RFID AUTOMATIC SELF CHECKOUT BASKET

DESIGN DOCUMENT

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Design Document for ECE 445, Senior Design, Spring 2026

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27 February 2026

Project No. 94

Contents

1. Introduction

1.1 Problem

Retail congestion remains a persistent source of inconvenience for customers and operational strain for businesses. Visible checkout delays may discourage customers from completing planned purchases, leading to lost revenue. Traditional checkout systems require businesses to staff multiple registers, increasing labor costs while still failing to eliminate congestion during peak hours.

Existing mobile self-checkout solutions allow users to scan items on their phone; however, there is no system in place to ensure that shoppers are scanning all of their items. While the honor system may work in some capacity, for many retail locations, this is not the case. Addressing checkout delays is therefore not only a matter of convenience but also an economic and safety concern. Improving transaction efficiency can enhance the shopping experience and help businesses operate effectively in a competitive environment.

1.2 Solution

For a solution to the issue, this project proposes the development of an automatic self-checkout shopping basket capable of identifying items as they are placed inside. The system will use UHF RFID technology to detect tagged products without manual scanning, while a system of load cells provides weight-based verification to detect discrepancies. Together, these sensing methods create a verification process that improves reliability.

The system will be coordinated by a microcontroller that communicates with a centralized server over WiFi. Visual feedback will be provided through an LED indicator to inform users of successful reads or potential errors. A public-facing web application will allow shoppers to easily see the items in their basket along with their current total price. By shifting item identification earlier in the shopping process, this design aims to reduce checkout congestion, lower staffing demands, and improve overall shopping efficiency.

1.3 Visual Aid

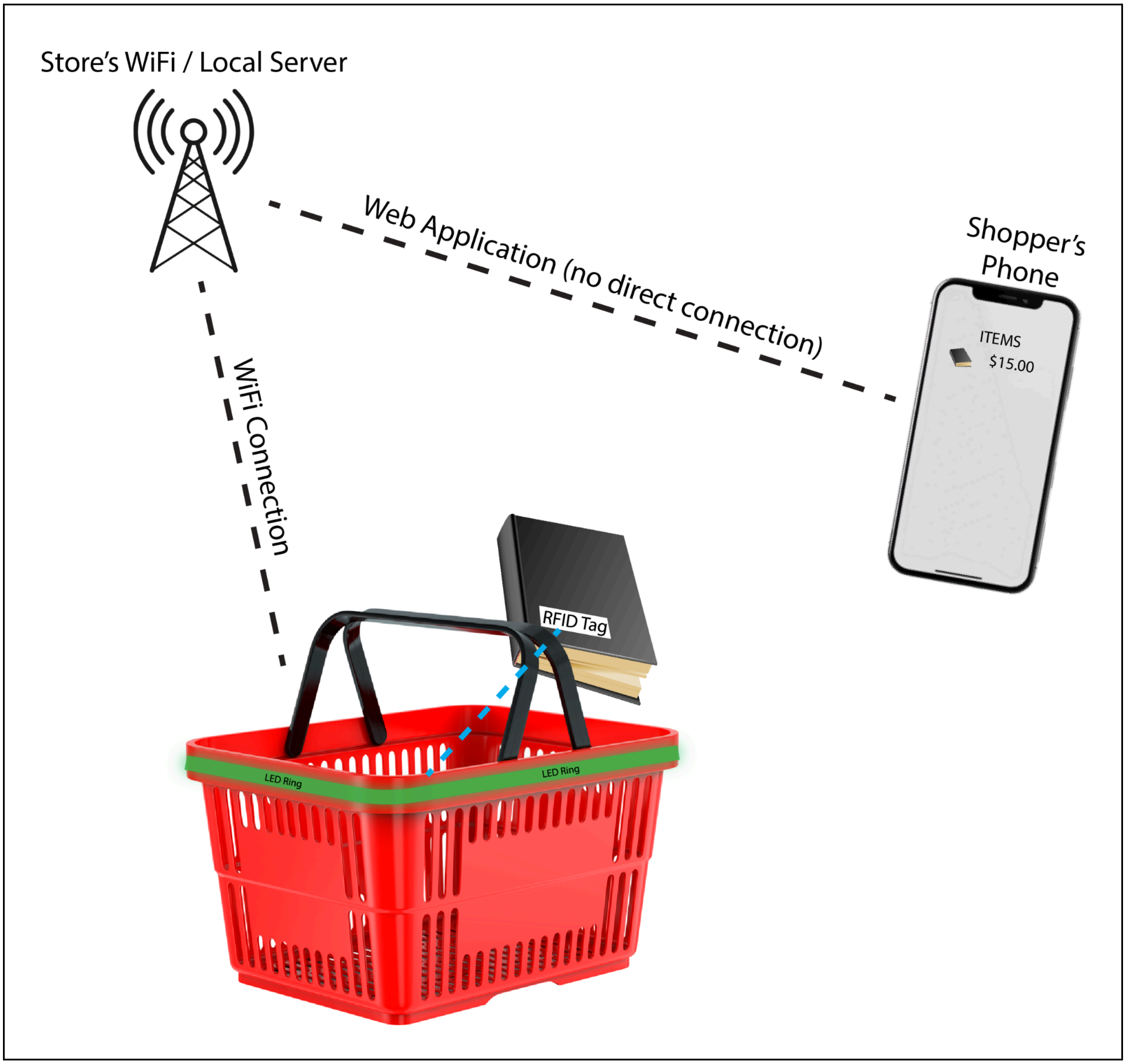

Figure 1: High-level representation of the proposed RFID self-checkout basket in context, illustrating its interaction with key external systems and the user

1.4 High-Level Requirements

1. The system shall automatically detect and correctly identify at least 95% of RFID-tagged items placed inside the basket within 5 seconds of insertion, and shall accurately distinguish items inside the basket from those outside by limiting unintended RFID reads to less than 5% for objects located more than 0.5m away.
2. The system shall successfully identify when an item weighing at least 500g has been placed inside of the basket but an RFID tag was not recognized and notify the user via a pulse or color change of the LED light.
3. The system shall update the user-facing web application with the current item list and running total with 100% accuracy within 10 seconds of any item being added or removed from the basket.

2. Design

2.1 Block Diagram

Our proposed high-level block diagram is shown in **Figure 2**, providing an overview of the interactions between the system's primary subsystems. Solid lines denote physical connections. Dashed lines denote wired connections.

