No Chips? No Problem. - Poker 2.0

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Contents

1 Introduction

1.1 Objective

Everyone plays games. One of the most common games people play are card games. One of the reasons card games are so popular is due to the simplicity of the materials needed as players only need a deck of cards to play. One of the most popular card games people play is poker. Poker is not only the most popular card game in the world, but it is also the most commonly referenced card game [1]. Different variants exist for the game of poker with the most common one being Texas Hold'em [2]. Texas Hold'em consists of 2-10 players with each player being dealt two cards each laying face-down [2]. The dealer (the person controlling and handling the deck of cards) then lays three cards on the table face-up [2]. From there, players going counter clockwise from the dealer begin their turn [2]. On a player's turn, he/she has an option of either checking, calling, folding, or raising [2]. After each rotation, the dealer lays another card face-up until there is a total of 5 cards face-up [2]. The entire round of poker ends with the player having the highest hand shown or only one player is remaining if the only players have folded [2]. The winner receives the pot. Poker has slowly evolved from being a physical, in-person card game to being played online with players facing off from around the globe. Las Vegas, one of the world's biggest casino epicenters, earned up to $8 million dollars in revenue from poker rooms in a single month [3]. While the popularity and demand for poker is undeniable, it is one of the rare card games that requires more material than a deck of cards. Specifically, to play a game of poker players need plastic coins called "poker chips". These "poker chips" indicate the amount of money each player is waging based on the color and label of the chip. The plastic coins are an integral part of the game as it entices players with the chance of winning money. However, not everyone has these plastic coins already in his/her possession, and those who do, may not have enough to go around based on the number of people wanting to play. This problem causes people to rely on going to business and corporations that supply the necessary materials. It would be nice to have a solution that simulates the game of poker that does not limit the amount of players wanting to play as well as those who may or may not have poker chips. A similar problem was proposed by Team 62 in Spring 2019 with their "Electronic Betting System for Poker" [10]. While we have used their project as an influence, we present an entirely different solution that we believe offers more versatility and further resolves other issues.

The goal of our project is to develop and implement a solution that is able to simulate a game of poker without limiting the number of players wanting to play and have the game be playable with people who have poker chips as well as those without poker chips. Additionally, we want to maintain the key components of poker like face-to-face interaction because it is important to see players' faces to see if they are bluffing or not. To solve these issues, we plan to create a main console unit which users access through mobile devices via Wifi. The main console unit allows players to insert poker chips into it, and the console senses how much each chip is worth based on color. We will utilize motors to funnel incoming inserted chips and sensors to detect them. If physical chips are used, the winner of each round collects his/her winnings from a pull-out tub located inside the control unit. Additionally, an LCD display will be mounted onto the control unit so every player can follow along together. The main console maintains its own website, and the number of devices which connect to it indicate how many players are currently playing, solving the issue of only a limited number of players being able to play the game at one time. The website will also indicate if electronic poker chips will be used or if the control unit senses no physical poker chips inserted. The interface will also provide players a display that allows them to call, check, raise, and fold as well as see the amount of money they currently have. Both components together will solve the issues previously mentioned to ensure our project solution adequately solves the proposed problem.

1.2 Background

We believe our proposed problem is worth solving as the game of poker is undeniably popular around the world, and we believe every person should be given the chance to play with as few limitations as possible. From the data shown in the previous section, we can safely say this problem is worth pursuing. Additionally, a couple of team members have had first-hand experience playing poker, so there is a personal connection to the problem itself.

Our design solution provides a more versatile and reliable product than Team 62's solution. WiFi connectivity is much more reliable than using RFID as RFID requires more readers to provide better accuracy [4]. More readers results in higher costs for the RFID infrastructure. Additionally, RFID can easily be interfered with by other RF signals as well as WiFi access points and since most households have a WiFi system in place it seems redundant to have a product require a completely different system to be installed. Within their final report, Team 62 did note how RFID was easily interferrable and unreliable suggesting in future designs a more reliable should be implemented [10]. Our design offers more versatility by allowing consumers to use our product if they have poker chips and if they do not have poker chips. Team 62's project, on the other hand, is not designed with the use of physical chips in mind. Furthermore, their solution also incorporates remotes for players to use to play, which limits the number of players to the number of remotes available. Using a website that can be connectable through mobile devices and/or laptops removes that limitation as players will only need to have a smartphone which, in today's society, most people already have.

On the market, there are a few existing solutions that attempt to solve our problem, but none that directly eliminate the problem entirely. One of these solutions that is commonly found is simulated poker online through mobile applications. There are a ton of online poker applications scattered throughout the app store. However, most of these online poker mobile applications remove the element of face-to-face interaction, which is a key component many players use to tell if other players are bluffing or not. There is one mobile application called Bold Poker that still gives players face-to-face interaction. Bold Poker simulates the table, dealer, cards, and poker chips on an iPad, while players can join in together through their mobile devices [4]. While this product does eliminate the issue of limiting the number of people wanting to play, it does not take into account those consumers who have poker chips already in their possession. Additionally, Bold Poker requires a 5 minute delay every 30 minutes calling it a “cigarette break” which can be very annoying and cumbersome [5]. To remove this “cigarette break” players have the option of paying $4.99 to unlock “uninterrupted” mode [5]. Bold Poker also requires players to have an iPad to simulate the poker table. No Android or other tablet can be used. This requirement severely limits the audience scope of this product as an iPad is not cheap and has a price tag northward of $300. Other solutions aimed to solve our design problem consist of building entire apparatuses to mimic a casino poker table or electronic slot machine. It should be noted that both these designs are currently patented, but have yet to reach the public as an eligible product. The casino poker table suggests the solution should consist of a full embodiment of a poker table with an electronic dealing system [6]. This solution still contains a limit on the number of players able to play with only six seats available. Additionally, this solution is only feasible for businesses and corporations who have the space and money to purchase such a product. The electronic slot machine has the same issues. The size of the machine makes it only feasible to business and corporations [7]. This slot machine also does not take into account physical poker chips, but rather makes everything electronic [7]. While there are solutions existing in the market or making their way to it, none of them provide direct solutions to the problem we are trying to directly solve. Problems like setting a limit on the numbers of players capable of playing and giving players the option of still playing poker despite not having physical poker chips are just some of the issues that still linger today. Our project solution aims to tackle and solve each of those issues as well as make it feasible to everyone.

1.3 Visual Aid

Figure 1 shows two diagrams of our console. The inside view displays internal components and measurements that a user would not normally see. The outside view shows what the product would look like when a player is using it.

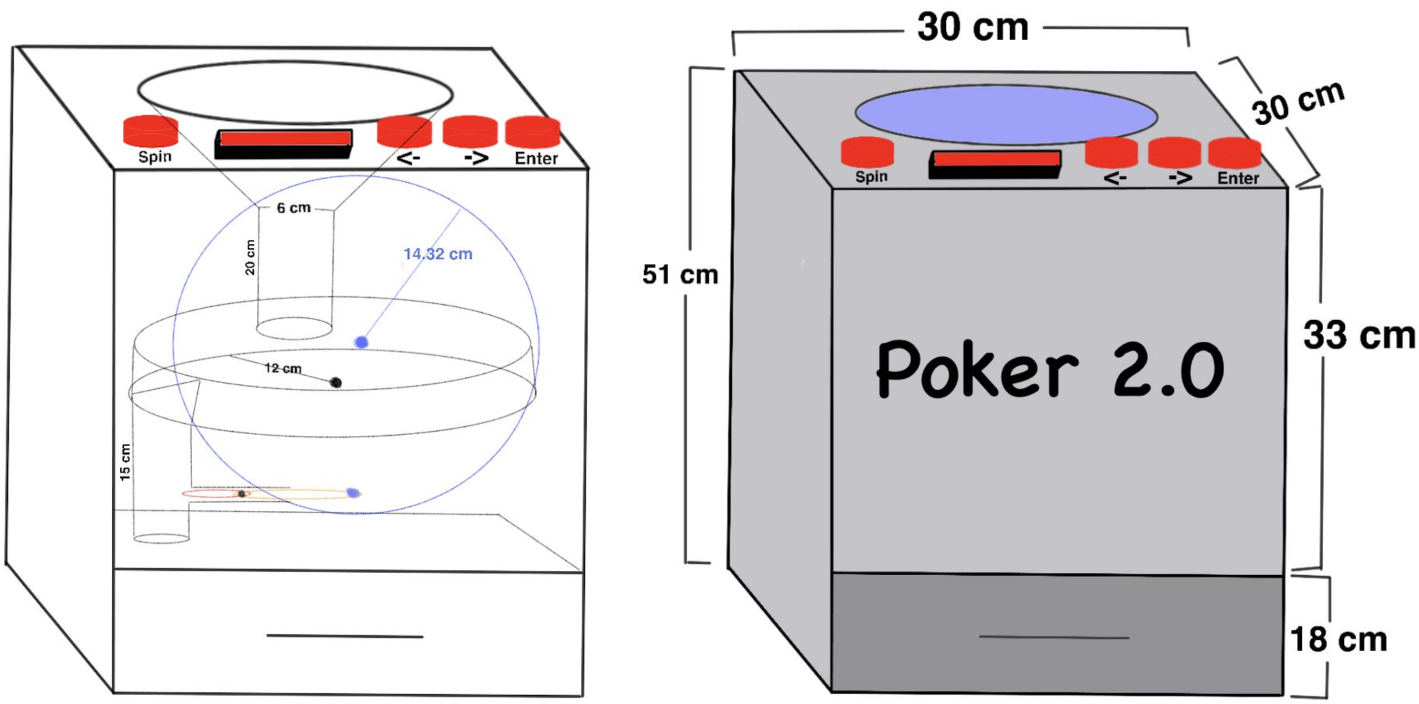

Figure 1. Inside view of console (left) and outside view of console (right).

1.4 High-Level Requirements List

- The entire system, main unit and website, correctly performs all functions of a poker game, specifically Texas Hold'em, without the use of physical poker chips.
- The poker chip detector must have greater than 95% accuracy in correctly determining the quantity and color (blue, black, green, red, or white) of chips inserted into the console during a person's turn.
- The console must be able to successfully handle requests from external devices for the "game dashboard" (an HTML file displaying players' money totals, whose turn it is, and options to buy in, check, call, raise, and fold) 70% of the time.

2 Design

The overall functionality of the entire system depends largely on one machine: the main console. Inside this machine, there are six subsystems: a power supply circuit, a motor driving circuit, a poker chip detector, a microcontroller unit, a Wifi module, and a user interface module. The console needs the power supply circuit to supply electrical power to all necessary electrical components. The motor driving circuit sends poker chips through the console, and the poker chip detector determines the quantity and color of chips passing by. During gameplay, the user interface module takes in input from buttons and outputs visual cues and feedback to an LCD display. As the game progresses, the Wifi module communicates with external devices, taking in gameplay actions (folding, raising, etc.) and sending out game information as requested. And finally, the microcontroller manages game state data, sensor readings from the poker chip detector, communication via the Wifi module, and I/O to/from the user interface module.

2.1 Block Diagram

Figure 2 shows how all of these modules physically connect with one another as well as how the console communicates with other devices on the wireless network (that is, through a router).

