Water Aliasing

Design Review

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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 waterproof, so that it is safe for operation.
- It should cost less than the commercial models available in the market today.
- The app must be intuitive and easily controllable by the user.
- The water droplets must appear to levitate as well as rise and fall in slow motion.

- 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)

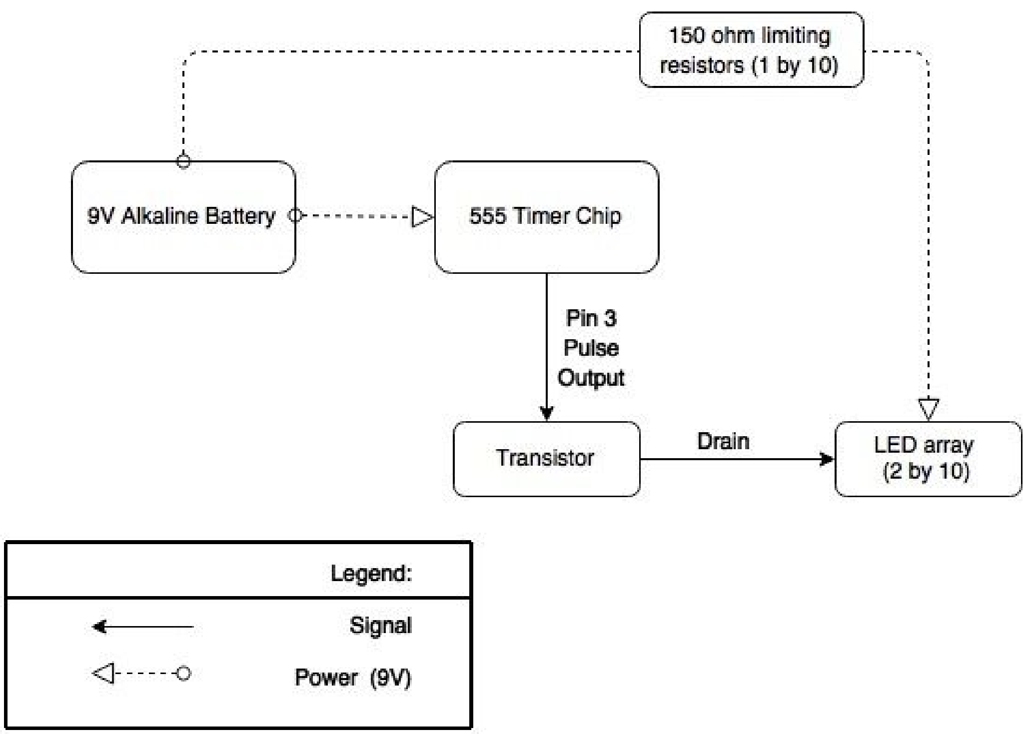

Figure 1 a) Block Diagram for Lighting Unit

b)