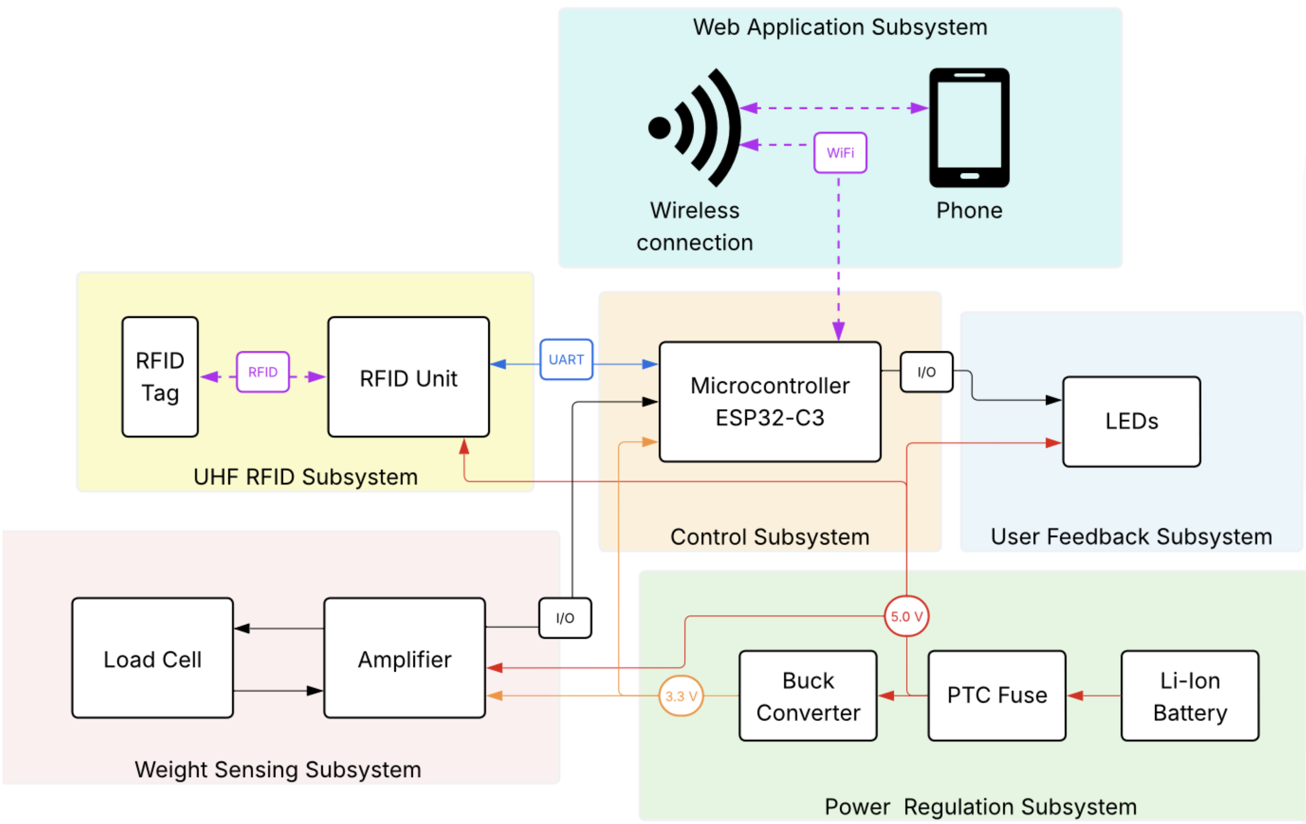

Figure 2: High-level block diagram of the RFID self-checkout basket system illustrating how the major subsystems integrate to support overall functionality.

2.2 Physical Design

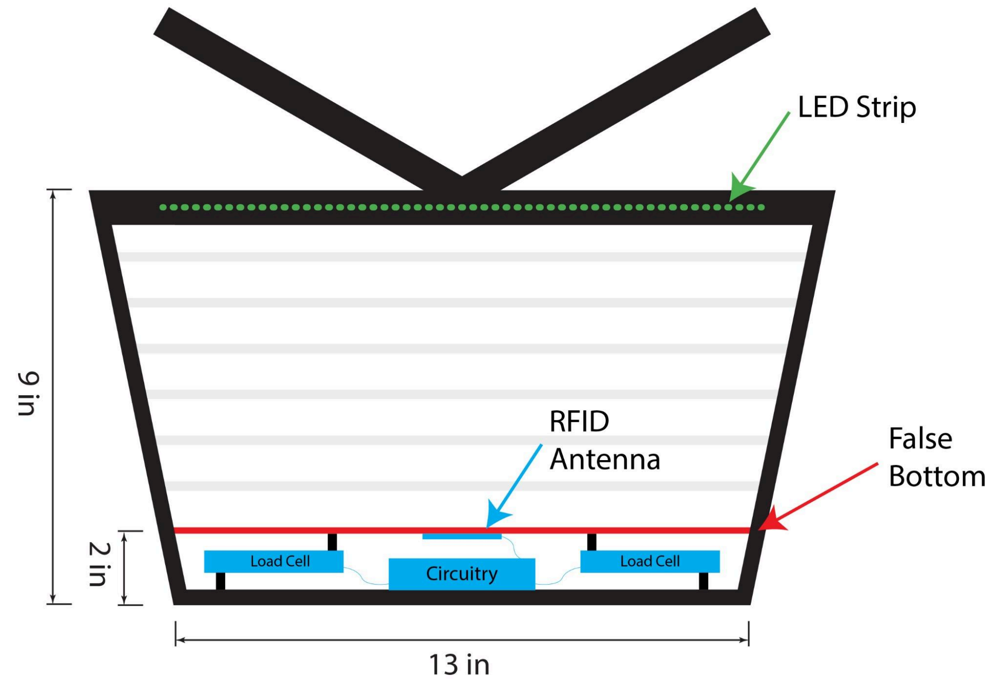

Figure 3: The physical design (to scale) of the basket, including a false bottom to act as the base of the scale. All circuitry with the exception of the LED strip will be under the false bottom made from a durable yet flexible material.

Figure 4: The grocery basket this project revolves around.

2.3 Functional Overview & Block Diagram Requirements

2.3.1 Sensing Subsystem

The Sensing Subsystem is responsible for providing physical validation of the basket's contents to prevent theft or identification errors. It utilizes an M5Stack U107 UHF RFID module and two 20kg load cells mounted to a "false-bottom" platform, which transfers the weight of the items to an HX711 amplifier.

The RFID module is responsible for detecting multiple simultaneous RFID tags between 860 and 960 Hz. Data from the module is relayed to the microcontroller through GPIO pins and the module's onboard UART at a baud rate of 115,200 [15]. The power/attenuation of the unit will be tuned between 18 and 26 dBm to effectively control the read range of the module to ensure that tags are only read from within the volume of the basket, approximately 0.25 m from the antenna in all directions.

