# Pen and Highlighter Vending Machine

**INTERIM REPORT**

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## Introduction

Pens are the most used stationery item in schools/universities. Thousands of pens could be collected as waste in one school/university per year. These can even relate to highlighters. If these are not recycled it can cause land filling or ends up as litter. According to the statistics it will take up to 10000 years to fully decompose these plastics which pens, and highlighters are made.

Pens and highlighters are smaller in diameters therefore community is not giving much attention to properly decomposing these plastic items. However, these could make equal harm for the nature as like other plastics.

Due to the heavy usage of plastics during the past decade and considering the damage caused by them to nature current world is heading towards plastic free culture. Hence stationary manufacturers are looking for recycling and reusing methods of those stationary items. Major defect here is that unlike bottles and other plastics, pens and highlighters are not being effectively collected. Minimality in size takes less attention of people therefore they just throw them away or burn them.

Moreover, these items are hard to sort from the garbage during the recycling process.

To address this alarming issue ‘Pen and highlighter exchange vending machine’ is proposed mainly to focus on collection of disposing pens and highlighters in universities and schools.

This machine will effectively collect pens and highlighters where students are able to obtain new pens and highlighters in exchange of used items. Bin sorting will sort pens and highlighters properly therefore these could be taken by manufacturers for the recycling process.

**Literature Survey**

Vending machines are made for number of commercial purposes across the world. Most popular of those are beverage (especially soft drinks) and snack vending machines. Some machines contain a small store of products (Ex: Soda vending machine) while others make the item lively inside the machine and provide to the customer (Ex: Coffee vending machine). Our design is similar to type one explained above.

Based on the literature survey, most vending machines have the following methods in common.

- [1] *Coin changer:* This is the method used to validate the coins inserted by the customer and the sorting. Magnetic field, diode and sensors are used for this purpose.
  When the coin passes the magnetic field, it is disturbed which helps to identify the metal type and the amount of metal the coin is made of.

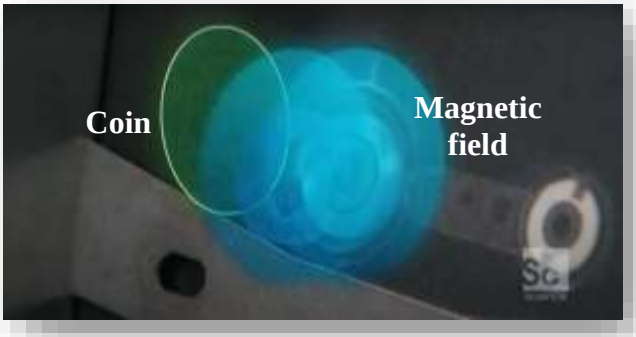


*Figure 1- Coin passing magnetic field*

  Thereafter it moves across two sets of diodes and its sensors. The time taken to move through these two sets of sensors will be counted to take the size of the coin.

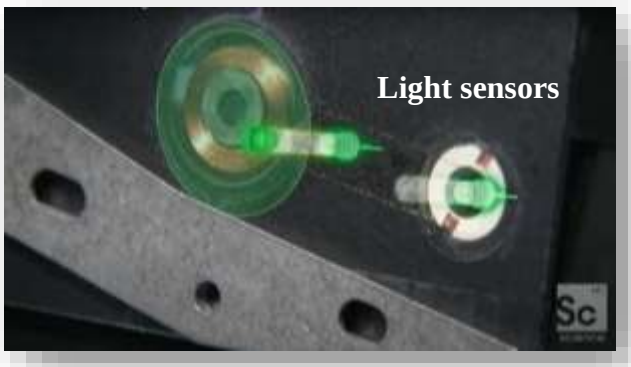


*Figure 2- Coin passing two sets of light sensors.*

  When the coins are identified as above, they are sorted using gates supported by motors. These gates are opened the respective coin to the respective place.

- *Feeder stacks:* Feeder stacks are used to store the products they are equipped with large wire spirals that holds the products. These are motor controlled which physically push forward until the product is fallen to the access area. [2]

*Figure 3 – Spiral of a vending machine*

- [3] *Drop sensors:* This is a recent feature added to the vending machines primarily to ensure the product is dispensed (Specially in snack vending machine). Snacks must pass through infrared light sensors once it is passed the machine confirms the transaction as complete. If not, it will give customer credit back to make another selection.


*Figure 4 – Drop sensors in snack vending machine*

Our pen and highlighter vending machine contains above techniques and it is less expensive implementation than the normal vending machine. Major difference of the machine is that this has not contain coin-based transaction instead disposing pens and highlighters could be used in exchange of new items. The validation of disposing items is done through Light sensors and Load cells.

Moreover, this machine has special feature when the disposing items are collected in the respective bins the bin level will be detected through capacitive sensors, and a message is sent to the manufacturers to clear the bins of the vending machine in each location. GSM module-based communication is essential in this stage.

## Aim and Objectives

***Aim:***

Design and develop a Pen and Highlighter Exchange Vending Machine to properly dispose pens/ highlighters used (specially) in schools and universities.