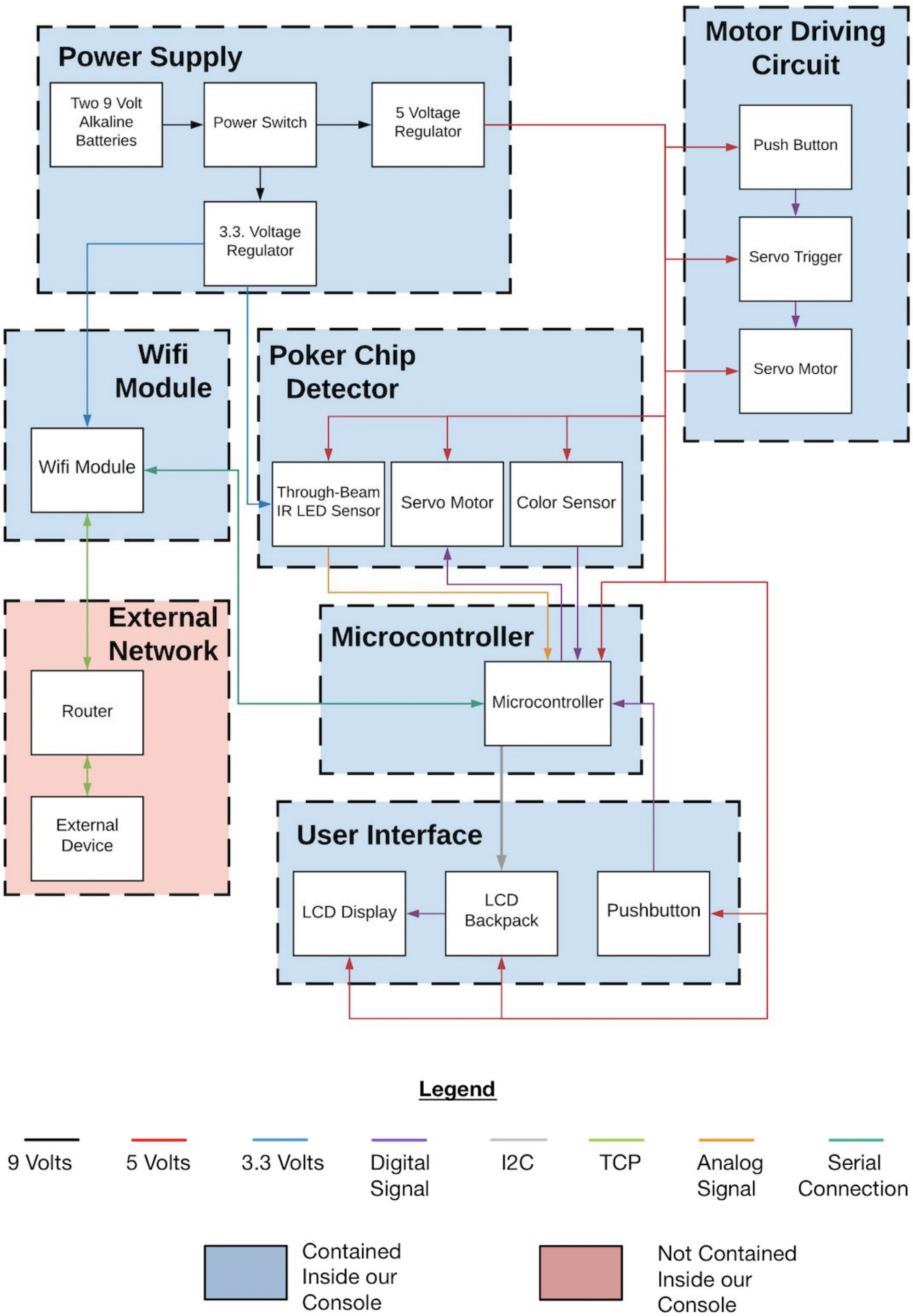

Figure 2. Block diagram.

2.2 Power Supply

Every single component in Figure 1 needs some kind of electrical power to operate. With this being said, in order for the console to function correctly, it needs a steady, reliable power supply. The components used in the power supply for this machine are a 5 V switching regulator, a 3.3 V switching regulator, two 9 V alkaline batteries connected in parallel, and a power switch. Figure 3 shows the schematic for this module.

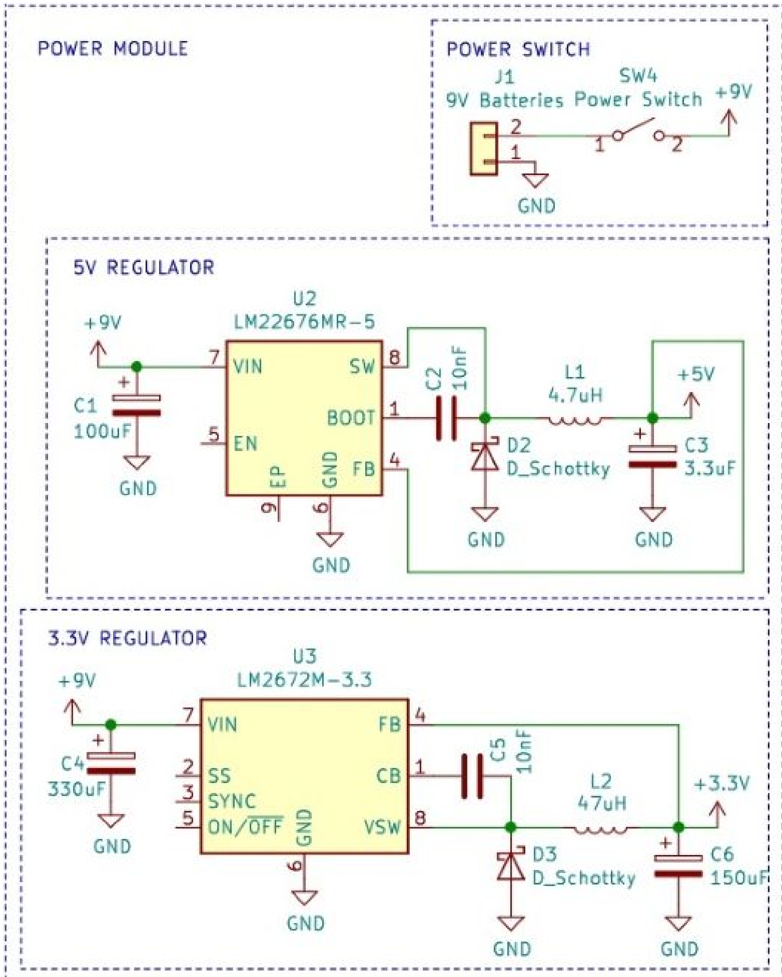

Figure 3. Console power module schematic.

2.2.1 5 V Switching Regulator

The microcontroller, servos, servo trigger, color sensor, IR sensor (part of the "Through-Beam IR LED Sensor"), pushbuttons, LCD display, and LCD backpack all use 5 V inputs. Therefore, there needs to be a regulator which ensures this voltage is available at all times. It must also be capable of outputting enough current for all of these components.

Unlike linear regulators which are very simple to operate, switching regulators—although more efficient—are more complex and require additional components. They need capacitors on the input and output to hold voltage steady, an inductor to prevent sudden surges in current on the output, a capacitor to provide gate voltage to the N-FET embedded inside the switching regulator, and a schottky diode for circuit protection. Equations (1)-(3) determine the specifications needed for the output inductor, the input capacitor, and the output capacitor, respectively, and come from the switching regulator's datasheet [11]. Overall, Table 1 describes the requirements and verifications for the 5 V switching regulator.

$$L = \frac{(V_{in} - V_{out}) \cdot V_{out}}{0.3 \cdot I_{out} \cdot F_{sw} \cdot V_{in}} = \frac{(9-5) \cdot 5}{0.3 \cdot 3 \cdot 500000 \cdot 9} \approx 4.94\ \mu H \rightarrow 4.7\ \mu H \quad (1)$$

$$C_{in} = \frac{I_{out}}{4 \cdot F_{sw} \cdot V_{ri}} = \frac{3}{4 \cdot 500000 \cdot 0.015} = 100\ \mu F \quad (2)$$

$$C_{out} = \frac{(V_{in} - V_{out}) \cdot V_{out}}{8 \cdot V_{in}} \cdot \frac{1}{F_{sw}^2 \cdot L \cdot V_{ro}} = \frac{(9-5) \cdot 5}{8 \cdot 9} \cdot \frac{1}{(500000)^2 \cdot (4.7 \times 10^{-6}) \cdot 0.1} \approx 4.7\ \mu F \quad (3)$$

Table 1. 5 V switching regulator requirements and verifications.

Requirements	Verifications
The voltage regulator must continuously supply an acceptable input voltage level for all of the following components: microcontroller (2.7 V to 5.5 V), servos (4.8 V to 6 V), servo trigger (1.8 V to 5.5 V), color sensor (2.7 V to 5.5 V), IR sensor (2.5 V to 5.5 V), pushbuttons (3 V to 5.7 V) LCD display (4.8 V to 5.2 V), and LCD backpack (2.0 V to 5.5 V). In this case, the acceptable output voltage range for the regulator is 4.8 V to 5.2 V.	A. Using an oscilloscope, construct a testing environment for the Power Supply subsystem B. Probe and check voltage of each component C. Ensure voltage tested is within requirement range for each component D. Set a timer for 10 minutes E. As timer runs, continuously check voltage of each component and ensure it is within necessary range
The voltage regulator must be able to handle the sum of the currents coming from these	A. Using an oscilloscope, construct a testing environment for the Power

Table 1. 5 V switching regulator requirements and verifications (continued).

same components. In this case, the current rating must be greater than 2.5 A.	Supply subsystem B. Probe the voltage of each component connected to the voltage regulator C. Ensure each component is still being supplied the necessary voltage specified in the requirement to ensure voltage regulator is still working

2.2.2 3.3 V Switching Regulator

Devices which use 3.3 V sources include an IR LED (part of the "Through-Beam IR LED Sensor") and the Wifi module. Just like the 5 V regulator, the 3.3 V regulator must supply enough current for both of these components. Additionally, just like the 5 V regulator, one needs to find the specifications for the inductor and capacitors used by the switching regulator found in the datasheet. In this case, however, one refers to tables and figures rather than performing calculations. Figure 4-5 and Tables 2-3 are examples of resources found in the datasheet used for this purpose [12]. One uses Figure 4 to find which region the voltage regulator will operate in. Then, using this region, one uses Table 2 to find the proper inductance for the circuit which, finally, allows one to use Table 3 and Figure 5 to find the best capacitor and voltage rating for that capacitor, respectively. With these details aside, Table 4 outlines the requirements and verifications for this module.

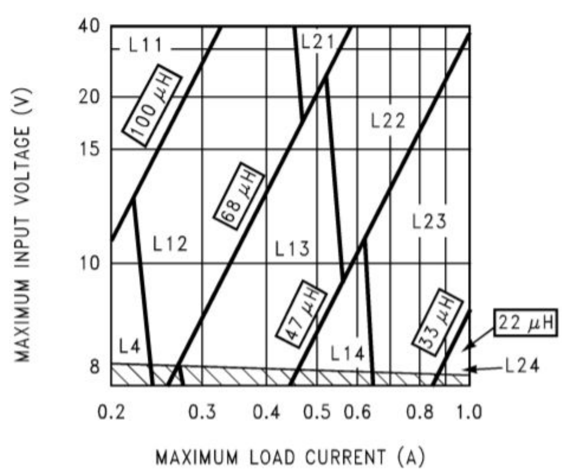

Figure 4. Inductor application curves.

Table 2. Inductor manufacturers' part numbers.

IND. REF. DESG.	INDUCTANCE (µH)	CURRENT (A)	SCHOTT		RENCO		PULSE ENGINEERING		COILCRAFT
			THROUGH HOLE	SURFACE MOUNT	THROUGH HOLE	SURFACE MOUNT	THROUGH HOLE	SURFACE MOUNT	SURFACE MOUNT
L4	68	0.32	67143940	67144310	RL-1284-68-43	RL1500-68	PE-53804	PE-53804-S	DO1608-683
L5	47	0.37	67148310	67148420	RL-1284-47-43	RL1500-47	PE-53805	PE-53805-S	DO1608-473
L6	33	0.44	67148320	67148430	RL-1284-33-43	RL1500-33	PE-53806	PE-53806-S	DO1608-333
L7	22	0.52	67148330	67148440	RL-1284-22-43	RL1500-22	PE-53807	PE-53807-S	DO1608-223
L9	220	0.32	67143960	67144330	RL-5470-3	RL1500-220	PE-53809	PE-53809-S	DO3308-224
L10	150	0.39	67143970	67144340	RL-5470-4	RL1500-150	PE-53810	PE-53810-S	DO3308-154
L11	100	0.48	67143980	67144350	RL-5470-5	RL1500-100	PE-53811	PE-53811-S	DO3308-104
L12	68	0.58	67143990	67144360	RL-5470-6	RL1500-68	PE-53812	PE-53812-S	DO3308-683
L13	47	0.70	67144000	67144380	RL-5470-7	RL1500-47	PE-53813	PE-53813-S	DO3308-473
L14	33	0.83	67148340	67148450	RL-1284-33-43	RL1500-33	PE-53814	PE-53814-S	DO3308-333
L15	22	0.99	67148350	67148460	RL-1284-22-43	RL1500-22	PE-53815	PE-53815-S	DO3308-223
L18	220	0.55	67144040	67144420	RL-5471-2	RL1500-220	PE-53818	PE-53818-S	DO3316-224
L19	150	0.66	67144050	67144430	RL-5471-3	RL1500-150	PE-53819	PE-53819-S	DO3316-154
L20	100	0.82	67144060	67144440	RL-5471-4	RL1500-100	PE-53820	PE-53820-S	DO3316-104
L21	68	0.99	67144070	67144450	RL-5471-5	RL1500-68	PE-53821	PE-53821-S	DO3316-683
L22	47	1.17	67144080	67144460	RL-5471-6	—	PE-53822	PE-53822-S	DO3316-473
L23	33	1.4	67144090	67144470	RL-5471-7	—	PE-53823	PE-53823-S	DO3316-333
L24	22	1.7	67148370	67148480	RL-1283-22-43	—	PE-53824	PE-53824-S	DO3316-223
L27	220	1	67144110	67144490	RL-5471-2	—	PE-53827	PE-53827-S	DO5022P-224
L28	150	1.2	67144120	67144500	RL-5471-3	—	PE-53828	PE-53828-S	DO5022P-154
L29	100	1.47	67144130	67144510	RL-5471-4	—	PE-53829	PE-53829-S	DO5022P-104
L30	68	1.78	67144140	67144520	RL-5471-5	—	PE-53830	PE-53830-S	DO5022P-683

Table 3. Output capacitor table.

