ELECTRONIC BAG TOSS

By

Travis DeMint

Kabir Singh

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TA: Ryan May

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Abstract

For our project we have designed and built an electronic scoring system for the game of cornhole/bags. We implemented an antenna/reader system along with individual RFID tags to detect bags found on the surface of the game board during the end of one round of play. Inductive and capacitive proximity sensors were also used to detect bags that have passed through the center hole of the board. The microcontroller takes all possible inputs and computes an “end of round” score for each respective team until the game is won by one of the two teams.

Contents

1. Introduction

Cornhole, or bags, was originally adopted from the Blackhawk Native American tribe who "filled pigs' bladders with dried beans and competitively tossed them for entertainment" [1]. They would throw these pigs' bladders at various objects and mentally remember which player was able to hit the furthest target [1]. As the game progressed into its current form, its primitive method of scoring did not change. We propose to update this traditional game into modern times by being able to electronically keep track of both teams' scores. The user will toss their respective teams' bags on the game board, depending on where they land; the system will tabulate a correct score for each team. Three points will be awarded for each bag detected through the hole and one point will be awarded for each bag found on the game board surface. The score will be updated as each round is completed on one of the two boards. A number display will showcase each team's score.

1.1 Objectives

The main goal we are trying to address with the completion of this project is for two teams, consisting of two players each, to be able to successfully play the game of bags without having to keep track of their own scores. As a player from each team faces off, the game board will continuously check for a team's bag, either on the board (1 point) or through the hole (3 points). If it detects either of these two cases the microcontroller will output the updated score for each team during the end of a round.

Benefits:

- Teams don't have to remember their scores from each round
- Aesthetically pleasing score display
- Compact design does not alter traditional rules of play
- Game board weight should not significantly change with added electronic components, allowing for ease of mobility between site to site

Features:

- Electronic scoring
- Capacitive Sensor to detect Team 1's bags through the center hole
- Inductive Sensor to detect Team 2's bags through the center hole
- LED's light up indicating bag going through center hole
- Scores update after each side has thrown their respective set of bags
- Communication between both boards to output correct score
- 4 distinct RFID Tags assigned to each team to differentiate when scoring
- Switch for users to store previous round score and start the next round
- LCD indicating status of each round and showing the winning team for each game

1.2 Block Diagram

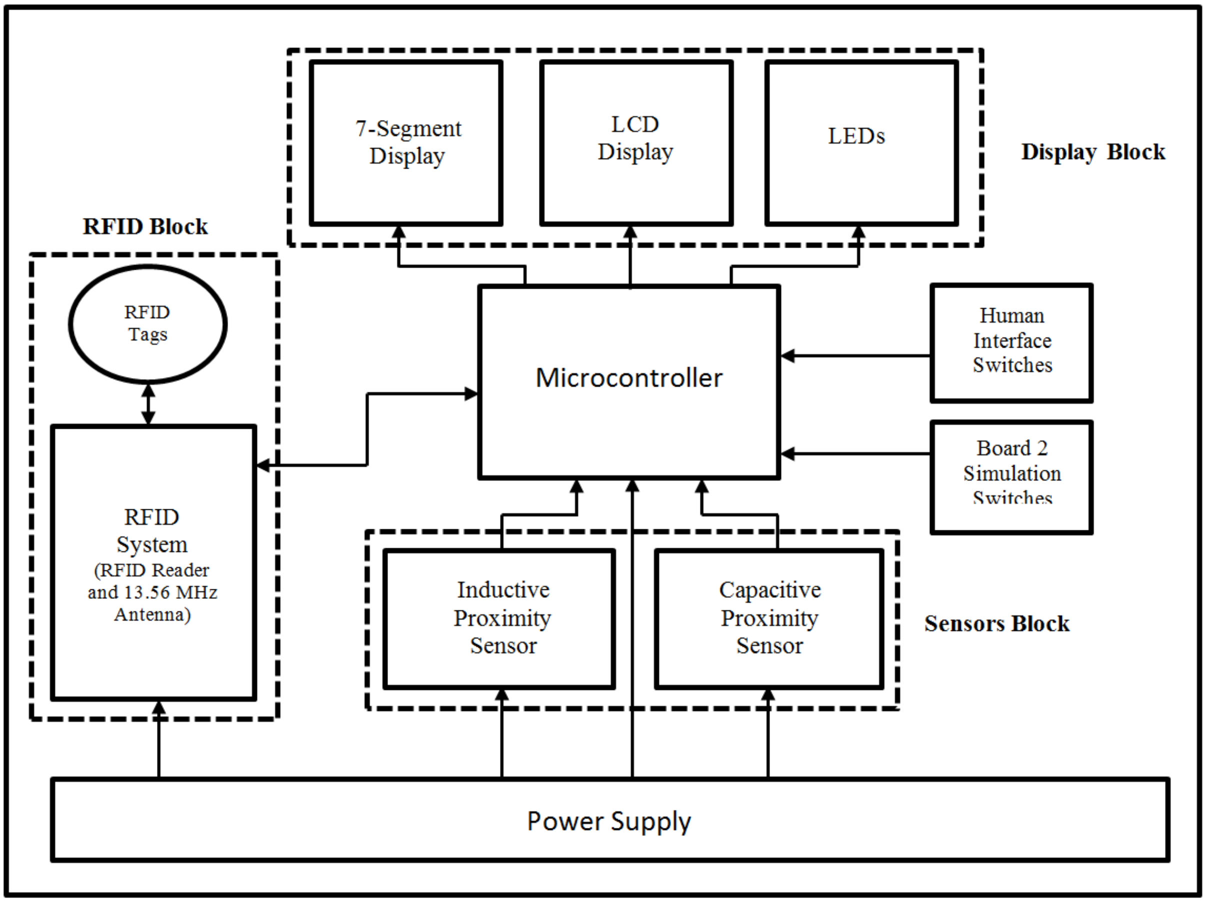

Figure 1.2 Block Diagram

1.2.1 RFID Block

The RFID Block consists of individual RFID tags to be placed in each of the eight bags. These tags will then be detected by the RFID system made up of an antenna connected to a RFID reader which converts the radio frequency signal received from the antenna into a readable serial string. This string is then sent to the microcontroller for further manipulation. Each time a bag is detected on the game board surface, once the "end of round" switch is flipped HIGH, the RFID block will communicate with the microcontroller to update the displayed score by a single point for each bag found on the surface.