***Objectives:***

- To implement reward-based collection of disposing pens/highlighters in schools/universities.
- To increase the effectiveness of collecting disposable pens/highlighters by sorting them to separate bins.
- To reduce the harm that can cause by schools and universities to the environment by these tiny plastic items as these are the places where pens and highlighters are mostly used.
- To reduce the cost of manufacturing new pens and highlighters of stationary companies as they could take the collected disposed items for reusing.

## System Description

### ➢ Block Diagram

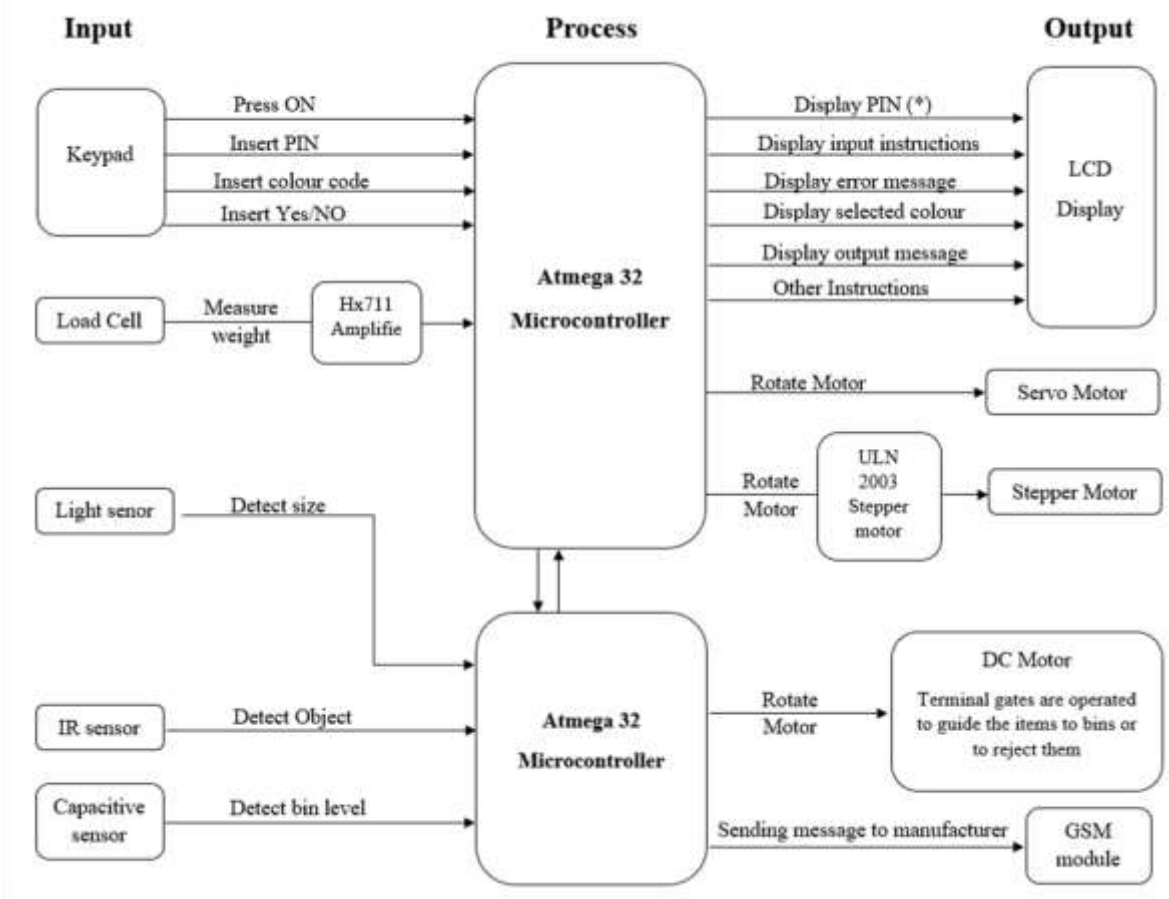


*Figure 5 – Main Block diagram*

### ➢ 3D View of The Pen and Highlighter Exchange Vending Machine

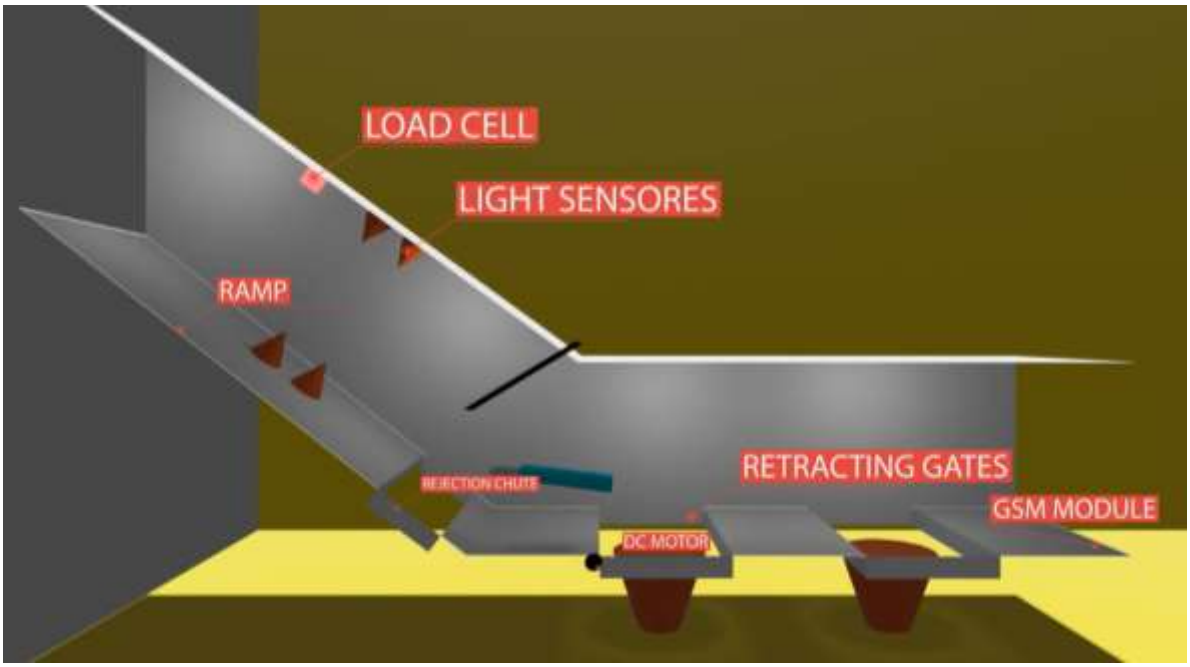


*Figure 6 – Inside view of the input section*

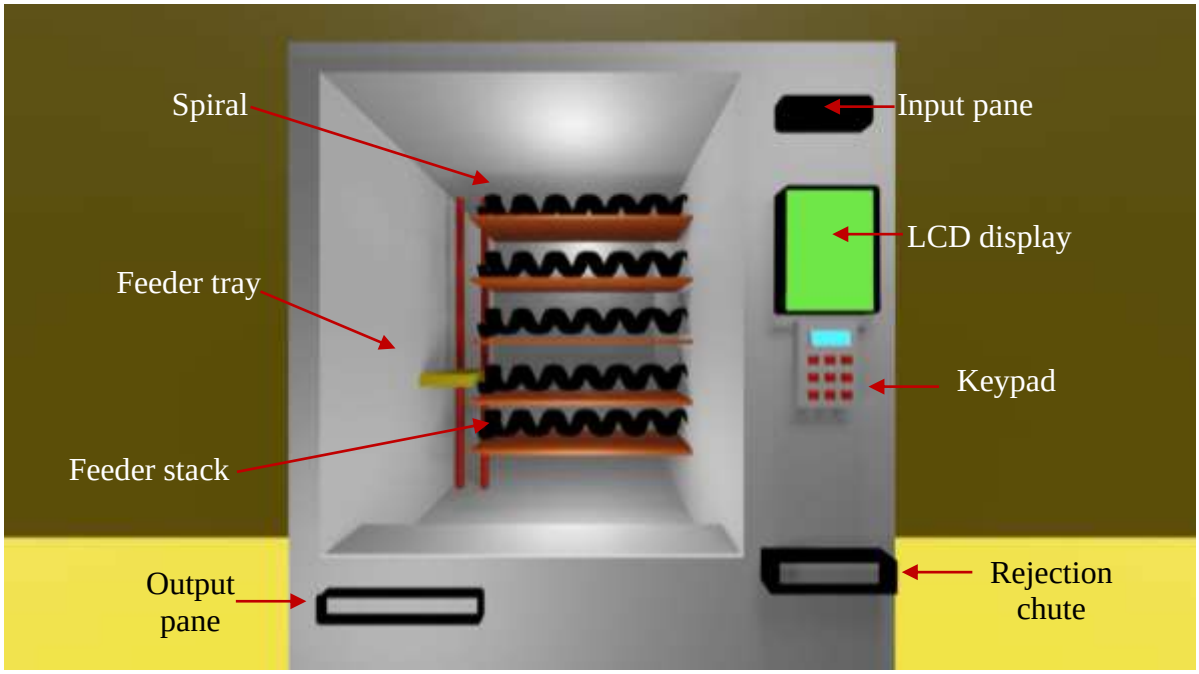


*Figure 7 – Outside view of the store section*

**Keypad and LDC Display**

Keypad is used as an input device to enter data to the machine such as PIN number, colour code and other yes/no commands. 4x4 matrix keypad is used for this purpose. 16x2 LCD display is used to display instructions and other important data to the consumer.

User may start the functions by entering the PIN number from the Keypad, this PIN number is used to identify the customer basically it will be the admission number of the student as this machine is introduced to schools and universities. This PIN number is displayed in Asterix form (*) when entering.

Thereafter input instructions will be displayed. Three disposing pens or 2 disposing highlighters are required to obtain a new item. Adhering to these users can insert disposing items from the input pane. These items are identified through an identification process.

