ECE 445
Senior Design Laboratory
Design Document

BAGS:

Bags Automated Game System

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February 23, 2023

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1. Introduction

1.1 Background

Cornhole, or bags, is one of the most beloved sports in the Midwest. The American Cornhole League boasts over 100,000 registered members who compete in roughly 25,000 tournaments per season [1]. It is also known as a great casual past-time, with as many as 25 million people playing the game worldwide [2]. The game is played with two opposing teams of two. The game consists of 8 total bags, 4 for each team, with two angled, opposing boards spaced around 15 feet away from each other. Players take turns throwing bean bags at the opposing boards in an attempt to either land their bag on the board or into the hole cut out on the board. Each bag on the board awards that player's team with one point while making it into the hole is three points. The game ends when either team reaches 21 points.

1.2 Problem

Due to its fairly simplistic nature, cornhole is a staple at events such as barbecues, tailgates, and other outdoor get togethers. Some other staples at these types of events are adults drinking, energetic children, and engaging conversations. While these are great and part of what makes these events fun, they are distractions that can affect one's ability to keep track of the score. This can lead to heated arguments that are heightened due to alcohol consumption or take away the competitive edge as it can devolve into just throwing bags back and forth with no clear objective. Once losing track of the score of the game, it can be difficult and frustrating to realize the players either need to start over or have no idea who has actually won the game.

1.3 Solution

To combat participants losing track of score, we will be removing the need for them to score the game entirely. This will be accomplished by creating a set of bags, a board with a sensor array, and an app that will automatically score the game for them.

The Bags Automated Game System is meant to appear as a normal cornhole game that can be played fully as a traditional cornhole set. Underneath the board, there will be an array of sensors mounted to the back that will be able to determine which bags are hitting the board and then when. The primary sensor to be used to do this on the board is the RFID detection system. RFID (Radio-frequency identification) uses electromagnetic fields to wirelessly communicate between objects for identification and location purposes [3]. To detect a bag falling into the hole, we will be placing IR emitter and receiver in the hole, which when momentarily broken, will determine that a bag has completely fallen into the hole.

These sensors will deliver the board information to the control unit which will communicate wirelessly via Bluetooth via an app on your phone. When the round is over, the user will be able to press the “End Round” button on the app to send a signal back to the board, indicating to the system that it is time to score the game and present that information on the app to the user. The score will be updated and shown to the user as well as current game statistics, including the percentage of bags that have hit the board. In doing this, we are creating a more efficient and automated way of cornhole score tracking that allows the user to play stress-free and not have to worry about forgetting the score or scoring incorrectly.