Each load cell is connected to an amplifier, which converts the micro-volt changes from the load cell bridges into a digital signal that is sampled by the microcontroller via GPIO at a rate of either 10 or 80 Hz. By measuring the total mass, the subsystem can detect if an untagged item has been added or if an RFID read was a "false positive" with no corresponding weight change. To ensure the Sensing Subsystem provides stable and accurate data up to the 20kg limit, a requirements & verification table can be found below.

Table 1: Sensing Subsystem – Requirements and Verification

Requirements	Verification
● Load cells and amplifier output a digital data signal proportional to the mass.	● Connect the load cell amplifier to both 3.3V and 5V power. Ensure no mass on the load cell(s). Connect CLK (J1, Pin 4) to a pulse generator to provide a clock. ● Using a multimeter, read the voltage between GND and AVDD (JP4, Pin 5) and log this in a table of mass vs. AVDD, Digital Output ● Using a logic analyzer, capture the 24-bit logical output from DAT (J1, Pin 3) during a clock cycle. ● Repeat the above two steps for multiple masses placed on the load cell(s). Plot mass vs. AVDD and ensure it is constant (trendline with slope 0 ± 0.125). Plot mass vs. DAT (as a number) and ensure the relationship is linear (linear trendline with $R^2 > 0.95$)
● Subsystem reliably detects passive UHF RFID tags located within 0.25m but not further than 0.5m from the antenna with at least 95% read probability within 2 seconds.	● Connect to the MCU via USB-C to gain access to debugging information, including tags that are currently within range. ● Ensure no tags are within 3 meters of the RFID antenna. ● Place one UHF tag inside of the basket as close as possible to the antenna and ensure that the correct tag ID is read and visible by the MCU within 2 seconds. ● Using a meter stick with one at as close to the antenna as possible, slowly move the tag away until it reaches 0.25m. Ensure the tag is still read at all times. ● Continue past 0.25m and ensure that the tag is no longer read somewhere between 0.25m and 0.5m. ● Repeat the above steps in multiple directions/axes (above, in front, behind, etc.) ● During all movements, hold the tag still for 10-20 seconds every 5-10cm. Verify that the tag is read correctly during at least 95% of all total hold time.

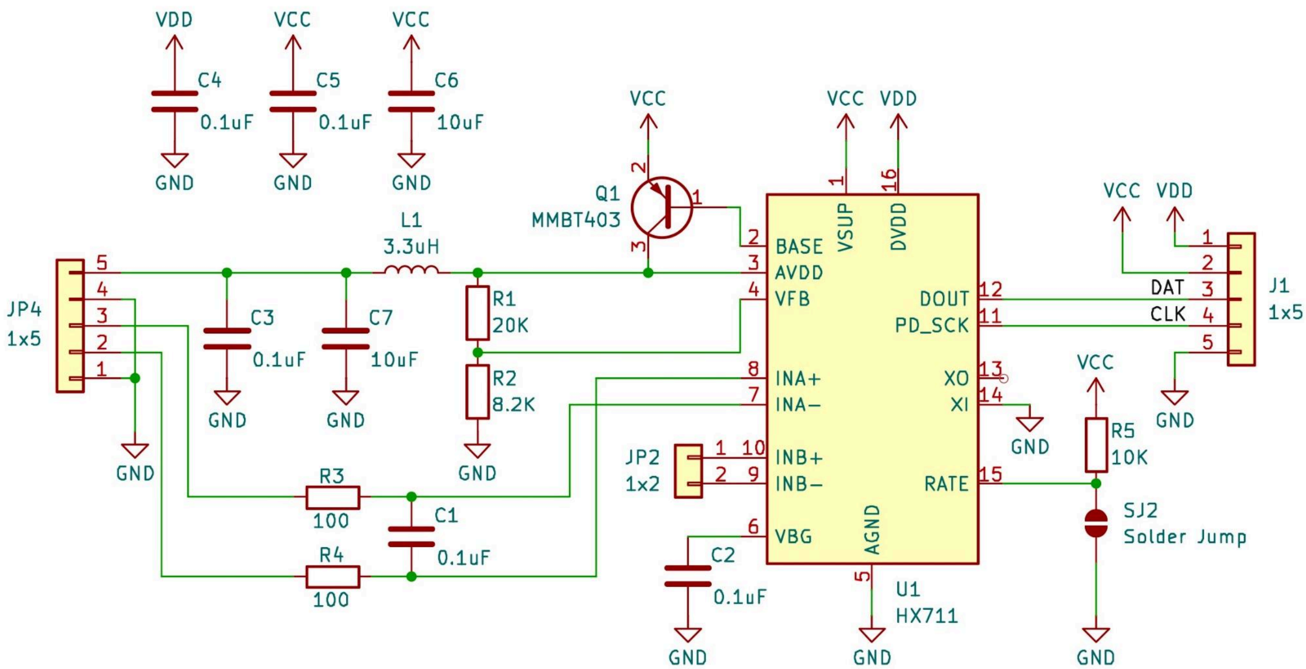

Figure 5: Schematic for the load cell amplifier circuit based on Ref. 22. J1 represents connections to the microcontroller subsystem and JP4 represents connections to the load cell(s).

2.3.2 Microcontroller Subsystem

The microcontroller (ESP32-S3-WROOM-1) subsystem is responsible for maintaining all state information and processing all data received from other subsystems. It is also responsible for communicating the state of the basket, including its contents, with the "store's" infrastructure via WiFi. Failure of this subsystem results in no other subsystem being able to intercommunicate and a total loss of functionality.

The subsystem will interface with an emulated "server" running locally on a separate computer, which will act as the host of the web application (Section 2.3.4). The subsystem shall communicate with the server via TCP endpoint to send data.

The MCU operates on the 3.3V power rail [5] and is capable of interfacing with external devices via USB-C for firmware updates. The sensing subsystem requires a CLK signal from the MCU for the load cell amplifier. The load cell amplifier provides mass data as a digital signal to a GPIO pin. The sensing subsystem also communicates with the UHF RFID module via UART utilizing two GPIO pins. One GPIO pin will provide data output to the user feedback subsystem.

Table 2.1: Microcontroller Subsystem – Requirements and Verification (Pt. 1)

Requirements	Verification
● Microcontroller correctly communicates with the LED Subsystem to produce the expected colors on different data signals from the Sensing Subsystem: ○ Solid white indicates the basket is ready for use ○ A green pulse within 5 seconds of an item being placed indicates successful detection of an item ○ A red pulse within 5 seconds of an item being placed indicates an error, such as a missing RFID tag or weight discrepancy	● Ensure the basket is empty and the system is powered on ● Visually confirm the LED strip is set to a constant Solid White pattern ● Add a tagged item to the basket ● Visually confirm the LED strip displays a Green pulsing pattern within 5 seconds ● Place an untagged weight into the basket to trigger a "Weight Mismatch" ● Visually confirm the LED strip displays a Red pulsing pattern within 5 seconds
● Microcontroller provides update to TCP server within 20 seconds with 95% accuracy based on input from Sensing Subsystem.	● Ensure the basket is empty (no items inside). ● Place a tagged item inside of the basket and start a stopwatch. ● Verify that the "server" has received the correct item ID via WiFi within 20 seconds. ● Repeat multiple times to ensure accuracy.

