Sudan University of Sciences and Technology
College of Engineering
Electrical Engineering

Design and Implementation Rubbish Separation Control System

تصميم وتنفيذ نظام التحكم في فصل النفاياتِ

A Project Submitted in Partial Fulfillment for the Requirements of the degree of B.Sc. (Honor) In Electrical Engineering (Control)

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الآيـة

قال تعالى :

(اللّهُ لاَ إِلَـهَ إِلاَّ هُوَ الْحَيُّ الْقَيُّومُ لاَ تَأْخُذُهُ سِنَةٌ وَلاَ نَوْمٌ لَّهُ مَا فِي السَّمَاوَاتِ وَمَا فِي الأَرْضِ مَن ذَا الَّذِي يَشْفَعُ عِنْدَهُ إِلاَّ بِإِذْنِهِ يَعْلَمُ مَا بَيْنَ أَيْدِيهِمْ وَمَا خَلْفَهُمْ وَلاَ يُحِيطُونَ بِشَيْءٍ مِّنْ عِلْمِهِ إِلاَّ بِمَا شَاء وَسِعَ كُرْسِيُّهُ السَّمَاوَاتِ وَالأَرْضَ وَلاَ يَؤُودُهُ حِفْظُهُمَا وَهُوَ الْعَلِيُّ الْعَظِيمُ).

[البقرة :255]

DEDICATION

Every challenging work needs self efforts as well as guidance of elders especially those who were very close to our hearts. Our humble effort is dedicated to our sweet and loving parents, our brothers, our sisters and our friends whose affection, love, encouragement and prays in days and nights make us able to get such success and honor. Without their love and support this project would have never been made possible.

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ABSTRACT

Traditional rubbish separation systems requires a lot of time and effort with low efficiency and cost-effective because of its reliance on the human element.

The main objective of this project is to develop the traditional system to an automatic control system for the process of sorting can separate the rubbish in different categories to make the sorting process easier and more efficient.

The methodology used in this study is to use of an electromechanical system consisting of microcontroller and sensor devices controls a set of barriers depending on the signals received from the sensors.

مستخلص

الأنظمة التقليدية لفصل النفايات تتطلب كثيرا من الوقت والجهد وتكون منخفضة الكفاءة وعالية التكلفة بسبب إعتمادها علي العنصر البشري.

الهدف الأساسي من هذا المشروع هو تطوير النظام التقليدي الي نظام تحكم آلي لعملية الفرز يمكنه فصل النفايات في فئاتها المختلفة لجعل عملية الفرز أسهل وذات كفاءة عالية.

المنهجية المتبعة في هذه الدراسة هي إستخدام نظام كهروميكانيكي يتكون من متحكم دقيق وأجهزة إستشعار يتحكم في مجموعة من الحواجز إعتمادا علي الإشارات المستقبلة من أجهزة الإستشعار.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF ABREVIATIONS

MEMS	Micro Electro Mechanical System
ADC	Analog to Digital Converter
DAC	Digital to Analog Converter
SFR	Special Function Register
PC	Personal Computer
RAM	Random Access Memory
ROM	Read Only Memory
EEPROM	Electrically Erasable Programmable Read Only Memory
CPU	Central Processer Unit
USB	Universal Serial Bus
LED	Light Emitting Diodes
PWM	Pulse Width Modulation
AC	Alternating Current
DC	Direct Current

CHAPTER ONE

INTRODUCTION

1.1 General

Rubbish sorting is the process by which rubbish is separated into different elements. Rubbish separating can occur manually at the household and collected through curbside collection schemes, or automatically separated in materials recovered facilities. Hand separating was the first method used in the history of rubbish separating. Rubbish is of commercial and industrial importance, especially since natural resources are constantly decreasing and their prices are constantly rising, and rubbish can be used instead of disposed of. Municipal rubbish utilization programs should there fore be incorporated into development plans and should be used as a natural source for low-cost industries. These programs are to find sorting methods for rubbish recycling. Recycling reduces the dependence of plants on natural materials as raw materials for their products, there by reducing the depletion of these natural materials. Environmental and economic benefits of rubbish recycling include reducing environmental pollution as a result of rubbish disposal by burying or burning, reducing dependence on raw material imports, providing new industrial opportunities for capitalists, creating new employment opportunities and saving energy. The most important industries depend on household rubbish; paper, glass, iron, aluminum, plastics and wood. The screening process is essential in recovering recyclable and recyclable materials from solid household rubbish. The most important materials that can be separated from the source are paper, glass, plastics and metal. The separation process is usually carried out at the rubbish sorting plant, where the blended rubbish is sorted before each material is sent to production plants for glass, paper and metal [1].

1.2 Problem Statement

Domestic rubbish collection, separating and disposal are major problems in many developing countries such as Sudan. The Rubbish sorting in traditional systems needs a lot of time and effort with low efficiency and cost-effective because of its reliance on the human element.

1.3 Objectives

The main objectives of the project are:

- Design of rubbish separation system using microcontroller.
- Implementation of rubbish separation system using microcontroller.
- Developing the traditional separation system into automatic separation system.

1.4 Methodology

- Design modeling for Rubbish separate control system
- Using system software (Protous simulation) to achieve the separation system response.

1.5 Layout

This study consists of five chapters; **Chapter One** gives an introduction, problem statement, Objectives, methodology and layout. **Chapter Two** discusses system overview and theoretical background of control systems, microcontroller, servo and DC motors, and sensors. **Chapter Three** presents the system hardware and software and system description. **Chapter Four** deals with system implementation fabrication and testing. Finally, **Chapter five** provides the conclusions and recommendations.

CHAPTER TWO
THEORETICAL BACKGROUND AND LITERATURE REVIEW

2.1 System Overview

The rubbish separeation system consists of a belt that is rubbish placed on it, and the belt was curled on two shafts, one of which is connected to the motor and the other is free movement. On one side the sensors were installed and on the other side the servo motors were installed. When the belt is run the rubbish passes in front of the sensors where each sensor detects a certain type of material, when the sensor detects the material, it sends a signal to the Arduino which it sends a signal to the servo motor, under which it moves a barrier at a certain angle to place the material in the assigned place.

2.2 Control System

In our daily lives there are numerous "objectives" that need to be accomplished. For instance, in the domestic domain, we need to regulate the temperature and humidity of homes and buildings for comfortable living. For transportation, the automobile and airplane were needed to control to go from one point to another accurately and safely. Industrially, manufacturing processes contain numerous objectives for products that will satisfy the precision and cost effectiveness requirements [2].

In recent years, control systems have assumed an increasingly important role in the development and advancement of modern civilization and technology. Practically every aspect of our day-to-day activities is affected by some type of control system. Control systems are found in abundance in all sectors of industry, such as quality control of manufactured products, automatic assembly lines, machine-tool control, space technology and weapon systems, computer control, transportation systems, power systems, robotics, MEMS, nanotechnology, and many others. Even the control of inventory and social and economic systems may be approached from the theory of automatic control. Since advances in the theory and practice of automatic control provide the means for attaining optimal performance of dynamic systems, improving productivity, relieving the drudgery of many routine repetitive manual operations, and more, most engineers and scientists must now have a good understanding of this field [2,3].

