DEVELOPMENT OF AN AUTOMATED COUNTER SYSTEM FOR SMALL AND MEDIUM ENTERPRISES

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(CPE/13/1083)

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CERTIFICATION

This project with the title

DEVELOPMENT OF AN AUTOMATED COUNTER SYSTEM FOR SMALL AND MEDIUM ENTERPRISES

Submitted by

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Has satisfied the regulations governing the award of degree of

BACHELOR OF ENGINEERING (B.Eng) in COMPUTER ENGINEERING,

Federal University Oye-Ekiti, Nigeria.

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DEDICATION

This report is dedicated to God Almighty, the Author and Finisher of my faith and to my wonderful parents for their guidance and immeasurable support.

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ABSTRACT

Counting is a very common activity in our daily lives and when inaccurate results are produced, it could cost us dearly in terms of loss in production, profit and finances. This inaccuracy is very common with the manual method of counting due to fatigue from task repetition over a long period of time. This project develops an automated counter system to solve the challenge of packaging items below or above advertised quantity to customers by many small scale business organizations with focus on lightweight items.

The automated counter system was designed as an embedded system. The entire system is made up of three major phases which are the conveying, sensing and counting phases. The conveying phase is made up of the conveyor belt, the DC (stepper) motor that drives it as well as the servomotor that drives the door system to open and close so items can move from the items dock onto the belt. The sensing phase comprises mainly of the ultrasonic sensor unit (HC-SR04) which detects an item within range on the conveyor belt while the counting phase is achieved by using the Arduino microcontroller (ATMEGA32p) to increment the value of the count variable in memory. The controller checks the count value against the constant maximum count value to display the value as appropriate on the liquid crystal display (LCD). The developed system is evaluated using mean time between failure (MTBF) and rate of occurrence of failure (ROCOF).

The system components were assembled and connected using a breadboard to test the prototype before transferring the design onto a veroboard and soldering components permanently. After successfully coupling the prototype components, hardware testing was carried out to determine the speed of the conveyor belt ($0.428\frac{m}{s}$), gate movement time delay (3.82s), voltage of adaptor (12V – 15V). After operating for a span of fifteen minutes, the MTBF gave a result of 0.0114hours/failure while the rate of occurrence of failure was 87.72failures/hour.

This project work designed and implemented a hardware prototype of an automated counter system. The developed prototype can be used in industries that produce lightweight items. A recommended improvement to the work done would be to develop a single power unit and incorporate a keypad to set the desired maximum count.

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CHAPTER ONE

INTRODUCTION

1.1 Preamble

In our world today, technology is being used by many business organizations to improve the quality of their product, achieve simplicity of tasks, solve problems or serve other purposes. Technology itself, refers to methods, systems, and devices which are the result of scientific knowledge being used for practical purposes (Ramey, 2013). For instance, our media of communication has greatly improved over the years and physical barriers to communication have reduced due to technology as we now have telephones, mobile phones, fax, emails, the internet.etc. compared to the traditional means of communication that involves humans having to travel long distances or wait for days before a mail is delivered to their mailbox just to achieve a message. This is to tell us how technology has affected our society. In a competitive market which is solely influenced by demand, it is important to always adopt whatever means is necessary to promote one's products and services and to be ahead of one's competitors in the market, applying technology in one's business operations is a good way to start.

Digital systems play an important role in technology, as they function to store, process and communicate information in digital form. Technology has so evolved that, a digital system can be integrated onto a single microcomputer circuit (Meuhlhauser, 2015). Microcomputer based systems have a general property of being able to perform a series of events based on the program burned on their chips. This makes object counting a task that can be accomplished using microcontrollers. Counting can as well be accomplished by making use of logic circuits.eg sequential circuits. Counting is a very important and unavoidable part of our daily activities because there is always a necessity for good record in whatever involves counting (Fehrman, 2017).

In developing countries like Nigeria, where there is constant increase in manufacturing industries, and new entrepreneurs implementing new business ideas everyday, designing this kind of system would find application in small scale businesses, where a few employees would have to handle all the aspects of production which is very stressful, leaving very tired employees to take care of the packing procedure thereby makes counting mistakes a very easy mark. It automates the counting aspect of the packing stage, prior to distribution. Several types of counting and conveying machines are available and the best means to achieve this design with low cost would be explored. Therefore, the development of an automated counter system for small and medium enterprises is the focus of this project.

1.2 Statement of the Problem

In many Nigerian industries today, manual counting of items is carried out and this has led to discrepancies in the number of packaged items. This is the case for most business organizations such as the soap making company, toilet paper mills and sachet water factories (Oyesola, 2017). Between production and distribution, such business enterprises require the packaging of the products. Traditionally, humans are employed to take care of the packaging stage, similar to manual involvement in the preceding production & successive distribution stages require certain protocols to be followed. Often times, consumers purchase the packaged product only to find that the number of items packaged is not up to the advertised quantity. This could have been a result of weariness on the part of the personnel that took care of the packaging, due to either continuous repetition of tasks or having to endure long working hours.

Sometimes, errors in counting could simply be because employees are not focused on carrying out their duties as a result of dissatisfaction at their employers. After all, for most small-scale businesses, workers may have to handle more than an aspect of total production and the labour is back breaking. Therefore, they might not discharge their duties well due to industrial chaos and crisis (Wokoma, 2011).

This project proposes a prototype to the problems stated above by counting items moving along a line of flow using an automated counter system. This regulates the number of items per pack, since machines cannot express dissatisfaction at their users nor do they produce erroneous results because of task repetition.

1.3 Aim and Objectives

The aim of this project is to design a prototype of an automated counter system for local small and medium scale enterprises (SMEs).

The specific objectives are:

i. To design an automated counter system.

ii. To implement the automated counter system using a hardware prototype.

iii. To evaluate the effectiveness of the developed system.

1.4 Methods of Study

The methods to be used in achieving this project will include the following:

i. Continual review of relevant literatures and materials on the internet related to embedded systems.

ii. Design of the microcontroller-based automated counter system prototype.

iii. Unit testing of distinct parts that make up the whole system prototype.

iv. Assembling the units into a whole entity.

v. Evaluation based on functional performance.

1.5 Scope of the Study

This project intends to focus its application to small scale businesses that package small items. Therefore, the proposed prototype would be built according to a specific range of predetermined weight which is between 0.0kg to 0.2kg for lightweight items such as soaps, toilet paper.etc. Any load greater than this weight range should not be applied to the machine as it may cause damage to it.

1.6 Significance of the Study

The automated counter system can be used in manufacturing industries that produce light weight items which comply with our pre-set range of weight values, hence reducing human labour. Below are a few reasons why this study is significant:

i. Use of indigenous materials: The development of this prototype is done using locally available materials that anyone can find around them and this makes it a solution that can be easily delivered.

ii. Increased efficiency: This study explores a solution that conserves time and energy and produces desired result.

iii. Improved effectiveness: Errors of counting are suppressed minimally and this makes it very effective.

1.7 Definition of Terms

The following are some of the terminologies used in this chapter and a brief explanation is provided for each of them. These terminologies are:

i. **Microcomputer:** A microcomputer is a complete computer on a smaller scale and usually contains a microprocessor (a central processing unit on a microchip), memory in the form of read-only memory and random access memory, I/O ports and a bus or system of interconnecting wires, housed in a single unit called the motherboard (Margaret, 2015).

ii. **Integrated circuit:** An integrated circuit is a semiconductor device, usually made of silicon, that can hold from hundreds to millions of electronic components (transistors, resistors and capacitors.etc) on a small chip and function as an amplifier, oscillator, timer, microprocessor, or even computer memory.

iii. **Digital system:** Digital systems are designed to process, store and communicate information in digital form. They are found in a wide range of applications, including process control, communication systems, digital instruments. Computers are digital machines because at their most basic level, they can distinguish between just two values, 0 and 1, or off and on (Crisp, 2000).

iv. **Microcontroller:** A microcontroller is a highly integrated chip that contains all the components comprising a controller. That includes a CPU, RAM and some form of ROM, I/O ports and timers. Unlike a general purpose computer which also includes all of these components, a microcontroller is designed for a very specific task, which is to control a particular system. This makes the simplification reduction of component parts possible, which ultimately reduces its cost of production.

CHAPTER TWO

LITERATURE REVIEW

2.1 Counting Devices

Mankind has learned to use the simplest counting devices for thousands of years ago. In our society when trade by barter was practiced, there arose the need to determine the number of objects used for exchange. One of the earliest solution was to use a weight equivalent which did not require an exact translation of its parts. The simplest counterweight scales, which became one of the first devices to quantify the mass were employed for this purpose. Other simple counting devices available to mankind were the Abacus, the counting board or salamis tablet.etc. More sophisticated devices for calculating were developed after the invention of gears (Ferro, 2005).

2.1.1 Counting Board

The counting board is precursor of the abacus, and the earliest known form of a counting device (excluding fingers and other very simple methods). Counting boards were made from natural material such as stone or wood, and the actual counting was done on the board with beads, pebbles (Weeks, 2010). Not many of these boards survive today because of the perishable materials used in their construction. The oldest known example of a counting board was discovered on the Greek Island of island of Salamis in 1899 (Richard, 2004). Five groups of markings appear on the tablet. The three sets of Greek symbols arranged along the left, right and bottom edges of the tablet are numbers from the acrophonic system. In the center of the tablet are a set of 5 parallel lines equally divided by a vertical line, capped with a semi-circle at the intersection of the bottom-most horizontal line and the single vertical line. Below these lines is a wide space with a horizontal crack dividing it. Below this crack is another group of eleven parallel lines, again divided into two sections by a line perpendicular to them but with the semi-circle at the top of the intersection; the third, sixth and ninth of these lines are marked with a cross where they intersect with the vertical line (Luis, 2003).

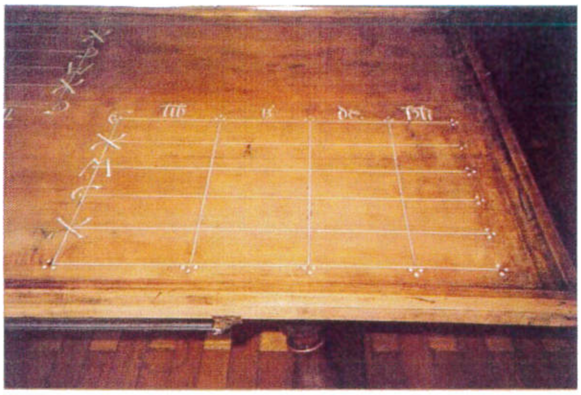


Figure 2.1: A typical counting board (Weeks, 2010).

2.1.2 Abacus

The Abacus, also called a counting frame, is a calculating tool used primarily in some parts of Asia for performing arithmetic processes (Renard, 2004). Today, abaci are often constructed as a bamboo frame with beads sliding on wires, but originally they were beans or stones moved in grooves in sand or on tablets of wood, stone, or metal. The abacus was in use centuries before the adoption of the written modern numeral system and is still widely used by merchants, traders and clerks in Asia, Africa and elsewhere (Anon, 2002).

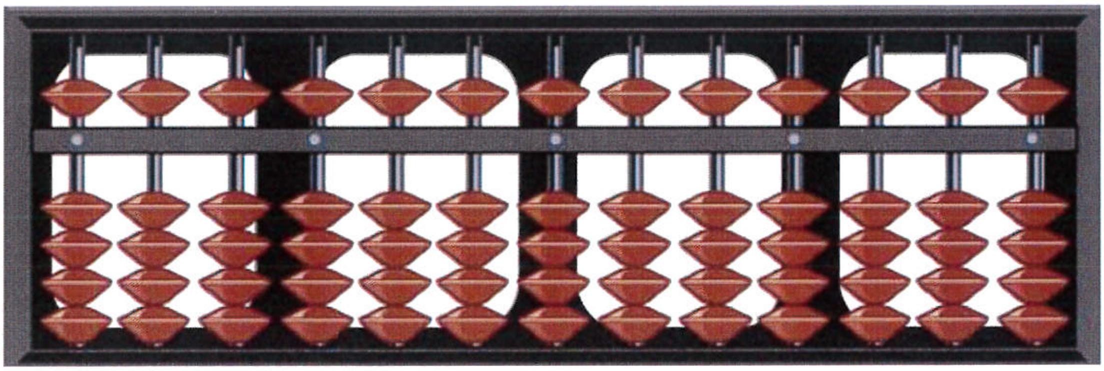


Figure 2.2: An Abacus device (Rutzler, 2017).

2.1.3 Calculating Clock

In 1623, the earliest known calculator was reported by German astronomer and mathematician, Wilhelm Schickard in a letter to his friend, Johannes Kepler along with design and construction of what he referred to as an "arithmeticum organum" ("arithmetical instrument") that he has invented which was later referred to as calculating clock. This instrument could perform the four basic arithmetic operations (addition, subtraction, multiplication and division). Calculating clock unit was so named because it could calculate the present hours of operation mechanism based on the sprockets and gears (Carlson, 2013).

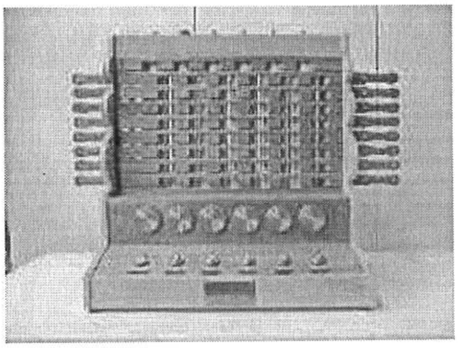


Figure 2.3: Replica of 1623 calculating clock (Carlson, 2013).

2.1.4 Adding Machine

Approximately in 1820, Charles Xavier Thomas created the first successfully commercially available calculator, the Adding machine, which could add, subtract, multiply and divide. Basically, it was based on the work of Leibniz Mechanical calculators. The adding machine was a class of mechanical calculator, usually specialized for bookkeeping calculations. In the United States, the earliest adding machines were usually built to read in dollars and cents. Adding machines were ubiquitous office equipment until they were phased out in favour of calculators in the 1970s and by personal computers beginning in about 1985. The older adding machines were rarely seen in American office settings by the year 2000 (Dill, 2017).

