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Mock Design Review Doc

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

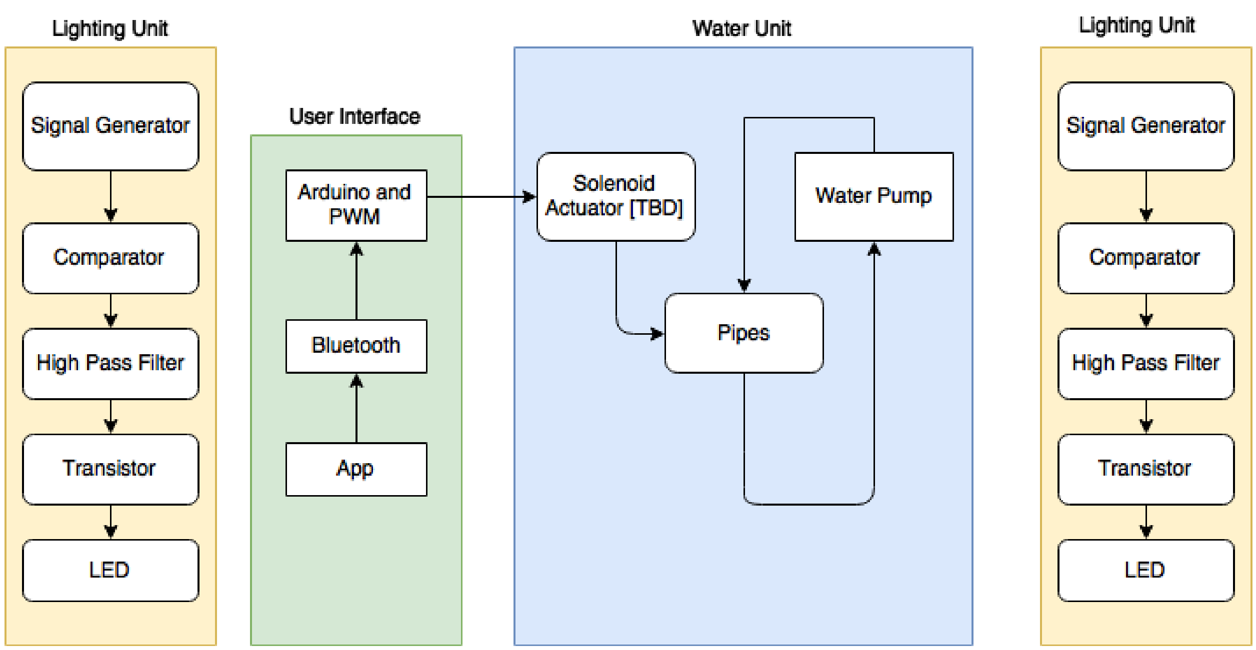
- The entire system must be compact and mostly waterproof, so that it is safe for operation.
- It should cost less than the commercial models available in the market today.
- It must be aesthetically pleasing to look at.

- 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".

Block diagram:



2.3. Lighting Unit

The lighting unit will be present on either side of our model to illuminate the water droplets as shown in *Figures 1* and *2*. The strobe light needs to be on for a very short period of time to create very clear droplets. The light will sample less movement of water in a shorter period of time. For achieving this, we will drive our own strobe light. The frequency we wish to achieve for our light is 100 Hz, the period being 10 mS. [3][4]

2.3.1 LED

We need the LEDs to be on for only 10 percent of the time. We can drive the LEDs 10 times its nominal current rating, which will provide more light. The brighter the LED is, the better the effect.

2.3.2 Comparator

The first part of our circuit design includes a comparator. A capacitor gets rid of the DC component of the signal coming from the signal generator (AC) and this resulting signal will be compared to a DC 2.5V signal to give a 0V-5V square wave.

2.3.3 High Pass Filter

The function of the high pass filter is to obtain signal widths much thinner than what we have originally. To mould our input analog signal into a proper digital wave, we pass the output of the high pass filter through another comparator.

2.3.4 Transistor

The last stage is a power FET transistor. A high at the gate will turn the transistor on like a switch. It has to be strong enough to handle the high currents running through the LEDs.

2.4 Water Unit

2.4.1 Water Pump

The water pump will be used to recycle the water we plan to use in this project, so we minimise wastage of water. The water is pumped upwards through a pipe so we can move the water cyclically.

