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Embedded Waste Management System with Solar Powered Battery

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Abstract- Many developing nations are experiencing rapid urbanization, resulting in high volume of solid waste generated. This can be said to be due to natural population increase and huge human movement from rural to urban areas. This thereby calls for efficient waste management or disposal. However, in many communities across nations, waste bins are typically placed in public places and do often overflow. Whereas they require very frequent disposal, they do not get disposed at proper time. This potentially leads to land, water and air pollution, and spread of diseases, thus creates unhygienic and ugly environmental conditions. Where the wastes are timely disposed, huge human efforts and logistics are involved. In view of the foregoing, this paper proposed an embedded waste management system (EWMS) with the aims of reducing human efforts, improve environmental cleanliness and enhance efficiency of waste disposal management authorities. The system is tested within an educational community in order to evaluate its effectiveness and possible wider implementation. The configuration of the proposed system is such that multiple waste bins are placed in strategic locations within each waste cluster (e.g. academic community−used as test case in this study) and linked via communication medium to waste management authority. Each bin has two embedded sensors (proximity and ultrasound sensors), a microcontroller unit and a GSM module for communication. Outcome of the evaluation shows that the proposed system worked as planned and effective in managing the disposal of wastes.

Keywords- *GSM, Microcontroller, Proximity Sensor, Ultrasonic Sensor, Waste Management*

I. INTRODUCTION

Rapid urbanization, due to natural population increase and huge human movement from rural to urban areas, results in high volume of solid waste generated. This resultant solid waste generation has rendered the traditional solid waste management system (whose main elements are collecting, transporting and disposing of solid waste) unsustainable and inefficient as urban centers continue to grapple with the challenges of huge volumes of uncollected solid waste [1].

With the increased worldwide calls for the promotion of environmental sustainability, scholars have developed interest in the concept of integrated sustainable waste management as opposed to the traditional waste management practices that did not pay much attention to environmental sustainability issues [1].

Resources consumed and wastes generated are major constituents of the living process of a human life. Also, human activities tends to alter wastes composition conditions, thereby poses a challenge in waste management. Consequences of wastes, if unmanaged or inadequately managed, besides space constrain and odor, could pose threats of epidemic diseases, air pollution and groundwater contamination [2].

It has been reported that collection, transfer and transport practices are affected by improper bin collection systems, poor route planning, lack of information about collection, insufficient infrastructure, poor roads and number of vehicles for waste collection. Organizing the informal sector and promoting micro-enterprises were mentioned as effective ways of extending affordable waste collection services [3].

Waste management is said to be affected by aspects or enabling factors that facilitate the performance of the system. These factors could be: technical, environmental, institutional, legal, financial, or socio-cultural. Technical factors relate to lack of technical skills among waste management personnel, inadequate infrastructure, bad roads and vehicles, shortage of relevant technologies and reliable data. On the other hand, environmental aspect of solid waste management is the lack of environmental control systems and evaluation of the real impacts [3].

It is generally believed that waste management is the sole duty and responsibility of government authorities, and that the public is not expected to contribute. The operational efficiency of solid waste management depends on the active participation of both the authorities and the citizens [3].

II. RELATED WORKS

Several researchers have proposed different solutions for solid waste management. However, some of the related works would be discussed.

In reference [4], the design of a smart waste bin using predictive algorithm was carried out. The study utilized artificial neural network (ANN) to forecast solid waste

generation in order to determine when waste management authority can come around to pick up waste.

Reference [5] In a relevant literature, a system is proposed whereby a web camera is mounted on the top of the waste bin with the load cell sensor. The camera continuously captures images and threshold point is set at particular level. Threshold level compares output images of the camera and load sensor, and the result is compared by microcontroller. After observing the images, it will give an idea of the level of waste in the bin and load cell sensor give exact weight of bin. The information is sent through GSM [5]. The limitation of this system is that it required high processing power due to the web camera and in the night, there are capturing problems.

