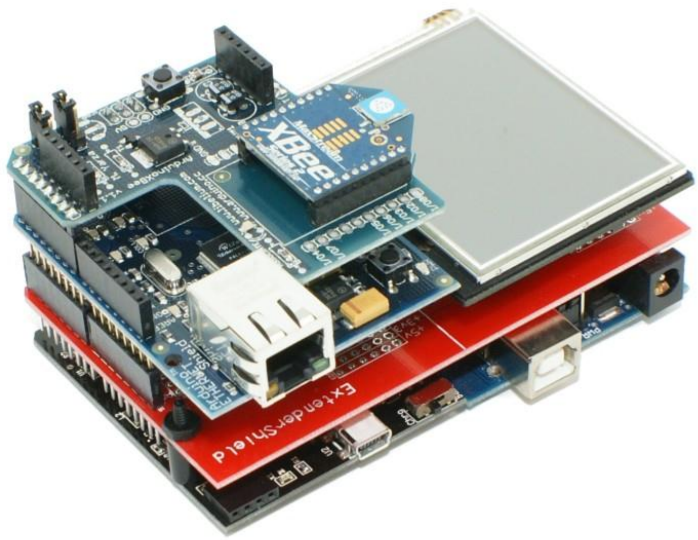

The Smart Cart – An Enhanced Shopping Experience

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Team 41

Contents

Motivation

The smart cart will be an all in one cart. It will allow the user to keep track of the total cost as and when items are added to the cart. It will also communicate wirelessly with an in store component to make easy payments on the go. In the case of any ambiguity, the shopper will also have the option of going up to the checkout counters. This new system would reduce the long wait times at the checkout counters, increase the efficiency of the checkout procedure, and would provide the shopper with up to date cost and total information which makes the whole experience more convenient.

Objective

This project aims to design a system which reads the barcode on each item that is placed in the cart and updates the product information which is available to the shopper. Pressure/Weight sensors will be used to detect the presence of new items in the cart.
The barcode scanner extracts the barcode which is transmitted to the microcontroller through an USB connection. The microcontroller reads information from a SD card inserted into the microcontroller. This SD card has all the information about the product. This data is then formatted and presented to the user for review and confirmation on a LCD screen.

New items in the cart will be detected by tracking the change in the output of pressure sensors. The same sensors will be used to detect when items are removed from the cart. A program will be implemented to confirm the removal from the shopper's shopping cart. Another program will be implemented to work as an anti-theft mechanism to prevent the shopper from leaving without a successful payment.

Benefits

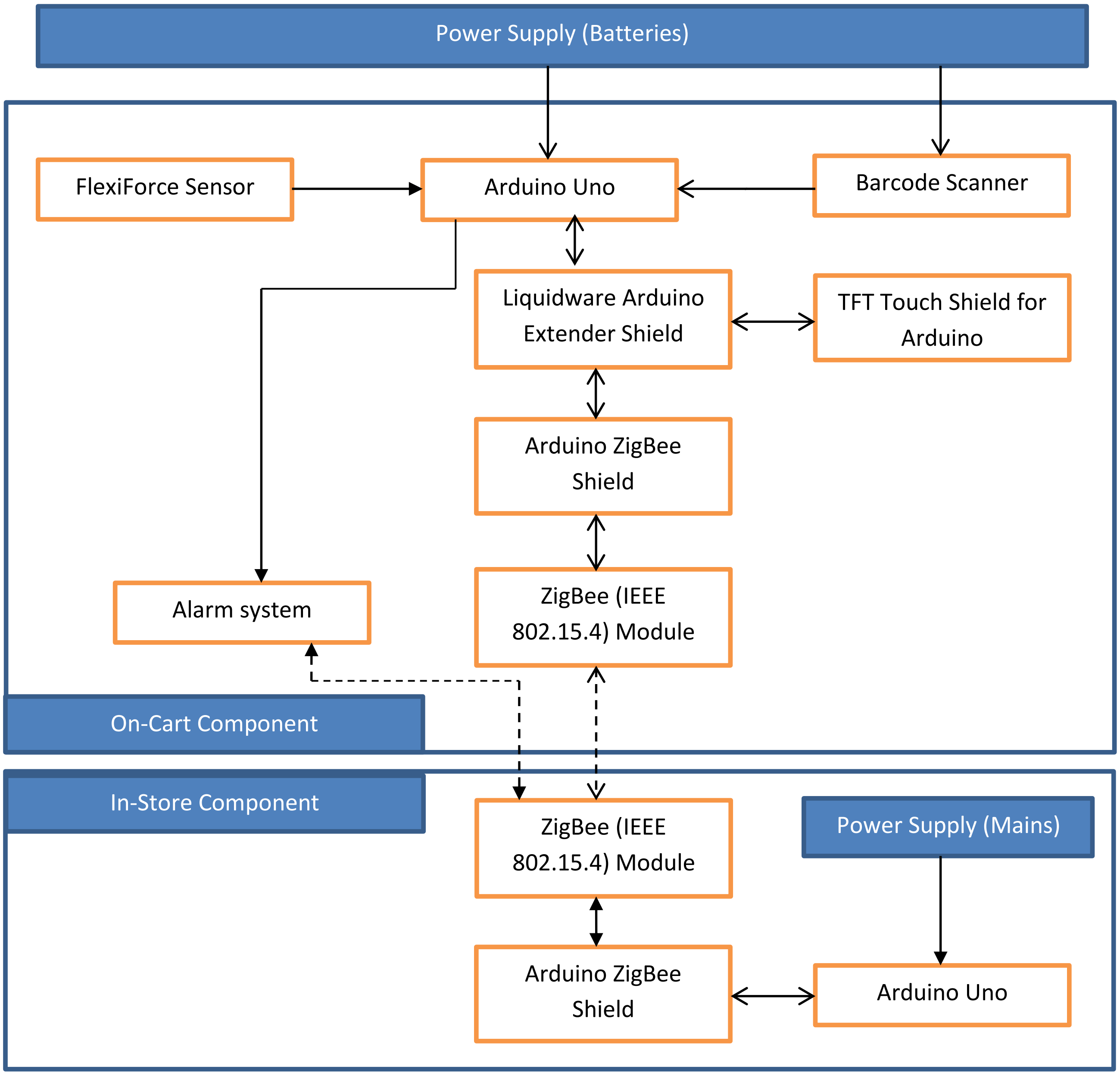
- Improve the shopping experience for all the patrons of the store
- Increase efficiency of the checkout process
- Eliminate long waiting queues at the checkout counter