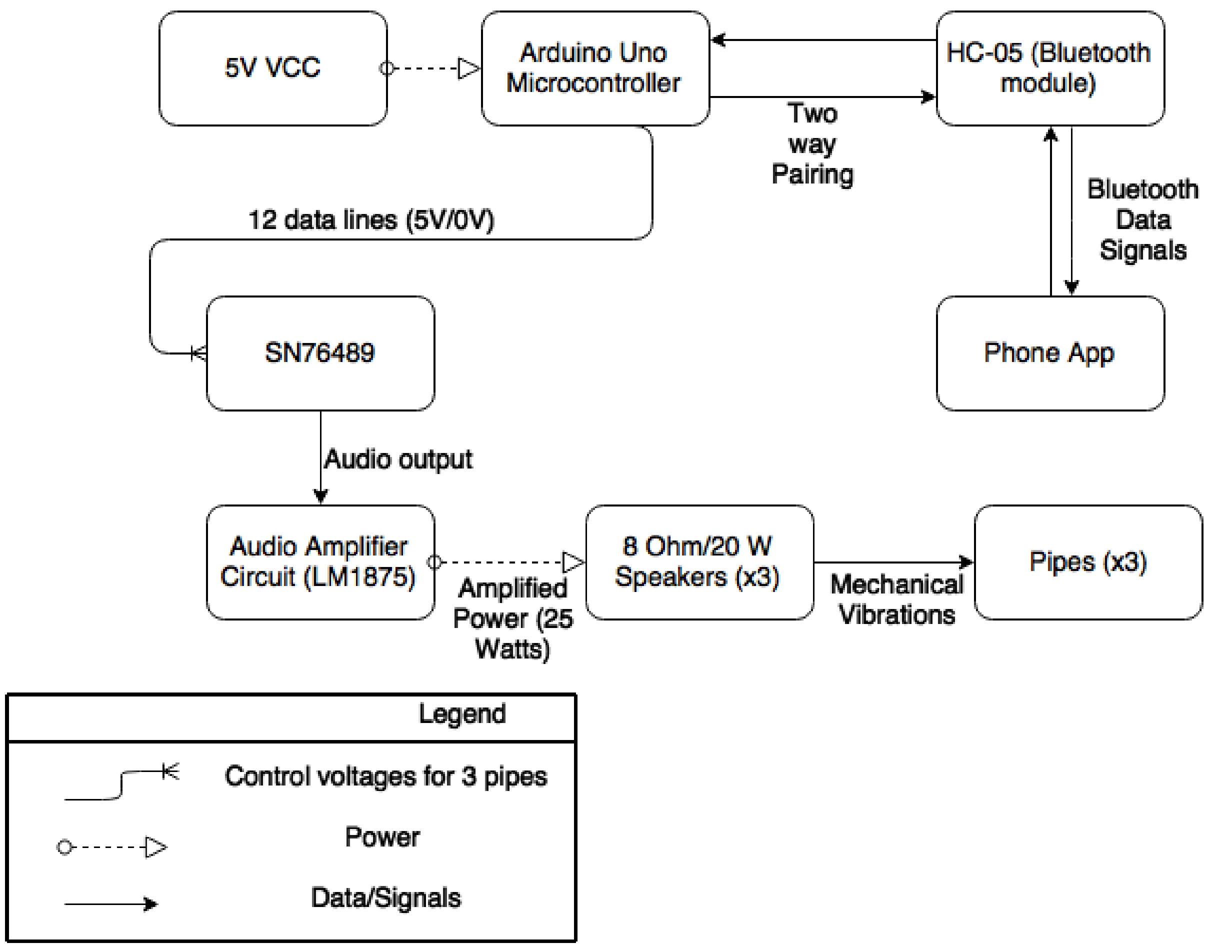

Figure 1 b): Block Diagram for our Water/User Interface Unit

2.2 Physical Design

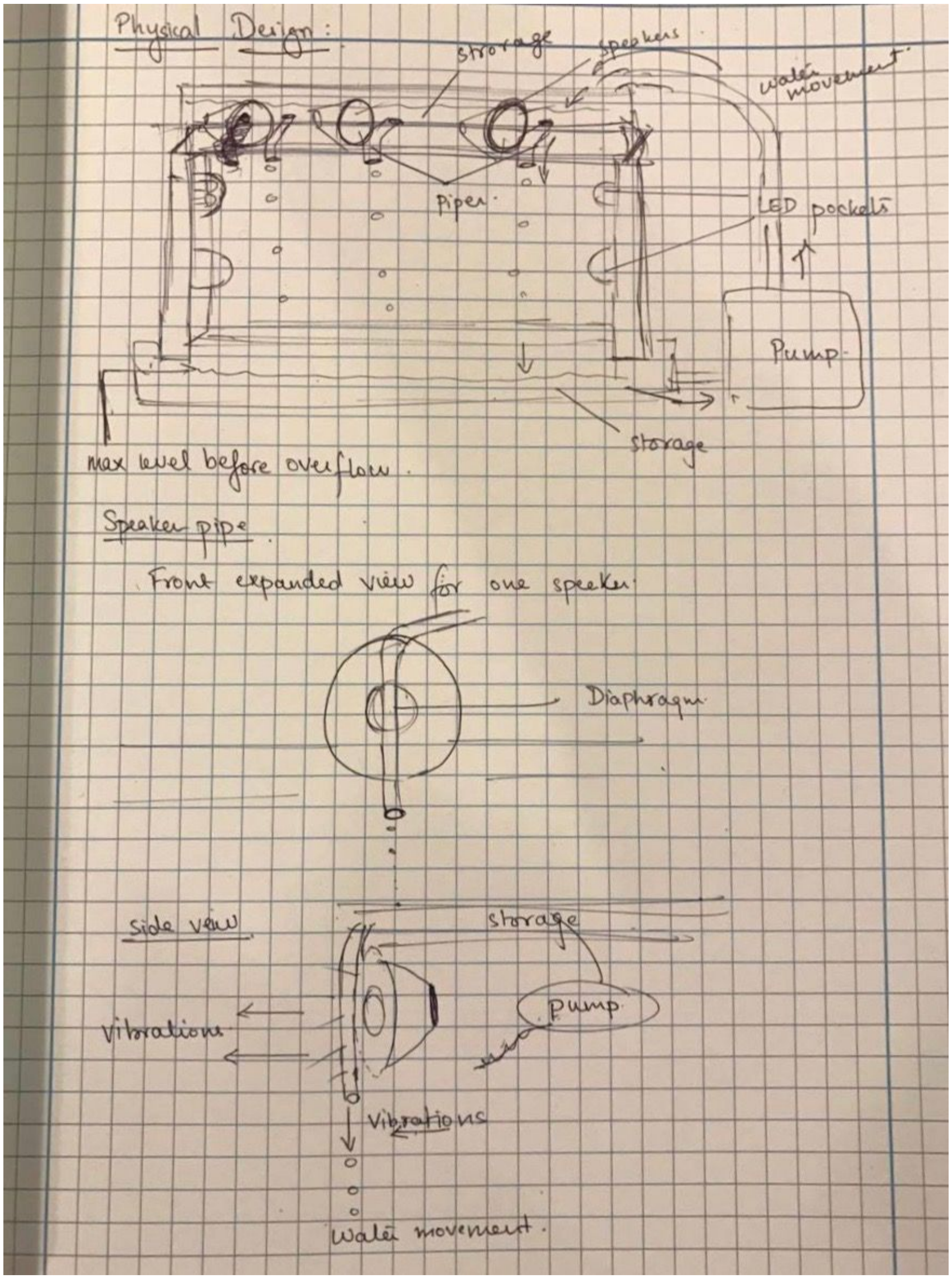

Figure 2: Physical Design including front and side views of entire system

2.3 Block Design

2.3.1 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 2.3.1: Electro-Optical Characteristics of LED [3]

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):

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

- Φv is the luminous flux, in measured in Lumens (lm),
- Iv is the luminous intensity, measured in Candela (cd), and
- Ω 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:

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

where:

- θ 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.

555 Circuit and Operation

We require these 20 LEDs to be strobed at a particular frequency of 60 Hz at all times. However, we would like to have the freedom to vary the frequency and duty cycle of the strobe in case we choose to have a different frequency or the time for which the LEDs are on for. The simplest way to achieve this is with the help of a 555 Timer IC chip. The external RC circuit connected to the inputs of the chip, along with diodes to control the charge and discharge times of the capacitor, will accomplish our goal of frequency variation.

