RADIO FREQUENCY IDENTIFICATION (RFID) BASED ELECTRONIC SHOPPING TROLLEY

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By

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A research dissertation submitted in partial fullfilment of the requirements for the degree in

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Abstract

There has been an emerging demand for quick and easy payment of bills in supermarkets. This project describes how to build an automated and time saving system for the world of retail which will make shopping experience impetuous, customer friendly and secure. In this dissertation, RFID based electronic is proposed that will be capable of generating a bill from the cart itself. The designed trolley helps the shop owner by reducing the shop assistances available on duty at one time the system will perform almost as a personal shop assistant for every single shopper in the shop, makes the best use of cart storage space The smart cart uses RFID technology for shopping and total. This innovative system will help the stores to see a rise in their sales along with delighting.

DECLARATION

I Shepherd Gwandira hereby declare that I am the sole author of this thesis. I authorize the University of Midlands state to lend this thesis to other institutions or individuals for the purpose of scholarly research.

Signature ___________________________

Date _______________________________

APPROVAL

This dissertation entitled "RADIO FREQUENCY IDENTIFICATION (RFID) BASED ELECTRONIC SHOPPING TROLLEY" by SHEPHERD GWANDIRA meets the regulations governing the award of a degree of BACHELOR OF SCIENCE HONOURS IN TELECOMMUNICATIONS of Midlands State University and is approved for its contribution to knowledge and literal presentation.

Supervisor…………………………………………………………

Date………………………………………………………………..

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Contents

CHAPTER 1

1.1 Introduction

The project is on the use of an RFID based electronic trolley, built up with an RFID reader to help calculate the total price of goods a customer put in a trolley before they go to the till to cash in.

1.2 Background

The student observed the problem as he was bored by spending a lot of time trying to calculate the exact total price of his goods at a shopping supermarket. This was very difficult as he needed a pen, a paper and a calculator or an adding machine. Also another problem was that some other shelves had no price tags for the goods so the student had to estimate the price judging on the previous price stock list. Again more time is spent when the till operator call the required supervisors to correct receipt mistakes for those customers who have wild guessed the prices of certain products wrongly. This required much time as the till operator will have entered and calculated the cost of all items. Another problem was that the prices on the shopping shelf and the calculated ones were not matching. This made the student end up paying for things on prices he never intended too in order to save the embarrassment of delaying other organized customers.

1.3 Aim of study

- To design a prototype that automatically adds and subtracts goods placed or removed in an RFID shopping trolley.

1.4 Purpose of study

- To design a prototype that calculates the total amount of cash for the goods in a shopping trolley.

1.5 Objectives of study

1.5.1 Main Objective

- To design an RFID based electronic trolley.

1.5.2 Minor Objectives

1) To enhance the speed of shopping experience by using an RFID system.

2) Save shoppers time, to shop what they want without over budgeting or under budgeting.

3) Make the reader to detect when goods are being removed or placed in the trolley.

4) Program the RFID tags

5) Displays the information about the product on the LCD.

6) Display the total on the LCD.

1.6 Hypothesis

The system will calculate the total price of goods a customer put in the trolley before they go to the till to cash in. The system should provide an interface to communicate with the customer so that they will shop successfully without any complications.

1.7 Problem statement

Customers having difficulties in calculating the total price of the goods they are about to buy. This result in customers failing to purchase the actual goods they may want.

1.8 Justification

The project will improve the overall shopping experience. Implementation of an RFID based electronic trolley system in shopping stores will help both the customers and the shop owners by increasing sales and saving customers time. This implies that they will be less shop assistances available on duty at one time, system will perform almost as a personal shop assistant for every single shopper in the shop. The RFID antenna should be able to detect when merchandise is placed on the cart by using the RFID system and displays the merchandise information on the LCD. The shopping trolley user interface will provide customers with:

1) Specifications of goods in the trolley by displaying them on the LCD.

2) Button to display the total cost of the goods.

3) Button to start and stop shopping

4) Button to help add or remove goods in the trolley

1.9 Literature review

A shopping trolley is a cart provided by a shop, particularly supermarkets, for usage by customers inside the shop to transport goods to the till counter during and after shopping. Consumers can then also use the cart to carry their bought goods to their cars also [1].

The RFID system was first used in libraries replacing the electro-magnetic and bar code systems in the late 1990s. About 130 libraries in North America are using RFID systems, but hundreds more are considering it. The major cost impediment is the price of each individual tag. Today, tags cost approximately fifty cents but prices continue to fall [2].

1.10 Application of RFID system currently

When the reader reads the tag, the data is delivered on to an application that makes use of the data. Examples of RFID applications and their uses fall into at least six categories

1) Access control (keyless entry)

2) Asset tracking (self-check-in and self-check-out)

3) Asset tagging and identification (inventory and shelving)

4) Authentication (counterfeit prevention)

5) Point-of-sale (POS) (Fast-track)

6) Supply chain management

The RFID system gives retailers an opportunity to decrease expenses and to improve services allowing clients to be attended quickly, precisely and personal services.

1.11 Assumption

- Low energy consumption, so that the shopping wagon doesn't run the risk of rapidly running out of power and allows supermarket navigation to all points.
- Signal that are strong and remain unaffected by obstructions, especially metal objects.
- All components in the system are safely connected (no electric shock to anyone pushing the trolley).
- The customer will not overload the trolley
- Goods are placed well in such a way that they are read correctly.

Reference

[1] SatishKamble, SachinMeshram, Rahul Thokal, RoshanGakre ,"Developing a multitasking shopping trolley based on RFID technology,"*International Journal of Soft Computing and Engineering (IJSCE) ISSN*: *2231-2307*, Volume-3, pp.156-160,6, January 2014.

[2] GalandeJayshree, RutujaGholap, and PreetiYadav,"RFID Based Automatic Billing Trolley,"*International Journal of Emerging Technology and Advanced Engineering* ,Vol. 4, (Issue 3), March 2014.

CHAPTER 2

Theoretical Aspects

2.1 Introduction

In this chapter the designer takes a step by step analysis of all the electronic components used in the designing of the RFID based electronic trolley prototype. This stage is important for any system designer for they must have a full understanding of the components used in their project. It gives a better understanding of all instruments and components used making it easy to troubleshoot any faults if they occur.

2.2 Goods recommended in the trolley

- Goods with the RFID tag so they can be read
- Goods which do not have a Faraday's cage (or the tag will not be read)

2.3 RFID components

A simple RFID system contains of three modules:

- An antenna or coil
- A transceiver (with decoder)
- A transponder (RF tag) electronically programmed with distinct data.

These are described on the next page

2.3.1 Antenna

The antenna radiates a radio signals to make the tag active then read and write information to it. Antennas are the conduits between the tag and the transceiver, which controls the structure's data attainment and communication. Antennas exist in different shapes and sizes. The electromagnetic field created by an antenna can be constantly present when many tags are expected continually to be read [3].

Fig 1 RFID reader and antenna [3]

Often the antenna is packaged with the transceiver and decoder. The reader radiates radio waves in ranges of anywhere from one inch to 100 feet or more, depending upon its power output and the radio frequency used. When an RFID tag passes through the electromagnetic zone, it detects the reader's activation signal. The reader decodes the data encoded in the tag's integrated circuit (silicon chip) and the data is passed to the Arduino Uno for processing [4].

2.3.2 RFID transponders (tags)

An antenna and transponder (transmitter/responder) are joined to make an RFID system**.** An RFID system reads the tags installed to the products to be identified. Two-way radio transmitter-receivers called interrogators or readers send a signal to the tag and read its response. RFID tags can be either passive, active or battery assisted passive. An active tag has an on-board battery and periodically transmits its ID signal. A battery assisted passive (BAP) has a small battery on board and is activated when in the presence of a RFID reader.

Fig 2 RFID tags [4]

Fig 3 RFID paper tag [5]

Active transponders can communicate over miles like ordinary radio communications. They are commonly used in navigation systems for commercial and private aircraft. A passive tag is cheaper and smaller because it has no battery. Passive transponder, as figure 3 shows rely on the energy given off by the reader for power in order for them to respond. Cheaper, passive RFID tags are the mostly used to for consumable goods [5].

Tags may either be read-only, having a factory-assigned serial number that is used as a key into a database, or may be read/write, where object-specific data can be written into the tag by the system user. [4].The size of the tag depends mostly on the antenna, area of use, and also on the frequency the tag is using. It can range from less than a millimetre. Some tags also have rewritable memory attached where the tag can store updates between reading cycles or new data like serial numbers. The microchip is visible in the centre of the tag.

RFID tags fall into three regions in respect to frequency:

1) Low frequency (LF, 30 - 500 kHz)

2) High frequency (HF, 10 - 15MHz)

3) Ultra high frequency (UHF, 850 - 950MHz, 2.4 - 2.5GHz, 5.8GHz)

Low frequency tags are cheaper than any of the higher frequency tags. They are fast enough for most applications, however for larger amounts of data the time a tag has to stay in a readers range will increase. Another advantage is that low frequency tags are least affected by the presence of fluids or metal. The disadvantage of such tags is their short reading range. The most common frequencies used for low frequency tags are 125 - 134.2 kHz and 140 - 148.5 kHz [6].

2.3.3 RFID reader

An RFID tag is read when the reader emits a radio signal that activates the transponder, which sends data back to the transceiver. RFID reader is used to read the present data in the RFID tag. RFID readers or receivers are composed of a radio frequency module, a control unit and an antenna to interrogate electronic tags via radio frequency (RF) communication. Many also include an interface that communicates with an application. Readers can be hand-held or mounted in strategic locations so as to ensure they are able to read the tags as the tags pass through an “interrogation zone.” RFID systems can be classified by the type of tag and reader. A

Passive Reader Active Tag (PRAT) system has a passive reader which only receives radio signals from active tags (battery operated, transmit only) [4].The RFID reader sends a pulse of radio energy to the tag and listens for the tag's response. The tag detects this energy and sends back a response that contains the tag's serial number and possibly other information as well. In simple RFID systems, the reader's pulse of energy functioned as an on-off switch; in more sophisticated systems, the reader's RF signal can contain commands to the tag, instructions to read or write memory that the tag contains, and even passwords. High frequency tags have higher transmission rates and ranges but also cost more than LF tags [7]. Smart tags are the most common member of this group and they work at 13.56MHz.

