Beer Pong Mat

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ECE 445 Senior Design Document

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Team 20

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1. Introduction

1.1 Problem

You would be hard pressed to find a college student or graduate in the United States who has never played a game of beer pong. This game, in which players take turns attempting to throw a ping pong ball into cups of beer across a table, has over the years evolved from a simple drinking game to a ubiquitous American pastime. People of all ages play this game, with or without alcohol, at parties, tailgates, and even on their iPhones, where users can use the GamePigeon app to challenge their friends to a virtual game of pong over text. Professional tournaments are even held for the game, with the largest such tournament, the World Series of Beer Pong (WSOBP), regularly having over a thousand participants.

Given that it is commonly played in an informal setting, beer pong, similar to games of wiffle ball or pickup basketball, is often the source of heated arguments amongst participants. Throughout an average game, cups may be shifted, spilled, or tilted in ways that give one team an unfair advantage over the other, and with no impartial official to make final decisions on what to do in these situations, players are often left feeling slighted. In addition, especially after many games are played in a row, it can be easy to lose track of the score, how many games each team has won, and whose turn it is. For such a prevalent game to have so much unnecessary unpredictability is unacceptable, and our goal is to ensure that future beer pongers are presented with an even playing field, so that each game is fair and every victory is that much sweeter.

1.2 Solution

To address these problems, we propose the construction of a mat that will indicate where to place each cup, whether each cup has the correct amount of liquid, and whether a cup was successfully hit by the opposing team. In addition, our design will indicate to players the current score, whose turn it is to throw, and how many games each team has won. This mat is intended to be placed upon a 6' folding table, the typical surface used for a game of beer pong. In addition, this mat is intended to be portable, so that users can bring it wherever they feel a game of pong must be played.

The placement of cups will be indicated through the use of LED rings, which will also light different colors to indicate whether the correct amount of liquid is in each cup. In order for our mat to sense whether a cup has the correct amount of liquid, we will use pressure sensors placed under the cups. Indentations in the mat will ensure that the cups are placed where they are supposed to be. A mini LCD screen on each side of the mat will display to both teams the score, wins, and whose turn it is.

Think of our solution as being to beer pong what a robot plate umpire is to baseball. By regulating the game through the use of technology, we eliminate the possibility of human error and ensure a fair game for all players. Figures 1, 2, and 3 are visual aids demonstrating the layout of our design and how we intend it to be used.

