International Journal of Advances in Engineering and Management (IJAEM)
Volume 7, Issue 11 Nov. 2025, pp: 44-53 www.ijaem.net ISSN: 2395-5252

# Design and Development of a Low-Cost Automated Colour-Based Object Sorting System Using Conveyor Belt Technology

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Date of Submission: 25-10-2025 Date of Acceptance: 05-11-2025

**ABSTRACT**
This paper, "Design and Development of a Low-Cost Automated Color-Based Object Sorting System Using Conveyor Belt Technology," presents the design and development of a low-cost automated system capable of sorting objects based on color using conveyor belt technology. The prototype utilizes a TCS3200 color sensor for object color detection and an Arduino Uno microcontroller for system control[1]. Color recognition is achieved through frequency analysis of the sensor's output. A stepper motor-driven conveyor belt transports objects to the sensor station, where each item is analyzed and sorted into designated compartments. Upon color detection, the microcontroller sends command signals to a servo motor, which then actuates sorting arms to direct the objects to their corresponding positions based on color. A 20x4 LCD module displays real-time information, including the detected color and object count. Experimental tests demonstrate that the proposed system offers a reliable and efficient solution for small- to medium-scale automated sorting applications, with the potential to enhance productivity and maintain product quality in industrial automation.
**Keywords:** Automated, Color-Based Object, Sorting System, Conveyor Belt.

## I. INTRODUCTION

Color is an intrinsic property that helps us perceive objects and interact with the environment[2]. Identifying differences in colors is important in navigating the world, and some humans and animals can do so through specialized cells in the retina[3].

Electricity and automation have made the world change incessantly in the past century[4]. Industries like power generation, food processing, cement, and supply chains have made efficient use of conveyor belt systems to separate and ship goods[5]. There is still a need for innovation to lessen breakdowns, costs, and tragedies. Conveyor belts, used in many industrial processes, serve to automate the movement of goods from one place to another. In crayon production, agricultural machinery, food processing, and many other industries, a color sort is a necessity [5]. For enhanced productivity and reduced human mistakes, automation is essential[6]. This paper proposes a color sorting system for detecting and classifying objects with a color sensor based on set thresholds that seeks to achieve automation with less human interference[6]. The system uses color sensors to determine the color of the object to be sorted[5]. It sends the data to a microcontroller, which controls a servomotor to pick the object and place it in the correct position. For this work, objects will be classified into three groups, which include; red, green, and blue[6]. The advanced machines being developed will be equipped with color detection features, allowing them to perform recognition, sorting, and object arrangement like human vision. With the system's effectiveness and accuracy, it can be a viable option for companies looking to improve their output[7].

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## II. METHODOLOGY

To grasp the fundamental concept underlying the operation of an automatic object sorting and counting system, it is essential to identify the equipment that comprises the entire system, as well as the steps involved in achieving its objectives[7]. This chapter delves into the analysis, design, and implementation of the complete system. The system is made up of several units: the power supply unit, driver units, sensing units, actuation units, and display units. Each of these units consists of various components, all of which possess specific specifications outlined in their datasheets, such as current ratings, voltage ratings, and power ratings. Consequently, accurate design calculations and implementations must be performed on each unit to ensure that the entire system functions as anticipated. Figure 1.0 illustrates the block diagram of the system.

### a. General System Concept in the Unit

The system consists of Units: Power supply unit, driver units, sensing units, actuation units and Display units. The Units themselves consist of some components and all such components have specifications based on datasheets, i.e., current ratings, voltage ratings and power ratings. Because of this, proper design calculations and implementation of the designs need to be done on every one of these units in order to make the whole system function properly as wanted. Figure 1.0 shows the system block diagram.

