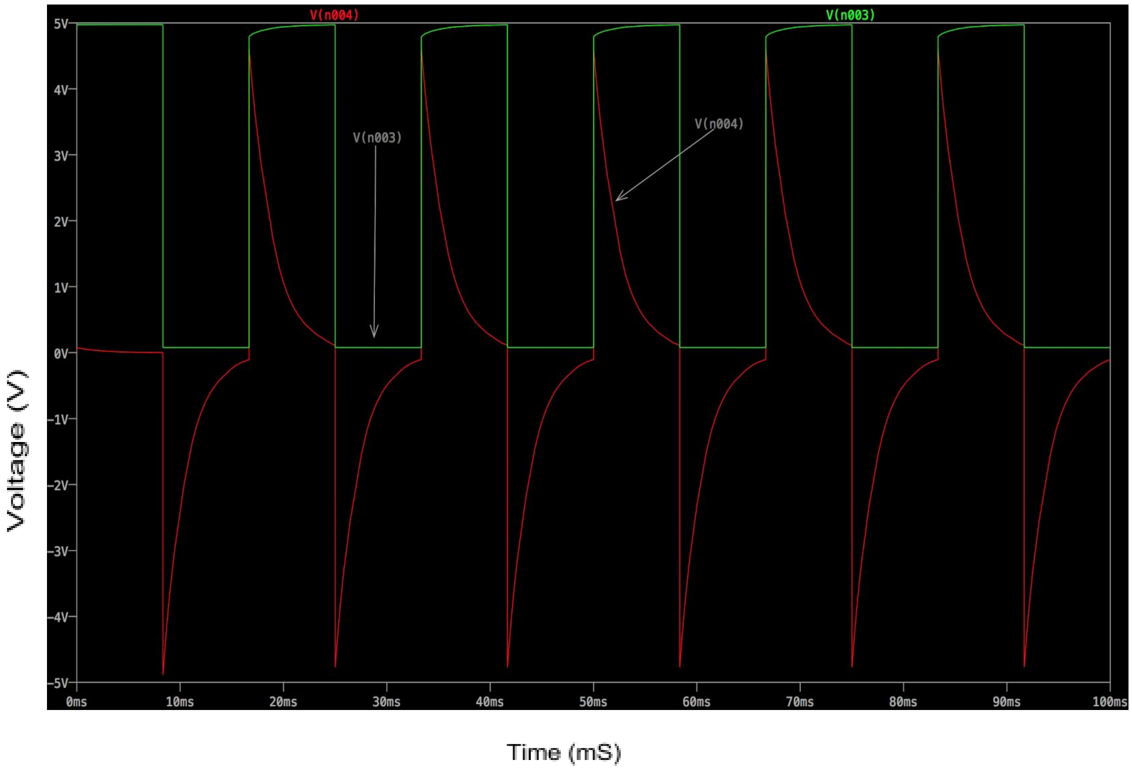


| Key | Value |
|---|---|
| V(n002) | Vref |
| V(n003) | Vout |
| V(n004) | Vin |

**Figure 10**: Simulation for Comparator

## Simulation for High Pass Filter

We also ran a simulation to see the output of our high pass filter and verify square wave to pulse conversion as seen from figure 11 below:



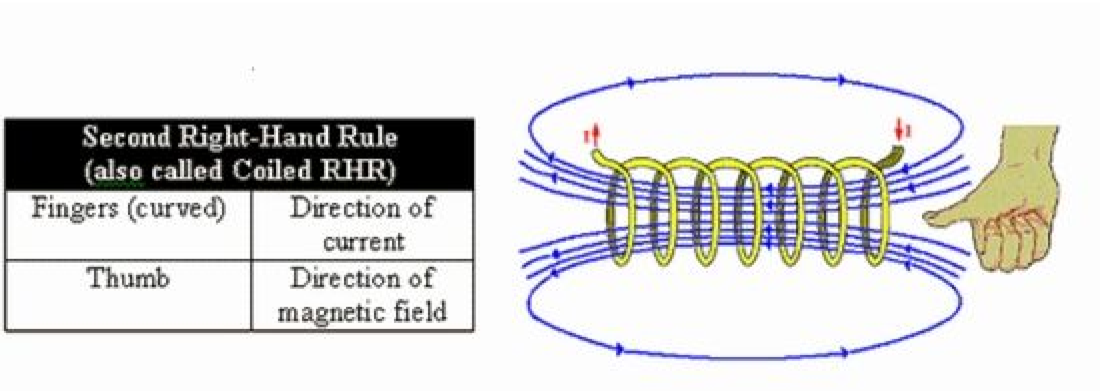
| Key | Value |
|---|---|
| V(n003) | Output of Comparator |
| V(n004) | Output of High Pass Filter |