The 555 Timer will be used in the astable mode for our application. In astable mode, the 555 timer acts as an oscillator that generates a square wave. The frequency of the wave can be adjusted by changing the values of two resistors and a capacitor connected to the chip. In the 555 Oscillator circuit, pin 2 and pin 6 are connected together allowing the circuit to re-trigger itself on each and every cycle allowing it to operate as a free running oscillator. During each cycle capacitor, C charges up through both timing resistors, R1and R2 but discharges itself only through resistor, R2 as the other side of R2 is connected to the *discharge* terminal, pin 7.
Then the capacitor charges up to 2/3Vcc (the upper comparator limit) which is determined by the 0.693(R1+R2)C combination and discharges itself down to 1/3Vcc (the lower comparator limit) determined by the 0.693(R2.C) combination. This results in an output waveform whose voltage level is approximately equal to Vcc – 1.5V and whose output “ON” and “OFF” time periods are determined by the capacitor and resistors combinations. The Vcc for the 555 IC can be anywhere

between 5-15V. For our circuit, we will use Vcc = 9V from an alkaline battery. The individual times required to complete one charge and discharge cycle of the output is therefore given as:

$$T_{on} = 0.693*(R1 + R2)*C \tag{3}$$

$$T_{off} = 0.693*(R2)*C \tag{4}$$

Where T_{on} and T_{off} are the lengths of high and low output pulses in seconds, R1 and R2 are the resistances and C is the capacitor we will choose. In figure 3 below, we see the 555 chip and its inputs and outputs:

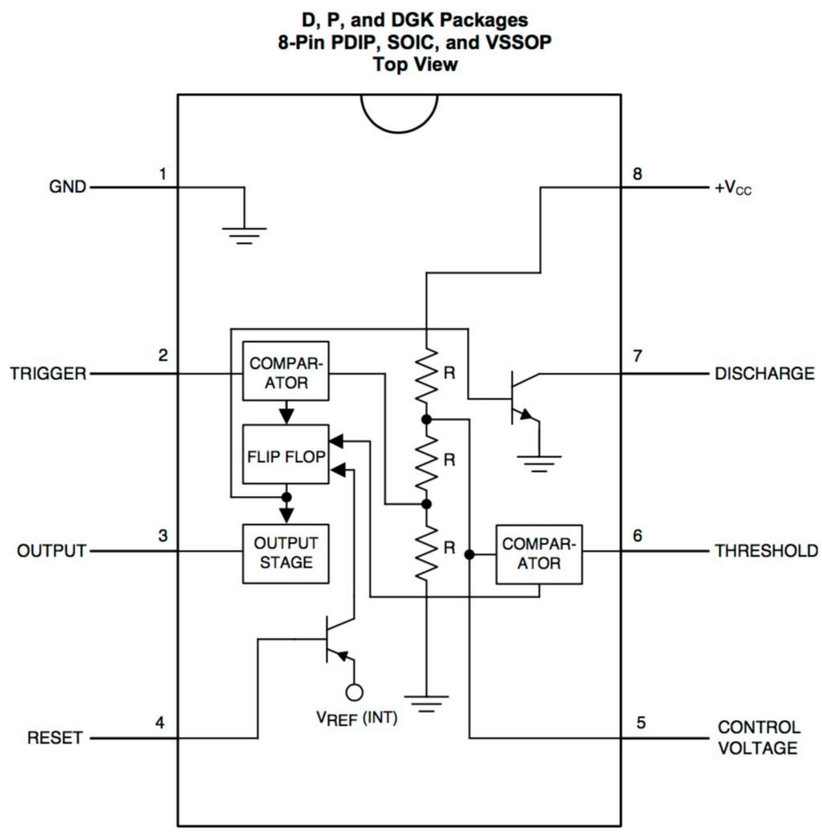

Figure 3: 555 Timer Pin Configuration for inputs and outputs [4]