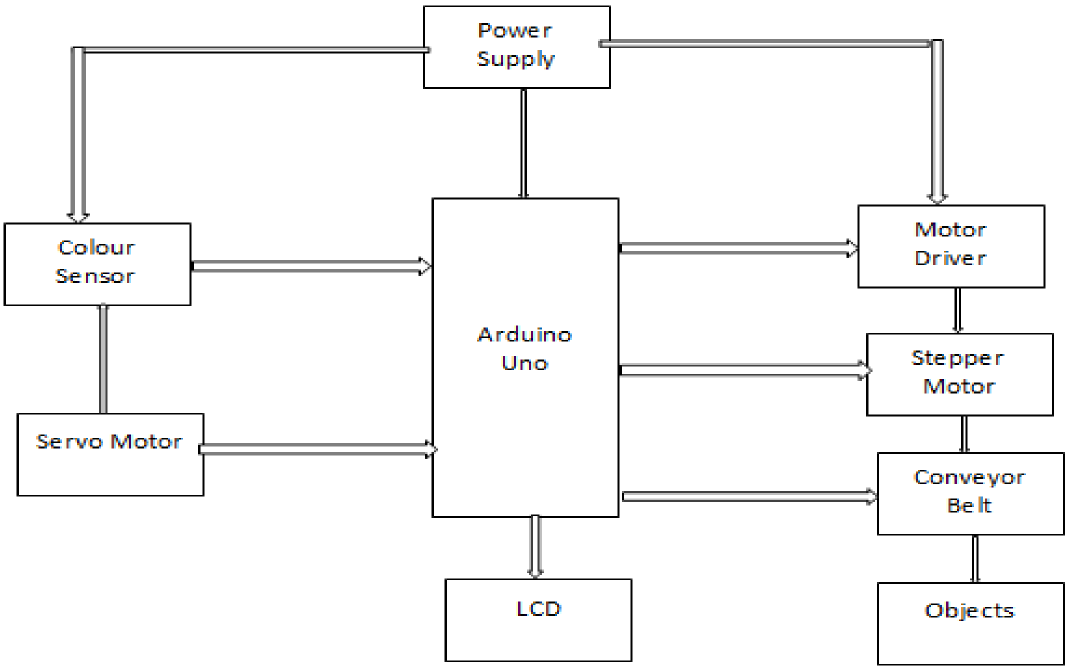


**Figure 1.0 System block diagram**

The design, analysis, and implementation method of the paper relies on both hardware and software components[8],[9]. The software consists of program codes that will be compiled and run using Arduino software and a simulation of the paper using Proteus software. While the hardware included assembling the conveyor belt, bread boarding, soldering, and casing [8].

### b. Software Development

C programming language was used in this paper to program the program, and was written on the Arduino platform[10]. The setup symbol "START" initializes the process of programming. The system is then initialized, connecting various units of the circuit. After this, the sound module captures available sound, if any, from the baby, and then it converts it to a signal input to the microcontroller, which further sends it via the

Bluetooth module. The digital output of the sound module is sent to the motor driver, which further drives the cradle motor. The program code is added at the end of the paper. Figure 1.1 is the flow chart.

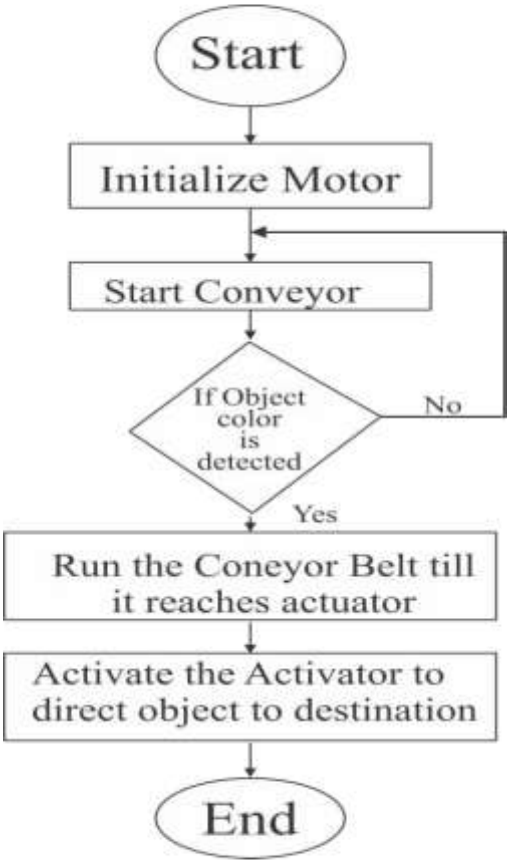


**Figure 1.1 System flowchart**

**c. Hardware Development**

The hardware development is divided into the following;

- ➢ Power Supply/charging unit
- ➢ Sensing Unit
- ➢ Conveyor Unit
- ➢ Actuation unit
- ➢ Display Unit

**d. Power Supply/Charging Unit**

This unit consists of a 12V DC Battery, a Voltage Regulator, and a Battery Charger for charging the system. The battery charger charges the system which is then stored by the 12V DC Battery, while the voltage regulator regulates the input to the microcontroller by providing a constant 12V.This unit consists of a transformer and a bridge rectification section as well as a charging circuit.