2.2.1 Advantages of control system

With control systems large equipment can be moved with precision that would otherwise be impossible. Huge antennas can be pointed toward the farthest reaches of the universe to pick up faint radio signal controlling these antennas by hand would be impossible. Because of control systems, elevators carry us quickly to our destination, automatically stopping at the right floor. The load and the speed could not provide by required power with alone; Motors provide the power, and control systems regulate the position and speed [3].

2.2.2 Historical review

The first significant work in automatic control was James Watt's centrifugal governor for the speed control of a steam engine in the eighteenth century. Other significant works in the early stages of development of control theory were due to Minor sky, Hazen and Nyquist among many others. In 1922, Minor sky worked on automatic controllers for steering ships and showed how stability could be determined from the differential equations describing the system.

In 1932 Nyquist developed a relatively simple procedure for determining the stability of closed-loop systems on the basis of open-loop response to steady state sinusoidal inputs. A significant date in the history of automatic feedback control systems is 1934, when Hazen’s paper ‘‘Theory of Servomechanisms’’ was published in the Journal of the Franklin Institute, marking the beginning of the very intense interest in this new field. It was in this paper that the word servomechanism originated, from the words servant (or slave) and mechanism. Black's important paper on feedback amplifiers appeared in the same year. After World War II, control theory was studied intensively and applications have proliferated many books and thousands of articles and technical papers have been written, and the application of control systems in the industrial and military fields has been extensive. This rapid growth of feedback control systems was accelerated by the equally rapid development and widespread use of computers. During the decade of the 1940 frequency response methods (especially the Bode diagram methods due to Bode) made it possible for engineers to design linear closed loop control systems that satisfied performance requirements. From the end of the 1940 to the early 1950 the root-locus method due to Evans was fully developed. The frequency response and root locus methods, which are the core of classical control theory, lead to systems that are stable and satisfy a set of more or less arbitrary performance requirements. Such systems are, in general, acceptable but not optimal in any meaningful sense. Classical control theory, which deals only with single input single output systems, becomes powerless for multiple input multiple output systems. Since about 1960, because the availability of digital computers made possible time domain analysis of complex systems, modern control theory, based on time domain analysis and synthesis using state variables, has been developed to cope with the increased complexity of modern plants and the stringent requirements on accuracy, weight, cost in military, space and industrial applications [3].

2.2.3 Open loop control system

Those systems in which the output has no effect on the control action are called open-loop control systems. In other words, in an open-loop control system the output is neither measured nor feedback for comparison with the input.

One practical example is a washing machine. Soaking, washing, and rinsing in the washer operate on a time basis. The machine does not measure the output signal, that is, the cleanliness of the clothes. In any open-loop control system the output is not compared with the reference input. Thus, to each reference input there corresponds a fixed operating condition; as a result, the accuracy of the system depends on calibration. In the presence of disturbances, an open-loop control system will not perform the desired task. Open-loop control can be used, in practice, only if the relationship between the input and output is known and if there are neither internal nor external disturbances. Clearly, such systems are not feedback control systems. Note that any control system that operates on a time basis is open loop. For instance, traffic control by means of signals operated on a time basis is another [3].

2.2.4 Closed-loop control systems

A system that maintains a prescribed relationship between the output and the reference input by comparing them and using the difference as a means of control is called a closed-loop control system. An example would be a room temperature control system. By measuring the actual room temperature and comparing it with the reference temperature, the thermostat turns the heating or cooling equipment on or off in such a way as to ensure that the room temperature remains at a comfortable level regardless of outside conditions. In a closed-loop control system the actuating error signal, which is the difference between the input signal and the feedback signal (which may be the output signal itself or a function of the output signal and its derivatives and/or integrals), is feedback to the controller so as to reduce the error and bring the output of the system to a desired value. The term closed-loop control always simplifies the use of feedback control action in order to reduce system error [3].

2.3 Nonlinear Systems

A system is nonlinear if the principle of superposition does not apply. Thus, for a nonlinear system the response to two inputs cannot be calculated by treating one input at a time and adding the results. Although many physical relationships are often represented by linear equations, in most cases actual relationships are not quite linear. In fact, a careful study of physical systems reveals that even so called "linear systems" are really linear only in limited operating ranges. In practice, many electromechanical systems, hydraulic systems, pneumatic systems, and so on, involve nonlinear relationships among the variables. For example, the output of a component may saturate for large input signals. There may be a dead space that affects small signals. (The dead space of a component is a small range of input variations to which the component is insensitive). Square-law nonlinearity may occur in some components. For instance, dampers used in physical systems may be linear for low-velocity operations but may become nonlinear at high velocities, and the damping force may become proportional to the square of the operating velocity. In control engineering a normal operation of the system may be around an equilibrium point, and the signals may be considered small signals around the equilibrium. (It should be pointed out that there are many exceptions to such a case). However, if the system operates around an equilibrium point and if the signals involved are small signals, then it is possible to approximate the nonlinear system by a linear system. Such a linear system is equivalent to the nonlinear system considered within a limited operating range. Such a linearized model (Linear Time-Invariant model) is very important in control engineering.

The linearization procedure to be presented in the following is based on the expansion of nonlinear function into a Taylor series about the operating point and the retention of only the linear term. Because of neglecting higher order terms of Taylor series expansion, these neglected terms must be small enough; that is, the variables deviate only slightly from the operating condition [2, 3].

2.4 Microcontroller

Microcontrollers are single-chip microcomputers, more suited for control and automation of machines and process. Microcontrollers have CPU, memory, input/output ports (I/O), timers and counters, ADC, DAC, serial ports, interrupt logic, oscillator circuitry and many more functional blocks on chip. Figure 2.1 shows a general functional blocks diagram of a microcontroller. Note that there may be variations in the functional blocks from device to device and from on manufacturer to another. All these functional blocks on a single integrated circuit (IC), results into a reduced size of control board, low power consumption, more reliability and ease of integration within an applications design. The usage of microcontrollers not only reduces the cost of automation, but also provides more flexibility. The designer is little bit relieved from the complex interfacing of external peripherals like ADC/DACs, etc. and can concentrate on applications and development aspects. The device can be programmed to make the system intelligent. This is possible because of the data processing and memory capability of microcontrollers. Microcontrollers have all the functional blocks which can fulfill the general needs of automations just to get an idea about the use of microcontrollers [4].