When identification process is successful colour code can be entered. Ex: Code ‘P1’ to obtain blue pen. This colour code as well as output message (to take out the new item) will be displayed in the LCD display.

If entered items are incorrect (something other than pen or highlighter) error message will be displayed in the LCD.

**Database**

Additionally, this machine is having a database which contains past buying details of the consumers. Each user is identified by the PIN number. When inserted disposing items are correctly identified, but the number of inputs is more or less than the requirement (Ex: disposing 4 pens or 1 highlighter) these items can be recorded under each client pin number in the database. When the user returns this count will be added to their new inserts and a total count will be taken as the input.

Total Inputs of disposing items = Current inserts + Past inserts

**Weight sensor and Light sensor**

Items inserted through the input pane must be identified properly. For this purpose, weight and size of the item is measured. Normally a pen and highlighters have following parameters:

| | Pen | Highlighter |
|---|---|---|
| Weight | 5g - 10g | 12g - 28g |
| Size | 15cm (approx.) | 11cm – 15cm |

TAL221 miniature load cell and two light sensors are used to measure the weight and the size of the item respectively. Time taken to disturb the light sensor beams will be counted to take the size of the item.

Item should be within both parameter range for the identification to be successful. If identification failed (when error item is inserted) it will be sent back through the rejection chute. If successful number of pens or highlighters entered will be counted and further proceedings will happen. This identification helps to sort the items and direct them to the respective collection bin.

**DC motors**

Four DC motors are used to operate terminal gates in this solution. Rejection chute door will be opened only when the inserted item is incorrect (identification failed), Terminal door will be open when identification became successful therefore to direct the pen or

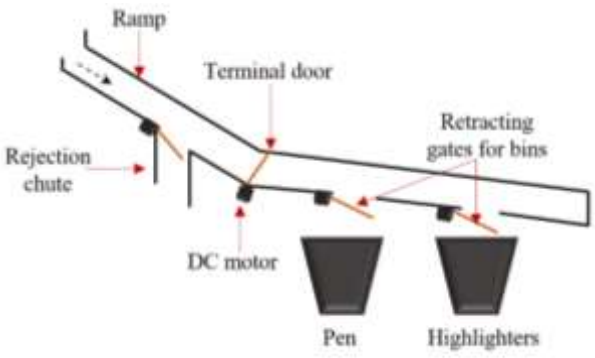


*Figure 8 – Terminal gates*

highlighter to the respective bin. Moreover, two retracting gates are placed above the pens bin and highlighters bin. If the item is a pen, door of the pens bin will open and vice versa. All these functions will be operated through DC motors**.**

**Servo Motors**

Store section of the machine has 5 racks (feeder stacks) to store new pens and highlighters. Each feeder stack has a spiral on it where each pen/ highlighter is placed in between the spiral. These spirals are attached to a servo motor~~s~~.The store contains ~~rack~~ racks of red, blue, and black pens with a code name of A1, A2, A3 respectively. Highlighters are with 2 colors and each rack is named as B1, B2.

*Figure 9 – Sample view of pens and highlighters arranged between spirals*

When the user selects the color code respective spiral will start functioning it will [5] push and rotate the spiral. When spiral is rotating it will release the pen/ highlighter from the spital and pushing the spiral will take the item out of the feeder stack. This movement will dispense the item to the feeder tray.

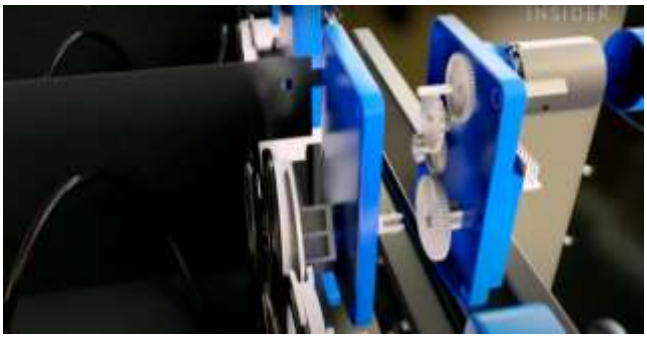

*Figure 10 – Servo motor rotation*

**Stepper motor**

A feeder tray is placed in a store section to collect the dispatching pens and highlighters from the feeder stacks. This tray moves vertically to the specific feeder stack according to the user's choice. For example, if user needs a blue pen and enters the code A1, feeder tray will move near to the rack which where blue pens are stored. When a pen is released by the movement of the spirals it will drop on to the feeder tray. Thereafter the tray will move downwards and stops near to the output pane.

28BYJ-48 unipolar stepper motor is used to move the feeder tray vertically. Stepper motor and the feeder tray is connected with a cable when motor rotates, the cable will rotate, and the tray will move up and down. This stepper motor could lift maximum weight of 100 or 200g as pens and highlighters are light items this motor is enough to up the feeder tray along with the item.