The figure below show the charging circuit diagram

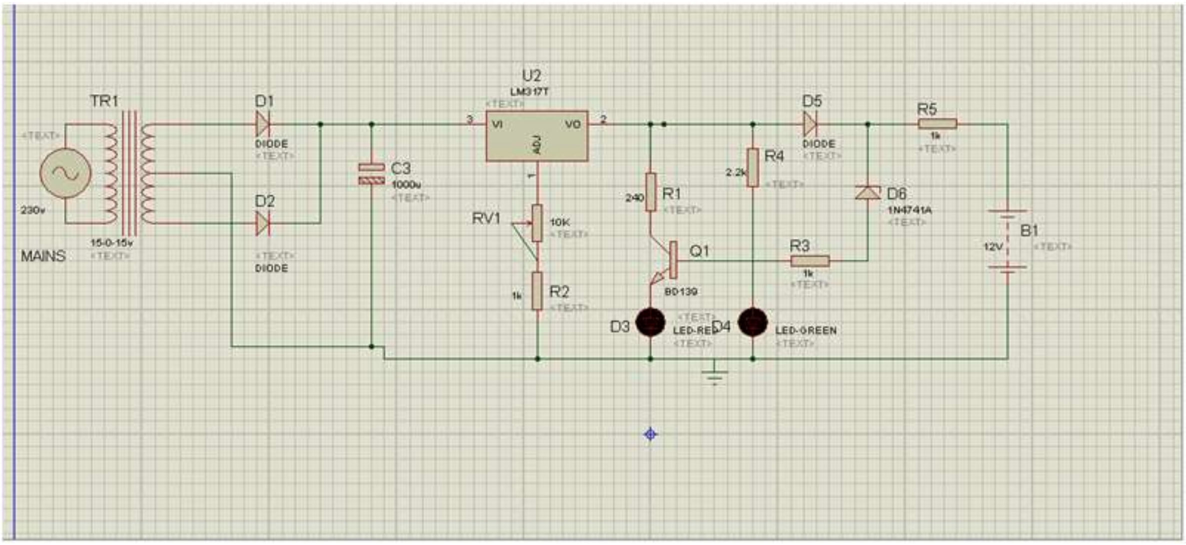


**Figure 1.3 charging circuit diagram**

**e. Rectification:**

In this paper, a center-tapped transformer and two diodes were used for full-wave rectification. In using the center-tap (C) as a common, the voltage A and B is 180 degrees out of phase. When A is positive, D1 will be forward-bias and conductive, while B will be negative, thus reverse-biasing D2, which is non-conductive. On the negative half cycle in relation to A, when D1 doesn't conduct, D2 will conduct.