2.4.2 Solenoid Actuator (TBD)

For the streams of water, we require a vibration to be produced at a certain frequency, either matching or being higher/lower than the frequency of light. This vibration can be brought about by speakers, which give us slightly distorted droplets. However, we need very clean droplets of water and this can be achieved by a more refined mechanical process. We consider a linear solenoid actuator, which converts basic electrical energy into a pushing or pulling motion. [5]

2.4.3 Pulse Width Modulator

For the streams of water, we require that the frequency of water droplets be changed in response to a signal received from a phone. To achieve this flexibility, we plan to use a PWM (Pulse

Width Modulator) [6]. Each stream of water will have it's own PWM, controlled by a PCB or Raspberry Pi [7], so that each stream can be controlled independently.

2.5 User Interaction

We envision our complete system to be 5 evenly spaced vertical streams of water. Each stream can be controlled by the user through an app on the phone.

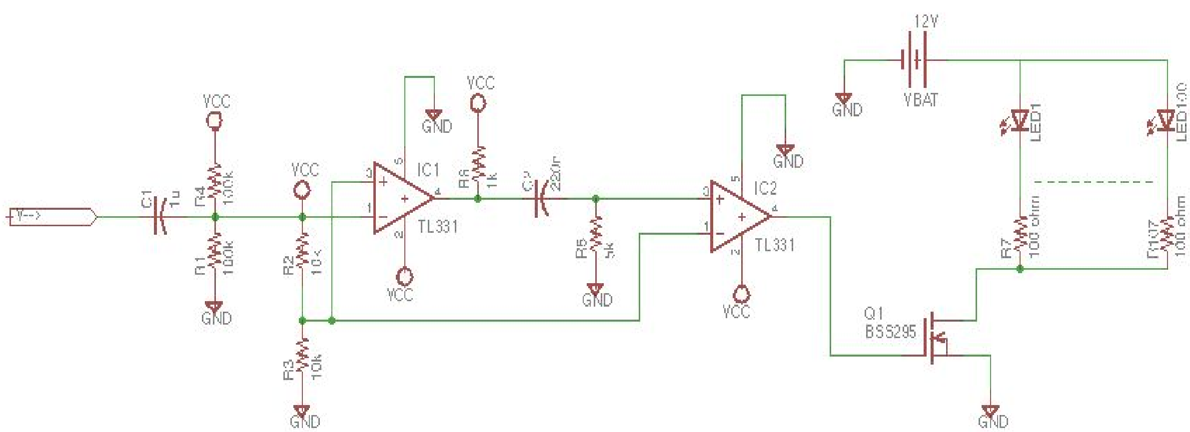
2.5.1 Mobile App

In the app, each of the 5 streams will have its own directional slider (similar to a volume slider on most smartphones). The top most point corresponds to the fastest upward motion of the droplets, the middle corresponds to them simply levitating, while the lowest point on each slider corresponds to the fastest downward motion of the droplets. The user can independently control any stream of water through the app to create any desired pattern.

2.5.2 Bluetooth

A Bluetooth transmitter (inbuilt in smartphones) will be used to send the signals from the app to the actuator via a PCB or a Raspberry Pi (using an hc-05 receiver for example).[8] The signal sent by the user can be used as a trigger to change water frequency to create the user specified illusion.

Schematic of Strobe Lighting Unit



Schematic for Strobe Lighting Unit

Design Components:

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.

Blocking Capacitor:

Our sinusoidal input waveform has some DC component which we need to get rid of. 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 x V (Charge = Capacitance x voltage)

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 x dV/dt (Current = Capacitance * rate of change in voltage)

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 having VCC = 5V and two 10Kohm resistors in parallel.

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

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

$$= 2.5V$$

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.

