Design and Construction of Solar Powered Automatic Wastebin

Isah Abubakar Ndakara[1], Odianosen Ehimare Okosun [2], Rahimat Oyiza Yakubu [3], Isiyaku Saleh[4], Abdulazeez Luqman O[5]
[1, 2,4,5]*Department of Electrical and Electronic Engineering, Federal University of Technology, Minna, Nigeria.*
[3]*Engineering Works and Services, Ajaokuta Steel Company Limited, Kogi, Nigeria.*
[1]is.abubakar@futminna.edu.ng, [2]o.okosun@futminna.edu.ng, [3]rahimayakubu@gmail.com, [4]isiyaku.saleh@futminna.edu.ng & [5]luqmanomeiza@gmail.com

***Abstract*— The vast increase in quantity and types of solid and poisonous waste due to economic growth, population growth and industrial pollution specifically in Nigeria, is becoming a problem. Providing a solution to this challenge is the motivation behind this research work. This paper presents the design and construction of solar powered automatic wastebin, in other to ensure effective and sustainable management of waste. The control system consists of a servomotor, ultrasonic sensor, Relay and an ATMEGA328 microcontroller programmed in C-Language. The system was designed to intelligently senses a situation where the user gets closer via the ultrasonic sensor. A servomotor is triggered to open in the sense that the waste can be trapped as soon as it receives a signal from the microcontroller. It remains open for 4 minutes and closes again. In a situation where the user remains, it takes maximum of 3 seconds to reactivate to its initial state. The results obtained from the test carried out on the system shows that the system open and closes at the required state thereby ensuring proper management and minimization of risks to the health and safety of the populace.**

Keywords— *Automatic; Microcontroller; Waste bin; Renewable Energy; Solar.*

I. INTRODUCTION

Environmental protection has become an important concern worldwide [3],[4]. This has urged individual the present era to have greater concern and management of waste. Waste are materials or substances either solid or liquid which are discarded or which are not useful and are also worthless examples are household trash, refuse, hazardous material or body water (excrete, urine etc.) [5],[6]. Waste can also be defined as materials placed in a particular place where they are not wanted. All these waste are being disposed temporarily into waste bin and set aside for permanent disposal [7],[8]. Disposing of waste has many environmental hazard to human and can cause serious health challenges.

Solid waste dumps are drastically contaminating the environmental conditions in developing countries. Negative environmental impacts from poor solid waste dumping can be easily observed in most part of developing world [9],[10]. In Pakistan, due to a lack of improper planning and funding, the solid waste management issue is becoming worse day by day. To outline some of the main causes of improper solid waste management in under developing countries, Rawalpindi city taken as a case study [20],[21]. This city is facing abruptly poor solid waste management crises as a result of high increase in industrialization, urbanization and inadequate funding. Poor habit of solid waste dumps is spreading different diseases in the study area [1]. It is investigated during the research that due to increase growth population, high increase in solid waste generation rate, lack of adequate management, lack of logistic implementation and funding, the solid waste management systems of Rawalpindi were not working effectively and efficiently [8], [9],[10], [11],[22]. The major causes for the inadequate municipal solid waste management systems in Rawalpindi are the unexpected invasion to the city, harsh weather conditions, lack of social awareness/community involvement, improper resources including inadequate equipment and insufficient funds[1][2]. An inefficient municipal solid waste management system may cause serious negative environmental impacts like infectious diseases, pollution of land and water[20],[21].