Although, there are many microcontrollers and even more programs available for microcontrollers, but most of them have most things in common. Thus if we able to learn any one of them then we can handle others also. Microcontroller is very fast device (slower than computer), so every instruction executed in Microcontroller at very fast speed. Its functioning is: When the power supply is turned ON, the quartz oscillator being enabled by Control Logic Register. In the first few milliseconds, while the first preparations are in progress, the parasite capacitors are being charged. When the Voltage level reaches its max value and frequency of quartz oscillator becomes stable, the process of writing bits on SFRs started. Everything occurs according to the clock of the oscillator and over all electronics starts working. All this takes very few Nano seconds. Program counter is reset to zero address of the program memory. Then the address of the instructions sent to Instruction Decoder which decodes the instructions and thus executes them. After execution of one instruction, the address of program counter is incremented by 1 and thus sending the address of next instruction to instruction decoder and executes the next instructions.

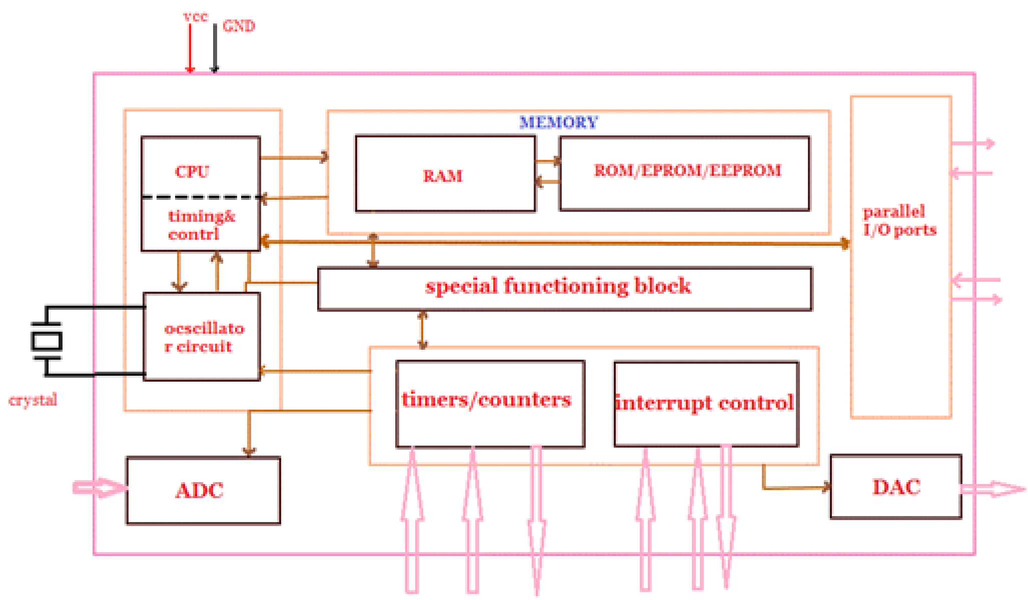

Figure 2.1: Microcontroller block diagram

2.4.1 History of microcontroller

The first computer system on a chip optimized for control applications was the Intel 8048 microcontroller with both RAM and ROM on the same chip. Most microcontrollers at that time had two variants; one had an erasable EEPROM variant which was only programmable once. The introduction of EEPROM memory allowed microcontrollers (beginning with the Microship PIC16x84) to be electically erased quickly without an expensive package as required for EPROM. Other companies rapidly followed suit, with both memory types. Now a days microcontrollers are low cost and readily available for hoppyists, with large online communits around certain processors.

2.4.2 Types of microcontrollers

The microcontrollers are divided categories according to their bits, memory, instruction sets and architecture Microcontrollers:

i) Bits

- 8-bits microcontroller executes logic & arithmetic operations. Examples of 8-bits micro controller is Intel 8031/8051.
- 16-bits microcontroller executes with greater accuracy and performance in contrast to 8-bit. Example of 16-bit microcontroller is Intel 8096.
- 32-bits microcontroller is employed mainly in automatically controlled appliances such as office machines, implantable medical appliances, etc. It requires 32-bit instructions to carry out any logical or arithmetic function.

ii) Memory

- External memory microcontroller: When an embedded structure is built with a microcontroller which does not comprise of all the functioning blocks existing on a chip it is named as external memory microcontroller. For illustration- 8031 microcontroller does not have program memory on the chip.
- Embedded memory microcontroller: When an embedded structure is built with a microcontroller which comprise of all the functioning blocks existing on a chip it is named as embedded memory microcontroller. For illustration- 8051 microcontroller has all program and data memory, counters and timers, interrupts, I/O ports and therefore its embedded memory microcontroller [5].

iii) Instruction

Depending on operation they perform, all instructions are divided in several groups:

- Arithmetic Instructions
- Branch Instructions
- Data Transfer Instructions
- Logic Instructions
- Bit-oriented Instructions

iv) Architecture

On the basis of architecture the types of microcontroller are:

- Havard Architecture: In Havard architecture separate storage and signal buses are provided for different set of instructions and data. This architecture has the entire data storage within the CPU and there is no access available for instruction storage as data. This architecture provides simultaneous access to an instructions and data stored inside internal buses of microcontroller.
- Von Neumann Architecture: This architecture of microcontroller was proposed by scientist John Von Neumann. In this architecture for both instruction and data a single data path or bus is present. Therefore the CPU performs a single operation at a time. It either performs read/write operation on data, or fetches a set of instruction from memory. Hence instruction fetch and a data transfer operation cannot occur simultaneously by using a common bus [6].

2.4.3 Microcontroller applications

Microcontrollers are intended for embedded devices, in comparison to the micro-processors which are used in PCs or other all-purpose devices. Microcontrollers are employed in automatically managed inventions and appliances like- power tools, implantable medical devices, automobile engine control systems, office machines, remote controls appliances, toys and many more embedded systems. By dipping the size and expenditure in comparison to a design that make use of a different micro-processor, I/O devices and memory, microcontrollers formulate it inexpensive to digitally control more and more appliances and operations. Mixed signal microcontrollers are general; putting together analog constituents required controlling non-digital electronic structures.

A) Application of microcontroller in day to day life devices:

- Light sensing and controlling devices.
- Temperature sensing and controlling devices.
- Fire detection and safety devices.
- Industrial instrumentation devices.
- Process control devices.

B) Application of microcontroller in industrial control devices:

- Industrial instrumentation devices.
- Process control devices.

c) Application of microcontroller in metering and measurement devices:

- Volt Meter.
- Measuring revolving objects.
- Current meter.
- Hand-held metering systems.

2.4.4 Arduino board

Arduino is a small microcontroller board with a USB plug to connect to the computer and a number of connection sockets that can be wired up to external electronics, such as motors, relays, light sensors, laser diodes, loudspeakers, microphones, etc. Arduino can either be powered through the

USB connection from the computer or from a 9V battery. Arduino can be controlled from the computer or programmed by the computer and then disconnected and allowed to work independently. The Arduino board it is an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software. It's intended for artists, designers, hobbyists, and anyone interested in creating interactive objects or environments in simple terms, the Arduino is a tiny computer system that can be programmed with instructions to interact with various forms of input and output. The current Arduino board model, the Uno, is quite small in size compared to the average human hand, as shown in Figure 2.2.