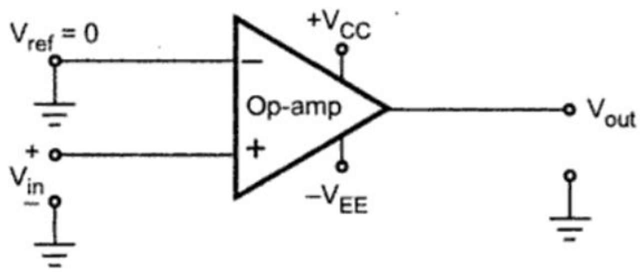


Figure: A basic non inverting comparator

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:

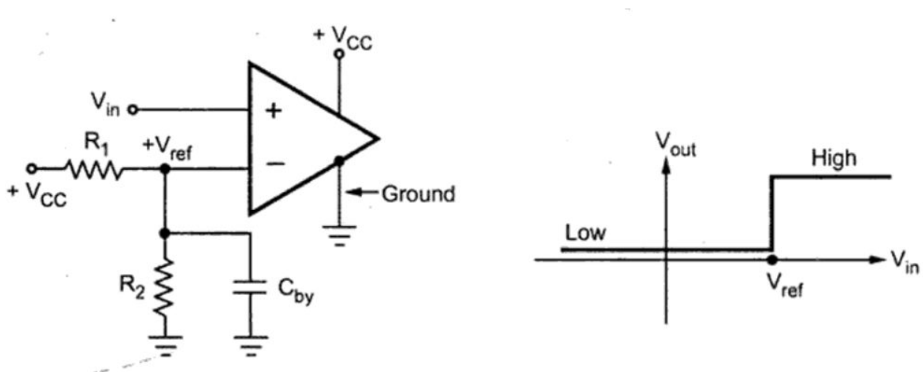


Figure: Single Supply Comparator and its transfer characteristics

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:

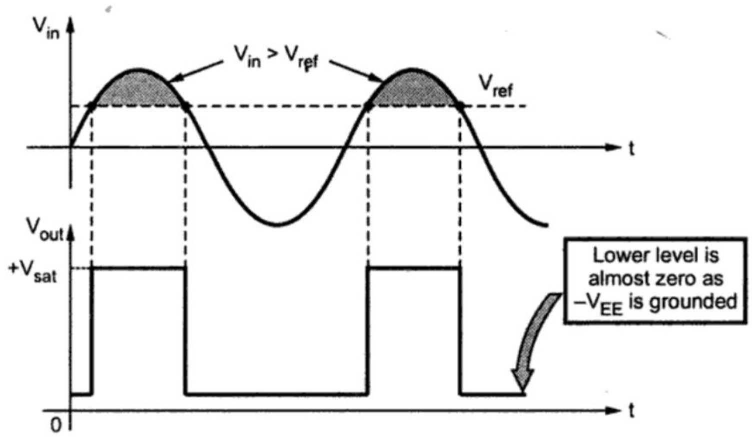


Figure: Waveform of single supply comparator

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:

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.

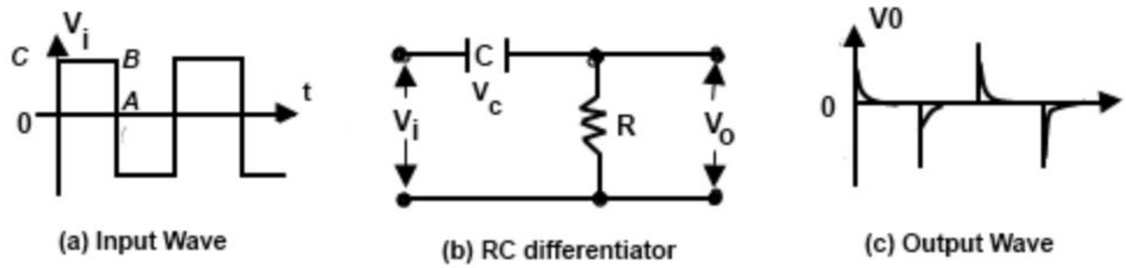


Figure: Differentiating Circuit showing square input and corresponding output

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 Xc should be ten or more times larger than R at the operating frequency.

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

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

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.

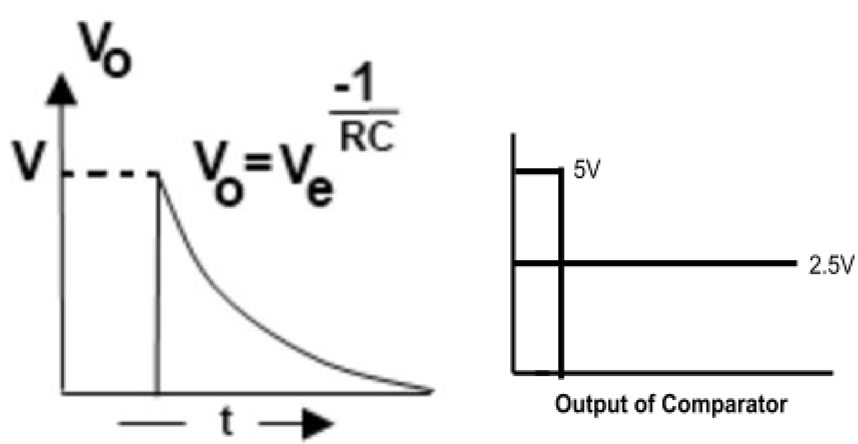


Figure: Output of High Pass Filter and Second Comparator

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.

