Automated Waste Seperation

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***Abstract*—The rapid increases in solid and hazardous waste volumes and types due to continued economic growth, urbanization, and industrialization have become an increasing problem in ensuring efficient and sustainable waste management for national and regional governments. The total municipal solid waste generated in 2006 has been estimated at 2.02 billion tons globally, representing an annual rise of 7 per cent since 2003. (Global Waste Management Market Report 2007). We must adequately control Segregation, handling, shipping and waste disposal to minimize the risk to patients, the public and the environment for their safety and health. When the waste is separated, its economic value is best realized. At present, no such separation system exists at the household level for dry, wet and metal debris. A cheap, easy-to-use solution for household segregation systems for direct processing is proposed in this report. The Automated Waste Separator (AWS) is an automated waste segregator. It is intended for sorting waste into metal waste, wet waste and dry waste. The AWS uses a mechanism to identify metallic elements and capacitive sensors in parallel to detect damp and dry waste. Experimental results show that the AWS is successfully used to segregate waste into metallic, wet and dry waste.**

***Index Terms*—component, formatting, style, styling, insert**

I. Introduction

II. Background Art,

Waste is any unwanted material or substance. It is generally discarded after primary use and is often considered to be of little or no economic value. However, waste management continues to be a significant challenge in urban areas, particularly in rapidly growing cities. A rise in the amount of waste produced has been seen in the high rate of population growth and the increase in human and economic activities. As more cities become industrialized, the congenital problem of waste management comes along with it. Technological and economic advancement has made the various kinds and types of solid waste more diverse, and their management is complex. Furthermore, the changing economic trend and urbanization in developing countries complicate solid waste management. Therefore, the waste's composition increases, but the amount of waste is also increasing from few kilograms to tonnage of waste produced. Though of little or no economic value, waste could be transformed by proper waste management into a product of high economic value. However, we can only realize the economic value of waste if it is segregated into various kinds. This project seeks to propose a system that could help waste collection companies realize the tremendous economic value of waste.

III. Literature Review

Waste is any substance that is discarded after primary use. It may be a by-product of a given process and is usually considered worthless and of no use. Rapid urban development facing developing countries, has come with severe environmental challenges concerning waste management. Solid waste arising domestic, social and industrial activities is increasing in quantity and variety due to the growing population rising standards of living in most African countries and development of technology. [1] Solid waste management (SWM) is a common term that encompasses a wide variety of activities and practices the describe unwanted residues of any given culture. Waste management or disposal shall comprise activities and actions required from the beginning until the final disposal point for waste management. It comprises waste collection, transportation, treatment and disposal, and waste monitoring and regulation.

Human activities generate waste that can be harmful to the environment, animal, plants and the ecosystem. [2] However, careful management can limit the damage done to the environment and conserve limited resources. Recently through communal and municipal action, conferences and training workshops, and government action, waste management has become a conjecture for responsible public health and safety. The fundamental environmental issue in industrial and developing countries worldwide is the identification and management of waste streams. As urbanization continues to occur, waste management becomes a significant challenge posing health and environmental problems for many countries. As a result, urbanization must be sustainable to reduce the ecological footprint while simultaneously improving the quality of life for our future generation. [3]

The characteristic of municipal solid waste (MSW) management coming for domestic, social, industrial and commercial activities is not only as a result of the growing population, rising standards of living and technological development but also as a result of the abundance and type of natural resources from a country or given locality. [4] The approach for MSW also varies and should be a function of the community. For instance, many studies on MSW management in developing countries show that quantity and waste composition varies based on the community and must adapt the waste management to suit these limitations. [4]

Waste management is poorly practised in less developed countries. The practise is primarily concerned with the collection and dumping of waste without any proper treatment methods. The form of control is mainly due to inadequate finance, poor law enforcement, and human resources. Moreover, current regulations do not adequately address waste management or disposal.

IV. Technical Field

At the industrial level, mixed waste is sorted using the following methods. First, manual sorting will remove more significant items. Then a large rotating drum, perforated with hole sizes, is sorted according to its size. Materials more diminutive than the diameter of the holes may fall, but large particles remain in the drum. Currently, based separators can be applied for electromagnet or eddy metal objects. Near-infrared scanners are used to distinguish different types of plastics by the material's ability to reflect light. X-rays can also be used for density-based separation of materials. How the waste segregation issue is resolved is by automating the whole process and reducing costs to adapt it at the household level.