2.4 RDM6300 (reader)

2.4.1 Overview

RDM6300 125KHz card reader mini-module is designed for reading code from 125KHz card compatible read-only tags and read/write card. It can be applied in

1) Office/home security

2) Personal identification

3) Access control

4) Anti-forgery

5) Interactive toy

6) Production control systems

2.4.2 RFID Reader Features

- Support external antenna
- Maximum effective distance up to 150mm
- Less than 100ms decoding time

- UART interface
- Support EM4100 compatible read only or read/write tags
- Small outline design

2.4.3 RFID Reader Specification

1) Module Type	RFID
2) Weight	15.00g
3) Model	IM120618002
4) Board Size	3.8 x 1.8 x 1.2cm
5) Version	1
6) Operation Level	Digital 5V
7) Power Supply	5V

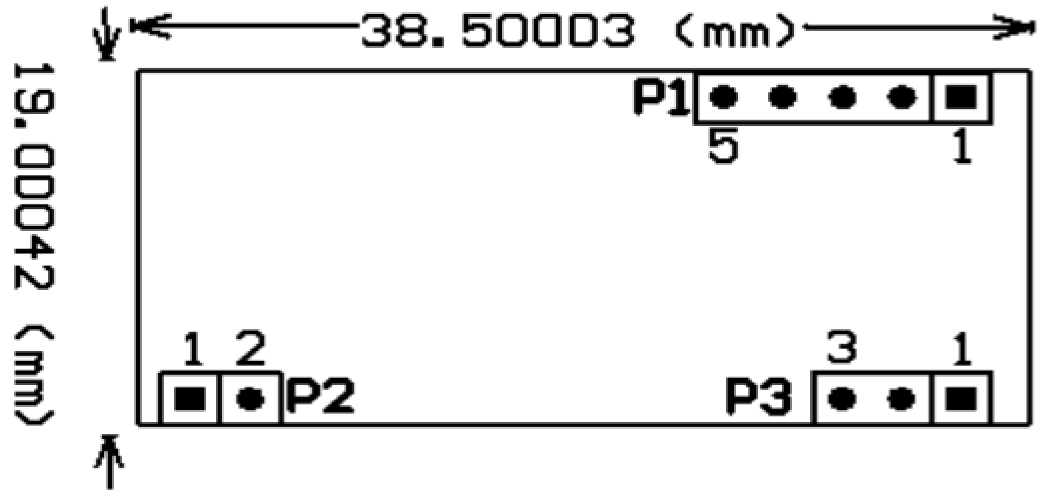

Fig 4 RFID reader sketch diagram [8]

2.4.4 How RFID systems works

At its most basic level, RFID is a wireless link to uniquely identify objects or people. It is sometimes called dedicated short range communication (DSRC). These systems communicate via radio signals that carry data either unidirectional or bidirectional. When a transponder enters the read zone, its data is captured by the reader and can then be transferred through standard interfaces to a programmable logic controller for storage or action. Radio frequency identification (commonly abbreviated to RFID) is so-named because it relates to the identification of objects using EM radiation at radio frequencies.

RFID systems may be categorized based on the band of the EM spectrum that they operate in.

1) Passive tag RFID systems require no power source, at the tag there is no battery. Instead, the tag uses the energy of the radio wave to power its operation, much like a crystal radio. This results in the lowest tag cost, but at the expense of performance.

2) Semi-passive tag RFID systems rely on a battery built into the tag in order to achieve better performance. The battery powers the internal circuitry of the tag during communication, but is not used to generate radio waves [8].

2.4.5 Benefits of RFID

Though RFID is not likely to entirely replace commonly used barcodes in the near future, the following advantages suggest to additionally applying RFID for added value of identification Although RFID is more costly than barcode, it proves to be indispensable for a variety of automated applications involving data acquisition and object identification. RFID benefits are

- Tag detection not requiring human intervention
- Reduces employment costs
- Eliminates human errors from data collection.
- RFID tags have a longer read range than barcodes
- Tags can have read/write memory capability, while barcodes do not.
- An RFID tag can store large amounts of data additionally to a unique identifier
- Unique item identification is easier to implement with RFID than with barcodes
- Its ability to identify items individually rather than generically**.**
- Tags are less sensitive to adverse conditions (dust, chemicals, physical damage etc.).
- Automatic reading at several places reduces time lags and inaccuracies in an inventory.
- Reduces provisioning costs.
- Reduces warranty claim processing costs.
- Line-of-sight not necessary
- Robust system

  -Transponders can be read through a whole number of substances e.g. snow, fog, ice.
- Scanning speed

  -RFID transponders can be read at remarkable speed even in difficult conditions.
- Better lifetime and high noise immunity.

2.4.6 Limitations of RFID

- Cost

Prices of active and passive tags (at least $0, 50 per tag) are even more of a hindrance, allowing their economic application only for scanning high-value goods overlong ranges.

- Collision

Attempting to read several tags at a time may result in signal collision and ultimately to data loss [5].

2.4.7 Trolley's functionality

The functioning of the system is explained below

When the customer purchase a product, he/she first swipe the RF tagged product on the RFID antenna and then places it into the trolley .While the customer is swiping the product, the price of the product is obtained and stored in the system's memory. Information stored in system's memory is compared with the lookup table. If matches are found then cost, name of respective product gets displayed on the LCD. Then they press the total button to display the total. If the product is unwanted it is swiped out after pressing the refund button. The trolley then deducts the amount of the unwanted products and re processes the total again [9].

2.4.8 Features of RFID based trolley

- Bill calculation at the trolley itself.
- Low chance of traffic & mismanagement.
- Reduction in support staff.

2.4.9 Range of operation of the RFID system

The term range naturally refers to the maximum operating distance between the reader antenna and the tag, and the field of the reader is the specific operating area. The frequency of operation used for an RFID system has a big effect on the operating range. Analysis of the physics of RFID communications shows that the optimum frequency is around 400-500MHz. Such analysis cannot be made generically - there are a number of factors to take into account and these will have different effects based on the intended application. Factors that will be affected by the choice of frequency include

1) Size of tag antenna,

2) Power delivery to the tag,

3) Cost and speed

If communication occurs over a short distance, relative to the wavelength of the radio wave, this is said to be near-field operation. Since HF (3-30MHz) RFID systems use waves with a wavelength of around 10-100m, if the distance of the communication is much less than this (which is the case with the RFID based electronic trolley) then this is a near-field communication. If a directional antenna is used, its radiation pattern will also affect the reader field.

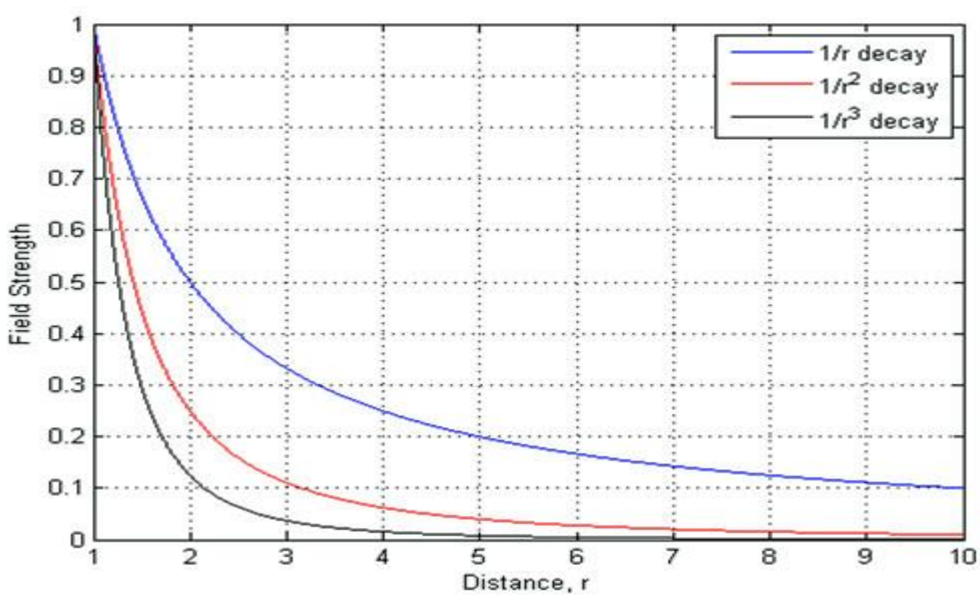

Fig 5 Variation of produced magnetic field and distance [3]

The ability of the reader to power and communicate to the tag is based on the inverse square law (1/r), as will the return path of reflected signals from the tag to the reader. Operation will also be affected by environmental conditions and interference from other radio sources at the same frequency [8]. For the variation between the magnetic field and distance is proved by the equation below and shown by the graph on fig 5 above.

$$P_a = \left(\frac{P_t G_t}{4\pi r^2}\right)\left(\frac{\lambda^2}{4\pi}\right) G_{tag} \qquad \text{……………………(1)}$$

As equation 1 illustrates, the power available at an antenna, P_a, is a function of various factors including the power and gain (efficiency) of the transmitter antenna (P_t and G_t), the distance from the transmitter (r), electromagnetic wavelength (λ), and gain (efficiency) of the RFID tag's antenna (G_{tag}). The conclusion from the equation is that to improve read range (r) without increasing transmit power, one must improve the gain of the RFID antenna. As a result, characterization of RFID tags often involves significant characterization of the antenna over a wide range of frequencies

2.5 Arduino Uno (Processing unit)

The Arduino Uno is a single board microcontroller board based on the ATmega328. It is connected to a computer with a USB cable or powered with an AC-to-DC adapter or battery to get started. The pins on the Arduino are the places where wires are connected to construct a circuit in conjunction with a breadboard and some wires.

Arduino Uno is intended to make building interactive objects or environments more accessible. The hardware consists of an open-source hardware board designed around an 8-bit Atmel AVR microcontroller, or a 32-bit Atmel ARM. It comes with a simple integrated development environment (IDE) that runs on regular personal computers and allows users to write programs for Arduino using C or C++ [10].