The duration of one full timing cycle is therefore equal to the sum of the two individual times that the capacitor charges and discharges added together and is given as:

$$T = T_{off} + T_{on} = 0.693*(R1 + R2)*C + 0.693*(R2)*C \tag{5}$$

$$= 0.693*C*(R1 + 2R2) \tag{6}$$

The output frequency of oscillations can be found by inverting the equation above for the total cycle time giving a final equation for the output frequency of an Astable 555 Oscillator as:

$$f = 1.44/ C*(R1 + 2R2) \quad (7)$$

This can be seen from the following extended circuit below in figure 4:

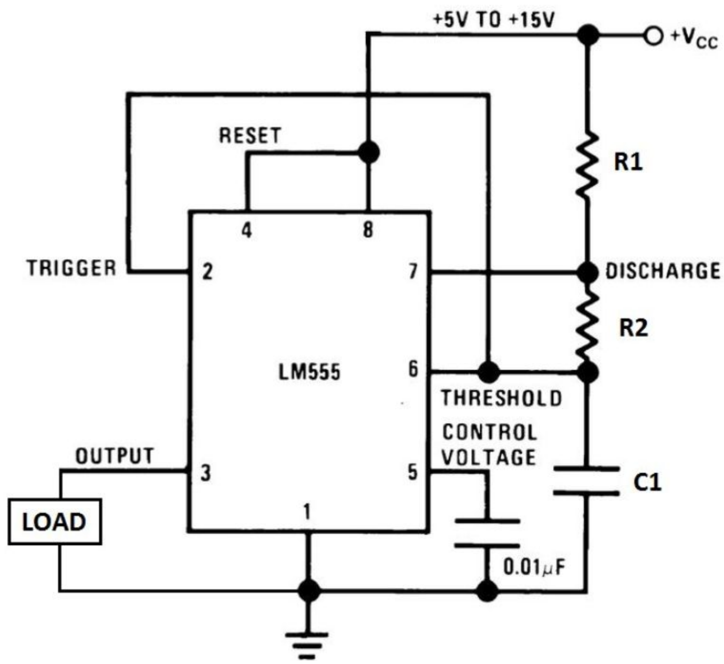

Figure 4: Square wave generating 555 circuit[4]

For out strobing lights, we require our duty cycle to be ~10%. In general astable circuits, we can obtain a duty cycle of 50-100 %. In order to obtain a duty cycle lower than 50 percent, we will need to use two diodes: D1 and D2 - to isolate the charging and discharging of the capacitor from each other.

D1 between the *trigger* input and the *discharge* input, the timing capacitor will now charge up directly through resistor R1 only, as resistor R2 is effectively shorted out by the diode. The capacitor discharges as normal through resistor, R2.

An additional diode, D2 can be connected in series with the discharge resistor, R2 if required to ensure that the timing capacitor will only charge up through D1 and not through the parallel path of R2. This is because during the charging process diode D2 is connected in reverse bias blocking the flow of current through itself.

Now the previous charging time of $T_1 = 0.693(R1 + R2)C$ is modified to take account of this new charging circuit and is given as: $0.693(R1 * C)$. The duty cycle is therefore given as D = R1/(R1 + R2). Then to generate a duty cycle of less than 50%, resistor R1 needs to be less than resistor R2.

The frequency of this circuit effectively thus becomes:

$$f = 1.44/ C*(R1 + 2R2) \qquad (8)$$

We must now select our resistors and capacitors to fulfil the constraints on our duty cycle as well as our frequency. The duty cycle of this pulse is given by:

$$\text{Duty cycle} = T_{on}/(T_{on} + T_{off}) \qquad (9)$$

$$= R1/ (R1 + R2) \qquad (10)$$

For our 10 percent duty cycle it is easy to see that the relationship between R1 and R2 is as follows:

$$R2 = 9*R1 \qquad (11)$$

With this relationship, we pick two values for R1 and corresponding R2. The frequency we choose for this circuit can be determined by these values, as well as the value for C. Once we determine the correct capacitor value for our frequency, we can always vary the resistor values in their correct ratio since we will use variable resistors of the order 10k to 100k ohms [5].

Going back to the output stage, the square wave will have a high of approximately 7.3V and a low of 0V. We will use a N-MOSFET to use as a switch for our LED array. 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 since they find a path to the ground.

Our 20 LEDs are arranged in a parallel circuit of 10 columns, with 2 of them in series in each branch of the array. The LEDs are powered with the 9V and have a 3.2V drop across each of them when on [3]. Each LED has peak performance at 20mA, which means each branch of the LED array needs around 20mA flowing through it for moderate brightness.