OUTPUT VOLTAGE (V)	INDUCTANCE (µH)	OUTPUT CAPACITOR					
		SURFACE MOUNT		THROUGH HOLE			
		SPRAGUE 594D SERIES (µF/V)	AVX TPS SERIES (µF/V)	SANYO OS-CON SA SERIES (µF/V)	SANYO MV-GX SERIES (µF/V)	NICHICON PL SERIES (µF/V)	PANASONIC HFQ SERIES (µF/V)
3.3	22	120/6.3	100/10	100/10	330/35	330/35	330/35
	33	120/6.3	100/10	68/10	220/35	220/35	220/35
	47	68/10	100/10	68/10	150/35	150/35	150/35
	68	120/6.3	100/10	100/10	120/35	120/35	120/35
	100	120/6.3	100/10	100/10	120/35	120/35	120/35
	150	120/6.3	100/10	100/10	120/35	120/35	120/35

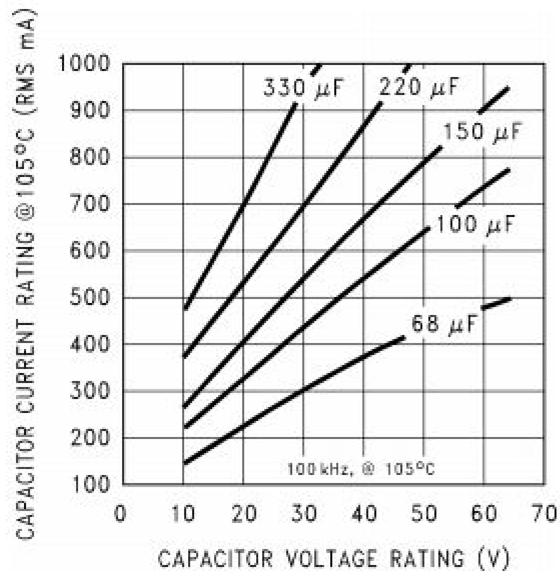

Figure 5. RMS current ratings for low ESR electrolytic capacitors (typical).

Table 4. 3.3 V switching regulator requirements and verifications.

Requirements	Verifications
The voltage regulator must continuously supply an acceptable input voltage level for all of the following components: IR LED (minimum of 1.3 V) and Wifi module (2.5 V to 3.6 V). In this case, the acceptable voltage range is 2.5 V to 3.6 V.	A. Using an oscilloscope, construct a testing environment for the Power Supply subsystem B. Probe and check voltage of each component C. Ensure voltage tested is within requirement range for each component D. Set a timer for 10 minutes E. As timer runs, continuously check voltage of each component and ensure it is within necessary range
The voltage regulator must be able to handle the sum of the currents coming from these same components. In this case, the current rating must be greater than 420 mA.	A. Using an oscilloscope, construct a testing environment for the Power Supply subsystem B. Probe the voltage of each component connected to the voltage regulator C. Ensure each component is still being supplied the necessary voltage specified in the requirement to ensure voltage regulator is still working

2.2.3 Two 9 V Alkaline Batteries

In order for the two voltage regulators to function correctly, they, too, must have acceptable voltage inputs. Voltage magnitude is not the only characteristic which matters for the choice of batteries, however. Other considerations include how long the batteries need to last and the maximum instantaneous current drawn from the battery. By using multiple batteries, these additional considerations are more easily satisfied which is why this design implements two 9 V batteries hooked up in parallel (instead of just one battery). Table 5 outlines the requirements and verifications for the two 9 V alkaline batteries.

Table 5. Two 9 V alkaline batteries requirements and verifications.

Requirements	Verifications
The batteries, together, must meet the voltage input requirements for the two voltage regulators: the 5 V regulator (4.5 V to 42 V) and the 3.3 V regulator (8 V to 40 V). In this case, the acceptable output voltage range for the batteries is 8.1 V to 40 V (8.1 V is chosen to account for the potential voltage drop across the power switch).	A. Using an oscilloscope, construct a testing environment for the Power Supply subsystem B. Probe and check output voltage of batteries C. Ensure voltage tested is within requirement range (8.1 V to 40 V) D. Probe voltage of each voltage regulator E. Ensure voltage tested is within requirement range of each regulator (5 V: 4.5 V to 42 V, 3.3 V: 8 V to 40 V)
The batteries, together, must be able to supply an instantaneous current greater than or equal to the maximum current draw of all of the downstream components during normal operating conditions. In this case, the batteries must be able to supply a steady current value of 3 A.	A. Using an oscilloscope, construct a testing environment for the Power Supply subsystem B. Probe the current coming from the batteries C. Ensure the current tested is ~ 3 A D. Set a timer for 10 minutes E. As timer decreases ensure current is still ~ 3 A

2.2.4 Power Switch

Because this system uses batteries to power itself, consumers will want to turn off the machine after they are done using it—if they do not do this, the batteries will die. One way of preserving battery life is to remove the batteries from the machine after each game finishes. This, however, is a pain for the consumer. Instead, turning on and off the machine should be as easy as flipping a switch. This is the purpose of the power switch: to disconnect the batteries from the circuit when the console is not in use. Additionally, when the switch is closed, the voltage drop across it should not noticeably impact the voltage seen at each of the voltage regulators. If this is not the case, the voltage observed at the regulators may not meet the input requirements needed for them to work. Table 6 outlines the requirements and verifications for the power switch.

Table 6. Power switch requirements and verifications.

Requirements	Verifications
When the power switch is open, it must provide isolation (less than 1 mA of current) between the batteries and the rest of the components.	A. Using an oscilloscope, construct a testing environment for the Power Supply subsystem B. Move the power switch so that it is open C. Probe the current the two voltage regulators D. Ensure current drawn is less than 1 mA
When the power switch is closed, the voltage drop across the switch must be less than 0.1 V.	A. Using an oscilloscope, construct a testing environment for the Power Supply subsystem B. Move the power switch so that it is closed C. Probe the voltage across power switch D. Ensure voltage drop less than 0.1 V

2.3 Motor Driving Circuit

At the top of the console, there is a drum that players put poker chips into which automatically directs the chips into the machine. The drum consists of a spinning disk located at the bottom of the drum which slides the chips into a slot in the console. To electrically control the spinning of the disk, the console uses a servo motor to physically rotate the disk and a servo trigger to drive the servo. A pushbutton is used with the servo trigger to turn the servo on and off. Figure 6 shows the schematic for this module.

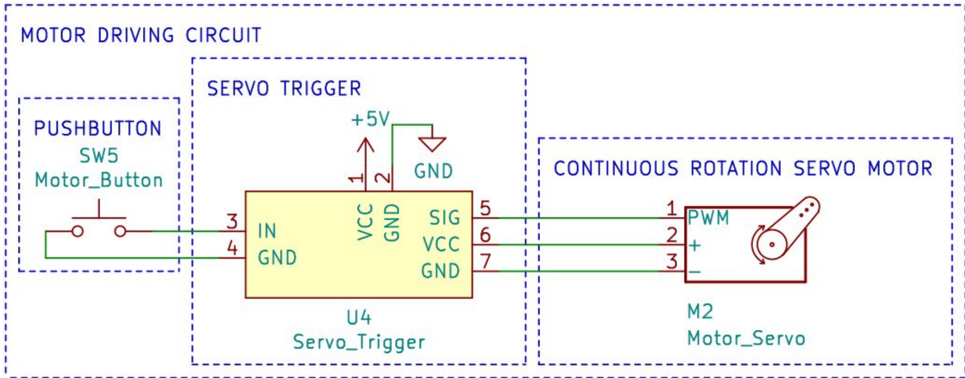

Figure 6. Console motor driving circuit schematic.

2.3.1 Continuous Rotation Servo Motor

The servo is the driving mechanism which rotates the spinning disk. Ultimately, the servo must have enough torque to spin the disk with poker chips laid on top of it. It must also spin fast enough to push the chips to the outside of the disk where they fall through a slot but not fast enough where chips can be launched out of the drum by accident. Also, since the drum needs to continuously spin in a clockwise direction, it cannot have a limited range of rotational motion. Table 7 outlines the requirements and verifications for the continuous rotation servo motor.

Table 7. Continuous rotation servo motor requirements and verifications.

Requirements	Verifications
The servo must spin at speeds faster than 0.5 rev/s under no-load conditions.	A. Ensure there is no-load on the continuous rotation servo motor B. Run the Motor Driving subsystem C. Observe the continuous rotation servo motor is spinning D. Mark a line at which the servo motor begins E. As it starts spinning begin a timer F. Stop the timer when the servo reaches the line again G. Calculate the rev/s using the time and the number of revolutions the servo motor spun H. Ensure the speed is faster than 0.5 rev/s

2.3.2 Servo Trigger

The continuous-rotation servo takes in a pulse train as input which tells the servo which direction to spin; without this pulse train, the servo does nothing. The microcontroller inside the console is capable of sending these pulses. The issue with this, however, is sending these pulses takes away valuable computation cycles from the microcontroller. Therefore, by using a servo trigger, the microcontroller no longer has to supply these pulses. Plus, it frees up a digital pin on the microcontroller to be used by other components. Table 8 outlines the requirements and verifications for the servo trigger.

Table 8. Servo trigger requirements and verifications.

Requirements	Verifications
The servo trigger must be able to supply pulses to the servo motor ranging from 500 µs to 2500 µs.	A. Set up an oscilloscope B. Run the Motor Driving subsystem C. Observe the servo trigger running D. Probe the servo trigger E. Ensure pulses being sent to the continuous-rotation servo ranging from 500 µs to 2500 µs

2.3.3 Pushbutton

Out of all of the components needed in this project, the servo motors consume the most power (when they are running). Therefore, in an effort to save power and extend battery life, the amount of time the servos run should be kept to a minimum. This is done via the use of a pushbutton. The servo trigger contains logic inside of it to toggle an internal state for controlling the motor. Each time the button is pressed, the servo trigger switches between two states: in the case of this project, those two states are on and off. Table 9 outlines the requirements and verifications for the pushbutton.

Table 9. Pushbutton requirements and verifications.

Requirements	Verifications
When one presses the pushbutton, the measured resistance between its two terminals must be less than 1 kΩ.	A. Using an oscilloscope, construct a testing environment for the Motor Driving subsystem B. Press the pushbutton

Table 9. Pushbutton requirements and verifications (continued).