2.5.1 Product Information

- ATMEGA328, ARDUINO UNO, I2C, BOARD
- Silicon Manufacturer: Arduino
- Core Architecture: ATmega
- Core Sub-Architecture: AVR
- Silicon Core Number: ATmega328
- Silicon Family Name: ATmega
- No. of Bits: 8bit
- Kit Contents: Board
- Features: :Powered via USB Connection, 2KB of SRAM, 1KB of EEPROM

2.5.2 Special features

- Microcontroller ATmega328
- Operating Voltage 5V
- Input Voltage (recommended) 7-12V
- Input Voltage (limits) 6-20V
- Digital I/O Pins 14 (of which 6 provide PWM output)
- Analog Input Pins 6
- Current per I/O Pin 40 mA
- DC Current for 3.3V Pin 50 mA
- Flash Memory 32 KB of which 0.5 KB used by boot loader
- SRAM 2 KB(ATmega328)
- EEPROM 1 KB(ATmega328)
- Clock Speed 16 MHz

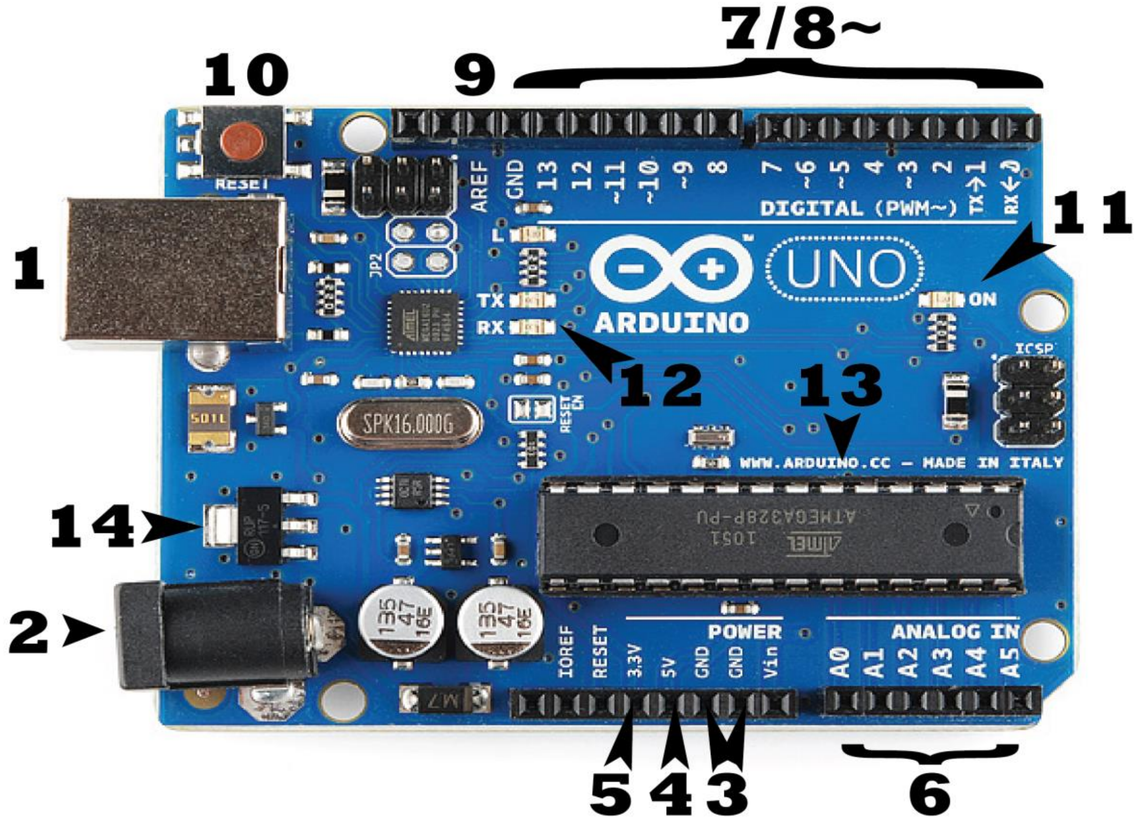

Fig 6 Arduino Uno photograph [10]

2.5.3 Arduino's working principle

Below are the individual components of an Ardiuno Uno module and their uses:

1) Power USB

The power USB connection is for loading code onto the Arduino Uno board.

2) Barrel Jack. A power supply greater than 20 Volts must not be used as it will over power. The recommended voltage for most Arduino models is between 6 and 12 Volts.

3) GND**:** Short for ‘Ground’. There are several GND pins on the Arduino, any of which can be used to ground your circuit.

4) 5V: the 5V pin supplies 5 volts of power.

5) 3.3V**:** 3.3V pin supplies 3.3 volts of power.

6) Analog**:** The pins under the ‘Analog In’ label (A0 through A5 on the Uno) are Analog In pins. These pins read the signal from an analog sensor and convert it into a digital value that we can read.

7) Digital**:** The digital pins (0 through 13 on the Uno). These pins can be used for both digital input and digital output.

8) PWM**:** Noticing the tilde (~) next to some of the digital pins (3, 5, 6, 9, 10, and 11 on the UNO), these pins act as normal digital pins, but can also be used for Pulse-Width Modulation (PWM) [11].

9) AREF**:** Stands for Analog Reference. It is used to set an external reference voltage (between 0 and 5 Volts) as the upper limit for the analog input pins.

10) Reset Button: It temporarily connects the reset pin to ground and restart any code that is loaded on the Arduino.

11) Power LED Indicator: This LED should lights up whenever the Arduino is plugged to a power source.

12) TX RX LEDs: TX is short for transmit, RX is short for receive. These LEDs will give visual indications whenever the Arduino is receiving or transmitting data (like when we’re loading a new program onto the board).

13) Main IC or Integrated Circuit: It’s usually from the ATmega line of IC’s from the ATMEL Company.

(14) Voltage Regulator: It controls the amount of voltage that is let into the Arduino board [12].

2.6 Buzzer

A buzzer is an audio signaling device, which may be mechanical, electromechanical, or piezoelectric. A buzzer is interfaced with the microcontroller to indicate scanning of the product by the RFID reader.

Fig 7 Buzzer pictures [11]

2.6.1Features

Part Code: STBUZZER

- Voltage: 3V -5V
- Kingsgate Buzzer - KPE-200
- Dimensions: 22.5mm Diameter, 19mm High, 28.5mm between mounting holes

A buzzer is also called a sounder. It’s a kind of miniaturization of electroacoustic device, in line with the work principle it is split up into piezoelectric and electromagnetic type two kinds large.

2.7 Push button

A push button switch is a small, sealed mechanism that completes an electric circuit when one press on it.

2.7.1 Operation of a push button

When it's on, a small metal spring inside makes contact with two wires, allowing electricity to flow. When it's off, the spring retracts, contact is interrupted, and current won't flow. The body of the switch is made of non-conducting plastic.

Fig 8 Push button [13]

The push button switch has thousands of familiar uses. It comes in two basic kinds: momentary and non-momentary.

2.7.2 Momentary Contact

Momentary switches work only as long as one press on them, like the buttons on a phone, calculator or door buzzer. They can be subdivided into normally-on and normally-off types.

Normally-Off

With the normally-off switch, there's no connection till one push the button. Most push button switches are used this way e.g. Doorbell buttons.

Normally-On

Here the switch conducts normally, but interrupts the circuit when one press on it. This is more specialized, and may be used in conjunction with a wiring trick [13].

2.7.3 Non-Momentary Contact

Non-momentary switches take one push to turn on, another to turn off. TVs and stereos use non-momentary switches for their power buttons.

2.8 Toggle switch

In terms of electrical use, it is defined as a device that allows or bars the flow of current. Toggle switch is one of the important devices of an electrical system with a definite purpose. The word toggle refers to the action of switching from one state to another. The concept behind the switch is fairly simple but it has extremely far reaching implications in electrical theory [14].

2.8.1 Specifications:

1) Contact rating: Dependent upon content material.

2) Mechanical life: 40,000 make and break cycles.

3) Maximum contact resistance: 10mΩ.

4) Initial voltage: 2V to 4V dc.

5) Current: 10mA for both silver and gold plated contacts.

6) Minimum Insulation resistance: 1,000MΩ.

7) Dielectric strength: 1,000Vrms at sea level.

8) Operating temperature: -30°C to 85°C

Fig 9 Toggle switch [14]

The switch generally has 2 positions

1) the on position

2) the off position

In case of a simple switch, when it is in the on position, the electrical circuit is completed to enable the flow of current while in the off position the circuit is incomplete and there is no current. Toggle switches slightly differ from normal switches in their working mechanism. It resembles a gate that has 2 parts to itself. When the gate is closed and the two parts are in contact, current flows through the system. This is the (On) position. When the gate is open and the two parts are detached from each other, the circuit is broken and no current flows through it this happens in the off position.

The most common types of toggle switches are the ones used to turn on and off electrical currents. Toggle switches are rated by the amount of current that flows through it in the on position. They are extremely crucial to successful operation of electrical system since they put the whole process into motion. Hence experts demarcate toggle switches as the last area where cost cutting should be attempted while manufacturing electrical systems [14].

2.9 LCD DISPLAY

LCD (Liquid Crystal Display) screen is an electronic display module and has a wide range of applications. A 16x2 LCD means that it can display 16 characters per line and there are 2 such lines.

*Fig 10 16*2 LCD display displaying information [17]*

In this LCD each character is displayed in 5x7 pixel matrix. This LCD has two registers

1) Command

2) Data.

The command register stores the command instructions given to the LCD. A command is an instruction given to LCD to do a predefined task like

✓ initializing

- ✓ clearing its screen
- ✓ setting the cursor position
- ✓ controlling display

The data register stores the data to be displayed on the LCD. The data is the ASCII value of the character to be displayed on the LCD [17]. Liquid crystal displays have materials which combine the properties of both liquids and crystals. Rather than having a melting point, they have a temperature range within which the molecules are almost as mobile as they would be in a liquid, but are grouped together in an ordered form similar to a crystal [15].

2.9.1 LCD advantages

LCDs are

- ➢ economical
- ➢ easily programmable
- ➢ have no limitation of displaying special
- ➢ Have custom characters (unlike in seven segments), animations.

An LCD consists of two glass panels, with the liquid crystal material sand witched in between them. The inner surface of the glass plates are coated with transparent electrodes which define the character, symbols or patterns to be displayed polymeric layers are present in between the electrodes and the liquid crystal, which makes the liquid crystal molecules to maintain a defined orientation angle.

One each polarizers are pasted outside the two glass panels. These polarizers would rotate the light rays passing through them to a definite angle, in a particular direction When the LCD is in the off state, light rays are rotated by the two polarizers and the liquid crystal, such that the light rays come out of the LCD without any orientation, and hence the LCD appears transparent.

When sufficient voltage is applied to the electrodes, the liquid crystal molecules would be aligned in a specific direction. The light rays passing through the LCD would be rotated by the polarizers, which would result in activating/highlighting the desired characters [9].

The LCD's are light weight with only a few millimeters thickness they consume less power, are compatible with low power electronic circuits, and can be powered for long durations. The LCD does not generate light and so light is needed to read the display. By using backlighting, reading is possible in the dark. The LCD has long life and a wide operating temperature range [17].

2.9.2 Handling Precautions

1) LCD panel is made of glass. Avoid subjecting to strong mechanical shock or applying strong pressure on to the surface of display area.

2) The polarizer used on the surface of display panel is easily scratched and damaged.

3) All unused input terminals should be connected to Vcc or GND. The selection of Vcc or GND will depend upon which connection will satisfy the desired logical function.

4) When power source voltage is not applied avoid applying input signal.

4) For long term storage, places of high temperature and humidity or direct sunlight should be avoided.

5) Caution should be taken not to get the liquid crystal fluid in one's mouth or hands if a panel is broken. If this occurs, immediately wash with water [18].

2.10 LED

LED's are distinct diodes that when connected in a circuit emits light. They are regularly used as "pilot" lights in electronic components to show whether the circuit is open or closed not. A clear (or often colored) epoxy case enclosed the heart of an LED, the semi-conductor chip.

2.10.1 Working principles of the Light Emitting Diode (LED)

The two LED wires prolonging below the LED epoxy enclosure indicate how the LED should be connected to a circuit. The LED lead negative side is indicated in two ways as shown in fig 10.