**Figure 11:** Simulation for High Pass Filter

### 2.2.2 Water Unit

**Solenoid and magnet**

To vibrate the pipe at a frequency of about 60 Hz (same as that of the strobe light), we are using a solenoid and magnet contraption. The solenoid will be passed alternating current (sine wave) which will lead to changing the magnetic field direction created by it. The direction of magnetic field of a solenoid can be given by the right-hand thumb rule. To find the direction of the magnetic field emanating from one end of the solenoid, just wrap the fingers of your right hand fingers in the same orientation (clockwise or counterclockwise) that the current is flowing. Your thumb will naturally point in the direction of the magnetic field. The figure below illustrates this clearly:



| Second Right-Hand Rule (also called Coiled RHR) | |
|---|---|
| Fingers (curved) | Direction of current |
| Thumb | Direction of magnetic field |

**Figure 12:** Right Hand Rule for Solenoids [5]

The magnet will be stuck onto the pipe, with it's magnetic field oriented in a way such that it is parallel to that of the solenoid's magnetic field. The changing direction of the magnetic field in the solenoid will cause the magnet (and by extension, the pipe) to move towards it or away from it. The AC current passed to it will have a frequency in the range 58 Hz - 62 Hz. Since the strobe light is strobing at a frequency of 60 Hz, a pipe vibrating at a frequency less than 60 Hz would create the aliased illusion of water droplets moving downwards in slow motion. Alternatively, a pipe vibrating at a frequency greater than 60 Hz would create the aliased illusion of water droplets moving upwards in slow motion. For the water droplets to appear as if they are levitating, the frequency of the pipe's vibration must be exactly the same as that of the light strobing, i.e. 60 Hz. The magnetic field should be strong enough to move the magnet as well as the pipe. The force exerted by this contraption is as follows:

$$F = B^2A/2\mu_0 \quad ^{[6]} \tag{13}$$

$B$ is the magnetic flux density created by the solenoid and the magnet
$A$ is the combined surface area of the two magnetized surfaces
$\mu_0$ is the magnetic permeability constant

To prevent magnetic fields from interfering with each other, they will be decoupled. This approach was recommended by the ECE electronics shop as well as our TA, Luke Wendt.

### Water Pump and Storage

The water pump we plan to use will be procured by the ECE Machine Shop. It will need to pump water from a tank at the bottom of our structure to a tank top of our structure. The height difference between the bottom of the bottom tank and the top of the top tank is less than 20 inches. The bottom tank will hold water upto a capacity of 200 ml. The reason we chose this capacity is that it is a combined total of the volume of the drops required to run the device correctly. The number of drops of water in motion per stream is 16, the calculation for which is:

$$S = ut + 0.5gt^2 \tag{14}$$

For the first droplet, $u \simeq 0$, therefore S = $0.5gt^2$

$$\text{Evaluating, } S = 0.5 * 9.8m/s^2 * (1/60\ s)^2 = 0.27\ cm = 0.106\ inches \tag{15}$$

Thus, the distance between each droplet increases by approximately 0.106 inches in a 60th of a second. The distance between the pipe nozzle and bottom water tank is approximated to be 15 inches. The number of droplets in each 15 inch column is then calculated as follows:

$$\sum_{n=1}^{x} n * 0.106 \leq 15 \tag{16}$$

$x$ is the maximum number of droplets, the quantity we need to find

The maximum value of $x$ that satisfies the above equation is 16.

We have 5 such streams, which adds up to 80 drops of water. On average, we estimate 10 drops per ml [7] leading to the conclusion that about 8 ml of water is dripping at any instant in time. We feel having 25 full rounds of water is a safe enough estimate leading to a total water capacity of 200ml. The top tank must also be able to hold 200 ml of water, to prevent spillage. Additionally, to prevent splashing of water, the bottom tank will be about 2 inches deeper [8] than the 200 ml capacity. The water pump must pump water to the top tank at least as fast as the water is dispensed from the system. The system is dispensing 5 drops every 60th of a second, or 300 drops every second. This approximates to 30 ml/sec.