	C. While button is pressed, measure resistance between the pushbutton's terminals D. Ensure measured resistance is less than 1 kΩ
When one is not pressing the pushbutton, the measured resistance between its two terminals must be greater than 10 kΩ.	A. Using an oscilloscope, construct a testing environment for the Motor Driving subsystem B. Do not press the pushbutton C. While unpressed, measure the resistance between the pushbutton's two terminals D. Ensure measured resistance is greater than 10 kΩ

2.4 Poker Chip Detector

In order for people to use poker chips with the console, somehow, the console must keep track of the quantity of chips inserted into it as well as the color—that is, the value—of each chip. Ultimately, there are three pieces of hardware which indirectly work together to accomplish these two objectives: a through-beam IR LED sensor, a color sensor, and a servo. As players insert chips into the spinning drum, chips fall one-by-one through the console. As each chip falls, the servo arm momentarily catches one chip at a time. Meanwhile a mechanical link attached to the servo arm positions a separate arm in a way which prevents other chips from falling down at the same time. Now, with the servo arm holding the poker chip steady, the through-beam IR LED sensor detects the presence of the chip and informs the microcontroller. Then, the microcontroller takes a reading from the color sensor and performs a sweep of the servo arm to let the chip drop into the bin as well as bring in another chip for the next reading. This process repeats until there are no longer any chips which need to be read. Figure 7 shows the schematic for this module.

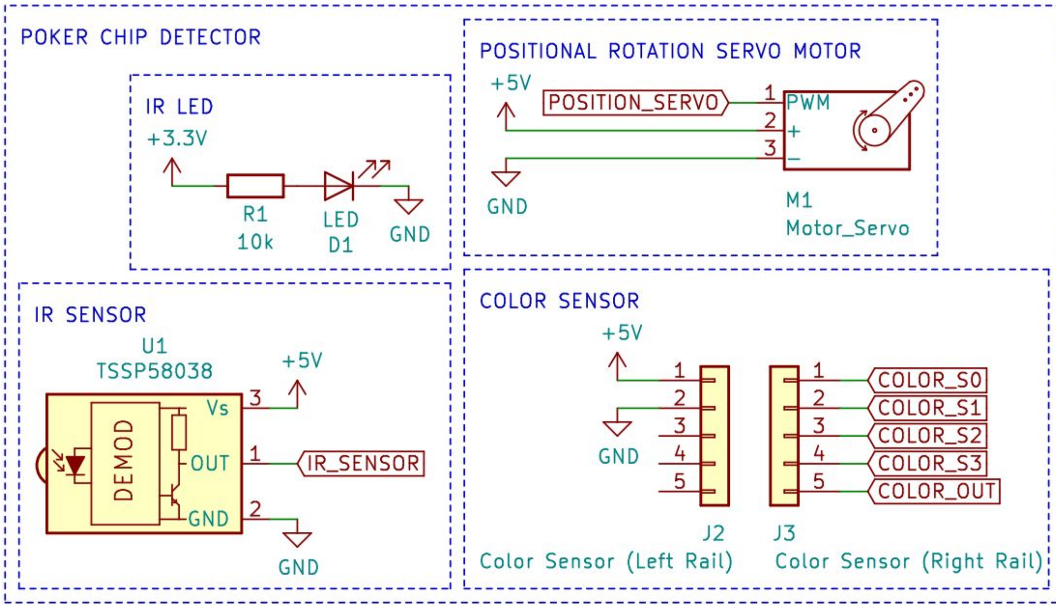

Figure 7. Console poker chip detector schematic.

2.4.1 Through-Beam IR LED Sensor

The through-beam IR LED sensor is responsible for sensing the presence of a poker chip as it falls through the console. The sensor is set up in a way where an IR LED (supplied by the 3.3 V source) sits on one side of the channel the chips falls through, and an IR sensor (supplied by the 5 V source) detects the light on the other side. When no chip is present, the IR LED emits light from one side of the channel to the other. The sensor detects this light, and therefore, the microcontroller knows no poker chip is present. When a poker chip falls down into the channel, however, the servo arm catches the chip, and the chip blocks the light coming from the IR LED going to the IR sensor. When the microcontroller reads from the IR sensor during this situation, it observes a low light reading and, thus, it knows a poker chip is present. Therefore, in order for this system to work effectively, it must be able to correctly differentiate when a chip is present and when it is not. Table 10 outlines the requirements and verifications for the through-beam IR LED sensor.

Table 10. Through-beam IR LED sensor requirements and verifications.

Requirements	Verifications
The difference in voltage between the scenario when there is a poker chip present and when there is not a poker chip present	A. Using an oscilloscope, construct a testing environment for the Motor Driving subsystem B. Insert a poker chip

Table 10. Through-beam IR LED sensor requirements and verifications (continued).

	C. Ensure poker chip is caught by servo arm D. While poker chip is caught, measure the voltage at the IR LED sensor E. Write down measure voltage F. Empty the poker chip and have it fall through G. While no poker chip is present, measure the voltage at the IR LED sensor H. Compare the two measurements I. Ensure the difference between the two measurements is greater than 1 V

2.4.2 Color Sensor

In the game of poker, different chips have different values. Thankfully, unlike values of coins or dollar bills which are sometimes difficult to identify without looking at text or shapes, values of poker chips are easily distinguishable by color. To determine how much money each person puts into the pot each round, the console uses a color sensor to detect the color of the center of each chip as it passes through the machine. Ultimately, for this project, the color sensor must be able to distinguish between the colors red, green, blue, white, and black. Table 11 outlines the requirements and verifications for the color sensor.

Table 11. Color sensor requirements and verifications.

Requirements	Verifications
The color sensor must distinguish between the colors red, green, blue, white, and black, and it must do this correctly at least 95% of the time.	A. Insert a variety of red, green, blue, black, and white color poker chips into the Motor Driving subsystem B. Write down color of each poker chip as they are caught by the servo arm C. Write down the color of the poker chip the color sensor measures D. Compare the results E. Ensure color sensor was able to correctly distinguish the colors as a rate of least 95% of the time

2.4.3 Positional Rotation Servo Motor

One of the challenges associated with trying to count and determine colors of chips passing through the console is the speed with which the chips move. If the poker chips move too quickly, the IR sensor and/or the color sensor may not sense them as they make their way through the machine. Therefore, to ensure all poker chips are accounted for, the console uses a servo motor to stop the motion of each chip—conveniently stopped in the same spot as the sensors—so the console can count and observe color for every chip passing by. Then, after the sensors take their readings, the motor performs a sweeping motion which allows the next chip to fall through. Table 12 outlines the requirements and verifications for the positional rotation servo motor.

Table 12. Positional rotation servo motor requirements and verifications.

Requirements	Verifications
The positional rotation servo motor must have a high enough torque to overcome the gravitational force of two poker chips stacked on top of each other. In this case, the torque must be greater than 0.1 kg-cm.	A. Insert two poker chips into the Motor Driving subsystem B. Ensure the chips are stacked together C. Run the Motor Driving subsystem D. Observe the positional rotation servo motor running E. Using a torque wrench and a fish/luggage scale to measure force F. Apply the wrench on the bolt and measure the force exerted G. Ensure the force is greater than 0.1 kg-cm
The positional rotation servo motor must rotate fast enough to allow throughput of at least 30 chips a minute when operating at its quickest capacity.	A. Insert at least 30 poker chips into the Motor Driving subsystem B. Run the Motor Driving subsystem C. Set a timer for one minute D. As the positional rotation servo motor runs, begin the timer. E. Ensure all thirty poker chips are through before the timer runs out

2.5 Microcontroller

At the heart of the console lies the ATmega328P microcontroller. Nearly every subsystem (with the exception of the motor driving circuit and the external network) directly interacts with the microcontroller, and as such, it is responsible for many different things. First of all, it is the device which houses game state data. It keeps a record of how much money each player has, how much money is in the pot, whose turn it is, and what round it is. Next, it is responsible for reading input from the "select" button on the user interface and printing values and instructions on the LCD screen. Additionally, it interprets the quantity and color of poker chips read by the poker chip detection subsystem and pulses the position rotation servo motor to let chips fall through the console. And finally, given all of the information it stores about the game, it interacts with the Wifi module which, in turn, interacts with the external network so people can access this data via a browser on their phone or laptop. Figure 8 shows the schematic for this module, and Table 13 outlines the requirements and verifications.

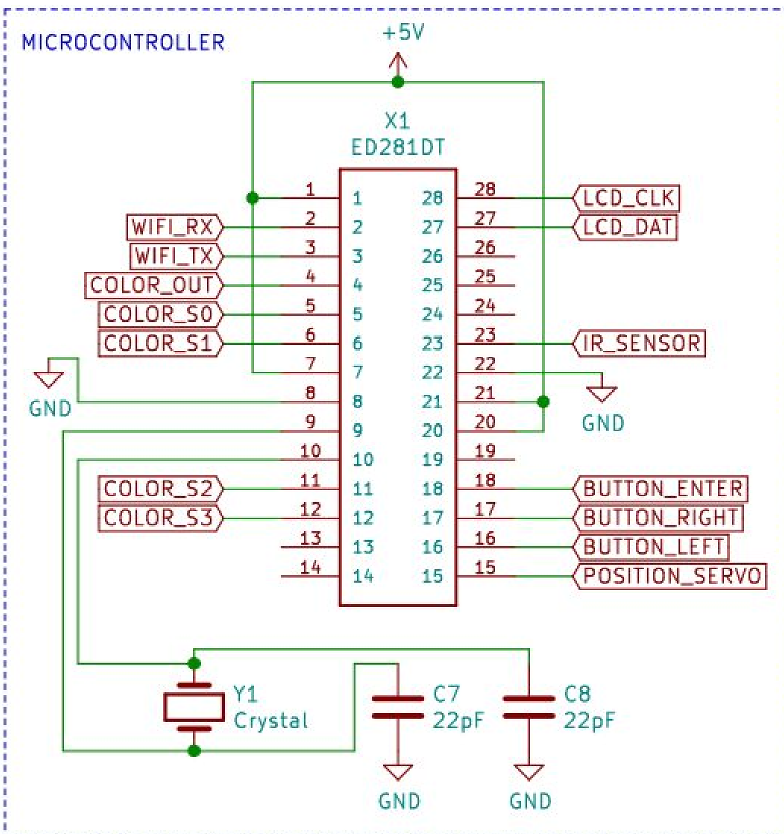

Figure 8. Console microcontroller schematic.

Table 13. Microcontroller requirements and verifications.

Requirements	Verifications
The microcontroller must have enough digital and analog pins to allow each of the aforementioned components to connect to it. More specifically, it needs at least 13 digital I/O pins (1 with PWM capability) and 1 analog input pin.	A. Look at the microcontroller B. Find and locate the digital and analog pins C. Ensure there are at least 13 digital pins D. Ensure one of those 13 digital pins has E. PWM capability F. Ensure there is 1 analog input pin
The microcontroller must communicate with external hardware via TTL-serial and I2C protocols.	A. Set-up the microcontroller to communicate via TTL-serial B. Set-up an oscilloscope C. Probe the output of the microcontroller D. Using the oscilloscope, ensure TTL-serial data is being outputted from the microcontroller E. Set-up the microcontroller to communicate via I2C F. Once again, probe the output of the microcontroller G. Using the oscilloscope, ensure I2C protocol data is being sent
The microcontroller must be fast enough to respond to HTTP requests coming from the Wifi module in under 25 seconds.	A. Set a timer for 24 seconds B. Using the wifi module, send a HTTP request to the microcontroller C. Begin the timer D. Ensure the microcontroller sends a response to back to the request before the timer ends
The microcontroller must check for the presence of poker chips (as well as color) at least every 5 seconds.	A. Set a timer for 5 seconds B. Insert poker chips into the Motor Driving subsystem C. Set up an oscilloscope D. Probe the signal lines coming from the IR and color sensor to the microcontroller

Table 13. Microcontroller requirements and verifications (continued).

	E. Run the Motor Driving subsystem F. Begin the timer G. Observe the poker chips being caught and checked H. Ensure the signal lines are sending data to the microcontroller for both the IR and color sensor

2.6 Wifi Module

Section 2.6 mentions the microcontroller is the component which maintains a record of information regarding the poker game. This data contained inside the microcontroller is not very useful by itself—somehow, this information needs to be shared with people playing the game. This project design uses a Wifi module connected to the microcontroller which allows users to request game information via a web browser. Going into the details of how this works, the microcontroller uses the Wifi module to connect to a wireless network provided from something such as a wireless router found in one's home. Once connected, players use an internet browser on their phones and/or laptops (assuming they are also part of the wireless network) to connect to the IP address of the console. Each time a user connects to the console through a browser, it sends an HTTP request to the Wifi module, and the Wifi module passes this request onto the microcontroller. From there, the microcontroller handles the request and sends an HTTP response through Wifi back to the external device (phone, laptop, etc.). Figure 9 shows the schematic for this module, and Table 14 outlines the requirements and verifications.