Improper municipal solid waste (MSW) disposal and management leads to all types of pollution air, soil, and water. Wrong dumping of wastes contaminates surface and underground water supplies. In urban areas, MSW clogs drains, causing stagnant water for insect breeding and floods during rainy period[17],[18],[19],[15],[16]. Uncontrolled burning of MSW and improper burning contributes significantly to urban air pollution [19],[20]. Greenhouse gases are formed from the decomposition of organic wastes on lands and untreated liquid pollutes surrounding soil and water bodies. Health and safety issues also arise from inadequate waste management [13],[14]. In the sense that insect and rodent vectors are attracted to the location of the waste bin and can spread diseases such as cholera and laser fever[11],[12]

Taking Federal University of Technology Minna (FUTMINNA) E-center as a case study, how is this our area of focus? Students are being supplied rough sheets so as to ease their solving or workings during examination or test as the case may be, they are in turn expected to drop it in the waste bin for proper waste disposal and management.

II. Review of Related Works

The work done by [19] on sensor nodes attached to an Arduino board based control station, that uses a Global System for Mobile Communication (GSM) module to send the sensor nodes data by Short Message Service) SMS to the garbage collecting vehicle and to a server hosting web application by a Wi-Fi connection. The sensor nodes of the smart bins relied on the ultrasonic sensor to sense the fullness percentage according to pre-calculated bin depth. Moreover, a Global Positioning System) GPS module is used to get the bin location. The GPS module and the ultrasonic sensor were controlled by Amica R2 NodeMCU microcontroller board which has a built-in Wi-Fi module, that is used to connect to the control station. However, the author did not consider powering the device with a solar panel in case of power outage.

Research on wireless sensor network is done by [22]. The bins in his work were equipped with an accelerometer sensor to detect the opening and closing of the bin lid, a temperature and humidity sensor to sense the present organic waste, and an ultrasonic sensor to monitor the fullness status of the bin. All these sensors were controlled by Zigbee Pro microcontroller board, which has a built-in (wireless Fidelity) Wi-Fi module that is used to send the sensors data to a gateway. This paper also used the same type of microcontroller board in the gateway to receive the bins data and send it to a control station, that contains a server, over GPRS. The server in the control station relies on Caspio database management system with a web based user interface. However, the paper did not consider an additional source of power supply

A paper by [17] examined the use of weight sensor and three IR sensors to check the full ness status of the smart bin and send the sensors data to a web page over Wi-Fi network to a mobile phone. However, the microcontroller board used in this paper was ARM LPC2148 which has lesser functions when compared to the Atmega328.

A report was done by students of California Polytechnic State University [20], they thoroughly exploited the economic and power consumption aspects of converting a conventional outdoor trash bin into a smart one. According to the literature, the project is based on u-blox C027-U20 microcontroller board, which has built-in GPS module and cellular module. The board is used to control HC-SR04 ultrasonic sensor, that measures the bin's fullness-level, and a temperature sensor for monitoring weather conditions and fire alerts. The setup is contained by 2×4×6 plastic box and powered by a 12V rechargeable lead-acid battery. The report mentioned that the system generates an HTTP POST request using the data from the sensors and send it to a web application, which is built using Python and Flask framework on top of an SQLite database. The web application receives the HTTP request and check if the bin is full then send SMS message using Twilio service. Moreover, Leaflet JavaScript library is used to virtualize the collected data on a map. However, the author did consider analysis in his report.

This paper focuses on designing and implementing a solar powered automatic wastebin in other to provide a high level of safety precaution through an advance algorithm embedded in a microcontroller to intelligently detect a situation whereby the device automatically opens as soon as an individual approach it.

III. METHODOLOGY

This section of the paper contains the processes involved to get the system working. This section mainly deals with designed aspect of the hardware and the analysis of individual unit that made up the device. Fig. 1. shows a block diagram representation of the device.