### Arduino Uno

Our choice of microcontroller is the Arduino Uno R3 A000066. The microcontroller will take in bluetooth signals from the HC-05 and accordingly set a duty cycle in the range 58 Hz - 62 Hz for each of the 5 solenoids to operate at. This functionality will be obtained by using Pulse Width Modulation [9]. The use of an Arduino Uno was recommended by our TA, Luke Wendt, since we are familiar with using it.

### Bluetooth

Our choice of bluetooth module is the HC-05 which will be soldered into the Arduino board. It operates at 3.3V power and 3.3V signal levels [10]. It will operate as a slave since it will be taking commands from the phone and relaying them to the microcontroller for use. We chose not to use the HC-06, which only operates as a slave as opposed to the HC-05 that can operate as either a master or a slave, since they cost the same and we might want to, for future development, include feedback to the phone from the bluetooth module.

### 2.2.3 User Interface

**Mobile App**

The app will be designed so that the user can control each of the 5 streams of water. The user must be able to control a stream without causing any change in the functionality of any other stream. The app will have 5 sliders parallel to each other, much like the volume slider on most smartphones nowadays. The default operation will be setting the slider to be in the center, which will send a signal to levitate the water droplets (60 Hz). Sliding the bar above or below the center will make the water droplets appear to move up or down in slow motion with velocity directly proportional to the displacement from the center.

## 2.3 Risk Analysis

We believe that the use of water poses the greatest risk in our project. We understand that the use of water in the lab is highly discouraged for fear of equipment damage. For this reason, it may be hard to demo our finished product in the lab. However, we can demo the working of individual modules of our system with the help of multimeters and oscilloscopes, by creating signals using basic function generators.

For the purpose of minimising water spillage in general, we plan to encase our entire model in a glass container. This will not be entirely problematic, since our model is small scale, ideally something the user can keep on a desk at home. Thus, we require the model to be compact. We will have to waterproof several components that may be in close proximity to water.

We need to take into consideration that once the stream of water falls to the bottom, it will splash due to coming in contact with the rest of the water that is accumulating over time. The pump action will not be instantaneous to cycle the water around the system. To mitigate this risk, we plan to have a container that is high enough to not let these drops of water spill out into the open.

The current values in our lighting circuit go as high as 1A in certain parts. A current of this magnitude could be fatal if not carefully dealt with. The addition of water in the project makes the risk of electrocution quite high. To deal with this, we plan on ensuring that the lighting circuit is kept in a waterproof box. Additionally, we plan on taking all the precautions mentioned in lab safety training in relation to dealing with currents of such a high magnitude.

## 3. Requirements and Verification Table

| Requirement | Verification | Points |
|---|---|---|
| Submodule: Comparator (1)<br>a) Comparator operates at 2V-36V thus, input to comparator from power supply must have offset 2.5V. Input sine wave of 5V amplitude must be offset from 0V to 2.5V.<br>b) Input to Comparator must have reference voltage = sine wave offset = 2.5V DC to create required square wave from sine wave.<br>c) Input sine wave must have a frequency = 60Hz, since this is the frequency of strobing. | a) Set up oscilloscope probes to measure the input voltage at the positive terminal of the single supply comparator to verify offset = $2.5 \pm 0.1V$.<br>b) Set up DMM probe to check DC voltage across resistor in voltage divider circuit to verify.<br>c) Check frequency of input wave at positive terminal of the single supply comparator to verify. | 5 |
| Submodule: High Pass Filter<br>a) Output waveform must decay by the amount -1/RC to reduce width of square wave (time for which signal is high).<br>b) Output waveform must start decay from 5V and should not lose voltage after filtering. | a) Use oscilloscope to probe across resistor in high pass circuit filter to check if amplitude of signal at time = RC is ~37% of 5V = $1.85 \pm 0.2V$.<br>b) Use oscilloscope to verify starting voltage $5 \pm 0.2V$. | 5 |
| Submodule: Comparator (2)<br>a) Output of Comparator (2) must have pulses of ~10% width of the original square wave width, but same frequency (60 Hz). | a) Use divisions of oscilloscope to calculate if time for which output pulse is high = 10% of 0.00833s. | 5 |

