DEVELOPMENT OF A SMART, AUTOMATED WASTE MANAGEMENT SYSTEM

Nkolika O. Nwazor (PhD)
Electrical/Electronic Engineering Department,
University of Port Harcourt,
Rivers State
NIGERIA
nkolika.nwazor@uniport.edu.ng

Nafiu Ibrahim
Electrical/Electronic Engineering Department,
University of Port Harcourt,
Rivers State
NIGERIA
naftalks@yahoo.com

Olanrewaju K. Seun
Electrical/Electronic Engineering Department,
University of Port Harcourt,
Rivers State
NIGERIA
olanseun@yahoo.co.uk

ABSTRACT

Indiscriminate dumping of refuse is a very big challenge in our societies today. It comes with the challenges of environmental pollution and degradation, wasting of scarce land, disease outbreaks and destruction of aquatic life to mention a few. Efficient waste management is therefore a very important factor if a country will have sustainable ecological development. The Smart Waste Management System proposed in this work seeks to address this. The system comprises the Power Supply, the State Sensors, the output display, the load driver, the load, the communication module and the control unit. The power supply supplies 12V dc to the relay and 5V dc to the microcontroller and its electronics components. The state sensors sense the state of the system and send the information to the control unit. The state sensors was implemented using limit switches, Light Emitting Diode and Light Dependent Resistor. The Output Display helps the users and the operators to know the state of the system and to take instructions on the actions required of them. Liquid Crystal Display was used to implement the output display. The Load Driver was used to drive the load and was implemented using relays interfaced to the controller via ULN2003. The Load represents the motor that drives the door mechanism of the smart waste bin. The Communication Module informs the operator when the waste system is filled up. This was implemented using SIM 900 module. The Control module coordinates the activities of the entire system and was implemented using Atmel microcontroller. If the system is implemented, it will contribute immensely to the ultimate goal of making our cities litter free and can also serve as a source of revenue generation.

Keywords: Smart, Waste management, control.

INTRODUCTION

Waste management has been a major challenge facing every nation. Waste management is more than just collecting waste. It is the collection, transport, processing, recycling, disposal and monitoring of waste materials (Belien et al, 2011). As the world population increases, the situation is getting worse as the amount of wastes generated also increases. Modernization and industrialization are also not helping issues as they also come with the challenge of increased wastes. With the increased waste generation comes the challenge of waste disposal.

The main goals of waste management are reducing waste production; ensuring that wastes are properly disposed and recycling and re-using disposed products. The common methods of waste disposal especially in the rural areas are dumping on the ground, burying under the ground, burning of flammable wastes and disposal in running waters or drainages. It is not

ISSN 2056-5860

uncommon to see indiscriminate dump sites along the roads, at the street corners, at different parts of the market and even in front of people's houses. The indiscriminate dumpsites have the challenges of air pollution, increased littering and the risk of pests and associated diseases. These dumpsites occupy valuable land space. Due to the growing concerns for environmental pollution, ground water resources contamination, blockage of drainage systems, public health and safety and scarcity of land, these methods are becoming a very big challenge to the society.

The task of resolving this problem requires an integrated approach that involves not only the policy of the government, but also demands active participation of corporations nationwide and most importantly, the public. The most efficient and most cost effective method of waste management is waste minimization. This is very difficult in developing countries where tons of solid wastes are generated daily. This work proposes a smart waste disposal system using integrated technologies for the efficient management of these wastes.

LITERATURE REVIEW

One of the main concerns with our environment has been solid waste management which in addition to disturbing the balance of the environment also has adverse effects on the health of the society. The identification, monitoring and management of wastes are part of the primary problems of the present era. The traditional way of manually monitoring the wastes in waste bins is a complex, cumbersome process and utilizes more human effort, time and cost which is not compatible with the present day technologies. Solid waste management is a big challenge in urban areas. Over the years, a lot of systems have been developed and various methods used for solid waste management.

The work in (Glouche and Couderc, 2013) talked about the use of Radio Frequency Identification (RFID) to improve waste management by providing early automatic identification of waste at bin level. The work proposed a smart bin application based on information self-contained in tags associated to each waste item. The wastes are tracked by smart bins using a RFID-based system without requiring the support of an external information system. This system cannot be easily implemented in developing nations where goods do not have RFID tags. It will also be expensive to implement. Bashir et al (2013) proposed an advanced method in which waste management is automated. The system makes use of radio frequency (RF) tags and web support. The proposed system would be able to automate the solid waste monitoring process and management of the overall collection process.

