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Smart City: Implementing a Clean Environment as aPanacea for Healthy Living

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Abstract

Rapid increase in population, has led to the improper waste management in cities resulting in increased pests and spreading of diseases. Nowadays, the Garbage Collecting Vehicle (GCV) collects the waste once in a week. So, the problem is overflowing of wastages on the roads. Hence, to overcome this limitation, this project was born. The aim of this project work is to design and construct a Smart Waste Bin, a system capable of detecting the presence of human and automatically open the bin for disposal, when the bin is full it prevents users from accessing the bin and automatically sends an SMS notification to appropriate waste disposal agency. In this design, Automatic control of the waste bin was achieved by using Ultrasonic sensors to sense the trash level, PIR sensor to detect the presence of human, SIM800L to send SMS notifications, an electromagnetic lock to keep the bin in lock position and a microcontroller programmed to compute and monitor the entire system. The system was able to successfully detect the level of trash, open the lid when human presence is sensed within, close the lid when the bin is filled, send an SMS alert to waste disposal agency, and successfully display the system happenings on an LCD screen. The design and construction of the "smart waste bin," using PIC16F887 microcontroller was successfully achieved, and it is a better alternative to the manual disposal of waste that is typical of the modern-day home. It is cheap, reliable, and flexible.

Keywords: Garbage, Garbage Collecting Vehicle, SMS Alert, Smart Waste Bin.

1. Introduction

During the last century the world population has been quadrupled, and there have been major relocations from rural to urban areas. Today 50% of the world's population inhabit cities and this number is expected to reach 70% by 2050 (Constantino. 2014). As the World's population shift towards urban areas, cities have been facing complex problems in resource management, health, pollution, traffic, and waste management (Chourabiet al., 2012).

The generation and disposal of waste in large quantities has created a greater concern over time for the world which is adversely affecting the human lives and environmental conditions(Eason et al.2021).

Wastes grow with population growth of any country. Segregation of waste is important for proper disposal of vast amount of garbage modern society produces in an environmentally sensible mode. People became adapted to tossing things away and never realize the consequences of their action. The common method of disposal of the

industrial waste is by uncontrolled and unplanned, and exposed dumping at the river sites and open areas. This method is injurious to plants, human health, and animal life(Suryawanshi et al., 2018).

Many a time, garbage's are left unattended and unnoticed for a longer period. These wastes include left over wastes from the public places like markets, industries etc. A good example of an uncontrolled waste bin in a public place is shown in Fig.1. In the modern era of technology driven society, we are in need to implement a system to automate the process of cleaning away the garbage. To further proceed with the process of automation, we suggest and implement garbage bins designed to help us with the technology. These smart bins can be implemented on a large scale and the traditional dustbins may be removed so that it can avoid dumped wastes on the roads. The garbage level in the bins can be easily monitored and kept informed periodically. The idea behind implementing this is to avoid pollution and dangerous hazards caused due to the garbage. The system implements the smart technology with the help of ultrasonic sensors placed over the bins to continuously detect the wastes that are being put inside the bins. The Arduino kit and GSM are used to send notifications to the registered authorities to enable them to initiate and complete the process of cleaning.

Figure 1. Uncontrolled Trash Bin

In the Paper proposed by Sandeep, a garbage disposal system is designed to monitor the garbage bins and inform the disposal authority about the garbage level collected through a web page. The data in the webpage is filtered and sent to the garbage collecting vehicles. The system uses ultrasonic sensors placed over the bins to detect the garbage level and compare it with the garbage bins depth. The system is implemented with the Arduino processor and LCD Screen which is used to display the status of the bins [Glossary of Environment Statistics].

Kanchan Mahajan., has proposed waste bin monitoring system using integrated technologies. Zigbee and Global System for Mobile Communication (GSM) are the best combinations used in the project. The system is implemented with the help of ARM 7 sensor. This controller passes a signal to the driver of the garbage truck informing about the location of the bins and those that needs immediate attention, by the use of GSM module.