1.2.2 Sensor Block

The sensor block is composed of an inductive and capacitive proximity sensor. These two sensors communicate with the microcontroller to distinguish between bags that have fallen through the center hole of the game board. Each of the sensors will trigger in a certain way when the two types of bags fall through the hole. Depending on the case picked up by the sensors, the microcontroller will increase one of the two team's score by three points for each detection. The distinguishing feature between the two sets of bags is that the red bags are filled with metallic BB's, triggering the inductive sensor, and the blue bags are filled with sand, triggering the capacitive sensor.

1.2.3 Display Block

The display block is made up of three different kinds of displays in order for the user to understand the status of the game at any point. The 7-segment displays are used to show each of the two team's scores until the end of a game has reached. The LCD is used to inform the users when a point update has occurred in the game. Its main feature, however, is to determine when the end of a game has taken place informing the users of the winning team and asking them to reset the game and play again. The LED display informs the users that a bag is passing through the center hole of either of the two game boards. The detection of a bag will trigger the eight LEDs to light up three times in a circular pattern.

2. Design

2.1 Design Alternatives

Our design stayed fairly consistent through the lifespan of our project. The two changes, however, that did take place were from the RFID Block and the Display Block, shown in Figure 1. Our initial design of the project had us using circular RFID transponder tags to communicate with the RFID reader/antenna system. After having a functioning RFID system, capable of detecting various types of 13.56 MHz transponders, we determined that we needed larger transponders in order to achieve the desired range of the entire game board surface. We replaced the smaller circular transponders with larger rectangular transponders and were able to achieve complete coverage of the game board. By increasing the area of the tag we were able to increase the reading range of the antenna.

The Display Block originally consisted of only the 7 segment display and LEDs. After having successfully completed the project, we found that there was no indication of when the game was to end. By adding the LCD to the Display Block we were able to inform the user of every point scored during the course of a game and determine a winner when a certain score was reached by one of the two teams.

2.2 Design Details

2.2.1 RFID Tags

Twelve, 45mm x 76mm Texas Instrument High Frequency RFID transponders were placed in the two sets of bags (ISO-15963 compliant). Two tags were placed in each of the bags containing the metallic BBs (Red Team), while a single tag was placed in the bags containing capacitive material (Blue Team). Each tag is represented by a unique label consisting of 16 ASCII characters, giving each bag a serial code to be transmitted at 13.56 MHz to the FEIG Electronic MR101 RFID Reader. The RFID tags are passive and receive their power from the signal sent from the FEIG Electronic 13.56 MHz RFID antenna. When radio waves from the 13.56 MHz antenna are encountered by a passive RFID tag, the coiled antenna within the tag forms a magnetic field. The tag draws power from it, energizing the circuits in the tag. The tag then sends the information encoded in the tag's memory.

Tag placement is crucial when implementing an RFID system. If the tag is not placed perpendicular to the electric field generated from the antenna, as depicted in Figure 2.2.1 below, reading range significantly decreases. In order to assure that each tag was close to perpendicular to the field produced by the antenna, we taped each tag to the inner surface of every bean bag.

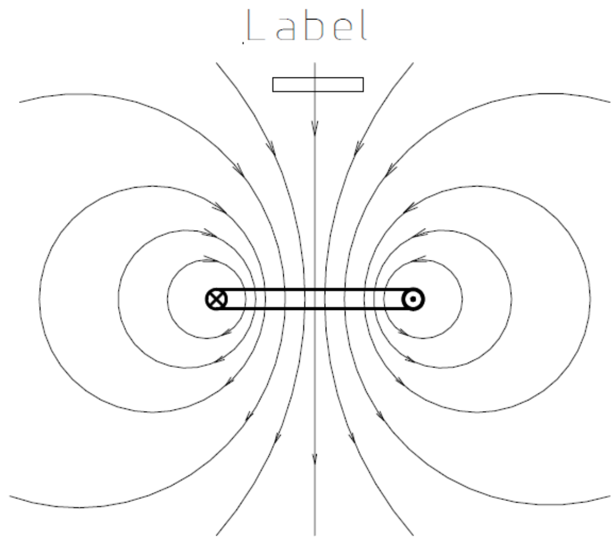

Figure 2.2.1

2.2.2 RFID System

This part of the project consisted of a FEIG Electronic ISC.ANT 300/300-A 13.56 MHz antenna connected to the 13.56 MHz MR101 RFID reader used to decipher each tag's 16 character ASCII code. The MR101 Reader has a built in anti-collision detection algorithm giving it the ability to detect up to 30 unique RFID tags at the same time. The reader is designed to have a transmitting power of 1 Watt which significantly decreases the detection range of the ISC.ANT 300 antenna from 25 inches from the center of the antenna (omnidirectional) to 16.5 inches from the center using the 45mm x 76 mm transponders mentioned above. The MR101 reader communicates the serial data received from the ISC.ANT 300 antenna using the RS232 interface. Data is sent serially to the microcontroller at a baud rate of 38400 bits per second, one bit at a time until the Reader does not detect any tags.