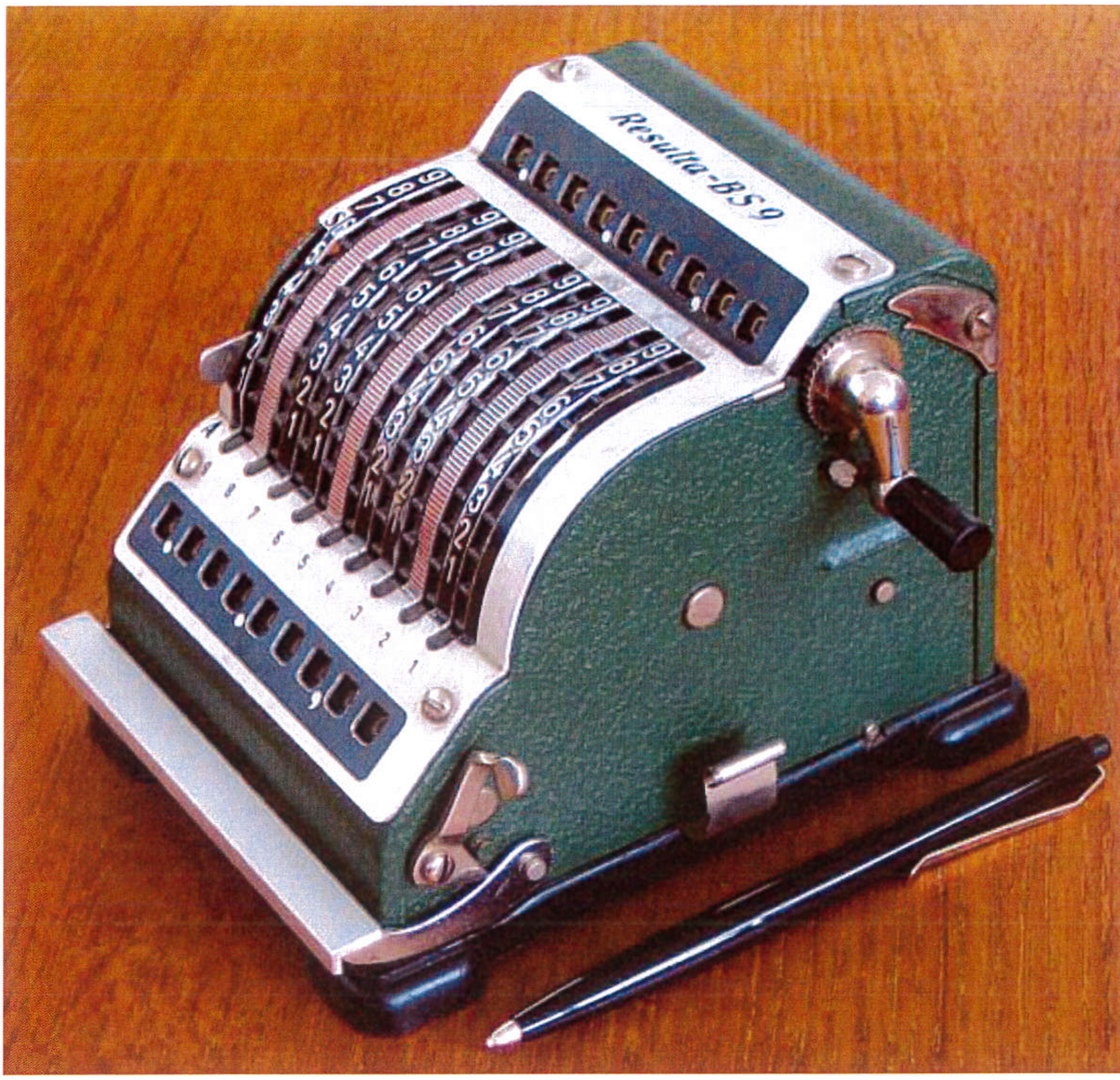


Figure 2.4: Resulta – BS9 Adding machine (Hamann, 2015).

2.2 Electromechanical Control System

Control system is an arrangement of one or more physical component connected or related in such a manner as to manage, command, direct or regulate itself or another system. It is also an interconnection of component that forms a system configuration that provides a desired system (Falohun, 2011). Electro-mechanical components and systems have been around since 1885, following the registration of a patent for a thermostatic system that automatically adjusted room temperatures in a residential building (Fitzsimmons, 2006).

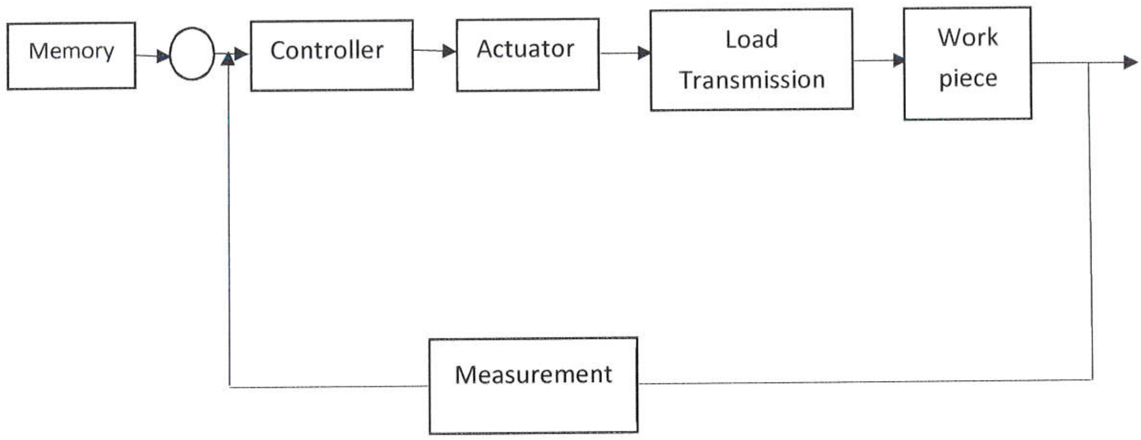


Figure 2.5: Description of a typical electromechanical control system (Fitzsimmons, 2006).

2.2.1 Open Loop Control System vs. Closed Loop Control System

A control system in which the control action is totally independent of output of the system then it is called open loop control system. Manual control system is also an open loop control system. Open loop control system does not have the ability to respond to change in load or to verify the achievement of the required action (Stengal, 1994). Practical examples of open loop control system are electric hand dryer, automatic washing machine, bread toaster.etc.

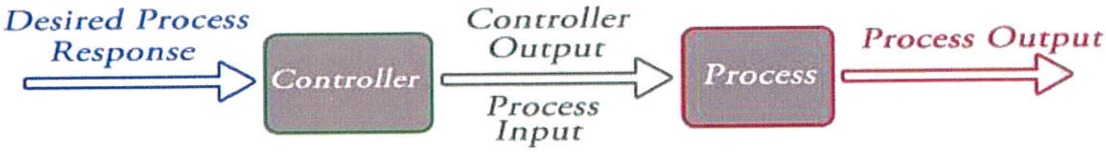


Figure 2.6: Schematic diagram of an open loop control system (Stengal, 1994).

A closed-loop control system is one which the control action from the controller is dependent on the desired and actual process variable i.e the output has an effect on the input quantity in such a manner that the input quantity will adjust itself based on the output generated. The input in a control system which could either be physical variable or abstract quantities in the stimulus or command fed into the system from an external source. Transducers are used in providing physical input converter to electrical signal from various forms. The electrical signals from the transducer are then converted by an analogue to digital converter for use in a digital computer. The processing unit produces the needed output signal in response to the control program built in the processing unit. The control is either programmed or hard-wired (Roth, 2009).

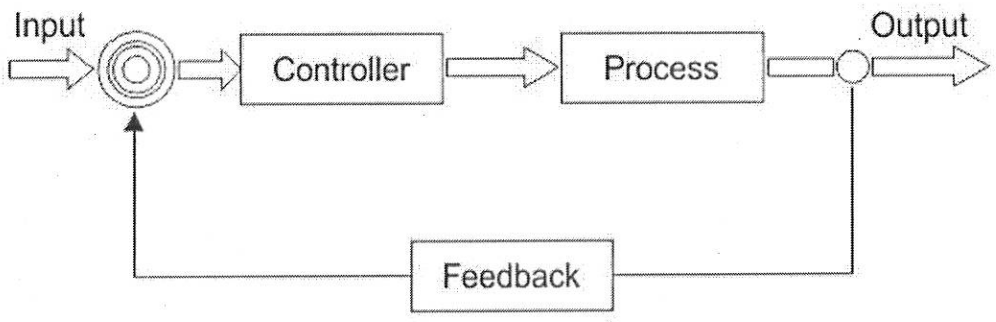


Figure 2.7: Schematic diagram of closed loop control system (Roth, 2009).

Closed loop systems could be analogue or digital closed loop control systems. Analogue closed loop deals with continuous analogue signal rather than sample data while digital closed loop deals with samples of digital signal.

Open loop control system can be converted in to closed loop control system by providing a feedback. This feedback automatically makes the suitable changes in the output due to external disturbance. In this way closed loop control system is called automatic control system. Examples are automatic electric iron, water level controller, an air conditioner.etc.

2.2.2 Motors

An electric motor is an electrical machine that converts electrical energy into mechanical energy. An electric motor is an electrical machine that converts electrical energy into mechanical energy. Electric motors produce linear or rotary force and has a moving part and a rotary part. The moving part is the rotor, which turns the shaft to deliver the mechanical power.

The stator is the stationary part of the motor's electromagnetic circuit and usually consists of either windings or permanent magnets (Guarnieri, 2014).

Figure 2.8: A DC motor (Guarnieri, 2014).

2.2.3 Servos

A servomechanism, sometimes shortened to servo, is an automatic device that uses error-sensing negative feedback to correct the action of a mechanism. The term correctly applies only to systems where the feedback or error-correction signals help control mechanical position, speed or other parameters (Younkin, 2007). Servos converts electrical energy into mechanical energy in form of rotation. Servos are preferred to rotors because they can be controlled via Arduino microcontroller to rotate to a certain degree via angular velocity calculations.

Figure 2.9: A servo motor (Younkin, 2007).

2.2.4 The Belt Conveyor System

A conveyor system is a common piece of mechanical handling equipment that moves materials from one location to another. Conveyor systems are often the lifeline to a company's ability to effectively move its product in a timely fashion and are especially useful in applications involving the transportation of heavy or bulky materials. Conveyor systems allow quick and efficient transportation for a wide variety of materials, which make them very popular in the material handling and packaging industries. Conveyor systems are widely used because of the following advantages:

i. Conveyors are able to safely transport materials from one level to another, which when done by human labour would be strenuous and expensive.
ii. They can be installed almost anywhere.
iii. They can move loads of all shapes, sizes and weights, depending on what application they were designed for. Also, many have advanced safety features that help prevent accidents.
iv. There are a variety of options available for running conveying systems, including the hydraulic, mechanical and fully automated systems, which are equipped to fit individual needs (Lodewijks, 2011).

Conventionally, human labour is employed in the carriage of items about, but that has turned out to be strenuous and causes increase in overall production cost (cost of labour). Making use of technology to reduce the mentioned setback, especially in small scale businesses involved in manufacturing is best done by automating as many operations or phases involved in production as possible. Most business organisations use different conveyor systems, depending on the kind of material the medium is intended to carry. Today, small scale businesses like the toilet paper mills make use of conveyor belts to carry the products around and deliver them to different sections where work is yet to be done on them. Therefore, in this project, conveyor belts would be used for the conveying aspect and other components would be integrated to make the counting possible, thus making up the automated counter system.

A belt conveyor system is one of many types of conveyor systems and is made up of two or more pulleys, with an endless loop of carrying medium (the conveyor belt itself, which rotates about the pulleys) that interchanges about them. The track bed is a belt made from a leather or rubber or elasto-plastic material and the belt width may vary from 300-2000mm. One or both of the pulleys are powered, moving the belt and the material on the belt forward. The powered hoist is baptized as the drive pulley while the unpowered pulley is called the idler (Khan et al, 2017).

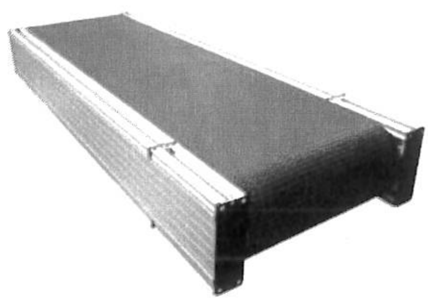


Figure 2.10: A typical conveyor belt (Khan et al, 2017).

Belt conveyors are the most commonly used powered conveyors because they are the most versatile and the least expensive. Product is conveyed directly on the belt so both regular and irregular shaped objects, large or small, light and heavy, can be transported successfully.

2.2.5 Industrial Robotics

Industrial robotics is a sub-branch in the industrial automation that aids in various manufacturing processes. Such manufacturing processes include; machining, welding, painting, assembling and material handling to name a few. Industrial robots utilizes various mechanical, electrical as well as software systems to allow for high precision, accuracy and speed that far exceeds any human performance. Automation has been achieved by various means including mechanical, hydraulic, pneumatic, electrical, electronic and computers, usually with two or more of these in combination. It involves the application of various control systems to enable operating equipment to carry out on their own, with little human intervention, tasks that require speed, endurance and precision (Adam, 2014).

The birth of industrial robot came shortly after World War II as United States saw the need for a quicker way to produce industrial and consumer goods. Servos, digital logic and solid state electronics allowed engineers to build better and faster systems and over time, these systems were improved and revised to the point where a single robot is capable of running 24 hours a day with little or no maintenance. In 1997, there were already 700,000 industrial robots in use, the number has risen to 1.8M in 2017 (Cox, 2017). Generally, industrial robotics find their application in large business organisations and would be too expensive for small scale businesses to adopt.

2.3 Digital Circuits for Automated Counter System

Digital circuits are circuits where the signal must be one of two discrete levels. A digital computer is defined as a combination of digital device and circuit that can perform a programmed sequence of operation with little or no human intervention (Clement, 2006). One characteristic of a digital system is its ability to manipulate discrete element of information.

2.3.1 Sequential Circuits vs. Combinational Circuits

These are circuits in which the outputs are function of both the inputs and the present state of storage element. They are defined as one in which the logic signal at the output depends on some sequence of signal that occurred earlier and the next state of the storage element. It is also a function of external inputs together with present state (Farhat, 2004). The basic sequential circuits are flip-flops which are electronic circuits that have two states and ability to switch state when an appropriate signal is applied to them.

Combinational circuits on the other hand, are circuits whose logic levels at any time at the output depend on the combination of the logic level at the input (Tocci, 2001). Thus, combinational circuits can have only one possible input combination. It is also a circuit which consists of logic gates whose output at anytime is determined by present combination of specified input. There are several combination circuits that are employed extensively in the design systems which are available in integrated circuits and they perform special digital functions. Examples are adder, comparator, decoder, encoder and multiplexer. Decoder is the type of combinational circuit needed in the design of a digitized microcomputer for automated counter system.

2.3.2 Counters

Counters are a special type of sequential circuits and the widest application of flip-flops. It is a group of flip-flops with a clock signal applied. The output of the counter can be used to count the number of pulses. Generally, counters consist of a flip-flop arrangement which can be synchronous counter or asynchronous counter. In synchronous counter, only one clock input is given to all flip-flops, whereas in asynchronous counter, the output of the flip flop is the clock signal from the nearby one (Singh, 2006). Depending on the way they are clocked, counters are of two basic types; asynchronous and synchronous counters.