Daniel et al., 2012 has proposed garbage bin monitoring system for dry solid wastes. This method implies that the dustbins interface with the Arduino, possessing weight sensors which collect information regarding the current status of refuse. All the data carried out are passed on to the application software of the system. The pressure sensor detects the level of garbage. Whenever the garbage level reaches threshold, the sensor notifies the Arduino Uno. The data from Arduino is uploaded to the cloud storage and the push notification is then sent to the android application running in the registered android mobile (Navghane et al., 2020).

Nalavadi et al., 2019, proposed IOT based smart garbage and waste collection bin. In this system, the waste bins are connected to a microcontroller with wireless IR system. The web page carries information about the status of the garbage through Wi-Fi. IR sensor is used to give status about different levels of garbage in the bin. The Weight sensor gets activated on crossing the threshold level. Their proposed work is to use sensor-based system which is inexpensive rather than to use expensive smart bins. Also, they use 3 IR sensors to indicate each level in dustbin and they have a wi-fi router to receive the instant status of the bin (Navghane et al., 2020).

In another paper, ultrasonic proximity sensor, inductive sensor, raspberry pi, GSM technology and artificial intelligence are involved in the process of cleaning the wastes. IR proximity sensors and load sensors are used to sense the load and its level of waste generated. When the threshold is reached, a signal is generated which is then transmitted to the RF transmitter. MATLAB based GUI are used. Ultrasonic sensors here detect the level of garbage and sends messages to the control room. GUI is used to display the location of the dustbin, status, date, and time of garbage collection (Prakashand Prabhu., 2012).

PG research institute has proposed garbage collection management system. GSM, Zigbee, PIC-controller, ultrasonic sensor, moisture sensors are used. Gas sensor have provided an indication to the cleaning authority and needs urgent attention. Here, the sensors placed at low level are used to measure the level of garbage in the dustbin. RF technology at lower section transmits the bin status to next section where zigbee and gsm are placed. Zigbee here is used for long distance communication where gsm is used for sending sms to the cleaner to clean the dustbin. Garbage level sensing process is performed by level sensor, some moist generated by the dustbin is sensed by the moist sensor and the toxic gases generated by the garbage is detected by the gas sensors (Anton, 2003).

Ranchanhas proposed waste bin monitoring system using IOT. In this proposal, Zigbee and Global System for Mobile Communication are the technologies used. The sensors are placed in the garbage bins at the public places and the threshold level indication is sent to the ARM7 controller. The controller will give the indication to the driver of garbage collection truck as to which garbage bin is completely filled and needs urgent attention. ARM7 will give indication by sending messages using GSM technology. Suchit., has proposed RFID based solid waste disposal. The use of RFID, GPS, GIS and GSM technologies are involved in the garbage monitoring. It consists of RFID tags mounted on containers, RFID reader mounted on trucks along with GPS for location tracking and GSM module for wireless communication. It is a web-based application (GSM Global system for Mobile Communications., 2014).

Bitan et al (2018), designed and constructed a smart waste monitoring system by interfacing it to the web using Wi-Fi technology.

The design designates a technique in which the garbage level could be checked at regular intervals, which would prevent the undesirable overflow of the bin. This system monitors the garbage bins and informs about the level of garbage collected in the garbage bins. For this, the system uses ultrasonic sensors placed over the bins to detect the garbage level and compare it with the garbage bins‟ depth. The system makes use of Arduino family microcontroller and a Wi-Fi modem for sending data to webserver that monitors the garbage levels. Programming in the Arduino UNO is done in such a way that once a particular level of filling is sensed, information message is sent requesting a clean-up.(Bitan et al., 2018).

Nagaruja et al., 2017, presented a smart dustbin for economic growth built on a microcontroller-based platform of Arduino Uno board, which is interfaced with GSM modem and Ultrasonic sensor. Ultrasonic sensor was placed at the top of the dustbin which will measure the status of the dustbin. The threshold status is set at 10cm. Arduino was programmed in such a way that when the dustbin is being filled, the remaining height from the threshold height will be displayed and once the garbage reaches the threshold level, ultrasonic sensor triggers the GSM modem which continuously alert the required authority until the garbage in the dustbin is squashed. Once the dustbin is squashed, people can reuse the dustbin(Nagaraju et al., 2017).