The MR101 RFID reader was the brain behind the RFID system. In order to have a functional reader we initially needed to load the ISO-Start program (provided with reader) in order to calibrate its settings to fit the desired requirement. In our case only reading mode was considered (as opposed to read/write) in order to get the necessary data from the antenna. The MR101 Reader uses an external 12-24 Volt power supply to power the reader/antenna combination.

2.2.3 Microcontroller

The microcontroller used in this design was the Arduino Mega 2560. The Arduino receives serial data from the RFID reader and digital data from the capacitive sensor, inductive sensor and the human interface switches. Using these inputs, the Arduino will compute a rounds score in two steps. First is when the "end of round" switch is triggered LOW, the microcontroller takes inputs from the sensors to add three points to a team whose bag is found passing through the center hole. The second step is initiated when the "end of round" switch is flipped to HIGH. In this case the Arduino detects all tags found on the boards' surface and determines how many extra points need to be added to each of the two teams. This two-step process is carried out until a winning team is determined and displayed on the LCD. In order for successful communication with the Arduino board, the RS232 data from the MR101 Reader needed to be converted to TTL type data. This was achieved by using the RS232 Arduino Shield made by CuteDigi. This shield is placed directly on top of the Arduino board and converts RS232 to TTL using the max232 chip and the TX and RX ports found on the Arduino Mega. By matching the baud rate to that of the reader (38400 bps), the microcontroller was able to compare all tags read in the RFID systems' field to 12 preset tag labels, updating the score anytime a match was detected.

The Arduino updates the score by sending digital signals to the 7 segment display depending on the score previously displayed. The Arduino Mega board is capable of being powered through an external power supply of 6-20 Volts. Our 12 Volt external battery was used to power this microcontroller.

2.2.4 Human Interface Switches

The human interface switches are designed to be physical switches that the user triggers when they wish to power the entire game, indicate the end of a round, reset the current game or simulate a game being played on the second board. The power switch is a SPST Rocker Switch, supplying 12 Volts to the MR101 Reader, capacitive sensor, inductive sensor and Arduino microcontroller. The "end of round" switch is a SPDT toggle switch designed to give points to the team whose bags are found on the surface of the game board. The reasoning behind this switch is to take into account the case when players are allowed to knock off bags already found resting on the game board. If a bag is knocked off the surface of the board by another bag, the knocked off bag can no longer be considered a score-able bag. The reset switch used was a momentary push button which resets the Arduino board to start the game from the beginning from any point in the game. Four SPDT toggle switches were used on the second board to simulate a game being played. Two switches were assigned to each of the two teams, one simulating three points and the other simulating one point.

2.2.5 7-Segment Display

Two 2-digit common cathode 7 segment displays were used to display the score for each of the two teams. These displays receive digital signals from the Arduino microcontroller when a score needs to be updated. In order to light each segment on the display a voltage of 2.2 Volts and current of 10 mA is required. A calculation for the required resistor value for each segment is shown below in equation 2.2.5.

$$R = \frac{Vs - Vf}{If} = \frac{5-2.2}{.01} = 280\ \Omega \qquad (2.2.5)$$

The source voltage is supplied at 5 Volts from the Arduino Mega microcontroller. Appendix B Figure B.1 shows the schematic for the 7 segment display connected to inputs of the microcontroller.

2.2.6 LED's

Eight high intensity green LED's were used to indicate to the user when any bag passes through the center hole or is simulated as passing through from the second game board. The LED's were mounted flush on the surface of the board around the center hole and programmed to light up three times in a circular fashion for each bag detection. The maximum current allowed to operate each of these LEDs is 10 mA. An 8-bit SIPO shift register was used to drive the eight LEDs. The shift register design was used to reduce the number of I/O pins consumed at the microcontroller and to limit the current going to each LED at 8 mA. Appendix B Figure B.2 shows the LED and shift register schematic used in designing our ring shaped PCB to fit around the center hole on the main game board.

2.2.7 LCD

The LCD used was driven by the Hitachi HD44780 driver, composed of a 16-pin interface. The purpose of the LCD was to communicate with the user when every point was added to the game board and determine the end of a game showing the winning team. The LCD also is capable of accounting for ties during the course of a game. It reads the scores after scoring has completed at the end of a round and determines if there is a winner. It is composed of two rows and 16 columns to fit your desired output message. The LCD is run through the Arduino microcontroller by adding the LiquidCrystal library. The LCD requires 5 Volts in order to power it up. This voltage is supplied by the Arduinos' 5 Volt output pin.

2.2.8 Sensor System

Cutler Hammer capacitive and inductive proximity sensors were used to make up the sensor system designed to detect and differentiate between bags passing through the center hole. The capacitive sensor is an unshielded sensor with a 30mm diameter while the inductive sensor is a shielded sensor also having a 30mm diameter. Both sensors had a maximum detection range of 10 mm and were powered using the 12 Volt battery. Both sensors are active low meaning they output 5 Volts when no detection occurs and 0 Volts when detection occurs. Figure 2.2.8 below shows the circuitry used to wire each of the two sensors. Table 2.2.8 below also indicates the output voltages and resistor values used in designing the sensor system. In order to achieve proper game functionality, a chute was attached to the center hole in order to force each bag passing through the center hole to follow a certain path for detection. Any time a bag is detected a digital LOW signal is sent to the microcontroller to update one of the teams' scores.