The authors in (Mahajan and Chitode, 2014) used Zigbee and Global System for Mobile Communication (GSM) in the design of waste management system. In the system, the sensors are placed in the common garbage bins placed at the public places. When the garbage reaches the level of the sensor, then that indication will be given to ARM 7 Controller. The controller will give indication to the driver of garbage collection truck as to which garbage bin is completely filled and needs urgent attention. ARM 7 will give indication by sending SMS using GSM technology.

METHODOLOGY

This research made use of a composite methodology which includes a modified form of waterfall methodology and prototyping methodology in its design and implementation.

System Design

In order to successfully implement the smart waste disposal system, several electronic components were considered. The choice of any component depends on their characteristic which is considered relevant to the design of the project. Other factors which include cost, efficiency and reliability were also considered in the use of various components. The design of this project will be done under two sub-section namely hardware and software design.

Hardware Design

In order to design the system hardware, the concept that is embodied in the system is presented in block diagram shown in figure1. The system comprises the State Sensors, the output display, the load driver, the load, the communication module and the control unit.

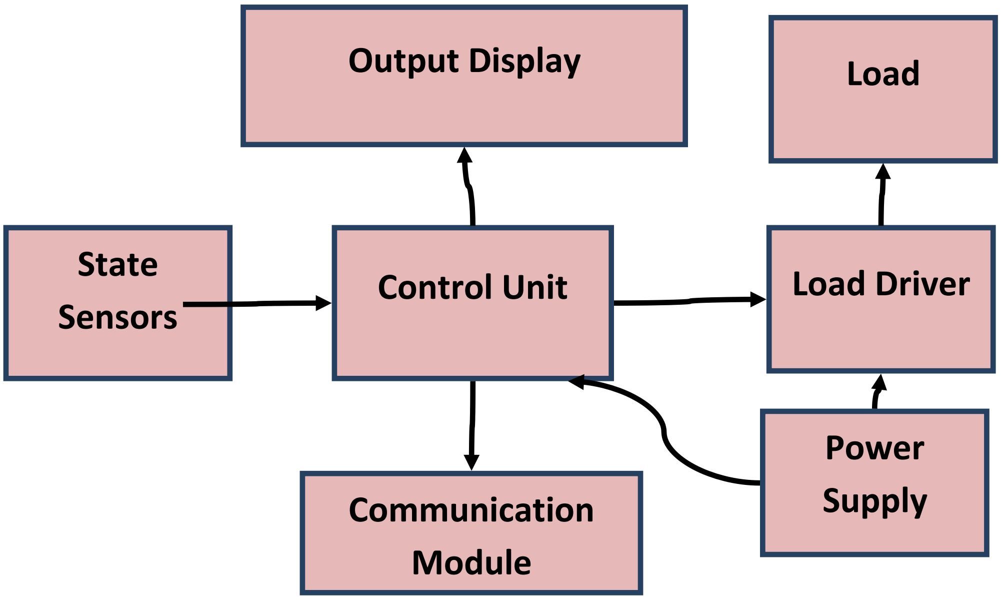

Figure1: Block diagram of Smart Waste Disposal System

The state sensors were implemented using limit switches and proximity sensor. These help the controller to know the state of the system. There are four states of the system: Smart bin door is open; the Smart bin door is closed; the Smart bin is filled up; the Smart bin is empty; a request is made to evacuate the waste in the Smart bin. The Output Display helps the users and the operators to know the state of the system at any time. HD 44780 based Liquid Crystal Display was used to implement the output display. The Load Driver was used to drive the load and it was implemented using relays interfaced to the controller via ULN2003. The ULN2003A is an array of seven NPN Darlington transistors capable of 500mA, 50V output. It features common-cathode flyback diodes for switching inductive loads. Generally it can also be used for interfacing with stepper motor, where the motor requires high ratings which cannot be provided by other interfacing devices.