1.4 Visual Aid

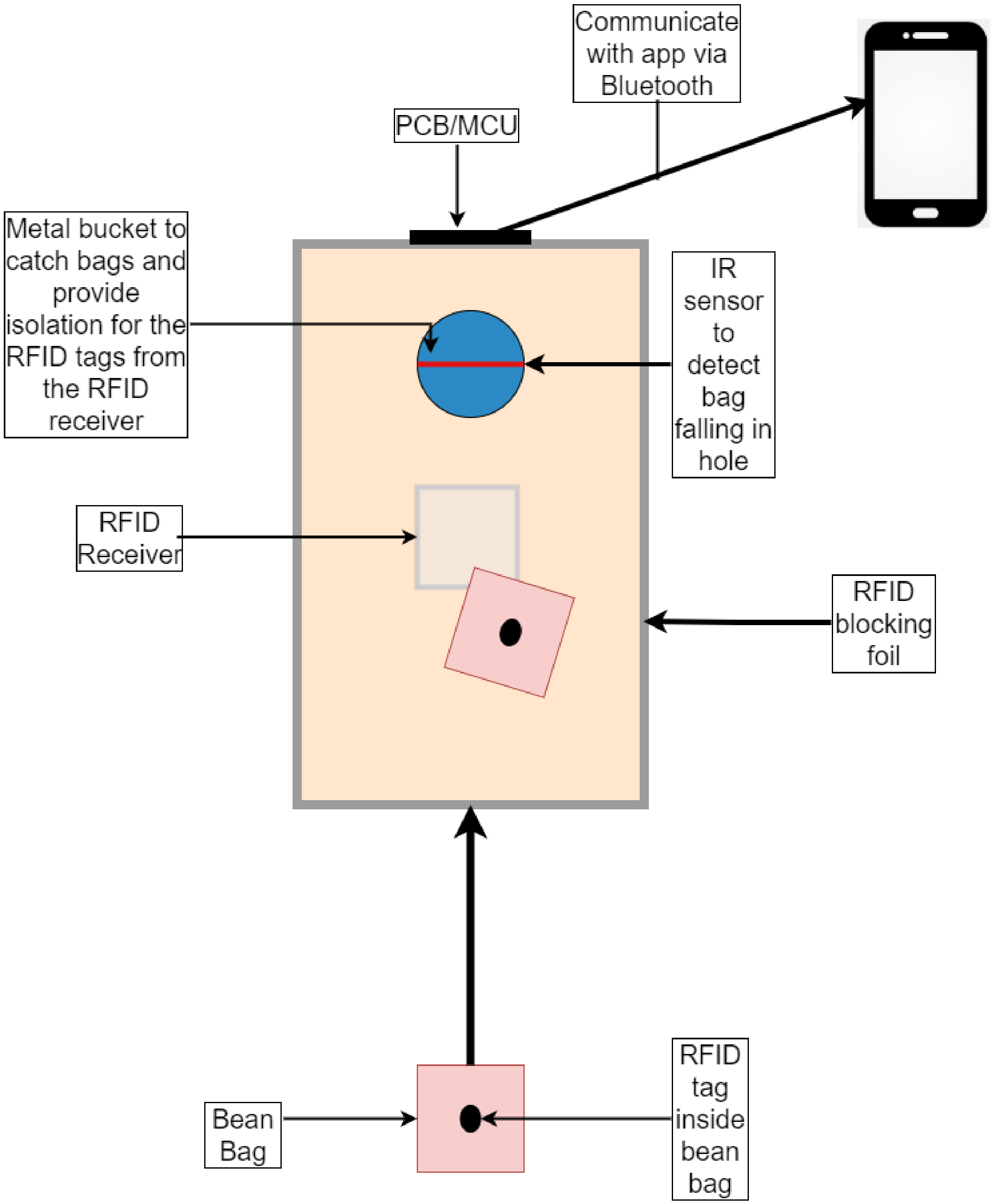


Figure 1: Visual Aid

2. Design

2.1 Block Diagram

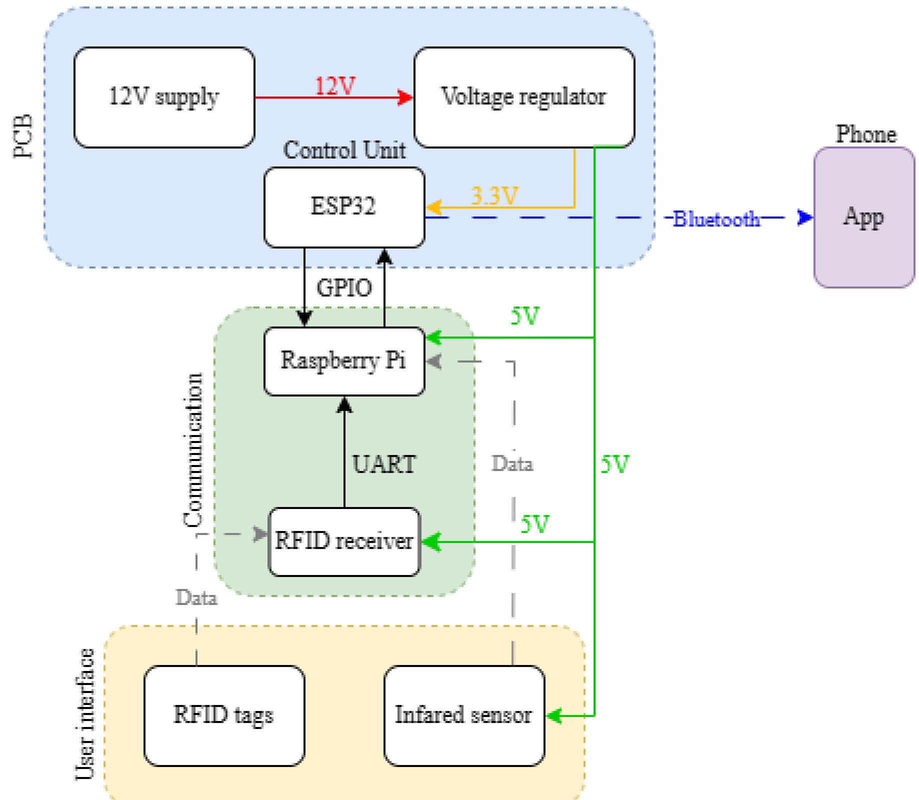


Figure 2: Block Diagram

2.2 Physical Design

It would be impossible to play cornhole without a physical board to make up the structural component of the game. For the physical board, we chose to purchase the EastPoint Sports standard plastic cornhole board. The board was chosen for its lightweight and portable size that allows us to conveniently transport it from place to place to test and demo. The dimensions of the board are 23.5x18x4.25 inches, as shown in Figure 3, creating a total board surface area of 423 square inches that can be fully covered by the read range of the Sparkfun M6E Nano RFID reader. The EastPoint Sports Cornhole board was also purchased for its convenient handles for portability as well as its compliance with project budget constraints [4].

The final reason that the EastPoint Sports board was chosen was for its plastic material makeup. Many traditional cornhole boards are wooden, which leads to significantly more signal loss through the surface of the board as opposed to a plastic board. Even for a board made out of plywood, it can be expected to see a signal loss of -4 dB to -6 dB. Another consequence of using a wooden cornhole board is the fact that wooden boards contain significantly more moisture than plastic boards. Since cornhole is traditionally played outside, it can be reasonable to assume that our board may face exposure to the elements. When plywood is exposed to moisture, this signal loss can jump up to -20 dB, making it impossible for our RFID reader to receive the signal [5]. In comparison, the EastPoint Sports board holds relatively little moisture, leading to a much smaller signal loss throughout the board. Plastic overall has relatively less signal loss throughout the material, making it a better choice for this project.

The electrical components will be mounted by the ECEB Machine Shop directly underneath the surface of the board. By being mounted directly under the board, the RFID reader should be able to more easily detect RFID tags with less signal loss. This location underneath the board also allows for less exposure to the elements, protecting components that could potentially be damaged by hazardous weather or exposure to the sun. To prevent the RFID reader from detecting RFID tags in bag misses and incorrectly counting those as hits, there will be a layer of RFID blocking material wrapped around the sides of the board, providing RF shielding that will allow the RF antenna to only detect the bags that land on the board itself. This will also provide further protection for the electrical components from the outside elements. For a further discussion on the shielding of the board, see the Tolerance Analysis section.