2.3.2.1 Asynchronous Counters

These are counters in which the flip flops are clocked separately, with the output of one serving as the clock input to the other (Ronald, 1977). It is also called a ripple counter due to the way the flip flops respond one after another in a rippling effect and it can either be an up or down counter. In principle, asynchronous counters are made up of a group of flip flops which cannot be activated concurrently, thereby generating an asynchronous operation (Singh, 2006).

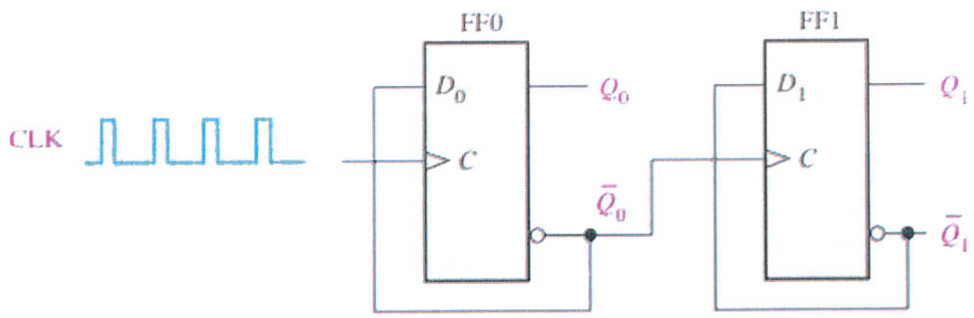


Figure 2.11: A 2-bit asynchronous binary counter (Floyd, 2015).

2.3.2.2 Synchronous counters

Contrary to how asynchronous counters work, synchronous counters are counters whose output bits change state simultaneously with no ripple. In this type of counters, the CLK inputs of all the flip flops are connected together and are activated by the input pulses. So, all the flip flops change states instantaneously (Singh, 2006).

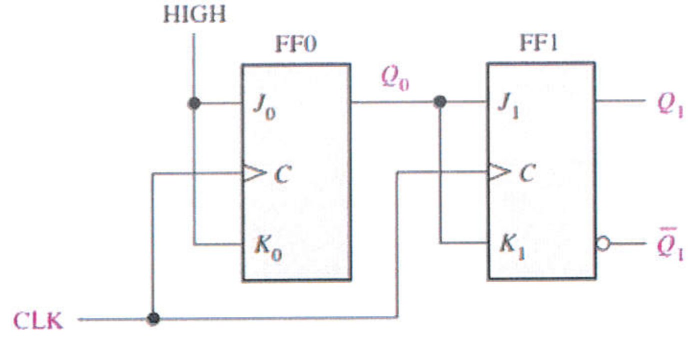


Figure 2.12: A 2-bit synchronous binary counter (Floyd, 2015).

A synchronous counter can be designed using J and K flip flop and some means of control must be generated to make flip flop toggle without being affected by a clock pulse. Synchronous up/down counters is suitable for the counter system to be developed.

2.3.3 Programmable Logic Controllers

Industrial automation incorporates programmable logic controllers in the manufacturing process. Programmable logic controllers (PLCs) are gigantic microcontrollers which use a processing system, allowing for variation of controls of inputs and outputs using simple programming (Iqbal, 2008).

PLCs make use of programmable memory, storing instructions and functions like logic, sequencing, timing, counting, etc. Using a logic based language, a PLC can receive a variety of inputs and return a variety of logical outputs, the input devices being sensors and output devices being motors, valves, etc. PLCs are similar to computers, however, while computers are optimized for calculations, PLCs are optimized for control task and use in industrial environments (Byres, 2011). They are built so that only basic logic-based programming knowledge is needed and to handle vibrations, high temperatures, humidity and noise. PLCs offer a higher speed, performance and reliability, compared to microcontrollers. PLCs make it unnecessary to rewire a system to change the control system. This flexibility leads to a cost-effective system for complex and varied control systems.

2.3.4 Microcomputer/Microcontroller

A microcomputer is a computer with a central processing unit (CPU) as a microprocessor. It is a dedicated or embedded computer which helps in monitoring and controlling the operations of a machine (Ceruzzi, 2012). The microcomputer is a very powerful tool that allows a designer to create sophisticated input-output data manipulation under program control. A typical microcomputer architecture comprises the microprocessor, memory as well as input/output units. The microprocessor consists of a central processing unit (CPU) and the control unit (CU). The CPU is the brain of the microcomputer and this is where all of the arithmetic and logic operations are performed.

The control unit sends out control signals to other parts of the microcomputer to perform the required instruction and also controls the microprocessor's internal operations (Clement, 1999). Memory is an integral part of a microcomputer system and can be grouped into program memory and data memory. The program memory is a non-volatile memory which stores program codes written by the programmer for instructing the microcomputer to perform specific tasks, but data stored in a program memory remains stored even when there's no power supply. Data memory is where the temporary data used in the program is stored, although it is volatile. i.e. data is lost immediately power is removed.

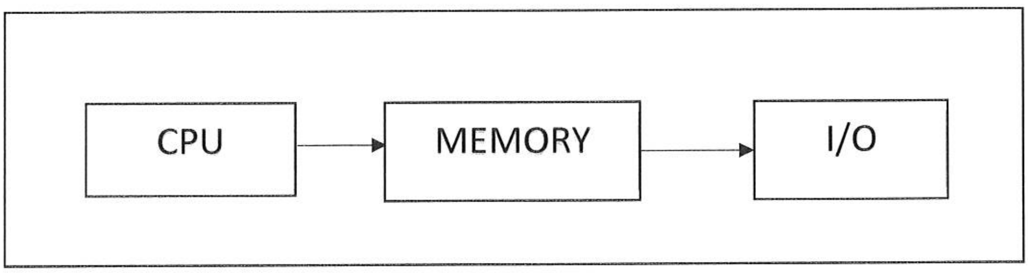


Figure 2.13: Simple microcomputer architecture (Ceruzzi, 2012).

Therefore, a microcomputer is smaller than general purpose computers. It includes a microprocessor, memory, and minimal input/output (I/O) circuitry mounted on a single printed circuit board. The single chip microcomputer is employed in a wide variety of control applications such as appliance control, automated teller machine, photocopying machines, automatic braking system and medical instruments.

Microcontrollers, however, are classified by the number of bits they process and the most popular ones used for microcomputer-based applications are 8-bit. 16 and 32 bits microcomputer are much more powerful but usually more expensive and not required in many small-to-medium size general purpose application where microcomputers are generally used. A microcontroller is a compact integrated circuit designed to govern a specific operation in an embedded system (Harris, 2012).

A microcontroller is also generally regarded as a computer, since it comprises all the basic components of any computer, which are:

i. **Processor:** All computers have a CPU (central processing unit) that executes programs.

ii. **Memory:** The CPU loads the program from somewhere in its memory unit and can also store data in memory

iii. **Input and output peripherals:** To receive input signals and display results.

All these units are usually present in a microcontroller and integrated together on a single chip. The following are characteristics of a microcontroller which makes them suitable for this project:

i. Microcontrollers can be embedded inside some other device (often a consumer product) so that they can control the features or actions of the product. Therefore, they are otherwise called "embedded controllers."

ii. Microcontrollers are dedicated to one task and run one specific program. The program is stored in ROM (read-only memory) and generally does not change.

iii. Microcontrollers are often low-power devices.

iv. A microcontroller is often small and low cost. The components are chosen to minimize size and to be as inexpensive as possible.

A programming language is a formal language that specifies a set of instructions that can be used to produce various kinds of output. Programming languages generally consist of instructions for a computer. Programming languages can be used to create programs that implement specific algorithms. The description of a programming language is usually split into the two components of syntax (form) and semantics (meaning) (Lévénez, 2011). A typical program consists of a sequence of commands written in a known programming language that a microcomputer executes sequentially. This is a computer program whose task is to translate the original code written in a particular language, C for instance, into its equivalent machine code of zeroes and ones that can be fed into the microcomputer.

C programming language is a general-purpose, imperative computer programming language, supporting structured programming, lexical variable scope and recursion. By design, C is relevant in programming microcomputer since it is composed of constructs that map efficiently to typical machine instructions. Therefore, it has found lasting use in applications that had formerly been coded in assembly language, including operating systems, as well as various application software for computers ranging from supercomputers to embedded systems. It was designed to be compiled using a relatively straightforward compiler to:

i. provide low-level access to memory,
ii. provide constructs that map efficiently to machine instructions,
iii. require minimal run-time support.

Despite its low-level capabilities, the language was designed to encourage cross-platform programming (Schultz, 2004).

2.4 Electrical circuits needed in the counter system

An electrical circuit is a path or line through which electric current flows. Various electrical components and devices are used in developing the counter system and includes:

i. **Voltage supply:** Microcomputers usually operate with the standard logic voltage of 5v. There are some that can operate at as low as 2.7v or even tolerate as high as 6v without any problem. All these ratings would have been stated in the manufacturer's data sheet of the microcontroller unit.

ii. **Clock and timer:** Clocks are often times, provided by connecting an external timing device to the microcomputer. Some have in-built timing circuits and they do not require any external timing components.

iii. **Reset input:** A reset input is used to reset the microcomputer into a known state such that the program execution starts from address "0" of the program memory.

iv. **Pause input button:** This is used to halt the operation of the microcomputer to give room for adjustment to items in transit.

v. **Potentiometer:** sA potentiometer is a three-terminal resistor in which the resistance is manually varied to control the flow of electronic current. It consists of three terminals among which two are fixed and one is variable. The two fixed terminals of the potentiometer are connected to both ends of the resistive element called track and third terminal is connected to the sliding wiper. The wiper that moves along the resistive element varies the resistance of the potentiometer. The resistance of the potentiometer is changed when the wiper is moved over the resistive path.

2.5 Sensors

The sensing unit takes care of the most critical function because all other operation in the system fairly depends on the sensing unit. The sensor is a device, module, or subsystem whose purpose is to detect events or changes in its environment and send the information to other electronics, frequently a computer processor (Kretschmar and Welsby, 2005).

Sensor as an input device which provides an output (signal) with respect to a specific physical quantity (input). Below are different types of sensors which operate by measuring one of the physical properties like temperature, resistance, capacitance, conduction, heat transfer and so on (Ravi, 2017).

2.5.1 Temperature sensors

One of the most common and most popular sensor is the temperature sensor. A temperature sensor, as the name suggests, senses the temperature i.e. it measures the changes in the temperature. In a temperature sensor, the changes in the temperature correspond to change in its physical property like resistance or voltage. There are different types of temperature sensors like temperature sensor ICs (like LM35), thermistors, thermocouples, RTD (Resistive

Temperature Devices), etc. Temperature sensors are used everywhere like computers, mobile phones, automobiles, air conditioning systems, industries etc (Ravi, 2017).

2.5.2 Proximity sensors

A proximity sensor is a non-contact type sensor that detects the presence of an object. Proximity Sensors can be implemented using different techniques like optical (like infrared or laser), ultrasonic, hall effect, capacitive. etc.

2.5.2.1 Infrared sensors

IR sensors or infrared sensors are light based sensor that are used in various applications like proximity and object detection. IR sensors are used as proximity sensors in almost all mobile phones.

There are two types of Infrared or IR sensors: transmissive type and reflective type. In transmissive type IR sensor, the IR transmitter (usually an IR LED) and the IR detector (usually a Photo Diode) are positioned facing each other so that when an object passes between them, the sensor detects the object. The other type of IR sensor is a reflective type IR sensor. In this, the transmitter and the detector are positioned adjacent to each other facing the object. When an object comes in front of the sensor, the sensor detects the object. (Ravi, 2017).

2.5.2.2 Ultrasonic sensors

As the name indicates, ultrasonic sensors measure distance by using ultrasonic waves. The sensor head emits an ultrasonic wave and receives the wave reflected back from the target. Ultrasonic Sensors measure the distance to the target by measuring the time between the emission and reception. While an optical sensor has a transmitter and receiver, an ultrasonic sensor uses a single ultrasonic element for both emission and reception. In a reflective model ultrasonic sensor, a single oscillator emits and receives ultrasonic waves alternately. This enables miniaturization of the sensor head.

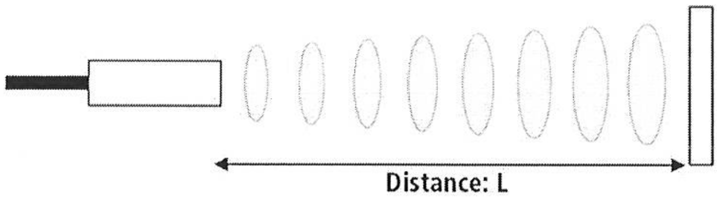


Figure 2.14: Schematic diagram of an ultrasonic sensor.

From diagram above, Distance $L = \frac{T}{2} \times C$. Where T is the time between the emission and reception, and C is the sonic speed. Note that the value of T is divided by 2 because T is the time for go-and-return distance. (Hussain, 2017). Since ultrasonic waves can reflect off a glass or liquid surface and return to the sensor head, even transparent targets can be detected. Presence detection is stable even for targets with complex shapes and detection itself is unaffected by accumulation of dust or dirt.

2.6 The Display Unit

This unit consists of seven segment display which converts the output of the counting process into form visible and understandable to people. There are different ways of displaying the alphanumeric values representing the number of count. In some devices, liquid crystal display (LCD) can be utilized while in some other devices, for instance, battery powered devices, driving LEDs are implemented. The Liquid crystal display is a flat panel display or other electronically modulated optical device that uses light-modulating properties of liquid crystals. It has low power consumption as compared to light emitting diodes and suitable for this project.

2.7 Related Work

Garner et al. (1990) reported the results of five field tests conducted to determine the feasibility of using commercially-available infrared light-beam sensors for counting, classifying, and perhaps weighing vehicles. A single, reflex-type infrared sensor mounted just off the shoulder and working off a retro-reflective raised pavement marker in the center of the outside traffic lane was used to count the tires on one end of each axle of a moving vehicle with accuracy comparable to human observers, although tests were not conducted in snow or heavy rain. Arrays of two or more infrared light beam sensors can be used to sense vehicle-body presence, to calculate vehicle speed, axle spacing, and tire-contact patch dimensions, to indicate single or dual tires, to detect direction of vehicle movement, and to sense over-height vehicles.

A real-time system for people counting based on single low-end non-calibrated video camera was developed by Lefloch et al. (2008) in response to the growing interest in video-based solutions for people monitoring and counting in business and security applications. During preliminary testing, it was discovered that several persons were considered to be a single person by automatic segmentation algorithms, due to occlusions or shadows, leading to under-counting. This setback was found to occur whenever multiple persons move closely. e.g. in shopping centers. Therefore, a background substraction was performed using an adaptive background model (updated over time based on motion information) and automatic thresholding. This took care of noises, illumination and static objects changes. Furthermore, post-processing of the segmentation results was performed in the HSV colour space, to remove shadows. Moving objects were tracked using an adaptive Kalman filter, allowing a robust estimation of the objects future positions even under heavy occlusion. The system was implemented in Matlab, and gives encouraging results even at high frame rates.