The figure below shows the rectification circuit

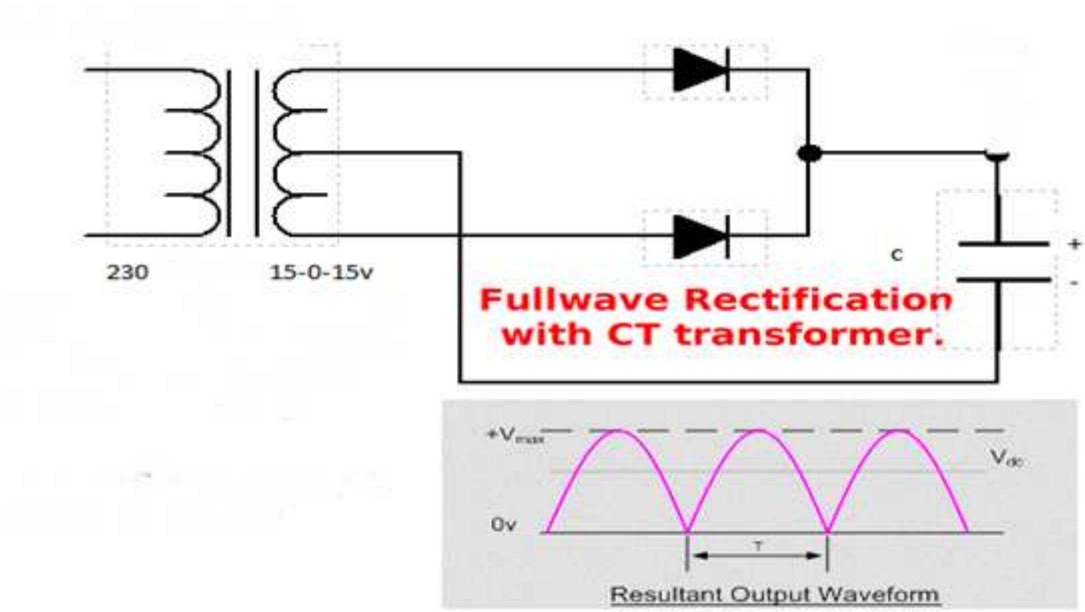


**Figure 1.4 Rectification**

**f. Parameters:**

Transformer type: single-phase step-down transformer
Input voltage 220/230V, 50Hz
Output voltage 2x 15V AC
Current rating Output current = 2A

**g. Filtering:**

Capacitors are used to serve as the filter components of the circuit that will hold the peak-to-peak ripples at approximately 5% of the peak voltage. Therefokre, using the values obtained, it is calculated as follows:

$I_{min} = I_{d.c} = 500mA$
(Measured and approximated.)

$V_{rms} = \sqrt{2} \times V_m$ ..............................................3.1

But $V_m = 24V$

$$V_{rms} = \sqrt{2} \times V_m$$
$$= \sqrt{2} \times 24$$
$$V_{rms} = 33.94V$$

Taking a 5% ripple factor of the peak voltage

$V_r = \text{ripple factor} \times V_p$ … … … … … … … … … … … … … … … … … … . … 3.2

$$V_r = RF \times V_p$$
$$= \frac{5}{100} \times 33.94$$
$$V_r = 0.05 \times 33.94$$
$$V_r = 1.697V$$

Using the relationship below to obtain the value of the Capacitor$C_1$.

$C_1 = \frac{I_{dc}}{4\sqrt{3}fV_r}$ … … … … … … … … … … … … … … . … … … .3.3

Where:

$C_1$ is the filtering capacitor
F is the frequency of the input supply
$I_{dc}$ is the current taken by the load

$$C_1 = \frac{500 \times 10^{-3}}{4\sqrt{3} \times 50 \times 1.697}$$
$$C_1 = 850.5\mu f$$

Using the idea of 20 – 30% addition of the calculated value to have a very close standard value obtainable at the market, in this paper design, a 20% addition is considered.

$$C_{1addition} = 850.5 \times 10^{-6} \times 20\%$$
$$C_{1addition} = 850.5 \times 10^{-6} \times \frac{20}{100}$$
$$= 170.1\mu f$$
$$\therefore C_1 = 850.5 \times 10^{-6} + 170.1 \times 10^{-6}$$
$$= (850.5 + 170.1)\mu f$$
$$C_1 = 1020.1\mu f$$

In view of the above, a filtering capacitor of 1000 µf was used.

**h. Regulation and Charging Circuit:**

Taken R1=200Ω, Rs=1Ω, Vo=13v

$Vout = 1.25v \times \frac{R2}{R1+1}$**................................3.4**

$$13 = 1.25 \times \frac{R2}{200 + 1}$$

R2= 2090.4 ≈2KΩ.

A 10KΩ variable resistor is used in place of R2 for the purpose of varying the output voltage.

**i. Sensing Unit**

These consist of the TCS3200, which is placed 3cm above the conveyor belt; it contains four white LEDs to illuminate the object's surface, whose color has to be detected. The intensity of the light reflected by the object is calculated. A frequency proportional to the intensity is produced by the converter, using which the microcontroller predicts the color of the object[11].

The figure below shows the schematic diagram of the sensing unit:

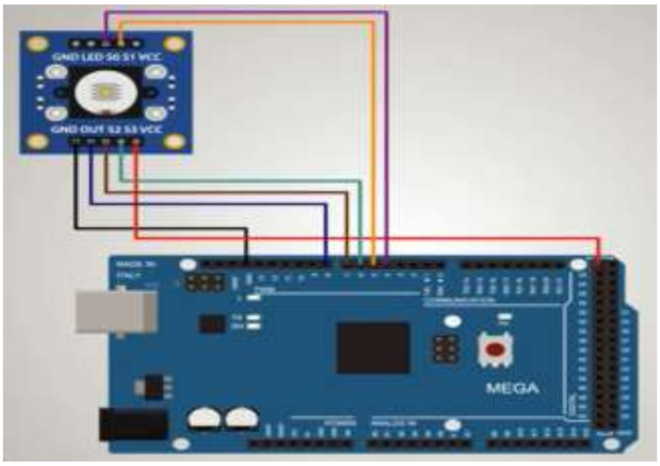


**Figure 1.5 Sensing Unit**

**j. Conveyor Unit**

The conveyor unit consists of the conveyor belt, which is driven by the stepper motor. The speed of the conveyor is controlled using the LM293 motor driver and is moving at a speed of 100rpm. Both the sensing unit and actuation unit are placed on the conveyor unit[11].