1.3 Visual Aid

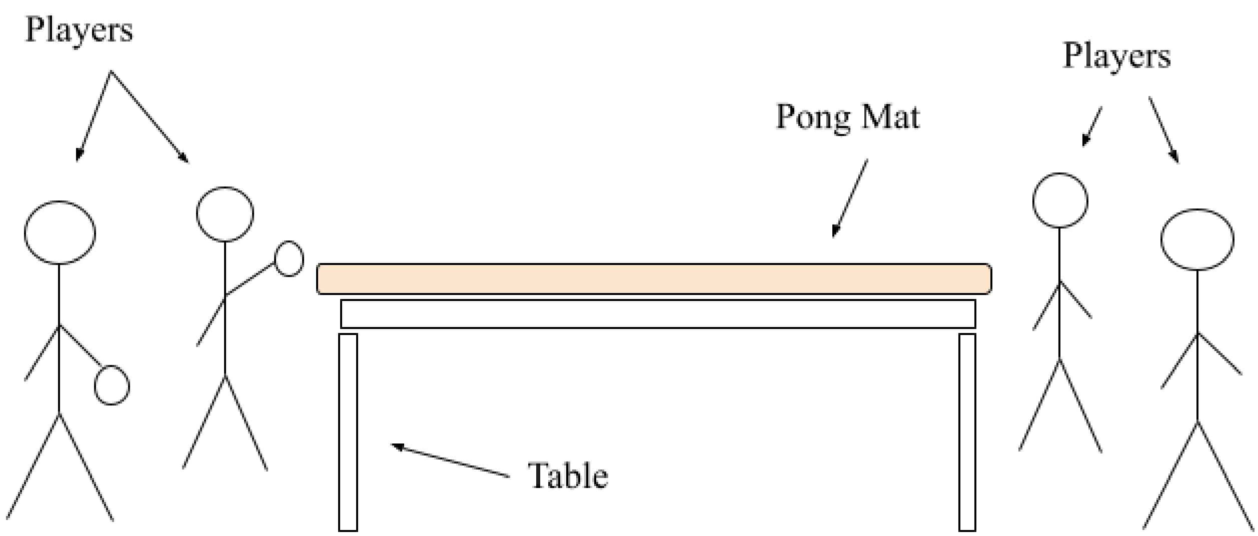

Figure 1

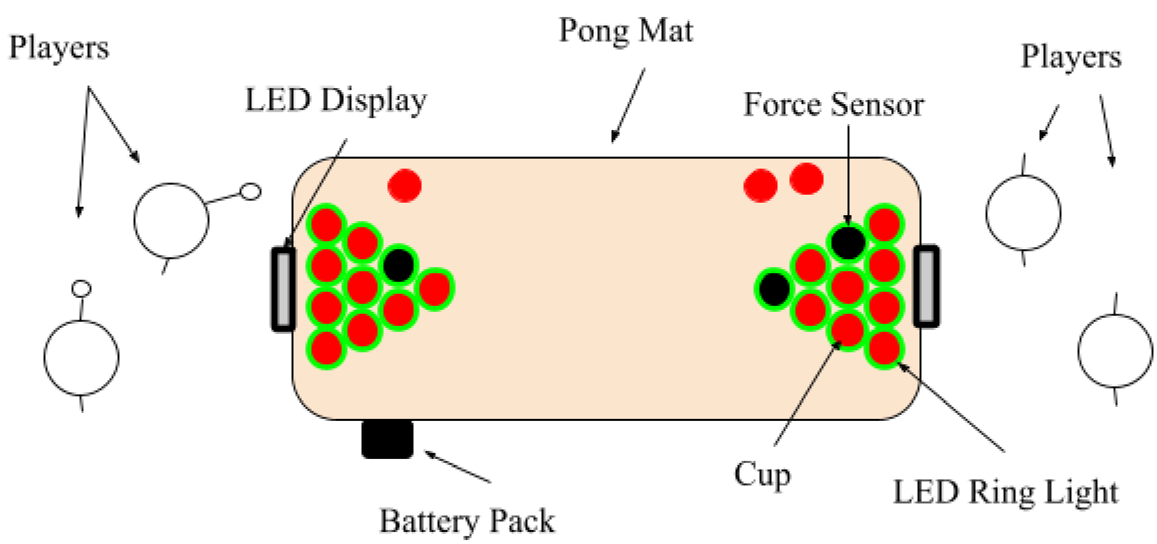

Figure 2

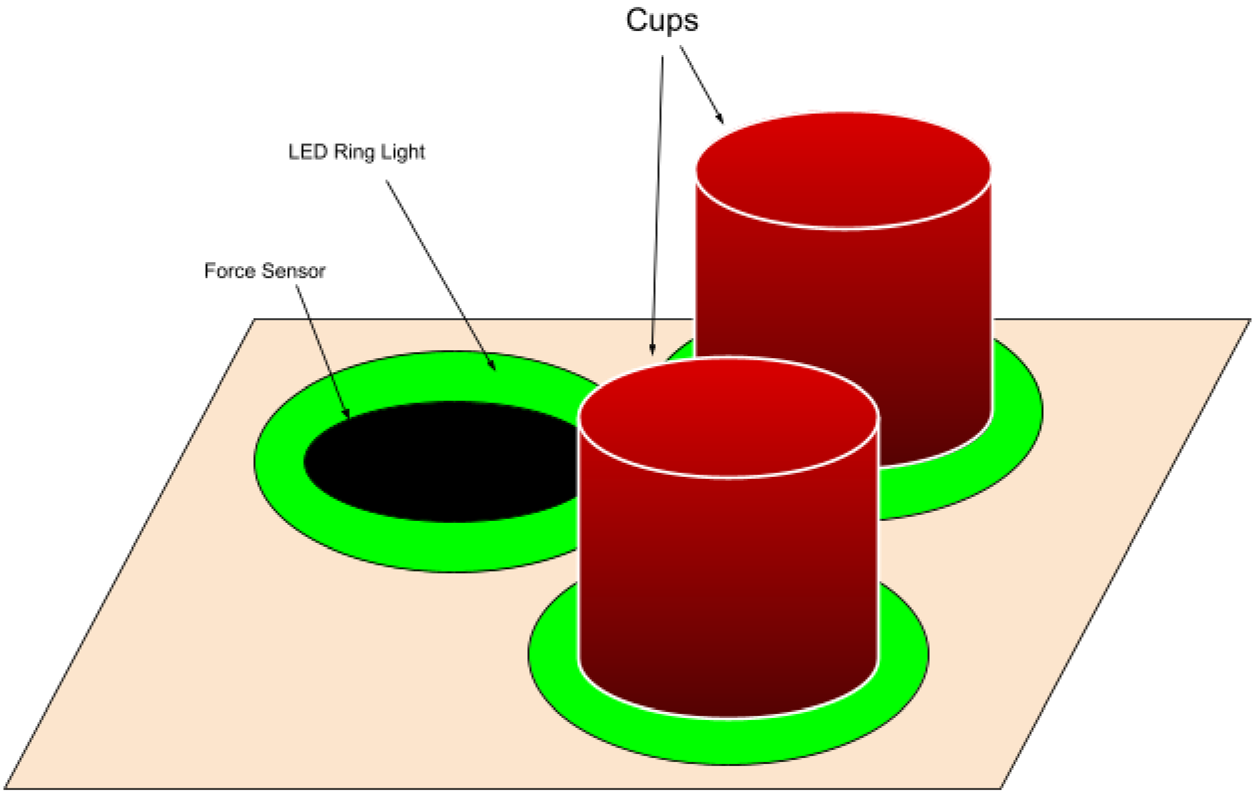

Figure 3

Figure 1 is a side profile of our pong mat, and shows four players engaging in a game of beer pong and using our mat. Figure 2 gives a bird's eye view of the mat, and shows the general layout of the mat, including the location of the twenty cups, LEDs, and force sensors, as well as the scorekeeping displays and the power subsystem. The cups off to the side of the table are those that have already been hit by the opposing team. In Figure 3 we see a close up side view of the cup sensors. Each cup sensor subsystem consists of an indentation in the mat that indicates where the cup is to be placed, a force sensor to detect if the correct amount of water is in each cup and to detect when a cup has been hit, a ring light to indicate whether a cup has the correct amount of water and whether it has been hit, and the cup itself. Each subsystem will also send data to the display screens on each side for scorekeeping purposes.

1.4 High Level Requirements

The three main characteristics we feel our design must exhibit in order to successfully solve the problems stated are as follows:

- **Portable:** One of the most appealing aspects of beer pong is its ability to be played wherever there are cups and balls. Our design should be portable enough to follow even the most adventurous ponger to wherever his or her chosen playing location may be. Portability is a hard characteristic to define in exact terms, but for our design to successfully solve the stated problems it should at the least be in some way reducible in size from its laid out, playable form, whether through folding, rolling, or some other method.
- **Accurate:** There's no point in using a mat to determine proper placement and volume if said mat can't do so accurately. Our design must incorporate tight tolerances to ensure the proper placement and filling of cups, or else it will merely reinforce the problem that it is supposed to solve. Traditionally, each cup is filled to be about ⅓ full of beer. Our design dimensions assume the user is playing with traditional 16 fl. oz. Solo Cups, which have a weight when empty of approximately 12 grams. Taking the average density of beer to be 1.050 g/cm^3 [1], this means that each