The need to estimate the number of customers or visitors in public places such as shopping malls, cinemas.etc. for marketing research or statistic purposes further prompted Widyanto et al. (2010) to develop a visitor counter system, capable of counting single and multiple object visitors using fuzzy measure theory for tracking and Boosting method for classification. Two systems were developed using different approaches. Euclidean distance was used to track a visitor based on his movement between each frame in one system, while fuzzy measure theory was used to track a visitor based on trust degree in the second system. Both system's performances were compared for their visitor tracking accuracy and their computational speed. Experimental results show that Euclidean distance and Fuzzy measure have similar accuracy for tracking visitor. However, Euclidean distance is faster than those of fuzzy measure theory in the computational speed.

Cooray et al. (2011) proposed a visual-based automatic coin counting system to take care of coin counting challenge in financial transactions. The system performs its intended function by using an image captured from a webcam. Image processing techniques such as gray image conversion and thresholding to a binary image were employed. Morphological operations and median filter was applied to remove noise. Classification of coins based on value was done by analyzing statistical properties and connected components.

Samuel et al. (2014) designed and implemented a microcontroller based automatic door and visitors counter. Their work aimed to be an improvement on electronic security designs, with the door set to automatically open once somebody approaches it without the need for any switch, button or handle. The system also has a module that serves as visitor counter and as such, counts the number of entries in and out of the building. The design is made of sensors that detect human presence and a dynamic display unit that displays different messages at specific time. The H-bridge driver IC controls the movement of the motor attached to the door. The whole system is controlled by an 8051microcontroller (89s51).

Colour object counting and sorting mechanism using image processing approach was a result of efforts made to design and implement an automatic technique to determine colour of object, colour based object counting and sorting using image processing technique by Telepatil et al. (2015). First, they captured the image of the object of interest using suitable image acquisition device. Image processing technique was then used to determine the colour of the object and as soon as the colour of the object is determined, the system will automatically count and sort the objects depending on its colour. The algorithm for object colour determination as well as colour based object counting was then developed in MATLAB.

Itsadatikom and Srinonchat (2015) also presented their work on enhancement machine vision for object counter. Their work uses an intraframe analysis technique for object counter. It is applied to object counting in which objects are located in different focus. The canny technique is used to detect and recognize the object. Then the intraframe relation is used to calculate and count the small components in each object. The results show that it provides counting accuracy of at least 98%.

Ni et al. (2016) also worked on the automatic detection and counting of circular shaped overlapped objects using circular hough transform and contour detection in an effort to be able to count the number of the objects in an image automatically. Because the objects in an image are sometimes overlapped with each other and even covered with different shaped objects, it is very difficult to detach these objects before counting them. Circular hough transform was used extensively to detect and count overlapped objects with circular shapes. However, it could not detach the overlapping circular objects efficiently, and the counting task provided inaccurate results when the circular objects were covered with random shaped objects. To deal with this problem, an integrated method was proposed based on the hough transform and contour detection methods.

A digital Visitor counter using 8051 Microcontroller (AT89C51) was also developed by Reddy et al. (2017). The main concept behind this project is known as "Visitor Counting" which measures the number of persons entering into any room like seminar hall, conference room, classroom. This function is implemented using a pair of infrared sensors. LED display placed outside the room displays this value of person count. This person count will be incremented if somebody enters inside the room and at that time lights are turned on. And Since this project uses 2 infrared sensors, it can be used as bidirectional person counter as well.

An automatic window using a PIC Microcontroller and stepper motor was designed by Okomba et al. (2017). The automatic system was developed with a focus on hospitals in order to allow medical staff and other supporting staff to concentrate on their primary responsibilities of taking care of patients. The system design includes a PIC16F877A microcontroller which gets activated when a moisture detector sensor sends a high logic signal to it. The microcontroller executes its embedded program by activating the stepper motor through a ULN2003 current-dependent integrated circuit (IC) chip resulting in stepwise control of the window. Hence, the window is automatically closed when rainfall is detected but opens and remains open when no rain is detected.

Praveen Kumar Rai (2017) gave an overview on the Object Rejection and Counting Machine. The system, operable either with a unidirectional or bidirectional conveyor system for transporting surface-mount or like electronic component deposited would be capable of accepting, receiving and collecting rejected surface mount electronic components. Additional embodiment would be to a system whereby a controllably intermittently operable conveyor belt accepts rejected component, maintains their separate identity, prevents further damage to the rejected component and allows the operator to inspect the rejected component without material interference with the production cycle.

An image processing based object counting approach for machine vision application was again proposed by Baygin et al. (2018) suitable for use in large manufacturing industries. First, an image of the object to be counted passing through the conveyor is taken through the camera. Then, colour conversion was done on the object of interest in RGB colour format into HSV colour space to obtain details of the image more clearly. The image was then reduced to a single channel, the saturation(s) channel before it was subjected to a Gaussian filter. Otsu thresholding method and Sobel edge detection algorithm was applied. Hough transform was then applied to the image removed from the edges so that geometric objects in the image can be detected. This approach performs automatic counting independently of product type and colour.

In this project, a different approach is taken altogether to ensure low cost of materials as well as ease of use and simple system circuitry so they can be adopted in small scale business organizations. A Stepper (DC) motor is used to drive the conveyor belt at high speed and input is provided to the control unit via an ultrasonic sensor module to detect the presence of an object. The control unit then sends a signal to the servomechanism which causes a door to open to allow passage of an item after a successful count with the current value of item count displayed on LCD.

CHAPTER THREE

DESIGN METHODOLOGY

3.1 Overview of the Microcontroller-based Automated Counter System

The use of microcontrollers for the purpose of control and monitoring is very common in industrial environments. This project also utilizes a microcontroller along with other circuits to control the line of flow and count products that await packing for distribution in a small or medium scale manufacturing enterprise.

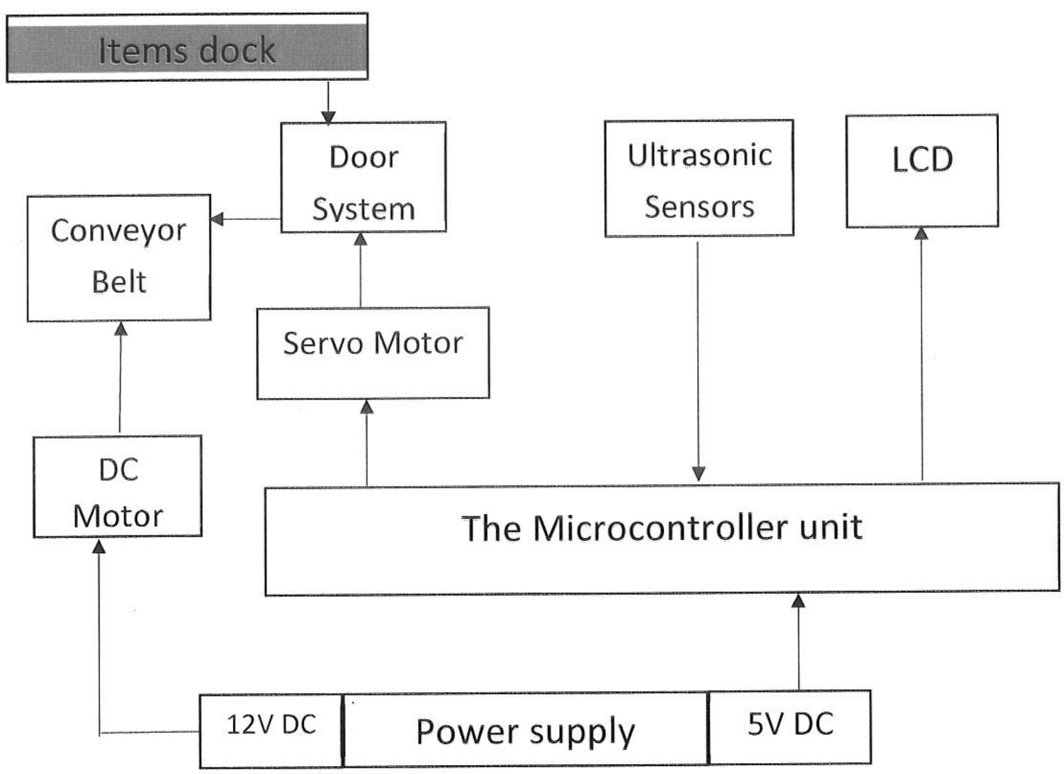


Figure 3.1: Block diagram of the automated counter system.

Figure 3.1 shows the block diagram of the automated counter system. The input to the microcontroller is the ultrasonic sensor which senses objects within range. The number of items that has been successfully sensed and counted by the controller is displayed on the Liquid Crystal Display (LCD). Servomotor is used to control the opening and closing of the door

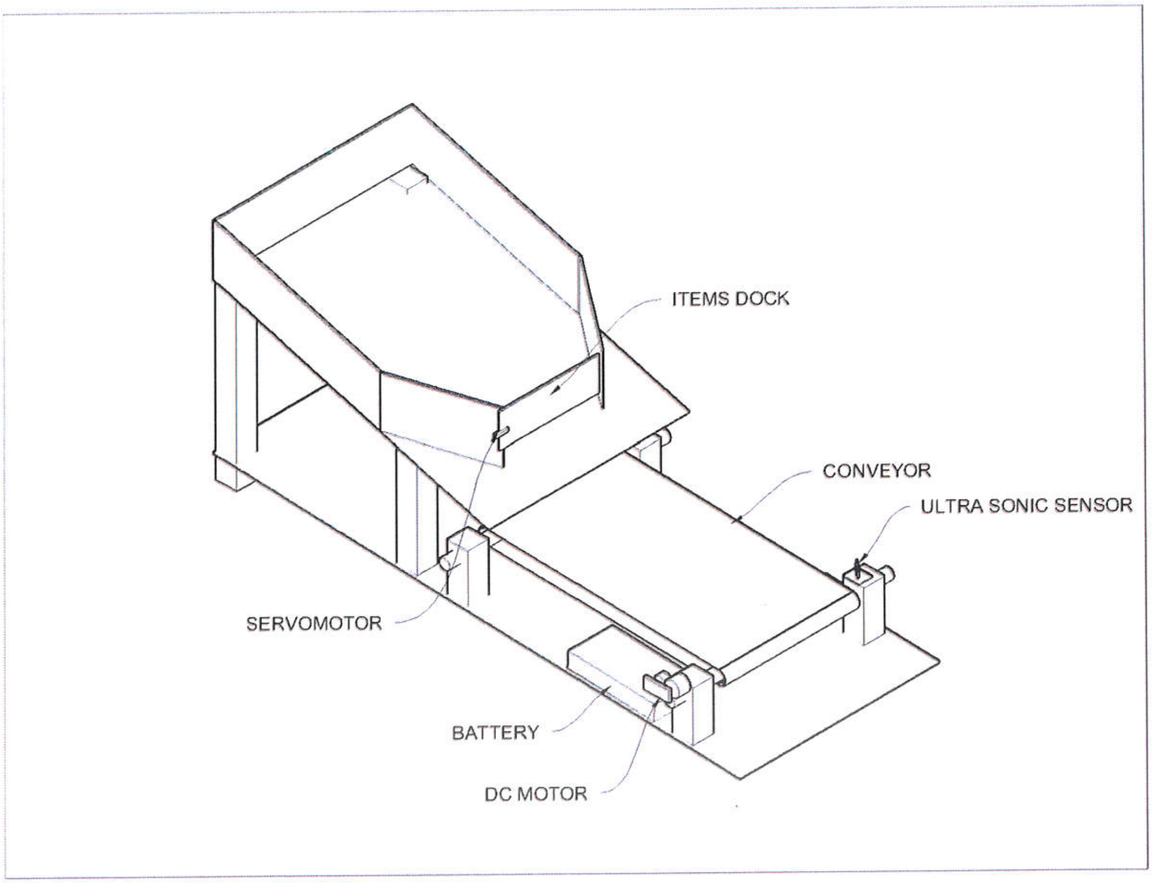


Figure 3.2: Mechatronics design of the system (Left-side view).

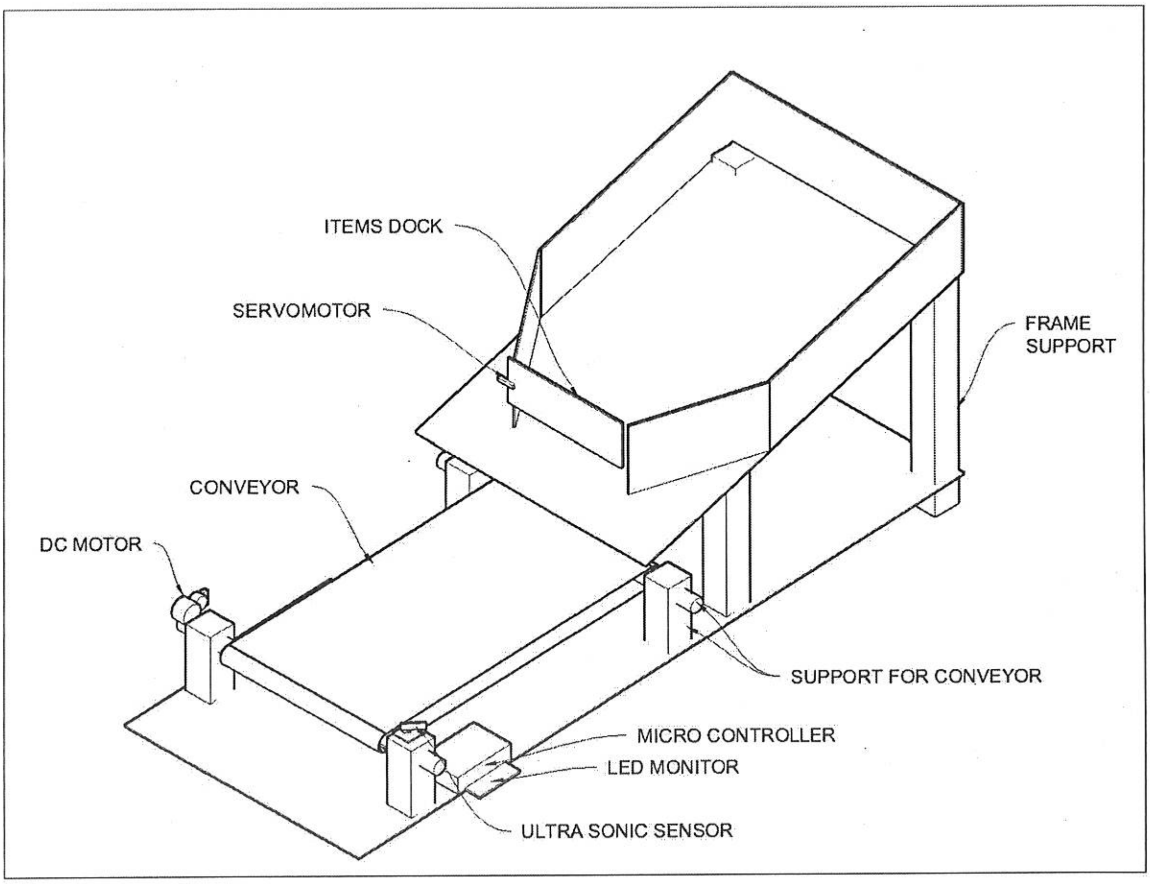


Figure 3.3: Mechatronics design of the system (Right-side view).