Figure 2.2: Arduino microcontroller board

Although it might not look like much to the new observer, the Arduino system allows creating devices that can interact with the world. By using an almost unlimited range of input and output devices, sensors, indicators, displays, motors, and more, the exact interactions required to create a functional device can be programmed. For example, artists have created installations with patterns of blinking lights that respond to the movements of passers-by, high school students have built autonomous robots that can detect an open flame and extinguish it, and geographers have designed systems that monitor temperature and humidity and transmit this data back to their offices via text message. In fact, there are infinite numbers of examples with a quick search on the Internet. By taking a quick tour of the Uno Starting at the left side of the board there are two connectors, as shown in Figure 2.3.

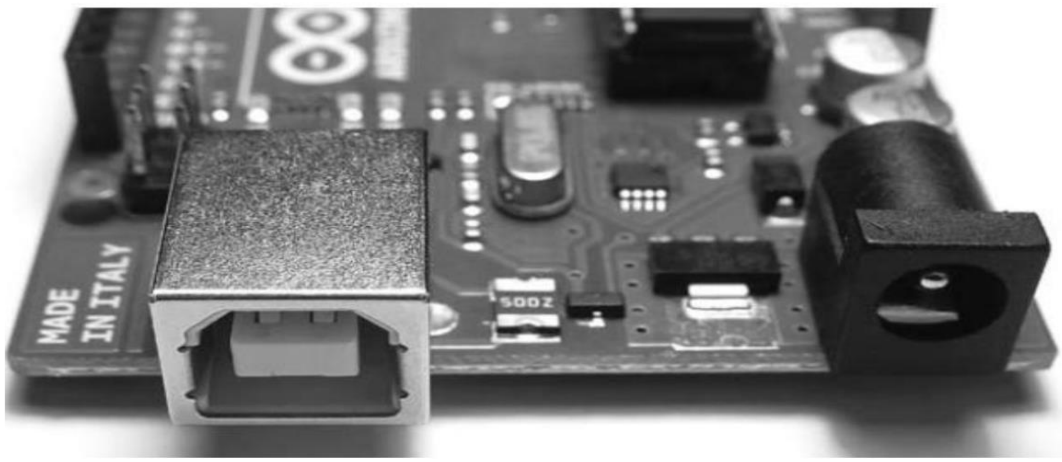

Figure 2.3: The USB and power connectors

On the far left is the USB connector. This connects the board to the computer for three reasons; to supply power to the board, to upload the instructions to the Arduino, and to send and receive from a computer. On the right is the power connector, this connector can power the Arduino with a standard mains power adapter. At the lower middle is the heart of the board: the microcontroller, as shown in Figure 2.4.

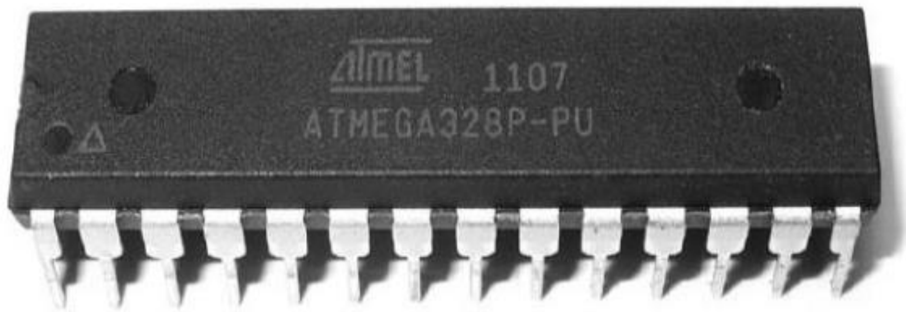

Figure 2.4: The Microcontroller

The microcontrollers represent the “brains” of the Arduino. It is a tiny computer that contains a processor to execute instructions, includes various types of memory to hold data and instructions from the sketches, and provides various avenues of sending and receiving data. The microcontroller has two rows of small sockets, as shown in Figure 2.5.

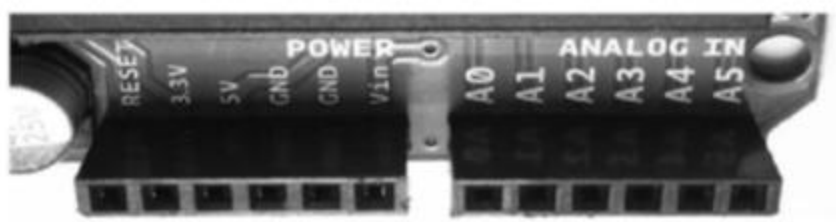

Figure 2.5: The power and analog sockets

The first row offers power connections and the ability to use an external RESET button. The second row offers six analog inputs that are used to measure electrical signals that vary in voltage. Furthermore, pins A4 and A5 can also be used for sending data to and receiving it from other devices. Along the top of the board there are two more rows of sockets, as shown in Figure 2.6.

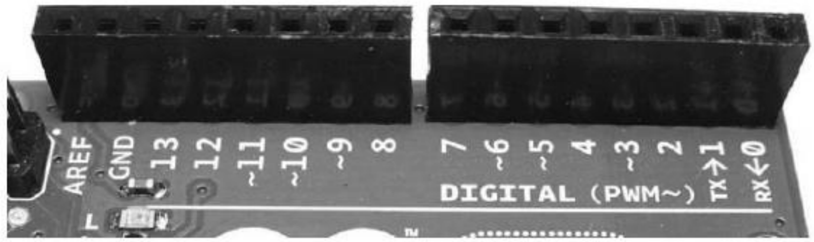

Figure 2.6: The digital input/output pins

Sockets (or pins) numbered 0 to 13 are digital input/output (I/O) pins. They can either detect whether or not an electrical signal is present or generate a signal on command. Pins 0 and 1 are also known as the serial port, which is used to send and receive data to other devices, such as a computer via the USB Connector circuit. The pins labelled with a tilde (~) can also generate a varying electrical signal, which can be useful for such things as creating lighting effects or controlling electric motors. Next there are some very useful devices called LEDs; these very tiny devices light up when a current passes through them. The Arduino board has four LEDs: one on the far right labelled ON, which indicates when the board has power, and three in another group, as shown in Figure 2.7. The LEDs labelled TX and RX light up when data is being transmitted or received between the Arduino and attached devices via the serial port and USB. The L-LED connected to the digital I/O pin number 13. The little black square part to the left of the LEDs is a tiny microcontroller that controls the USB interface that allows Arduino to send data to and receive it from a computer.

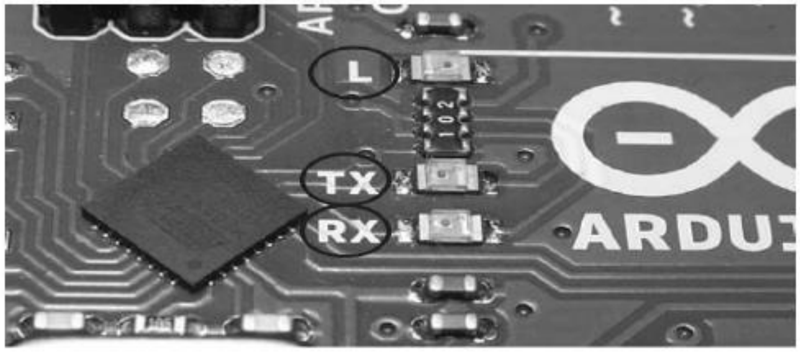

Figure 2.7: The onboard LEDs

And, finally, the RESET button is shown in Figure 2.8.