The Load represents the motor that drives the door mechanism of smart waste bin management system. A DC motor is any of a class of electrical machines that converts direct current electrical power into mechanical power. The Communication Module notifies the Smart waste bin management system operator when the waste system is filled up. This was implemented using SIM 900 module. This is a GSM/GPRS-compatible Quad-band cell phone, which works on a frequency of 850/900/1800/1900MHz and which can be used not only to access the Internet, but also for oral communication (provided that it is connected to a microphone and a small loud speaker) and for SMSs. Internally, the module is managed by an AMR926EJ-S processor, which controls phone communication, data communication (through an integrated TCP/IP stack), and (through an UART and a TTL serial interface) the communication with the circuit interfaced with the cell phone itself. The processor is also in charge of a SIM card (3 or 1.8 V) which needs to be attached to the outer wall of the module. The TTL serial interface is in charge not only of communicating all the data relative to the SMS already received and those that come in during TCP/IP sessions in GPRS (the data-rate is determined by GPRS class 10: max. 85.6 kbps), but also of receiving the circuit commands (in our case, coming from the PIC governing the remote control) that can be either AT standard or AT-enhanced SIMCom type. The module is supplied with continuous energy (between 3.4 and 4.5 V) and absorbs a maximum of 0.8A during transmission. The Control Unit coordinates the activities of the entire system and will be implemented using Atmel microcontroller, AT89C51.

DESIGN ANALYSIS

The State Sensors

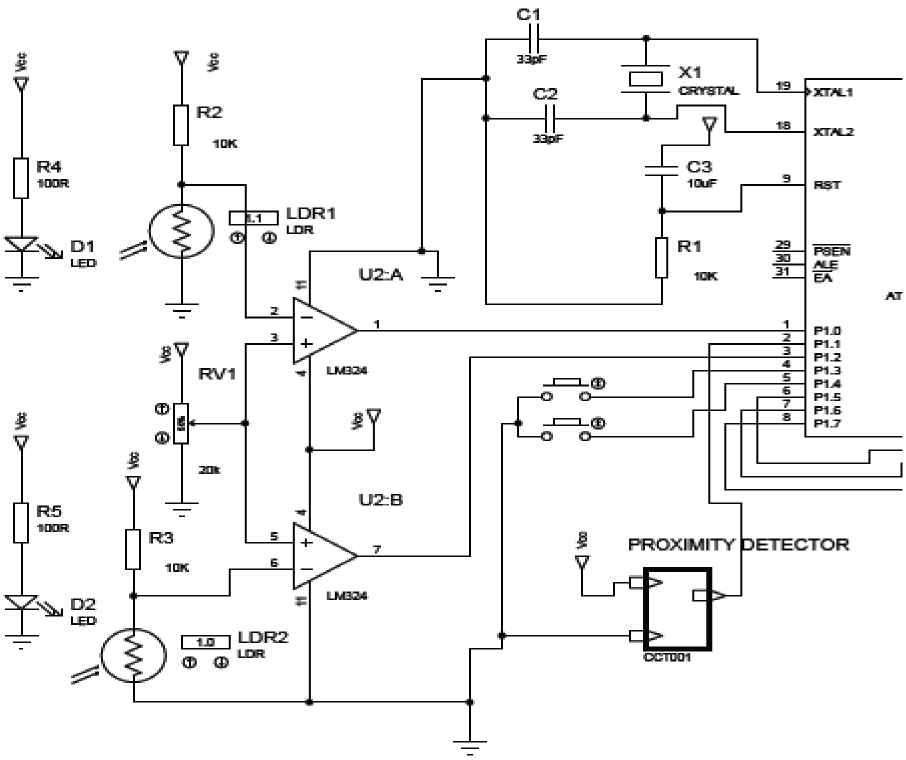

Figure 2: The Input Interface for the State Sensors

Figure 2 is the input interface for the state sensors. Open and close Limit switches help the controller to know the state of the door during opening and closing operations. The door of the waste bin is normally closed. The proximity sensor senses the presence of a user when he/she is within a certain distance and sends the signal to the controller. The stepper motor is then triggered to open the lid of the waste bin for the user to drop the waste after which the bin motor automatically closes the bin. The controller monitors the level of waste in the bin via the operational amplifiers configured as comparators. The laser LEDs transmits light to the light dependent resistor (LDR). When the waste material blocks the light rays on both ways (p1.0 and p1.2), it means that the bin is filled up. The door closes and the proximity sensor is cut off to prevent the opening of the lid when another user approaches and the state of the system is displayed on the LCD. At the same time, an SMS alert is sent to the operators