Power Considerations of the LED circuit

To know the limiting resistor we require in each branch:

$$R = \frac{9V - 2*3.2V}{20mA} = 130 \text{ ohm} \quad (12)$$

We round this off to using a 150 ohm resistor in each arm. The current in this case is 17.33mA. The total current running through all the branches is 10 times this current ie. 173.3 mA.

The power dissipated by each of these LEDs is $V*I$ = 3.2V*17.33mA = 55.456 mW.
Power dissipated by all 20 of them will be 1109.02 mW.

The power dissipated by each of the resistors is I^2R = 17.33 mA^2 * 150 Ω = 45.049 mW. The total power dissipated in all the 10 resistors is 450.049 mW.

The total power dissipated in our strobing circuit is 1559.069 mW.

Our transistor provides a resistance of about 0.01 ohms which is almost negligible and we do not include this in our power considerations. The transistor can handle breakdown current of 27A, so we can account for all the current flowing through it and it will not result in the transistor burning [6]. We will also limit the current flowing through the base of the transistor with a 10k ohm resistor to limit the current coming out of the 555 chip.

Below is a final schematic of the completed circuit:

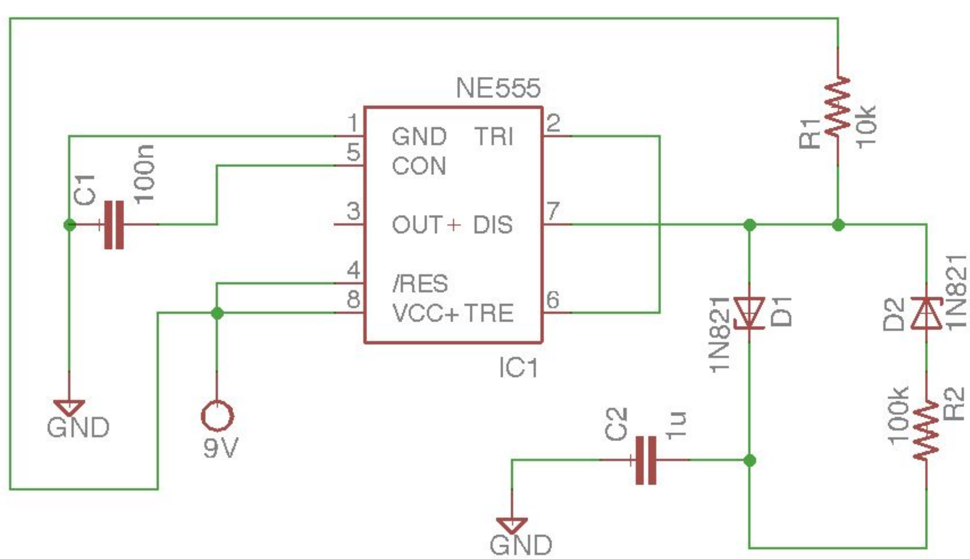

Figure 5: Complete schematic of LED strobe [5]

We simulated the circuit on LTspice to see the output waveform. As shown below in Figure 6, we see pulses at about 10 percent duty cycle and these are the pulses we desire for our transistor input.