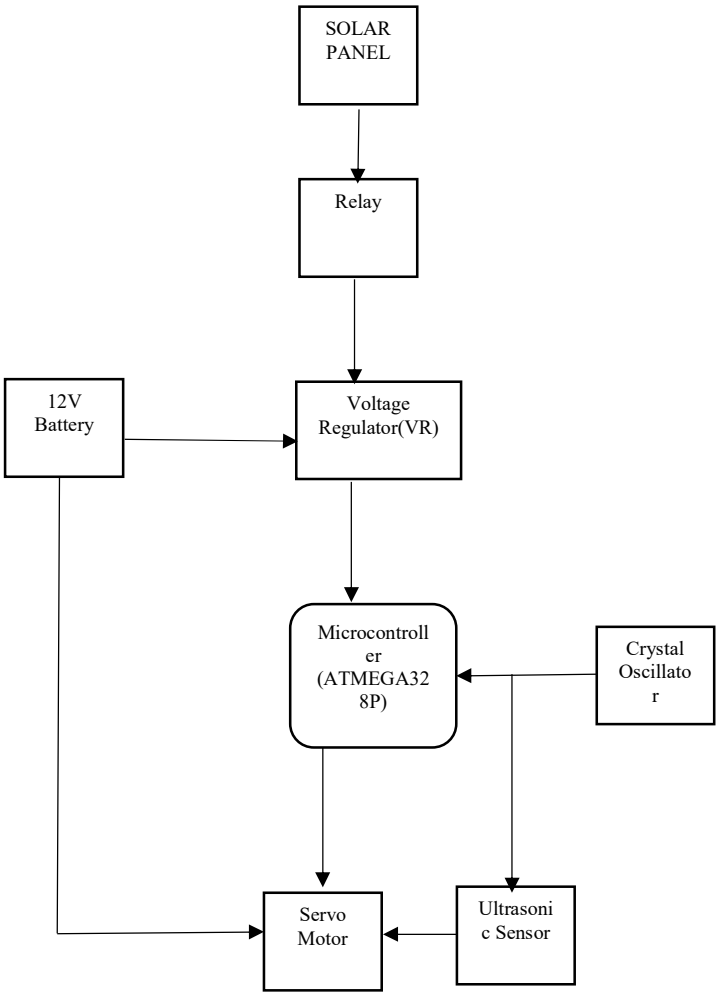

Fig. 1. Block Diagram of the Device.

A. Power supply Unit

A 20W solar panel was used as the energy source, this solar panel supplies a 12V through the diode to the relay. The relay

serves as a control circuit to the battery in which it monitors the charging of the battery and also as a cut out circuit as soon as the battery is fully charged. This can be detected by the user through the help of a LED indicator.

B. Relay Unit

The main function of the relay is to open or close a circuit. they are either normally open(NO) or normally closed(NC). It has five operational pins which are (the input pins, the normally open pin, normally closed pin and the common). As a result of this operation it is used in this paper as normally open in other to protect the battery from over charging.

C. Battery Unit

The battery supplies 12V through the regulator to the microcontroller switch which is controlled by the microcontroller. The battery is connected to a steady 5V regulator so as to supply a constant 5V.two capacitors are connected before and after the regulator so as a to filter small ripples in the circuit and also to isolate noise in the circuit especially from the relay.

D. Charging Unit

The charging unit comprises of a transformer, rectifier and regulator. The relay was used to cutoff the battery when fully charged. When a positive voltage is applied to the input terminal the relay it energizes.

E. Ultrasonic Senor Unit

The Sensor has four (4) pins namely, the trigger pin, Echo pin,5V input and a ground pin. The input 5V from the regulator. The microcontroller gives a command through pin 13 to the Echo pin to sends wave signals at a particular distance as soon as an object comes closer to it sends signal back to the trigger pin then a command signal is sends through pin 14 to the microcontroller.

F. Crystal Oscillator Unit

Crystals are used to generate signals for the microcontroller. They are basically classified into two (2) namely;

1. Sinusoidal oscillator
2. Non-sinusoidal oscillator

For the purpose of this paper a non-sinusoidal oscillator was used which helps the microcontroller execute commands. By default, the microcontroller has an oscillator frequency on its own which is 8MHz but using this might not be efficient, the manufacturer gives room for an external crystal oscillator of about 20MHz, but for safety a 16MHz frequency was selected which means it can execute a total of sixteen million instructions just in one second as specified by the manufacture, two capacitors are to be connected to the two input of the crystal oscillator and the two terminal has to be grounded. In summary the crystal oscillator acts as an executing factor for instructions performed by the microcontroller.