V. Summary of Invention

This study looks at the waste management system within less developed countries to add value to the generated waste. It first analyses the kind of waste that is developed and how the waste is being managed. Then, it looks at how the waste generated could be helpful in man's activities and the effects of the existing waste management systems on the environment. The study talks mainly about the automation of a waste segregation system. It brings out the need for waste segregation at the source as a significant factor in realizing the true potential of waste. The study seeks to design and implement a system that would identify and segregate waste at the source. This is a small scale separation identifications and separation system and could be achieved using a microcontroller and an FPGA. We chose the Arduino and FPGA to fulfil this function.

A. Technical Problem

This Invention is setup to solve the problem of waste management on a small scale and mostly at Household levels.Furthermore when this is carried out succesful then it makes it easier to manage waste at higher levels.Waste management is the purposeful, systematic control of the generation, storage, collection, transportation, separation, processing, recycling recovery and disposal of solid waste in a sanitary, acceptable and economical manner. Waste management involves a broad range of actors performing various functions to help maintain the health and well-being of the population and the environment in human settlements in a clean, safe and enjoyable physical environment.

The type of waste generated by a given locality depends mainly on the activities of that locality. This implies a tremendous amount of industrial waste in highly industrialized countries, and municipal waste will be most significant in developing countries. Waste management methods, therefore, depend on the type of waste that is produced in the given locality. The waste composition of various countries is shown in the figure below. It is grouped into three categories, i.e. low-income countries, middle and high-income countries.

B. Solution to problem

The waste is pushed into the system via a flap. An IR sensor can detect this in the proposed approach, and the entire system begins. First, the waste comes under the metal detection system. This system is used for metallic waste detection. The object then falls into the sensing module of capacitive sensing. This module makes a distinction from wet to dry waste. A circular base containing dry, wet and metal waste containers shall be rotated once the debris has been identified. Immediately the container matches the type of waste placed under it, and the collapsible flap is lowered. Next, the garbage is thrown into the receptacle, and the flap is raised.The wastes can now be collected separately from the containers and forwarded for further processing.The diagrams below explain how this process is being carried out.

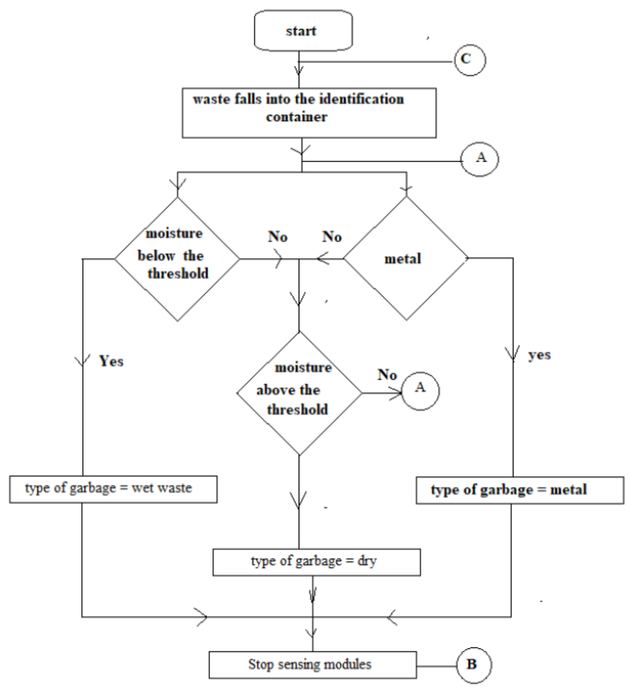

Fig. 1. Global Architecture

C. Advantageous Effects of Invention

Waste hierarchy could be classified into reduction, reuse and recycling, which ranks waste management strategies appropriate for waste minimisation. Most waste minimisation strategies are founded on the ranking of waste. The goal of the waste hierarchy is the maximum amount of resources and the minimum quantity of waste generated. Waste management is represented as a pyramid because the basic premise is that policies should promote measures to prevent waste generation. The first step or preferred action is to seek alternative uses