This project presents an alternative in managing domestic waste especially in residential areas via a smart garbage monitoring system, which is developed based on Arduino Uno. This system will automatically monitor the garbage level at each bin and will alert the waste collation management in the case where the bins are almost full.

2. Methodology

The method of automatic control of the smart waste bin employed in this project consists majorly of the following units:

- A sensing unit for monitoring trash level in the bin,
- A controlling unit which acts as the brain for the control system and is responsible for doing the core work in the control of the system,
- An indicating unit which shows the level of trash and act as a visual aid to user in the trash bin,
- A switching unit that simply triggers the servo motor ON and OFF, depending on the signal received from the microcontroller to OPEN or CLOSE the bin,
- A GSM modem to send and receive SMS to/from the appropriate waste disposal body,
- A PIR sensor unit to detect the presence of coming human close to the bin for waste disposal.

The project was designed and implemented using the top to bottom approach method.

The block diagram is shown in Figure 2

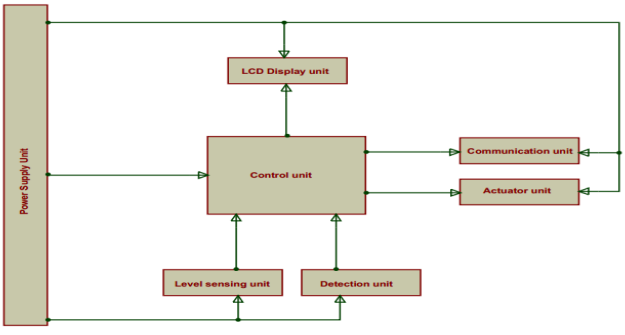

Figure 2. Block Diagram of the System

2.1Choice of Transformer

A 220V/12V step-down transformer designated as TR_1 in the circuit diagram, was chosen for the design of the power supply.

The turns-ratio of the transformer is given by;

$$N = \frac{E_p}{E_s} = \frac{N_p}{N_s} = \frac{I_p}{I_s} \quad (1)$$

Where;

N = transformer turn ratio. For this circuit the design specification is as follows;

Rated Primary Voltage, E_p = 220VAC

Rated Secondary voltage, E_s = 12VAC

Primary turn, Np

Secondary turn, Ns

Rated Secondary current, I_s = 1A

Primary current, $I_p = \frac{E_p \times I_s}{E_s} = \frac{220 \times 1}{12} = 18.33A \quad (2)$

Peak Primary voltage, E_p peak = $E_p\sqrt{2}$

E_p peak = $220\sqrt{2}$

E_p peak = 311.13VAC

Peak Secondary voltage, E_s peak = E_p peak $\times (\frac{E_s}{E_p})$

E_s peak = $311.13 \times (\frac{12}{220})$ (3)

E_s peak = 13.67V

Therefore, the maximum peak voltage supplied by the transformer is approximately 14VAC. Which is quite suitable for the circuit requirement of 12V and 5V respectively.

The other sections are choice of bridge rectifier, choice of capacitor filter, choice of line voltage regulator and choice of LCD display.

2.1.2 LEVEL SENSING UNIT

The level sensing unit is composed of an ultrasonic sensor and is used for monitoring the level of trash in the bin. The output from the ultrasonic sensor is fed into the digital input pin of the microcontroller for processing as shown in fig 4. Its capability to sense object within a range of 2cm – 400cm makes it quite suitable for the project.

2.1.1 Choice of Detection Unit

The detection unit is composed of an ultrasonic sensor, which is chosen because it has a typical supply voltage of 5V – 12V, current consumption is minimum, within the range of 100uA – 1mA and has a sensitivity range of up to 400cm (4 meter), which is used to obtain the desired range of values. The output of the echo of sensor can be easily fed into the digital input pin of the PIC microcontroller as shown in fig. 3.