Features

- User interface with LCD monitor to provide immediate feedback to user inputs
- Automated shopping item detection
- Automated communication system to make payments at counter
- Automated data formatting and organization for use by the shopper
- Alarm beeping functionality to prevent theft (for use in the case of non-payment for items in cart)

Design

Block Diagram



Block Descriptions

1. **Arduino Uno**

   Arduino Uno is the primary microcontroller of the whole system. It is based on the Atmel ATMega328 microprocessor. The Uno will be used for data processing, controlling the ZigBee shield, LCD shield, reading data from the alarm system and for reading data from the FlexiForce sensor.

2. **Arduino Extender Shield**

   The Arduino extender shield is used to support multiple shields which require access to the same pin–outs on the Uno. It essentially provides a hack to avoid tedious port mapping.

3. **Arduino ZigBee Shield**

   ZigBee shield provides an easy technique to interface the ZigBee module with the Uno. It allows easy access to well-known wireless libraries that come with the Arduino.

4. **ZigBee Module**

   The module provides the device with the wireless communication capabilities that will be used as part of the anti-theft mechanism and payment process. The module will constantly transmit a pre-defined pulse as long as no payment is processed. The pulse changes to hold different information once the payment is processed. Both these pulses are received by the same module present in-store.

   The Uno connected to the in-store component decodes the data and transmits a pre-defined pulse in response. Based on the information encoded in the in-store transmission, the on-cart Uno sends an information and this would help trigger the alarm system.

5. **Alarm System**

   When the cart reaches a certain distance to the in store component and if there is any discrepancy between the weight of the cart and the weight of the scanned items, the alarm system would trigger. There would be a sound something like a buzzer which would indicate a theft.

6. **USB to serial adapter**

   Since there is only one USB-B port available on the Uno, a USB to serial adapter will be used in order to fulfill barcode scanning requirements for the component that is not connected directly to the Uno.

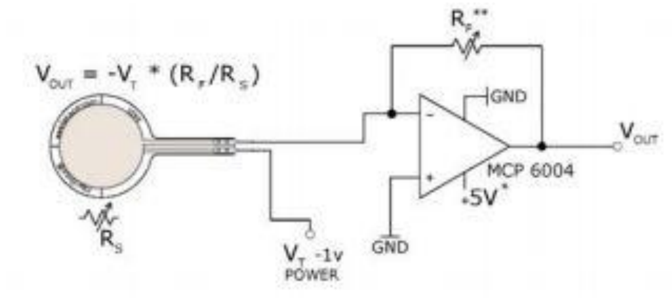
7. **FlexiForce Sensor**

   The sensor will be used to detect the presence of new items and also notify the shopper if certain items have not been scanned. Therefore, if the sensor shows a weight change of 10lbs. and the products scanned only total up to 8lbs., the shopper will be notified immediately about the discrepancy. Similarly, if items are removed, the sensor will show a negative change which the Uno will interpret and notify the shopper.

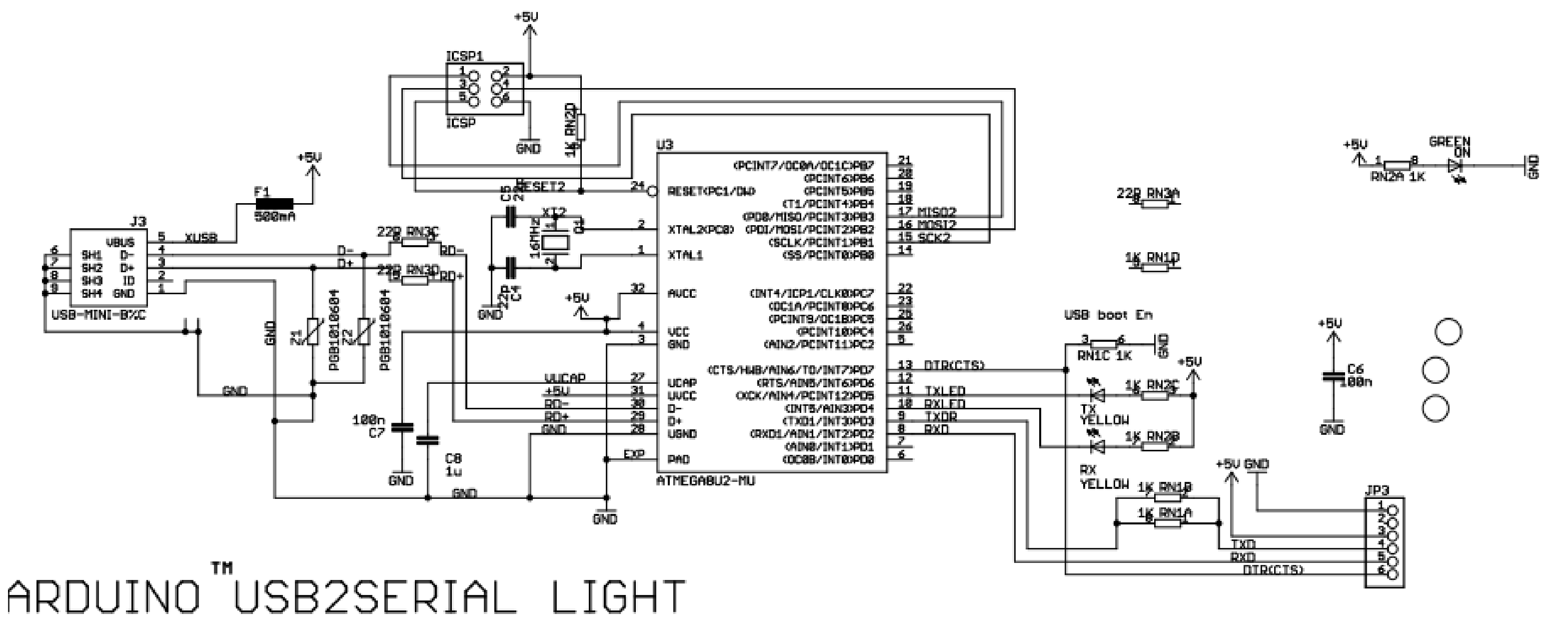
8. **Barcode Scanner**
   The barcode scanner is the source of all the product data that will be available to the Uno. It is a normal scanner which transmits the data through USB port to the Uno. The Uno will in turn look up the code on the database and put out this data on the LCD screen.
9. **TFT Touch Shield**
   The touch shield integrates with the Uno seamlessly. It comprises of a 2.8” TFT LCD touchscreen and microSD slot for additional data. The card will be used to hold the product database. The shield comes standard with LCD driver libraries that will work easily with the Uno. The data to the screen will come from the Uno over which the shield connects. The user will interact with the device through the touchscreen. The user will be able to perform actions such as delete items, view the items already in the cart, etc.
10. **Payment Process**
   As soon as the cart reaches at a certain distance to the payment terminal the cart would transmit all the info related to the payment i.e price, quantity, item list. Then the person could go ahead with the payment process and could pay by cash or card. In this way the customer could carry out a simple and faster check out.