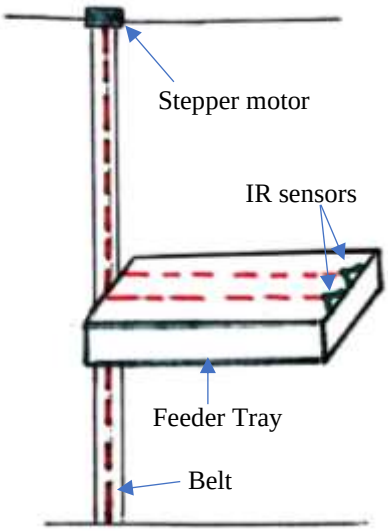


*Figure 11- Feeder Tray*

**IR sensor**

To ensure that the pen or highlighter has dispensed on to the feeder tray, two IR sensors are placed on it. When an item falls on to the tray, IR sensor beams are disturbed which confirms that the item has fallen to the tray. If this is not detected, then the process will repeat for twice.

**Capacitive sensors and GSM module**

As mentioned above disposing pens and highlighters are sorted and collected in two bins separately. When each bin is filled a capacitive sensor placed near the open end of the bin will detect it. Capacitive sensors work as a level detector as it has the ability to see through insulating materials such a wood and plastic.

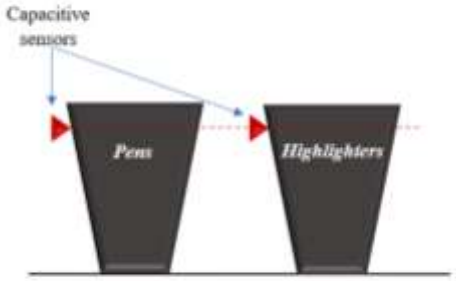


*Figure 12- Capacitive sensors*

When a capacitive sensor detects that a bin is filled, a text message is sent through a GSM module to the manufacturer, stating that pens/ highlighters bin of the specific vending machine is filled and need to be cleared. This will help the manufacturers to collect the items on time.