3.2.1 Circuit Design

The circuit design that shows the overall circuit connectivity of the basic components used in the automated counter system was designed using the Fritzing software and is shown in Figure 3.4. The circuit design shows the pin connection of components such as the ultrasonic sensor, servomotor, LCD, potentiometer to the Arduino board.

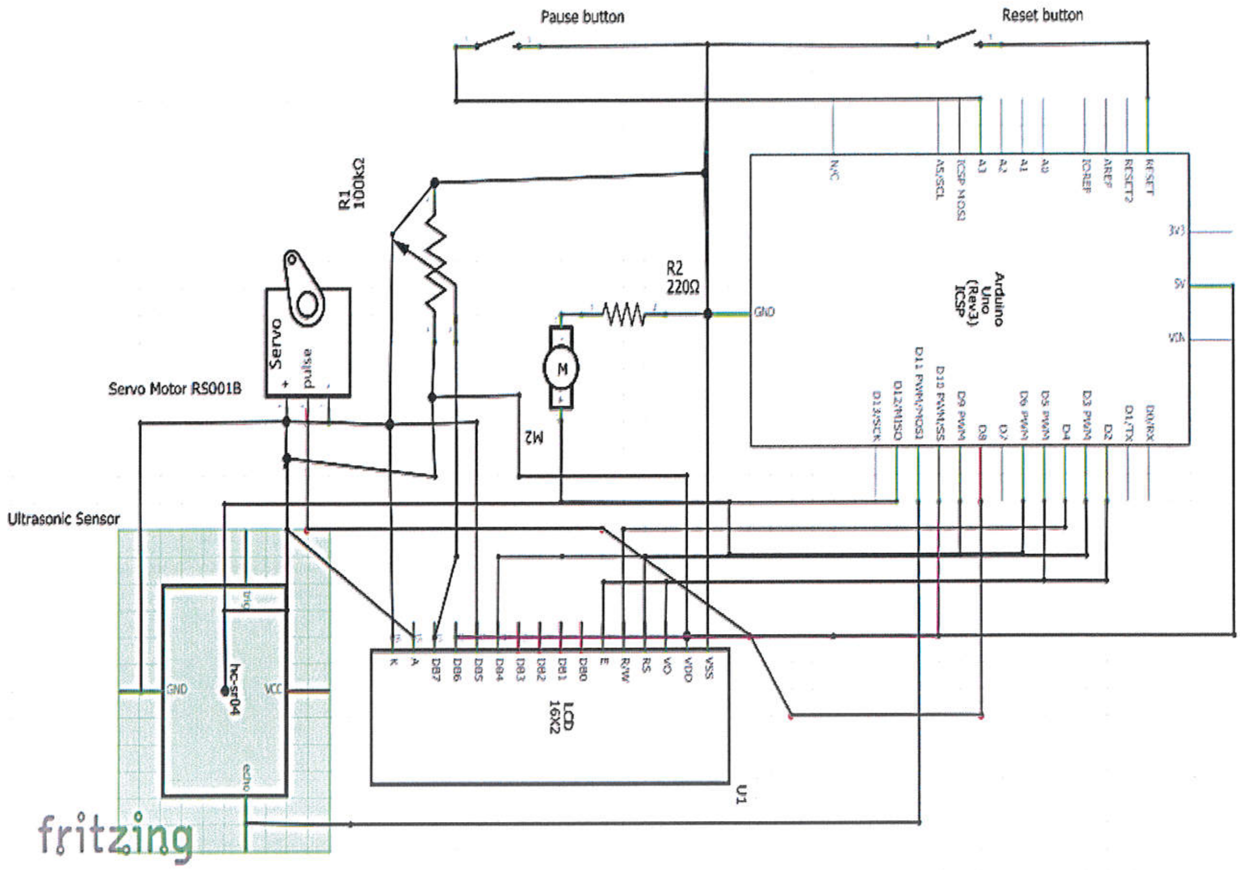


Figure 3.4: Circuit diagram of the automated counter system.

This project therefore describes three phases of operation involved in the overall implementation. These are:

i. **The conveying phase:** This project would be accomplished using a DIY(Do-It-Yourself) conveyor belt. This is only so because industrial conveyor belts are generally very expensive, so a close approximation would be developed using less expensive materials. Conveying would be handled by dc motor driving the designed conveyor belt system using suitable gears. Conveying of item begins as soon as the items are let out from the physical zone guarded by a door one after the other but the conveyor belt keeps running as long as it is powered.

ii. **The sensing phase:** Mounted on a wall near the conveyor belt would be an ultrasonic sensor for detection of objects passing through so that such objects in transit can be counted.

iii. **The counting phase:** As soon as the sensor does its job and senses an item coming through, counting occurs and the value of a counter in the Arduino memory is updated. That will be the number of items that has left the physical boundary and has been counted. This is displayed on a LCD as output and could be read by a human operator.

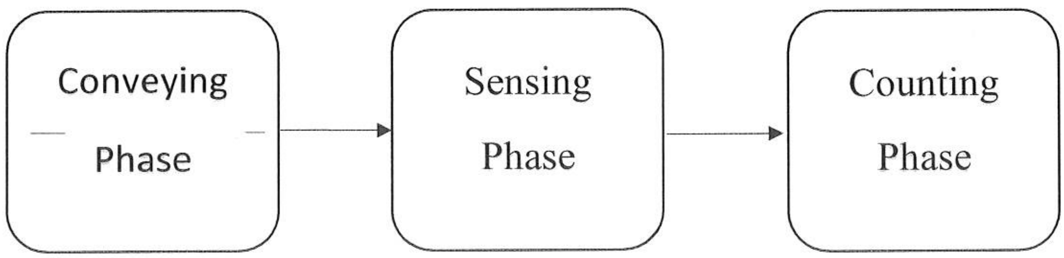


Figure 3.5: Phases of operation.

3.2.2 Model of the Automated Counter System

The 3D-design model of the developed prototype was rendered using 3DMax software and is shown in Figure 3.6. It is a representation of the automated counter system into which the required electrical and mechanical components would be incorporated and integrated to work together. The hardware model for this system is developed and would be used to test the operability of the proposed system.

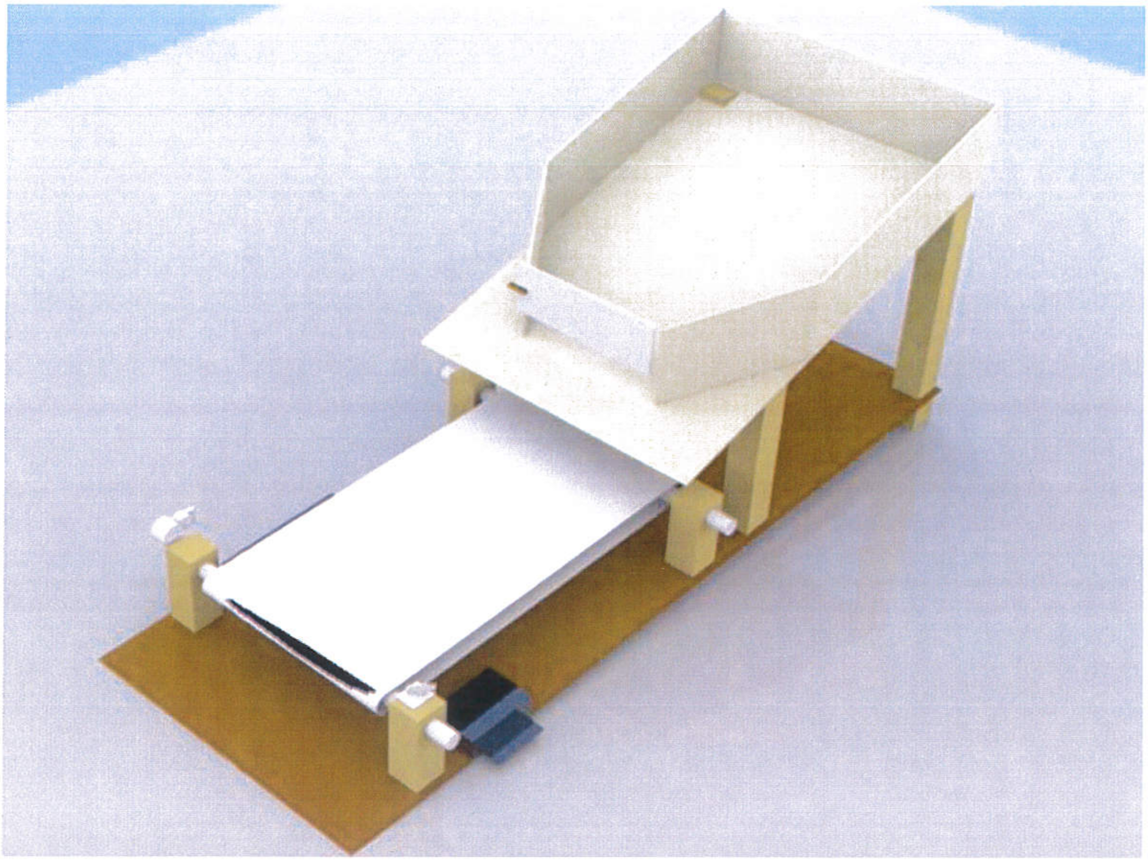


Figure 3.6: Model of the automated counter system.

3.3 Items Dock

The part described as the items dock is the container opening tilted at an angle of 47° so that items can easily slide over towards the controlled entrance. It is made by joining cardboards cut to suitable pieces together. Items that are to be counted are placed into this dock so they can follow a single line on to the conveyor belt. This funnel-shaped cardboard would have moderate space for the system's operator to put in random amount of products they would like counted concurrently. This section is an integral part of the system as there would be no item to sense or count if there is nothing here in the first place.

3.4 Servomotor and Door System

Attached to the entrance of the items dock is a door system whose opening and closing operation is controlled by a servomotor. The servo motor would cause the attached barricade

And so, the final formula would be given as:

$$Distance\ in\ cm = (\frac{time\ duration}{2})/29.1 \qquad (3.3)$$

The schema of the HC-SR04 is shown in the Figure 3.7 while Table 3.1 gives the description of the pins of the HC-SR04 Ultrasonic sensor.

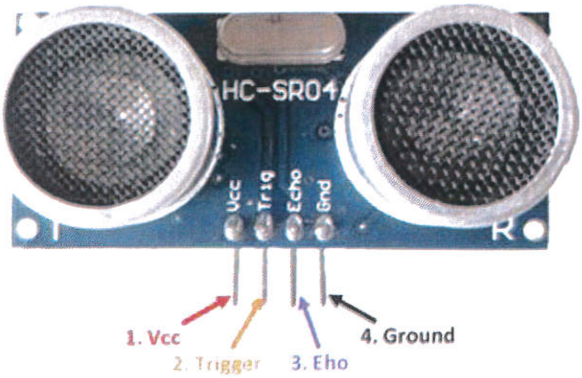


Figure 3.7: HC-SR04 Ultrasonic sensor.

Table 3.1: HC-SR04 Ultrasonic sensor pin configuration (Santos, 2013).

Pin Number	Pin Name	Description	Arduino
1	Vcc	The Vcc pin powers the sensor, typically with +5v.	5V
2	Trigger	Trigger pin is an input pin. This pin has to be kept high for 10us to initialize measurement by sending US wave.	Pin 11
3	Echo	Echo pin is an output pin. This pin goes high for a period of time which will be equal to the time taken for the US wave to return back to the sensor.	Pin 12
4	Ground	This pin is connected to the Ground of the system.	GND

3.7 Microcontroller

The microcontroller is an integral part of the system. The microcontroller used for this project is the Arduino Uno board which is based on the ATMEGA328P. It is the data processing unit of the system and solely responsible for receiving the signal from the ultrasonic sensor and also control the movement of the servomotor. It performs the count operation, stores the count state and provides the necessary signal for showing the count value on the Liquid Crystal Display screen.

3.7.1 Arduino Uno Description

Arduino Uno is a low-power 8-bit microcontroller board based on AVR microcontroller called ATmega328P. Along with ATmega328P, it consists of other components such as crystal oscillator, serial communication, voltage regulator, etc. to support the microcontroller.

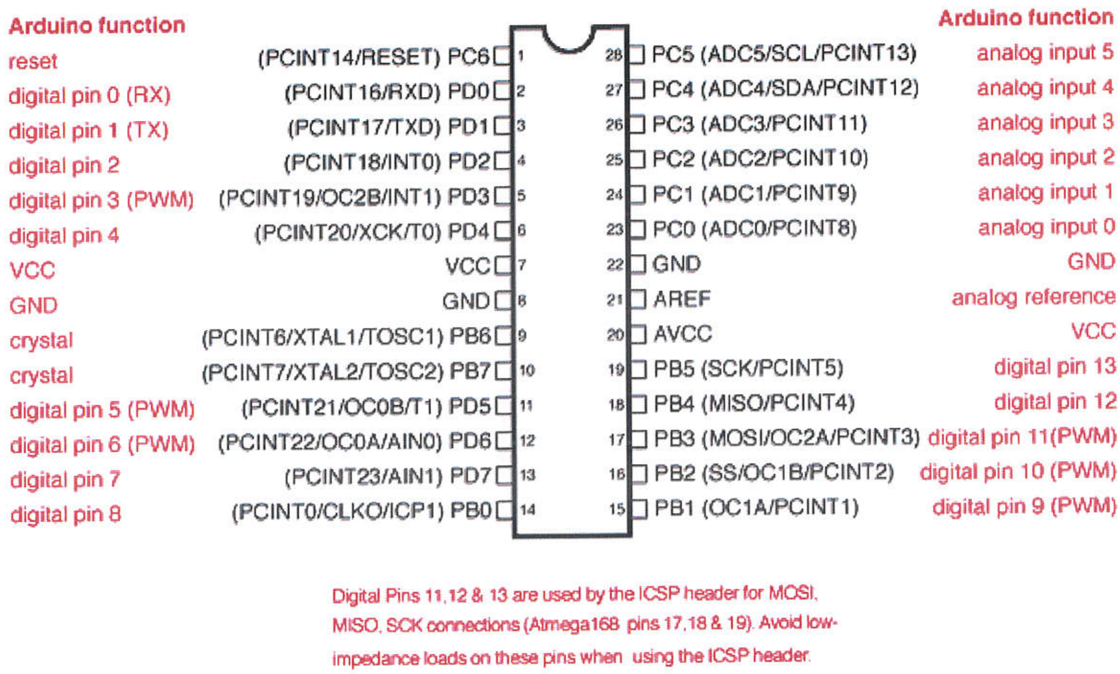
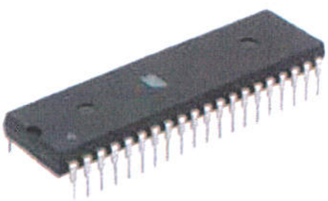
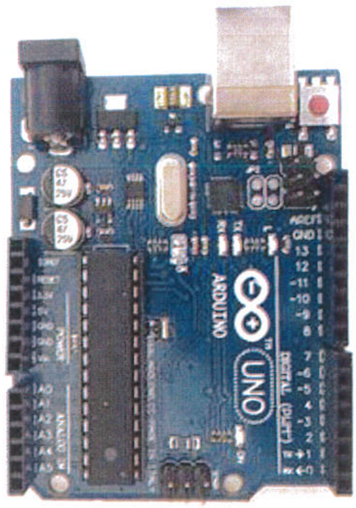


Figure 3.8: Pin description of the ATmega328p (Component101, 2018).