Circuit Schematics

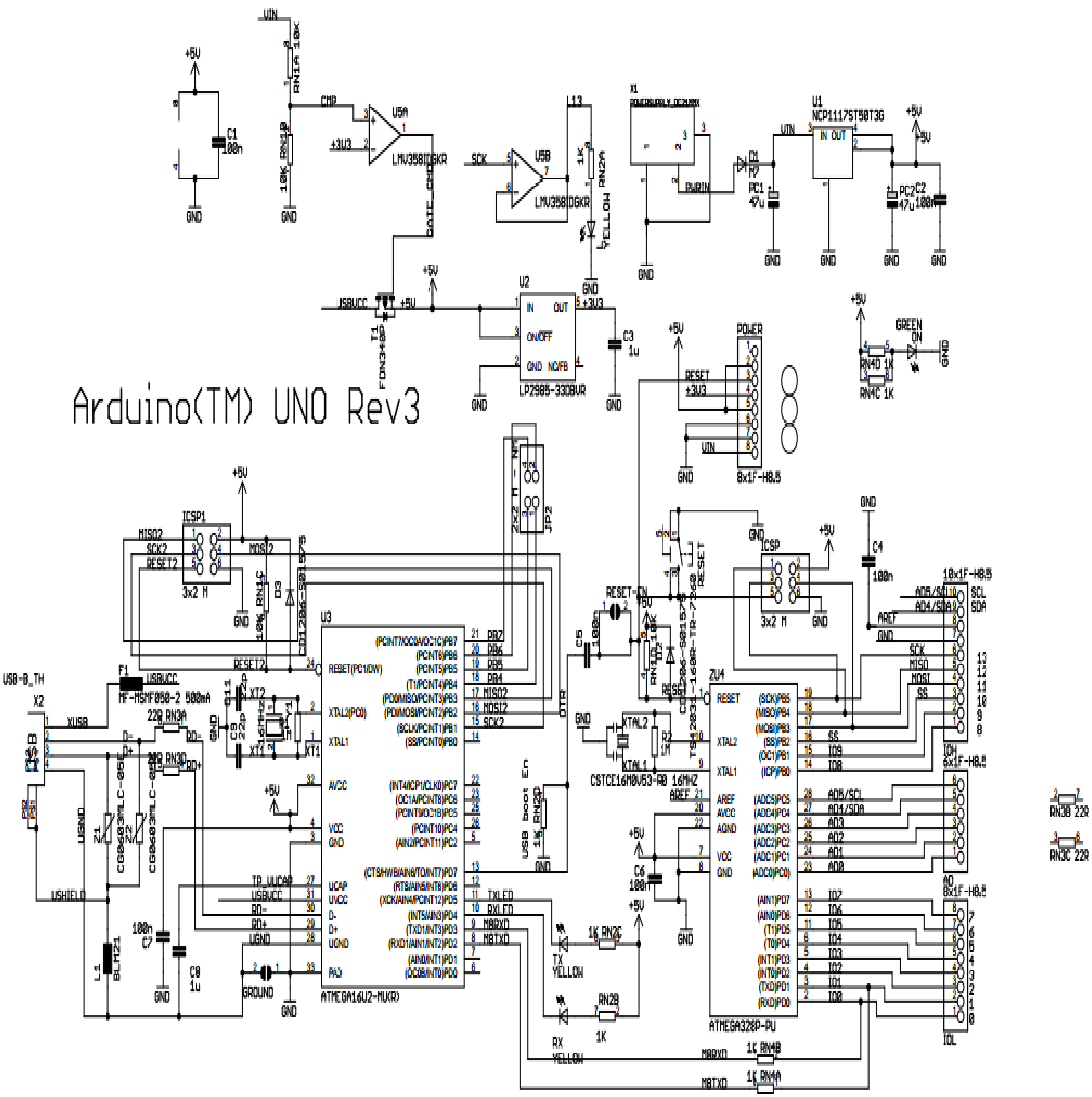
FlexiForce Sensor



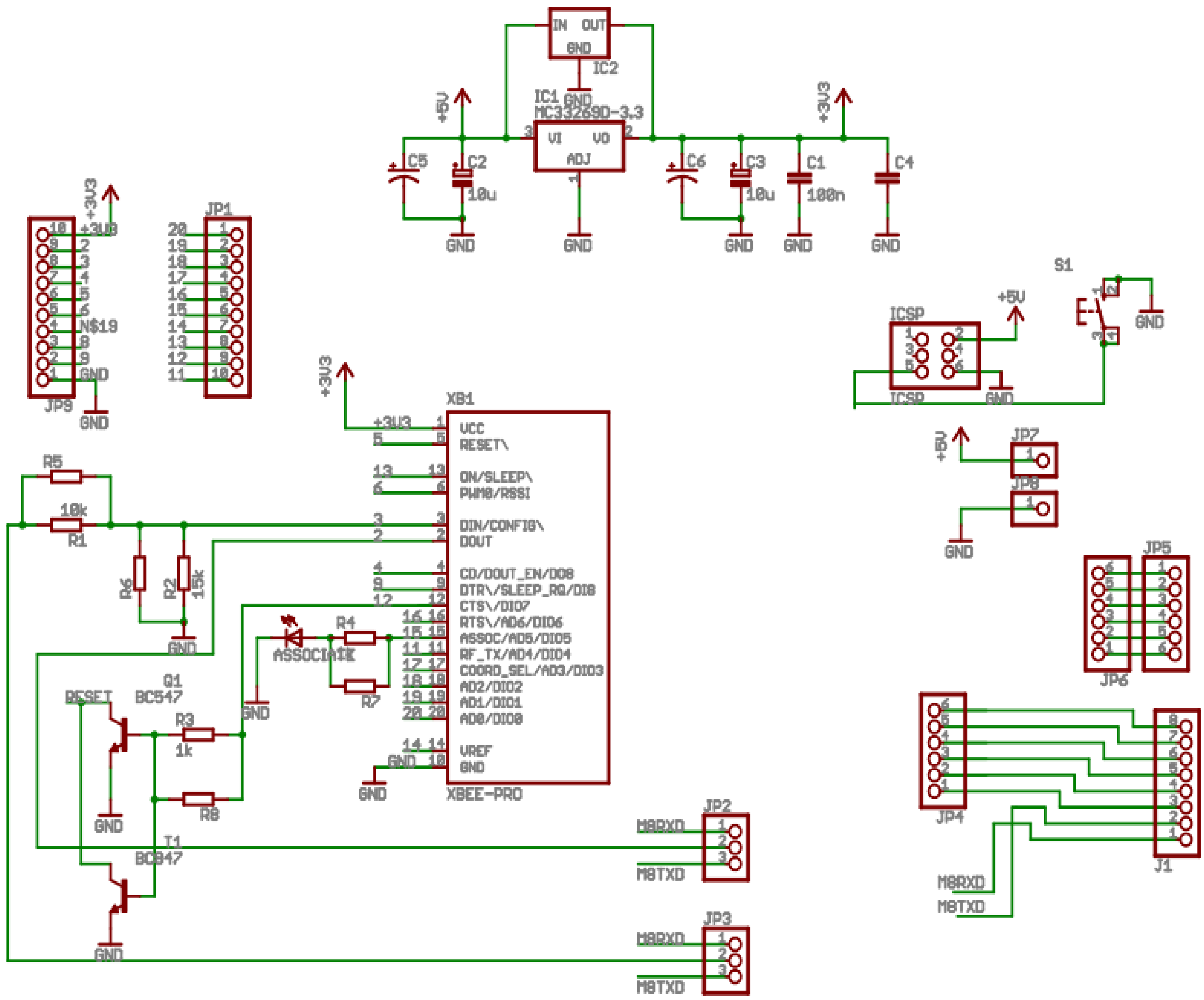