Table 2.2: Microcontroller Subsystem – Requirements and Verification (Pt. 2)

Requirements	**Verification**
● Microcontroller recognizes when an item has been placed in the basket (determined by weight) but an RFID tag has not been recognized by the Sensing Subsystem within 20 seconds with 95% accuracy.	● Ensure the basket is empty (no items inside). ● Place an item weighing at least 500g with no RFID tag inside of the basket and start a stopwatch. ● Verify that the "server" has received a "missing item" signal via WiFi within 20 seconds and that the LEDs correctly display the expected result (as described above) ● Repeat multiple times to ensure accuracy.
● The microcontroller correctly detects the expected weight ±10% at least 95% of the time	● Connect to the MCU via USB-C to gain access to debugging information; specifically the weight information from the Sensing Subsystem. ● With an empty basket, power on the system and check that the basket shows 0kg ● Add an item with a known weight and verify that the detected weight matches with ±10% of the kg ● Repeat the above step with multiple items to ensure that overall accuracy remains.
● The microcontroller shall provide a data update to the backend at a frequency of approximately 1Hz (once per second) to maintain real-time synchronization	● Connect the MCU to the laptop's emulated backend server ● Record the arrival time of 10 consecutive data packets ● Verify that each interval of package arrival falls within the acceptable range of 1.0s±0.2s
● The microcontroller shall be capable of transmitting a list of at least 15 unique tag IDs simultaneously without data corruption	● Place 15 tagged items into the basket ● Observe the JSON output on the emulated laptop backend server ● Verify all 15 unique IDs are listed in the data array and match the physical tags

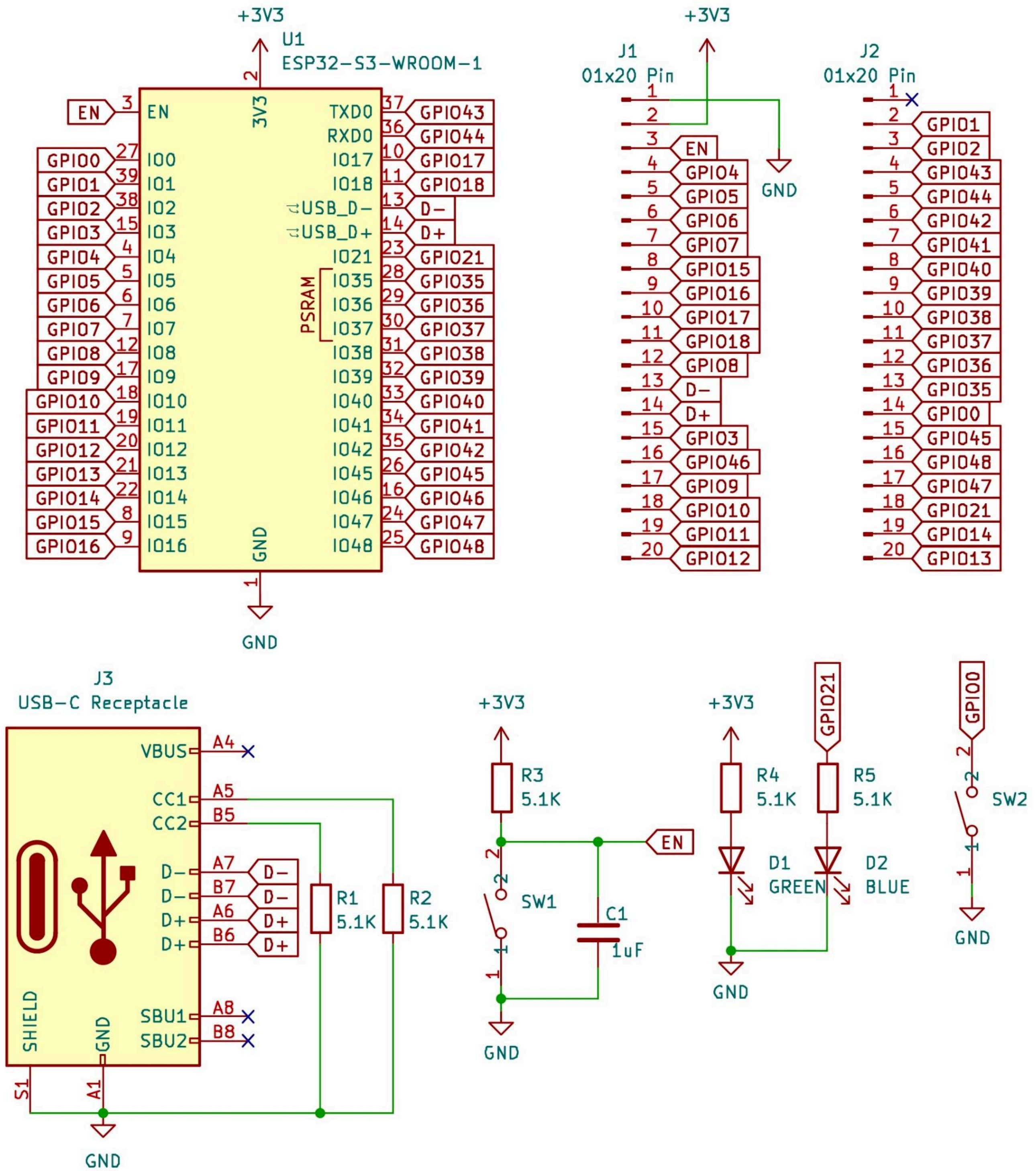

Figure 6: Schematic for the microcontroller based on Ref. 1. GPIO pins used to interface with other subsystems.

2.3.3 Power Regulation Subsystem

The power subsystem is designed to provide stable and regulated operation for all system components using a single-cell 3.7 V nominal lithium-ion battery as the primary energy source. The battery is rechargeable via a USB-C input to safely charge the cell to 4.20 V while providing over-current and protection. The battery output feeds a high-efficiency DC-DC boost converter to generate a regulated 5.0 V rail capable of supporting currents up to 3 A for high-demand components such as the RFID module and system LEDs. This architecture ensures reliable regulation across the battery discharge range (approximately 3.0 V to 4.2 V) while maintaining safe battery operation and stable subsystem performance.