Another study presents a novel approach to garbage collection technique and interaction through a Smart bin. The smart bin is developed using ARM LPC2148 microcontroller with ultrasonic sensors and pressure sensing resistor. Ultrasonic sensor senses the level of bin and Pressure Sensing Resistor (PSR) helps to measure the weight. This system provides web interaction to user. It provides Hypertext Markup Language (HTML) pages where it shows the current level of dustbin. User is able to see the current status of bin on the web pages. This system provides Radio Frequency Identification (RFID) tag for authentication control to specify user [5]. Limitation of this system is that user is not able to access web page every time, and sometimes pressure sensing sensor gives wrong output.

Similarly, a study describes a system based on Zigbee technology, GSM etc. The system enables remote monitoring of solid waste bin in real time; it has capability to inform the authorized person when the garbage bin is about to full. Such technologies can enable effective solid waste collection, transportation monitoring and its management for greener environment [6]. However, it's incapable of controlling the overflowing of waste bins if the bins are not collected on time.

Also in [6], a system is proposed in which "Smart Bin" is used to manage the waste collection system of an entire city. The system involves smart bins that are connected through cellular networks. The interconnection of the smart bins is enabled by network of sensors. This configuration enables the generation of a large amount of data. The data is analyzed and visualized at real time, thus provides insights into the status of waste around the city. However, this model is difficult to implement in large cities.

III. MATERIALS AND METHODS

In this section, the proposed system is described in terms of the materials and their configuration.

A. System Description

The proposed System consists, amongst others, of a microcontroller unit (MCU), which is the brain of an embedded system. The waste bin transmits signals to indicate that they are 90% full and should be emptied. Via the mobile communications network, the signals are sent to waste management authority. This is taken as a basis to plan the best route for waste collection garbage trucks to travel only to those containers that actually need to be emptied [7].

The proximity sensors detect motion close to the bin and send signal to the MCU. If the waste level is lower than 90% of the volume of the bin, then the cover of the bin will be unlocked so that waste can be disposed of in it. The proximity sensors are three in number, each will be installed on either side of the bin, and the third in the front. This is to sense motion from any direction towards the bin.

Ultrasonic sensors are installed in the waste bin to detect the fill level regardless of what has been deposited inside. An ultrasonic sensor consists of a high frequency sound transmitter and receiver. Its transmitter constantly emits sound which when hits a surface bounces back onto the receiver located beside the transmitter. The sensor senses the waste level in the bin. Its output is fed to a MCU pin for measurement. The MCU reads the total time in which the sensor output is high. This total time is proportional to the distance between the sensor and the obstructing waste particle. The default distance is the length of the internal dimension of the bin's top square surface; this is measured to be about 40cm. If the measured length is much less than this value, then the bin level is about 90% full. The MCU will send message signal, by means of the GSM module, to the GSM phones of waste management authority.

A solenoid door lock, which is an electromagnetic lock, is installed on the bin cover; it has to be energized in order to open it. The solenoid driver increases the current from the MCU to a level acceptable to the solenoid door lock.

The sensors are fixed on to the waste bin. The connection between the circuit board and the sensors is made with the help of connecting wires. The MCU is pre-programmed to carry out its control functions. The GSM module is also connected to the same circuit board. The power supply to the system is given with the help of a rechargeable battery with solar connection. The process flow for the EWMS is illustrated in a flow chart of figure 1.

The whole system contains majorly, Power Supply stage, Microcontroller Unit (MCU), Proximity Sensors, Ultrasonic Sensors, Charger Relay /Charger Relay Driver, Solenoid Door Lock /Solenoid Relay Driver, Alarm Buzzer / Alarm Buzzer Driver, Liquid Crystal Display (LCD). The complete circuit is shown in the block diagram of figure 2.

B. System Configuration

Presented below are the detail descriptions of the system's materials configuration.

1) Ultrasonic Sensor

The ultrasonic sensor (HC-SR04) is an economical sensor that provides 2cm to 400cmof non-contact measurement functionality with a ranging accuracy that can reach up to 3mm. Each module includes an ultrasonic transmitter, a receiver and a control circuit. It is a four pin module – VCC (Power), Trig (Trigger), Echo (Receive), and GND (Ground). The sensor is used in applications where measuring distance or sensing objects are required [8]. The HC-SR04 emits high frequency sound wave at regular interval which propagates in air at the velocity of sound. When sound strikes the object, the

waves are reflected back as echo signals to the sensor which themselves calculates distance to the destination [9].