to come and evacuate the waste. Once the bin is shut in this state, it can only be opened by when the operator presses the override button 4 times. This information is known only to the operator to avoid users overloading the system. Another press of the push button after evacuation will reset the system. This will help prevent the dumping of refuse on the ground. It will help improve the aesthetic value of the environment.
R_1 laser diode requires 0.05A for optimal performance according to the data sheet.
$V_{cc} = 5V$
Therefore,

$$R_1 = R_5 = \frac{Vcc}{I} = \frac{5}{0.05} = 100\Omega \quad (1)$$

The resistance of the LDR on dark condition is 10k. For good operation of the system, it is necessary that R_2 forms a good voltage divider between $R_2$and R_{LDR} .
Now,

$$V = \frac{R_{LDR}\ X\ V_{CC}}{R_2 + R_{LDR}}\ X\ V_{CC} \quad (2)$$

For good voltage division, it is expected that V should be 2.5V at dark condition

$$\frac{2.5}{5} = \frac{10000}{R_2+10000}$$

$$2.5R_2 + 25000 = 50000$$

$$2.5R_2 = 25000$$

$$R_2 = \frac{25000}{2.5} = 10000 = 10K\Omega$$

The Output Display
In most applications, the "R/W" line is grounded. This simplifies the application because when data is read back, the microcontroller I/O pins have to be alternated between input and output modes. In this case, "R/W" is connected to ground and just waits the maximum amount of time for each instruction (4.1 ms for clearing the display or moving the cursor/display to the "home position", 160 µs for all other commands) and also the application software is simpler. It also frees up a microcontroller pin for other uses. Before sending commands or data to the LCD module, the Module must be initialized. Once the initialization is complete, the LCD can be written to with data or instructions as required. Each character to display is written like the control bytes, except that the "RS" line is set. The connection of LCD to microcontroller is shown in the figure 3.

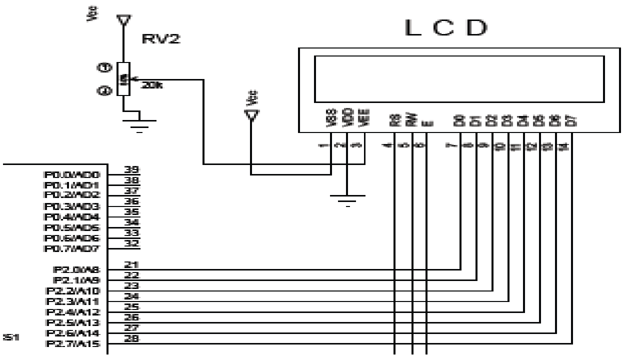

Figure 3: LCD Interface to the microcontroller
The LCD shows the state of the system at any point in time. Pin2 is the ground; pin1 is the V_{cc} while pin3 is the contrast. A is the anode of the backlight while k is the cathode of the backlight. From datasheet, the LCD requires at least 5mA to come on and $10K\Omega < R_{v2} < 40K\Omega$. Using a current of 25mA for a brighter screen,