G. Software Imlementation

The flowchart shown in Fig. 2. shows the algorithm of the solar powered wastebin. Considering a set value(x) of 4cm.

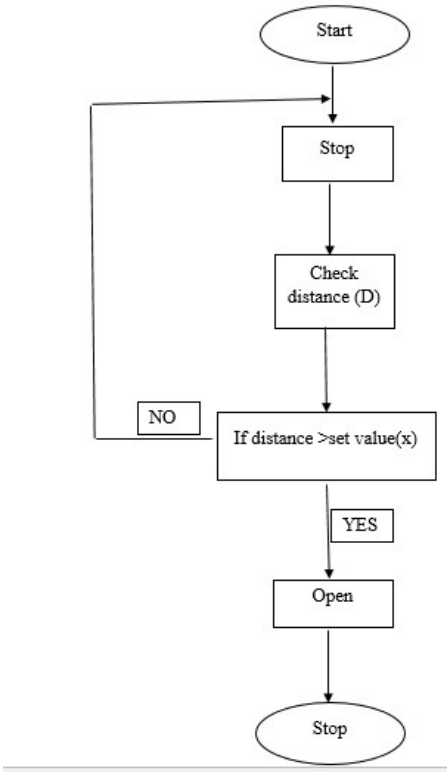

Fig. 2. Flowchart of the Automatic Solar powered Wastebin

H. Circuit Diagram of the device

The circuit diagram of the design which integrate all the whole block diagram required to form the circuitry is shown in Fig. 3.

III. RESULTS AND DISCUSSION

The following results have been obtained after simulating the design on Proteus ISIS software which was later transferred to Vero-board for final implementation. Table I, II, and III shows the results from different testing points whereas Plate I and II shows the prototype system. It was observed that from TP1-TP19 the expected and measured DC Volts was not having much difference. This depict the accuracy of the device.

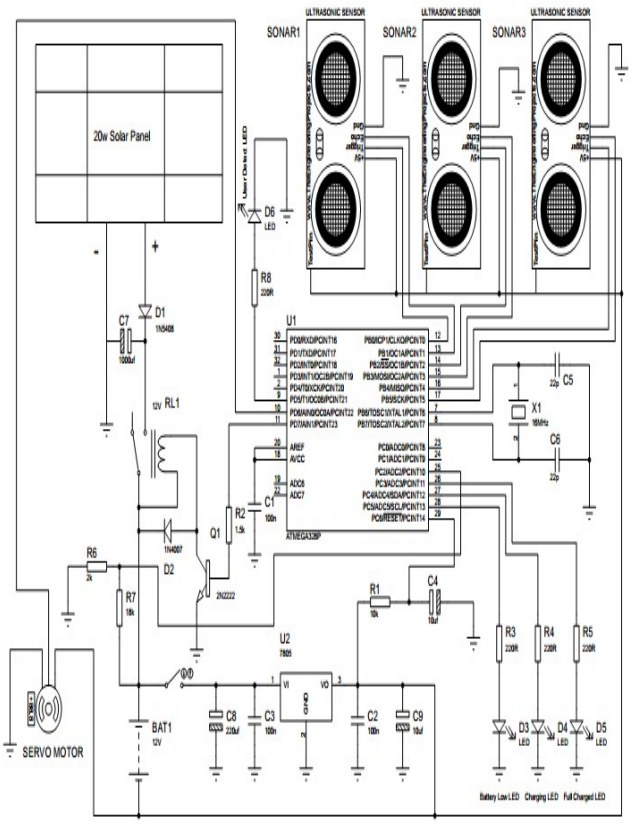

Fig. 3. Circuit Diagram of Solar Powered Automatic Wastebin

Table 4.1 Result obtained from different testing point.