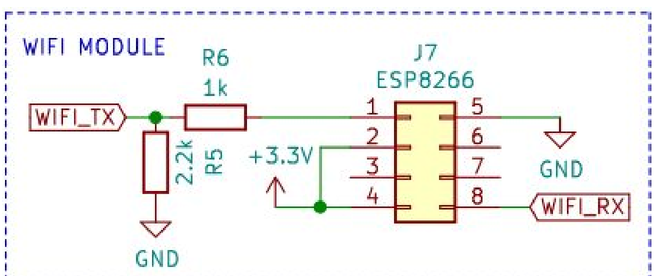

Figure 9. Console wifi module schematic.

Table 14. Wifi module requirements and verifications.

Requirements	Verifications
The Wifi module must successfully connect to a pre-defined wireless network upon startup of the machine (that is, when someone turns on the power switch) at least 80% of the time.	A. Turn on the Power Supply subsystem B. Ensure Wifi module is being powered on C. Ensure user's wifi router is on and running D. Connect wifi module to user's wifi router by obtaining necessary credentials E. Ensure wifi module is connected F. Toggle the Power Supply subsystem on and off a few times G. Ensure wifi module can connect to wifi router when powered on at 80% of the time

2.7 User Interface

When people use the console to play poker in the absence of poker chips, most of the user input throughout the game comes in the form of HTTP requests over Wifi. When chips are used, however, it makes sense to transfer functionality from people's phones to the physical console (since players are already using the console at that point to keep track of money totals via poker chips throughout the game). With this being said, the console needs a simple way to take input from users and display new game data based on these inputs. This is done through a 16x2 LCD screen connected to an LCD backpack, and 3 pushbuttons. Figure 10 shows the schematic for this module.

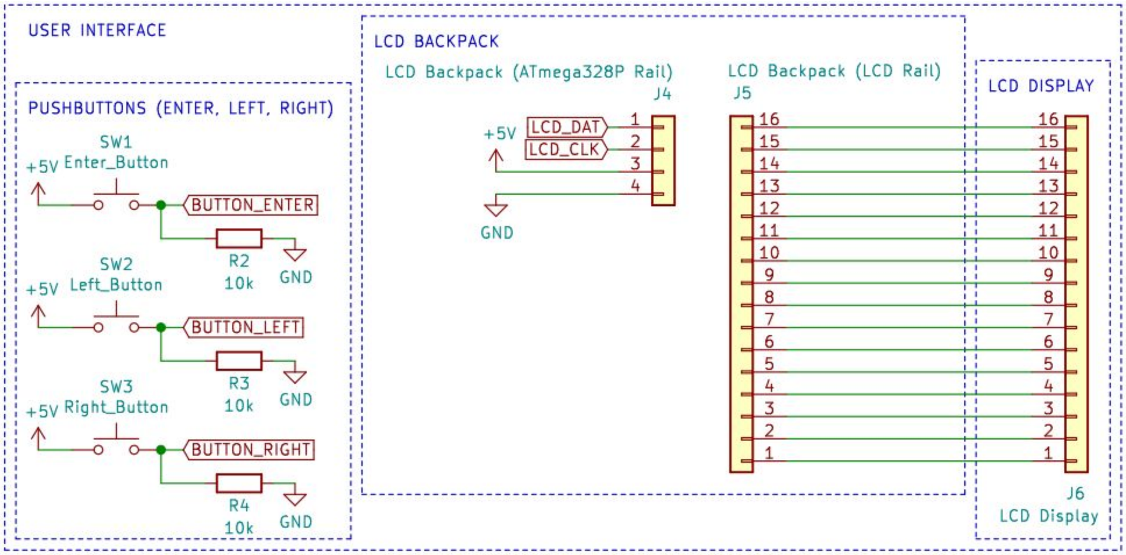

Figure 10. Console wifi module schematic.

2.7.1 LCD Display

In order for users to connect to the microcontroller via Wifi, they must, first, know the console's IP address on the network. This is one of the applications which makes the LCD useful for this project: displaying the IP address. Once the game begins—and thus, no more connections to the console need to be made—the LCD can, instead, display game data such as players' money totals, how much money is currently in the pot, and how much more money a player must put in to stay in the game. Table 15 outlines the requirements and verifications for the LCD display.

Table 15. LCD display requirements and verifications.

Requirements	Verifications
The LCD screen must be large enough to display one player's name (limited to 7 characters), his/her money total (limited to 8 digits), the amount of money needed to keep playing in a given round (limited to 7 digits), and the total amount of money currently in the pot (limited to 8 digits), all on one screen.	A. Simulate a game of poker (Turn the Power Supply subsystem on and insert poker chips) B. Ensure LCD is on and displaying IP address C. Have players connect to IP address and input their names D. Start the game E. Ensure LCD display can display a player's name up to 7 characters as well as amount of money and pot up to 7 digits

2.7.2 LCD Display Backpack

One issue with 16x2 LCD displays is, without the use of external hardware, they use up many digital pins on the microcontroller. In a project like this, many other components also need to use these pins, and therefore, the best practice in this situation is to reduce device footprints when possible. To reduce the number of pins needed to interact with an LCD display, LCD backpacks convert the parallel data signals used by the LCD display to serial I2C signals used by a microcontroller. This project implements this strategy to reduce the number of pins needed for the LCD display down to two pins. Table 16 outlines the requirements and verifications for the LCD display backpack.

Table 16. LCD display backpack requirements and verifications.

Requirements	Verifications
The LCD display backpack must use the same parallel communication protocol as the LCD display which is chosen (that is, four data lines, one enable line, and one register select line).	A. Carefully inspect the LCD Display Backpack component B. Locate the data lines C. Ensure there are four data lines D. Locate and ensure there is one enable line E. Locate and ensure there is one register select line

2.7.3 Pushbuttons

The console uses three pushbuttons for user input. When a player wants to display a different player's money total on the LCD, he/she uses the two buttons marked "<-" and "->" to cycle between the players. In regard to the other button marked "ENTER," players use this to lock in their bets after each turn. For example, if a group of people are playing poker using chips with the console and it is Player 3's turn, if he/she wants to make a bet, Player 3 puts the desired number of chips into the machine and presses enter. If other players want to call or raise, they put their chips in and press enter when it is their turn. And finally, if players want to fold, they simply abstain from putting in any chips and press enter, and the machine will know they are trying to fold. Table 17 outlines the requirements and verifications for the pushbuttons.

Table 17. Pushbuttons requirements and verifications.

Requirements	Verifications
When one presses the pushbutton, the measured resistance between its two terminals must be less than 1 kΩ.	A. Using an oscilloscope, construct a testing environment for the Motor Driving subsystem B. Press the pushbutton C. While button is pressed, measure resistance between the pushbutton's terminals D. Ensure measured resistance is less than 1 kΩ
When one is not pressing the pushbutton, the measured resistance between its two terminals must be greater than 10 kΩ.	A. Using an oscilloscope, construct a testing environment for the Motor Driving subsystem B. Do not press the pushbutton C. While unpressed, measure the resistance between the pushbutton's two terminals D. Ensure measured resistance is greater than 10 kΩ

2.8 External Network

One of the key advantages of this system's design as opposed to the past group's solution is one does not need to buy a remote for each person who wants to play. Instead, players use their own phones. Section 2.7 mentions the microcontroller used in this project interfaces with a Wifi module so it can wirelessly communicate with devices such as phones and laptops. More specifically, the Wifi module connects to a wireless network (likely provided by a wireless router), and as phones join the network, they send client requests to the console (which, essentially, acts as a server) through the router. The console then responds to the requests and sends back game information to those devices in the form of HTML web pages.

2.8.1 Wireless Router

The wireless router's job is to direct communication from players' phones to the console and vice versa. It does this by creating its own wireless network and having devices join the network before the game begins. Table 18 outlines the requirements and verifications for the wireless router.

Table 18. Wireless router requirements and verifications.

Requirements	Verifications
The number of IP addresses available for use on the router's WLAN must be greater than or equal to the number of people wanting to play, plus one (for the console itself).	A. Turn on the wireless router B. Locate the the IP addresses available by accessing the network settings and finding the router C. Ensure the number of IP addresses are greater than number of people wanted to play plus one for the console

2.8.2 External Devices

Because the console uses Wifi as the communication method for sending and receiving information, any device with 2.4GHz Wifi capabilities can connect to the console. With this being said, however, the application protocol used by the microcontroller is HTTP. So in order to send valid requests and properly read data coming from the microcontroller, the receiving device must use an application that uses HTTP and can display HTML files. An internet browser, for example, satisfies these requirements. Figure 11 shows an example flowchart representing the sequence of steps a player goes through to complete a round of poker, and Table 19 outlines the requirements and verifications for the external devices used with the game.

Table 19. External devices requirements and verifications.

Requirements	Verifications
Each external device must run an application which sends/receives HTTP requests/messages and is able to display HTML files.	A. Turn on the Power Supply subsystem B. Simulate a game of poker C. Have players connect to the IP address of the game D. On each player device, make sure it can send and receive HTTP by opening http web browsers and responding to prompts within the browser E. Ensure each player device can display HTML files by attempting to open a HTML file

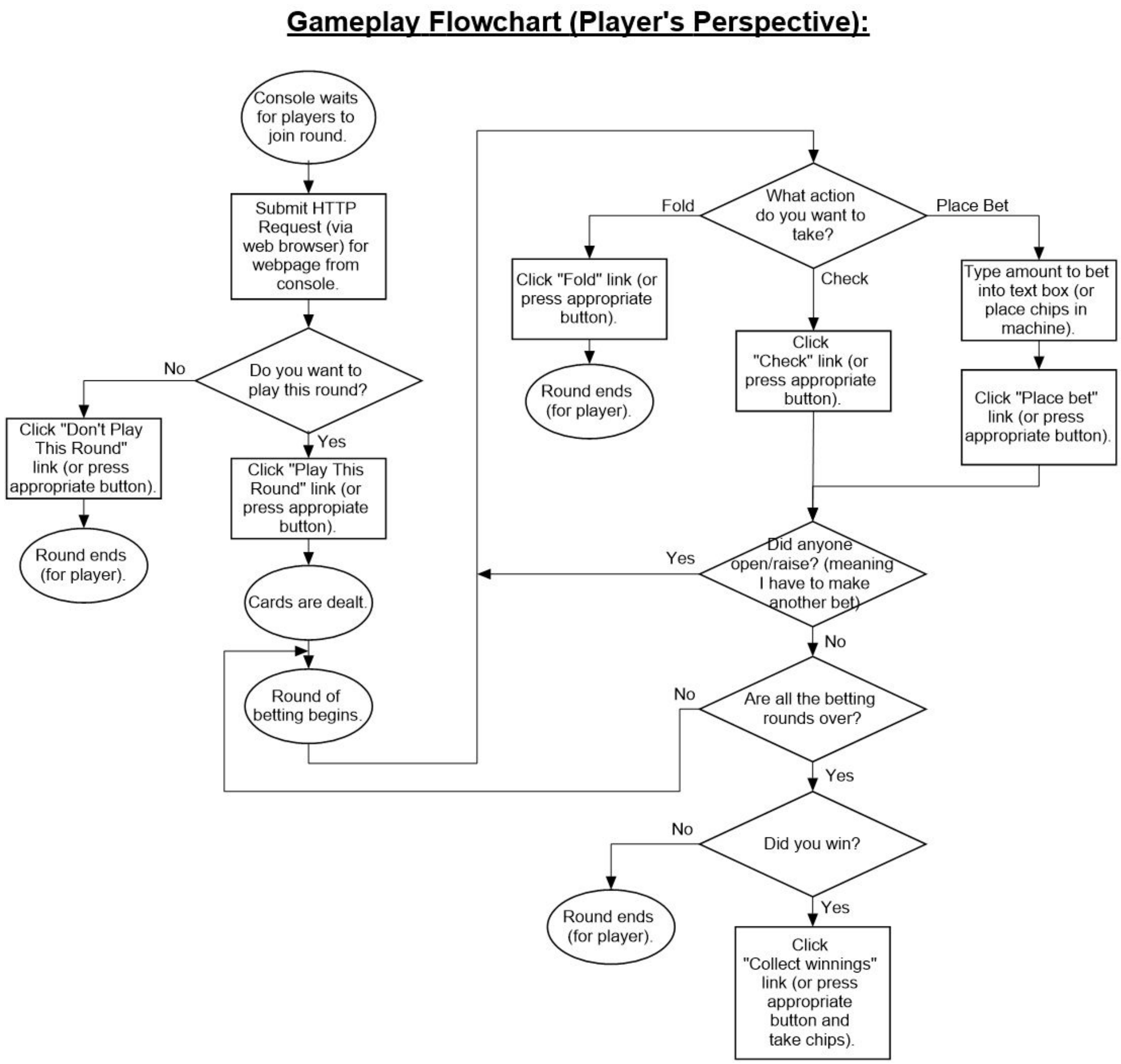

Figure 11. Gameplay flowchart (from player's perspective).