$$V_A = IR_{v2} \quad (3)$$

$$5 = 0.00025\ X\ R_{v2}$$

$$R_{v2} = 20K\Omega$$

Power Supply Unit

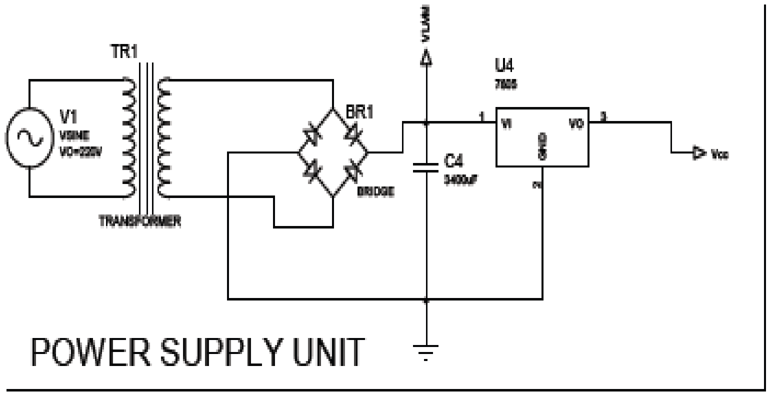

Figure 4: Power Supply

The circuit diagram of the power supply is shown in figure 4. It consists of a step-down transformer, bridge diode, a filter capacitor and a voltage regulator. The power supply supplies the power that can drive the motor as well as other the electronics components in the system. The power supply provides the 12V for the relay and dc motor and 5V dc for the microcontroller and its electronics components. The supply transformer is a 220V/12v, 1000mA step-down transformer. This steps down the 220V AC input voltage to 12V AC. A bridge rectifier rectifies the already stepped down AC voltage to DC voltage. A filter capacitor filters the rectified DC voltage to remove unwanted ripples existing in the rectified DC voltage. This capacitor was chosen by careful calculation and experiments. The 12V dc supply needed for the relays and motors is tapped out. A 7805 voltage regulator generates +5Volts voltage level required for the microcontroller and its electronics. The value of the smoothening capacitor is derived as follows:

$$C = \frac{0.8\ X\ I}{2\Delta V f} = \frac{0.8\ X\ 1}{2.5\ X\ 50\ X\ 2} = 320\mu F \qquad (4)$$

Where the power factor is 0.8

The ripple voltage = ΔV = 2.5V
The frequency = f = 50Hz
Load current = I = 1A

The Microcontroller Interface to the Motor

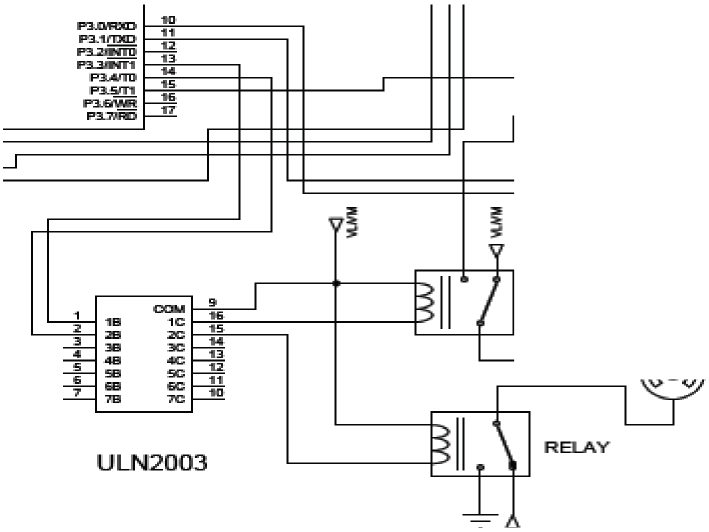

Figure 5: Microcontroller's interface to the motor

Figure 5 is the microcontroller's interface to the motor that drives the smart bin's door. ULN 2003 is the driver that drives the load through the dc relay. ULN 2003 eliminates the use of transistors and free will diode configuration in driving the load making the circuit neater and the component count low, thus the system is more reliable. The relay is a 12V dc. $V_L = V_m$ = 12V dc which is the terminal voltage of the motor.

The Software Design

The software design involves the design of the flowchart for the AT89C51 control program. Because of the critical nature of software, structured programming and top-down software development methodologies are usually used by many microprocessor system application designers. In structured programming, each software component is first described in terms of a few fairly abstract statements, and then they are iteratively refined until they could be expressed in the algorithm. The application program, that is, the set of instructions directing the microprocessor's execution of a specific task must first be developed and then loaded into the memory unit. The algorithms of the design are presented in the figure 6.