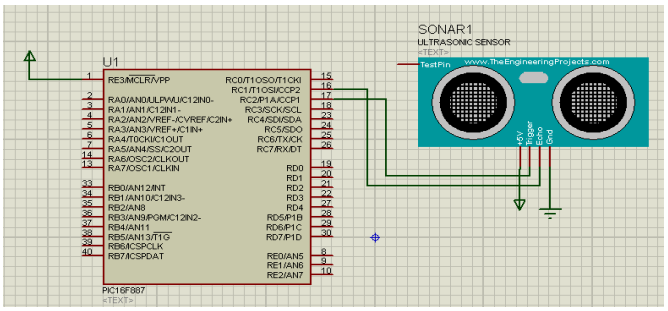

Figure 3. Detection circuit

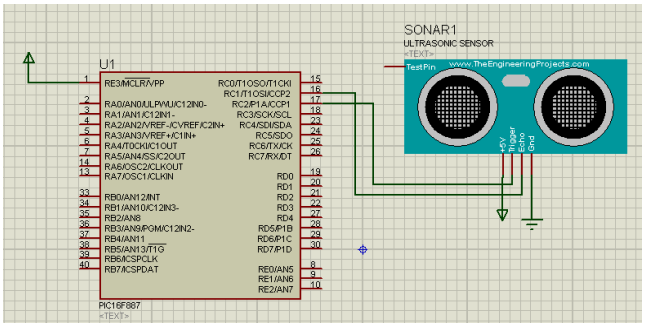

Figure 4. Level Sensing Circuit

2.1.3 Control Unit

The control unit is the backbone of the system. It consists of a microcontroller which is responsible

for monitoring and integrating the system to perform as desired, display the status on the LCD, sense the level of trash in the bin, detect the presence of human being and sends an SMS to the appropriate authority when bin is filled.

The microcontroller chosen for this project was the PIC16F887. It is an 8-bit microcontroller with low power consumption, digital input/output and in-built ADC. The PIC16F887 comes in a single chip which consists of Microprocessor. 14 channel analog pins, 13 digital pins, 32KB flash memory with read-while-write capabilities, 256bytes EEPROM memory, 368 bytes RAM memory, 8K ROM memory in flash technology, 35 general purpose input/output lines, 32 general purpose working registers, three flexible timer/counters with compare modes, internal and external interrupts, serial programmable USART, a byte-oriented 2-wire serial interface, SPI serial port, 12C mode, 14-channel 10-bit Analog to Digital converter (ADC), programmable timer with internal oscillator, and 8MHz to 31KHz software selectable frequency, power saving sleep mode. It operates between voltages of 2.0V – 5.5V and operating frequency of 0 – 20MHz.

Figure 5 shows the basic connection for proper operation of the PIC16F887.

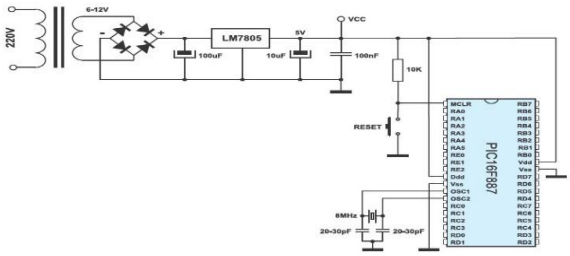

Figure 5: Basic Connections of the PIC16F887 Microcontroller.

The pins used for the hardware microcontroller interface are tabulated in table 1;

Table 1: Table of Microcontroller Pin Selection

Hardware	Number of pins required for interface	Pins used for interface
GSM output	2 pins	RC6
Door mechanism	2 pins	RD6 - RD7
Level sensing circuit	2	RC1 – RC2
Detection circuit	1	RD5
LCD display	6 pins	RB0 - RB5

An IC socket is used as a placeholder for the microcontroller to allow safe removal and insertion of the microcontroller and prevent damage from heat during soldering to the Vero board.

2.1.4 Software Implementation

The program written for the microcontroller functions by executing instructions in a specified order, thus the program instructions must be organized in the desired order to avoid improper co-ordination of events during operation. The flowchart given in figure 6 shows the core instructions in the program and the order it will be executed by the microcontroller.