2.9 Tolerance Analysis

One of the most important aspects of this project in terms of gameplay is the console accepting poker chips quickly and reading them accurately to give the players the correct credit. While we brainstormed many different ideas on how to accept the chips, one way became the clear winner for our purposes.

2.9.1 Rotating Disk

Some antique coin counters utilized a spinning disk. A user would place their coins on this disk and the centripetal force pushes the coins to the outside to be sent through a slot that can only fit one coin at a time [13]. We decided that this solution is better than a slot to insert each chip individually since, in poker, a player can go all in and would spend a very long time doing so. With the spinning disk, a player can simply dump all their chips and not have to do anymore work. Some questions that arise with the spinning disk are how large should the disk be, how fast can the chips go through the collector, and how fast will it spin? The average poker chip's diameter is 39 mm but some chips are 40 mm [14]. We decided that a good size disk would be one that can fit a row to accept the chips and have enough room for other chips to go around the circle again. We also want to avoid having a larger than necessary disk so our overall design will be more portable. We selected a radius of 12 cm so that almost three chips can fit in a line. We have selected the 1528-1496-ND Continuous Rotation Servo Motor, and from its datasheet, we know it has an average angular velocity of 1 rotation / 1.08 seconds or 0.9259 rotations / 1 second [21].

If our chips are lined back to back on this rotating disk, which is very possible they will be if someone adds a lot of chips, we want to know how fast these chips will be entering the exit slot so we can calculate if our sensors will have enough time to find the color and prevent blockage in our system. Figures 12-13 show how we can identify the angle of the disk each chip will fill. We have decided to simplify this expression by treating the chips as a flat line with the length of the diameter of a chip. This will make the calculations easier and will also speed up the rate the chips will exit giving us a little leeway.

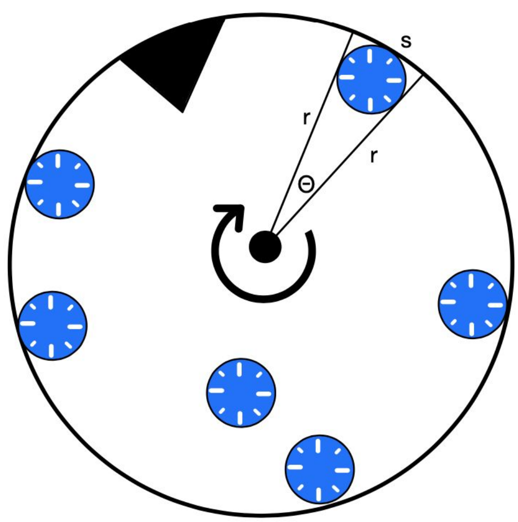

Figure 12. Diagram showing angle Θ that covers a poker chip. Rotating disk has radius r, and s is the arclength of that angle Θ.

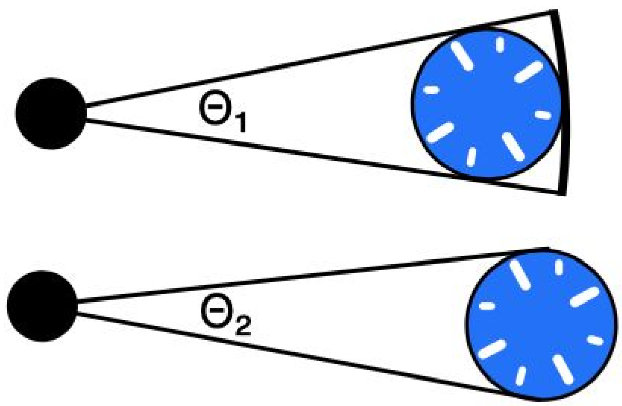

Figure 13. Simplification by making the arclength a straight line with length of the diameter of a poker chip in order to solve for Θ.

In order to find Θ, we can break this triangle up into two identical right triangles as shown in Figure 14. We can solve for a by using Pythagorean Theorem as shown in Equation (4). We can use Equation (5) to solve for a shown in Equations (6)-(8).

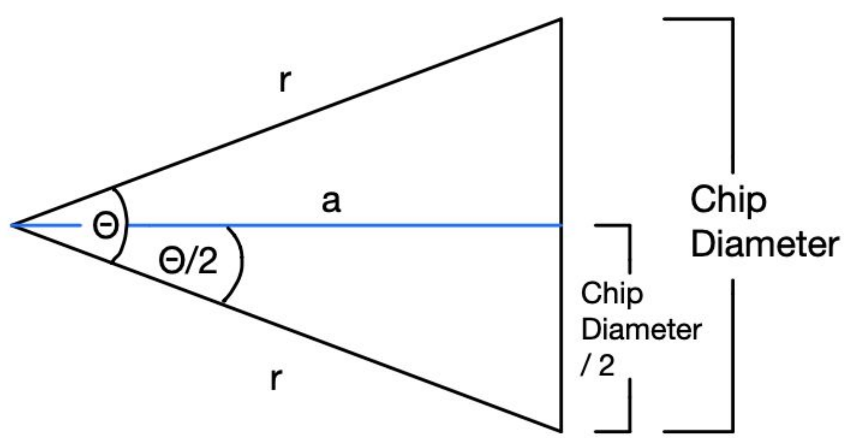

Figure 14. Isosceles triangle formed by radius r, Θ, and poker chip's diameter.

$$a^2 + b^2 = c^2, \text{ where } c \text{ is hypotenuse of a right triangle and } a \text{ and } b \text{ are other sides} \quad (4)$$

$$a^2 + 19.5^2 = 120^2 \quad (5)$$

$$a^2 = 120^2 - 19.5^2 \quad (6)$$

$$a = \sqrt{(120^2 - 19.5^2)} \quad (7)$$

$$a = 118.4\ cm \quad (8)$$

Now we can use this r to solve for Θ/2 shown in Equations (9)-(10). We can take that Θ/2 and multiply by 2 to get Θ in Equation (11).

$$\Theta/2 = tan^{-1}((chip\ diameter\ /\ 2)\ /\ a\ ) = 9.35° \quad (9)$$

$$\Theta/2 = tan^{-1}(19.5\ /\ 118.4) = 9.35° \quad (10)$$

$$\Theta = 9.35° * 2 = 18.7° \quad (11)$$

We will now take this Θ and multiply it by the average angular velocity of the rotation disk shown in Equation (12) to find out how much time it takes for a chip to move one chip length on the edge of the disk.

$$(1.08\ s\ /\ 360°) * 18.7° = 0.0561\ s \quad (12)$$

This tells us the rotating disk may spit out a chip slightly slower than every 56.1 ms, and we need to deal with them or they can become clogged up.

2.9.2 Color Sensor

One of the most important parts of this system is the color sensor. The color sensor will scan each chip and give it value and without it, we would not be able to use poker chips. In order for the color sensor to translate the color, it needs to be able to see the chip for a minimum amount of time. The color sensor has 4 LEDs on it with different frames to detect intensities of red, green, and blue. The fourth LED is a clear frame, but we will not use that one. The datasheet for the color sensor has sample code that gives each LED a 10 ms timer for getting the values [15]. The color sensor is also required to do two digitalWrites in order to turn a different LED and each digitalWrite takes about two ms [16]. Using Equation (13), we can see that the color sensor needs about 42 ms to test the three different color intensities.

$$(10\ \text{ms} + 2 * 2\ \text{ms}) * 3 = 42\ \text{ms} \quad (13)$$

The question now is where can this color sensor go in order to have enough time to read the values. The tangential velocity of the chip leaving our rotating disk is derived in Equations (14)- (15) by taking the center of mass distance of the poker chip on the outer wall of the rotating disk and multiplying it by the average angular velocity. In reality, the disk will most likely bounce around slowing down the tangential velocity, but we will need to be prepared for the case where it does not.

$$Center\ of\ Mass\ of\ Poker\ Chip\ Radius = (120\ mm - 39\ mm)\ /\ 2 = 100.5\ mm \quad (14)$$

$$V_{tan} = 0.1005\ m * 2\pi\ /\ 1.08\ s = 0.58468\ m/s \quad (15)$$

If we place the color sensor right where the chip exits the rotating disk, the chip will only be in front of the color sensor for a limited amount of time shown by Figure 15.

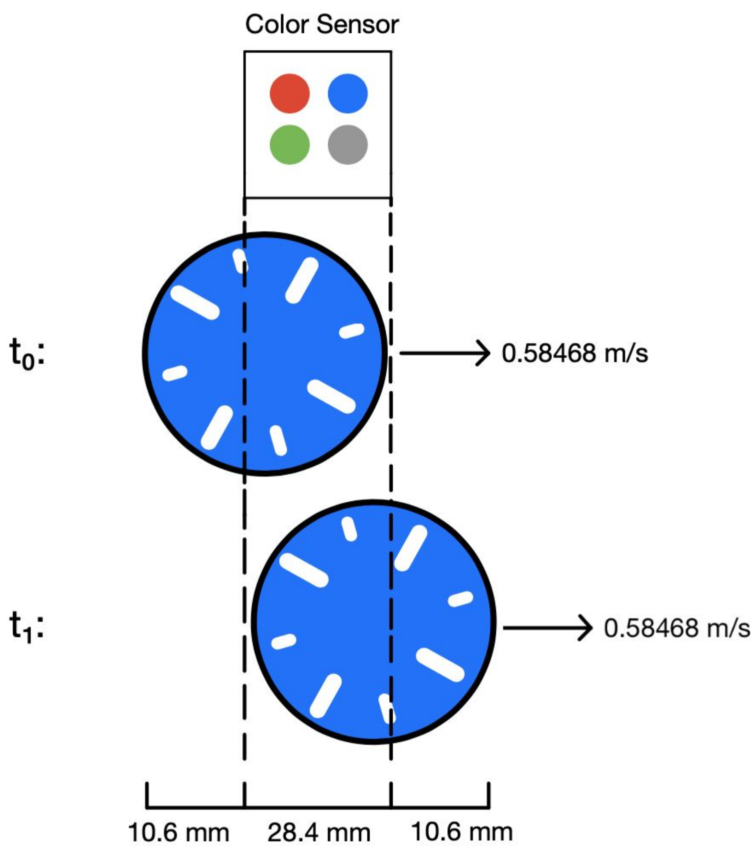

Figure 15. Diagram showing how long the chip will be in front of the color sensor at the tangential velocity from the rotating disk.

Then Equation (16) shows us how much time the chip will spend in front of the color sensor.

$$t_1 - t_0 = 10.6\ mm * (1\ m\ /\ 1000\ mm) * (1\ s\ /\ 0.58468\ m) = 0.01813\ s \quad (16)$$

Because the color sensor needs to be in front of the chip for at least 42 ms, we can see that having the sensor right at the exit of the rotating disk will not work.

2.9.3 Servo Motor

We need to stop the chips after they come out the rotating disk just long enough for the color sensor to read the values. After that we want to make sure we go to the next chip so that the tube does not get clogged up. In order to do this, we are going to utilize a servo to halt a chip, move to let that chip through, then stop the next chip. In Figure 16 we can see that the width of the tube for the chips to pass through is 42 mm so that there is enough room for both 39 mm chips and 40 mm chips to fit. Our servo will be connected to a disk that can push a lever in and out of the tube to control the traffic of chips.