cup will need to weigh approximately 178 grams when filled (12 grams + (1.050 g/cm^3 x 29.5735 cm^3 / fl. oz. x 16 fl. oz. x ⅓)). While each cup should contain roughly the same amount of beer, users will not want to waste time trying to pour exactly the right amount of beer into each cup; therefore, our design will "approve" cups be between ¼ full and ½ full, which leads to an acceptable weight range of 137 g to 250 g. Through the use of force sensors (discussed further in Section 2.2) our mat should be able to sense differences in weight down to the gram to ensure accurate measurement of cups.
- **Intuitive:** Players need to be able to focus on perfecting their shot or defending against bounces, not figuring out how to operate the mat. Our design needs to be extremely simple for users in order to improve the game of beer pong and not serve as an anchor on the boat of fun. Like

portability, intuitiveness is not a quality to which exact quantitative constraints can be given, so our main goal is to minimize the number of buttons on the user interface as well as the number of button presses needed to begin a game, so that anyone can learn to use the mat in a matter of minutes.

2. Design

2.1 Block Diagram

A block diagram of our design is shown below in figure 4. Our overall system is made up of four subsystems: Power, Control, UI, and Cup Sensors.

- The power subsystem consists of a 5V battery that supplies DC power to each subsystem, as well as a voltage regulator.
- The control subsystem consists mainly of our microcontroller chip. This subsystem is the brain of our design, and is in charge of reading the pressure sensors to ensure cups are properly filled, turning the LEDs on/off and changing their color, using input from the buttons to begin and reset games, and updating the LCD display.
- The overall Cup Sensor subsystem consists of twenty cup sensors, ten on each side of the table. Each individual cup sensor consists of a pressure sensor used to determine the weight of the cup and an LED ring used to indicate to the user whether a cup is at the proper weight.
- The overall UI subsystem consists of the two LCD displays, one on each side of the table, which display the score of the current game as well as the overall win count to each user, and the two buttons that are used by the user to start the game and restart the game.