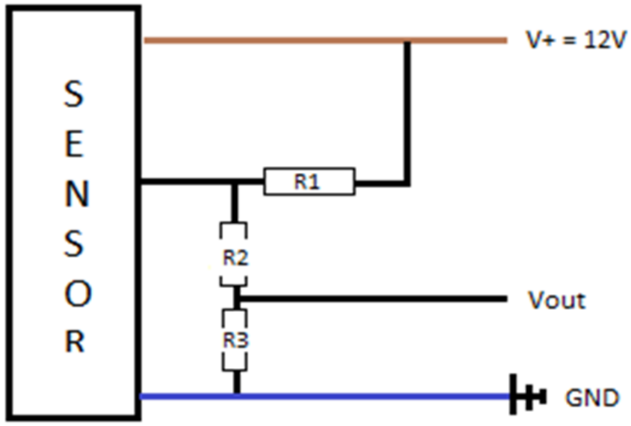

Figure 3.2.8 Sensor System Circuit

Table 2.2.8 Sensor System Resistor Values and Output Voltages

	Inductive	Capacitive
R1	14.25 kΩ	14.25 kΩ
R2	8 kΩ	14.25 kΩ
R3	14.25 kΩ	14.25 kΩ
Vout No Detection	4.7 V	4.8 V
Vout Detection	0.3 V	0.4 V

Each of the two sensors described above work on the principle of emitting an electromagnetic field to sense the changes in field produced when a certain object crosses its detection range. The inductive sensor emits a magnetic field and detects field change from conductive objects. The capacitive sensor emits an electric field and measures changes in field when either a conductive or dielectric material crosses its detection range. Figure 2.2.9 below represents a visual description of how the sensors work.

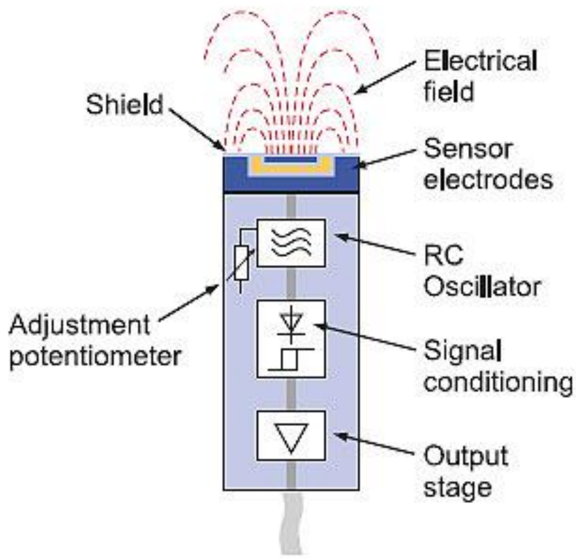

Figure 2.2.9 Sensor Functionality [2]

2.2.9 Power Supply

A 12 Volt DC Power Sonic battery is used to provide the power for all elements in the block diagram (RFID system, sensor system and Arduino microcontroller). The battery capacity is rated at 8 Amp hours. When the game is powered and is only using the RFID system, the current draw is found to be 600 mA. When the sensor system is used for detection, the current draw is found to be 720 mA. The equation 2.2.9 below determines the expected battery life of our game when only considering the extreme current draw situation.

$$Battery\ Life = \frac{Capacity}{Current\ Draw} = \frac{8000\ mA\ Hrs}{720\ mA} \approx 11\text{ Hrs} \qquad (2.2.9)$$

2.2.10 Board 2 Block

The board 2 block is identical to the main board block in theory. It will use the exact same components in the exact same fashion as are currently used on the main board. In order to cut costs and still show proper game functionality we proposed to only design and build one game board and simulate the other. Two sets of switches are designated to each team for the simulation. The first switch simulates one point and the second one simulates three points. Simulated scores from this board are sent to the Arduino microcontroller to update the score on the 7 segment display. The two boards are connected together using a wired connection from game board 2 directly to the Arduino microcontroller located on the main game board. This connection will allow us to demonstrate the ability of our design to communicate between the two game boards.

3. Design Verification

In order to ensure the proper functionality of the entire game board, multiple verification and testing procedures were carried out. Each subcomponent was tested independently and was verified for proper functionality. The test carried out and their corresponding results for each system is described below. The final Requirement and Verification table can be found in Appendix A Table A.1.

3.1 Sensor System

The sensor system is a vital part to the scoring of the game. Each sensor is active low and when detection of a desired object occurs, they output a low voltage. The sensors output logic high of approximately 4.8 V nominally and output a logic low of approximately .25V when activated. Under normal operating conditions the capacitive and inductive sensors will detect the blue bags and only the inductive sensor will detect the metallic filled red bags. In order to verify the proper functionality of each sensor, they were tested by passing each bag through their field of view. Upon testing, the sensors performed as anticipated.

3.1.1 Sensor Scoring System

To ensure proper functionality of the scoring displays with each of the sensors, each of the 7-segment displays were initialized to 00, 01, and 02 in order to simulate any possible scoring scenarios. Detection by a sensor relates to a 3 point score so we expected the respective displays to increase by 3 with each positive detection. Also, each display was programmed to increase up to a value of 24. This ensured that a tied score of 21 could be resolved with a tie breaker at the end of the round. Our testing results for the interface between the sensors and score displays can be seen in tables 3.1.1 and 3.1.2 below. As shown, each system performed as expected.

Table 3.1.1 Display test determining whether each scoring case has been taken into account. Bags in this test contain the metallic BBs.

Display 1 - Team 1 with Metallic Material Present in Bag			
Staring Value	00	01	02
Next value with each positive detection by inductive sensor ↓	03	04	05
	06	07	08
	09	10	11
	12	13	14
	15	16	17
	18	19	20
	21	22	23
	24		

Table 3.1.2 Display test determining whether each scoring case has been taken into account. Bags in this test contain no metallic material.