USB Adapter Layout



Arduino Uno Pin Layout



Arduino XBee Shield Pin Layout



XBee Frequency and Channel Distribution

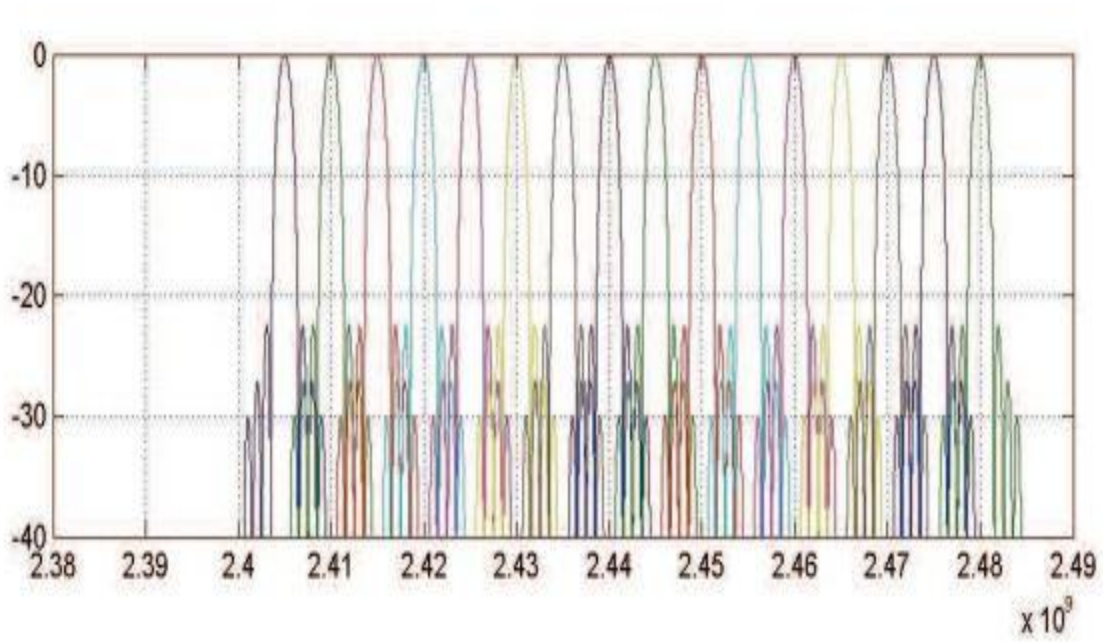
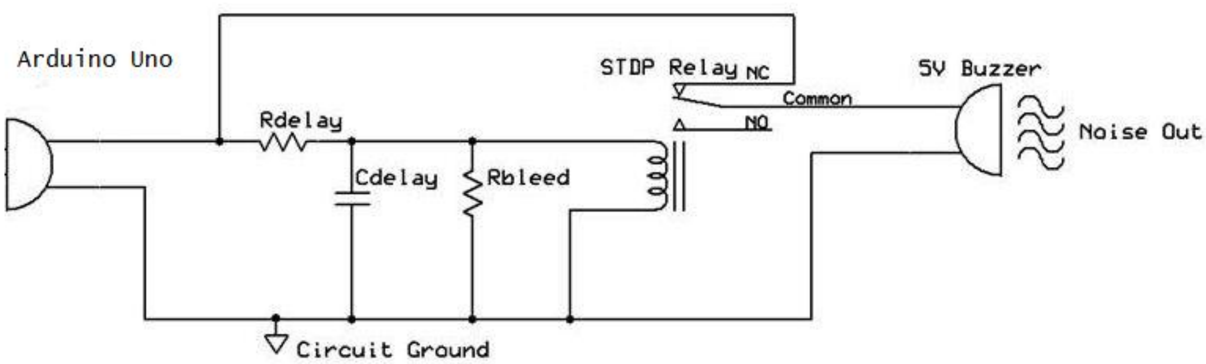
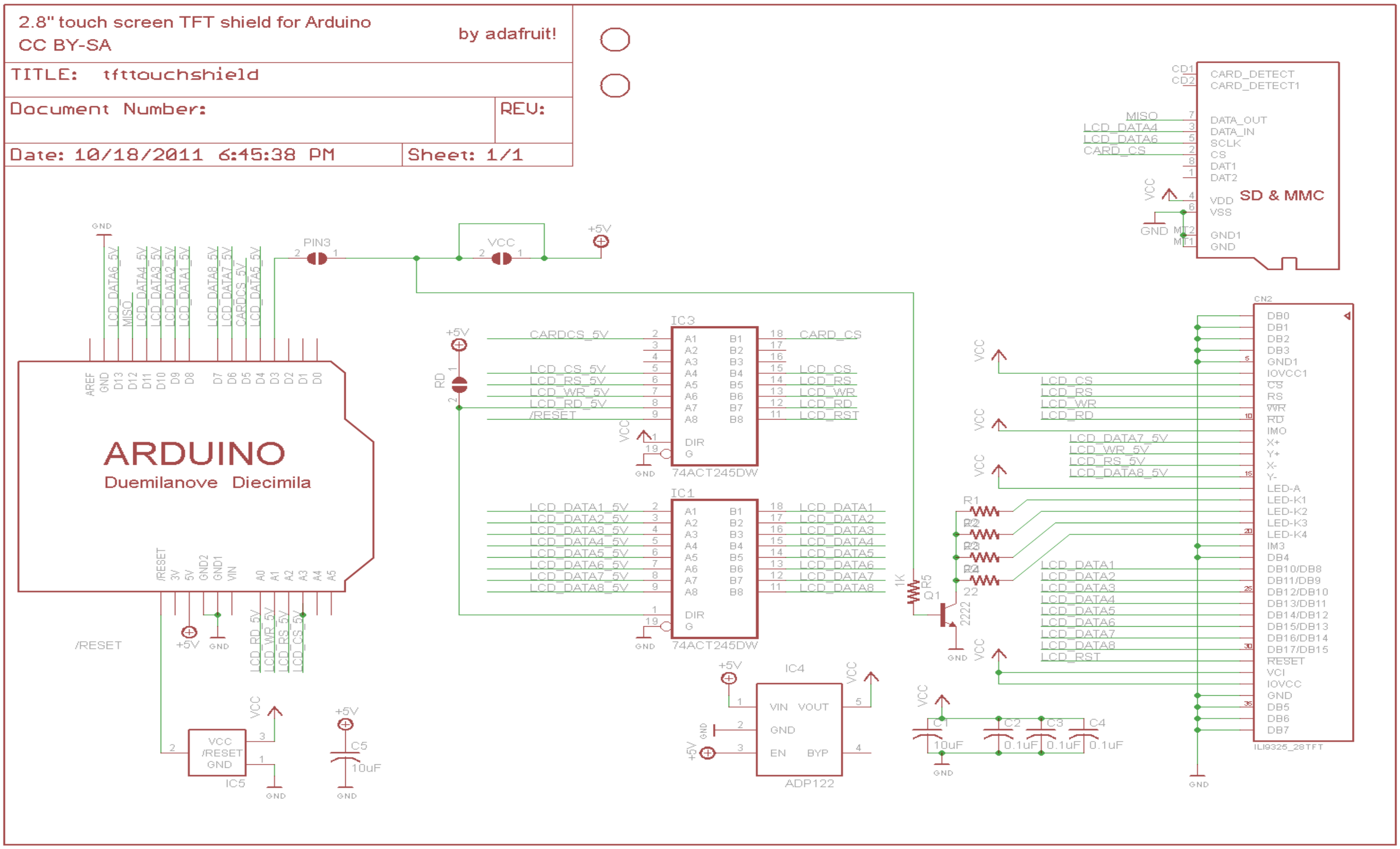