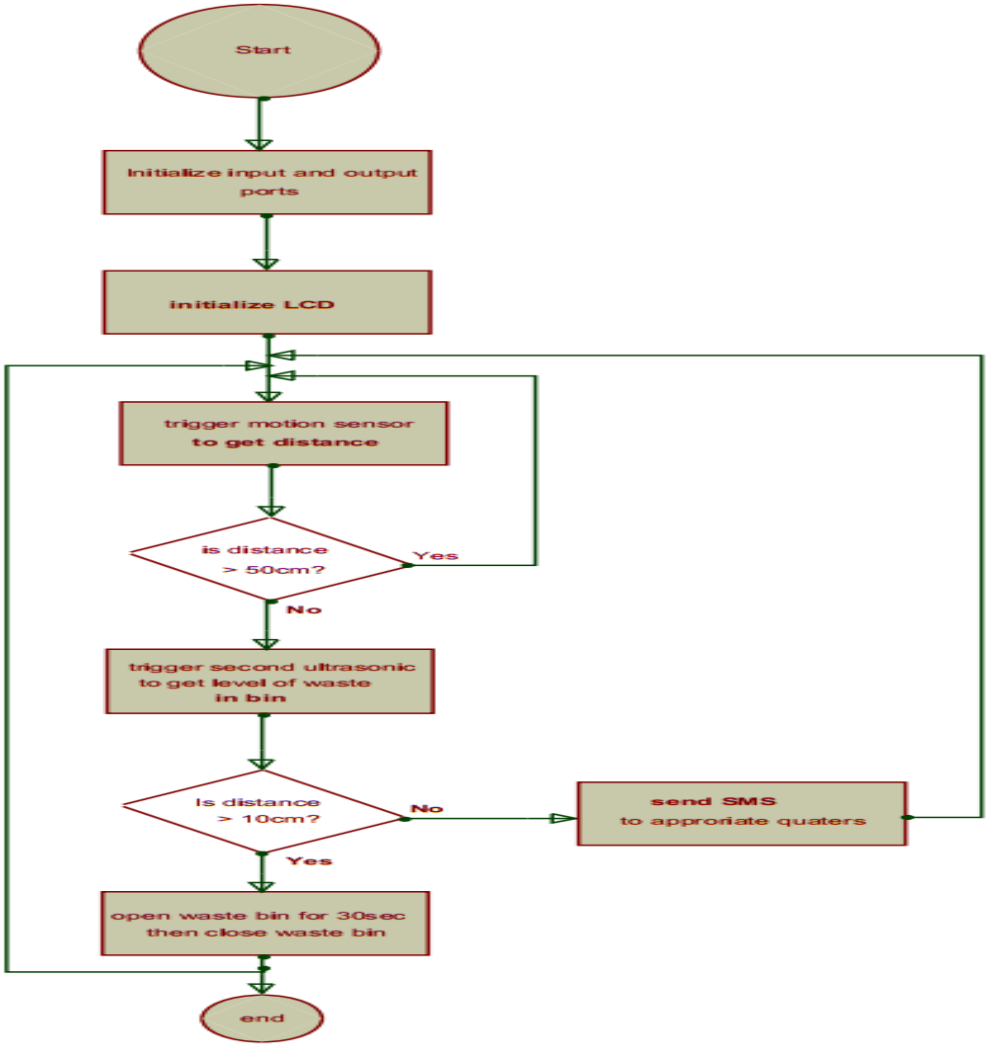

Figure 6: Flow Chart of Smart Waste Bin

2.1.5 Mode of Operation

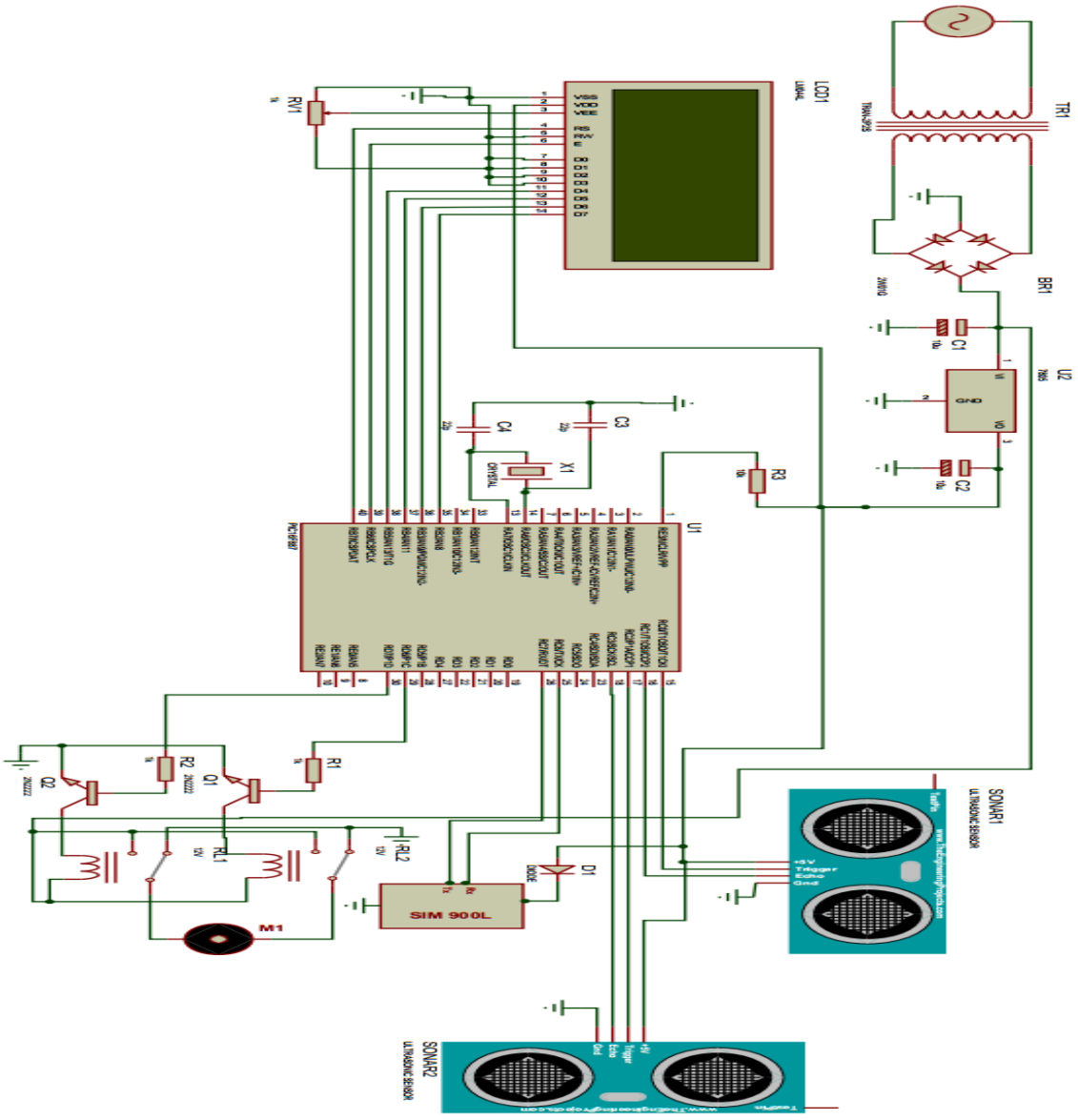

Figure 7. Circuit Diagram of Smart Waste Bin

Figure 7 is a complete circuit diagram of the smart waste bin. The system monitors the level of trash in the bin, open the bin lid automatically when it detects the presence of human in a close range and sends an SMS alert whenever the bin filled and ensures the bin remains close until it has been disposed.

The system is connected to AC mains which has a voltage of 220VAC, which was then stepped down by a step-down transformer, passed through a rectifier to produce a DC voltage and then passed

through the filtering circuit to remove ripples, and finally, passed to a voltage regulator to produce a constant DC voltage of 5 volts. This 5V DC is then fed to power up the LCD, Ultrasonic sensors, GSM modem and to the microcontroller, while 12V is directly fed to the motor driver circuit.

LCD is connected to RB2 – RB7, GSM modem is connected to RC6 – RC7, ultrasonic for motion sensor is connected to RC2 – RC3, Ultrasonic sensor is connected to RC0 – RC1 and the H-bridge motor door mechanism circuit, which is made up of complementary pair of NPN transistor is connected to RD6 – RD7 of microcontroller, consists of RL1, RL2, R1, R2, Q1 and Q2.