Display 2 – Team 2 with Metallic Material Absent in Bag			
Staring Value	00	01	02
Next value with each positive detection by capacitive sensor ↓	03	04	05
	06	07	08
	09	10	11
	12	13	14
	15	16	17
	18	19	20
	21	22	23
	24		

3.1.2 Sensor LED System

The sensor system also consists of eight LEDs placed in a circular pattern around the game board's center hole. Under normal operation, these LEDs will be lit anytime one of either teams' bags pass through the hole. In order to verify proper functionality, each of the eight bags were passed through the center hole and the LEDs were observed lighting up as designed.

3.2 RFID System

Proper functionality of the RFID system requires it to uniquely identify up to all eight bags present on the game on one time. The verification of this process required multiple steps. First, the ISO Start software provided by FEIG electronics was used to configure the RFID reader and obtain the twelve unique serial IDs of the tags being used. Once the twelve IDs were obtained, the Arduino Mega was programed to print all serial tag IDs that were read by the RFID reader. Once this was accomplished, code was written in order to store IDs read by the reader within an array in the Arduino's memory. From there, the array was compared with the known IDs of the tags and if a match was made, the Arduino would update the score appropriately. Upon completion of these steps, the game board was tested for the ability to simultaneously identify up to eight bags at once. This test was a success and the game board was able to score all eight bags, verifying all main requirements for the RFID system.

3.2.1 RFID Shielding

To ensure proper scoring of the RFID system, areas within the antenna's range needed to be avoided. This entailed shielding all of the area below the face of the game board. To achieve this, aluminum foil was placed securely around the inner walls of the sides, front, and back of the game board. Once the shielding was in place, testing was performed on the system to ensure no bags below the plane of the game board were scored. Testing involved placing bags around all edges of the game board and attempting to score them with the RFID system. Upon testing, no bags were detected around the perimeter of the board and with this result, the shielding requirement was verified.

3.3 Human Interface

Human interface switches can be found on both the primary game board and the secondary game board. The switches on the primary board are used for powering the game, scoring at the end of a round, and resetting the score at the end of the game. The ones found on the secondary board are used for simulating scoring similar to that on the primary board. Each set of switches were required to perform as designed and were tested accordingly.

3.3.1 Primary Board

Switches on the primary board are implemented for powering the game board, scoring at the end of a round, and resetting the score. In order to test and verify their functionality, each switch was tested and was shown to operate as desired.

3.3.2 Secondary Board

For communication with the primary board, four SPDT switches were used to simulate scoring scenarios on the secondary board. The signals for these switches were then sent to the Arduino located on the primary board and used to update the score accordingly. To test these switches, they were simply flipped on and off under multiple conditions and were found to work as expected.

3.4 Complete Game Functionality

Upon completion of testing of all subsystems of the project, testing was completed on the game as an entirety. The game was powered by the 12V and was tested under a variety of possible scoring scenarios. Multiple combinations sensor scoring and RFID scoring were simulated and the game performed flawlessly. With the verification of this requirement, all requirements were verified for the entire project.

4. Costs

4.1 Parts

Table 1.1 Parts List and Prices

PARTS					
Part	**Part Number**	**Manufacturer Name**	**Unit Price**	**Quantity**	**Total Price**
Cornhole/Bags Set		Original Tailgate Toss	$62	1	$62
Microcontroller	Arduino Mega 2560	Arduino	$58	1	$58
RFID Tags	RI-I02-114A-01	Texas Instruments	$0.86	12	$10.31
RFID Reader	ISC.MR101.M-A	FEIG Electronics	$501.60	1	$501.60
Antenna	ISC.ANT 300/300-A	FEIG Electronics	$473.85	1	$473.85
LED's	HLM P3507	Avago Technologies	$0.15	8	$1.20
7-Segment Display	LDD-HTC512RI	Lumex	$1.37	2	$2.74
12 V Battery	PSH-1280 F2	Power Sonic	$21.95	1	$21.95
Capacitive Prox. Sensor	E57-30GS10-C	Cutler Hammer	$197.37	1	$197.37
Inductive Prox. Sensor	E53KAL30T110E	Cutler Hammer	$57.51	1	$57.51
SPST Toggle Switch	275-648	Radio Shack	$3.19	5	$15.95
Momentary Push Button	275-618	Radio Shack	$3.19	1	$3.19
SPST Rocker Switch	275-013	Radio Shack	$3.19	1	$3.19
300 Ohm Resistor	20J300E	Ohmite	$1.01	36	$36.36
16 kOhm Resistor	20J16K	Ohmite	$2.12	6	$12.72
9 Pin D-Subminature Plug	DS-9P	Pan Pacific	$0.50	2	$1.00
RS232 Arduino Shield	610074725992	CuteDigi	$11.90	1	$11.90
8-bit SIPO Shift Register	74LS164	Texas Instruments	$1.95	1	$1.95
LCD Screen	LCM-S01602DSF	Lumex	$11.37	1	$11.37

PCB	$15	2	$30.00
TOTAL		85	**$1,514.16**

4.2 Labor

Table 4.2 Labor Cost

LABOR COST	
Employee	**Cost**
Kabir Singh	($40/hr) x (2.5) x (180 hr) = $18,000.00
Travis DeMint	($40/hr) x (2.5) x (180 hr) = $18,000.00
TOTAL	**$36,000.00**

4.3 Total Cost

Total Project Cost = $36,000 + $1,514.16 = $37,514.16

5. Conclusion

5.1 Accomplishments

With the conclusion of this project, all requirements and verifications were met. The project exhibits proper functionality of the entire system and is able to electronically score a complete game of bags. This project removes the burden of scoring from the players and provides a new, fun and exciting means of scoring the game of bags. It allows the users to concentrate on having fun and makes the entire experience of playing bags more enjoyable for those evolved. It also adds visually stimulating effects to the game and gives it more of a modern "cool" factor that the game of bags has been missing.