Arduino Uno has 14 digital input/output pins (out of which 6 can be used as PWM outputs), 6 analog input pins, a USB connection, a Power barrel jack, an ICSP (In-Circuit Serial Programming) header and a reset button. This controller also comes with 2KB SRAM, 32KB of flash memory, 1KB of EEPROM. The operating voltage is 5V. The recommended input voltage is within the range of 7-12V while the input voltage limit is between 6-20V.

The Arduino Uno board and the ATMEGA328p Microcontroller is shown in Figure 3.8.





(a) ATMEGA 328p Microcontroller. (b)The Arduino Uno microcontroller board.

Figure 3.9: The ATMEGA 328p Microcontroller and the Arduino Uno board with the controller IC.

3.7.2 Microcontroller Programming

The microcontroller board was programmed using the Arduino board programmer. The codes for the system operation were written using the Arduino software (IDE). The program code was then compiled using the compiler that is provided in the Arduino IDE. With the aid of a USB cable (used for interfacing the Arduino board to the PC), the compiled program code was then uploaded to the Arduino board (on which the ATMEGA 328p microcontroller was connected). Upon completion of the program code upload onto the microcontroller memory, the code remains stored in memory for subsequent execution. The program code for this project can be found in Appendix A.

3.8 Liquid Crystal Display (LCD)

The display units in embedded systems are generally used for providing information and some kind of feedback to the users. This can be made possible through the use of a microcontroller programmed to control the characters displayed on the screen by connecting the pins as appropriate (Okomba et al., 2015). A 16x2 matrix Liquid Crystal Display was used in the circuit design to continually display the current value of already counted items. It is shown in Figure 3.10.

3.8.1 16x2 Liquid Crystal Display (LCD)

A liquid crystal display (LCD) is a flat-panel display or other electronically modulated optical device that uses the light-modulating properties of liquid crystals. A 16x2 LCD display is a very basic module and is very commonly used in various devices and circuits. These modules are preferred over seven segments and other multi segment LEDs. The reasons being that LCDs are more economical, easily programmable, have no limitation of displaying special & even custom characters (unlike in seven segments).etc. A 16x2 LCD means it can display 16 characters per line and there are 2 such lines.

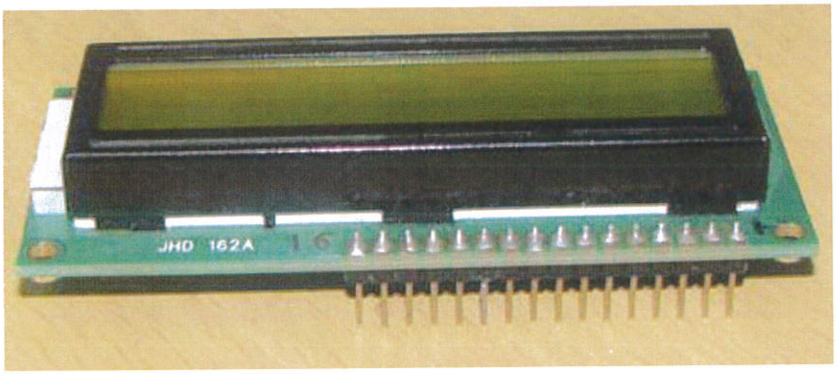


Figure 3.10: 16x2 Liquid crystal display

3.8.2 LCD Pin Description

The pin description of the Liquid Crystal Display is given in Table 3.2.

Table 3.2: LCD Pin Description (Kushagra, 2012).

Pin No	Function	Name
1	Ground (0V)	Ground
2	Supply voltage; 5V (4.7V – 5.3V)	Vcc
3	Contrast adjustment; through a variable resistor	V_{EE}
4	Selects command register when low; and data register when high	Register Select
5	Low to write to the register; High to read from the register	Read/write
6	Sends data to data pins when a high to low pulse is given	Enable
7	8-bit data pins	DB0
8		DB1
9		DB2
10		DB3
11		DB4
12		DB5
13		DB6
14		DB7
15	Backlight V_{CC} (5V)	Led+
16	Backlight Ground (0V)	Led-

3.9 Power Supply

This project makes use of two separate power sources each supplying 5V and 12V DC respectively. The 5V is used to power the Arduino board while the 12V is used to power the DC motor which controls the movement of the conveyor belt. The Arduino board can be powered with a separate adapter or USB-to-Serial cable while the 12V DC can be supplied via batteries connected together or a 12V DC adapter.

3.9.1 DC Power Supply via USB-to-Serial cable or Battery

The microcontroller board used in this project can be powered via the USB connection or with an external power supply but we are going to use the USB-to-Serial cable to power the board. This is the same cable that is used to load program code onto microcontroller memory and it powers the board simultaneously. Once the serial end is plugged into the serial port of the Arduino board, the USB end can be plugged into a computer system or a power bank capable of supplying 5V steady DC. To make things convenient, a power bank would be used as it is more portable compared to computer systems.

Once power is supplied to the board, it in turn supplies power to components like the servomotor, ultrasonic sensor and the 16x2 LCD. The Arduino Uno which is the microcontroller board used has 4 power pins and they are:

a. **VIN:** This is the input voltage to the Arduino board when it is using an external power source and not the 5 volts from the USB connector or other regulated power source. Voltage can be supplied through this pin and also accessed through this pin if supplied via the power jack.

b. **5V:** This pin outputs a regulated 5V from the regulator on the board. The board can be supplied with power either from the DC power jack (7-12V), the USB connector (5V) or the VIN pin of the board (7-12V). Supplying voltage via the 5V or 3.3V pins bypasses the regulator.

c. **3.3V:** A 3.3volt supply generated by the on-board regulator. Maximum current draw is 50mA.

d. **GND:** Ground pins.

A battery on the other hand is a device which consists of one or more electrochemical cells with external connections provided to power electrical components. It converts stored chemical energy into valuable electrical energy. For the purpose of this project, five battery connectors are made available so as to be able to provide an alternative operating current source for powering the DC motor that would drive the gears to move the fabricated conveyor belt.

Figure 3.11: 9V battery cells.

3.9.2 AC to DC Adapter

This is used to supply the required operating power for the DC motor that would drive the gears to cause the steady movement of the conveyor belt fabricated for the purpose of this project. The task of turning alternating current into direct current is called rectification and the electronic circuit that does the job is called a rectifier. The most common way of converting AC to DC is to use one or more diodes which allow current to pass in only one direction. This is generally present in AC to DC adapter circuits. There are two types of rectifiers; the half-wave which uses a single diode (simple enough to build but not very efficient) and full-wave which uses two diodes.

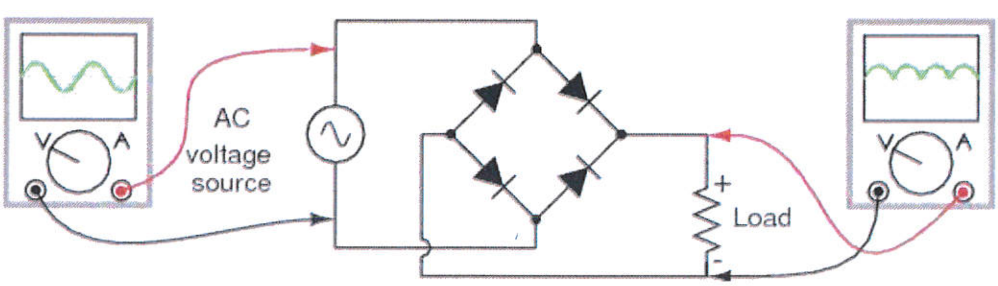


Figure 3.12: Full-wave bridge rectifier (Singh, 2006).

CHAPTER FOUR

IMPLEMENTATION AND RESULTS

4.1 System Construction

This entails the transformation of the design on paper into a finished hardware. After carrying out all the paper design and analysis, the project was implemented, constructed and tested to ensure its working ability. The construction of this project comprised of four stages:

a. The implementation of the whole project on a solder-less experiment board (breadboard).

b. The soldering of the circuits on Veroboard.

c. The integration and coupling of all individual parts of the project into one entity.

d. Connecting individual units to their appropriate power source.

The following safety precautions were taken during the construction of the project work.

i. The right components were used.

ii. The power ratings of each component were checked before use.

iii. Adequate care was taken while soldering to prevent the component from burning.

4.2 Component Implementation on Solderless Experiment Board

Firstly, the microcontroller (after it has been programmed using the Arduino IDE), the ultrasonic sensor, LCD, servomotor, potentiometer were all set up on a breadboard and interconnected with each other as seen in the circuit diagram in Figure 3.4. Interconnections were done using jumper wires and multimeter was used to test every component to verify whether they are in good condition or not. The multimeter was also used to measure voltage and current that gets to every component present in the overall circuit.

4.3 Component Implementation on Vero Board

When the components have been successfully laid out and tested on the breadboard, the components were transferred to the vero board and were soldered to the vero board as seen in Figure 4.1. The microcontroller was also screwed on to the vero board.

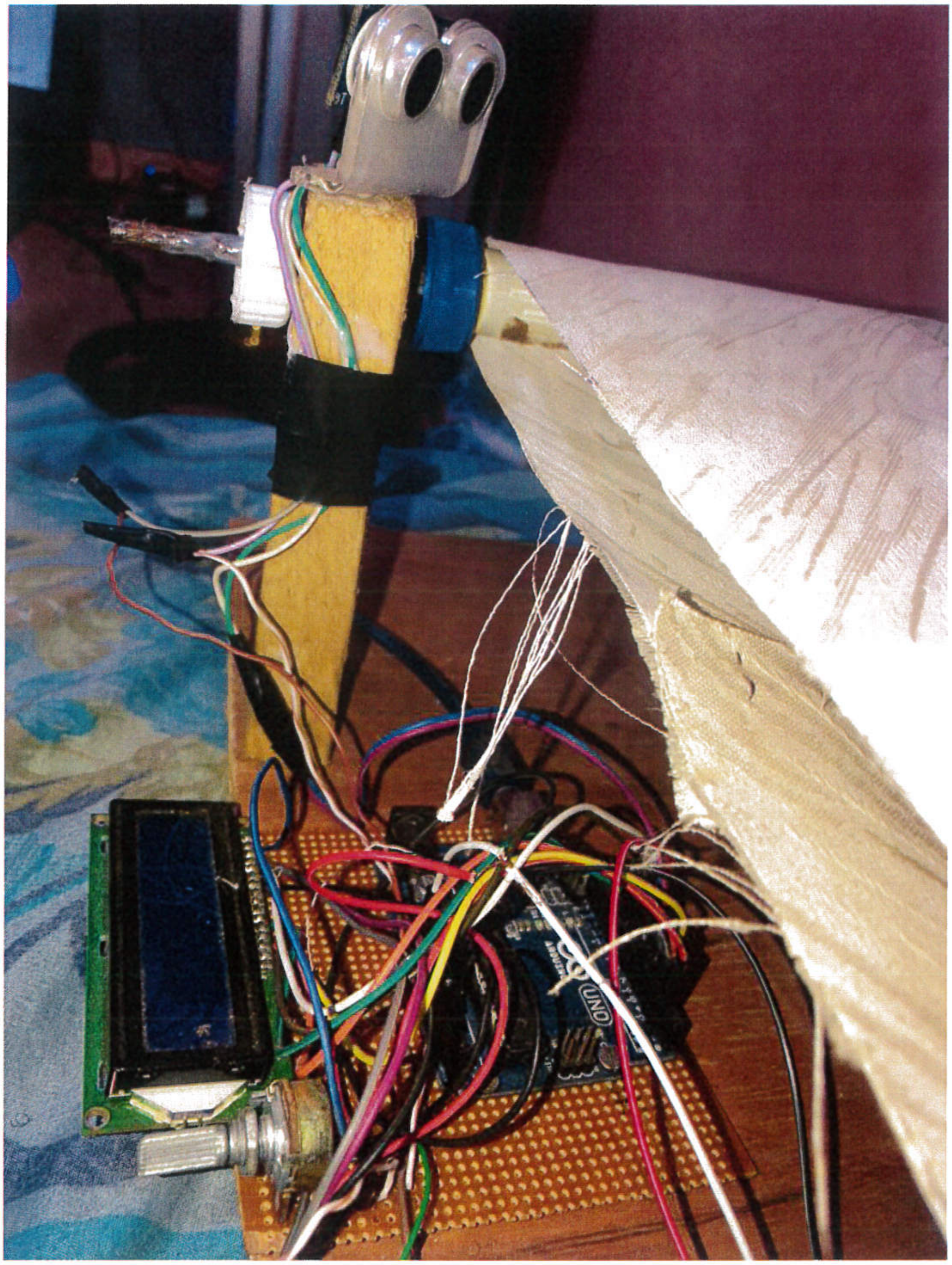


Figure 4.1: Component implementation on vero board.

4.4 Coupling of prototype components

After a successful components interconnection, the whole connection is tested to check whether or not it is in good working condition. If the connection performs the intended function, then there is need to couple the components together into a single entity. For this project, a wooden support is used and the components and units are screwed or nailed to the walls or glued as appropriate. The vero board which contains the LCD is placed on the right side of the base support while the batteries used to power the DC motor were placed on the opposite side of the already screwed veroboard. The ultrasonic sensor is mounted on the upper part of the right wall supporting the conveyor belt system while the DC motor along with the supplementary gears were screwed to the upper left wall of the belt conveyor system. A USB connector flows outwards for powering the microcontroller board. The Figure 4.2 shows the developed prototype of the automated counter system.

Figure 4.2: Hardware prototype of the automated counter system.

4.5 Hardware Testing

When different component parts that influence the efficiency of the system were tested, the results obtained were a bit different from design specifications.