## Testing and Implementation

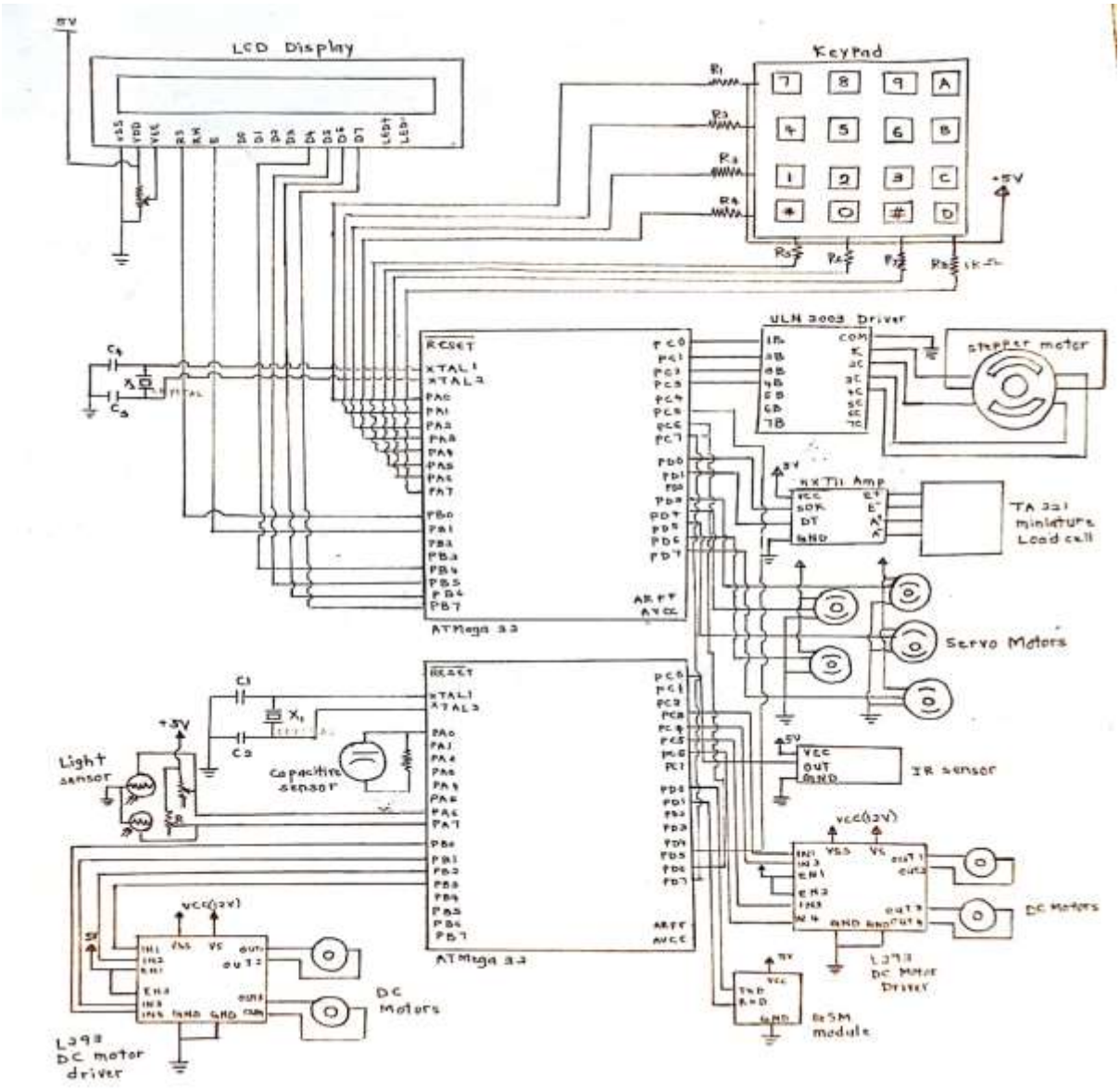


*Figure 13 – Main Circuit diagram*

## Action Plan for Remaining Work

This is the action plan for the remaining work and as a team we are planning to work according to this to achieve the aim of designing and developing the pen and highlighter vending machine to collect disposing pens and highlighters.

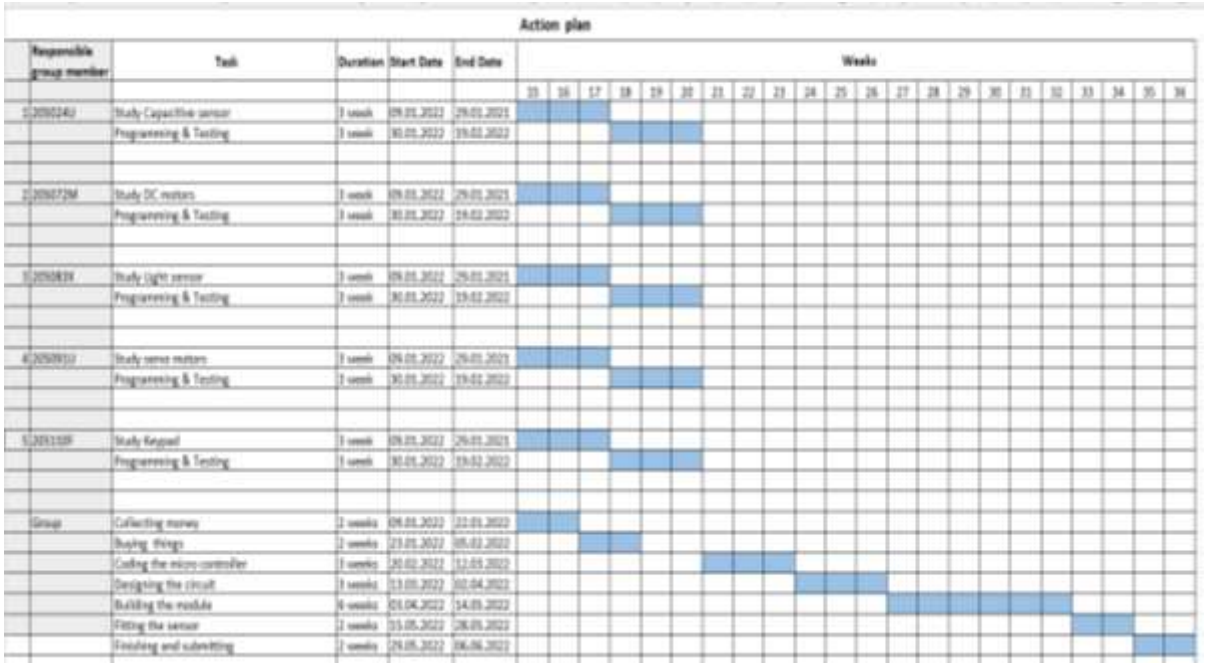


*Table 1 – Action Plan*

**Estimated Cost and Expenditure so far**

| Resource Requirement | Price per unit (LKR) | Quantity | Amount (LKR) |
|---|---|---|---|
| Light sensors | 420 | 2 | 840 |
| TAL221 Miniature Load cell | 450 | 1 | 450 |
| Capacitive sensor | 183 | 2 | 366 |
| IR sensors | 190 | 2 | 380 |
| Servo motors | 390 | 5 | 1950 |
| 28BYJ-48 Unipolar Stepper Motor | 1890 | 1 | 1890 |
| ULN 2003 Stepper motor driver | 130 | 1 | 130 |
| DC motors | 318 | 4 | 1272 |
| (4x4) Keypad | 160 | 1 | 160 |
| (16x2) LCD Display | 500 | 1 | 500 |
| SIM900A GSM module | 1820 | 1 | 1820 |
| Atmega 32 Microcontroller | 550 | 2 | 1100 |
| Metal wires | 300 | 1 | 300 |
| Cables | 500 | | 500 |
| Power supply (12V,20A) | 2200 | 1 | 2200 |
| Wood | 1000 | 6 | 6000 |
| Nails, Nuts, and bolts | 1000 | | 1000 |
| Bins | 245 | 2 | 490 |
| Breadboards | 230 | 2 | 460 |
| HX711 Amplifier | 250 | 1 | 250 |
| **Total** | | | **22058** |

*Table 2 – Cost estimation and expenditure so far*

**References**

[1] Youtu.be. 2009. *Deconstructed - The Coin Changer - How It Works?* [online] Available at: https://youtu.be/ayAml62fzOk [Accessed 29 November 2021].