The system design is such a way that when power is supplied to the unit, the ultrasonic sensor connected to RC3 sends an infrared wave around the system. When the ultrasonic for motion sensing senses the presence of human close to the bin, it sends a command to the control unit, which triggers the ultrasonic sensor connected to RC0 and RC1 to check the level of the bin. If the bin is not filled the control system processes this signal and triggers the motor (M1) to rotate in a clockwise direction by sending a logic 0V to the H-bridge circuit through R1, which makes Q1 to conduct and after about 5secs the microcontroller sends 5V logic to the H-bridge circuit through R2 making Q2 to conduct indicating a polarity reversal to rotate the motor in an anticlockwise direction and the bin closes. If the bin is filled up and a user tries to access the bin, a visual warning will display on the liquid crystal display (LCD) informing the user that the bin is not accessible and the bin will remain lock, while an SMS alert notification will be sent to the appropriate authority for disposal of the bin via SIM 900 module connected to RC6 and RC7 of microcontroller.

2.1.6 Constructed System

The position of the Vero board, various sensor nodes and power supply unit were marked on the base of the plastic casing. Holes were bored through the plastic base with the aid of a hand drill. The sensors, door mechanism, power supply, and LCD were then secured to the plastic base using screws, bolts and washers. And the LCD was fastened to the base of the plastic cover. The finished hardware is seen in Figure 8 and 9.

Figure 8. Pictorial View of the Fabricated Work

Figure 9. Open View of Smart Waste Bin

3. Results and Results Analysis

After completing the various test, like continuity test, voltage test and current test, the whole units were then integrated together to make up the complete system and the SMS notification is as shown in Fig 10

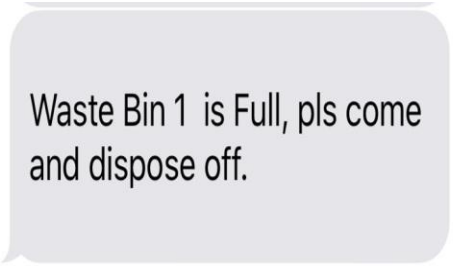

Fig 10: SMS notification when waste bin is full.

- **Measurement Test Results**

The bin level was tested separately before it was integrated into the whole system. The ultrasonic level sensor was tested using the Arduino IDE to determine the accuracy of its distance measurements. An Arduino IDE displayed the distance in centimeters (cm) through the serial monitor from the observing computer. The system as a whole was finally tested with a prototype or experimental bin. The bin container made of plastic material, has a top internal diameter of 50cm and its depth, as measured by the ultrasonic sensor from its sensing position on top of the tank is also 50 cm. From the program, the predetermined minimum and maximum water levels for the trash bin as measured by the sensor were given as;

Minimum level = 50cm

Maximum level = 4cm

Level difference = 50cm – 4cm = 46cm

Table 2 Compares Between Smart Waste Bin and the Conventional Waste Bin

Digital trash bin	Conventional trash bin
It's easier to manage based as it closes automatically when bin is filled up as measured by the level sensor	Its cumbersome to manage as it does not close after trash bin is filled up
The appropriate authorities get alerted immediately it filled notwithstanding the day and time (i.e., even if it gets filled in a day)	Trash bin gets filled up within Eight (8) days before the appropriate authorities comes for disposal
It notifies the appropriate agency when bin is filled up	It does no form of notification
Trash is less accessible	Animals can easily

to animals	access it
It keeps the environment clean	The environment is usually messed up if not properly handled
Disposal time for smart waste bin is 24 hours because of alert received.	Disposal time for conventional waste bin is 192 hours (8 days) when the truck arrives.

Conclusion

This study presents the design of a smart waste bin implemented on a PIC Microcontroller, which is responsible for monitoring and integrating the system to perform as desired, display the status on the LCD, sense the level of trash in the bin, detect the presence of human being and sends an SMS to the appropriate authority when bin is filled. This when implemented makes a city clean and smart.

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