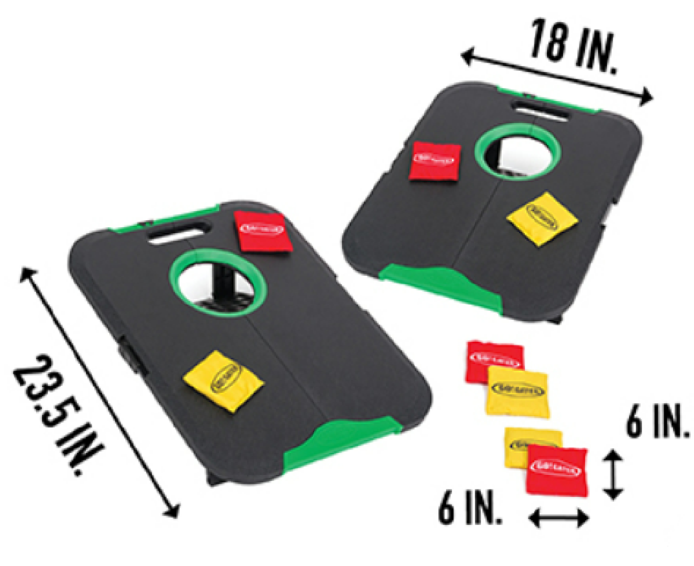


Figure 3: Physical Cornhole Dimensions

2.3 Subsystems

2.3.1 Power Subsystem

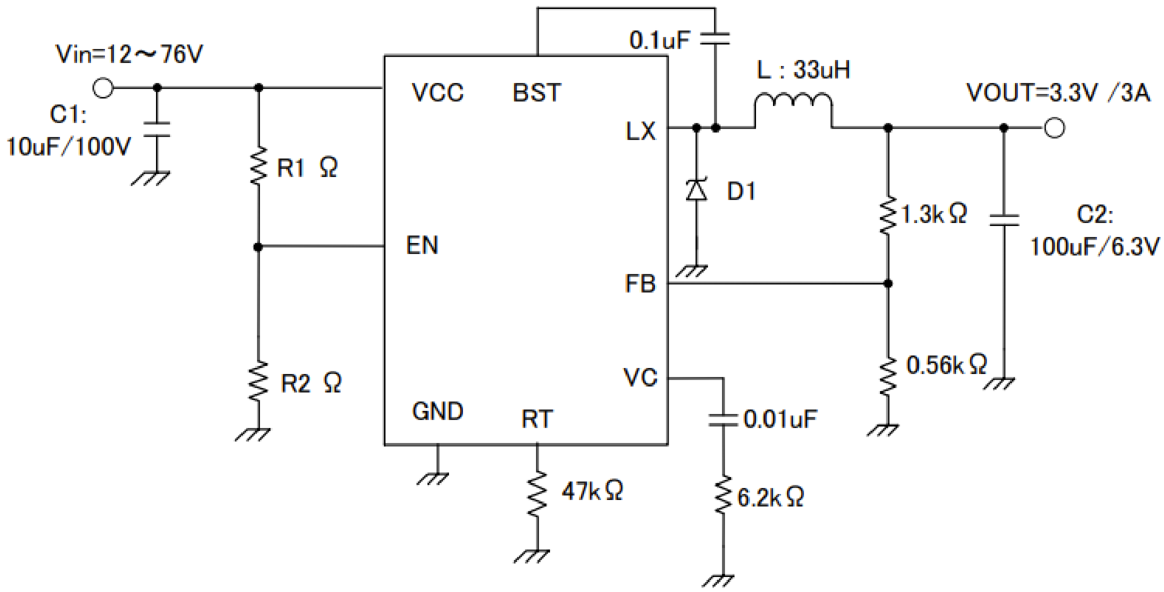
The power subsystem will be located on the PCB and will provide adequate power to all our components including the Raspberry Pi, ESP32, IR emitter/receiver combo, and the RFID receiver. It consists of 12V battery and two buck switch regulators and will be mounted underneath the surface of the cornhole board. We will need to provide regulated voltage to the microcontroller (ESP32), the IR emitter/receiver, the RFID receiver (SparkFun Simultaneous RFID Reader with M6E Nano module), and the Raspberry Pi from our 12V battery. The ESP32 is physically attached to the PCB alongside the buck switch regulators, Raspberry Pi and RFID receiver. In order to power all the other components that aren't directly attached, the appropriate wiring will be made to sufficiently power the IR emitter and receiver.

The main purpose of our PCB is to supply voltage to all the necessary components and to ensure that enough voltage and current is delivered to ensure all the components are properly working.

	Vishay / Small Signal & Opto Products (SSP) TSOP4838- Infrared Transmitter	Siliconix / Vishay TSOP34838- Infrared Receiver	ESP32 WiFi-BT-BLE MCU Module /	Raspberry Pi 3 B+	Simultaneous RFID Reader
Current Draw	5 mA	3 mA	Min (not transmitting Bluetooth): 500 mA Max (transmitting Bluetooth): 630 mA	2.5 A	170 mA
Voltage Draw	5 V	5 V	3.3 V	5 V	5 V

According to the ESP32 datasheet [6], a 3.3V DC input is needed. In order to step down from 12V to 3.3V, we will be using the BD9G341AEFJ 1ch Buck Converter Integrated FET. It has capabilities of taking inputs in the range of 12-76V and stepping down to a desired voltage based on its configuration. Using the suggested configuration in BD9G341AEFJ's datasheet [7] (fig. 4) will provide the needed 3.3V to power the ESP32 as well as plenty of current to meet the 630mA the ESP32 draws when emitting Bluetooth.