TEST POINT	DESCRIPTION	EXPECTED DC V	MEASURED DC V
TP1	Output voltage from the solar panel	12V	12.5V
TP2	Output voltage after the diode	12V	12.8V
TP3	Output voltage after the relay	12V	13.0V
TP4	Input voltage to the base of the transistor before activation	5V	4.91V
TP5	Output voltage from the emitter before activation	5V	5V
TP6	Voltage value at the collector before activation	5V	5V
TP7	Activation voltage for the base	5V	5V
TP8	Voltage value at emitter during activation	5V	5V
TP9	Voltage value at collector during activation	5V	4.9V
TP10	Voltage value into the battery	12V	13V
TP11	Voltage value before the voltage regulator	12V	12.2V
TP12	Voltage value after the voltage regulator	5V	5V
TP13	Voltage value for RESET pin of the microcontroller	5V	5V
TP14	Input voltage to the 5V pin of the ultrasonic sensor	5V	5V
TP15	Voltage value for indicator pin 26	2.5V	2.5V
TP16	Voltage value for indicator pin 27	2.5V	2.4V
TP17	Voltage value for indicator pin 28	2.5V	2.5V
TP18	Voltage value for indicator pin 9	2.5V	2.5V
TP19	Input voltage value from battery to servo motor	12V	11.9V

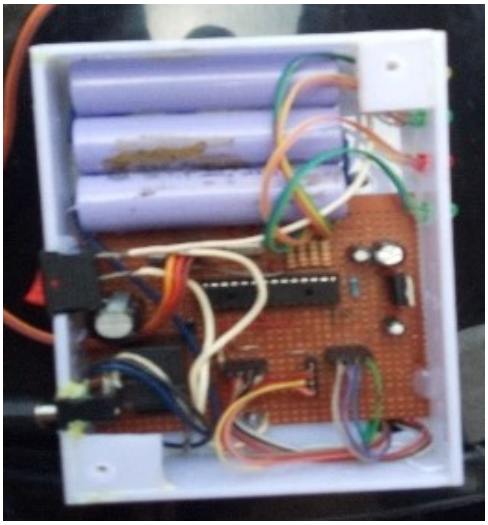

Plate I: Coupled Circuit Diagram on a Vero Board

Plate II: Prototype System

IV. CONCLUSION

In this paper, an automatic solar powered wastebin was designed and implemented, considering the additional feature of the servomotor, opening and closing of the system was executed. It senses a situation where the user gets closer via the ultrasonic sensor. A servomotor is triggered to open in the sense that the waste can be trapped as soon as it receives a signal from the microcontroller. It remains open for 4 minutes and closes again. In a situation where the user remains, it takes maximum of 3 seconds to reactivate to its initial state

REFERENCES

[1] A. Ahsan, M. Alamgir, M. M. El-Sergany, S. Shams, M. K. Rowshon, and N. N. N. Daud, "Assessment of Municipal Solid Waste Management System in a Developing Country," *Chinese J. Eng.*, vol. 2014, pp. 1–11, 2014.

[2] A. B. Nabegu, "An Analysis of Municipal Solid Waste in Kano Metropolis, Nigeria," *J. Hum. Ecol.*, vol. 31, no. 2, pp. 111–119, 2010.

[3] A. Khan and N. K. Prince, "Advanced Dustbin System," *Australian J. Eng.*, vol. 2, no. 1, pp. 178–181, 2017.

[4] A. Omran and M. Gavrilescu, "Municipal solid waste management in developing countries: A perspective on Vietnam," *Environ. Eng. Manag. J.*, vol. 7, no. 4, pp. 469–478, 2008.

[5] A. Zanella, N. Bui, A. Castellani, L. Vangelista, and M. Zorzi, "Internet of Things for Smart Cities," IEEE Internet Things J., vol. 1, no. 1, pp. 22–32, 2014.