The ultrasonic sensor switches to receive mode after emitting sound waves. The time between emitting and receiving is proportional to the distance of the object from the sensor [7]. Functionally, ultrasonic sensor generates high-frequency sound wave, evaluates the echo received back, and then measures the time interval between sending the signal and receiving the echo to determine the distance to an object. Ultrasonic sensor is shown in figure 3.

Two ultrasonic sensors are used, one adjacent to the other and are used for level sensing. When powered with 5V, each of the sensors will be active waiting for a trigger pulse of 10 µs duration. When triggered, it will raise its output and at the same time, send out sound of very high frequency. On hitting an obstacle, it will bounce back to the sensor as an echo signal. When the echo is received, the sensor's output will become low. The time for the output to move from high to low is measured by the MCU; this is used to calculate distance measured.

2) Proximity Sensors or PIR Sensors

Proximity sensors allow you to sense motion. The sensor is capable of detecting whether a human is within or outside the sensors range. It's an inexpensive sensor, with low-power, small in size, easy to use, and don't wear out easily. These sensors are often referred to as PIR, "Passive Infrared", "Pyroelectric", or "IR motion" sensors [10]. Most of these sensors use Micro Power PIR Motion Detector IC. This chip takes the output of the sensor and does some minor processing on it to emit a digital output pulse from the analogue sensor [10]. The sensor is shown in figure 4.

3) GSM Module

GSM (Global System for Mobile communications) is a standard developed to describe the protocols for second-generation (2G) digital cellular networks used by mobile phones. GSM networks operate in a number of different carrier frequency ranges (separated into GSM frequency ranges for 2G and UMTS [Universal Mobile Telecommunications System] frequency bands for 3G), with most 2G GSM networks operating in the 900 MHz or 1800 MHz bands [7], including Nigeria.

The GSM module used in this project is a SIM800L. This is a miniature cellular module which offers 2G GSM / GPRS (General Packet Radio Service) transmission, sending and receiving SMS (Short Message Service) and making and receiving voice calls. It supports SIMCom enhanced AT commands. Its low cost and small footprint and quad band frequency support make it a perfect solution for a project of this type that requires long range connectivity. Because it uses serial communication method, it is easy to interface with the UART (Universal Asynchronous Receiver–Transmitter) of most popular microcontrollers [11]. SIM800L is shown in figure 5.

4) Microcontroller Unit (MCU)

A microcontroller is a small and low-cost compact integrated circuit (microcomputer), which is designed to perform specific task of embedded systems like receiving remote signals. Typically, microcontroller consists of the processor, the memory (RAM, ROM, and EPROM), serial ports, peripherals (timers, counters), etc. on a single chip [12].

The microcontroller chip that has been selected for this project is PIC18F4550. It belongs to the family of PIC18 microcontroller. This family of devices offers the advantages of high computational performance at an economical price – with the addition of high endurance, enhanced flash program memory. In addition to these features, this PIC18 family introduces design enhancements that make its microcontrollers a logical choice for high-performance, power sensitive applications [13]. Figure 6 shows the Pin configuration of the MCU.

The microcontroller is the brain of this project and performs the following:

i. It runs in real time i.e. it responds or reacts immediately whenever the sensors detect motion or "full" level.

ii. It senses and interprets ultrasonic and proximity sensors' outputs.

iii. It receives messages in form of serial data from the GSM module and processes it.

iv. It sends message via the GSM module to the pre-registered numbers.

v. It generates digital control signal to energize or de-energize the door lock when required.

vi. It also generates digital control signal to ON and OFF the buzzer.

IV. RESULT AND DISCUSSION

A. Design Simulation

Prior to the construction of the project, the circuit was first designed using Proteus Design Suite 7.6. The code was written and compiled using MIKROBASIC PRO for PIC and then embedded on the microcontroller. This was done in order to see how the circuit would work under real conditions. The GSM modem was also connected via COM ports on the computer so as to send commands to the working circuit and see real time simulation of the circuit. After this, the components were assembled and tested on a breadboard to be double sure. With the two simulations, a functional circuit was established and seen to perform the required tasks.