4.5.1 Voltage of Adaptor

The adaptor used to power the DC motor requires nothing less than 12V to supply the DC motor with the necessary power needed to drive the gears that make the conveyor belt move. When batteries are used, they couldn't power the DC motor for a long time and get weakened after a short period of time. The voltage output of the adaptor used is between a range of 12V – 15V and that is just enough to make the DC motor work without damaging it.

4.5.2 Speed of Conveyor Belt

The speed of the conveyor belt is incredibly fast and would make the system effective for replacement of manual counting. Speed is defined as the distance travelled per unit time and is expressed mathematically as:

$$Speed = \frac{Distance}{Time} \qquad (4.1)$$

Speed is regarded as a scalar quantity and describes how fast an object is moving. The SI unit for speed is $\frac{m}{s}$ $(meters\ per\ second)$ (Jones, 2019).

For the conveyor belt, the length of the belt would be the distance travelled since it only moves about a fixed axis. The length of the belt when measured with a measuring tape is 1.164m and the time it takes the belt to revolve back to its starting point is 2.72s. Therefore, the speed of the conveyor belt is $0.428^{m}/_{s}$.

4.5.3 Distance Between Sensor and Item Detected

The distance specified in the program code for the items moving over the conveyor belt to be detected by the ultrasonic sensor is 10 inches away from the sensor. This means any item caught at that distance would be detected by the sensor and counted.

4.5.4 Timing of Gate

The movement of the gate is to be controlled by the servomotor and this determines how fast the gate can open and close so that it can strictly enforce the "one item at any time instant" rule. However, the time delay specified for the servomotor after opening the door is 2 seconds before closing the door again. But practically, the door waits for approximately 3.82 seconds before it closes again.

4.5.5 Delay Between Powering On

The DC motor begins to operate immediately its switch is powered on but it takes the Arduino board over 2 seconds to initialize all connected components before full operation begins. At this point, the LCD displays "TISSUE CONVEYOR AND COUNTER" on its screen.

4.6 System Operation

The algorithm implemented for performing automated counter system is shown below.

Step 1: Start.

Step 2: Input tissue into carriage.

Step 3: Input maximum count.

Step 4: Initialize and display LCD screen.

Step 5: Door opens and closes every 2 seconds.

Step 6: Tissue is transported via the conveyor.

Step 7: Is distance between tissue and ultrasonic sensor <= 10inches?

Step 7.1: If yes, counter increments by 1.

Step 7.2: Else, go to step 5.

Step 8: Is counter equal maximum count?

Step 8.1: If yes, set counter = 0 and reset LCD screen.

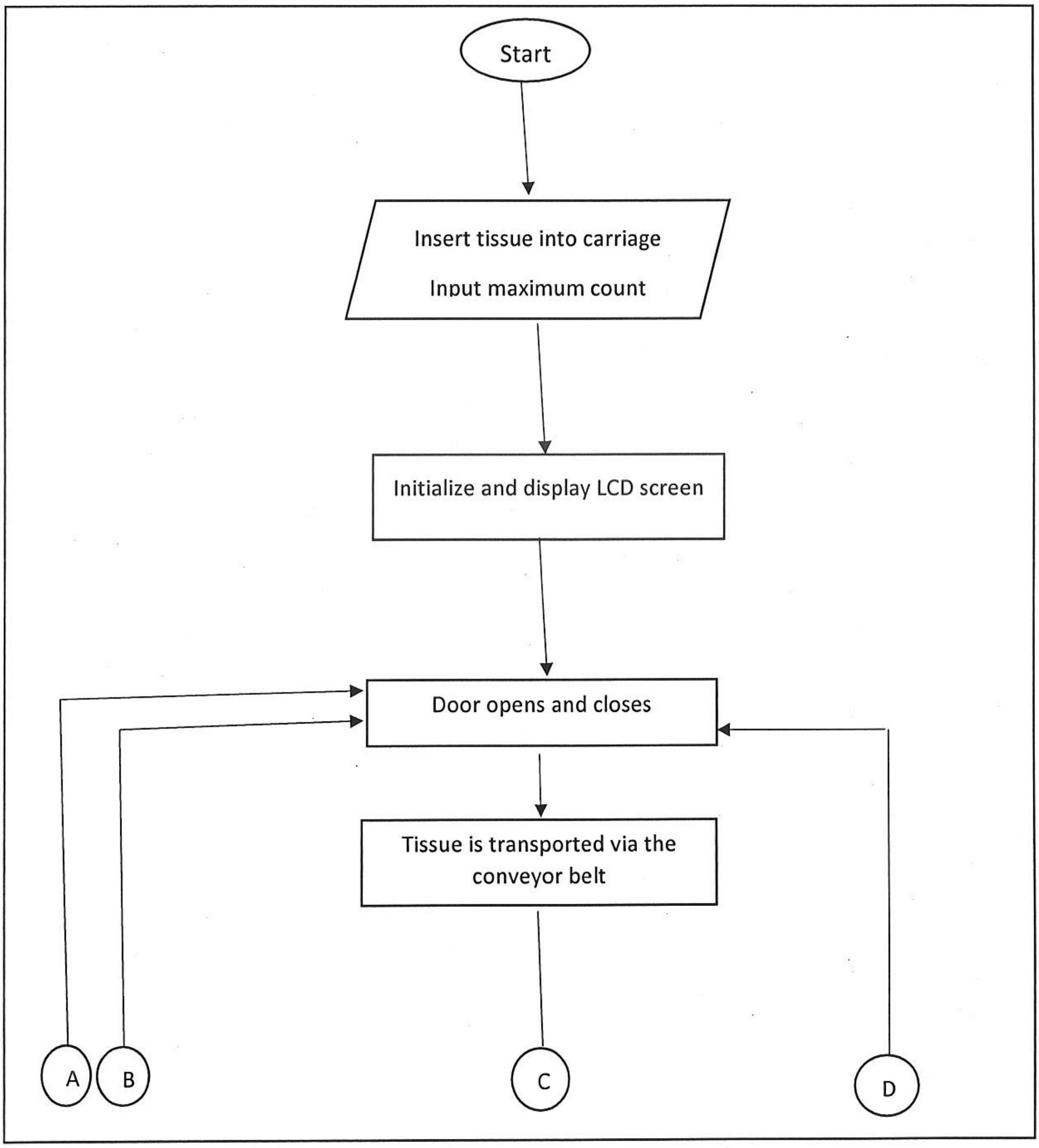
Step 8.2: Else, go to step 5.

Step 9: Is tissue carriage empty?

Step 9.1: If yes, end.

Step 9.2: Else, go to step 5.

The flowchart of the system operation is shown in Figure 4.3.



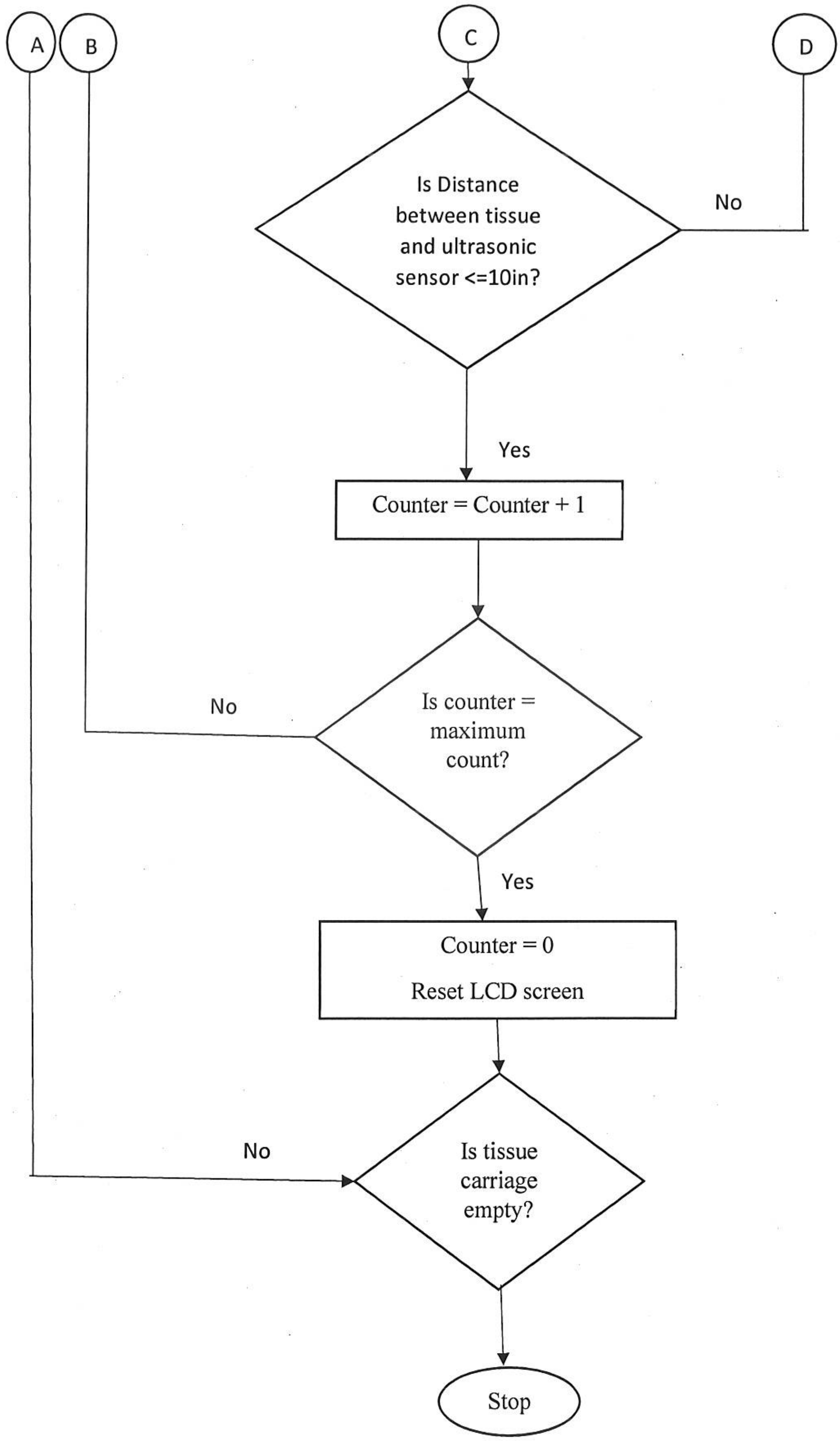


Figure 4.3: Flowchart of the automated counter system operation.

4.7 System Evaluation

In order to ensure that all the safety specifications and requirements are met, the performance of the system has been evaluated according to real life situations. The two major metrics that have been used are the Mean time between failure (MTBF) and Rate of occurrence of failure.

Errors are instances during program execution when the operation deviates from intended function. These errors are regarded as failure in this report and could come in form of:

i. Sensor not detecting the passage of an item.
ii. The door not opening for an item to go through.
iii. More than one item goes through the door before the door closes again.
iv. The sensor detecting more than one item passing through as one.

Below is a table which shows the number of errors encountered for a testing period of 15 minutes on a per-minute basis.

Table 4.1: Number of errors that occurred on a per-minute basis during testing.

Minute number	Number of errors that occured
1	3
2	1
3	2
4	0
5	1
6	4
7	2
8	0
9	0
10	4

11	2
12	1
13	0
14	0
15	2

From the table given above, the performance of the prototype can be evaluated using hardware performance metrics such as:

a. **Mean time between failure (MTBF)** – Mean value of the length of time between consecutive failures, given by:

$$MTBF = \frac{Total\ operational\ time}{Total\ number\ of\ failures} \quad (4.2)$$

MTBF measures the predicted time that passes between one previous failure of a mechanical/electrical system to the next failure during normal operation. (Christiansen, 2018). The system was observed for a span of 15 minutes and a total of 22 errors were counted. Applying the formula above gives the value of the mean time between failure in terms of hours/failure (where 15 minutes is equal to 0.25 hours) as 0.0114hours/failure.

b. **Rate of occurrence of failure** – Number of failures occurring in a unit time interval. Failure rate is given as the inverse of the MTBF.

This can simply be calculated as the inverse of MTBF.

i.e. ROCOF = $\frac{1}{MTBF}$ (4.3)

For this system developed, the rate of occurrence of failure = $\frac{1}{0.0114}$ = 87.72failures/hour.

Table 4.2: Results of the performance metrics.

Metric	Result
MTBF	0.0114hours/failure
ROCOF	87.72failures/hour

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In this project, an automated counter system for small and medium enterprises was developed and implemented using microcontroller. The microcontroller was used to control the opening and closing of the door guarding a physical boundary to control the number of items that can move onto the conveyor belt at any instant of time. The HC-SR04 ultrasonic sensor was used to detect the presence of an item within range, which causes the number of items counted, which is a value stored in the microcontroller memory to be increased and the current count value was displayed on the 16x2 LCD screen. The DC motor on the other hand was used to move the conveyor belt continuously such that any item that is dropped on it would be transported to the end of the belt and dropped off and this would continue for any item that moves onto the conveyor belt as long as the DC motor driving the conveyor belt is powered. The microcontroller used is the Arduino Uno board which is based on the ATMEGA 328p datasheet.

5.2 Challenges

There were a lot of challenges encountered while developing the hardware prototype. Some of them are:

i. Difficulty in selecting a suitable material for the conveyor belt.
ii. Getting gears that are strong enough to support the DC motor.
iii. Obtaining a DC (stepper) motor with enough power to drive the fabricated belt.
iv. Getting welded rods with enough thickness to support the conveyor belt frame.
v. Changing the material used for the gate structure continuously until the servomotor could move the gate with ease.
vi. Items coming out of the items dock in multiples rather than one after the other.

vii. Sensor detecting more than one item passing on the conveyor belt as a single item.

viii. Item not moving out of the dock freely enough and getting pinned by the closing door.

5.3 Recommendations

Although the aim of this project was achieved, however, some improvements are recommended. These are:

1. The project can be made more portable by designing a single power source that rectifies the input AC power to DC and regulates the voltage such that 5V can be supplied to the Arduino board and corresponding 12V to DC motor.
2. An input keypad can be incorporated to allow the system operator set the desired maximum count value.
3. A digital image processing algorithm with a camera for making sure items on the conveyor belt meets the company's production standard before it gets to the sensing range with a mechanical support to sweep substandard items off the belt.

REFERENCES

Anon. (2002). "Abacus middle ages, region of origin Middle East", The History of Computing Project. Retrieved from http://www.thocp.net/hardware/abacus.html on 23rd February, 2019.

Baygin, Mehmet., Karakose, Mehmet., Sarimaden, Alisan. and Akin, Erhan. (2018). An Image Processing based Object Counting Approach for Machine Vision Application. *International Conference on Advances and Innovations in Engineering (ICAIE)*. Retrieved from https://arxiv.org/abs/1802.05911 on 17th September, 2018.

Byres, Eric. (2011). "PLC Security Risk: Controller Operating Systems - Tofino Industrial Security Solution". Retrieved from http://www.tofinosecurity.com/blog/plc-security-risk-controller-operating-systems on 25th February, 2019.