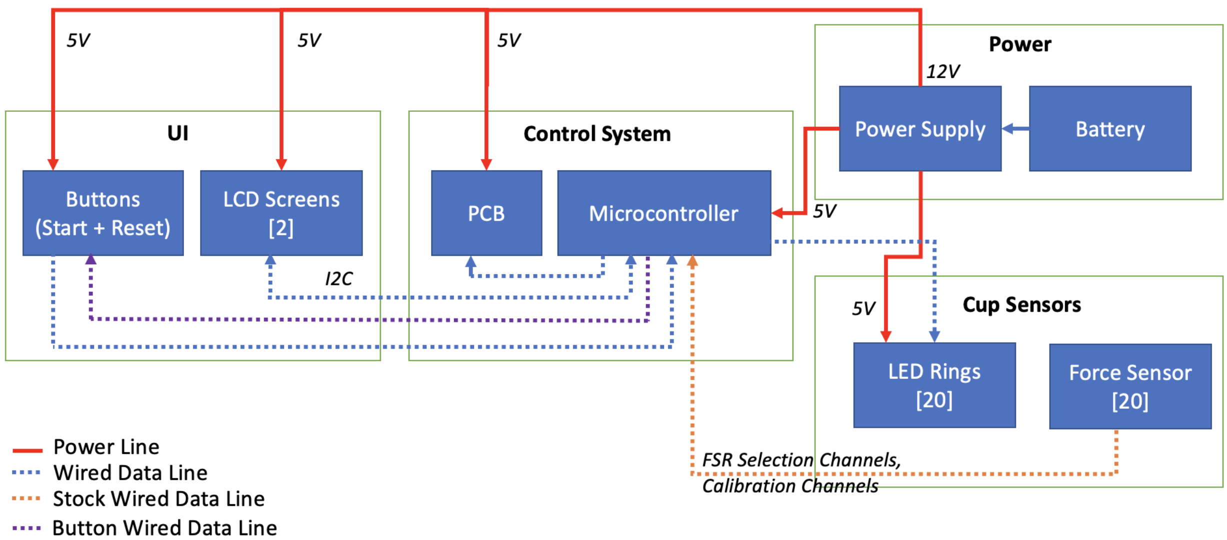

Figure 4

2.2 Subsystem 1 – Cup Sensors

Each cup sensor consists of a force sensitive resistor (FSR) and an LED ring. The FSRs are used as weight sensors to determine whether a cup is filled with the proper amount of liquid. This is done using a voltage divider circuit, as shown in Figure 5. Each FSR will have one pin tied to ground and the other tied to a resistor of constant resistance that is connected on the other side to the positive power supply. The voltage in between the FSR and fixed resistor will be connected to an analog read pin on the microcontroller. When a cup is placed on the FSR, its resistance will go down, thus increasing the voltage drop across it, decreasing the voltage drop across the fixed resistor, and changing the voltage read by the microcontroller. It is in this way that the microcontroller will be able to know when the weight of the cup changes, and through careful tuning, we can determine a voltage range that corresponds to the acceptable weight range of the cup. The force sensitive resistors are passive components,and therefore do not require a dedicated connection to the power subsystem.

The LED rings, on the other hand, are active components, and each one must be connected directly to the power subsystem (see Figure 6). In addition to these two connections, each LED will also be connected to a digital output pin on the microcontroller (see Figure 7) that can feed it serial data and tell it when to turn on/off and what color to turn to. A program written to the microcontroller will effectively read the weight of each pressure sensor through the use of the aforementioned voltage divider circuits and, using this information, tell the LED what to do. When a cup is within the acceptable weight range, the corresponding LED ring will shine green; otherwise, it will shine red.