**k. Actuation Unit**

This unit consist of SG90 tower servo motor which carried out the final sorting operation. Initially it is set at angle of $0^0$ which block the path to the final destination, and based on the object colour detected the microcontroller will send a command signal to the servo motor to rotate either clockwise or counter clockwise at different angle which leads the object to the desired destination. The figure below shows the schematic diagram of the actuation unit[10]:

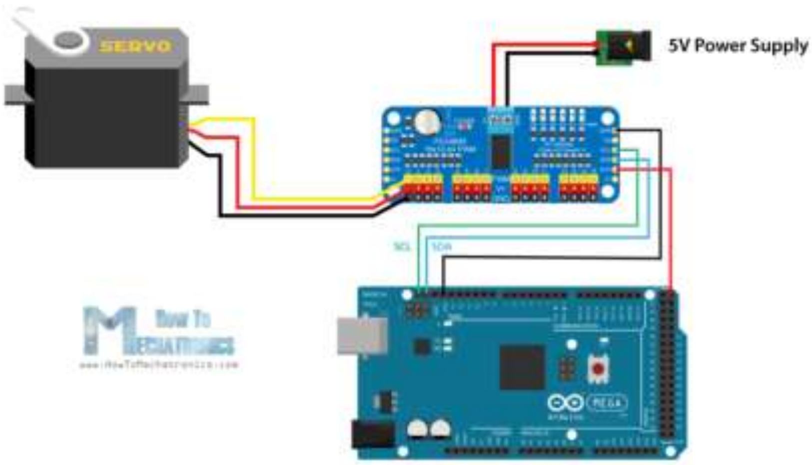


**Figure 1.6 Actuation Unit**

l. **Display Unit**

The display unit consist of a liquid crystal display (LCD 20*4) that displays the physical behavior of the system most particularly the initialization message, paper title and color detected and count[12].

L293D DC motor driver:

L293D is dual H-bridge motor driver ICs. It can control the rotation of two motors in clockwise and anti-clockwise direction. The pin-out of IC is as discussed below[13]:

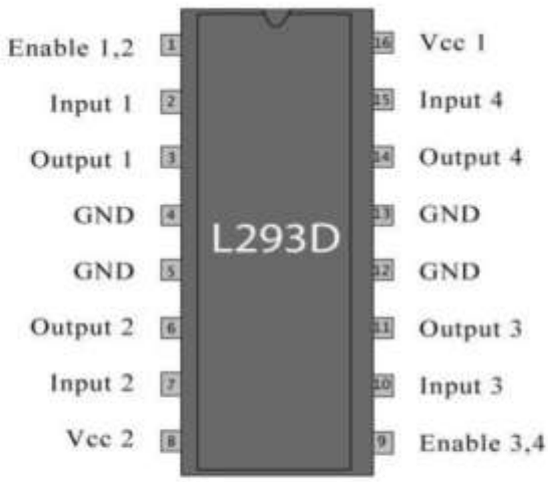


**Figure 1.7 The pin-out of the l293D.**

Enable pins: They are pin 1 and pin 9. Pin 1 is used to enable Half-H drivers 1 and 2. Pin 9 is used to enable H-bridge drivers 3and 4.These pins can be used to provide speed control for the motor using the PWM technique.

• VCC1: This is pin 16, used to provide power. Connect it to a 5V supply.

• VCC2: This is pin 8, which serves to power the motor. Supply a positive voltage to it as per the motor rating.

• GND: These are pins 4, 5, 12, and 13 should be connected to the common GND of the circuit.

• Inputs: These are pins 2, 7, 10, and 15 are input pins through which control signals are supplied by microcontrollers or other circuits/ICs.

• Outputs: These are pins 3, 6, 11, and 14 that serve as output pins. Depending on the input signal output signal results.