B. Testing and Result

When the system is powered up, the buzzer beeps and the progress is displayed on its internal LCD (used mainly for operation monitoring and troubleshooting).

Then, the contacts of those that will monitor the status of the bin in a particular location are registered. To actualize the foregoing, the following syntax is utilized:

"**REGSTARTS<tel-1> <tel-2> <tel-3> ….<tel-n> LOCATION REGENDS**"

[NOTE: "REGSTARTS" and **"REGENDS"** signify start and end of registration of the contacts listed respectively. Each contact number (i.e. <tel-1>, <tel-2>, …, <tel-n>) is an eleven digits of a typical mobile phone number. Space is not allowed between **REGSTARTS** and <tel-1>. However, there must be space between two consecutive phone numbers; as well as between the last phone number and bin-location. If the syntax is not followed, an error message is sent back to the administrator, thus the registration must be redone.]

In order to evaluate the proposed system, the above syntax was used to register four phone numbers. The numbers were sent to the SIM card in the GSM module as shown thus:

"**REGSTARTS**08035371478 08023445208 08033406618 08084214994 ECE DEPT. **REGENDS**"

This should usually be done by an administrator appointed by the waste management authority. The above information says: "register the (contacts listed) to monitor bin (the label of this bin would have been embedded into the program, in this case, bin 001) located at ECE Dept.

After a successful registration, the system sent an acknowledgement message to confirm the registration. The message read:

"THE DATA 08035371478 08023445208 08033406618 08084214994 ECE DEPT. HAS BEEN REGISTERED SUCCESSFULLY /MSG FROM WASTE BIN S/N 001 AT ADDRESS: ECE DEPT. **/"**

The bin was then filled with different wastes, and on getting to about 90% of its height; the bin started sending "bin full" message and also calling the four pre-registered GSM numbers. At the same time, the bin remains permanently locked until after the bin is emptied. The bin full message read:

"THE WASTE BIN IS NOW 90% FULL, PLS ATTEND TO IT ON TIME /MSG FROM WASTE BIN S/N 001 AT ADDRESS: ECE DEPT. **/"**

V. CONCLUSION

In this study, an attempt is made to provide a comprehensive review of waste generation, characteristics, collection and transportation. This work implements embedded waste management system using embedded waste bins. The study aim to provide possible solution for solid waste management where waste management authority gets notification at anytime and anywhere through GSM technology [5]. The system informs the waste management authority of the status of the bins. The authority then arranges to collect the waste. In this way, the system monitors the solid waste collection process. This technique would provide solid waste collection in time and also overcome the disadvantages like use of minimum route, low fuel use, clean and green environment and available vehicle. The technologies involved in the proposed system are good enough to ensure the good management of solid waste collection process for greener environment [14]. Future work could include bins equipped with GPRS enabled embedded system for tracking movement of waste bins and web server for effective graphic user interface and controlling action.