Carlson, Jessica. (2013). William Schickard's calculating device: the calculating clock. Retrieved from http://howcalculatorgothere.tripod.com/id4.html on 23rd February, 2019.

Ceruzzi, Paul. (2012). Computing: A concise history. Cambridge, MA: MIT Press. p. 105.

Christiansen, Bryan. (2018). MTTR, MTBF or MTTF? – A simple guide to failure metrics. Retrieved from https://limblecmms.com/blog/mttr-mtbf-mttf-guide-to-failure-metrics/ on 7th December, 2018.

Clement, A.J. (1999). Microcomputer Supported Chips Incorporated with Coding and Decoding. Prentice Hall.

Clement, Alan. (2006). The Principle of Computer Hardware. Oxford University Press.

Component101. (2018). Arduino Uno. Retrieved from https://components101.com/microcontrollers/arduino-uno on 26th February, 2019.

Cooray, Thilan., Fernando, Shehan. (2011). Visual-based automatic coin counting system. *SAITM Research Symposium on Engineering Advancements (SAITM – RSEA 2011).*

Cox, Simon. (2017). "Worries about premature industrialisation". The Economist. Retrieved from https://www.economist.com/special-report/2017/10/05/worries-about-premature-industrialisation on 23rd February, 2019.

Crisp, John. (2000). Introduction to Digital Systems. Newnes: Burlington, MA.

Dill, Margo. (2017). "How does adding machine work?" Retrieved from https://sciencing.com/adding-machine-work-4599934.html on 23rd February, 2019.

Electrical Technology. (2015). "What is Industrial Automation | Types of Industrial Automation". Retrieved from https://www.electricaltechnology.org/2015/09/what-is-industrial-automation.html on 28th March, 2018.

Farhat, Hassan A. (2004). Digital Design and Computer Organization. CRC Press.

Fehrman, Craig. (2017). Why do we count. Retrieved from https://fivethirtyeight.com/features/why-do-we-count/ on 25th February, 2019.

Fernandes, Luis. (2003). A brief history of the Abacus. Retrieved from https://web.archive.org/web/20080116044411/http://www.ee.ryerson.ca:8080/~elf/abacus/history.html on 14th April, 2018.

Ferro, Swedin Eric., David L. (2005). "Computers: The Life Story of a Technology". Santa Barbara, CA: Greenwood.

Fitzsimmons, Gerry. (2006). "Electromechanical Vs. Digital Control Systems; Decoding the differences". Retrieved from http://www.cimcorefrigeration.com/pdf/Electro-Mechanical%20vs.%20DDC%20Systems.pdf on 17th June, 2018.

Floyd, Thomas L. (2015). Digital Fundamentals (11th ed.). Published by Pearson Education. ISBN 978-0-13-273796-8.

Forene, Otomewo. (2012). Design and Construction of a microcontroller-based object counting machine. Unpublished Undergraduate Project. Ladoke Akintola University of Technology.

Garner, Joseph E., Lee, Clyde E., and Huang, Liren. (1990). Infrared sensors for counting, classifying, and weighing vehicles. *Center for Transportation Research.* The University of Texas, Austin, Texas.

Guarnieri, M. (2014). "Electricity in the age of Enlightenment". *IEEE Industrial Electronics Magazine.*

Hamann, C. (2015). Resulta – BS9. Retrieved from http://public.beuth-hochschule.de/hamann/workshop/resulta/res-bs9.html on 23rd February, 2019.

Harris, David. and Harris, Sarah. (2012). Digital Design and Computer Architecture (Second edition) p. 515.

Hussain, Arbaz. (2017). Distance calculation with ultrasonic sensor. Retrieved from https://hackster.io/arbazhussain/distance-calculation-with-ultrasonic-sensor-26d63e on 12th April, 2018.

Iqbal, S. (2008). "Programmable Logic Controllers (PLCs): Workhorse of Industrial Automation". 68-69. *Institution of Electrical and Electronics Engineers (IEEEP).* pg. 27–31.

Itsadatikom, N. and Srinonchat, J. (2015). Enhancement Machine Vision for Object Counter. *International Journal of Electronics and Electrical Engineering.* Vol. 3, No. 6, December 2015.

Jones, Andrew Zimmerman. (2019). Definition of speed in physics. Retrieved from https://www.thoughtco.com/speed-2699009 on 27th February, 2019.

Khan, Nasif Hassan., Sarkar, Deb Kumar., Siddique, Asif., Rahman, Mamunur. and Chakraborty, Swarup. (2017). Fabrication of a Conveyor Belt with Object Sorting and Counting Facility.

Kretschmar, M. and Welsby, S. (2005). Capacitive and Inductive Displacement Sensors. *Sensor Technology Handbook.* J. Wilson editor, Newnes: Burlington, MA.

Kushagra. (2012). LCD. Retrieved from https://www.engineersgarage.com/electronic-components/16x2-lcd-module-datasheet on 17th July, 2018.

Lefloch, D., Cheikh, F.A, Hardeberg, J.Y, Gouton, P., Picot-Clemente, R. (2008). Real-time people counting system using a single video camera. *The International Society for Optical Engineering (Vol. 6811).* Bellingham, Washington: SPIE.

Lévénez, Éric. (2011). "Computer Languages History". Retrieved from http://www.levenez.com/lang/ on 13th September, 2018.

Lodewijks, G. (2011), The Next Generation Low Loss Conveyor Belts. *The Beltcon 16 conference, Johannesburg, Republic of South Africa.*

Lowe, Richard. (2004). Computer and Internet history. Retrieved from https://web.archive.org/web/20080512010449/http://www.webmythology.com/COMPUTERHISTORY_L1800.htm on 17th June, 2018.

Muehlhauser, Luke. (2015). Intelligence Explosion FAQ. Retrieved from https://intelligence.org/ie-faq/#WhenWillTheSingularity on 25th February, 2019.

Ni, Jianjun., Khan, Zubair., Wang, Shihao., Wang, Kang. and Haider, Syed Kamran. (2016). Automatic detection and counting of circular shaped overlapped objects using circular Hough transform and Contour detection. *12th World Congress on Intelligent Control and Automation (WCICA).*

Okomba, N., Adeyanju, I., Adeleye, O., Omodunbi, B., and Okwor, C. (2015). Prototyping of an Arduino Micro-Controlled Digital Display System. *African Journal of Computing & ICT Vol 8. No. 1 Issue 2.*

Okomba, Nnamdi S., Okwor, Candidus O., Adeyanju, Ibrahim A., and Ezea, Hilary. (2017). Design of an Automatic Window Using a PIC Microcontroller and Stepper Motor. *FUOYE Journal of Engineering and Technology Vol. 2, Issue 2.*

Oyesola, Bimbola. (2017). Tissue paper production guarantees stable cash flow. Retrieved from sunnewsonline.com/tissue-paper-production-guarantees-stable-cash-flow/ on 17th July, 2018.

Rafiquzzaman, Mohamed. (2014). Introduction to Digital Systems - Fundamentals of Digital logic and microcontrollers (6th edition).

Rai, Praveen Kumar. (2017). Overview on the Object Rejection and Counting Machine. *ELK Asia Pacific Journals – 978-93-85537-06-6ARIMPIE -2017.*

Ramey, Karehka. (2013). What is Technology – Meaning of Technology and its use. Retrieved from https://www.useoftechnology.com/what-is-technology/ on 23rd February, 2019.

Ravi. (2017). Different types of sensors. Retrieved from https://www.electronicshub.org/different-types-sensors/ on 26th February, 2019.

Reddy Naveen K., Srikanth K., Teja Mohan B. (2017). Digital Visitor counter using 8051 Microcontroller (AT89C51). Unpublished Undergraduate Project. Nalla Narasimha Reddy Group of Institutions Integrated Campus.

Renard, Guy. (2004). Pre 1800. Retrieved from https://web.archive.org/web/20080512010449/http://www.webmythology.com/COMPUTERHISTORY_L1800.htm on 25th February, 2019.

Robinson, Adam. (2014). Industrial Automation: A Brief History of Manufacturing Application & The Current State and Future Outlook. Retrieved from http://cerasis.com/2014/10/22/industrial-automation/ on 14th April, 2018.

Roth, C.R. (2009). Fundamentals of Logic Design. Control Engineering, 3:41-47.

Rouse, Margaret. (2015). Microcomputer Definition. Retrieved from http://internetofthingsagenda.techtarget.com/definition/microcomputer on 2nd April, 2018.

Rouse, Margaret. (2017). Microcontroller. Retrieved from https://internetofthingsagenda.techtarget.com/definition/microcontroller on 2nd April, 2018.

Rutzler, Sarah. (2017). What is the abacus. Retrieved from https://www.mathgenie.com/blog/what-is-the-abacus on 23rd February, 2019.

Samuel, Diarah Reuben., Dickson, Egbune O., Aaron, Adedayo Banji. (2014). Design and implementation of a microcontroller based automatic door and visitors counter. *International Journal of Scientific Research and Education. IJSRE Volume 2 Issue 3.*

Santos, Rui. (2013). Complete Guide for Ultrasonic Sensor HC-SR04 with Arduino. Retrieved from https://randomnerdtutorials.com/complete-guide-for-ultrasonic-sensor-hc-sr04/ on 8th August, 2018.

Schultz, Thomas. (2004). C and the 8051 (3rd ed.). Otsego, MI: PageFree Publishing Inc. p. 20.

Singh, Arun Kumar. (2006). Digital Principles Foundation of Circuit Design and Application. New Age Publishers.

Stengal, Robert F. (1994). Open and Close Loop System. Longman Press, 4:72-77.

Swaine, Michael R, Freiberger, Paul A. (2008). Calculating clock. Retrieved from https://www.britannica.com/technology/Calculating-Clock on 13th April, 2018.

Telepatil, Avadhoot R. and Jadhav, Prashant M. (2015). Colour object counting and sorting mechanism using image processing approach. *International Journal of Modern Trends in Engineering and Research. Vol. 2, Issue 3.*

Tocci, Ronald. (1994). Digital System: Principle and Application. Mira publishing 8:182-194

Weeks, Chris. (2010). "Counting Boards - A Very Brief History of Counting Boards", Convergence. Retrieved from https://www.maa.org/press/periodicals/convergence/counting-boards-a-very-brief-history-of-counting-boards on 23rd February, 2019.

Widyanto, M. Rahmat, Ferandi Ferdi., Tangel, Martin Leonard. (2010). A visitor counter system using Fuzzy measure theory and boosting method.

Wokoma, Chiemela U. (2011). "The effects of industrial conflicts and strikes in Nigeria: A socio-economic analysis". *International Journal of Development and Management Review (INJODEMAR) Vol. 6.*

Younkin, G. W. (2007). Industrial Servo Control Systems – Fundamentals and Applications (Second edition).

APPENDIX A

PROGRAM CODE FOR THE AUTOMATED COUNTER SYSTEM

The program code incorporated as the software aspect of this project is written using the Arduino IDE and the code for successful implementation is found below.

```
#include <LiquidCrystal.h>
#include <Servo.h>

LiquidCrystal lcd(12,11,5,4,3,2); // creates an obeject to access the LCD library

Servo servo;//creates an obeject to access the servo library
//Defines the pin for the ultrasonic sensor
#define trigPin 6
#define echoPin 7

//Counting process
int counter = 0; //Stores the count state
int currentState = 0; //Initially the current state is zero
int previousState = 0; //Initially previous state is zero as well
boolean servo_state = true;

int countValue = 12; //Maximum count value, can be changed by the operator

void setup() {
 // put your setup code here, to run once:
```

```
Serial.begin(9600); //Begins the serial monitor
lcd.begin(16,2); //Begins the lcd screen
servo.attach(9); // Sets the servo pin

lcd.setCursor(0,0);
lcd.print("TISSUE CONVEYOR");
lcd.setCursor(0,1);
lcd.print("AND COUNTER");

delay(2000);
lcd.clear();
pinMode(trigPin, OUTPUT);
pinMode(echoPin, INPUT);

servo.write(150); // OPEN THE DOOR
delay(2000);
servo.write(55);// CLOSE THE DOOR

}

void loop() {
```

```
 // put your main code here, to run repeatedly:
 long duration ,cm,in;
//Sets up the ultrasonic sensor for receiving and sending signals
 digitalWrite(trigPin,LOW);
 delayMicroseconds(2);
 digitalWrite(trigPin,HIGH);
 delayMicroseconds(10);
 digitalWrite(trigPin,LOW);

 duration = pulseIn(echoPin,HIGH); // STORES ANY SOUND CAUGHT IN DURATION


//convert time to distance
cm = microsecondsToCentimeters(duration);
in = microsecondsToInches(duration);
Serial.print("distance: ");
Serial.println(in);
 if(in <= 10){
  currentState = 1;
  }
 else{
  currentState = 0;
  }
 delay(100);
```

```
}

if (currentState != previousState){ //PreviousState is always false so when current state doesn't equal prev state, then it runs this block of code

    if(currentState == 1){

     counter = counter + 1;

     Serial.print("Counter: ");

     Serial.println(counter);

     lcd.setCursor(0,0); //set the lcd cursor to the 1st row and 1st column

     lcd.print("Counter: ");

     lcd.print(counter);



     servo.write(150); // OPEN THE DOOR

     delay(2000);

     servo.write(55);// CLOSE THE DOOR


//It ends here

    if(counter == countValue){

     counter = 0;

     lcd.clear();

      }

     }


  }


}
```

```
long microsecondsToCentimeters(long microseconds){ // converts from time to dist
  return (microseconds/2)/29.1;
 }
long microsecondsToInches(long microseconds) {
 return microseconds / 74 / 2;
}
```

APPENDIX B

BILL OF ENGINEERING MEASUREMENT AND EVALUATION (BEME)

For the complete development of the microcontroller-based automated counter system prototype, the items used are highlighted in the Table A below:

Table B.1: BEME for the entire automated counter system prototype

S/N	ITEM	QTY	RATE (IN NAIRA)	AMOUNT (IN NAIRA)
1	Arduino Uno board	1	4,000.00	4,000.00
2	Servomotor	1	2,500.00	2,500.00
3	Jumper wires	40	20.00	800.00
4	DC (Stepper) motor	1	5,200.00	5,200.00
5	Ultrasonic sensor	1	1,500.00	1,500.00
6	Ultrasonic sensor holder	1	500.00	500.00
7	LCD	1	2000.00	2000.00
8	Potentiometer	1	200.00	200.00
9	12V DC adaptor	1	2,500.00	2,500.00
10	Breadboard	1	1000.00	1000.00
11	Soldering led and soldering iron		3,000.00	3,000.00
12	Conveyor belt and wooden frame		10,000.00	10,000.00
13	Vero board	1	500.00	1000.00
14	Power bank	1	5,000.00	5,000.00
	TOTAL			**39,200.00**