| | | |
|---|---|---|
| | b) Output signal must be pulsing every $0.01667 \pm 0.002$ s on the oscilloscope waveform. | |
| Submodule: Transistor<br>a) Transistor must turn on and off according to input pulse from comparator (2) at the same frequency. | a) Measure the voltage across the gate and source of the transistor. This voltage must be alternating between 0 and 5 $V \pm 0.5V$ .<br>b) Use oscilloscope to also check frequency of input pulse, this must be 60 Hz. | 5 |
| Submodule: LED<br>a) Current running through LED must be > 20mA for turn on, voltage across them must be >3.2V.<br>b) Room must be dark enough to not overpower LED lighting. | a) Using DMM, check the voltage and currents across each LED in the parallel circuit to verify.<br>b) Verify by conducting demo in a relatively dark room, not in the open. | 5 |
| Submodule: Solenoid and Magnet<br>a) Given a lower limit frequency of 58 Hz, the magnet must not move more than 0.5 inches either side of its base position.<br>b) A solenoid vibrating one pipe must not interfere with the magnetic field of nearby pipes. They must be decoupled. | a) Without the water flowing, vibrate the magnet using the solenoid at 58 Hz, measure displacement using a scale.<br>b) Keep two solenoids next to their pipes, turn on one solenoid and measure the displacement using a scale. Then turn on the second solenoid and check if the vibrations in the first one were affected by checking both, the displacement of the first magnet, as well as the new frequency of vibration versus the expected frequency of vibration. | 8 |
| Submodule: Water Pump and Storage<br>a) Both water tanks must not leak any water. | a) Fill both the water tanks to maximum capacity and check if any | 4 |

| | | |
|---|---|---|
| b) The bottom water tank must be resistant to splashes, to prevent the water droplets from splashing outside the tank.<br>c) The total amount of water in the device must never exceed 200ml. Create an overflow point at the 200 ml mark inside the tank, beyond which water is emptied from the tank to an external storage area. | water leaks out.<br>b) With just the skeletal structure of the tank (without any electrical component), drip drops of water from a height of 15 inches and check to see if any water spilled outside the bottom tank.<br>c) Add water to the tank until user sees the water overflowing into the external storage. | |
| Submodule: Arduino Uno<br>a) Must be able to produce frequencies in the range 58 Hz - 62 Hz $\pm 0.1$ Hz.<br>b) Must be able to read data correctly from bluetooth module. | a) Test the output frequency using an oscilloscope.<br>b) Test using laptop, connect to arduino and print data to screen relayed from HC-05 to arduino. | 5 |
| Submodule: Bluetooth Module<br>a) HC-05 must be able to receive data via bluetooth. The data must correspond to the position of the button along the slider on the phone app. For example, at the highest point, the data transmitted should be the integer 5. No room for error. | b) Set one slider to its highest point. The data received by the HC-05 can be printed ot the screen on a laptop. | 4 |
| Submodule: Mobile App<br>a) Must be able to send data regarding position of slider to bluetooth module.<br>b) Each slider must cause changes in strictly only their corresponding pipes. | a) Print data sent from phone to screen and print data received by bluetooth module to screen.<br>b) Move the button along one slider and print the data received. Move the button along another slider. Check if the data is different. | 4 |
| **Total** | | **50** |

**Table 3:** Requirements and Verification

## 4. Tolerance Analysis

For our design to function correctly, our most basic need is to not have very bright ambient lighting. We require the room in which we will perform the demo to be moderately dark, so that our LEDs can be comparatively very bright. We are using 20 LEDs for our strobe lighting. This provides the same luminous intensity as three incandescent bulbs. We require that no point in our circuit should ever have current > 1A flowing through it. Due to this reason, we limit our use of LEDs in our parallel lighting circuit and try to extract as much brightness from them as possible by controlling the ambient lighting.

Another very important factor we have to take into consideration is that we should have enough water circulating in our entire system at all times so as to not have any discontinuity. We have calculated the amount of water we will use to ensure this in above section 2.1.2. We also require visible clean water droplets that have enough distance between them to be distinguishable. We achieve this by having a strobing frequency of 60 Hz and calculating the distances between them, also derived in section 2.1.2.