The driver provides outputs to move the motor according to the input signals. These actions are shown in the table below.

**Table 1.1**: Operation of L293D

| Input 1 | Input 2 | Output 1 | Output 2 | Motor Status |
|---|---|---|---|---|
| Logic 0 | Logic 0 | 0 | 0 | Stop |
| Logic 0 | Logic 1 | +ve | 0 | Clockwise |
| Logic 1 | Logic 0 | 0 | +ve | Anti-clockwise |
| Logic 1 | Logic 1 | +ve | +ve | Brake |

**m. Charge Regulator LM7812**

LM7812 is an adjustable voltage integrated-circuit voltage regulator for a wide variety of applications. The L7812 voltage regulator provides a 12V Positive voltage as output and can provide on-card local regulation, eliminating the distribution problems associated with single-point regulation. Although fundamentally designed as a fixed voltage regulator, it can be obtained with an adjustable voltage by using external components. The table below gives the pin description of LM7812[14].

**Table 1.2:**LM7812 Description

| **Pin Number** | **Pin Name** | **Description** |
|---|---|---|
| 1 | Input (V+) | Unregulated Input Voltage |
| 2 | Ground | Connected to Ground |
| 3 | Output (Vo) | Outputs Regulated +12V |

The color to be sensed by the color sensor is selected via the two pins S2 and S3. By these two pins, logic control, we can control the sensor whose color light intensity is to be sensed. Let's assume we need to sense RED color intensity; we need to set both pins LOW. After doing that then the sensor senses the intensity and it provides the value to the control system in the module[15].

Table 1.3

| **S2** | **S3** | **Photodiode Type** |
|---|---|---|
| L | L | Red |
| L | H | Blue |
| H | L | Clear (no filter) |
| H | H | Green |

If the light falls on the TCS230 we can choose the different type of photodiode by different combination of S2 and S3. See the shape below.

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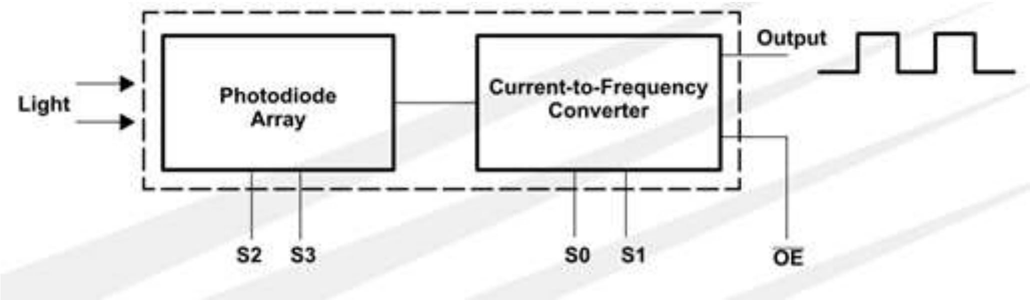


**Figure 1.8 TCS3200 internal structure**

So we have a system which sends out a square wave whose frequency depends on light intensity of color which is selected by S2 and S3.

The signal frequency sent by module can be modulated depending on use. We can change the output signal frequency bandwidth.

**Table 1.4:** TCS3200

| **S0** | **S1** | **Output Frequency Scaling ($f_0$)** |
|---|---|---|
| L | L | Power Down |
| L | H | 2% |
| H | L | 20% |
| H | H | 100% |

The frequency scaling is done by two bits, S0 and S1. For convenience, we are going to limit the frequency scaling to 20%. This is done by setting S0 to high and S1 to LOW. This feature comes in handy when we are using the module on a system with a low clock[13].

## III. RESULT

To achieve the effective testing of these components and the entire system, the following were used:

- Digital Multimeter
- Bread board
- Proteus simulation software

**Testing and Results**

Different types of testing were carried out in implementing this I, these are:

**TCS 3200 Colour Sensor Range:**

The overall range of operation of the TCS 3200 colour sensor is (3cm) as designed by the manufacturer and indicated in the data sheet, but based on the frequency scaling factor, the range can be varied from (0cm-3cm) as shown in the table below[1].