A resettable PTC fuse will be incorporated to provide overcurrent protection by limiting excessive current flow during fault conditions. The range at which this component trips is desired to trip at is 5A. According to the datasheet [13], the fuse has a hold current of 3A and a trip current of 5A, so, as a result, we do not want our RFID module to be exceeding a demand of 3A. A linear regulator (LDO), such as the XC6206xxxMR module, will step the 3.7-4.2 input from a battery (rated for 3.7) down to a regulated 3.3V output for the microcontroller etc.

$$p_{loss} = (V_{in} - V_{out})\ I$$

The “extra voltage” is handled by the LDO component and is distributed as heat instead. This 3.3V output will be connected to the power pin of the microcontroller and load module. It will remain stable (±5% error) and never turn off until the battery is discharged. Moreover, we have a diode that will protect us from electrostatic discharge or random transient voltage. The diode will “avalanche” to ground, creating a short connection for clamping voltages of 10.5-11.5V [4]. With the use of decoupling capacitors, we drive a stable connection to the ETA9740, which acts as a charger for the LiPo battery. This component has LEDs that give us indication of charging status etc. We also utilize another function of this chip which is power boosting. This will allow us to input a 5V onto the connection. Afterwards, we’ll filter this connection through some more capacitors and a zener diode, that according to the documentation [21], is rated 5.6V before we form a connection to ground. Together, the decoupling capacitors and Zener diode stabilize and protect the 5 V rail by reducing noise, handling load spikes, and clamping over-voltage events. This ensures reliable and safe operation of all subsystems throughout the shopping process.

Table 3: Power Regulation Subsystem – Requirements & Verification

Requirements	Verification
• The subsystem shall recharge a 3.7 V Li-ion battery using a 4.7–5.0 V USB-C input and regulate the battery voltage to 4.20 V ±5%, preventing over-charging.	• While Plugged in, USB-C board will confirm power delivery to load (battery) via LEDs • Measure charging voltage at +/- terminals and examine the voltage rises to correct level. Monitor battery voltage and charge current using multimeter. Confirm whether we read 4.20 V ±5% and reach 0A at full charge. • The battery will be discharged to approximately 3.0 V prior to testing. A regulated 4.7-5.3 V input will be applied via the USB-C connector. Battery voltage and charging current will be continuously monitored using a digital multimeter and/or oscilloscope.
• The subsystem shall provide a regulated 5 V ±5% output rail capable of supplying 1-3A continuously	• The 5 V output will first be measured under open circuit conditions to confirm nominal regulation. A programmable load will then sweep current from 0 A to 3 A while output voltage is monitored. Voltage must remain within 4.7 V to 5.3 V across the full load range. A transient 3 A load pulse will be applied to simulate RFID burst current demand. Output voltage will be observed using an oscilloscope to confirm that droop remains within acceptable limits and that no system reset occurs. • Measure the output with no load attached right after USB-C has been unplugged with a multimeter to ensure a (±5%) 5.0 V is being outputted
• The subsystem provides a regulated and stable DC 3.3-3.6V + minimum of 500mA-1A rail for appropriate loads	• The 3.3 V output will be measured under open circuit conditions and then tested. Output voltage must remain between 3.3V with ±5% error. The 3.3 V rail will also be monitored during 5 V transient load events to confirm no coupling-induced instability

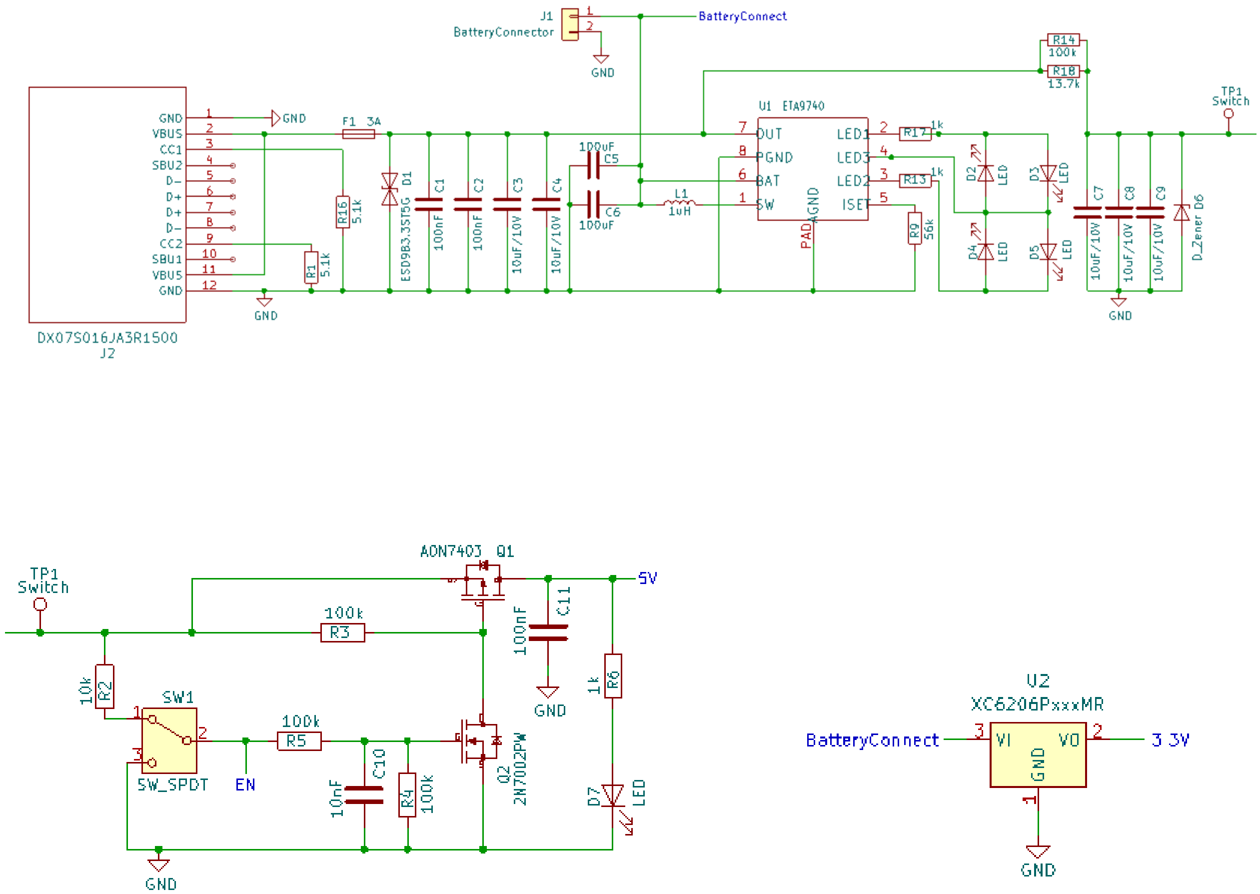

Figure 7: Schematics for the Power Regulation Subsystem.