5.2 Challenges/Uncertainties

The most challenging part of this project was the RFID system and more specifically the RFID antenna's range. Once the correct RFID reader and configuration software was obtained, the RFID system as a whole became much more trivial. The antenna and its corresponding range, on the other hand, proved to be a bit more problematic. Originally the design called for a set of RFID transponders that were of a disk shape with a diameter of 22 mm. It became apparent rather quickly that with this set up, the design's theoretical antenna range was fairly larger than the actual measured value. By fine tuning the antenna placement and changing the design to include rectangular RFID inlay transponders with a much larger antenna area (45mm x 76mm), the desired antenna range was achieved. With this achievement, the uncertainty of antenna range and complete game board coverage was evaded.

5.3 Ethical considerations

With all engineering design projects, ethical issues must be taken into consideration. This particular project contains a few ethical considerations that must be addressed. Rule five of the IEEE Code of Ethics states "to improve the understanding of technology, its appropriate application, and potential consequences". This guideline directly pertains to the RFID system used in the project and its associated radiation frequency. There are certain frequency allocations which are set aside for multiple applications. For this certain application, the RFID system will be operating at a HF (High Frequency) of 13.5 MHz. This particular frequency falls within the industrial, scientific and medical (ISM) radio band which is allocated internationally for the use of radio frequency energy for industrial, scientific and medical purposes. This frequency is the appropriate and ethical choice for the RFID system used in this project. Our choice of 13.5 MHz will prevent any interfere with important frequencies within the electromagnetic spectrum. Another important ethical consideration that needs to be addressed is rule three of the IEEE Code of Ethics. The code states "to be honest and realistic in stating claims or estimates based on available data". For this project we will be testing multiple sensors and a RFID detection system. When stating nominal sensing ranges and limitations of our systems we will remain honest and report the correct values for the devices used. Also when recording our test results we will not exaggerate what we observe in the lab. If our systems do not perform as intended will make the appropriate accommodations within our project in order to complete a satisfactory end product. Finally, all references used in this project will be given the proper credit and will be acknowledged when it is the appropriate time to do so.

5.4 Future work

In order to completely finish this project and bring to marketable state, the secondary game board will need to become an exact replication of the primary board. For this to happen, one would need to obtain a second RFID antenna, RFID reader, Arduino MEGA, 12V battery, inductive proximity sensor, and capacitive proximity sensor. With these additional parts the secondary board could be completed as an exact replica of the first. From there the second board would need to communicate with the first either wirelessly or through a wired connection. The primary board's Arduino is already coded for the communication and could take advantage of the digital I/O that was assigned to the four human interface switches placed on the secondary board. It would then use the signals from the second board to calculate the total score just as it does now. Once these additions are made and the second board is brought to the state of the primary one, the project would be completely finished.

References

1. Cornhole/Bags History, “Cornhole”, http://en.wikipedia.org/wiki/Cornhole

2. Design World, http://www.designworldonline.com/articles/5427/208/The-Search-for-a-Better-Proximity-Sensor-Starts-Here.aspx

3. Association for Automatic Identification and Mobility, “General RFID Information”,

   http://www.aimglobal.org/technologies/rfid/rfid_faqs.asp

4. The Electronics Hobbyist, “Arduino 2-Digit 7-Segment Display Counter Part 1”,

   http://www.theelectronicshobbyist.com/blog/arduino-2-digit-7-segment-display-counter/

5. Sparkfun Electronics, “Arduino Mega 2560”, http://www.sparkfun.com/products/11061

6. Arduino, “Arduino Mega 2560”, http://arduino.cc/en/Main/ArduinoBoardMega2560

7. Arduino, “ATmega2560-Arduino Pin Mapping”, http://arduino.cc/en/Hacking/PinMapping2560

8. Arduino, “RS-232”, http://arduino.cc/hu/Tutorial/ArduinoSoftwareRS232

9. Wikipedia, “ISM Band”, http://en.wikipedia.org/wiki/ISM_band

10. American Cornhole Association, http://www.playcornhole.org/rules.shtml

Appendix A Requirement and Verification Table

Table A.1 Requirement and Verifications

Requirement	Testing/Verification	Verification Status
1. RFID Tags each have a unique serial code.	1. Each of the eight RFID tags will be individually detected using the antenna and reader system to determine each tags unique serial code to distinguish Team 1 from Team 2.	✓
2. The RFID system is able to pick up all tags located on surface of game board	2. The 13.56 MHz antenna is able detect up to 1.6 ft. from all sides of the antenna. The antenna has dimensions of 1.05 ft. by 1.10 ft. In order to detect the entire surface of game board the antenna needs to detect up to 1 ft. in all directions. Bags containing tags will be placed on the edges of game board to ensure proper detection and shielding.	✓
3. The Microcontroller should be able to detect signal from various inputs to distinguish correct score for each team and output this score to the display. a. Capacitive sensor detection giving Team 1 three points. b. Inductive sensor detection giving Team 2 three points. c. RFID tag differentiation giving the correct team the extra point.	3. After having programmed the microcontroller to correctly output the score for each team, we will supply it with predetermined inputs to test that all cases correctly function to output a valid score. a. Providing a HIGH input to demonstrate a bag being detected by the capacitive senor causing microcontroller to increase Team 1's score by three points. b. Providing a HIGH input to demonstrate a bag being detected	✓