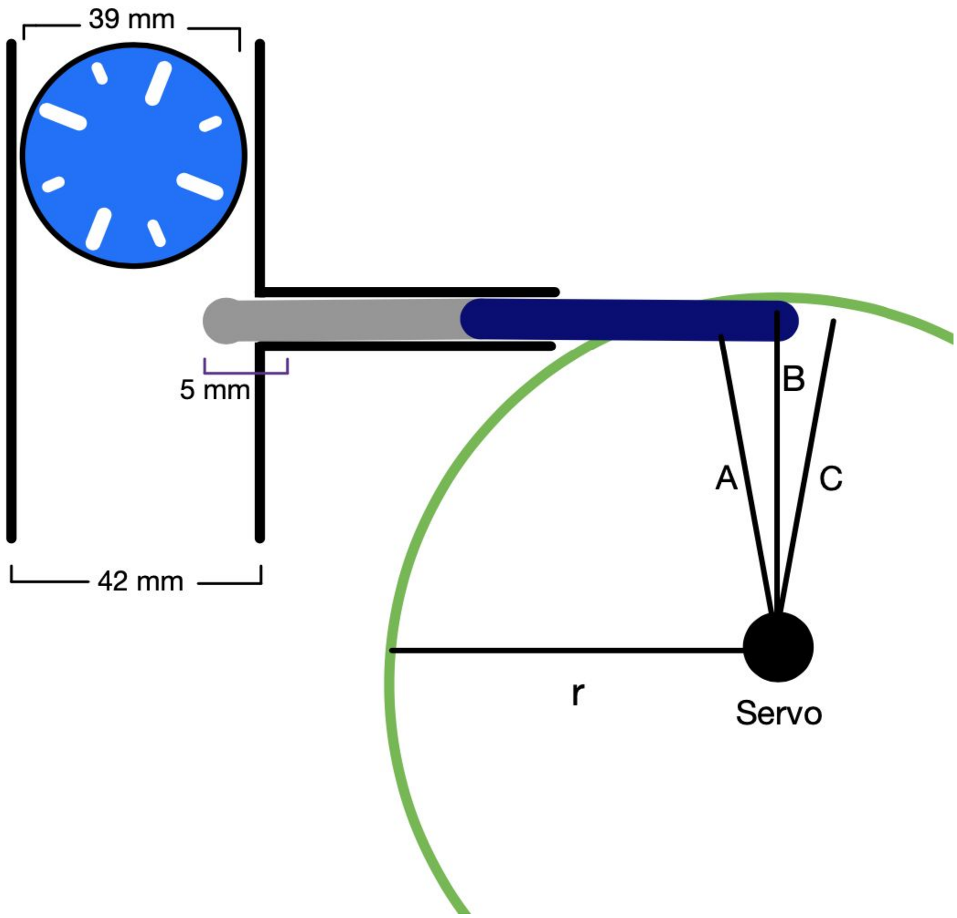

Figure 16. Diagram of chip size compared to the tube as well as the servo disk connected to a lever to control chip traffic in the tube.

Because our rotating disk can possibly spit out a new chip a little bit slower than every 56.1 ms, we need to rotate the chips as closely to the time it takes the color sensor to read the values as we can (42 ms). We want our lever to move about five mm to make sure there is enough room to block the chip and completely let it through as well. According to the Arduino tutorial for servo motors, it is good to give the servo motor 15 ms per degree [17]. In one cycle our servo will need to go out and then come back. If we move two degrees out and then two degrees back in, that will take 60 ms which is about all we will have time to do. Although two degrees does not seem very significant, we can make our disk that the servo is connected to large enough that two degrees can give us our requested lever distance. Figure 16 shows how our servo connected to our disk and lever will look. In the diagram, we have listed three different positions on our servo's disk labeled "A", "B", and "C". Equations (17)-(21) show how large the radius of this disk needs to be to move the lever five mm in two degrees. We also simplified these equation a little since the arclength of two degrees will almost be flat, we decided to treat the five mm we want to move as our arclength.

$$s = r\,\Theta \tag{17}$$

$$0.005\,m = r * 2° \tag{18}$$

$$0.005\,m = r * 2° * (2\pi / 360°) \tag{19}$$

$$r = (0.005\,m * 360°) / (2° * 2\pi) \tag{20}$$

$$r = 0.1432\,m \tag{21}$$

While this seems like it should be sufficient for the system, we still need to consider the speed at which the next chip will fall after we pull out this lever. Will the lever be able to go back in before the next chip falls through? Figure 17 shows the different stages the lever can take.

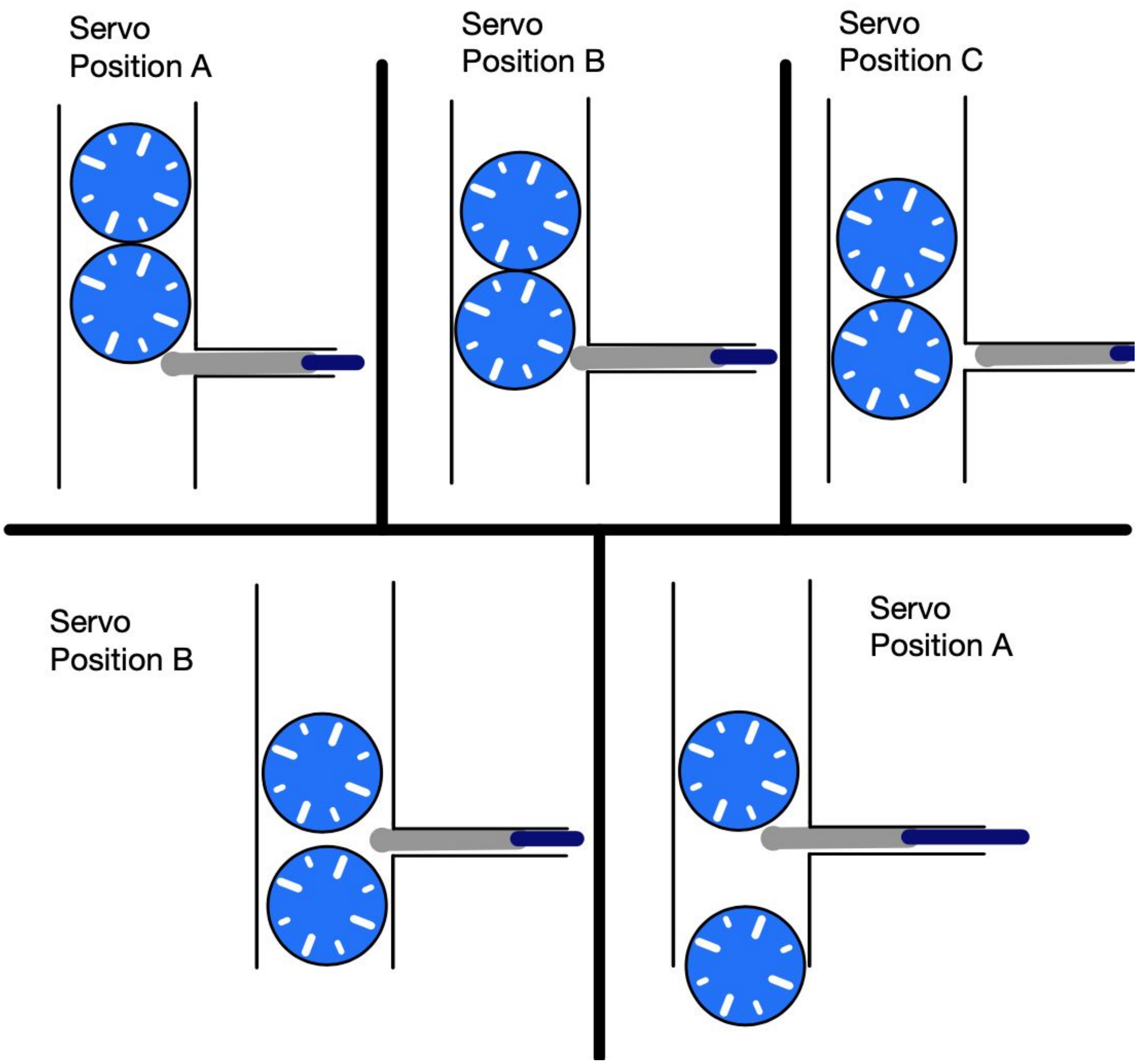

Figure 17. The lever positions based on the servo motor positions.

While the lever is moving out of the tube, the current chip begins to slide, so we will just calculate how long it takes the chip to fall half its diameter and see if we can move our servo back in enough time to catch the next chip. Just a reminder that it takes our servo 30 ms to move back. When the lever moves out, the only force acting on the chip is gravity and we will be using an equation to calculate the amount of time it takes an object moving at v_i to fall y distance in Equations (22)-(24) [18].

$$t = (-v_i \pm \sqrt{(v_i^2 + 2gy)}) / g \tag{22}$$

$$t = \sqrt{(2gy)} / g \tag{23}$$

$$t = \sqrt{(2 * 9.8\ m/s^2 * 0.0195\ m) / 9.8\ m/s^2} = 0.0631\ s \quad (24)$$

This means that the servo will have more than enough time to go back in before the next chip falls through so we can just decrease the speed of this servo and it will be sufficient.

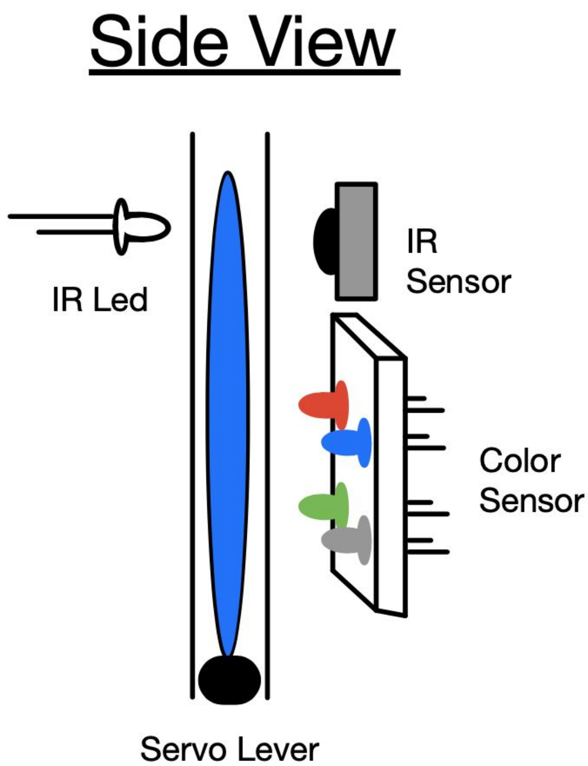

Figure 18. Side view of IR LED, IR sensor, color sensor, and servo lever.

Figure 18 shows a side view of how our sensors will be oriented when our servo lever is in place holding the chip. With this implementation and following these measurements and calculations, our rotating disk will be able to quickly move chips and our servo will be able to stop the chips just long enough for our color sensor to properly get the color intensity values without clogging up the tube.

3 Project Differences

Our project problem was heavily influenced by Team 62's Spring 2019 project, "Electronic Chip/Betting System." In Team 62's design solution they decided to make RFID enabled remotes as the primary source of communication between the players and the center console. Additionally, their solution was designed that all of the betting would be electronic, so no physical poker chips would be needed. These two main components of Team 62's project design are the two main improvement areas our solution improves upon. Instead of using RFID communication, our design solution utilizes Wifi. At its current state, Wifi is not only more reliable and stable than RFID communication, but it is also more practical as many consumers have Wifi access points/sources already in place. Furthermore, this RFID communication was implemented in remotes that would interact with Team 62's center console. Using remotes restricts the number of players available to play based on the number of remotes. Since poker is usually played with 5+ people, a more practical approach to remove the limitations on the number of players capable of playing is using everyday electronics like smartphones and laptops. Having our design solution incorporate Wifi communication, we can allow players to play through such devices. Finally, our solution provides more versatility than Team 62's solution by giving users the ability to use physical poker chips if they have them by implementing a poker chip reading mechanism where players insert their poker chips into the console which detects their respective values and then updates scores on the LCD screen as well as on the HTML pages sent to the external devices.