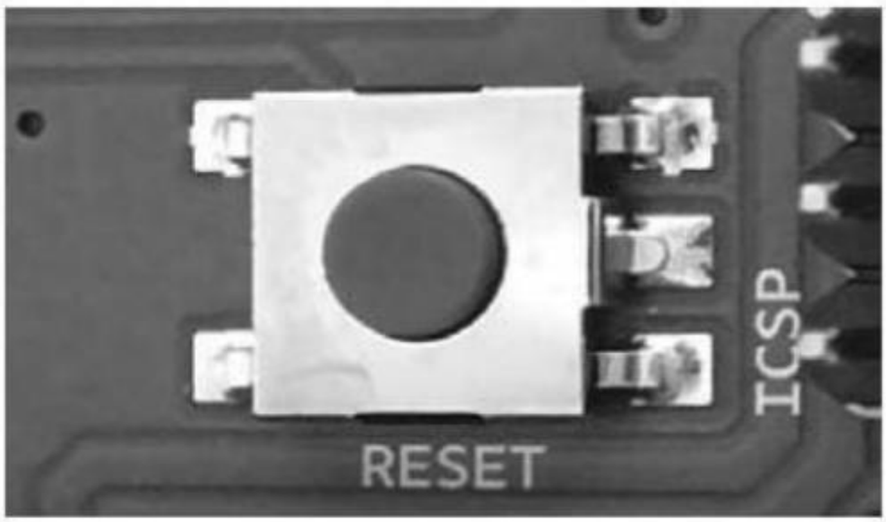

Figure 2.8: The RESET button

2.5 Servo Motor

A servo motor is a rotary actuator or linear actuator that allows for precise control of angular or linear position, velocity and acceleration. It consists of a suitable motor coupled to a sensor for position feedback. Servo motors have been around for a long time and are utilized in many applications. They are small in size but pack a big punch and are very energy-efficient. These features allow them to be used to operate remote-controlled or radio-controlled toy cars, robots and airplanes. Servo motors are also used in industrial applications, robotics, in-line manufacturing, pharmaceutics and food services, as shown in Figure 2.9.

Figure 2.9: Servo Motor

The servo circuitry is built right inside the motor unit and has a positionable shaft, which usually is fitted with a gear. The motor is controlled with an electric signal which determines the amount of movement of the shaft, as shown in Figure 2.10.

Figure 2.10: Servo Motor Shaft

Inside the servo motor there is a pretty simple set-up: a small DC motor, potentiometer, and a control circuit as shown in Figure 2.11. The motor is attached by gears to the control wheel. As the motor rotates, the potentiometer's resistance changes, so the control circuit can precisely regulate how much movement there is and in which direction. When the shaft of the motor is at the desired position, power supplied to the motor is stopped. If not, the motor is turned in the appropriate direction. The desired position is sent via electrical pulses through the signal wire. The motor's speed is proportional to the difference between its actual position and desired position. So if the motor is near the desired position, it will turn slowly, otherwise it will turn fast. This is called proportional control.

Figure 2.11: Inside the servo motor

2.5.1 Control of servo motor

Servos are controlled by sending an electrical pulse of variable width, or PWM, through the control wire. There is a minimum pulse, a maximum pulse, and a repetition rate. A servo motor cans usually only turn 90 degrees in either direction for a total of 180-degree movement. The motor's neutral position is defined as the position where the servo has the same amount of potential rotation in the both the clockwise or counter-clockwise direction. The PWM sent to the motor determines position of the shaft, and based on the duration of the pulse sent via the control wire; the rotor will turn to the desired position. The servo motor expects to see a pulse every 20 milliseconds (ms) and the length of the pulse will determine how far the motor turns. For example, a 1.5ms pulse will make the motor turn to the 90-degree position. Shorter than 1.5ms moves it to 0 degrees, and any longer than 1.5ms will turn the servo to 180 degrees. As shown in Figure 2.12.

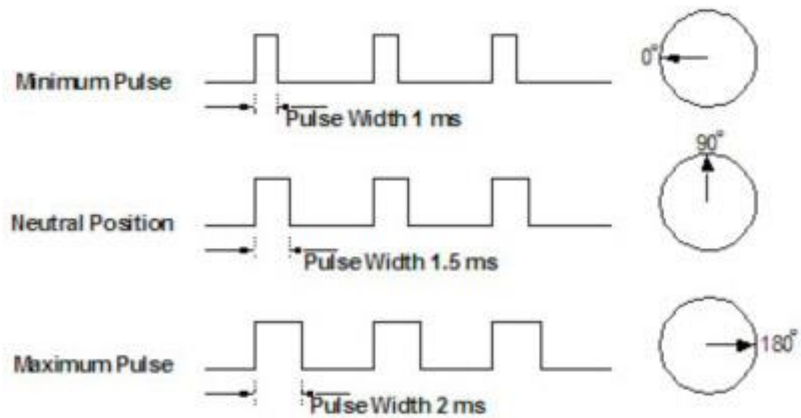

Figure 2.12: Variable pulse width control servo position

When these servos are commanded to move, they will move to the position and hold that position. If an external force pushes against the servo while the servo is holding a position, the servo will resist from moving out of that position. The maximum amount of force the servo can exert is called the torque rating of the servo. Servos will not hold their position forever though; the position pulse must be repeated to instruct the servo to stay in position.

2.5.2 Types of servo motors

There are two types of servo motors - AC and DC. AC servo can handle higher current surges and tend to be used in industrial machinery. DC servos are not designed for high current surges and are usually better suited for smaller applications. Generally speaking, DC motors are less expensive than their AC counterparts. These are also servo motors that have been built specifically for continuous rotation, making it an easy way to get your robot moving. They feature two ball bearings on the output shaft for reduced friction and easy access to the rest-point adjustment potentiometer.

2.5.3 Servo motor applications

Servos are used in radio-controlled airplanes to position control surfaces like elevators, rudders, walking a robot, or operating grippers. Servo motors are small, have built-in control circuitry and have good power for their size. In food services and pharmaceuticals, the tools are designed to be used in harsher environments, where the potential for corrosion is high due to being washed at high pressures and temperatures repeatedly to maintain strict hygiene standards. Servos are also used in in-line manufacturing, where high repetition yet precise work is necessary.