Table 1.5

| S0 | S1 | FREQUENCY SCALE FACTOR | SENSOR RANGE (CM) |
|---|---|---|---|
| L | L | Power down | 0 |
| L | H | 2% | 3 |
| H | L | 20% | 2 |
| H | H | 100% | 1 |

**Light Intensity Test:**

The tests are carried out indoors and outdoors to record the results, and the values showed that the RGB values taken in a place with low intensity of light are less compared to those taken in a place with high light intensity. This is due to the presence of more than a single light outdoors, which affected the results. The Tests are shown in Tables 4.3 and 4.3 respectively[1].

Table 1.6: RGB filter during outdoor test.

| 0BJECTS COLOURS | RED FILTERS | BLUE FILTERS | GREEN FILTERS |
|---|---|---|---|
| RED | 130 | 225 | 200 |
| BLUE | 230 | 120 | 130 |
| GREEN | 230 | 130 | 110 |

Table 1.7 RGB Filter during Indoor Test.

| OBJECTS COLOURS | RED FILTERS | BLUE FILTERS | GREEN FILTERS |
|---|---|---|---|
| RED | 150 | 190 | 188 |
| BLUE | 130 | 170 | 169 |
| GREEN | 160 | 168 | 170 |

It can be seen from Tables 1.6 and 1.7 that the values of the filter are different when tested outdoors and indoors. The presence of other light has caused the TCS3200 colour sensor filters to record RGB (Red, Green, and Blue) values that are closer to each other[1]. For example, the most obvious result is when tested with a green object outdoors, the green filter and blue filter showed very close G and B values. This might cause the system to detect it as an error and not carry out sorting tasks as planned when two filters share the same reading. This means the system fails to detect if it is a blue ball or a green ball. The same things happen in this outdoor experiment. The colour sensor will detect and record inconsistent RGB value which has high R and B values[1].

This scenario suggests that the light is affecting the result and should be avoided. In the situation where more than one light is present, it is advisable to just focus on a single light surface. The RGB result will be more reliable when tested indoors or in a confined space. Besides preventing the presence of too much unwanted light, in order to get the optimum result, there are other factors that need to be considered throughout the experiment, which is listed below. It is the best to choose the objects with high concentration of colour, so that the surrounding ray will not affect the result too much. For example, dark green, dark blue and dark red is chosen instead of light version of them. This is to increase the accuracy of the RGB values of an object and thus increase the efficiency of the recognition and sorting process by this system[1].

Power Supply:
Table 4 gives the details of the power supply usage theoretically and as measured.

Table 1.8 Power supply

| S/N | Supply | Theoretical Voltage(V) | Measured Voltage(V) |
|---|---|---|---|
| 1 | LM 7812 | 12 | 11.7 |
| 2 | Regulator LM117 | 3.3 | 3.29 |
| 3 | Regulator LM7805 | 5 | 4.91 |

**Battery Charging Time**
The time at which the charger constructed charges the battery, as tested at different time intervals is shown in Table 5.

Table Battery charging time

| S/N | Charging Time Difference (min) | Charging Voltage Difference (V) |
|---|---|---|
| 1 | 53 | 0.43 |
| 2 | 5 | 0.01 |
| 3 | 17 | 0.07 |
| 4 | 45 | 0.22 |
| Average | 30 | 0.1825 |

**Breadboard Test**

The specified components for this paper were tested using a breadboard to ensure their reliability to be used for the implementation. Section-by-section testing was conducted, and integration followed immediately.

## IV. DISCUSSION OF RESULTS

Based on the results obtained from the tests carried out, it can be observed that the response of the TCS 3200 colour sensor is excellent in indoor that is when there is less or no presence of other light rays. Also, the maximum range of operation of the sensor is 3cm; therefore, the sensor is placed at the appropriate position so that the colored objects moving on the conveyor belt can be sensed.

However, one of the paper objectives is not achieved, which is integrating all the system's sub-units together. But based on the tests carried out, the paper is 70% accurate.

## V. CONCLUSION

Finally, this work has presented an automated object sorting and counting system. As such, the system demonstrated the aim of the paper. Hence, the paper was successful, and the aim was achieved.

## VI. RECOMMENDATION

Based on the results obtained and the level of achievements, the following recommendations will help to increase the efficiency and functionality of the work.

- In subsequent design, appropriate speed control for the stepper motor should be designed to integrate the overall units of the system
- pH sensors can be installed for food industry applications to check the freshness.
- Sensors can be replaced by cameras for digital processing, which is done using MATLAB
- A load cell can be used for measurement and control of the weight of the product
- A power supply switching circuit should be designed so that an automatic change of supply will be obtained between the battery supply and the mains.

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