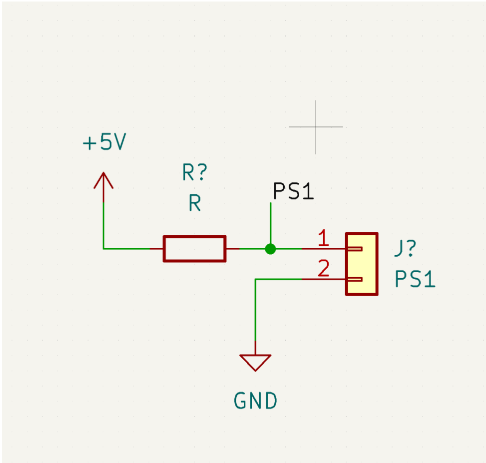

Figure 5

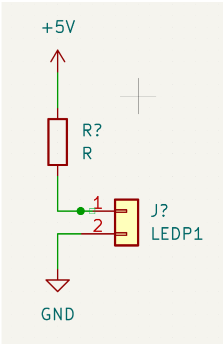

Figure 6

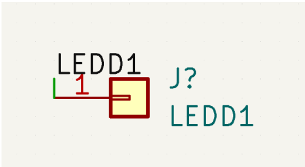

Figure 7

Requirements - Force Sensors	**Verification**
The force sensors need to ensure that small changes in weight can be detected due to a corresponding change in resistance and cause an onset of FSR response. Break Force Range is within 20g - 100 g Force Resolution is > 0.5% full scale	• Connect the two tabs of the force sensitive resistors to a multimeter in a resistance-measure mode • Vary the range of weights on the force sensor ranging from small changes (~ 5 - 10 g) to significant changes (~ 50 g <) • Graph resistance v weight based on the data table created, and analyze the sensitivity of the force sensor
The force sensors shouldn't essentially change the values of the LED i.e. the range of determining resistances/weights should be well defined when there is no significant change in the weight of the water in the cups Range of weights based on level of water: 182g - 132g	• Connect the force sensor to the microcontroller • Vary the range of weights on the force sensor ranging from small changes (~ 5 - 10 g) to significant changes (~ 50 g <) • Based on the following changes in weight, experiment and identify the point when the LED values change based on a predetermined range
The force sensors should be durable in high temperatures since each force sensor is next to a	• Connect the two tabs of the force sensitive resistors to a multimeter in a

heat emitting LED ring light (60W)	resistance-measure mode ● Turn the LED rings on while keeping them close to the force sensitive resistors ● Graph the resistance obtained by force sensitive resistor over a period of time and analyze any changes

Requirements - LED Rings	**Verification**
The LED rings need DC Voltage of 5V to draw a current of 1.44A to be powered on	● Connect the LED Rings in parallel to a 5V power source and in series to a multimeter in a diode mode ● When a voltage of 5V is supplied to the LED rings, detect if the LEDs turn on and measure the current required by each LED ● Additionally, measure the current and voltage used by all the LED rings to differentiate the varying brightness of the LED rings
The power consumption for the 20 LED rings should be atleast ~0.36A such that all the LEDs can be lit up synchronously	● Connect the LED Rings in parallel to a 5V power source and in series to a multimeter in a diode mode ● When a voltage of 5V is supplied to the

	LED rings, detect the total current drawn by the LED rings ● Measure the current and voltage used by all the LED rings to calculate the power consumption, compare the power consumption used with the brightness required for the project ● Compare the power consumption characteristics with different colors based on varying levels of current
The LED rings should remain off until the weight drops below a certain level turning it on	● Connect the LED Rings in parallel to a 5V power source and to a microcontroller ● Vary the range of weights on the force sensor ranging from small changes (~ 5 - 10 g) to significant changes (~ 50 g <) ● Based on the following changes in weight, experiment and identify the point when the LED values change based on a predetermined range

2.3 Subsystem 2 - UI (Buttons & LCD)

The UI involves the LCD screen that displays the score of each team and the current/next player alongside 2 buttons - Reset and Stop. The LCD screen is power supplied 5V and connected to the microcontroller which decides the characters (max: 32) printed, and updates the variables score and player number respectively. The component of the LCD screen is connected to the potentiometer which provides the contrast resolution of the blue background and white characters. On the other hand, the buttons Reset and Stop are connected alongside the LCD screen. The button Reset restarts the values to default values i.e. player 1 and score 0. The button Stop stops the values from getting updated and ends the game. The buttons are connected to the microcontroller and power supplied by 5V.

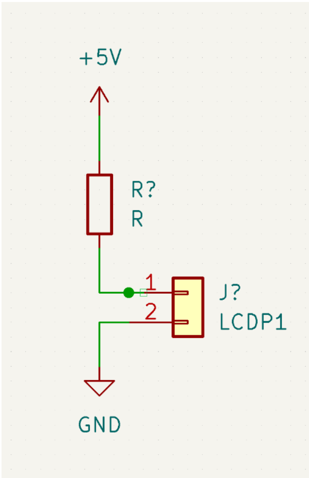

Figure 8

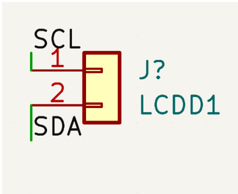

Figure 9

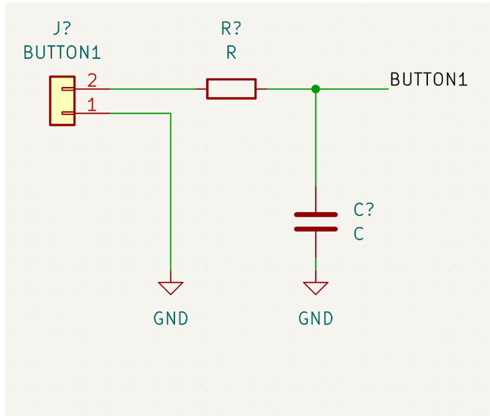

Figure 10

Requirements - LCD Screen	**Verification**
The LCD Screen needs DC Voltage of 5V to be powered on	• Connect the LCD Screen to a 5V power source and in series to a multimeter in a diode mode • When a voltage of 5V is supplied to the LCD Screen, detect if the LCD Screen turns on with characters being visually displayed
The LCD Screen should have an appropriate resolution and high contrast ratio such that words can be easily visible	• Connect the LCD Screen to the
The LCD screen should be able to display words	• Connect the LCD Screen to a 5V power