2.6 Sensors

Sensor is a device that when exposed to a physical phenomenon (temperature, displacement, force, etc.) produces a proportional output signal (electrical, mechanical, magnetic, etc.). The term transducer is often used synonymously with sensors. However, ideally, a sensor is a device that responds to a change in the physical phenomenon. On the other hand, a transducer is a device that converts one form of energy into another form of energy. Sensors are transducers when they sense one form of energy input and output in a different form of energy. For example, a thermocouple responds to a temperature change (thermal energy) and outputs a proportional change in electromotive force (electrical energy). Therefore, a thermocouple can be called a sensor and or transducer.

Sensors and actuators are two critical components of every closed loop control system. Such a system is also called a mechatronics system. A typical mechatronics system. A sensing unit can be as simple as a single sensor or can consist of additional components such as filters, amplifiers, modulators, and other signal conditioners. The controller accepts the information from the sensing unit, makes decisions based on the control algorithm, and outputs commands to the actuating unit. The actuating unit consists of an actuator and optionally a power supply and a coupling mechanism [7].

2.6.1 Proximity sensors

They are used to sense the proximity of an object relative to another object. They usually provide a on or off signal indicating the presence or absence of an object. Inductance, capacitance, photoelectric, and hall effect types are widely used as proximity sensors. Inductance proximity sensors consist of a coil wound around a soft iron core. The inductance of the sensor changes when a ferrous object is in its proximity. This change is converted to a voltage-triggered switch. Capacitance types are similar to inductance except the proximity of an object changes the gap and affects the capacitance. Photoelectric sensors are normally aligned with an infrared light source. The proximity of a moving object interrupts the light beam causing the voltage level to change. Hall Effect voltage is produced when a current-carrying conductor is exposed to a transverse magnetic field. The voltage is proportional to transverse distance between the Hall Effect sensor and an object in its proximity.

CHAPTER THREE

SYSTEM HARDWARE AND SOFTWARE

3.1 System Description

The Rubbish separation system consists of three sensors which considers as system's input, an Arduino which is controller of system, three servo motors which use to moves rubbish to the specified places, DC Motor, and belt. The belt was curled on two shafts, one of these shafts is connected to the DC motor and the other is free movement. On one side the sensors were installed and on the other side the servo motors were installed. When the belt is run the rubbish passes in front of the sensors where each sensor detects a certain type of material, when the sensor detects the material it sends a signal to the Arduino which it sends a signal to the servo motor, under which it moves at a certain angle to place the material in the specified place as shown in Figure 3.1.

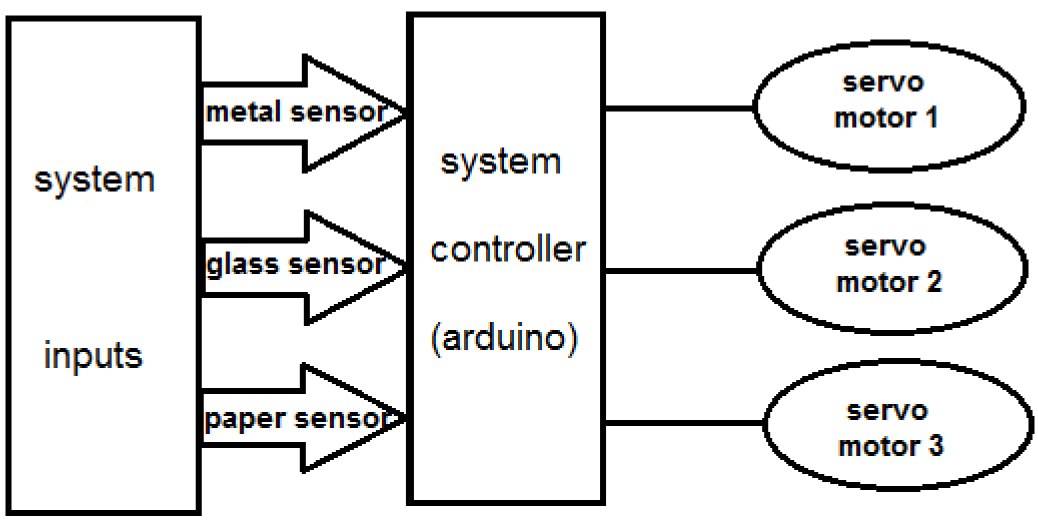

Figure 3.1: The System diagram

3.2 System Components

The rubbish separation system consist of many electrical components, these components are:

3.2.1 Arduino uno board

Arduino uno as shown in Figure 3.2 is a microcontroller board based on the ATmega328P microcontroller. It has 14 digital input/output pins (of which 6 can be used as pulse width modulation (PWM) outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, header and a reset button.

Figure 3.2: Arduino Uno

Specification:

General:

Input Voltage	7-12 V
Digital I/O Pins	14 (of which 6 provide PWM output)
PWM Output	6
PCB Size	53.4 x 68.6 mm
Weight	25 g
Product Code	A000066 (TH); A000073 (SMD)

Arduino Microcontroller:

Microcontroller	ATmega328
Architecture	AVR
Operating Voltage	5 V
Flash memory	32 KB of which 0.5 KB used by bootloader
SRAM	2 KB
Clock Speed	16 MHz
Analog I/O Pins	6
EEPROM	1 KB
DC Current per I/O Pins	40 mA on I/O Pins; 50 mA on 3,3 V Pin

3.2.2 Servo Motor

This high torque MG996R digital servo as shown in Figure 3.3, features metal gearing resulting in extra high 10kg stalling torque in a tiny package. This high torque standard servo can rotate approximately 120 degrees (60 in each direction).

Figure 3.3: Servo Motor

Specification:

MG996R is an upgraded version of MG995 servo

Weight:	55g
Dimension:	40.7×19.7×42.9mm
Stall torque:	9.4kg/cm (4.8V); 11kg/cm (6.0V)
Operating speed:	0.19sec/60degree (4.8v); 0.15 sec/60degree (6.0V)
Operating voltage:	4.8~ 6.6V
Gear Type:	Metal gear
Temperature range:	0- 55deg
Servo Plug:	JR (Fits JR and Futaba)
Dead band width:	1us
Servo wire length:	32 cm

3.2.3 Sensors

NJK-500 Hall Proximity switch NPN 3-wires normally open type as shown in Figure 3.4. This Inductive Proximity Switch Sensor is ideal for detecting the presence ferrous or magnetic object to determine rotational speed, the presence or absence of parts, or position limits.

Figure 3.4: Hall Proximity sensor

Specifications:

NJK5002C (8002C)

Output NPN, N.O. (Normally Open)

3 Wire Type: (Black=Signal Output, Brown= +VDC Power In, Blue=Ground)

Detecting Distance: 5-10mm

Supply Voltage: DC +5-30VDC

Max Current: 150mA

Operating Temperature: -25C to +55C

Sensor: 40mm x 12mm (1.5'' x0.47'') (LxD)

Cable Length: 1145mm/45.

3.2.4 DC – motor

Direct current motors, as the name implies, use direct-unidirectional current. DC motors are used in special application where high torque starting or smooth acceleration over a broad speed rang is required as shown in Figure 3.5.