- by the side of the bulb which is flat
- by the shorter side extending from the LED.

The negative lead should be connected to the negative terminal of the power supplying source. LED's operate at relative low voltages between about 1 and 4 volts, and draw currents between about 10 and 40 mill amperes.

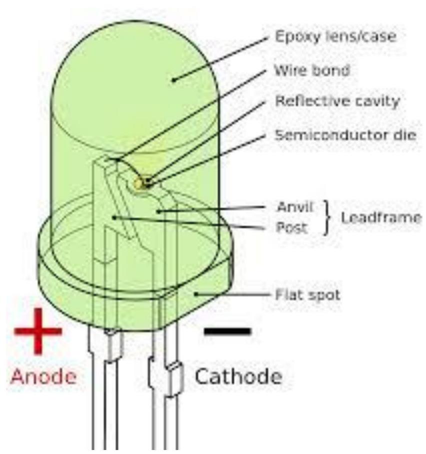

Fig 11 LED Light emitting diode [19]

Voltages and currents substantially above these values can melt a LED chip. The most important part of a light emitting diode (LED) is the semi-conductor chip located in the center of the bulb. The chip has two regions separated by a junction. The p region is dominated by positive electric charges, and the n region is dominated by negative electric charges. The junction acts as a barrier to the flow of electrons between the p and the n regions. Only when sufficient voltage is applied to the semi-conductor chip, can the current flow and the electrons cross the junction into the p region. In the absence of a large enough electric potential difference (voltage) across the LED leads, the junction presents an electric potential barrier to the flow of electrons [19].

2.10.2 Lighting of LED and determination of the color of light.

Electrons can move easily in only one direction across the junction between the p and n regions when sufficient voltage is applied to the chip across the leads of the LED. They are many more positive than the negative charges in the p region. The electrons are more numerous in the n region than the positive electric charges. Electrons in the n region will have enough energy to move across the junction into the p region when a voltage is applied and the current starts to flow. When they reach the p region the electrons are quickly attracted to the positive charges due to the mutual Coulomb forces of attraction between two different electric charges. If an electron sufficiently moves close to a positive charge in the p region, the two charges re-combine.

When an electron rejoins with a positive charge, the conversion of electric potential energy to electromagnetic energy is done. Per each recombination of a negative and a positive charge, a quantum of EM energy is radiated in the photonic form of light with a frequency characteristic of the semi-conductor material. Photons can be emitted by any material in a very narrow frequency range only [20].

2.10.3 Energy Emitted by LED

The voltage is proportional to electric energy, which is the voltage required to cause electrons to flow across the p-n junction. The emitted light energy given by (E) thus:

$$\mathbf{E = qV(Joules)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathbf{2}$$

where q = electric charge of an electron

V = required amount of voltage to light the LED

Electric energy is proportional to voltage and this is a general statement that applies to LED's and any circuit. The electric charge constant q is of a single electron, -1.6 x 10-19 Coulomb.

The wavelength of light is related to the frequency of light. To examine the light from the LED the spectrometer can be used, and also to approximate the peak wavelength of the light radiated by the LED.

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CHAPTER 3

Methodology

3.1 Introduction

This chapter will discuss in detail each subsystem that leads to the proper functioning of the prototype. It comprises of a detailed description of the design of each subsystem, how the elements are interfaced with the central processing unit, the software selection and implementation, block diagram of the whole system and the flow chart for the execution of the program.

3.2 Structure of the system

The whole system consist of the following hardware

1) RFID reader

2) RFID tags

3) Buzzer

4) LCD

5) LED

6) Three buttons

7) Trolley unit

The prototype consists of three main subsystems zone which are:

1) Interface to the customer zone

2) Goods detection zone

3) Carriage zone area

3.3 RFID antenna connections

An RFID sensor is plugged to the board as shown by the picture below. To interface 3 wires are required, one for the serial line (communication) and the other two for power supplying. The wires as connected as stated below.

Pin 1 of the RFID reader is for transmitting the detected signal from back scattering to the Arduino Uno from the antenna. Pin 2 is for receiving a signal from the built circuit and in this case it's not used. Pin 4 is connected to the ground in circuit to ground the reader. Pin 5 is connected to Vcc(+5) the power.

3.4 Connections between RDM6300 and Arduino Uno

Steps when connecting the RDM6300 and Arduino Uno

1) The RFID sensor the Tx from RFID circuit board goes to Digital PIN2 on the Arduino Board.

2) Connect 5VDC and GROUND from the RFID module to the Arduino.

3) Pin 2 is coded to read.

4) The Arduino is set up to read the serial connections at 9600 bps on pin 2 using Soft Serial.

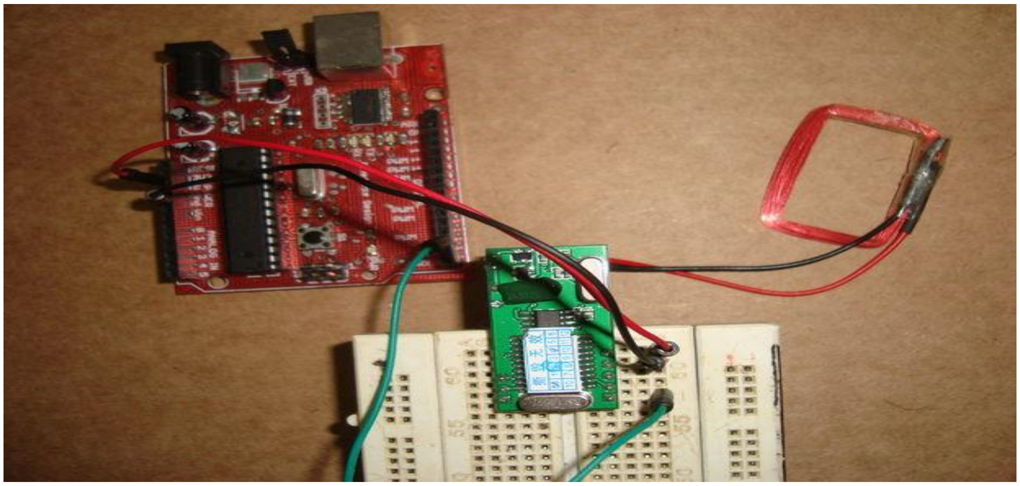

Fig 12 Connections between the Arduino Uno and the RFID antenna [22]

3.5 Physics behind the detection of the tag

The diagram below shows how the reader and the tag interact in terms of the fields produced and how they will propagate at different distances from each other. The fields show they interact when data is changed between the reader and tag. The passive tag is powered by the reader in order to obtain the non-volatile information in it. This is done by rectifying the voltage across it.

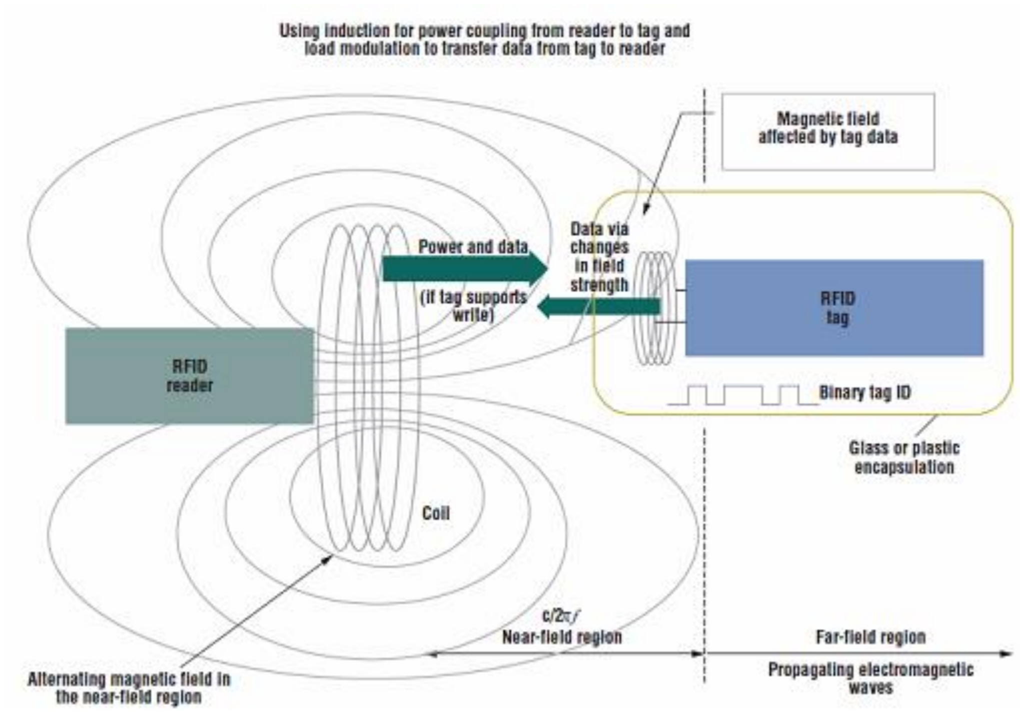

Fig 13 Magnetic interaction between the RFID reader and tag [22]

3.6 System architecture

This part show how all the components of the whole system are connected. The connections of resistor, buttons, RFID reader, LCD, Arduino Uno and LED are made using copper wire. The simulation is shown in fig 13 this was produced using the Proteus Software.