## 5. Cost and Schedule:

### 5.1 Cost Analysis:

#### 5.1.1 Labor

| Name | Hours Invested | Hourly Rate | Total cost = hourly rate x hours invester x 2.5 |
|---|---|---|---|
| Atreyee | 300 | $30.00 | $22,500.00 |
| Siddharth | 300 | $30.00 | $22,500.00 |
| **Total** | 600 | $30.00 | $45,000.00 |

**Table 5.1.1** Labor Costs

#### 5.1.2 Parts

| Part and | Part number | Unit Cost | Total Cost |
|---|---|---|---|

| | | | |
|---|---|---|---|
| Quantity | | | |
| LED (x25) | 1080-1008-ND | $0.44960 | $11.24 |
| Comparator (x2) | LM2903M | $0.98 | $1.96 |
| Transistor | FQP30N06 | $1.10 | $1.10 |
| Regulator | 78L05BP | $0.48 | $0.48 |
| Bluetooth Receiver | HC - 05 | $8.00 | $8.00 |
| Arduino Uno | A000066 | $25.00 | $25.00 |
| **Total** | | | $47.73 |

**Table 5.1.2** Parts List and Cost

### 5.1.3 Grand Total

| **Section** | **Cost** |
|---|---|
| Labor | $45,000.00 |
| Parts | $59.73 |
| **Total** | $49,047.73 |

**Table 5.1.3** Total Costs of Labor and Parts

## 5.2 Schedule:

| Week | Task | Responsibility |
|---|---|---|
| Feb 27 | Design Encasement for Final Product and Order with Machine Shop<br>Design Encasement for Final Product and Order with Machine Shop | Atreyee<br>Siddharth |
| Mar 6 | Order Parts (comparator, transistor etc.) | Atreyee |

| | | |
|---|---|---|
| | Begin Programming Arduino | Siddharth |
| Mar 13 | Assemble circuit prototype<br>Test circuit prototype | Atreyee<br>Siddharth |
| Mar 27 | Debug circuitry for strobe<br>Assemble water/magnet/coil fixture | Atreyee<br>Siddharth |
| Apr 3 | Solder modules together<br>Finalize software changes | Atreyee<br>Siddharth |
| Apr 10 | Test modules separately in lab according to R and V table<br>Test app with arduino | Atreyee<br>Siddharth |
| Apr 17 | Test with water, Solve final Issues<br>Test with water, Solve final Issues | Atreyee<br>Siddharth |
| Apr 24 | Final Demo and presentation<br>Final Demo and presentation | Atreyee<br>Siddharth |
| May 1 | Final Report<br>Final Report | Atreyee<br>Siddharth |

**Table 5.2** Schedule

## 6. Ethics and Safety

Since this is predominantly water based project, our primary concern is to make sure this project is safe and does not cause any electrical mishaps during its development phase. In order to see the effects our chosen frequencies have on our system, we will need to test with water at all times. This is in conflict with the IEEE code of ethics [11] (1): “ ... making decisions consistent with the safety, health, and welfare of the public, and to disclose promptly factors that might endanger the public or the environment”, since our project may endanger the environment or the safety of others who may be helping us.

Strobing light may cause seizures and there is a high amount of current running through certain parts of a circuit at a time so we have to keep this in mind while working with our components.

There is another group this semester with a very similar project dealing with water aliasing. We plan to collaborate with them during the initial research phase to conduct the research behind the physics involved such as the frequencies involved, the droplet formation and human perception. We keep in mind the IEEE Code of Ethics (7): “to seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, and to credit properly the contributions of others” and (9): “to assist colleagues and co-workers in their professional development…”. These are important factors to ensure a smooth collaboration between the two groups which can result in individual, well functioning projects.

We will also be mindful of wastage and conservation of water, since this is a water heavy project. We will use a water pump that can pump water to about 3 or 3.5 feet, which will be ideal for our project needs. This is in accordance with the IEEE code (1).

We are also aware of all the resources available to us during the entire course of this semester and adhering to the ACM Code of Ethics and Professional Conduct [12] (2.4): “ Accept and provide appropriate professional review”, we will perform honestly and proficiently at peer reviews and provide our views as critically as possible. We will take any and all critique pertaining to our work from our teaching assistants and professors to improve our product.

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