Figure 3.5: DC-Motor

Specification:

RK-370CC-14230 DC Motor

Motor parameters:

Model:	RK-370CC-14230
Diameter:	24.4 mm
Height:	30.8MM (not include output shaft)
Output shaft diameter:	2.0 mm
Output shaft length:	15.5 mm
Operating range:	DC 12~30 V
Nominal voltage:	30 V
No-load speed:	20700 rpm
No-load current:	0.11 A
Max efficiency speed:	17460 rpm
Max efficiency current:	0.59 A

Max efficiency torque:	6.13 mN.m (62.5 g.cm)
Max efficiency output:	11.2 W
Stall torque:	39.2 mN.m(400 g.cm)
Stall current:	3.2 A
Weight:	51g

3.3 System Software

The system software consists of the code and the Simulation , the Arduino code was being used for effective communication and fast processing between components and the controller.

3.3.1 Flow chart

The flow chart show the sequence of rubbish separation system when the materials were detected by the sensors as shown in Figure 3.6.

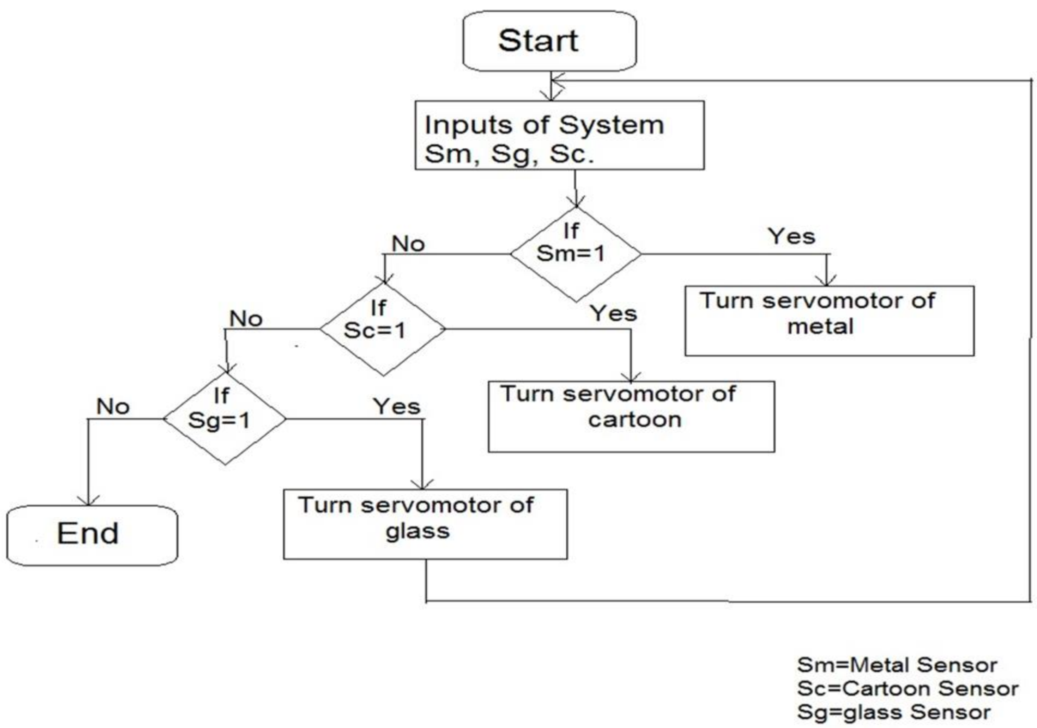

Figure 3.6: System Flow Chart

3.3.2 Arduino code

```
#include<Servo.h>
Servo metal;
Servo glass;
Servo cartoon;
void setup() {
  metal.attach(13);
  glass.attach(12);
  cartoon.attach(11);
 }
void loop() {
   boolean metalicsensor = digitalRead(2);
  boolean glasssensor = digitalRead(1);
  boolean cartoonsensor = digitalRead(0);
if (metalicsensor == 0 && glasssensor == 0 && cartoonsensor == 0)
{
 metal.write(0);
 glass.write(0);
 cartoon.write(0);
}

  else if (metalicsensor ==1)
  {
    metal.write(75);
    delay(1000);
    metal.write(0);
  }
  else if(metalicsensor == 1 && glasssensor == 0 && cartoonsensor == 1)
```

```
  {
    glass.write(75);
    delay(1000);
    glass.write(0);
  }
 else if(metalicsensor == 1 && glasssensor == 1 && cartoonsensor == 0) {
  cartoon.write(75);
  delay(1000);
  cartoon.write(0);
 }
}
```

3.3.3 System simulation

After the code of the system was written now it's possible to create a simulation environment in which to test and view the results of various inputs and controller. The system was simulated by Protues simulation Program, all the components of the system was drawn in the simulation and software code was used to teach Arduino Microcontroller to run the Rubbish separation system according to requirements.

CHAPTER FOUR

SYSTEM IMPLEMENTATION AND TESTING

4.1 System Implementation

Rubbish separation system practical model divided into two parts:

The mechanical part which consists of frame, shafts, belt, chairs, and deflectors as shown in Figure 4.1and Figure 4.2.

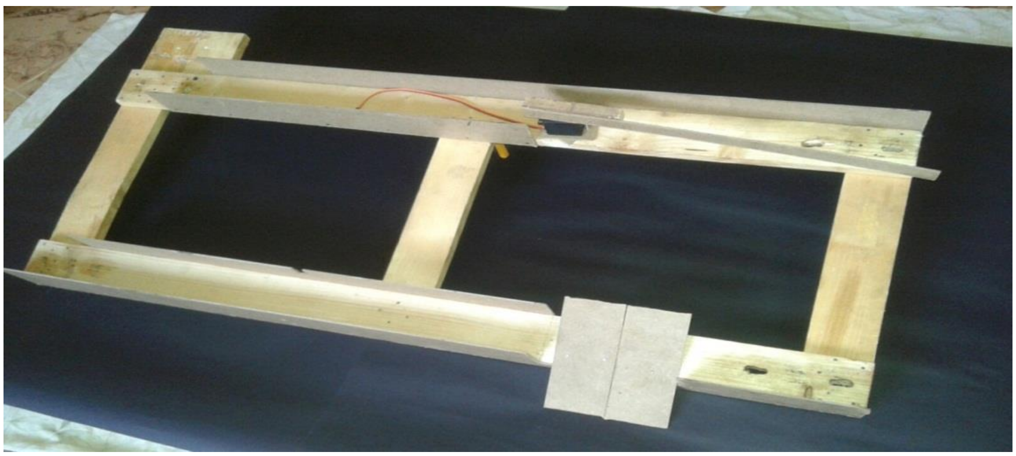

Figure 4.1: The system frame

Figure 4.2: The Shaft on chairs and DC motor

The belt was curled on two shafts, one of these shafts is connected to the DC motor and the other is free movement and the deflector linked with the servo motor and metal sensor placed on side of the belt as shown in Figure 4.3.