and counts on the screen	source and microcontroller ● Control the microcontroller such that words can be pushed out to the LCD screen ● Record the boolean value for the data values been printed to the LCD as read from the microcontroller using serial debugging ● Detect if the words are visible on the LCD screen with a high contrast ratio ● Ensure that the maximum number of characters that need to be displayed at a time is 32 through the recording of a boolean variable from the microcontroller
The refresh rate of the LCD screen is high such that the words and counts get updated after every frame with reduced delays	● Connect the LCD Screen to a 5V power source and microcontroller ● Control the microcontroller such that words can be pushed out to the LCD screen ● Detect if the words are visible on the LCD screen with a high contrast ratio ● Calculate the time taken for the words and counts to get updated after a frame or a player move

The LCD screen should be able to update to 0 when Reset button is pressed and stop updating once the Stop button is pressed	• Connect the LCD Screen to a 5V power source and microcontroller • Press the Reset button and detect if the words and counts on the LCD screen return a default value. A boolean variable can be used to test this through the microcontroller • Press the Stop button and detect if the words and counts on the LCD screen change when there's a move made by the player. A boolean variable can be used to test this through the microcontroller

Requirements - Buttons	**Verification**
Ensure that pressing the buttons affect the values showcased by the LCD screen	• Connect the LCD Screen and buttons to a 5V power source and microcontroller • Press the Reset button and detect if the words and counts on the LCD screen return a default value. A boolean variable can be used to test this through the microcontroller • Press the Stop button and detect if the words and counts on the LCD screen change when there's a move made by the

	player. A boolean variable can be used to test this through the microcontroller

2.4 Subsystem 3 – Control

The control system is the headquarters of our project. We need to make sure everything goes smoothly. Our PCB will need to connect everything together, whereas our microcontroller will take in data from various sources and send outputs to the user interface parts. The control system will need to work fast, so we need speeds over 8 MIPS. Keeping track of data can be done in the memory section of our microcontroller. The force sensors act as the data provider, and once the data is received, we then send signals from the microcontroller to LEDs and the LCD display to act as our UI.

Requirements - Control	**Verification**
The control system needs to have low latency rate to ensure quick syncing of the components	• Connect the control system to all the components, the power supplied is 12V • Test the code written to the microcontroller by comparing and shifting the weights of the cups, getting a ball in a cup/ removing the cup, etc. • Detect and record if the data transfer is quick by the measuring the time taken for turning on/off of the LEDs and the

	responsiveness of the LCD screen
The control system must ensure that the current state of the components (LCD, LEDs) remain consistent unless changed	• Connect the control system to all the components, the power supplied is 12V • Test the code written to the microcontroller by comparing and shifting the weights of the cups, getting a ball in a cup/ removing the cup, etc. • Detect and record if the LEDs remain off unless a significant amount of weight has been shifted, and on until the weight has returned to the default value. • Detect and record if the LCD screen showcases the same values when there is no player movement, the reset or stop button has not been pressed

2.5 Subsystem 4 – Power

The power subsystem is the foundation of our project. Without power, we would not be able to run any other sub system. The power will be coming from a 12V battery in which we connect with our PCB which then delivers that power elsewhere in our project. Being the foundation, it is crucial that we supply enough power to our project in order to get everything to run smoothly, for example if we supply too little power, the LEDs will not be bright enough to give the user any feedback. In figure 11 below we show how the power is provided to the system.

Requirements - Power	**Verification**
The battery needs to supply a DC Voltage of 12V to the numerous components	• Connect the battery in parallel to a voltmeter • Identify the value obtained by the voltmeter and compare it to ~12V to ensure that the voltage is sufficient for the circuit

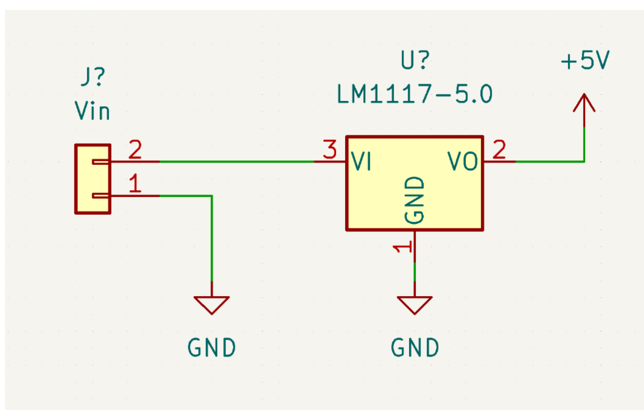

Figure 11

3. Tolerance Analysis

One of the main components of our design relies on a force sensitive resistor. After conducting research on the resistor's documentation, we have found that it has a tolerance of ±5% to ±25. This part also has a 100 gram to 10 kilogram sensitivity, and as described in another section of this document, we know that each sensor should weigh about 178 grams which is enough for this sensor. Figure 12 below shows how the conductance versus force, and the resistance returned from the sensor.