Calculation for Current passing through LED circuit:

In order to turn on the LEDs in the circuit, we need to pass a minimum current of 20mA (turn on voltage) through them. With 100 LEDs in our parallel array, we need to decide the value of resistors that can limit the current reaching the LEDs from the transistor. The LEDs are powered with a 12 V battery. The current running from the transistor has a cap of ~10A and in this case each branch of the LED array has about .1A flowing through it. The voltage drop across the LED is 3.2V from the datasheet. the The value of resistor is chosen as follows:

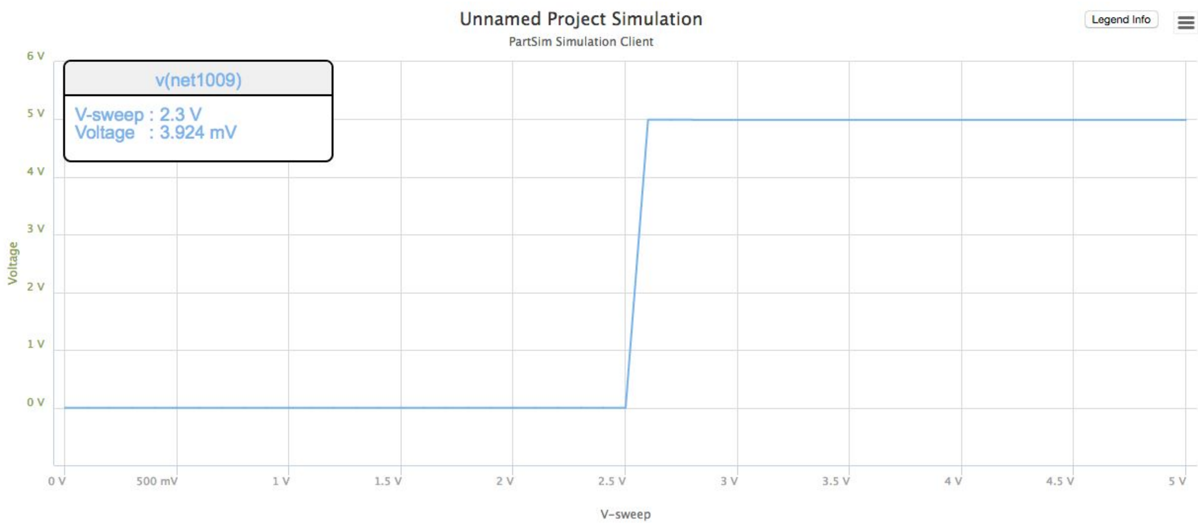
Desired resistor value (in ohms) = (Power supply voltage − LED voltage) / current (in amps)
= (12V - 3.2V) / 0.1A
= (8.8V) / 0.1A
= 88 ohm

To be safe, we plan to use ~ 100 ohm resistor in our design.

Simulation 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.

Our results were as follows:



As we can see from this plot we have a jump from -Vsat at 0 V to +Vsat at 5V. We see some non ideal behavior in the jump and 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.

2.6 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.

We have also considered the heating of the solenoid actuators due to overuse. Longer periods involving direct power supply to the coil will make it hot and may affect operation. This, however, will not be a cause of any risk since our actuators will be using an "intermittent duty cycle", operating at the frequency we want to run our water at. This will be achieved through the pulse width modulation.

3. 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 [9] (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 [10] (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.

4. References

[1] Amazon.com, 'Levitating Waters', 2017. [Online]. Available: https://www.amazon.com/Levitating-Waters-Plug-Funtime-Gifts/dp/B01CRU01PY/ref=sr_1_3?s=home-garden&ie=UTF8&qid=1486601806&sr=1-3&keywords=levitating+water [Accessed: 06-Feb-2017]

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