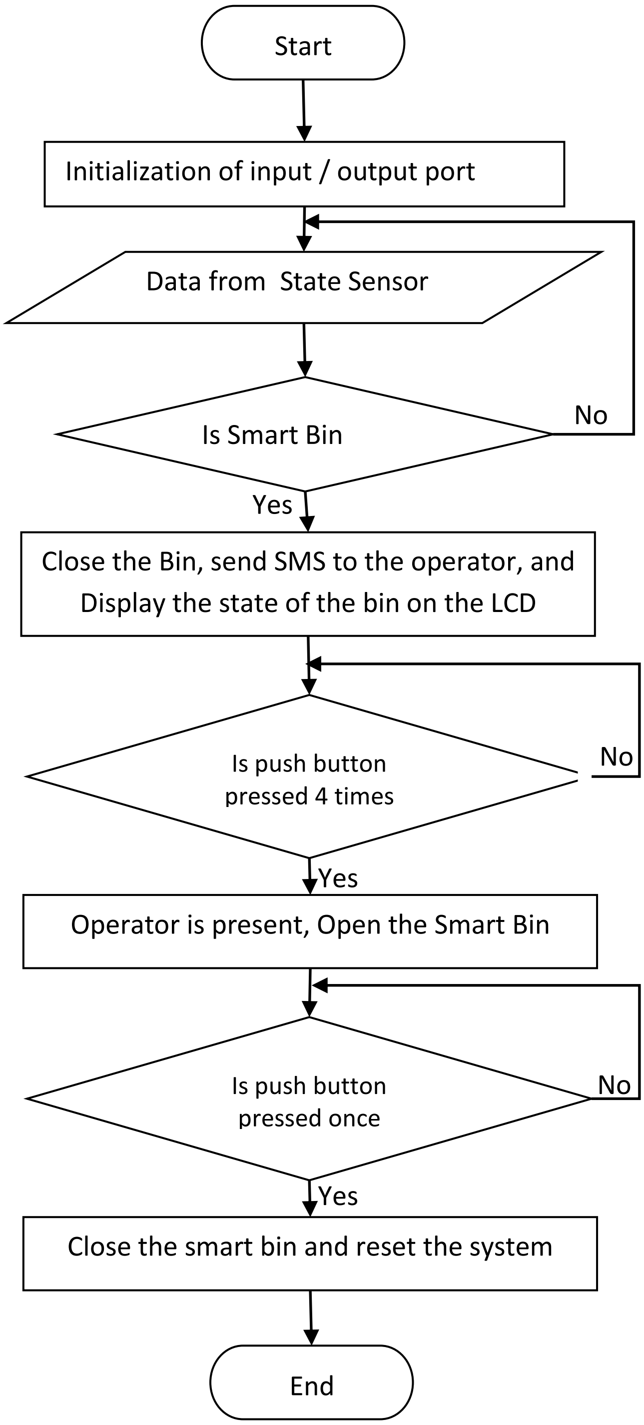

Figure 6: Flowchart for the system

RESULTS

This section involves the testing of the system, final implementation and discussion of the results obtained. This involves the integration of the different components of the design to achieve a complete working device. The complete circuit diagram was tested on a bread board, patterned and etched on a printed circuit board. The components were mounted following the design as shown in figure 7.