The second main component that is critical to the success of our project are the ring LEDs. For our usage of ring LEDs, they can tolerate a voltage range of 3.5V to 5.5V for power supply (VDD), and -0.5V to 0.5V for logic input (Vin). Each RGB chip characteristic also has its own power supply for working voltage, which we need to keep in mind when passing voltage through the LEDs. In figure 13 below, we can see a graph with emission distribution and different wavelengths shown at their respective emission percentage. For the LEDs we need to ensure that we maximize the voltage through it without going over the upper limit so we can get the maximum effect of the LEDs. These LEDs have a typical speed of 800 Khz which is fast enough for us to use to ensure that we can keep synchronicity among all the LEDs.

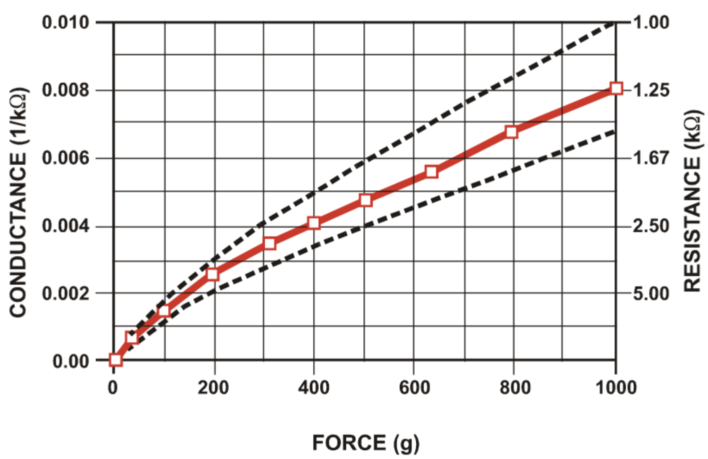

Figure 12: Conductance vs. Force [4]

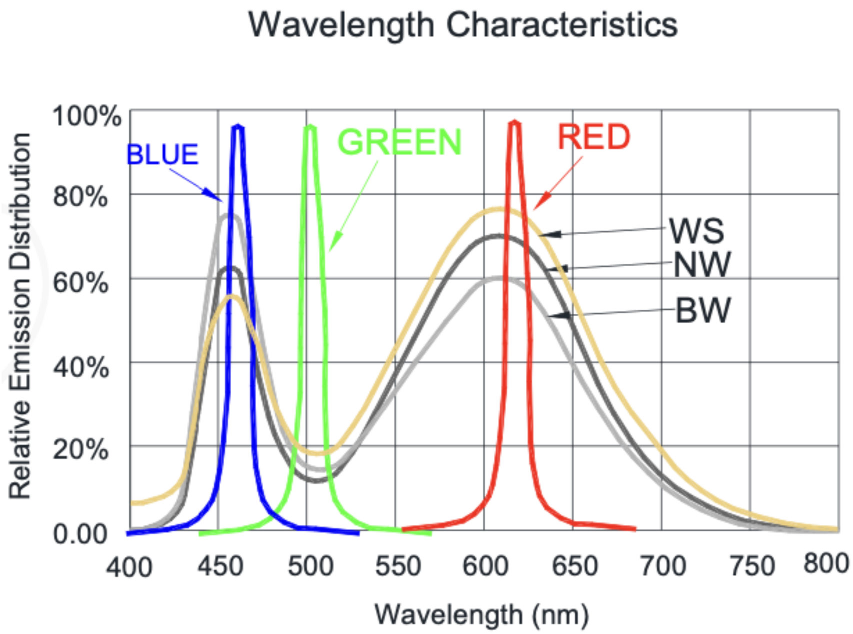

Figure 13: Wavelength Characteristics [5]

4. Cost and Schedule

4.1 Cost Analysis

On average, UIUC ECE graduates make $92,500 out of college. Assuming a 40 hour work week, and taking into account vacation and sick days, this averages out to about $47.20 an hour, which is the number we will use to calculate labor costs for the three members of the team. We expect to spend 10 hours per week each working on this project, and with 10 weeks left until our final presentation, our labor costs are estimated to be $14160 (3 people x $47.20 an hour x 10 hours / week x 10 weeks).

The below table lists all the parts that will be used in this project, as well as their quantity, unit cost, and total cost.