Reference Characteristics of Typical Application Circuits
Vout=3.3V, f=200kHz
(All the external components can be substituted by equivalents)

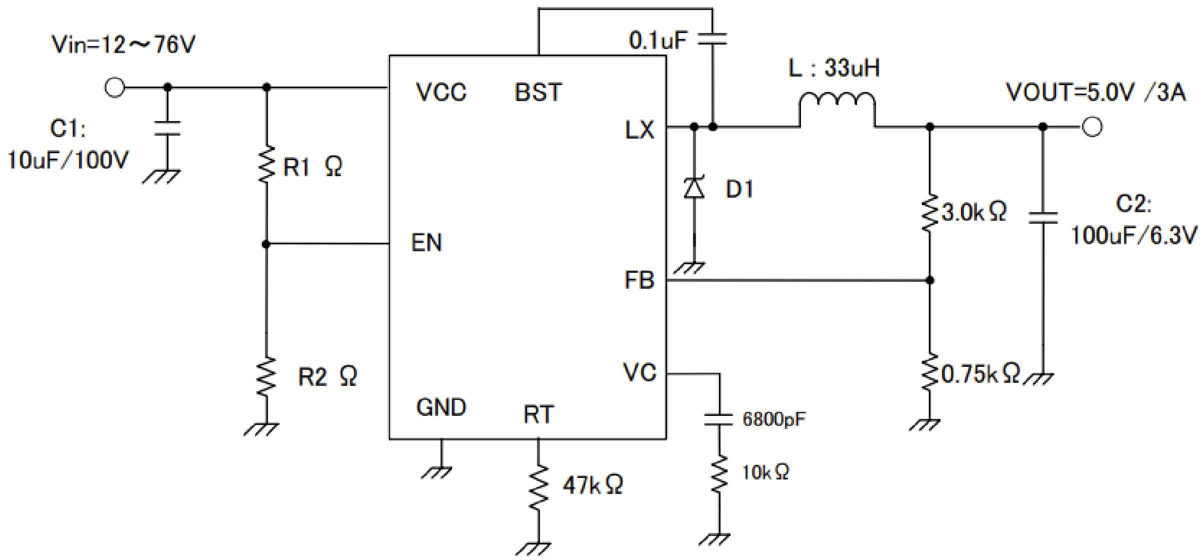


Parts :	L	:SUMIDA	CDRH129HF	33μH
	C1	:TDK	C5750X7S2A106K	10μF/100V
	C2	:TDK	C4532X5R0J107M	100μF/6.3V
	D1	:Rohm	RB095BGE-90TL	

Figure 4: 3.3V converter configuration

For the IR emitter/receiver, the RFID reader, and the Raspberry Pi we will be using the BD9G341AEFJ, the same buck converter used to step down to 3.3V for the ESP32. We will use the configuration provided in the BD9G341AEFJ's datasheet (fig. 5) to provide the 5V needed for our IR system and RFID reader. The RFID reader can operate with a range of 3.7V-5V DC input. According to the M6E Nano's datasheet [8], only 3.7V is needed to produce maximum output power of 27dBm (Fig. 6). Despite this, we are opting to deliver 5V to it because we already have a converter to step down to 5V for the IR emitter/receiver and implementing a third converter would introduce more losses.

Reference Characteristics of Typical Application Circuits
Vout=5V, f=200kHz
(All the external components can be substituted by equivalents)



Parts :	L	:SUMIDA	CDRH129HF	33μH
	C1	:TDK	C5750X7S2A106K	10μF/100V
	C2	:TDK	C4532X5R0J107M	100μF/6.3V
	D1	:Rohm	RB095BGE-90TL	

Figure 5: 5V converter configuration

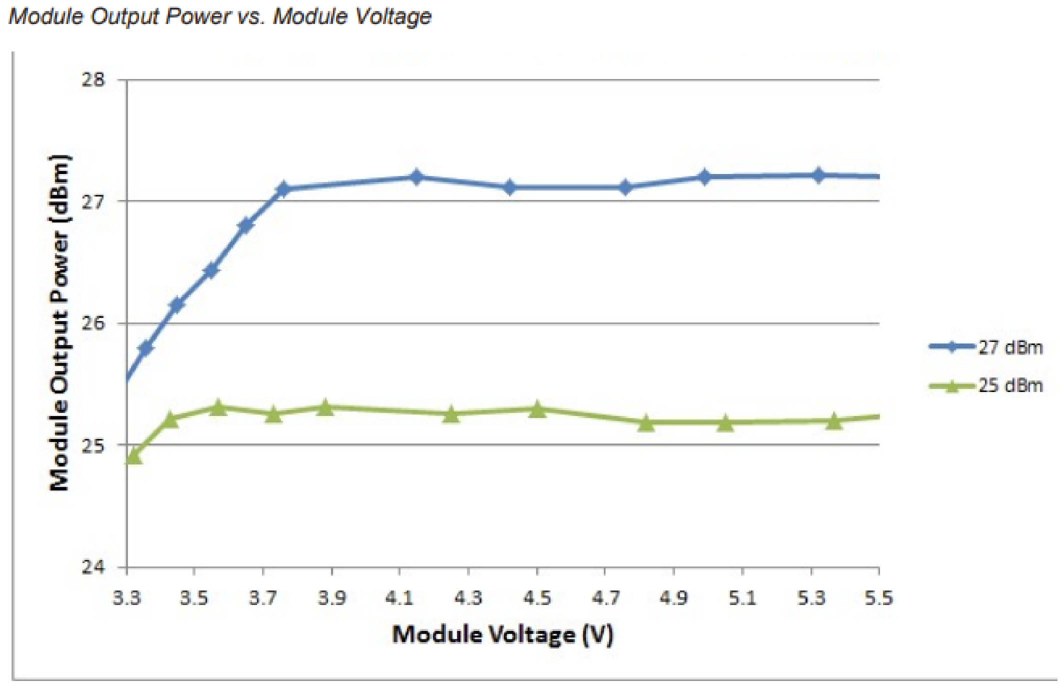


Figure 6: RFID receiver output power vs. voltage

Requirement	**Verification**
BD9G341AEFJ Buck Converter must be able to safely take an input of 12V from the battery and step down to 5V +/-5% (4.75V-5.25V) and appropriate currents for each component: - IR emitter: 3-7mA - IR receiver: 1-5mA - RFID receiver: 100-200mA - Raspberry Pi 3: 2-3A	1. Use an oscilloscope to probe and display the voltage output of the 12V battery. 2. Use an oscilloscope to probe and display the voltage and current output of only the buck converter. 3. Observe if current and voltage outputs are within desired voltage range.
BD9G341AEFJ Buck Converter must be able to safely take an input of 12V from the battery and step down to 3.3V +/-5% (3.135V-3.465V) while providing 500mA-660mA to supply power. to the ESP32	1. Use an oscilloscope to probe and display the voltage output of the 12V battery. 2. Use an oscilloscope to probe and display the voltage output of only the buck converter. 3. Observe if current and voltage outputs are within desired voltage and current ranges.