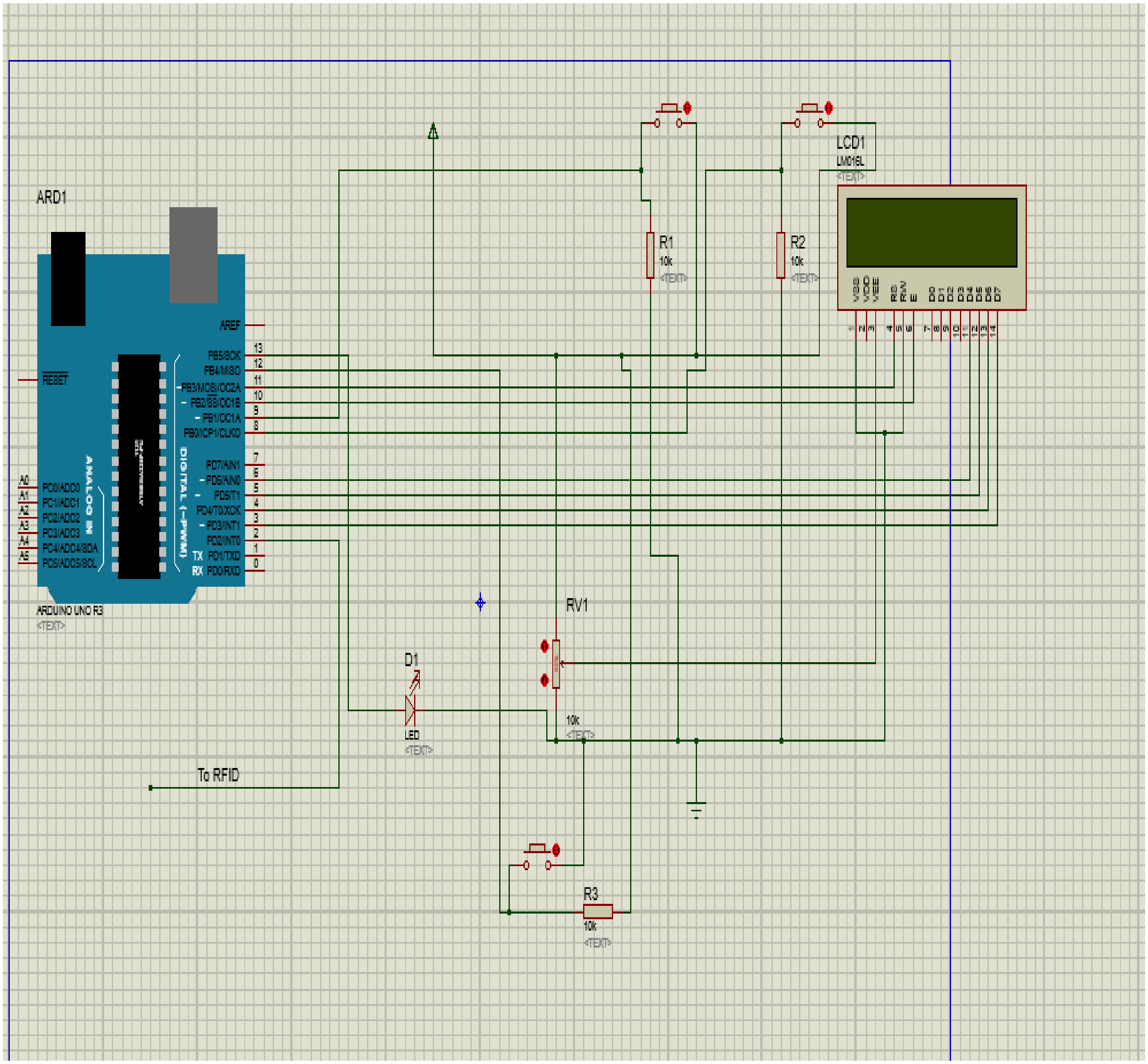

Fig 14 System architecture

Pins connections between the Arduino Uno, LCD, buzzer and LED are a follows:

- Pin 2 of the Arduino is connected to RFID Tx.
- Pin 3 of the Arduino is connected to D7 on the LCD.
- Pin 4 of the Arduino is connected to D6 on the LCD.

- Pin 5 of the Arduino is connected to D5 on the LCD.
- Pin 6 of the Arduino is connected to D4 on the LCD.
- Pin 7 of the Arduino is connected to the buzzer.
- Pin 8 of the Arduino is connected to the start shopping button.
- Pin 9 of the Arduino is connected to the total button.
- Pin 10 of the Arduino is connected to E on the LCD.
- Pin 11 of the Arduino is connected to RS on the LCD.
- Pin 12 of the Arduino is connected to the green LED
- Ground pin of the Arduino is connected to Vss on the LCD.
- +5V pin of the Arduino is connected to VDD on the LCD.
- Ground pin of the Arduino is connected to Vo on the LCD.
- Ground pin of the Arduino is connected to RW on the LCD

3.7 How the LED is connected to the Arduino Uno

An abbreviation LED stands for Light-Emitting Diode – it's basically a small light that can be turned on and off with a button. A resistor is placed to reduce the amount current passing to the LED.

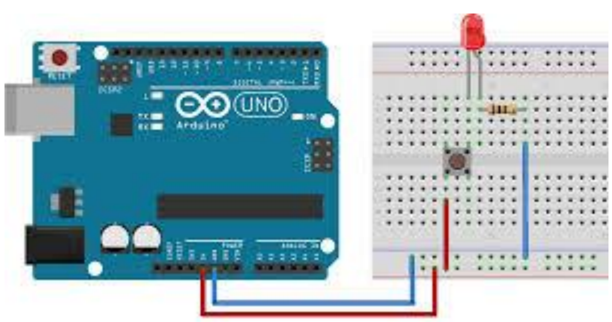

Fig 15 LED connections to Arduino Uno [22]

3.8 Step on connecting the buttons

The Arduino board is connected to the button by three wires.

1) The ground and the 5 volt wires are connected from the Arduino Uno to the bread board.

2) From the digital pin 2 the third wire is connected to one leg of the pushbutton.

3) At that same push buttons leg a connection through a resistor (10K Ohms) to ground is made.

4) To the 5 volt supply the other leg of the button is connected.

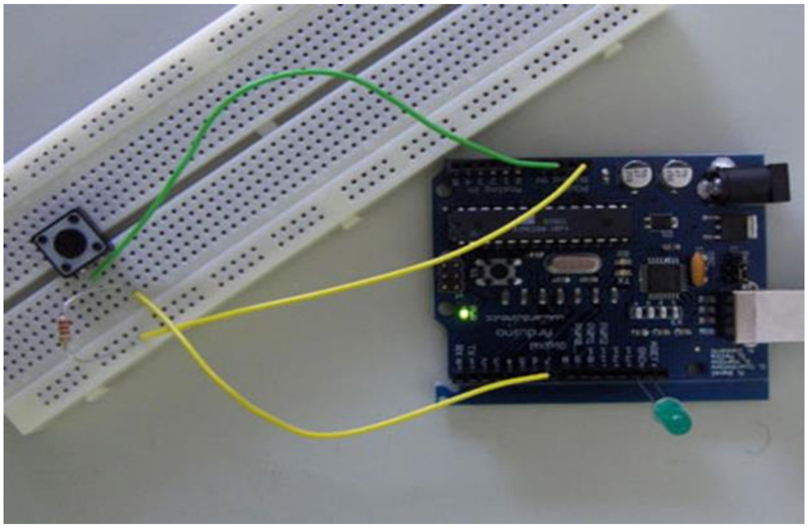

Fig 16 Button connections to Arduino Uno [22]

The sketch diagram on fig 16 clearly shows the exact pin connections.The two yellow wires and one green wires.

3.9 Software description

The RFID hardware uses the embedded c programming language, that is the RFID receiver (fitted in trolley) and transmitter (RFID tags) that looks up for the specific information about the item and mapping it with its with price. The embedded C programming ensures perfect billing is reached. The Arduino Uno is coded using the C language.

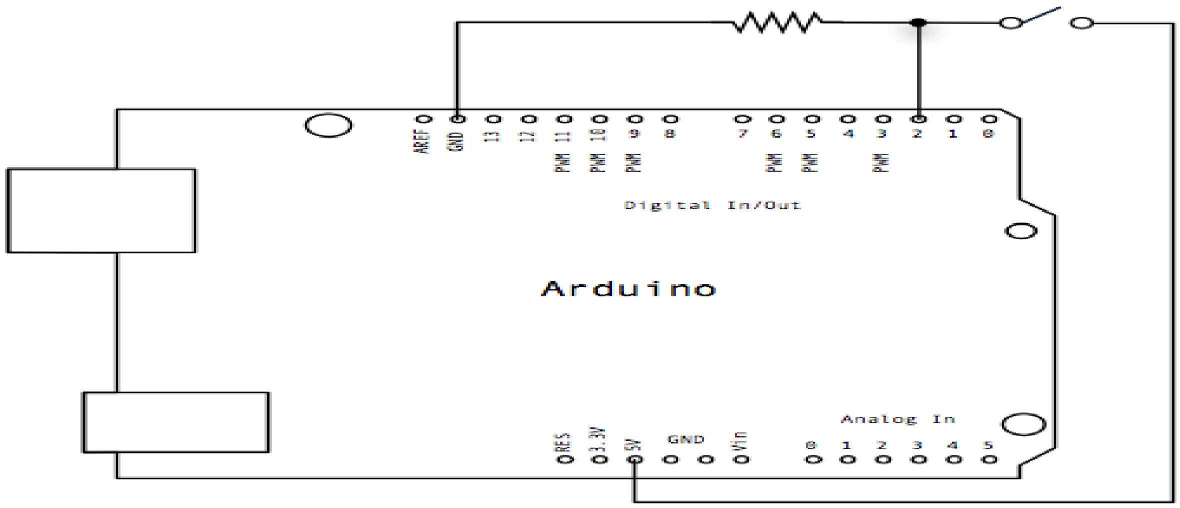

Fig 17 Sketch diagram of button connections to the Arduino Uno

3.10 Data flow on using the trolley

The flow diagram below shows how the customer should operate the shopping trolley. Failure to follow the steps will result in obtaining negative results or damage to the system.

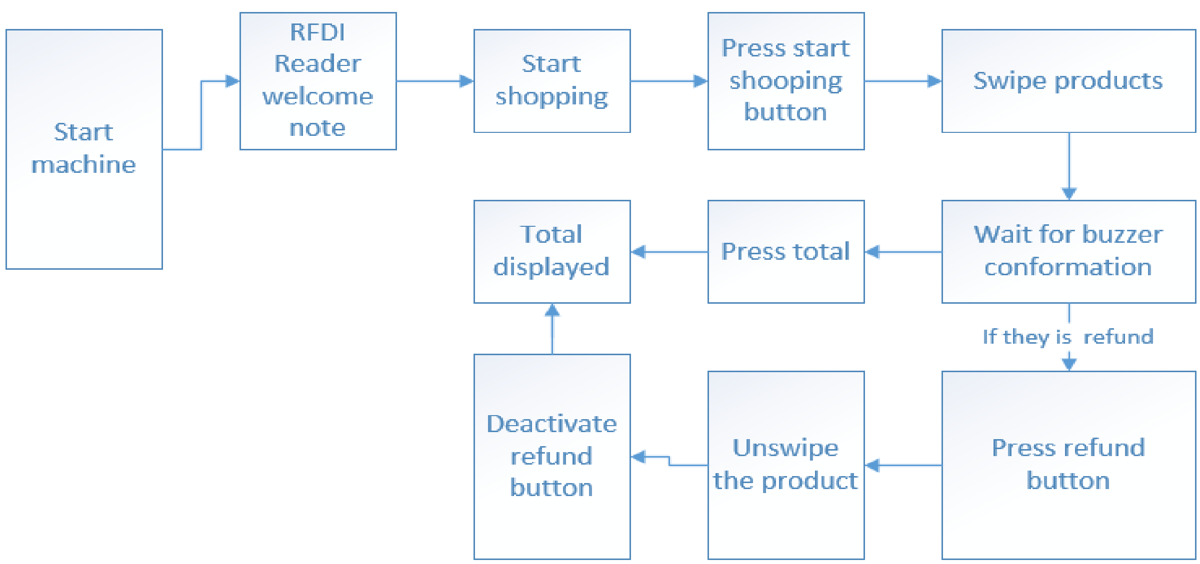

Fig 18 Shopping procedure processes

.