Component	Manufacturer	Quantity	Unit Cost	Total Cost
WS2812B 24-bit	DIYmall	20	$4.80	$96.00

Ring LEDs				
Thin Film Force Sensing Resistors	Walfront	20	$4.14	$82.70
I2C 1602 LCD Display Module	GeeekPi	2	$5.50	$11.00
R7FS3A77C3A01 CNB MCU	Renesas Electronics	1	$16.18	$16.18
1 uF Capacitors	Murata Electronics	10	$0.032	$0.32
10 kOhm Surface Mount Resistors	Vishay/Dale	30	$0.029	$0.87
Push Buttons	Weideer	5	$1.80	$8.99

The total cost of all parts is $216.06. When added to the previously calculated labor cost, this puts the total estimated cost for our project at $14376.06.

4.2 Schedule

Notable Dates	Major Deadlines	Keith	Spencer	Nishita
Feb. 28	PCB Board Reviews	Component Research & KiCad design	Component Research & KiCad design	Component Research & KiCad design

Feb. 29	Design Review	Design Document Revisions & Order Parts	KiCad Design for PCBs	Design Document Revisions
Mar. 7	First Round of PCBway Orders	Final Touches on PCB Design	Final Touches on PCB Design	Final Touches on PCB Design
Mar. 8 - Mar. 11	Building	Soldering	Soldering	Software Research & Begin Framework for use of components
Mar. 12 - Mar. 21	Spring Break	Having Fun!	Having Fun!	Having Fun!
Mar. 20 - Mar. 28	Testing	Software design for individual components & User flow designing	Hardware to Software integration	Software design for individual components & test environment for testing programmable components
Mar. 28	Second Round PCBway Orders	KiCad Design & Software improvements	KiCad Design	KiCad Design & Software improvements

Mar. 29 - Apr. 4	Building	Soldering & component wiring	Soldering & component wiring	Software Improvements & Component wiring
Apr. 5 - Apr. 17	Testing	Software & user flow improvements & hardware fixes	Hardware design fixes & component integration	Software improvements & hardware to software component integration
Apr. 18	Mock Project Demo	Prepare slideshow deck & Begin final paper framework	Prepare slideshow deck & Begin final paper framework	Prepare slideshow deck & Begin final paper framework
Apr. 24 - Apr. 26	Final Demo	Final touches on preparation for final demo	Final touches on preparation for final demo	Final touches on preparation for final demo
May 1 - May 3	Final Presentation & Papers	Final Demo! & Final Paper Edits	Final Demo! & Final Paper Edits	Final Demo! & Final Paper Edits

5. Ethical Concerns

Our team does not foresee any ethical issues arising during the development of our project, seeing as all necessary testing can be done in a safe and harmless manner. The main ethical concern we have is the fact that our project, being an accessory for a game commonly played with alcohol, may encourage unhealthy and unsafe drinking habits, which would be in direct contradiction to our duty as engineers to ensure the good health and safety of the users of our project and in conflict with Section I.1 of the IEEE Code of Ethics [2] as well as 1.2 of the ACM Code Of Ethics [3]. However, considering the widespread popularity of the game of beer pong, we do not believe that our project will be introducing anyone to this game and perhaps by extension binge drinking. Theoretically, if our product was mass produced, we would include with it a disclaimer stating that the creators do not encourage binge drinking, as well as a warning detailing the harmful effects of binge drinking and the danger of alcohol poisoning. We do not want to encourage unhealthy drinking habits of any sort – rather, we hope with this project to help streamline an already immensely popular game that can be played in a safe and controlled manner.

In addition, we as a team will need to work to ensure that our project is completed in an ethical manner with regards to plagiarism that complies with section 1.5 of the IEEE Code of Ethics [2]. Given that this project will likely involve a significant amount of research, our team will have to take care to ensure credit is given where it is due and that all sources used are included in our reports and properly cited.

6. Safety Concerns

We have no concerns regarding mechanical or lab safety. The one safety concern that we will need to address is the fact that beer pong is a game played with liquids, and that cups full of liquid will by design be in close proximity to our project and therefore to electrical components. Due to the low voltage requirements of this project, this does not pose any extreme danger, but it will need to be addressed in order to prevent the destruction of our product and/or minor injuries to the user. This issue can easily be remedied through the use of protective encasing for sensitive electronics. The pressure sensors will be covered with a thin waterproof material that keeps water out while also not interfering with the pressure readings of the sensor. The LED ring lights will also need to be covered in a manner that protects them from water while not interfering with their ability to be seen. The main microcontroller and power units encasings do not have special requirements apart from being waterproof, as the user will not actively interact with these units.

7. Citations

[1] Manning, Martin, P. "Understanding Specific Gravity and Extract. Brewing Techniques." *Brewers Market Guide*. September 1993.

[2] “IEEE Code of Ethics,” *IEEE*. [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: 17-Feb-2023].

[3] “ACM Code of Ethics and Professional Conduct” *Code of Ethics*. [Online]. Available: https://www.acm.org/about-acm/acm-code-of-ethics-and-professional-conduct. [Accessed: 17-Feb-2023].