[2] Madehow.com. 2021. *How vending machine is made - material, manufacture, history, used, parts, components, structure, product, industry, History*. [online] Available at: http://www.madehow.com/Volume-7/Vending-Machine.html [Accessed 29 November 2021].

[3] eVending. 2021. *iVend Vending Machine | Vending Machine Drop Sensor*. [online] Available at: https://www.evending.com/guaranteed-vend-sensors/ [Accessed 29 November 2021].

[4]"SIM900A GSM module Interfacing with AVR ATmega16/ATmega32 | AVR A..", *Electronicwings.com*, 2010. [Online]. Available: https://www.electronicwings.com/avr-atmega/sim900a-gsm-module-interfacing-with-atmega1632-. [Accessed: 25- Nov- 2021].

[5]"Modern vending machines", *Youtube.com*, 2015. [Online]. Available: https://www.youtube.com/watch?v=0Or-2miFkuA. [Accessed: 14- Dec- 2021].

# Appendix

## Individuals Contribution to the Project

**Name of the student:**

**GSM Module**

Being the leader of the group, I divided the work among the group members. According to the action plan I worked on the *GSM module*.

GSM or global system for mobile communication is a digital cellular system used for long distance communication. Main function of the GSM module in our machine is to send a text message to the stationary manufacturer, stating that disposing pens or highlighters bin is filled therefore, the disposing items can be collected and clear the bins.

According to the findings there are various GSM modules available in the market Ex: SIM900, SIM808, SIM800 and SIM700. So, I have chosen SIM900A module which has following features,[4]

- Send / receive SMS
- Make / receive voice calls
- Send / receive data over GPRS

- Communicate serially with the microcontrollers, PC using AT commands.


*Figure A1 – SIM 900A GSM module*

To communicate serially RS232 serial ports are used. RXD pin to receive data, TXD pin to transmit data. To connected to a cellular network, modem requires a SIM card provided by a cellular network. SIM card slot is available to hold this SIM. GSM antenna mainly used for wireless applications for easiness we are using the module with antenna.

Specifications:

- Chip power range 3.2V – 4.8V
- Low power consumption:1mA (sleep mode)
- AT command control
- Quad Band 850/900 MHz
- Baud Rate 9600bps
- Antenna interface circuit (SMA bend female port)
- SIM card circuit (flip SIM slot)

Sri Lankan quad band rate or the frequency band rate which mobile phones supports is 900 / 1800 MHz, therefore this selected module is compatible with Sri Lankan GSM frequency band.

**Name of the student:**

**Load Cell**

One of the Components allocated for me in this project is the *weight sensor*. In our project we are using a load cell to measure the weight of pens and highlighters that user inputs.

A load cell usually comprises 4 strain gauges. Its primary use is to measure force or strain. The resistance of a strain gauge, change when a force is applied. Load cell strain gauge will deform when a pressure is applied, in our machine when the pen or highlighter drops to the platform a pressure will generate. When this strain gauge is deforming it will generate an electrical signal.

*Figure A2 -TAL221 Miniature load cell*

In our machine we are using a platform to catch the pen or highlighter. Load cell is calibrated to zero including the weight of the platform. By calibrating to zero we can ensure accurate readings.

In normal vending machines which use coins, weight sensor is used to measure the weight of the coin and direct it to the correct collection bin. In our vending machine we can use weight sensors to measure the weights of the pens and highlighters. Pens weight in a range of 5g to 10g depending on the local brands of the pens available. A highlighter weight in a range of 12g to 28g. The load cell we are using is TAL221 miniature load cell. This load cell can measure up to 100g. Depending on that weight we measured using the weight sensor or load cell we can direct the pens to the pen's collection bin and highlighters to the highlighter's collection bin. If someone input something other than a pen or highlighter then the weight will not match with the previously stated weights. It will return to the customer through the rejection chute.

Specifications:

- Voltage: 6V

*HX711 amplifier*

The electrical signals generated are in millivolts, so they need to be further amplified for that we can use HX711 weighing sensor module. This HX711 module amplifies the low electric output of load cells. This amplifier and the load cell will be wired using four wires.

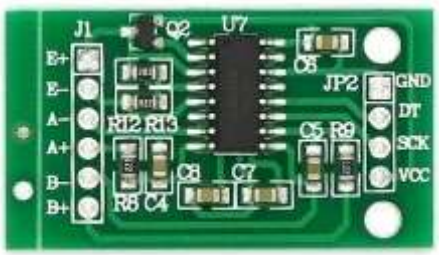


*Figure A3 -HX711 Amplifier*

- Red wire and E+
- Black wire and E-
- White wire and A-

- Green wire and A+

Specifications:

- Current: normal operation < 1.5mA
- Voltage: Operation voltage 5V
- Operation temperature range: -40 ~ +85℃

Load cell is connecting to the HX711 amplifier. HX711 amplifier is connecting to the microcontroller.