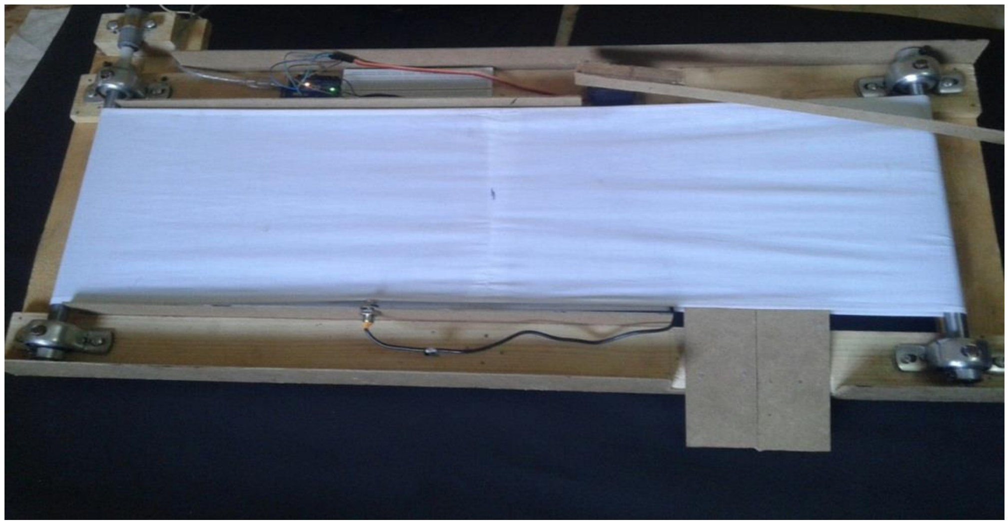

Figure 4.3: Shaft on chairs and the belt was curled

And the electrical part consists of Arduino UNO, DC motor, metal sensor, power supply and servo motor. The Arduino was uploaded with code to control the system. The DC motor was energized from external power supply which running the belt , and the sensor (Ground, signal, power) connected to Arduino board in pins [GND,D2,5V]. The servo motor was energized from power supply and its signal came from Arduino board as shown in Figure 4.4.

4.2 System Testing

When the DC motor was energized, the belt was running.at first the metal Piece was put on the belt and pass in front of the metal sensor , this piece was detected, then the barrier deflected the piece into specified place as shown in Figure 4.5 and Figure 4.6.

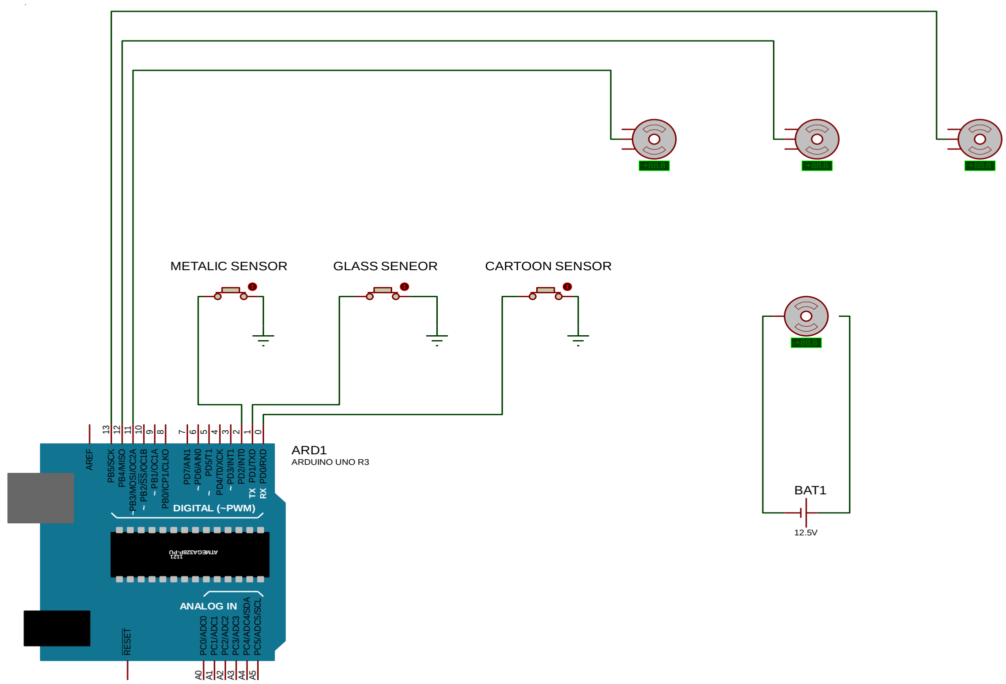

Figure 4.4: The control circuit

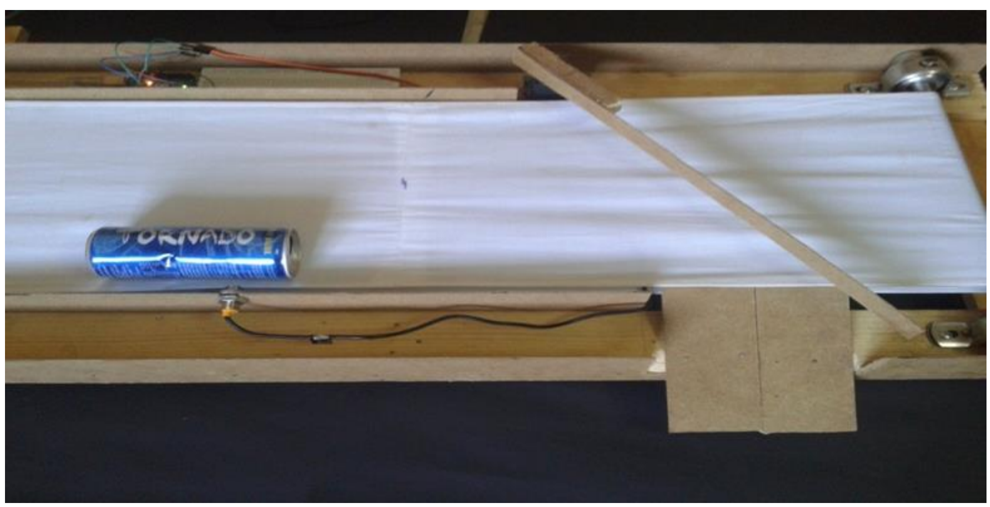

Figure 4.5: The sensor response to the metal material

Figure 4.6: The metal material deflected for assignment place

When nonmetal piece pass in front of sensor there was no effect and the barrier does not move and the nonmetal piece arrived to end of the belt as shown in Figure 4.7.

Figure 4.7: The sensor response to the plastic material

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The traditional system of the rubbish separation was developed to smart system by using the microcontroller and sensors. In this project the metals were separated successfully from the other materials. And the separation process becomes easier and high efficiency.

5.2 Recommendation

1. Use of other sensors to separate more materials.
2. Adjustment of distance between the separated materials.

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