One of the main areas our design solution improves upon from Team 62's solution is the primary communication between the game devices and the main console unit. In Team 62's design, RFID was used to communicate whose turn it was to the main console with an RF transceiver doing the rest of the communication. Within our design solution, this communication is Wifi between external devices (smartphones, laptops) and the main console. While both communication methods are within the 2.4-GHz spectrum, Wifi provides a more accurate and reliable solution due to the fact that it has a faster data rate, and both RFID and RF can be interfered with based on its surrounding environment. The signals sent from RFID enabled tags to readers are easily susceptible to interference. Interference from other RF emitting devices like radios and TVs as well as Wifi access points can negatively impact the RFID system's performance. Additionally, any obstruction between the reader and tag(s) can cause the line-of-sight signal to weaken the RFID system as well. Line-of-sight is the property of acoustic wave propagation in which the wave travels in a direct path from the source to the receiver. Calculating the line-of-sight (LoS) is given by Equation (25)

$$d_l = \sqrt{2Rh} \qquad (25)$$

where d_l is the line of sight, R is the radius of the Earth, and h is the height of the antenna [19]. However, this line-of-sight calculation only holds if there is no obstruction of the signal. Things like absorption, reflection, and diffraction from objects can deter the line-of-sight signal which can cause the RFID system to have poor performance. To determine the quality of the RF transceiver, we can use Shannon's formula, shown in Equation (26), to calculate the data rate of the given channel based on bandwidth. Shannon's formula is given by:

$$d = B * log_2(1 + SNR) \quad (26)$$

with d being the data rate, B is bandwidth, SNR is signal-to-noise ratio. SNR can be computed by taking the average signal power divided by the average noise power. This is shown in Equation (27):

$$SNR = \frac{P_{signal}}{P_{noise}} \quad (27)$$

An average SNR in a home environment can reach 40 decibels (dB), while an average bandwidth (B) from an RF transceiver is less than 1MHz [20]. Using these values, we can roughly measure the data rate for an RF transceiver, shown in Equations (28)-(29):

$$d = 1MHz * log_2(1 + 40dB) \quad (28)$$

$$d = 1.585\ Mbits/sec \quad (29)$$

From this calculation, we can see on average the RF transceiver can transmit ~1.585Mbps. Using the 2.4-GHz spectrum, most Wifi routers can achieve around 150Mbps [22]. From these results, we can see that in terms of data transfer rates Wifi has higher throughput rates than a RF transceiver. This is in addition to the fact that RFID signals can easily be succumbed to interferences which can result in potential signal loss. Translating this to Team 62's design, the RFID remotes have the potential to cause slow gameplay if signals are lossed or dropped as they are transmitted to the main console. Additionally, the RF transceiver data rates are not as good as Wifi, so updates of the poker game can be slow too. We can see our design solution of incorporating a Wifi communication service between external devices (smartphones, laptops) and the main game console provides a more accurate and reliable solution in terms of communication protocol than an RFID, RF embedded system like Team 62's design.

4 Cost and Schedule

Sections 4.1 and 4.2 cover logistical information for this project including labor costs, parts costs, vendor choices for ordering, and project scheduling.

4.1 Cost Analysis

Our development costs come from three people working ten hours a week at $50 per hour per person. The expected duration of the project is 10 weeks, and therefore, labor costs are $60,000 as shown in Equation (30).

$$3 \times \$50/hour \times 10\ hours/week \times 16\ weeks \times 2.5 = \$60,000 \quad (30)$$

The itemized cost for materials and parts for one prototype are shown in Table 20 and add up to a total of $124.60. Buying in bulk (100+ parts per order) reduces this value to $101.55.

Table 20. Itemized cost of parts.

Part	Cost (Prototype)	Cost (Bulk - 100 parts)
Power Supply		
5 V Switching Regulator (Digikey; 296-43596-1-ND)	$4.20	$2.93
Schottky Diode (Digikey; 1727-5841-1-ND)	$0.42	$0.19
47 µH Inductor (Digikey; AIAP-03-470K-ND)	$1.33	$0.89
100 µF Capacitor (Digikey; PCE3750CT-ND)	$0.12	$0.12
4.7 µF Capacitor (Digikey; PCE4304CT-ND)	$0.42	$0.19
10 nF Capacitor (Digikey; 490-13295-1-ND)	$0.10	$0.02
3.3 V Switching Regulator (Digikey; LM2672N-3.3/NOPB-ND)	$4.20	$2.93

Table 20. Itemized cost of parts (continued).

Schottky Diode (Digikey; 1727-5841-1-ND)	$0.42	$0.19
47 µH Inductor (Digikey; AIAP-03-470K-ND)	$1.33	$0.89
330 µF Capacitor (Digikey; PCE3888CT-ND)	$0.59	$0.28
150 µF Capacitor (Digikey; 493-2204-1-ND)	$0.51	$0.24
10 nF Capacitor (Digikey; 490-13295-1-ND)	$0.10	$0.02
9 V Batteries (x2) (Digikey; N145-ND)	$4.26	$3.08
Battery Holder (x2) (Digikey; BC9VPC-ND)	$4.16	$2.88
Power Switch (Digikey; 2299-TE6-1A-DC-1-PB-ND)	$1.15	$1.00
SUBTOTAL	*$23.31*	*$15.85*
Motor Driving Circuit		
Continuous Rotation Servo Motor (Digikey; 1528-1496-ND)	$11.95	$11.95
Servo Trigger (Sparkfun; WIG-13872)	$12.95	$11.01
Pushbutton (Digikey; 401-1992-ND)	$0.93	$0.77
SUBTOTAL	*$25.83*	*$23.73*
Poker Chip Detector		
IR Sensor (Digikey; TSSP4056-ND)	$1.45	$0.77
IR LED (Digikey; 511-1363-ND)	$0.68	$0.34

Table 20. Itemized cost of parts (continued).

22 Ω Resistor (Digikey; 22WCT-ND)	$0.22	$0.07
Color Sensor (Digikey; 1738-1035-ND)	$7.98	$7.98
Positional Rotation Servo Motor (Digikey; 1528-1075-ND)	$12.00	$12.00
SUBTOTAL	*$22.33*	*$21.16*
Microcontroller		
ATMEGA328P-PU Microcontroller (Digikey; ATMEGA328P-PU-ND)	$2.08	$1.73
28 Pin DIP Socket (Digikey; ED3050-5-ND)	$0.33	$0.22
22 pF Capacitor (Digikey; 399-1926-ND)	$0.44	$0.44
16 MHz Crystal (Digikey; 300-6034-ND)	$0.54	$0.36
SUBTOTAL	*$3.39*	*$2.75*
Wifi Module		
ESP8266 Wifi Module (Amazon; B00O34AGSU)	$6.55	$6.55
2.2 kΩ Resistor (Digikey; CF14JT2K20CT-ND)	$0.10	$0.02
1 kΩ Resistor (Digikey; CF14JT1K00CT-ND)	$0.10	$0.02
SUBTOTAL	*$6.75*	*$6.59*
User Interface		
LCD Display (Adafruit; 181)	$9.95	$9.95
LCD Backpack (Adafruit; 292)	$9.95	$7.96

Table 20. Itemized cost of parts (continued).

Pushbuttons (x3) (Digikey; 401-1992-ND)	$2.79	$2.31
10 kΩ Resistors (x3) (Digikey; 10KQBK-ND)	$0.30	$0.09
SUBTOTAL	*$22.99*	*$20.31*
Other		
PCB (PCBWay)	$5.00	$1.16
Casing	$15.00	$10.00
SUBTOTAL	*$20.00*	*$11.16*
Total Cost	$124.60	$101.55

4.2 Schedule

The desired overall time frame for this project is ten weeks. The design document serves as the start of the whole process, and from there, building and testing the console begins, followed by a demonstration, a presentation, and a final paper summarizing the results of the project.

Table 21. Semester schedule with work distribution.

Week	TJ	Nathaniel	Zach
Week 1	Work on the design document.		
Week 2	Create detailed flowchart outlining logical states console will transition through during game	Create CAD model for physical design of console	Create PCB layout, and submit design for approval
Week 3	Research HTTP methods used by browsers	Work with the Fab Lab to 3D print parts for design	Place order for parts
Week 4	Begin designing web pages sent by	Physically assemble console, and mount	Upon arrival of parts and PCB, solder parts onto

Table 21. Semester schedule with work distribution (continued).

	microcontroller to external devices	motors when they arrive	PCB
Week 5	Test sending HTML code to external devices from microcontroller via Wifi module	Install and test motor driving circuit for spinning drum and poker chip detector	Install and test color sensor; submit secondary PCB order, if necessary
Week 6	Write code for displaying messages to LCD during game	Synchronize chip detection and color readings with motor movement	Install LCD screen and buttons inside console
Week 7	Incorporate code from all modules; test code with actual assembled console	Install batteries and battery holders inside console and ensure no loose connections are present	Solder any remaining parts and create extra PCBs, if ordered
Week 8	Prepare for mock demo		
Week 9	Final stages of software and hardware integration testing		
Week 10	Prepare for final presentation and complete final report		

5 Safety and Ethics

There are a few safety and ethical concerns that reside with our project. One of the main safety concerns comes from the batteries that will be used to power the chip reading system and LCD monitor within the main unit. These batteries can explode if they become overcharged or reach an extreme heat temperature [8]. Additionally, these batteries should not be charged in extreme cold temperatures either as they can deteriorate and leak chemical acid [8]. To ensure safety, we will adequately test and monitor the battery cell temperature to ensure its overall quality and performance.

With our project design containing electronics like the IR sensor and the color sensor, the safety issue of exposed wires arises. Exposed wires can cause detrimental damage to both the other electronics surrounding it and the users with burns and shocks being the common injuries. To safely and effectively avoid the safety concern, we plan to insulate the wires through the use of electrical or thermal insulating tape. Additionally, we will also verify our electronic components are being supplied with the correct amount of voltage and current going through each of them by testing each individual part and seeing if it meets the necessary requirements/limits. To ensure our wires are safely insulated, we will test them and ensure they do not conduct any electricity as well as not heat up to dangerous temperatures.

To avoid our electronics from getting exposed to water or wet situations, we plan to enclose them within a casing. This casing will allow our solution to be played/used in a variety of different locations without the worry of damage or shorting any of the electronics. The casing will help prevent water from getting in and damaging the electronics. This casing allows us to address and mitigate yet another safety issue.

Another safety concern stems from the motor driving circuit. This mechanism will utilize servo motors that will exert force on a spinning disk to push the received chips to the outer edge of it before going down a channel chute. The concern that arises is possible injury from these motors when inserting a chip into the mechanism. To combat this safety concern, we plan on abstracting away the motor driving circuit from the user. We plan to have a funnel that opens up wide enough for a player to insert multiple chips at once. This funnel will be raised high enough that a person will not be able to stick their finger through the funnel and reach the rotating disk.

An ethical concern our project raises involves the containment of private user data. We plan on utilizing an HTML website to maintain, distribute, and update game data for players. Some of this data includes the player's amount of money remaining and the current amount of the pot for that round. This issue raises the concern of possible data leaks or piracy that can take place through malicious software attacks focused on web application data. These issues go against the IEEE Code of Ethics #9 - “to avoid injuring others, their property, reputation, or employment by false or malicious action” [9]. To mitigate this issue, we will implement a web application firewall that will check all incoming traffic and prevent any incoming, malicious attacks. Additionally, we plan on encrypting the game data as well for an extra layer of protection against attackers. Finally, we will provide a notification to users to remind them to check to make sure their external device currently has no malicious software embedded into it that can potentially compromise the website.

Since the game of poker involves the aspect of money, both the mobile device and LCD display should reflect the correct amount of money that each player currently has as well as the correct amount of money in the pot. Our project raises the concern these values can possibly be skewed. This concern violates the IEEE Code of Ethics #3 - “to be honest and realistic in stating claims or estimates based on available data” [9]. To avoid violation, we will accurately store the correct user inputted data as well as perform correct arithmetic on these values. Lastly, we will effectively update these now-changed values and correctly display them on the proper interfaces, so users can properly see them.

Finally, to avoid violation of IEEE Code of Ethics #1 - “hold paramount the safety, health, and welfare of the public, to strive to comply with ethical design and sustainable development practices, and to disclose promptly factors that might endanger the public or the environment” [9]; we accept responsibility for our design. Our project aims to ensure the safety of its users and while we hope to test all possible scenarios there are a billion more that may occur. Specifically, we want to ensure users are completely safe from the mechanics within the main unit like the chip reading system. Therefore, we accept responsibility for faults in our design and ensure we take appropriate action to ensure better user safety when these faults occur by updating our design.

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