**Name of the student:**

**IR Sensor**

According to the action plan, I'm currently studying about the *IR sensor*. IR sensor can detect the motion.

Here we are using an IR sensor to detect the object. To ensure the item has been dispensed IR sensor on the feeder tray will detect the object

First, I found the IR sensor/obstacle sensor module that we needed for this machine. This sensor module has many features.

- 5V DC operating voltage
- I/ 0 pins are 5v and 3.3v compliant
- Adjustable sensing range
- 20mA supply current


*Figure A4 – IR Sensor*

The sensor has 3 pins,

1. VCC – Power supply 5v
2. GND – Ground
3. OUT – Digital output to Microcontroller input

In the vending machine, when stepper motor rotates feeder tray will move near to the correct stack and collect the requested item. To confirm that the item has been dispensed properly to the tray, IR sensor on the feeder tray will detect the object. If not, the process will happen again.

It is a very special sensor that can use to detect the motion. This process will repeat twice if the item has not dispensed properly.

**Name of the student:**

**Stepper Motor**

According to the action plan I worked on *stepper motor*.

Stepper motor is a special DC motor which rotates discrete angular steps in response to a programmed sequence of the input pulses.

I am using stepper motor here to control the movement of feeder tray. Feeder tray must move(vertically) near to the specific color track depending on user input's color and the type. If user inputs blue color pen feeder tray must move near to the blue color pen's track. If user inputs highlighter, it must move near to highlighter's track. Cable wires will be connected with stepper motor and feeder tray. So, by that stepper motor can be able to control the feeder tray's movement.

Each pen's weight is 0.01kg and each highlighter's weight is about 0.028kg. So based on my calculation feeder tray must lift maximum weight about 100g or 200g.So here I should consider about the torque of the stepper motor.

Variable reluctant stepper motor, permanent magnet stepper motor, hybrid stepper motor are the types of stepper motor. In these types I decided to choose hybrid stepper motor because only that kind of stepper motor is available in the Market. Other types of stepper motors are rare in the Market. So, I decided to use 28-BYJ-48 unipolar stepper motor. Because the maximum torque of 5V unipolar motor in 2ms delay is 910g. I will use only one stepper motor for this action.

*Figure A5 - 28BYJ-48 unipolar stepper motor*

I will make coding like 2 phase excitations. So, from that I can achieve step angle like 90, 180,270,360 and I need to rotate the motor in clockwise and anti-clockwise direction.
These are the features:

- Maximum voltage is 5V.

- Maximum current is 240mA.
- Small, inexpensive, and high-quality geared stepper motor.
- 5 wires and 32 teeth.
- 4-phase stepper motor.

*Figure A6 – ULN2003 stepper motor driver*

The 28BYJ-48 stepper Motor and ULN2003 stepper motor driver is a widely popular combination because of the stability and reliability of the system. ULN2003 stepper motor driver is used with this stepper motor.

These are the features:

- It is 16 pin IC
- It loads up to 500mA
- It loads up to 50V
- Popular combination for 28BYJ-48 unipolar stepper motor

**Name of the student:**

**Keypad**

In our project, I have studied about both hardware and software components. I was responsible for implementing the keypad for our machine. After referring various types of keypads, I choose the 4×4 matrix keypad because it suits for the functions of our project.

*Figure A7 – 4x4 Keypad module*

Specifications of 4x4 Keypad:

- Maximum voltage 24V
- Maximum current 30mA
- Operating temperature 0°C to + 50°C
- Ultra-thin design
- Easy to interface any micro controller
- Excellent prize

So, this type of reasons I choose 4×4 matrix keypad in our project.

I studied the inner organization of the keypad which I could get a better idea about how it works, how it can be implemented with the Atmega 32.and how it develops the code according to our requirement. The working of the 4×4 matrix 2 ways,

1.Rows are input column are output

2.Column are input rows are output

In our project I am going to connect keypad to microcontroller. I am going to connect eight pins of keypad to eight pins (PortA0-PortA7) of controller.

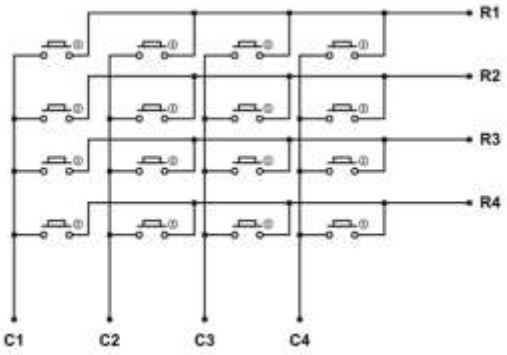


*Figure A8 –Internal structure of Keypad module*

Registers are those which connect the lines. The values of register 1kΩ.I have connected each register to each column and rows and for start we power four pins of controller. For powering for rows of keypad at this time the other four pins are taken as input. By this we get the button pressed by the user. This matrix addresses are directed to corresponding number, and this number shown on LCD.