2.3.4 Web Application Subsystem

The Web Application serves as the shopper's primary interface, allowing them to view a live, synchronized list of items and their running total. It communicates with the basket's Control Subsystem via a cloud-based API over WiFi. The application is designed to be responsive, supporting standard smartphone resolutions to provide a clear and transparent checkout experience. In the event of a communication failure, the app is responsible for alerting the user that the basket is "offline." To ensure the Web Application remains synchronized with the physical basket and provides a responsive UI, a requirements & verification table can be found below.

Table 4: Web Application Subsystem – Requirements and Verification

Requirements	**Verification**
● Provides a running total of the basket contents, updating with each new item addition or removal.	● Add three items with known prices to the basket ● Verify that the UI total equals the sum of those items ● Remove one item and confirm that the total reflects the summation of the prices of the remaining items
● The interface shall remain responsive on standard smartphones or tablets, supporting a minimum resolution of 720×1280 pixels	● Load the app on an emulator set to 720x1280 resolution ● Visually verify that all UI items are visible, aligned, and functional
● Failure to update the item list within the time window, or failure to synchronize with the basket, shall trigger an error notification on the UI	● Power off the basket while the web application is active and connected ● Confirm that some type of error alert appears on the application interface within 20 seconds

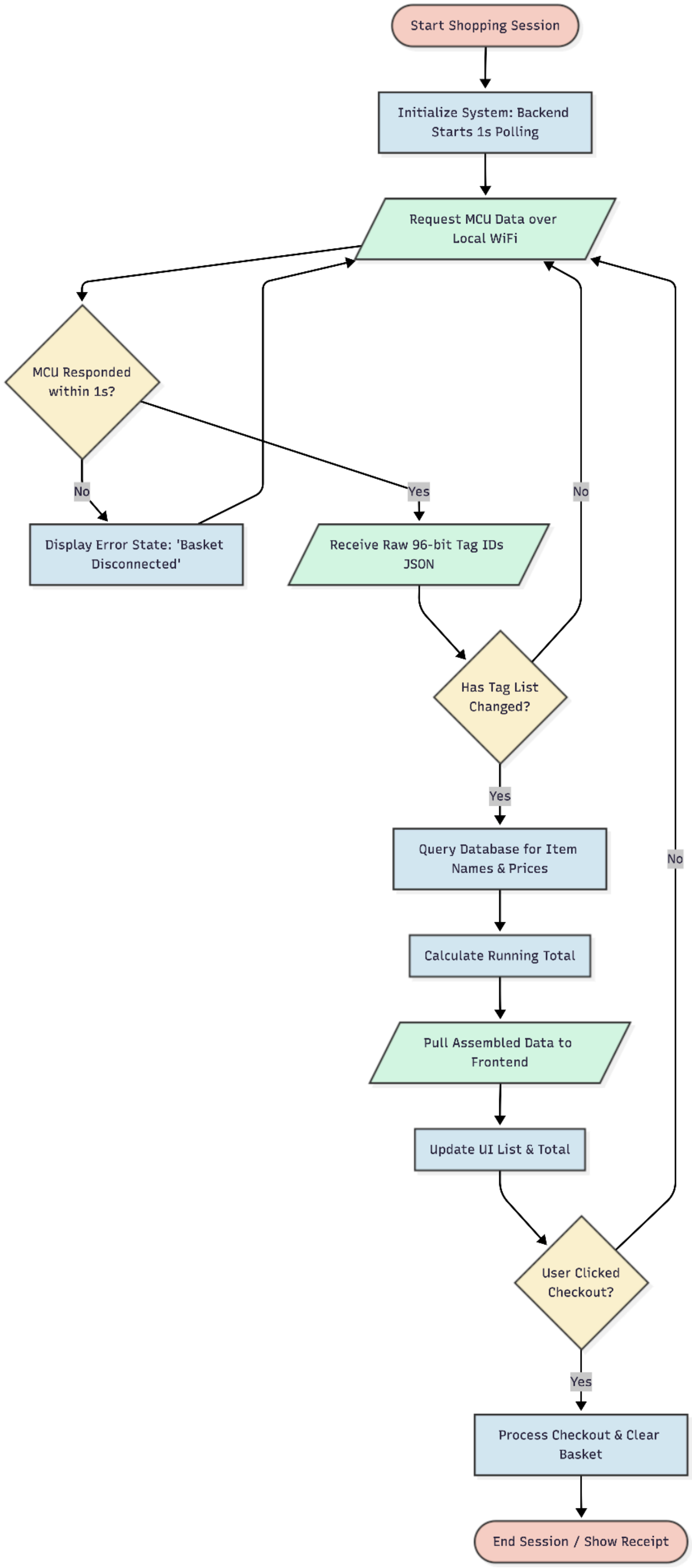

Figure 8: Flowchart of Web Application BackEnd, FrontEnd, and Server Communication

2.3.5 User Feedback Subsystem

The LED Status Indicator provides immediate visual confirmation of the basket's state to the user without requiring them to look at their phone. This subsystem uses a WS2812B RGB LED strip driven by the microcontroller through a 74HCT245 logic level shifter to ensure 5V signal integrity. The LEDs display distinct patterns: solid white indicates "Ready," a green pulse indicates "Success," and a pulsing red indicates a "Mismatch Error." To ensure the LED feedback is timely, visible, and does not interfere with the power stability of other sensors, a requirements & verification table can be found below along with a schematic.