A 12V battery must be able to provide sufficient power to ESP32, IR emitter/receiver, RFID receiver, and Raspberry Pi simultaneously.	1. Use an oscilloscope to prove and display the voltage output of the 12V battery. 2. Use an oscilloscope to probe and display the voltage and current inputs to a device while all others are also connected. 3. Observe if current and voltage outputs are within desired ranges for each device while all devices are connected. 4. Repeat the process for each device. 5. Play a test game, utilizing all devices to determine if all sensors and receivers are working as expected.
Enclosure containing the PCB/Power system must be able to stand up to a sustained amount of rain.	1. Spray board with a hose shower attachment for 10 minutes to simulate rain. 2. Try to play a game of cornhole while the board is being sprayed with water with no functionality issues or part failures. 3. Try to play a game of cornhole two hours after being sprayed with water or until fully dry. 4. Check for any water leakage/damage inside of the enclosure.

2.3.2 User Interface Subsystem

The user interface subsystem consists of the sensor components that will actively be interacted with during gameplay. This consists of two main components: the RFID tags located in each game bag and the infrared sensor that will detect game bags that go in the hole. The RFID tags will interface with the RF antenna whose data will be read by the RFID reader (for more information, see P.15). The infrared sensor will be placed across the hole underneath the cornhole board. When a bag falls in the hole, the infrared sensor will sense a momentary obstruction that will later be transferred into game data indicating 3 points. The infrared sensor data will be sent to the Raspberry Pi where it will be processed and stored before being sent via Bluetooth to the mobile app to be calculated into the game score. These components are vital to the scoring of the game as they are the sensors that will actively detect the bag hits which will eventually become the game score.

RFID Tags

For the RFID detection system, we will be using passive RFID tags in each of the bags to function with the RFID reader. The SparkFun M6E Nano is able to read EPCglobal Gen 2 passive tags in the 859-960 MHz range [9]. We decided to work with the Sparkfun UHF Adhesive RFID Tags as they operate at the same frequency range as the reader and are easily attached via adhesive to the fabric material on the inside of the bags. Their paper thin design means that the weight of the bags will not be drastically impacted and the tags will not be destroyed after throwing the bags at the board. Each tag comes with a TID (Truly Unique ID) and is able to be read and written to, which would allow us to be able to distinguish between each team's bags [10].

IR Emitter/Receiver

For the infrared emitter, we will be using the Vishay TSOP4838. The device emits a 38 kHz beam that will be received by our receiver, the Vishay TSOP34838. Both of these devices were selected because they each draw very little current and have strong immunity to ambient light, a useful feature for a game played in sunshine such as cornhole. When a connection between the emitter and receiver is established, the receiver outputs a high voltage signal. When this connection is broken, the receiver's output voltage will be low [11][12]. This data will be sent to the Raspberry Pi via one of its GPIO pins, where it will be processed to award the throwing team 3 points.

Requirement	**Verification**
The IR emitter must be able to emit a strong enough signal to be detected by the receiver. Receiver must also have a meaningful change in output voltage when the connection is broken (going from 4.7V-5.3V when connected to -0.3V-+0.3V when connection is broken)	1. Place the IR emitter and receiver pair 6 inches apart (same length as the diameter of the hole). 2. Supply 5V of power to both emitter and receiver and probe and display the output pin of the receiver with an oscilloscope, as well as connect the receiver to an inverter that connects to an LED on a breadboard 3. When IR emitter and receiver connection is established, receiver output should be in the range of 4.7V-5.3V. 4. Cover the emitter or receiver with a fabric to observe change in output. Voltage output should now be in the range of -0.3V-+0.3V and the LED should light up
Bags that have fallen into the hole should not be detected by the RFID receiver.	1. Drop a singular bag into the metal bucket inside the hole 2. Check the Universal Reader Assistant to run the READ EPC command. 3. If a tag is detected by the READ EPC command, the hole has not been successfully shielded and needs further RF shielding. If a tag is not detected, the system is working as intended. [13]
The RFID tags must be able to	1. M6E Nano board will be connected to a laptop

be read through the material of the bag and board.	computer for power by plugging in the serial breakout board via USB. 2. The Universal Reader Assistant program will be run, which is a Windows program designed to help test capabilities of M6E-Nano. 3. The Universal Reader Assistant will connect to the board, sending a ping to verify the module's existence. 4. The tag will be fastened in the game bag, This game bag will be placed under a sheet of plastic approximately 1" thick, and the RFID reader will be placed on top. 5. The READ EPC function will be run. If the tag is correctly detected, the function will return with "RESPONSE_SUCCESS" and the EPC (Electronic Product Code) will be stored in the array. 6. The game bag will be moved in increasing intervals (1", 2", 3" and so on) until it is no longer able to be read by the RFID reader, and this maximum read distance will be recorded. [13] *See also Verification Procedure #1 for control unit for a similar procedure setup to test RFID reader functionality.
Multiple RFID tags must be able to be read at the same time.	1. Similar process will be used as the previous verification method to set up the RFID components. 2. Another RFID tag will again be placed in a separate game bag and placed under an approx 1" sheet of plastic which will be underneath the RFID reader. 3. Using the Universal Reader Assistant set to constant read, the READ EPC function will be used to detect the bag. 4. If that bag is detected, another RFID tag will be added in a separate game bag. 5. The number of bags will keep increasing until the RFID reader either fails to detect a bag or until the number of bags reaches 8 total.