	by the inductive senor causing microcontroller to increase Team 2's score by three points. c. Providing the microcontroller with several serial inputs representing unique tags to test whether program can distinguish between each team's tags and update the score accordingly.	
4. The human interface switches correctly function to allow for smooth game play. a. Power on/off switch b. Game play/Score switch c. Reset button	4. Each of the switches will be individually tested to assure proper game function. a. Assuring 12 volts is supplied to game board when switch is flipped to on position and 0 volts supplied when switch is flipped to off position. b. Flipping switch to game play mode will supply LOW voltage to the microcontroller to update score for bags going through center hole but not for bags on the surface of the board. Flipping switch to score mode will supply HIGH voltage to allow for bags on the game board to be scored up and displayed in the output. c. Pushing reset button will supply HIGH voltage to reset entire game.	✓

5. Each 7 segment display correctly outputs its respective teams score.	5. Predetermined inputs will be supplied to the microcontroller from both game boards to determine whether the 7 segment display output is correctly displaying the computed score for each team.	✓
6. LED's light up when bag is detected through the center hole.	6. Predetermined inputs will be supplied to the microcontroller to determine whether the LED lights correctly function in our system to indicate a bag passing through the center hole on the game board.	✓
7. The capacitive sensor is able to detect Team 1's bags through the center hole.	7. We will isolate the capacitive sensor form the rest of the system and place each one of Team 1's bags in front of the sensor within its given range (25mm) to determine if a HIGH output will be sent to the microcontroller. LABVIEW will be used to simulate this detection as shown in the simulation above.	✓
8. The inductive sensor is able to detect Team 2's bags through the center hole.	8. We will isolate the inductive sensor form the rest of the system and place each one of Team 2's bags containing metal BB's in front of the sensor within its given range (15mm) to determine if a HIGH output will be sent to the microcontroller. LABVIEW will be used to simulate this detection.	✓
9. A single 12-volt power supply battery will be used to power the entire system.	9. The battery will be individually tested with all components (sensors, reader and antenna, LED's and the 7-segment display). Individual tests will allow us	✓

	to determine battery life for the entire game when the system is fully wired up.	
10. Board 2 can effectively communicate with the microcontroller on board 1 to output correct score on display.	10. Switches will be flipped up/down to simulate point accumulation on board 2 for both teams. Switch 1 will be used to add points to team 1's score (up=3pts, down=1pt) and switch 2 will be used to add points to team 2's score using the same method as mentioned for switch 1. Accumulated points will be sent to the microcontroller on board 1 to be displayed on the 7 segment display. This test will show the ability to communicate between both boards.	✓
11. LCD Screen informs users regarding status of a game.	11. The LCD screen will inform users to begin tossing at start of every new game. Once game is in progress the screen will inform users of each point accumulated during a game. The LCD screen will inform the users of a winning team, determined by the microcontroller, and ask to reset for a new game. Each scoring case will be simulated to verify that the LCD is outputting correct messages at each stage.	✓