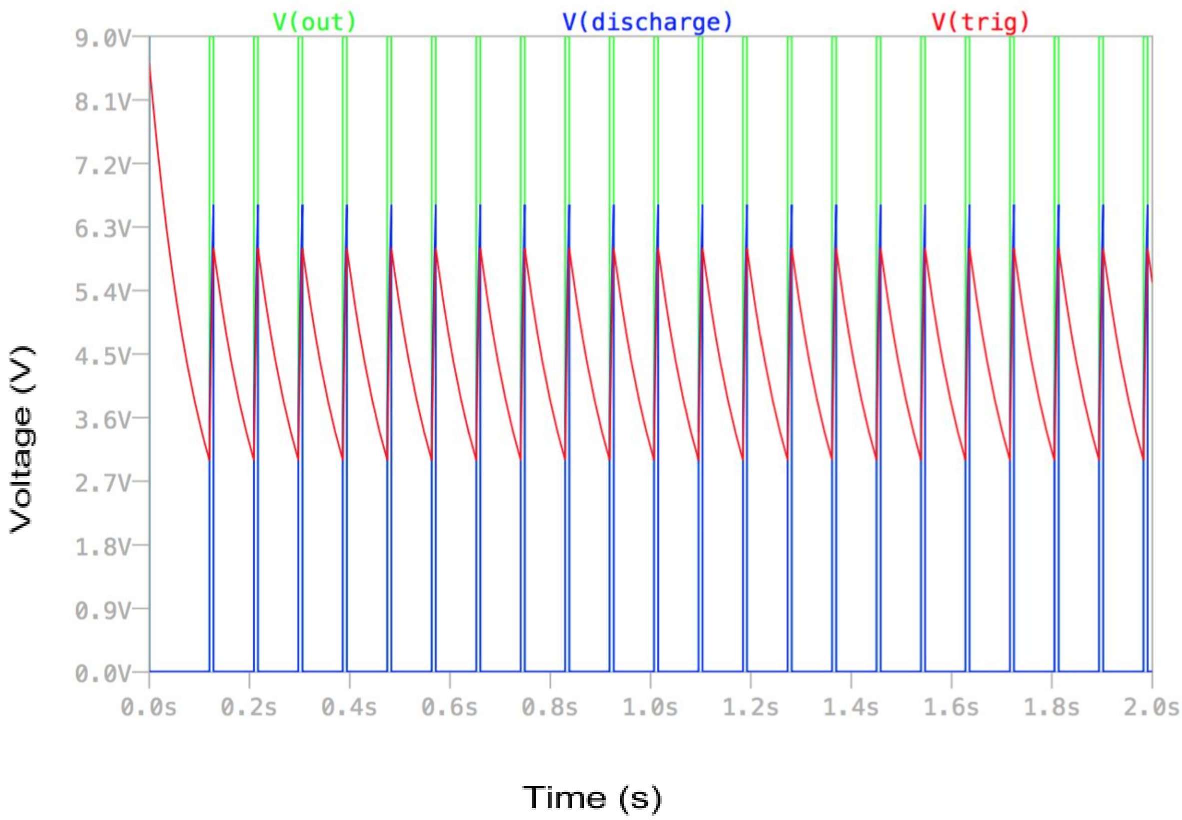

Figure 6: Simulation showing output (Vout) of 555 Timer and discharge and trigger voltages

2.3.2 User Interface

Mobile App

The app will be designed so that the user can control each of the 3 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 3 columns of 3 buttons each, named as up, levitate, down. The default operation will be to levitate the water droplets. Pressing the up or down buttons will cause the corresponding water stream to move up or down in slow motion.

2.3.3 Water Unit

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:

$$S = ut + 0.5gt^2 \quad (14)$$

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

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

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:

$$\sum_{n=1}^{x} n * 0.106 \leq 15 \quad (16)$$

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 3 such streams, which adds up to 48 drops of water. On average, we estimate 10 drops per ml [7] leading to the conclusion that about 5 ml of water is dripping at any instant in time. We feel having 40 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 3 drops every 60th of a second, or 180 drops every second. This approximates to 18 ml/sec.

Bluetooth

Our choice of bluetooth module is the HC-05 which will be used on 2 PWM pins on the microcontroller (ATmega2560). It operates at 3.3V power and 3.3V signal levels [9]. The HC-05 receives data from the mobile app and transmits it to the microcontroller as bits, sent in packets.

The bluetooth module is paired with the phone so that it can relay data and messages to and from the phone.

Arduino Mega 2560

Our choice of microcontroller is the Arduino Mega 2560 (based on the ATmega2560) [10]. The microcontroller will take in packets of data from the HC-05, unpack them, and accordingly set the data bits on the corresponding SN76489. This can be done by the SendByte() which uses the inbuilt DigitalWrite() function [11]. This microcontroller can be programmed using Arduino Software (IDE). The output pins of the microcontroller will be connected to each of the sound generator chips.

SN76489

To generate sounds of frequencies 58 Hz, 60 Hz, and 62 Hz, we are using the cheap and popular SN76489 sound generator chip. It generates sounds of frequencies given by the following equation:

$$f = N/(32 * n) \tag{17}$$ [12]

N is the frequency of the input clock

n is the desired frequency given by setting 10 bits (F9-F0) on the IC

For the clock, we plan on using a 555-timer chip to generate a clock signal. Unlike our 555 circuit for the strobe lights, this will output a signal of 50 percent duty cycle. The resistors in this case will be equal so that the charging and discharging times will be the same. The SN76489 requires only a 5V VCC to operate. The audio output is clean but very weak and is put through an amplifier circuit before being outputted to the speaker for use.

Speakers

Our design contains 3 speakers, one to vibrate each pipe. The speakers should be powerful enough to vibrate the pipes as well as operate without consuming too much power (>40W) at frequencies as low as 60 Hz. Our choice of speaker is the Dynavox LY401F. Its main features include 6 ohm impedance and a power handling RMS rating of 20 Watts [13].

The output of the SN76489 is too weak to drive the speakers, hence we must build an amplifier circuit for this purpose. There are two considerations to be made for this:

- The amplifier has to be 25 percent more powerful than the speaker. Hence, in our case, we must have a power output of 25W from our amplifier circuit.
- We must match the impedance of our circuit to the impedance of our speakers so as to not burn either of them out. We will build our amplifier circuit to handle speaker impedances in the range of 4-8 ohms.

Audio Amplifier

We use the following circuit below to amplify the output of our sound generator IC to drive our speakers.