3.11 Power measurements

A loop antenna was used to find the voltage across the RFID antenna. The voltage across the antenna was measured at different distance. Multiple voltage readings were obtained and averaged.

The voltage was measured with the loop antenna being horizontal to the RFID antenna and while it was vertical too as shown on fig 18. The relationship between voltage and distance was proved to be correct as shown by the graphs below. After obtaining the voltage the power was calculated using the resistance and voltage equation. Power = ((voltage) ^2)/resistance).

The resistance of the loop antenna was measured using the multimeter (fluke). The apparatus were set up as shown below.

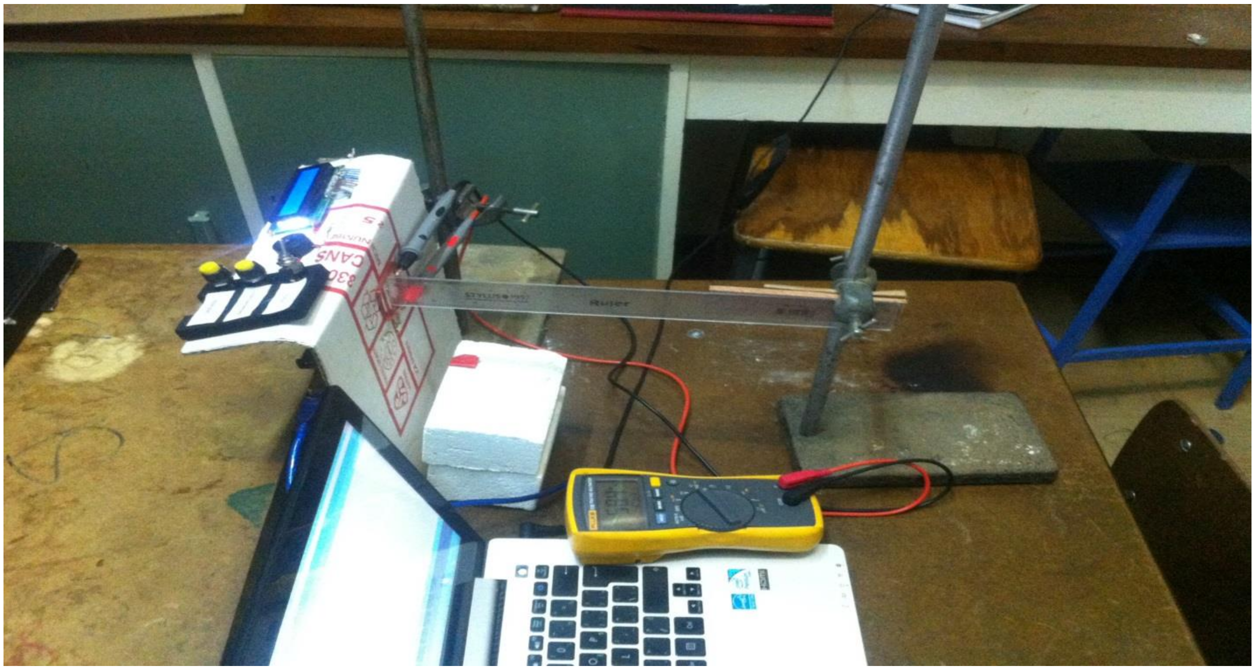

Fig 19 Voltage measurement setup

Reference

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CHAPTER 4

Results and Analysis

4.1 Introduction

This chapter presents the results of the project, from the circuit designed and the results obtained during circuit the circuit test operation. The results are presented in tabular form and the graphical plots giving the analysis and interpretation.

4.2 RFID trolley prototype

The prototype was built with four wheels for easy navigation in the shop as shown on fig 18 below also a handle to help control the trolley is fitted too. For the shopping process the interface contains a buzzer, LCD and buttons as shown on fig 19.

Fig 20 Trolley prototype image

Fig 21 Trolley user interface

Table 1 Table of results showing the voltages across an antenna loop oriented vertically with the corresponding distance and the average voltage

Distance(mm)	Voltage(mV)1	voltage (mV)2	voltage (mV)3	Average (mV)
0.1	55.5	52.6	55.5	54.5
0.5	34.4	32.7	42.3	36.5
1.0	23.6	24.6	31.4	26.5
1.5	18.9	18.7	22.9	20.2
2.0	13.0	13.0	17.9	14.6
2.5	10.9	10.0	13.0	11.3
3.0	8.8	7.9	9.9	8.9
3.5	7.0	6.4	7.5	7.0
4.0	5.7	5.5	5.3	5.5
4.5	4.7	4.6	4.5	4.6
5.0	4.0	3.9	4.0	4.0
5.5	3.6	3.4	3.4	3.5
6.0	2.9	3.0	3.1	3.0
6.5	2.5	2.7	2.9	2.7
7.0	2.4	2.3	2.6	2.4
7.5	2.4	2.2	2.4	2.3
8.0	2.1	2.1	2.1	2.1
8.5	0.0	2.1	0.0	0.7

Table 1 shows the results obtained by measuring the voltage across a loop antenna. The loop antenna was held vertical to the RFID antenna. Three readings were obtained with the same length measurements. The difference on the readings was due to the change in EM fields so taking many readings and averaging them will eliminate these errors.

The maximum voltage average reading was 54.5 milli volts and was obtained at a distance of 0.1mm close to the RFID almost in contact. The results showed that the two varied inversely and that's being correct according to the theory.

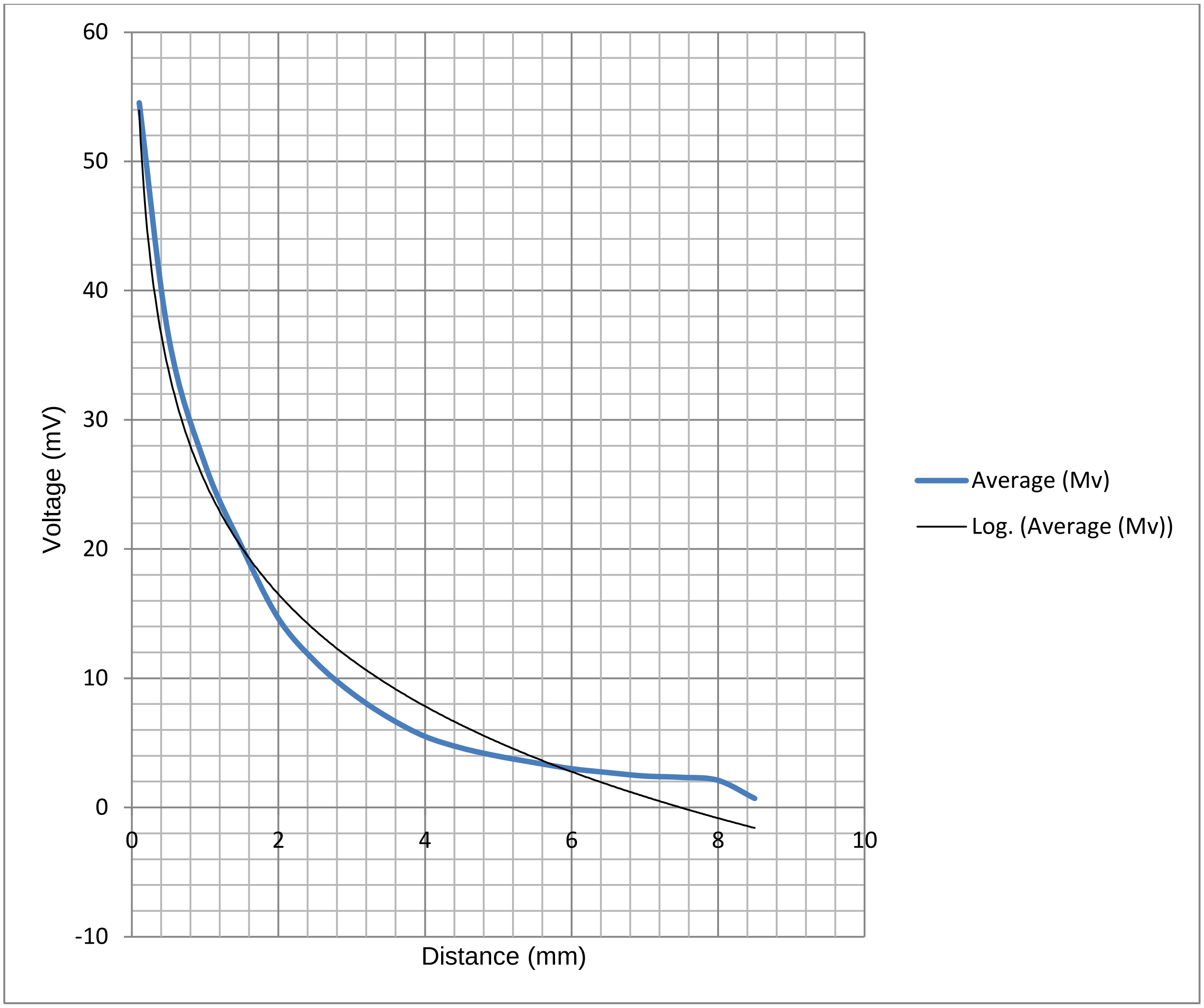

Fig 22 Variation of voltage with distance for a loop antenna oriented vertical

The graph on fig 20 shows the variation of voltage and distance which tend to vary inversely from the results obtained. High voltage readings are obtained in the read range zone close to the RFID antenna. The results showed that the two vary inversely to each other. As one parameter is increased the other is decreased. The voltages obtained in the vertical form showed that were a little bit low compared to the ones obtained in the horizontal format.

Table 2 Table of results showing the voltages across an antenna loop oriented vertically with the corresponding distance and the average voltage

Distance(mm)	voltage (mV)	voltage (mV) 2	voltage (mV) 3	Average (mV)
0.1	63.4	66.6	66.3	65.4
0.5	37.7	43.6	52.4	44.6
1.0	22.9	32.5	35.2	30.2
1.5	18.9	21.2	25.3	21.8
2.0	13.0	16.9	15.3	15.1
2.5	10.8	11.4	12.0	11.4
3.0	8.4	8.5	8.9	8.6
3.5	6.9	6.8	7.2	7.0
4.0	5.5	5.3	5.9	5.6
4.5	4.9	4.4	4.9	4.7
5.0	3.7	3.9	4.3	4.0
5.5	3.5	3.4	3.9	3.
6.0	3.2	2.9	3.4	3.2
6.5	2.9	2.6	2.9	2.8
7.0	2.6	2.4	2.7	2.6
7.5	2.4	2.4	2.5	2.4
8.0	2.1	2.1	2.3	2.2

Table 2 shows the results obtained by measuring the voltage across a loop antenna. The loop antenna was held horizontal to the RFID antenna. Three readings were obtained with the same length measurements. The difference on the readings was due to the change in EM fields so taking many readings and averaging them will eliminate these errors.