Appendix B Schematics

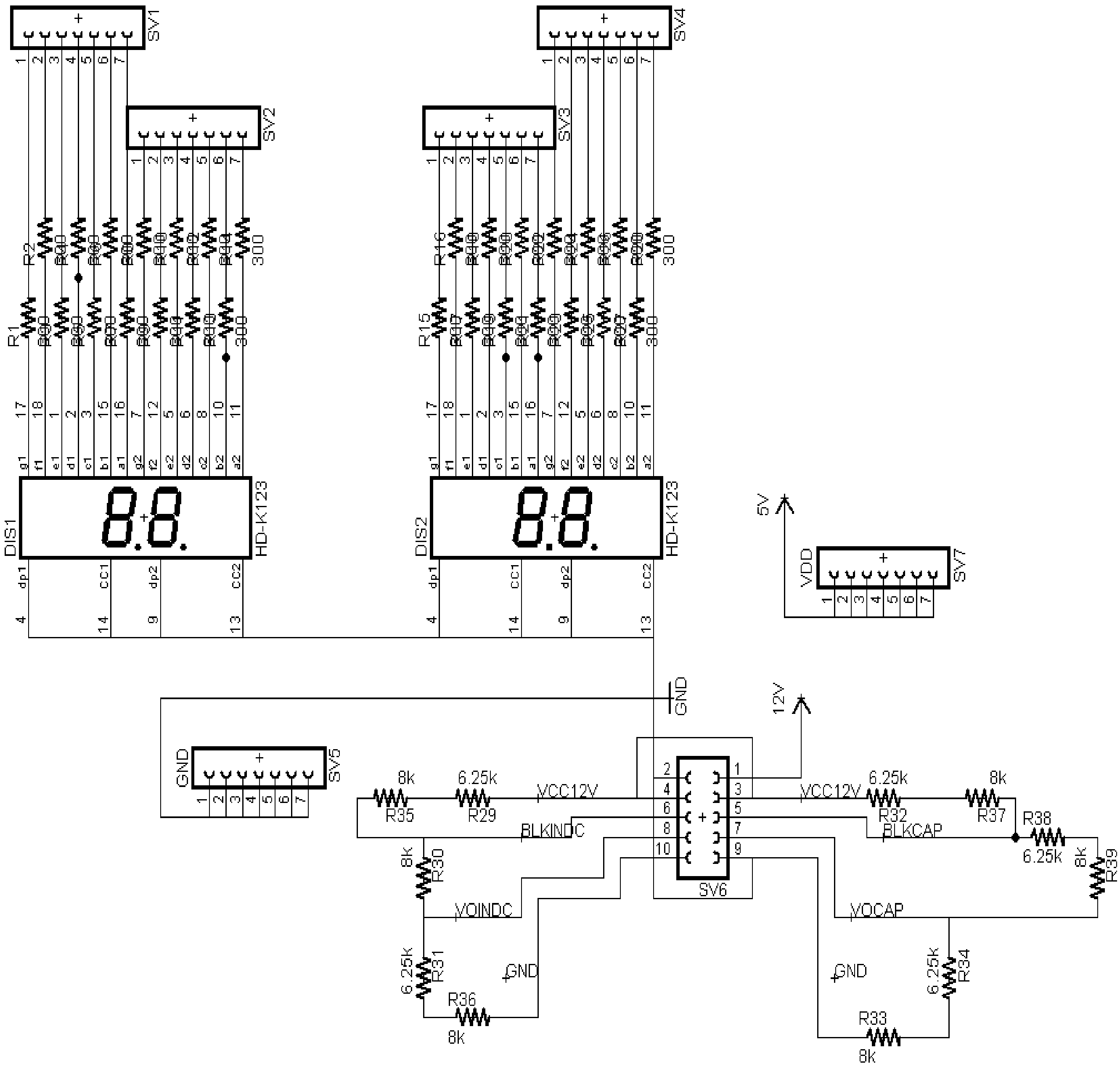

Figure B.1 7-Segment Display and Sensor Connection Schematic

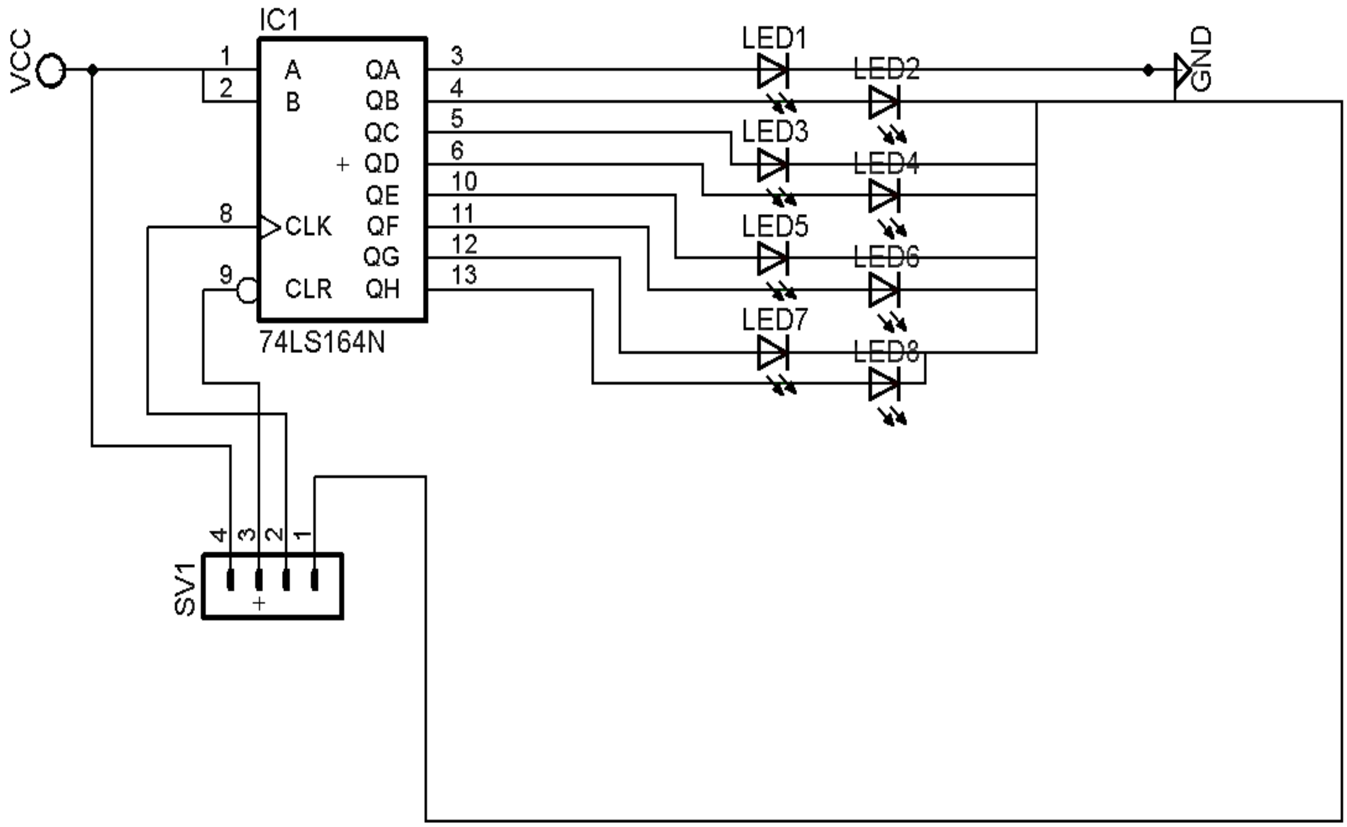

Figure B.2 LED Schematic connected with the 8-bit Shift Register

Appendix C Abbreviations

Table C.1 Abbreviations

V	Volts
mV	Millivolts
A	Amps
mA	Milliamps
W	Watts
Hrs	Hours
SIPO	Serial In Parallel Out
SPST	Single Pole Single Throw
SPDT	Single Pole Double Throw
RFID	Radio-Frequency Identification
I/O	Input/Output
PCB	Printed Circuit Board
GND	Ground