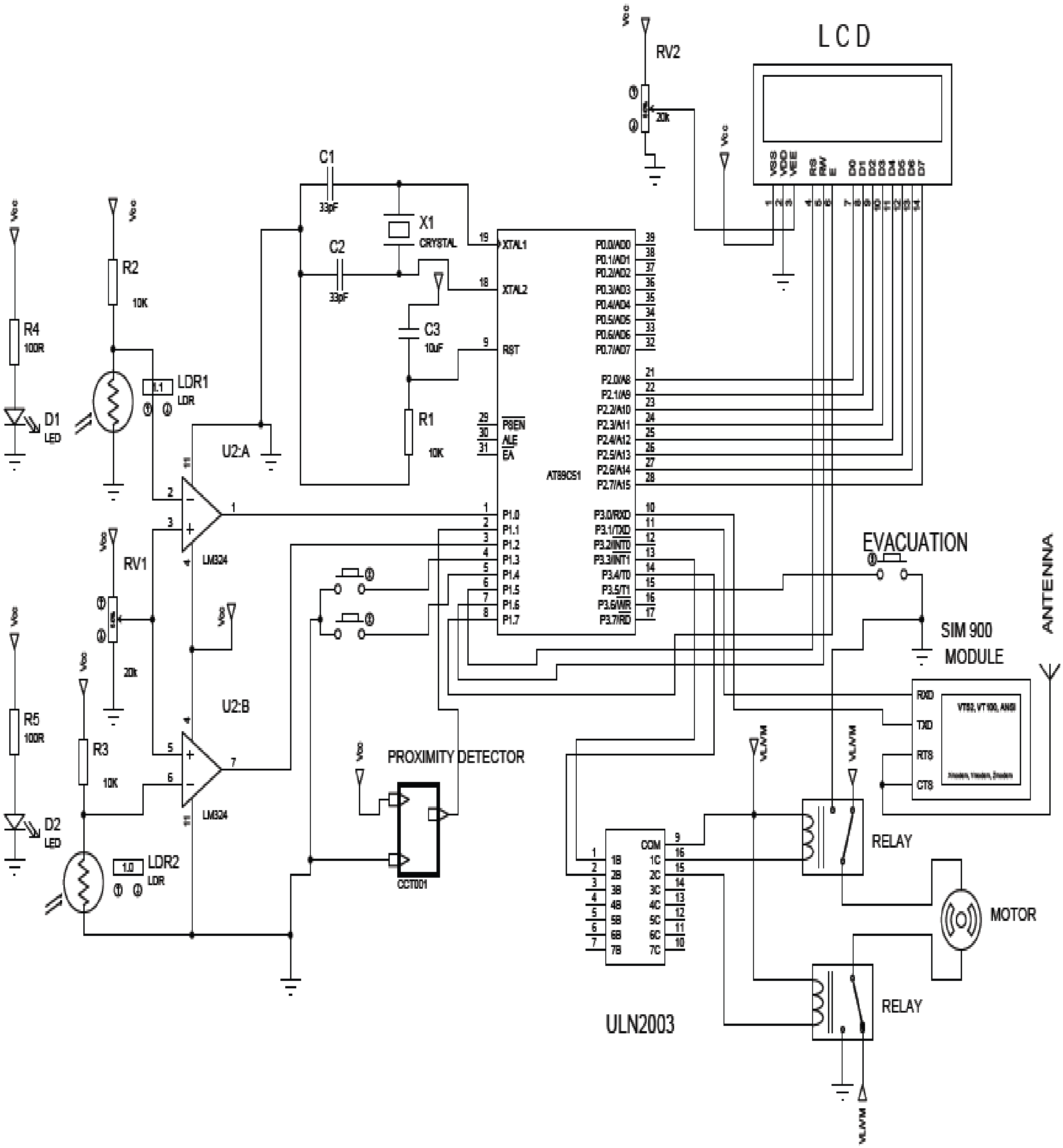

Figure 7: Complete Circuit Diagram

CONCLUSIONS

This work presented an enhanced solution to the problem of waste disposal especially in the cities in developing nations like Nigeria where a lot of wastes are generated. The automation of the opening and closing of the lids will ensure that very high standard of hygiene is maintained as the user will not have any contact with the bin. Environmental pollution and littering of the environment is minimized as the lid of the bin will be shut to the users until the disposal truck empties it thus the user will not be allowed to over fill the bin. Timely disposal of the wastes is ensured as the system automatically sends an SMS alert to the disposal truck driver once the bin is full thereby ensuring that the bin is made empty to avoid dumping of refuse on the floor.

REFERENCES

Adil Bashir, Shoaib Amin Banday, Ab. Rouf Khan, Mohammad Shafi (2013). Concept, Design and Implementation of Automatic Waste Management System; *International Journal on Recent and Innovation Trends in Computing and Communication ISSN 2321 – 8169, 1*, 7, P. 604 – 609

Jeroen Beliën, Liesje De Boeck and Jonas Van Ackere (2011) Municipal Solid Waste Collection Problems: A Literature Review. *HUB RESEARCH PAPERS, ECONOMICS & MANAGEMENT*

Kanchan Mahajan and J.S.Chitode (2014). Waste Bin Monitoring System Using Integrated Technologies. *International Journal of Innovative Research in Science, Engineering and Technology 3*, 7

Stephen Herman (2009). Limit Switches; *Industrial Motor Control* Ch.11 ISBN1435442393

Yann Glouche and Paul Couderc (2013). A Smart Waste Management with Self-Describing objects; *The Second International Conference on Smart Systems, Devices and Technologies* Retrieved from https://hal.inria.fr/hal-00924270/document