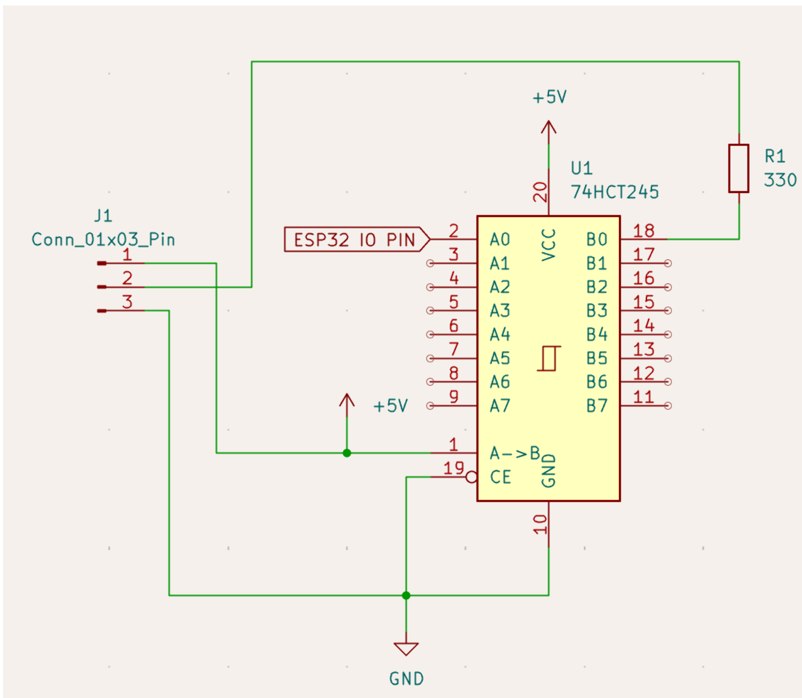

Figure 9: LED Subsystem Schematic based on Ref. 6

Table 5: User Feedback Subsystem – Requirements and Verification

Requirements	Verification
● The expected LED color is produced when a simulated data signal is sent to the Data Line	● Connect the GND pin of the ADALM1000 to the GND rail of breadboard ● Connect Channel A (Orange) to the ESP32 side of the 74HCT245 (3.3V input) ● Connect Channel B (Blue) to the LED side of the 74HCT245 (5V output) after the resistor ● Upload a "Solid White" test script (Hex: 0xFFFFF) to the ESP32 to create a consistent, repeating pulse train on the data line ● Open the Oscilloscope tool in Scopy and enable both Channel A and Channel B ● Use the Measure panel to add "Max Voltage" for both channels. Confirm that Channel A reaches 3.3V (±10%) and Channel B reaches 5.0V (±10%) to check the level shifter ● Observe the physical LED strip to see if it flows White ● Update the ESP32 code to "Solid Red" (0xFF0000) and visually confirm that it turns Red ● Repeat for Green (0x00FF00)
● LEDs shall be visible under standard store lighting and at distances up to 1 meter away	● Activate the LED under standard overhead fluorescent lighting ● Stand 1 meter away from the LED and confirm the color and state are clearly distinguishable
● The subsystem shall consume no more than 500mA on the 5V rail during peak operation to prevent power instability	● Set the LED strip to White (R, G, and B all at 255) ● Measure the current draw on the 5V rail using a multimeter in series ● Confirm the current draw is ≤ 500mA

2.5 Tolerance Analysis

A critical risk to the completion of this project is proper calibration of the RFID read zone and ensuring that the reader is capable of reading multiple devices piled on top of one another. It will be necessary to limit the range to only within the basket with a very small tolerance of just a few inches. Should the range be too high, the basket will incorrectly read items that are nearby, but not in the shopper's basket. Should the range be too low, the basket will not identify all of the items inside.

The basket shall have a signal strong enough to "wake" a tag at the furthest spot from the reader ($d_{max} = 0.25\ m$), yet the signal must be weak enough outside of the basket's range ($d_{lim} = 0.5\ m$).

In free space, doubling distance results in a 6 dB drop in forward-link power. Because UHF RFID relies on a two-way backscatter link, the total received signal strength decreases by approximately 12 dB when distance doubles.

Given that UHF RFID operates between at 915 MHz, the wavelength $\lambda \approx 0.33\ m$. Based on the specifications of the reader, the minimum power (P_t) is 18 dBm. We will assume that the gain of the reader and tag respectively $G_t = G_r = 1\ dBi$. The sensitivity of the tags is approximately -18 dBm.

Based on the Friis Transmission Equation $P_{tag} = P_t + G_t + G_r - 20log_{10}(\frac{4\pi R}{\lambda})$, the power received at the tag with the reader on its lowest setting at a distance d_{max} is then:

$$P_{tag} = 18\,dB + 1\,dBi + 1\,dBi - 20log_{10}(\frac{4\pi(0.25m)}{0.33}) \approx 0.43\,dBm$$

Given that the tags' sensitivity is -18 dBm, this is enough power to activate the tag. At d_{lim}, only an additional 12 dB of additional loss occurs, meaning that through free-space, the system would still transmit enough power to read a tag.

To ensure that the system does not read a tag at d_{lim}, we will therefore control the orientation of the antenna to face strictly upwards (given that the antenna is directional) and add shielding to the basket to provide the necessary minimum of 6dB of additional loss. It is also necessary to note the system will not be performing in true free-space and it is impossible to accurately estimate the attenuation provided by the basket alone without shielding. But, even when assuming free-space, the addition of just a thin layer of aluminum would provide between 5 and 10 dB of additional attenuation, making the overall tuning of the system feasible.

3. Cost Analysis and Schedule

3.1 Cost Analysis

Table 6.1: Itemized List of Components and Costs (Pt. 1)

Description	Manufacturer	Quantity	Price	Link
Black Shopping Basket	Regency Mobile Products	1	$6.49	Link
UHF RFID Module M5Stack U107	M5Stack Technology Co., Ltd.	1	$79.00	Link
Set of Two 20kg Load Cells	Wishiot	1	$11.99	Link
3.3ft of SW2812B Strip LEDs	SHENZHENSHI COYU TECHNOLOGY CO., LIMITED	1	$7.99	Link
2011 Battery	Adafruit Industries LLC	1	$12.50	Link
B78108E1471M009 Inductor (0.47uH)	EPCOS - TDK Electronics	3	$0.81	Link
MMBT4403LT3G Surface Mount Transistor	onsemi	3	$0.39	Link
RK73B2ATTD563J Surface Mount Resistor (56k)	KOA Speer Electronics, Inc.	5	$0.50	Link
RMCF0805FT13K7 Surface Mount Resistor (13.7k)	Stackpole Electronics Inc	5	$0.50	Link
RG2012P-203-B-T5 Surface Mount Resistor (20k)	Susumu	10	$1.00	Link
RMCF0805FT8K20 Surface Mount Resistor (8.2k)	Stackpole Electronics Inc	10	$1.00	Link
CRCW0805100RFKEA Surface Mount Resistor (100)	Vishay Dale	10	$1.00	Link
MLZ2012M3R3ATD69 Surface Mount Inductor (3.3uH)	TDK Corporation	3	$0.90	Link
MLZ2012N1R0LTD25 Surface Mount Inductor (1uH)	TDK Corporation	3	$0.33	Link
C0805C104K5RACTU Surface Mount Capacitor (0.1uF)	KEMET	5	$0.40	Link

Table 6.2: Itemized List of Components and Costs (Pt. 2)

Description	Manufacturer	Quantity	Price	Link
DX07S016JA3R1500 USB-C Receptacle	JAE Electronics	3	$5.61	Link
1812L300MR Fuse	Littelfuse Inc.	1	$2.02	Link
ESD9B3.3ST5G ESD Protection Diode	onsemi	1	$0.16	Link
ETA9740 Power Manager IC	etasolution	5	$1.37	Link
MMSZ4689-E3-08 Zener Diode	Vishay General Semiconductor - Diodes Division	1	$0.15	Link
JS202011SCQN Slide Switch	C&K	1	$0.79	Link
2N7002PW N-Type Mosfet	Diotec Semiconductor	1	$0.20	Link
DMPH3010LK3-13 P-Type Mosfet	Diodes Incorporated	1	$1.38	Link
PMIC-XC6206PMR Voltage Regulator	Torex Semiconductor Ltd	1	$0.53	Link
		Total:	**$136.51**	

Table 7: Itemized List of Labor Hours

Item	Hours	Price	Total
Group Member Labor	450	$54/hr	$24,300
Machine Shop Labor	5	$30	$150
		Total:	**$24,450**

Note: Estimating approx. 2.5 hours of work per member per day, 60 total working days, 3 team members.