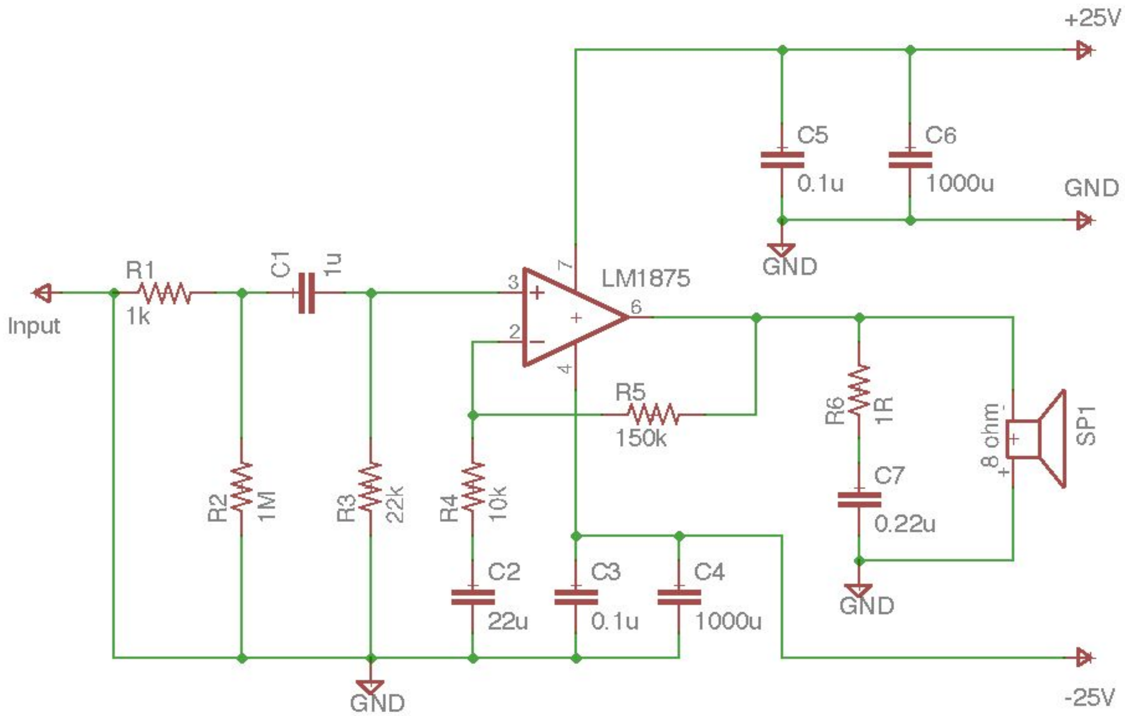

Figure 7: Circuit Schematic of audio amplifier circuit [14]

This circuit uses the positive and negative power supply to get the audio signal with both the positive and negative halves of the signal swing. The sound that comes out is crystal clear due to this. The input signal from our soundcard is through R1, R2, C1 and R3 to limit the the noise to the ground in the signal appropriately. The modified signal is then sent to the input pin of the LM1875, a non-inverting amplifier with non-return phase. The amplified signal goes out of the 4 output pins to access the speakers.The R6 and C4 eliminate noise mixed with the output down to the ground. A part of the audio output pin 4 of integrated circuit will be fed back into place through R5 to pin 2, where R4 and R5 determines the rate of boost up and can be calculated from *R5/R4*. The C2 is placed to meet high frequencies better.

The LM1875 is a class AB type amplifier with a low distortion at the frequencies we wish it to operate at. When overloaded, it has protection consists of both internal current limit and thermal shutdown. Other features is high gain, fast slew rate and a wide bandwidth, large output voltage swing, high current capability, and a very wide supply range [14].

2.4 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 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.

3. Requirements and Verification Table

Requirement	Verification	Points
Module: Strobe light		
1) The duty cycle of the output from the 555 timer circuit must be 10%±3% for good strobing effect.	a) Choose resistor values such that discharging resistor has a value 9 times the charging resistor. b) Set up oscilloscope probes to measure the output voltage at pin 3 of the 555 chip to verify this duty cycle. c) Use divisions of oscilloscope to calculate if time for which output pulse is high = 10±3% of 0.01667s.	8
2) The frequency of the output wave must be constant at 60 Hz±0.2Hz.	a) Choose resistor and capacitor values, while keeping ratio between resistors R1 and R2 constant at all times. (9:1) b) Check frequency of output wave at pin 3 of 555 to verify that frequency lies between 60±0.2 Hz.	7
3) Current through each branch of the LED array must never exceed 20mA (peak brightness). We will use 150 ohm limiting resistor in each branch to achieve this.	a) Use DMM to measure voltage drop across LEDs in each branch. This should be 3.2±0.2V for each LED. b) Measure the current in each branch with the DMM. This will be 17.33± 1mA. c) Total current at the drain of the transistor will be 173.33±10mA. This can be verified with the DMM by probing at the drain.	6
4) High current must not enter the transistor gate from the output of the 555. We will place a 10k ohm resistor before	a) Probe at the gate of the NMOS transistor to check current at gate. This	3