Figure 1: Fc = 2405 + 5 (k – 11) in megahertz, for k = 11, 12, …, 26

Buzzer Schematic

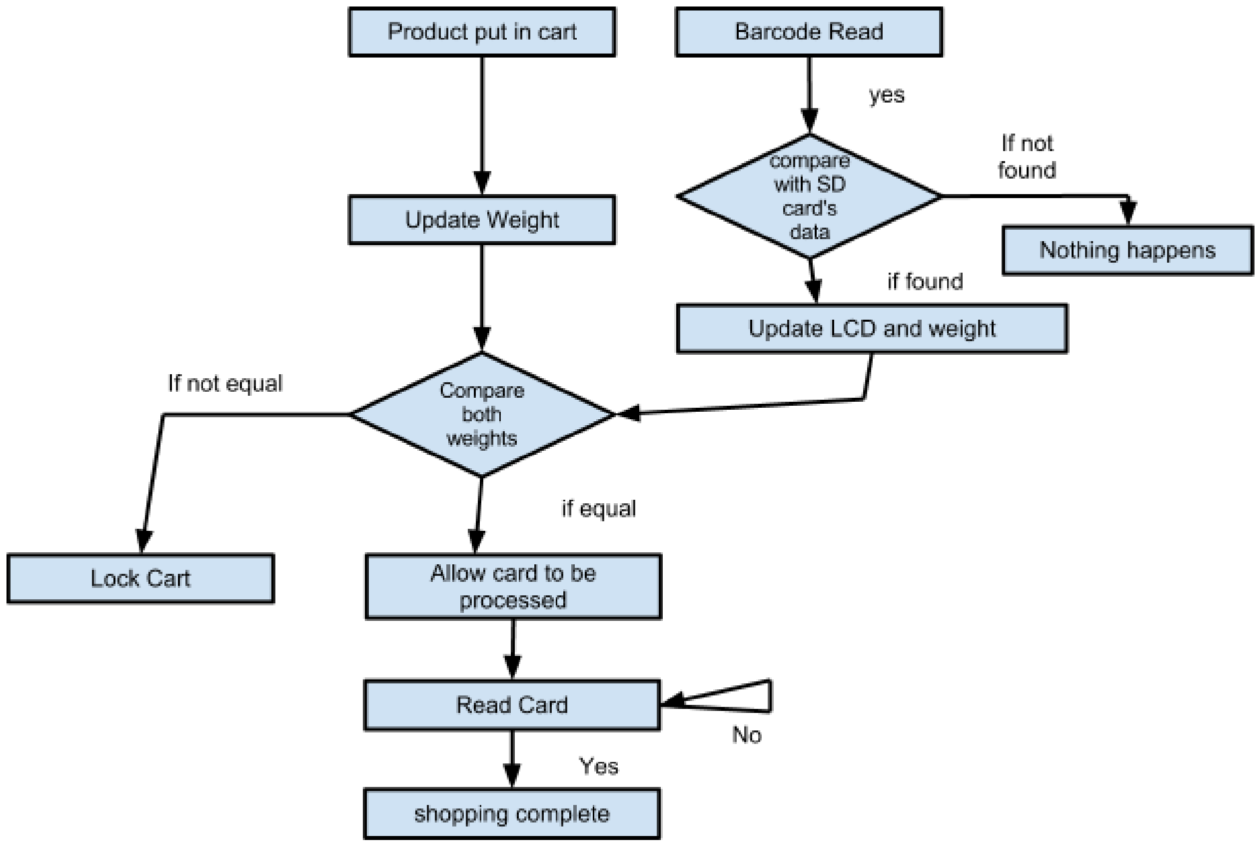


LCD Pin Layout and Arduino Connection

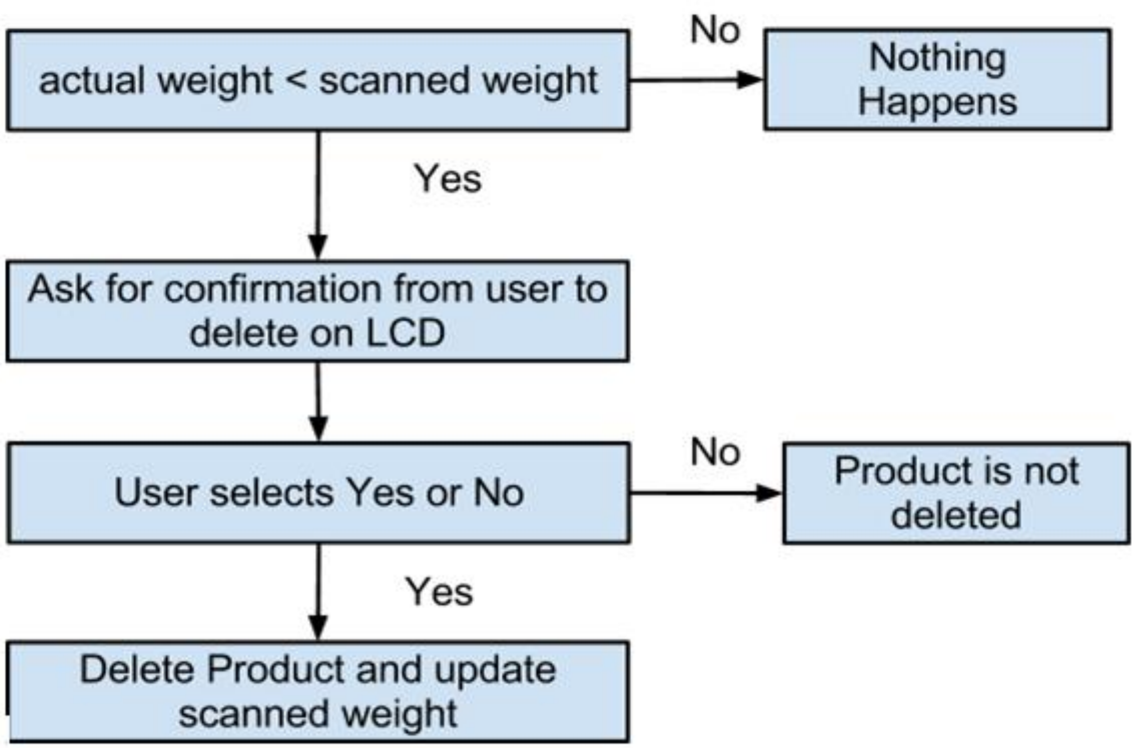


Flowcharts

The following is a functional flowchart for the device:



Removing a product from the cart



Calculations

Power Calculations

Source of Consumption	Active Consumption (mA)	Hours of Active operation (hr.)	Total Active Consumption (mAh)	Idle Consumption (mA)	Hours of Idle Consumption (hr.)	Total Idle Consumption (mAh	Total Consumption (mAh)
Barcode Scanner	100	2-4	200-400	40	20-22	800-880	1200-1280
Alarm Beeper	35	1	35	0	23	0	35
Arduino Uno	200	2-4	400-800	50	20-22	1000-1100	1400-1900
LCD Screen	60	2-4	120-240	13	20-22	260-286	280-526
XBee Module (0dBm)	95	2-4	190-380	0	20-22	0	190-380

Table 1: Estimated power draw of each component

Total Consumption = (1280 + 35 + 1900 + 526 + 380)mAh

= 4121 mAh

Battery capacity = 10000 mAh

Single charge use = (10000/4121) days

= 2.43 days

Therefore, the device will need 3 recharges every week. This is a decent first order estimation and reasonable for the first prototype.

XBee Module Loss Calculation

$P_R = [(P_T G_T G_R \lambda^2)]/ [(4\pi)^2 d^2]$ -------------------------------------- (Eq. 1)

Where,

P_R -> Received power

P_T -> Transmit power

λ -> Wavelength

G_T -> Gain of Transmitter antenna

G_R -> Gain of Receiver antenna

d -> Distance

$P_R (d_0) = P_R (d)*(d_o/d)^2$ -- (Eq. 2)

Where,

$P_R (d_0)$ -> Received power at required distance

P_R (d) -> Received power at reference distance (= 1m for indoor applications)

d_0 -> Required distance

d -> Reference distance

The chosen XBee module has a transmit power of 1mW (or 0dBm).

The reference distance is 1m.

Assuming unity receiver and transmitter gain, and using d = reference distance = 1m in Eq. 1, we get:

$P_R (1m) = [(0.001*1*1*(0.125)^2)]/ [(4\pi)^2*)1)^2] = 0.00158$ mW = -28.0 dBm -------- Eq. 3

Plugging Eq. 3 in Eq. 2 for a 3m (10 feet) range, we get:

$P_R (3m) = P_R (1m)*(1/3)^2 = -28dBm – 20log(1/3) = -28 – 9.54 = -37.54$ dBm

At transmit power of 0dBm, the received strength in -37.54 dBm. This is **54dB higher** than the XBee module **sensitivity (92dBm)**. **Therefore, we can transmit at lower than 0dBm in order to conserve power (if required).**

Requirements and Verification

Requirement	Verification
1. Input voltage provided to each component is in the range: a. 7-12V provided to Arduino b. 1-1.5V provided to sensor c. Constant 5V provided to Barcode scanner	1. A potentiometer will be used to divide the voltage to desired values for the components placed in parallel a. Use DMM to check input to potentiometer is 7-9V b. Use DMM to check input to Arduino is 7-9V c. Use DMM to measure output of the 2 potentiometer branches which should be 1-1.5V for sensor and 4-5V for Arduino
2. Sensor senses small variations in weight from 0 to 1000 lbs. a. 1-1.5V supply provided to sensor b. Constant 5V provided as supply rails to Op-Amp in drive circuit c. Voltage changes with respect to change in weight	2. Connect feedback resistance to the drive circuit to amplify output a. Increase feedback resistance in order to achieve voltage change of 5mV b. Increase weight on sensor to verify 5mV steps c. Obtain trade-off between resolution and resistance value to check for performance degradation
3. ZigBee module transmits enough power such that received levels fall within sensitivity for various receiver distances. a. Constant 0dBm power output from transmitter b. Modulation error rates within IEEE standards specifications	3. Connect ZigBee module antenna to spectrum analyzer a. Check that antenna has very low S11 value at 2.4GHz to ensure successful radiation b. Transmit using one module and receive with other module c. Ensure transmit power is 0dBm using spectrum analyzer d. Measure received power spectrum on a spectrum analyzer to verify prior calculation estimates e. Check this spectrum for various receiver distances f. Compare received and transmitted spectrum to check for possible degradation
4. Verify software programs are working correctly a. Weight is correctly inferred from voltage change on the sensor b. Barcode data is correctly read into USB	4. The software that will be written for the device will define the degree of success achieved. a. Check the register holding the weight information using the Arduino debugger

c. Barcode data is correctly correlated to product database d. ZigBee module data correctly demodulated	b. Manually check the register holding the barcode data to verify that it translates to a correct value c. Manually check the database for the product matching the data and confirm if the software is pulling the same data d. Use ZigBee emulator to transmit a known pulse (eg. All 1's) and verify using the same emulator that the same pulse is received.
5. Verify latency rates of the system a. Time taken for barcode data to be read and deciphered b. Time taken to run the code to correlate the data to a product c. Time taken to transmit data to LCD	5. The success of the device depends on how quickly the data can be processed and shown to the user a. Manual timing will be used to estimate the system latency (eg. Using a stopwatch)

Tolerance Analysis

Block Name and description	Testing Focus	Acceptable result ranges
• Battery (Power Supply) – The main supply that will provide power to all critical devices in the cart like microcontroller, barcode scanner.	• Battery provides the within 5% of expected voltage • Battery capacity stays constant even during discharging period • Full capacity (within 5%) is retained even after multiple charge and discharge cycles • Battery provides rated voltage at its terminals even after multiple recharge cycles	• According to Table 1 (Power Calculations on Page 12), the battery can last up to 3 days. This is assuming that a cart is used for roughly 4 hours per day. • With capacity loss and voltage loss which is inherent in a rechargeable battery, a change of 15% in estimated usage time is acceptable (**in the long run)**

The single most critical component of the device is the battery (power supply). In order for this device to be successfully deployed storewide, it is critical that the time between charges for the battery be maximized i.e. battery life needs to be optimized. The store management would ideally like the device to be functional over multiple degrees of use per day. Unfortunately, the more the device is used, the greater the drain will be on the battery's power. The device will need to be tested for various use cases involving different periods of active use of the device and track how our battery power depletes.