3.2 Schedule

Table 8: Schedule for Project Progression

Week	Task	Person
February 22nd - February 28th	Finalize component selection and place orders	Jada & Jacob
	Complete KiCAD Load Cell Amplifier and MCU KiCAD	Jacob
	Work on Power Subsystem KiCAD	Oscar
	PCB FIRST ROUND ORDERS - KiCAD and Load Cell Amplifier Breakout Boards	Everyone
March 1st - March 7th	Breadboard Testing: Power Subsystem (Regulate 3.7V to 5V/3.3V)	Oscar
	Breadboard Testing: MCU logic and UART communication	Jacob
	Breadboard Testing: LED Logic: Verify 3.3V to 5V signal shift via 74HCT245	Jada
	PCB SECOND ROUND ORDERS - Power Subsystem Breakout Board	Everyone
March 8th - March 14th	UHF RFID Tuning: Calibrate 915MHz frequency and test 96-bit tag IDs	Jacob
	LED Pattern Testing: Code/test Green, Red, and White pulses on breadboard	Jada
	Experiment with metal shielding to limit RFID range to < 0.5m	Oscar
	Integrate Design: Combine all subsystems into one master KiCAD PCB layout (Everyone)	Everyone
	PCB THIRD ROUND ORDERS - Fully Integrated PCB	Everyone
March 15th - March 21st	**SPRING BREAK**	
	Potential KiCAD Designing if needed	Everyone
	Leave basket with Machine Shop to be worked on over Spring Break	Everyone
March 22nd - March 28th	Solder PCBs: ESP32, and Load Cell Amplifier	Jacob
	Solder PCB: 74HCT245	Oscar
	Test LED patterns based on simulated sensor triggers	Jada
	PCB FOURTH ROUND ORDERS - Potential Revisions	
March 29th - April 4th	Build Web Application UI and Backend (API/WebSocket setup)	Jacob & Jada

	Web App Testing: Verify 720x1280 resolution responsiveness	Jada
	Battery Life Testing: Verify subsystem draw supports shopping duration	Oscar
April 5th - April 11th	Firmware Integration: Link RFID tag detection to Weight Sensing logic	Jacob
	System Calibration: Ensure 0.5lb weight change triggers error if no tag read	Jada
	Cable Management: Secure all 5V/3.3V wiring within the basket frame	Oscar
April 12th - April 18th	Final Mounting: Place PCB and LED strip (WS2812B) into the basket	Everyone
	Accuracy Test: 95% identification accuracy for 10+ items	Jada
	Verify 1-second Web App refresh rate via browser Network Tab	Jacob
	Resolve any "false positive" RFID reads outside 12-inch range	Oscar
April 19th - April 25th	**MOCK DEMOS**	Everyone
	Resolve any issues pointed out in Mock Demo	Everyone
April 26th - May 2nd	**FINAL DEMOS**	Everyone
May 3rd - May 6th	Final Paper	Everyone
	Finalize Lab Notebook	Everyone

4. Societal Impact, Engineering Standards, Ethics, and Safety Considerations

The proposed smart basket must be created with the intent safety, transparency, and professional responsibility as primary considerations. In alignment with the IEEE Code of Ethics Section I.1 [9], which states that engineers must "hold paramount the safety, health, and welfare of the public," our system prioritizes accurate billing, electrical safety, and secure operation. Because the basket integrates electronic components, batteries, and a wireless communication system, careful attention is given to voltage regulation, current limitation, and proper design in order to prevent short circuits. Protective elements such as regulated power supplies and overcurrent protection devices (such as PTC) are incorporated to minimize electrical hazards. Additionally, the basket will be made out of a durable plastic material that does not pose an immediate threat to the user and is safely able to support a minimum of 30 pounds. Moreover, the basket poses a perfectly safe environment for our electronic components and subsystems.

Consistent with IEEE Code of Ethics Section I.1 and I.2 [9], which encourage engineers to avoid harm and improve understanding of technology's societal implications, the Smart Basket is designed to collect only transaction-related item data. Communication between the basket and the web application will transmit only item-related information, reducing privacy risks. Transparency will also be emphasized by allowing shoppers to view their item list and running total in real time, helping users identify mistakes before checkout.

In addition to privacy considerations, the project complies with applicable engineering standards and regulatory requirements. The selected UHF RFID module operates within the legally authorized Industrial, Scientific, and Medical (ISM) band of 902–928 MHz in the United States, consistent with FCC Part 15 Subpart C [8] regulations for unlicensed intentional radiators. The module's output power and antenna configuration are selected to remain within FCC emission limits and avoid harmful interference with other wireless systems. Any commercial deployment would require FCC certification or use of a pre-certified module to ensure regulatory compliance. Electrical components, including the battery management system and power regulation circuitry, are selected in alignment with relevant UL safety standards for lithium-ion battery systems and power supplies [19], reducing risks related to overheating, short-circuiting, or fire hazards.

Furthermore, the system acknowledges potential misuse scenarios, such as attempts to shield RFID tags or manipulate weight measurements. To address these risks, cross-verification between sensing mechanisms and inconsistency alerts are implemented. While complete elimination of misuse is unrealistic, these safeguards demonstrate a commitment to responsible engineering design and public trust. From a safety perspective, the design includes regulated voltage rails (5V and 3.3V), overcurrent protection, and proper grounding practices to reduce electrical hazards. Enclosure design will prevent user access to exposed conductors, and charging circuitry will follow manufacturer specifications and workplace electrical safety guidance consistent with OSHA electrical safety principles [16]. While complete elimination of misuse is unrealistic, these safeguards demonstrate a commitment to responsible engineering design, public trust, and user safety.

By reducing checkout times, the system may improve accessibility for individuals with limited mobility or time constraints while enhancing overall customer satisfaction. Businesses could benefit from improved operational efficiency and reduced congestion without fully replacing human workers, instead allowing employees to focus on customer assistance and higher-value tasks. Environmentally, the system encourages efficient store layouts with less physical space dedicated to checkout infrastructure and reduced paper receipt usage when paired with digital transaction records.

By adhering to IEEE's ethical framework, this project aims not only to improve retail efficiency but also to ensure that technological innovation remains safe, transparent, and socially responsible.

5. Citations

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