2.3.4 Control Subsystem

The control subsystem is the brains of the operation that will function as a central location where the sensor data from the user interface subsystem will be received and stored as well as be able to communicate with the other subsystems. The control subsystem is divided into two main groups: the communications and the microcontroller. The microcontroller we have decided to use is an ESP32, which we have decided to use for its Bluetooth capability and compatibility with the Raspberry Pi 3. The ESP32 module will be connected to the Raspberry Pi via GPIO pins and will be used to enable Bluetooth capabilities on the Raspberry Pi. Bluetooth capabilities are needed on the Raspberry Pi to allow for sensor data stored in the RPI to be wirelessly communicated between the game board electronics and the mobile app. The other primary group within the control subsystem is the communications system, which consists of the RFID Reader and Raspberry Pi 3 itself.

RFID Reader Detection, Communication System

To detect the bags that land on the cornhole board, we will be relying on RFID detection. Radio-frequency identification (RFID) is used to communicate wirelessly with the passive RFID tags via electromagnetic waves. The RF antenna, conveniently built into the RFID reader, is used to transmit data to the RFID reader in the form of radio waves. The RFID reader then converts this data into a more usable form of data that signifies if the antenna was able to pick up any RFID tag signals in the read range [3]. This information is then transferred through UART to the Raspberry Pi, where the data can be stored in a database to later be analyzed to create the game score.

The Raspberry works in conjunction with the RFID receiver to act as a communication system on behalf of the control unit to properly send data over the ESP32 module to then show information over to the app via Bluetooth.

One of the most vital aspects of this project is ensuring that the RFID reader is able to read the RFID tags through both the material of the bag and the board. To do this, it is necessary that our RFID reader has a read range sufficient to cover the entirety of the cornhole board. Our cornhole board has dimensions of 23.5 x 18” [4], meaning that if the RFID reader was mounted underneath the very center of the board, it would need to have a read range of at least 12” in every direction. RFID read range is dependent on a number of factors, the primary one being the frequency band in which it is operating. To obtain a read range of around 12”, it was determined that we needed to operate within a high-frequency RFID system. The most ideal frequency band to operate at for this system was researched to be 859 MHz to 930 MHz, which typically delivers a read distance of up to 7 feet away [14]. From there, it was decided that the most ideal RFID reader to cover the set read range was the SparkFun Simultaneous RFID Reader- M6E Nano. The M6E Nano was chosen for a variety of reasons, as shown below:

1. **Ability to Read Simultaneous Tags**

The M6E-Nano is able to read multiple unique tags simultaneously. This is instrumental to our project as the sensor array needs to be able to locate each individual bag and be able to determine the differences between each bag in order to correctly assign points between teams.

2. **Powerful Onboard Antenna**

This RFID reader contains an onboard antenna that is able to read from a distance of 1-2 feet. This is ideal due to the size of our board and allows us to avoid having to purchase an external antenna. The onboard antenna is also linearly polarized, which is ideal as we only care about bags that land on the flat cornhole board plane.

3. **Read Range**

As mentioned before, the primary reasoning behind our choice in RFID antenna was its read range. The 1-2 feet of read range given by the onboard antenna should be sufficient for covering the entirety of the board, as well as allowing the tags to be read through the plastic material. [9]

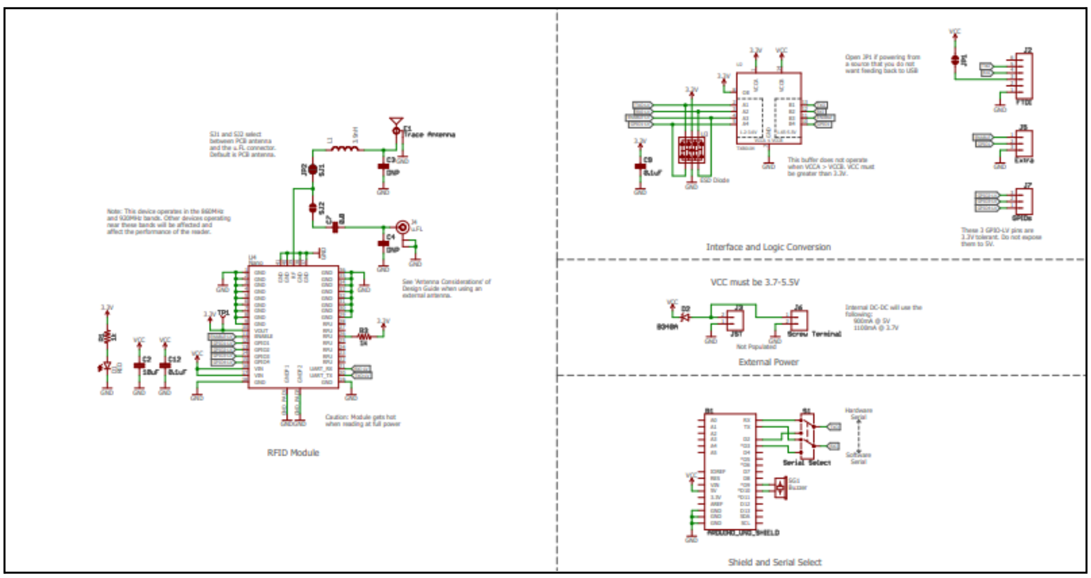


Figure 7: SparkFun M6E Nano Schematic [9]