The maximum voltage average reading was 65.4 milli volts and was obtained at a distance of 0.1mm close to the RFID almost in contact. The results showed that the two varied inversely and that's being correct according to the theory. Comparing with the vertical part more energy is collected in the horizontal due to the large surface area.

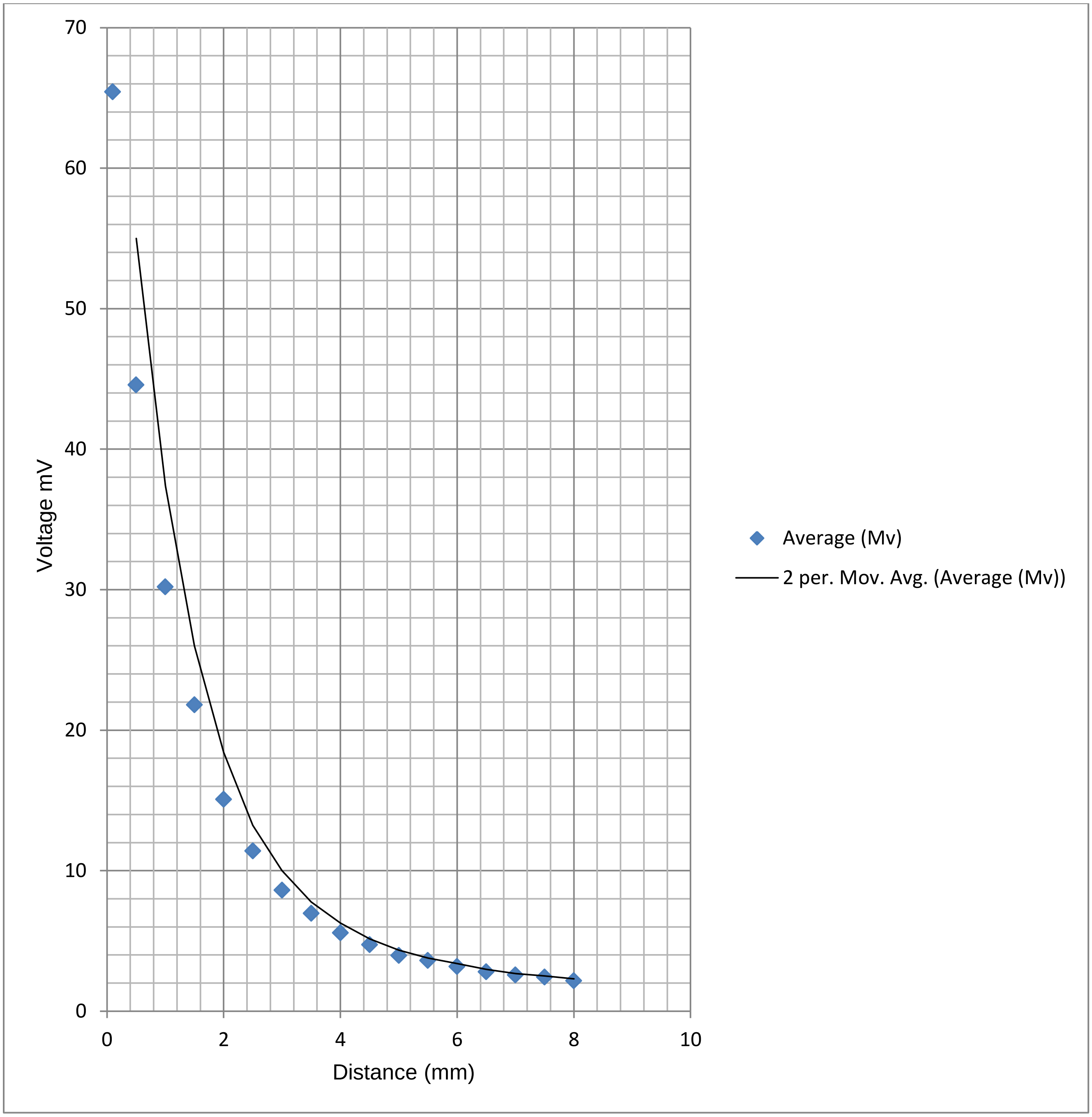

Fig 23 Variation of voltage and distance for a loop antenna oriented horizontal

The graph on fig 21 shows the variation of voltage and distance which tend to vary inversely from the results obtained. High voltage readings are obtained in the read range zone close to the RFID antenna. The results showed that the two vary inversely to each other. As one parameter is increased the other is decreased.

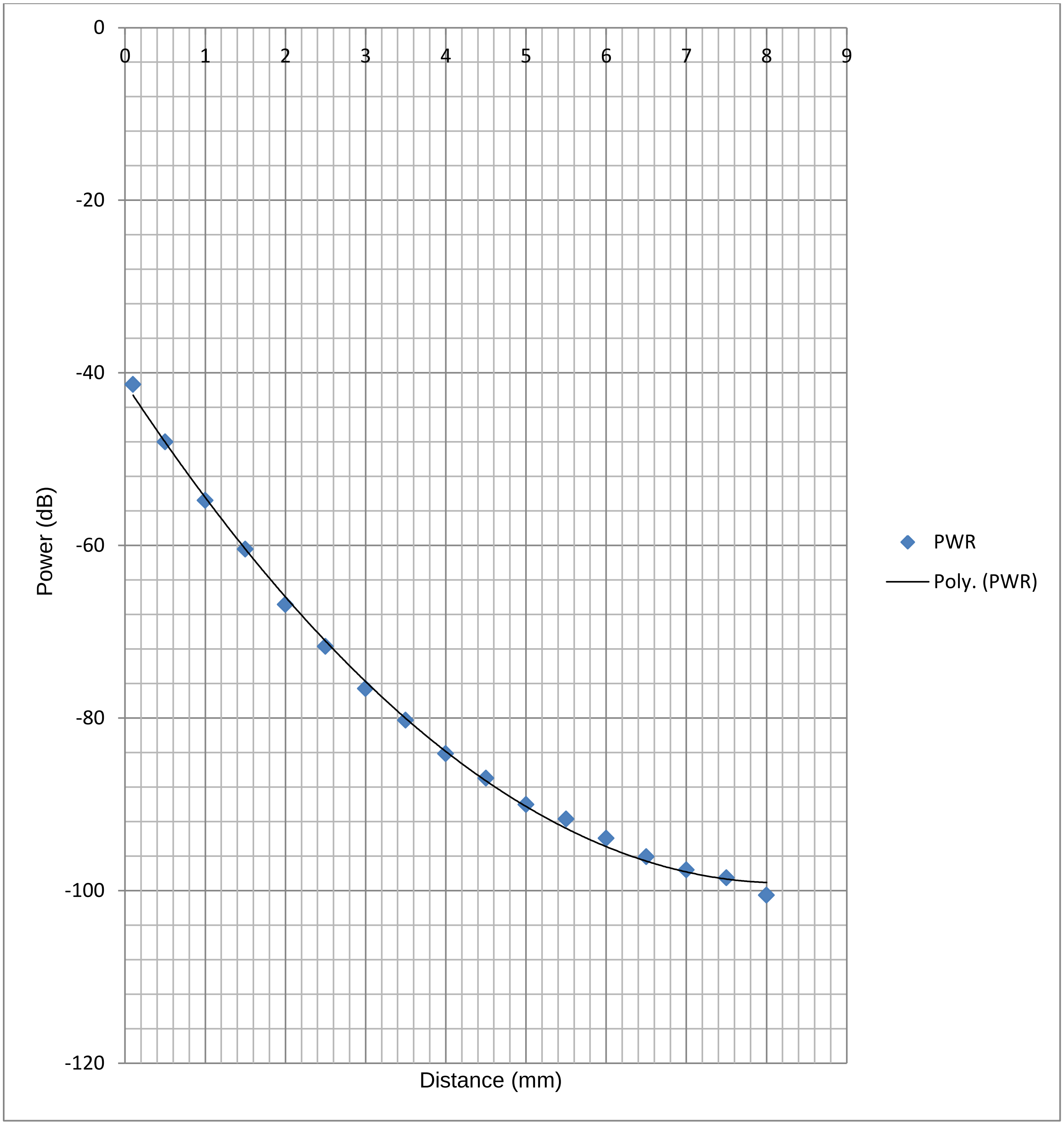

Fig 24Variation of power and distane obtained from the average vertical voltage

Using the voltages obtained the power can be calculated and the variation of power with the distance is obtained. The loop antenna used had the resistance of 0.5 omhs. The graph showed that it power varied inversely with the distance. The power is greater close to the antenna and it decreases as the tags are moved away from the read range zone.

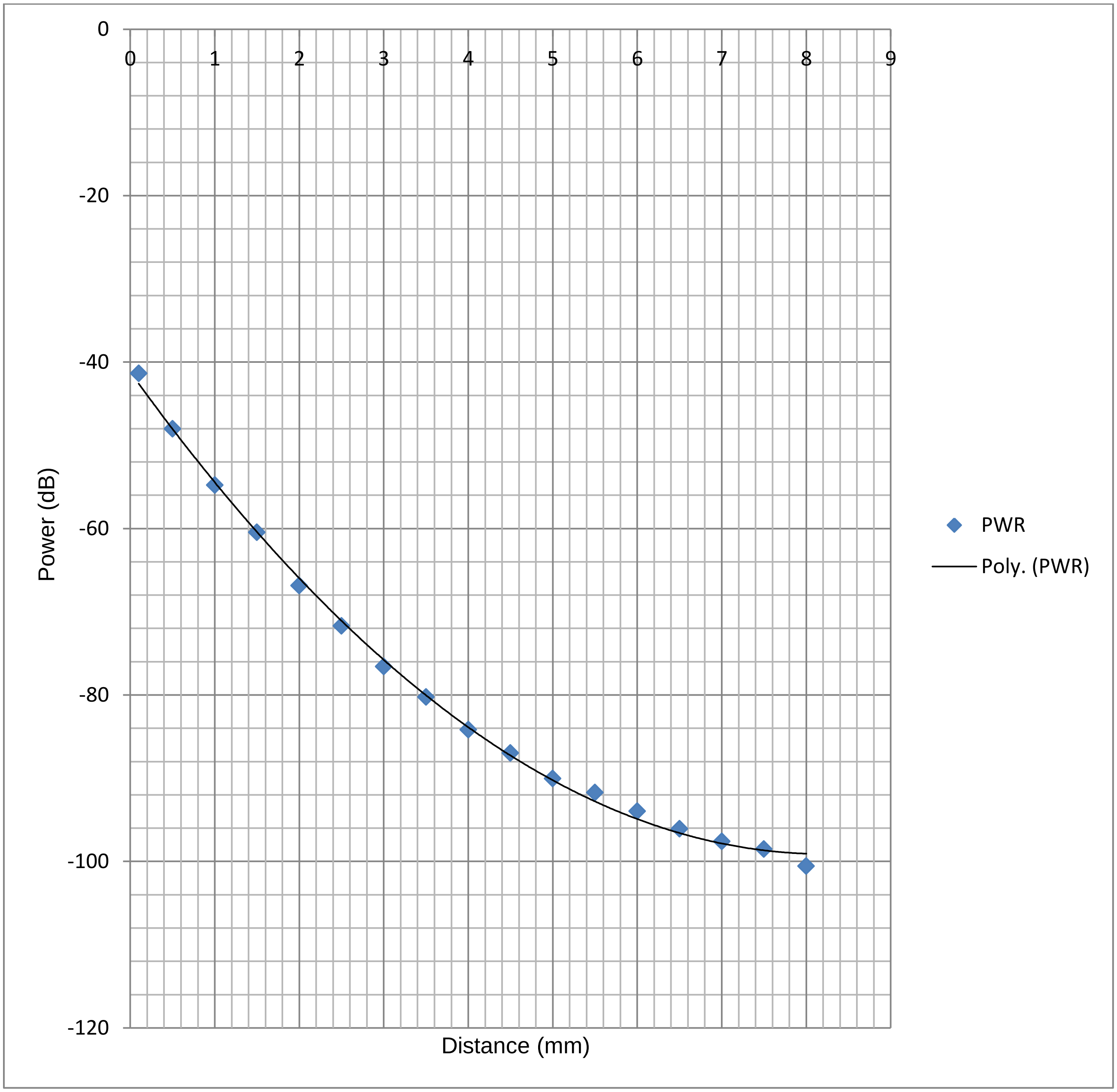

Fig 25 Variation of power and distance obtained from the average horizontal voltage