[6] B. Chowdhury and M. U. Chowdhury, "RFID-based Real-time Smart Waste Management System," in Australasian Telecommunication Networks and Applications Conference, 2007, no. December, pp. 175–180.

[7] D. O. Adeagbo, E. Achuenu, and I. M. Oyemogun, "Construction Material Waste Management Practices in Selected ConstructionSites in Abuja, Nigeria," *FUTA J. Manag. Technol. Constr.Mater. Waste Manag.*, vol. 1, no. 2, p. 96, 2016.

[8] E. Amasuomo and J. Baird, "Solid Waste Management Trends in Nigeria," *J. Manag. Sustain.*, vol. 6, no. 4, p. 35, 2016.

[9] I. Skenderovic, "Environmental pollution and waste management," *Balk. J. Heal. Sci. ases.*, vol. 3, no. 1, pp. 1–10, 2015.

[10] J. A. Opara and V. O. Charles-Unadike, "Management of Biodegradable Waste among Rural Residents in Southern Nigeria: Implications for Environmental Public Health," *Mediterr. J. Soc. Sci.*, vol. 8, no. 3, pp. 321–326, 2017.

[11] J. Babayemi and K. Dauda, "Evaluation of Solid Waste Generation, Categories and Disposal Options in Developing Countries: A Case Study of Nigeria," *J. Appl. Sci. Environ. Manag.*, vol. 13, no. 3, 2010.

[12] J. P. Charlesworth and J. A. G. Temple, Engineering applications of ultrasonic time-of-flight diffraction, 2nd ed. Exeter, UK: Research studies press Ltd., 1989.

[13] K. Culgin, D. Mangan, and J. Pool, "Benefit-cost analysis of Big Belly solar trash compactors in city of Seattle parks," *Evans Sch. Rev.*, vol. 3, no. 1, pp. 51–61, 2013.

[14] K. Kamali, J. Lamyabanu, R. Madhumitha, M. Menaka, and R. Revathi, "Solar Powered Smart Garbage Can for Waste Segregation," *int J. Appl. Sci. Environ. Manag.*,vol. 9, no. 3, pp. 20163–20164, 2019

[15] K. N. P. George Halkos, "Efficient waste management practices: A review," *Munich Pers. RePRc Arch.*, no. 71518, 2014.

[16] P. Agarwal, S. Sharma, L. Gupta, and B. Manideep, "Smart Electronic Garbage Management System- Based IOT," *Asia J. Eng.*, no. 1, pp. 93–96, 2017.

[17] S. S. Navghane, M. S. Killedar, and V. M. Rohokale, "IoT Based Smart Garbage and Waste Collection Bin," Int. J. Adv. Res. Electron. Commun. Eng., vol. 5, no. 5, pp. 1576–1578, 2016.

[18] S. Sharma and S. Singh, "Smart Dustbin Management System," *Int. J. Eng. Sci. Res. Technol.*, vol. 7, no. 5, pp. 169–175, 2018.

[19] S. Zavare, R. Parashare, S. Patil, P. Rathod, and P. V. Babanne, "Smart City Waste Management System Using GSM," Int. J. Comput. Sci. Trends Technol., vol. 5, no. 3, pp. 74–78, 2017.

[20] T. Ambrose, C. Ford, and M. Norris, "Smart City Trash Cans," California Polytechnic State University, 2015.

[21] T. Gamsjäger, "Electronic Engineering 2 : Resistors , Elementary Resistor Circuits and the Electronic Engineering Resistors , Elementary Resistor Circuits and the Resistor Paradox Thomas Gamsjäger," *Canada J.Eng.*, no. August, 2017.

[22] T. Singh, R. Mahajan, and D. Bagai, "Smart Waste Management using Wireless Sensor Network," Int. J. Innov. Res. Comput. Commun. Eng., vol. 4, no. 6, pp. 10343–10347, 2016.