Requirement	**Verification**
1. RFID reader must be able to correctly receive signals from the RFID tags that exist within the game bags.	1. M6E Nano board will be connected to a laptop computer by plugging in the serial breakout board via USB. 2. The Universal Reader Assistant program will be run,

	which is a Windows program designed to help test capabilities of M6E-Nano. 3. The Universal Reader Assistant will connect to the board, sending a ping to verify the module's existence. 4. A tag will be placed within a game bag and placed next to the M6E Nano. 5. The READ EPC function will be run. If the tag is correctly detected, the function will return with "RESPONSE_SUCCESS" and the EPC (Electronic Product Code) will be stored in the array. [13]
2. Raspberry Pi must be able to communicate signals from the RFID receiver through GPIO pins.	1. Once it has been verified that the RFID reader is able to receive the signal of the bags, it is time to ensure that the Raspberry Pi can communicate this data through its GPIO pins. 2. The M6E-Nano will be configured to constantly read the tags placed within its range using the Constant Read function set up via Universal Reader Assistant. 3. External power supply will be connected to Raspberry Pi to provide it with 5 V power. 4. M6E Nano will be connected to Raspberry Pi via UART. Tags will be placed directly next to M6E Nano to pick up a signal. 5. Voltage will be probed at Raspberry Pi GPIO pins using a digital multimeter to ensure signal is being received and output. Voltage increases should correspond with the tags being placed next to the RFID reader.
3. The ESP32 must be able to communicate via Bluetooth with both the Raspberry pi and the app.	1. The Serial Bluetooth Terminal app will be downloaded to an Android phone. 2. The ESP32 will be connected to the Raspberry Pi via GPIO. Using the Raspberry Pi, an object of class 'BluetoothSerial' will be created and communication will begin using the 'begin()' function. 3. In a loop function, read data from BluetoothSerial and print it on the Serial Monitor. The opposite will then be done, and data will be written to BluetoothSerial. 4. After writing data to BluetoothSerial, the Bluetooth Terminal App will print that data on screen. 5. After typing data in the app and sending it back over Bluetooth, the BluetoothSerial will print this data on the Serial Monitor. 6. By doing this, we can ensure Bluetooth communications are working both ways on the ESP32. [15]

2.3.4 App Subsystem

The app subsystem is responsible for keeping track of game statistics, which information will be received through the ESP32 Bluetooth module. This application will be made via Unity, a game development software. Although it may seem more intuitive to work with Android Studio, past projects have shown inconsistent communication results with Bluetooth and the app. To circumvent this issue, a Bluetooth LE asset will be purchased to ensure consistent communication results from the ESP32 module to the app [16].

The app itself doesn't have any direct impacts on the actual gameplay of bags, rather it is a medium to manage score, game statistics and methods for improvement. An important aspect of the app is to effectively gather data from the ESP32 module, create game statistics, and keep track of the game.

Requirement	**Verification**
1. Receive data from the ESP32 module via Bluetooth	1. A test signal will be created using Raspberry Pi to communicate to the ESP32 module once the ESP32 module Bluetooth connection has been verified to work. 2. The signal will be sent to the app via Bluetooth to ensure the signal is received and the app is able to connect to Bluetooth. a. Test data received is echoed onto the app.
2. After marking the end of the round, the app can produce game scores within 60 seconds.	1. Working with the procedure from above, use a stopwatch to measure the time it takes from the information to be sent from the board electronics to the mobile app. a. If too slow, latency must be low.
3. The app is responsive to user inputs.	1. Upon pressing the "End Round" button, the app should send a signal back to the board system to score the game. 2. We will code the app to send a "1" as data back to the Raspberry Pi when the "End Round" button is pushed. 3. If the Raspberry Pi receives the 1 signal, the app has shown that it can respond to user inputs and both read and write inputs. 4. In the final product, the user should be able to open up past game history (up to the last two or three games) and the score of the game. This will be checked against the known score of the game to ensure it is accurate.

2.4 Tolerance Analysis

RF Shielding

The focal point of the entire cornhole board system is the sensor array on the board used to determine where the bags are thrown, specifically the RFID detection system. One of the most challenging portions of this project is ensuring that the RFID detection only detects bags that have fallen on the face of the board. We need to ensure that bags that either miss the board entirely or fall into the hole are not counted by the RFID reader. To accomplish this, there are a series of precautions we plan to implement into our project.

Outer Board Shielding

To eliminate the possibility of bags that are misses being detected as hits on the board, we plan to wrap the outer perimeter of the board with RF shielding fabric. For this fabric, we chose RFID Blocking Fabric sold by SpecialtyFabric. This fabric is described as "Woven Nickel Copper Radiation Proof Conductive EMP shielding nylon fabric." It is extremely thin, allowing for easy transport, and large enough to cover the outer perimeter of the board. The shielding efficiency of this fabric is 70-84 dB, which should be sufficient to successfully shield the bag misses. It shields signals in the frequency range 30MHz-1500MHz [17]. This is ideal to shield signals coming from the tags at the 859-930 MHz range but not absorbing signals needed for Bluetooth communications at the 2.4GHz frequency band.

Inner Hole Shielding

For the same reason as the previous item on the list, we also want to shield the inner hole so bags that fall in the hole are not counted as also being on the board. To do so, we plan to fasten a small metal bucket underneath the hole, so tags located in the hole are not received by the RF antenna. The inside of the bucket will be covered again with the RFID blocking fabric to absorb signals coming from the tags in the 859-960MHz range. This should provide around 70-84 dB of shielding effectiveness [17].

These shielding tactics together coupled with the read range of the antenna discussed on P.16 should together create a well-defined RFID read zone that will allow the RF antenna to only pick up signals from the tags on the board itself. Our last precaution is running the RF antenna at the full 27dBm power output. This will help to extend the read range of the antenna slightly and allow us to further create a well-defined read zone [18].

Power Consumption

Another challenge faced is providing enough power to all our components to run for a sufficient amount of time. The battery's lifespan should be expected to last about an hour to two.