Using the voltages obtained the power can be calculated and the variation of power with the distance is obtained. The loop antenna used had the resistance of 0.5 omhs. The graph showed that it power varied inversely with the distance. The power is greater close to the antenna and it decreases as the tags are moved away from the read range zone.

4.3 Analysis

1) Part of the details about the goods was not shown on the LCD since the 16*2 LCD type proved to be small for the task.

2) The LCD proved to be clear as the information was read easily.

3) The interface proved to be user friendly to the user.

4) The system proved to save time and enhanced the shopping experience.

5) The trolley's database must be updated for every new stock.

6) Goods should be placed in the trolley as long as they can be read by the antenna and as long as there is space.

7) Holding the product stationary in front of the antenna will make it to be read continuously after every 4 seconds.

8) When the tag in product is perpendicular to the antenna the tag is not read also.

9) The antenna can detect then tag in the read range of 6,6cm and below.

10) The antenna cannot read goods with two piled tags; therefore it reads one tag at a time

11) The antenna cannot read goods swiped at fast speed. To avoid these speeds conformation of the buzzer is necessary.

12) The buzzer sounds simultaneously when the goods are read (no time delay)

13) The signal is blocked by thick metals but can pass through plastic and paper also depending on the thickness which can block the fields too.

14) The antenna radiates the same constant power all the time the signal strength depends on the distance at which the product is placed at.

15) The horizontal part proved to measure much power due to a large surface area as compared to the vertical part which had a small surface area.

16) The project showed positive results as it produced the correct relationship between the antenna power and distance. The graphs showed to be decaying exponential.

CHAPTER 5

Conclusion

5.1 Introduction

The prototype of the RFID (Radio frequency indefication) based electronic trolley was successful thereby leaving the designer of the system at an advanced point. From the results and analsysis achieved, the RFID (Radio frequency indefication) based electronic trolley prototype can be achieved.

5.2 Recommendations

- A battery for the trolley should be installed to make it easy to move when demonstrating the prototype model.
- A larger display unit and more sophisticated system should be used.
- Facilities of payment within the cart by using swapping card can be added to the system also.

5.3 Further Recommendations

- The real project should be done so as to try and automate the present trolleys at supermarkets and wholesales in Zimbabwe.

5.4 Conclusion

The planned aims were magnificently achieved in the sample model developed. The developed prototype is easy to use, and does not require any advanced training.. The student learnt the system that can be used for smart shopping to save time, energy and money of the customers.

APPENDIX A

Software algorithm

```
#include <LiquidCrystal.h>

#include <SoftwareSerial.h>

#define NOTE_DS2 78

#define NOTE_FS3 185

SoftwareSerial RFID(2, 3); // RX and TX

int data1 = 0;

int ok = -1 ;

int yes = 13;

double total = 0.0;

int bu = NOTE_DS2;

int sa = NOTE_FS3;

int buzzer= 7;

int cha[7];

int tag1[14] = {2,55,52,48,48,49,50,48,52,57,70,70,68,3};

int tag2[14] = {2,55,52,48,48,49,55,49,51,55,52,48,52,3};

int tag3[14] = {2,55,52,48,48,49,50,51,53,69,69,66,68,3};

int newtag[14] = { 0,0,0,0,0,0,0,0,0,0,0,0,0,0}; // used for read comparisons

double price1 = 10.50;

double price2 = 3.50;

double price3 = 5.00;

int button = 8, button2= 9, button3= 12;

LiquidCrystal lcd(11,10,6,5,4,3);
```

```
void setup() {
  // put your setup code here, to run once:
   RFID.begin(9600); // start serial to RFID reader
 // start serial to PC
lcd.begin(16,2);
pinMode(yes, OUTPUT); // for status LEDs
pinMode(buzzer, OUTPUT);
pinMode(button , INPUT);
pinMode(button2 , INPUT);
pinMode(button3,INPUT);
lcd.setCursor(0,0);
lcd.println("RFID READER");
delay(2000);
lcd.setCursor(0,0);
  lcd.println("Start shopping");
    delay(3000);
    lcd.clear();
lcd.clear();
}
boolean comparetag(int aa[14], int bb[14])
{
boolean ff = false;
int fg = 0;
for (int cc = 0 ; cc < 14 ; cc++)
{
```

```
if (aa[cc] == bb[cc])
{
fg++;
}
}
if (fg == 14)
{
ff = true;
}
return ff;
}
void checkmytags() // compares each tag against the tag just read
{
ok = 0; // this variable helps decision-making,
if (comparetag(newtag, tag1) == true)
{
  ok++;
  lcd.setCursor(0,0);
  lcd.println("black label 350mls");
  lcd.setCursor(7,1);
  lcd.print("$");
  lcd.println( price1);
  total = total + price1;
Serial.println(total);
}
```

```
if (comparetag(newtag, tag2) == true)
{
ok++;
lcd.setCursor(0,0);
lcd.println("Nestle Cremora 500grms");
lcd.setCursor(7,1);
lcd.print("$");
lcd.println( price2);
total = total + price2;
}
if (comparetag(newtag,tag3)==true)
{
  ok++;
lcd.setCursor(0,0);
lcd.println("Cornflakes 250grms");
lcd.setCursor(5,1);
lcd.print("$");
lcd.println(price3);
total = total + price3;
}}
void readTags()
{
  ok = -1;
if (RFID.available() > 0)
{
```

```
// read tag numbers
delay(1000); // needed to allow time for the data to come in from the serial buffer.
for (int z = 0 ; z < 14 ; z++) // read the rest of the tag
{
data1 = RFID.read();
newtag[z] = data1;
}
RFID.flush(); // stops multiple reads
// do the tags match up?
checkmytags();
}
// now do something based on tag type
if (ok > 0) // if we had a match
{
//  lcd.setCursor(0,0);
//lcd.println("Accepted");
digitalWrite(yes, HIGH);
tone(7 , sa , 1000);
delay(1000);
digitalWrite(yes, LOW);
noTone(7);
ok = -1;
}
else if (ok == 0) // if we didn't have a match
ok = -1;
```

```
}
}
void readTag()
{
  ok = -1;
if (RFID.available() > 0)
{
// read tag numbers
delay(1000); // needed to allow time for the data to come in from the serial buffer.
for (int z = 0 ; z < 14 ; z++) // read the rest of the tag
{
data1 = RFID.read();
newtag[z] = data1;
}
RFID.flush(); // stops multiple reads
// do the tags match up?
checkmytag();}
if (ok > 0) // if we had a match
{
//  lcd.setCursor(0,0);
//lcd.println("Accepted");
digitalWrite(yes, HIGH);
tone(7 , sa , 1000);
delay(1000);
digitalWrite(yes, LOW);
```

```
noTone(7);
ok = -1;
}
else if (ok == 0) // if we didn't have a match
{
ok = -1;
}
}
void checkmytag() // compares each tag against the tag just read
{
ok = 0; // this variable helps decision-making,

// if it is 1 we have a match, zero is a read but no match,
// -1 is no read attempt made
if (comparetag(newtag, tag1) == true)
{
  ok++;
  lcd.setCursor(0,0);
  lcd.println("black label 350mls");
  lcd.setCursor(0,1);
lcd.println( "removed");
  total = total - price1;
}
if (comparetag(newtag, tag2) == true)
{
```

```
ok++;
lcd.setCursor(0,0);
lcd.println("Nestle Cremora 500grms");
lcd.setCursor(0,1);
lcd.println( "removed");
total = total - price2;
}
if (comparetag(newtag,tag3)==true)
{
  ok++;
lcd.setCursor(0,0);
lcd.println("Cornflakes 250grms");
lcd.setCursor(0,1);
lcd.println("removed");
total = total - price3;
}}
void loop() {
  // put your main code here, to run repeatedly:
  if ((digitalRead(button)== HIGH ) && ((digitalRead(button2 )== LOW) )){
  readTags();
     lcd.clear();
    lcd.setCursor(0,0);
    lcd.print("shopping in progress");
    delay(1000);
    lcd.clear();
```

```
  }
if(digitalRead(button)== LOW){
  total= 0.0;
}
if (digitalRead(button2 )== HIGH && (digitalRead(button)== HIGH) )
{
  lcd.setCursor(0,0);
  lcd.println("the total is");
  lcd.setCursor(5,1);
  lcd.print("$");
  lcd.println(total);
  }
if (digitalRead(button3)== HIGH && (digitalRead(button)== HIGH)){
  lcd.clear();
  readTag();
}
 }
```

APPENDIX B

List of figures

APPENDIX C

List of tables

APPENDIX D

List of abbreviations

LF - Low Frequency

HF - High Frequency

UHF - Ultra High Frequency

RFID - Radio Frequency Identification

PRAT - Passive Reader Active Tag

DSRC - Dedicated Short Range

EEPROM – Electrical Erasable Programmable Read Only Memory

SRAM –Synchronous Random Accessed Memory

LED – Light Emitting Diode

Tx and Rx – Transmit and Receive

APPENDIX E

List of components

Component	Voltage Value	Quantity
Arduino Uno	5 -12 V	1
RFID reader	5V	1
RFID antenna	5V	2
Buzzer	3V- 5V	1
16*2 LCD	5V	1
Push button	3V-5V	2
Toggle switch	3V-5V	1
LED (green)	-----	1
Resistor	10kΩ	3
RFID tags	-----	3