A DMM will be used to track voltage changes over the course of usage and a large load will be connected to the power supply to verify the capacity. The current draw will also be measured using a DMM.

Schedule

Week	Kartik Sanghi	Rohan Singh	Nikhil Raman
1/23	Brainstorm project ideas	Brainstorm project ideas	Brainstorm project ideas
1/30	Research possible design solutions	Research possible design solutions	Research possible design solutions
2/6	Write Proposal (Testing and verification)	Write Proposal (Cost and Scheduling)	Write proposal (Design and objectives)
2/13	Acquire parts	Come up with design flowcharts	Draw up circuit schematics
2/20 (All work towards design review)	Test parts and update requirements and tolerance analysis	Perform necessary simulations and required calculations	Update block diagram and design considerations
2/27	Design power supply for each component	Design in-store transceiver circuit	Design on-cart transceiver circuit
3/5	Build and test power supply	Build and test in-store transceiver	Build and test on-cart transceiver
3/12	Interface microcontroller with power supply	Interface microcontroller with barcode reader	Interface microcontroller with RF circuitry
3/12	Connect with Wal-mart and improve design specs		
3/19	Spring Break Chilling in Mexico	Spring Break Chilling in Mexico	Spring Break Chilling in Mexico
3/26	Interface microcontroller with LCD monitor	Interface microcontroller with weight sensor	Design Alarm mechanism
4/2	Test LCD interface	Test sensor interface	Test scanner interface
4/9	Integrate product database with device memory	Design casing for extremities	Interface microcontroller with alarm system
4/16	Integrate and test microcontroller	Integrate and test sensors and barcode scanner	Integrate and test alarm mechanism and RF Circuitry
4/23	Write final report (Testing and verification)	Write final report (Cost, measurements and future scope)	Write final report (Design)
4/30	Demo and graduate!!		

Cost Analysis

Labor

Employee Name	Hourly Rate	Estimated No. of Hours	Total = Rate*Hours*2.5
Rohan Singh	$40	160	$16,000
Kartik Sanghi	$40	160	$16,000
Nikhil Raman	$40	160	$16,000

Bill of Materials

Parts Needed

Description	Manufacturer	For	Price ($)	Quantity	Total ($)
Arduino Uno	Adafruit	Microcontroller	29.95	2	59.9
TFT touch Shield	Adafruit	Display	59	1	59
Xbee Shield with radio module	Liquid Ware	Transceiver	59.37	2	118.74
Bardcode scanner	Amazon	Reading UPC	29.97	1	29.97
Go between shield	sparkfun	Microcontroller	13.95	1	13.95
USB Adapter	Arduino	Microcontroller	14.98	1	14.98
Alarm Buzzer	sparkfun	Theft system	2.00	1	2.00
Battery	Tenergy	Power Supply	41.99	2	83.98
Flexi Force Sensor	Tekscan	Weight monitoring	65	1	65

Grand total = Parts needed + Labor cost

= $447.52 + $48,000

= $48,447.52

Wal-Mart Budget Per Store

When preparing an implementation budget for Wal-Mart, it is critical that the following issues be considered:

1. Implementation consultants: The cost incurred by Wal-Mart in paying their engineering team who will coordinate the transition
2. Materials: The actual device cost
3. Manpower Usage: The actual labor (number of people) involved in modifying the carts
4. Cost towards disruption (if any): Many carts may be out of commission when they are being modified
5. Any utilities used: Electricity and water used

Consultants:

The engineering department at Wal-Mart and any consultants that are used are the largest component of the budget. Using an estimated number of 15 such employees for this project and an hourly wage of $40 per employee, the total cost (using a 3 day approximation for the implementation timeframe) comes out to $14,400.00

Material Cost:

The final value for materials comes out to $467.18

Manpower usage:

As explained above, this section includes the wages of the employees physically placing this device on the carts. It is not necessary for these employees to be technically capable. Estimating the hourly wage for such employees to be around $15 (considerable rounding up) and the time taken to physically place a device on the cart to be a maximum of 1 hour, the labor cost per cart would be $15. Approximating that 250 carts will be equipped, the total cost is $3750.

Cost towards disruption:

When the carts are being modified, they cannot be used for shopping. Therefore, it is essential that the modification process be taken up during the relatively lean hours of operation. Estimating (based on the fact that hundreds of carts are available at any given point at a single Wal-Mart store) that around 5 carts that would normally be used for shopping are actually being modified and using an estimated income per cart to Wal-Mart of $150, the cost of disruption per day would be $750.

The whole process must not take more than 3 days to be successfully implemented on all carts and this yields total cost of disruption of $2250.

Utilities used:

The cost of utilities used would be negligible compared to the typical total daily utilities bill of a Wal-Mart store.

Total Cost **= Consultants + Materials + Labor + Cost toward disruption**

= $14,400 + $447.52 + $3,750 + $2,250

= $20,847.52

It must be noted that while the implementation cost is steep, the benefits of a happy shopper goes a long way in increasing the store profitability.

Ethics and Citations

Ethical Considerations

Most of the IEEE codes of Ethics have been religiously followed. A few Codes of Ethics are directly applicable to the projects which are:

- To be honest and realistic in stating claims or estimates based on available data
- To improve the understanding of technology; its appropriate application, and potential consequences
- To seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, and to credit properly the contributions of others

These pointers directly relate to this project and it is important to credit Walmart for this idea and rest of the ethical codes are not directly related to this project but have been taken care of.

Citations

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