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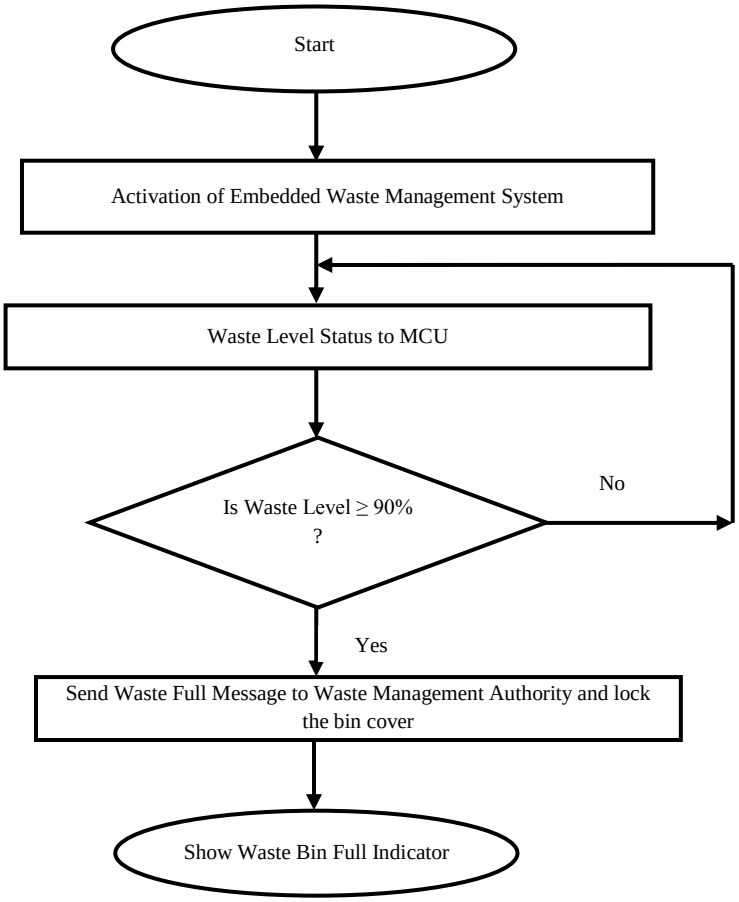