	Vishay / Small Signal & Opto Products (SSP) TSOP4838- Infrared Transmitter	Siliconix / Vishay TSOP34838- Infrared Receiver	ESP32 WiFi-BT-BLE MCU Module /	Raspberry Pi 3 B+	Simultaneous RFID Reader
Current Draw	5 mA	3 mA	Min:500 mA Max: 630 mA	2.5 A	170 mA
Voltage Draw	5 V	5 V	3.3 V	5 V	5 V
Power Draw (P= V * I)	0.025 W	0.015 W	Min: 1.65 W Max: 2.08 W	12.5 W	0.85 W

Our battery is rated at 12 V with an 8Ah capacity. Using P= V*I, this gives us a capacity of 96Wh. Using values from the table above, we can calculate the power draw levels.

- In a standby state, the power draw is 15.04 Wh
- While transmitting Bluetooth, the power draw is 15.47 Wh

The longevity of our battery is mostly limited by our current draw, as the Raspberry Pi 3 B+ draws 2.5 A for operation. At a minimum we are drawing 3.178 A of current for the whole system and when we are transmitting through Bluetooth we are drawing 3.308 A. Given the rating of our battery is 8Ah, we can expect 2.42-2.52 hours of continuous play before needing to recharge the battery. This is fine for the purpose of our product, as events where bags are played most are not happening every day of the week and tend to not last more than 2.5 hours regardless.

3. Cost and Schedule

3.1 Cost Analysis

The first calculation needed to decide the total cost of this project is the total cost of all the components that are going to be used. The sum of all the components listed in the table below adds up to be $382.47. Subtracting components we already own, this becomes a total cost of $339.95. We must also calculate the total labor costs associated with this project. For this project, we can expect an hourly rate of $40 for our work. The entirety of the senior design project from project approval to the end of the course is around 12 weeks. Assuming we spend around 15 hours a week each on this project, and using the fact that our team is 3 people, the total cost of labor would be $40/hr x 15 hrs/week * 12 weeks * 3 team members = $21,600. This would add up to a total project cost of $21,939.95.

Description	Manufacturer	Quantity	Extended Price	Link
Simultaneous RFID Reader	SparkFun Electronics	1	$224.95	Link
UHF RFID Tags- Adhesive (5 pack)	SparkFun Electronics	2	$2.95	Link
Switching Voltage Regulators 1ch Buck Converter Integrated FET	Mouser Electronics	2	$4.62	Link
Vishay / Small Signal & Opto Products (SSP) TSOP4838- Infrared Transmitter	RS Americas	1	$0.63	Link
Siliconix / Vishay TSOP34838- Infrared Receiver	RS Americas	1	$0.60	Link
Gater, Cornhole, Light Up and Standard Available, Easy Storage, Light Weight Perfect for Outdoor and Indoor Play	EastPoint Sports Go!	1	$29.99	Link
Red LED *	Rohm Semiconductor (Already Owned)	1	$0.53	Link
Micro USB to USB cable *	Best Buy Essentials (Already Owned)	1	$6.99	Link
XR-46F Plastic Electronics Enclosure	Polycase	1	$7.97	Link
Raspberry Pi 3 B+ *	SparkFun Electronics (Already Owned)	1	$35.00	Link

ESP32 WiFi-BT-BLE MCU Module / ESP-WROOM-32	Adafruit	1	$3.95	Link
RFID Blocking Fabric	SpecialtyFabric	1	$10.73	Link
Bluetooth LE Asset for iOS, tvOS, and Android	Unity Asset Store	1	$20.00	Link
12-Volt 9 Ah UPS Battery Replacement for APC BE550G	The Home Depot	1	$24.99	Link
Tin Pail with Handle	Walmart	1	$1.00	Link

* The Indicated component is already owned and does not need to be purchased.

3.2 Schedule

Date	Huq	Epplin	Schaufelberger
20 - 27	Software researching, PCB drafting	Components researching and ordering	Components researching and ordering
27 - Mar 5	Software applications are in the works PCB design is finalized	PCB design is finalized Sensor and components all ordered, actual building begins	Sensor and components all ordered, actual building begins Begin working on modularization
5 - 12	PCB design finalized, order is sent out Teamwork evaluation filled out Software development	PCB design finalized, order is sent out Teamwork evaluation filled out RF shielding prototyping	PCB design finalized, order is sent out Teamwork evaluation filled out Firmware in progress
12 - 19	Spring break	Spring break	Spring break
19 - 26	Document updating Software development	Document updating Unit testing of subsystems RF shielding testing	Document updating Unit testing of subsystems Firmware development
26 - Apr 2	Software done Debugging	Debugging RF shielding + systems completed	Firmware testing
2 - 9	Debugging and testing software with firmware Mock demo testing Mock presentation preparation	Debugging and testing software with RF shielding Mock demo testing Mock presentation preparation	Debugging and testing software with firmware Mock demo testing Mock presentation preparation
9 - 17	Final presentation preparation Final paper work	Final presentation preparation Final paper work	Final presentation preparation Final paper work
17 - 24	Mock demos Final demos	Mock demos Final demos	Mock demos Final demos

4. Ethics and Safety

For a successful senior design project, it is imperative that safety and ethics policies are followed throughout the entire process.

For a successful project, any potential safety concerns with the project must be addressed (IEEE Code of Ethics I.1) [19]. Because our project is an auto-scoring cornhole game, there are not many immediate safety risks to users. However, there is the potential of electrical shock or fire due to faulty wiring or degradation of the board in inclement weather. This can be remedied by ensuring the wiring in our design is done with proper wires and that the board is built with weather-withstanding materials to protect the electronics. Although there is always going to be some risk, every care will be taken to minimize the little risk our project poses. \\

Ethical concerns must also be addressed to ensure that our senior design project is compliant with IEEE standards. Due to the nature of our project, the main ethical concern would most likely be plagiarism. In this project, designers will be researching several different components and methods and looking at other products in the automated game industry, such as auto-scoring dart boards. It is vital to make every effort to ensure each source is correctly cited and referenced in the senior design process.

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