the gate to ensure this.	must be <20mA.	
Module: Water Unit <u>Submodule: Water pump and Tank</u> 1) Both water tanks must not leak any water.	a) Fill both the water tanks to maximum capacity and check if any water leaks out.	0
2) The bottom water tank must be resistant to splashes, to prevent the water droplets from splashing outside the tank.	a) 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.	1
3) 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.	a) Add water to the tank until user sees the water overflowing to an external location (like a drain) without the risk of the water expelled coming in contact with any part of the device.	0
4) The water pump must be able to pump water at the rate of at least 18ml/sec.	a) This comes from the data sheet or specs of the pump purchased.	0
<u>Submodule: Microcontroller</u> 1) Must be able to send data to sound generator chip and do so without causing distortion due to presence of old data while setting new data on sound generator chip.	a) Using testing LEDs, see that the correct LEDs turn on when setting data bits to high or low b) Measure the output of the SN76489 in response to changing data sent from microcontroller.	3
2) Must be able to unpack and read data correctly from bluetooth module.	a) Test using laptop, connect to arduino and print data (characters) to screen relayed from HC-05 to arduino.	2
<u>Submodule: Sound Generator</u>		

1) Must be able to generate sounds of frequencies 58 Hz, 60 Hz, and 62 Hz.	a) Set the data bits and input clock to theoretically produce a frequency of 60 Hz. Check the output on the Oscilloscope. Repeat for 58 Hz and 62 Hz using same input clock.	0
2) It requires a clock signal of 50 percent duty cycle to be created with another 555 timer circuit.	a) Choose resistors for the new 555 circuit with R1 equal to R1 and probe output pin with oscilloscope to check duty cycle of square wave output which should be 50 ± 2 percent.	3
3) The frequency must be able to change in less than 0.5 seconds of pressing a button on the app.	a) Measure the time between pressing the button and seeing a visible change in the movement of water droplets.	2
<u>Submodule: Audio Amplifier</u>		
1) It should not cause too much distortion (<0.2 Hz) for audio input in the frequency range 58 Hz - 62 Hz.	a) Run the output of the amplifier through a network analyzer (VSA) and test the signal. b) To check the stability of the frequency, use the continuous peak search option on the VSA and reduce the resolution bandwidth and span. c) Observe the largest frequency drift, it should be on the order of 0.2 Hz.	8
<u>Submodule: Speakers</u>		
1) Speakers must not be able to produce frequencies in range of 58-62 Hz.	a) This comes from the datasheet of the speakers [13].	0
2) Speakers must be able to vibrate the pipe with water. It should not be vibrating with a large amplitude such that water sprays outside of the physical framework built.	a) Play speaker on full volume, attach a pipe and see if it vibrates with a large amplitude. If the vibration is too large, reduce volume. Test again with water (This time increase the volume because with the added weight of water, the pipe will vibrate less).	2

Module: User Interface App 1) Must be able to send data regarding position of slider to bluetooth module.	 a) Print data sent from phone to screen and print data received by bluetooth module to screen.	 2
2) Each button must cause changes in strictly only their corresponding pipes.	a) Press the button for one pipe and print the data received. Press the button for another pipe then. Check if the data received is different.	3
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 will limit our ambient lighting to 50 percent of the LED lighting i.e. ~40 lumens.

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 2.3.3. 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 2.3.3.

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	$20.00	$15,000.00
Siddharth	300	$20.00	$15,000.00
Total	600	$30.00	$30,000.00

Table 5.1.1 Labor Costs

5.1.2 Parts

Part and Quantity	Part number	Unit Cost	Total Cost
LED (x25)	1080-1008-ND	$0.4496	$11.24
Timer IC (x4)	NE555P	$0.39	$1.56
Audio Amplifier IC (x3)	LM1875	$2.75	$8.25
Sound Generator IC (x3)	SN76489AN	$0.94	$2.82
Bluetooth Module	HC-05	$4.83	$4.83
Arduino Mega 2560 Rev3	A000067	$36.99	$36.99
Dynavox(x3)	LY401F	$19.99	$59.97
Total			$125.66

Table 5.1.2 Parts List and Cost

5.1.3 Grand Total

Section	Cost
Labor	$30,000.00
Parts	$125.66
Total	$30,125.66

Table 5.1.3 Total Costs of Labor and Parts

5.2 Schedule

Week	Task	Responsibility
Mar 6	Work on redesigning the project	Both
Mar 13	Order Parts (All ICs, microcontroller, etc.) Turn in PCB design to be made Finalize design with Machine Shop	Both
Mar 27	Build and debug circuitry for strobe light Program the microcontroller and phone app (Android)	Atreyee Siddharth
Apr 3	Fix any issues with strobing circuit, solder modules together Complete all programming and mathematical calculations as well as debugging for the bluetooth module and microcontroller	Atreyee Siddharth
Apr 10	Integrate amplifier circuit and speakers Integrate sound generator chip with amplifier circuit and speakers, relay data to sound generator chip from 555 timer and microcontroller for varying frequency	Atreyee Siddharth
Apr 17	Test with water after getting approval, solve final issues	Both
Apr 24	Final Demo and presentation	Both
May 1	Final Report	Both

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 [15] (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 [16] (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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