Figure 1. Process Flowchart for Embedded Waste Management System

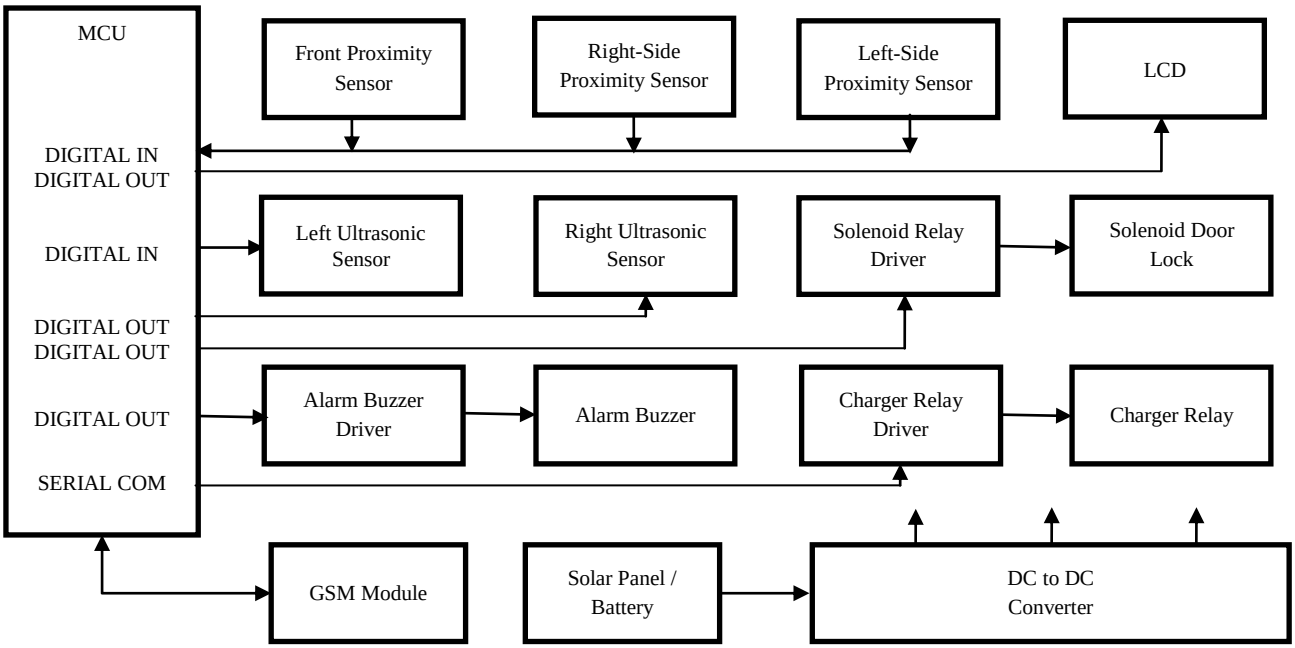

Figure 2. Block Diagram of an Embedded Waste Management

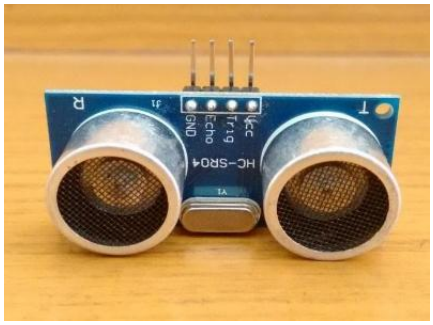

Figure 3. Ultrasonic Sensor[7]

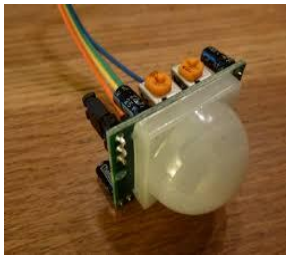

Figure 4. PIR Sensor[10]

Figure 5. SIM800L GSM Module

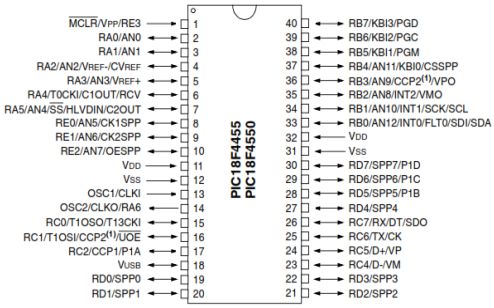

Figure 6. Pin Diagram of a PIC18F4550 Microcontroller [13]

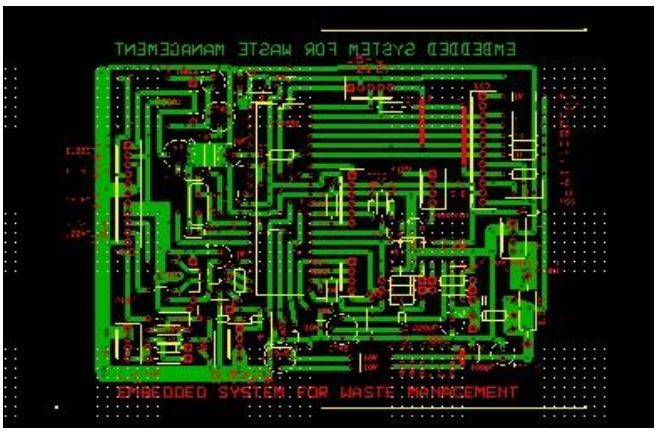

Figure 7. Designing of EWMS Circuit Using Express PCB

Figure 8. PCB Assembly

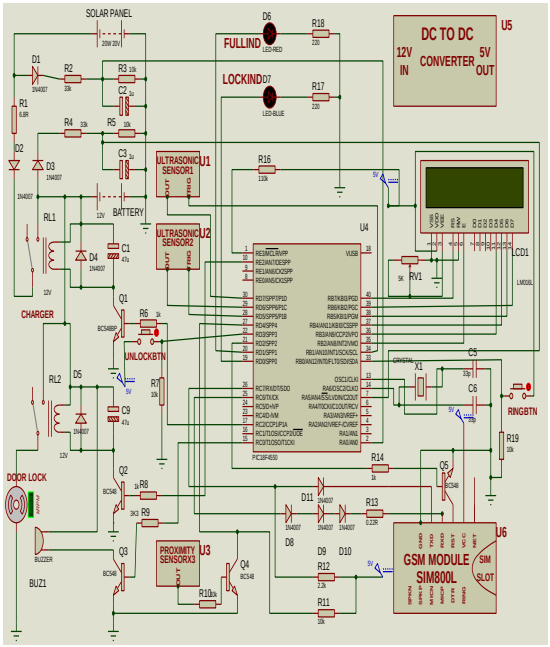

Figure 9. The Complete Circuit Diagram

Figure 10. The EWMS Constructed