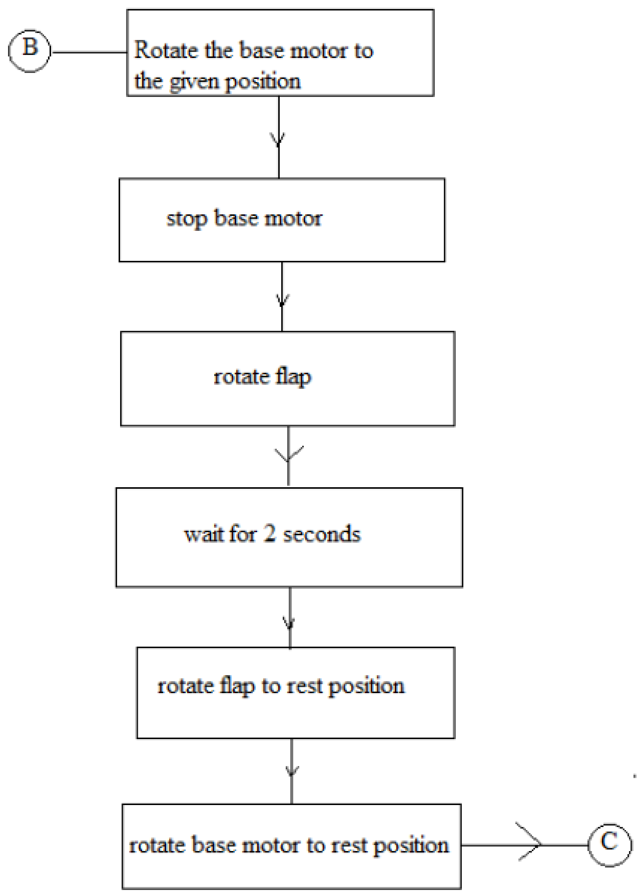

Fig. 2. Global Architecture 2

for the waste generated, i.e. by reuse. The next is recycling which includes composting. Following this step is material recovery and destruction to energy. The ultimate action involves disposal at deposits or combustion without recovery of energy. The last step is the final waste recourse not prevented from being diverted or recuperated. The hierarchy of waste represents the advance of a product or material through the sequential stages of the waste pyramid. The order is the later part of each product's life-cycle.
The significant advantages of waste segregation are; first, it keeps the environment clean, conducive and healthy. Furthermore, it Saves the planet and equally conserves energy for later use. It also helps to reduce environmental pollution to a minimum. Water treatment minimizes environmental health, to name a few impacts of waste. It can also enable the recycling of resources, like paper, canned goods, glass, to name a few. Dispose of solid, liquid, gaseous or dangerous substances is included in various waste disposal systems.

VI. Brief Descriptions of Drawings

In order to realise this project, the following tools were used.

a) Metal detector: In this tool we had other tools functioning together to produce an output.They include a capacitor, inductor , a coil, and resistors.Here is how we realised this part.First of all we will describe the functioning with an Arduino which was the original idea, and then move over to the FPGA which what was finally used due to the fact that it had to implemented in the way of High Level Synthesis. A metal detector is a device used for detecting metal and is often employed as a security device and commonly used at places like shops, airports, cinemas and many more. To achieve the functionality of the metal detector in this project, we used a coil and a capacitor responsible for detecting metal.

Whenever current passes through the coil, it generates a magnetic field around it. The transformation in that magnetic field produces an electric field. According to the faraday law, a voltage drop across the spindle caused by this electric field resists the magnetic field change, and its inductance is developed. When any metal comes near the coil, the coil changes its inductance. This change in inductance depends on the metal type. It decreases for nonmagnetic metals and increases for ferromagnetic material like iron. Depending on the core of the coil, the inductance value changes drastically. Here the medium of the flow of the magnetic field generated by the inductor is nothing but air. Such inductors have inductances of shallow values of about a few millihenries.

Since the coil wound here is an air-cored one, it acts as the core for the air-cored inductor when a metal piece is brought near the coil. By metal acting as the core, the inductance of the coil changes or increases considerably. With a sudden rise in the coil's inductance, the overall reactance or impedance of the LC circuit changes by a considerable amount when considered without the metal piece. The inductances of the coil for the presence of metal have been found in this project. We provide the LR high pass filter with a block wave or pulse generated by Arduino. As a result, in all situations, short spikes are generated. The pulse of the tips produced is 21. is proportional to the inductance of the coil. So with the help of these spike pulses, we can measure the inductance of the coil. But here, it is difficult to measure the inductance precisely with the spike because those spikes are of concise duration (approximately 0.5 microseconds), which is difficult to measure by Arduino. So instead of this, we use a capacitor charged by the rising pulse or spike and requires a few pulses to charge to the capacitor to the point where the Arduino analogue pin can read its voltage. The Arduino reads the voltage of this analogue pin using an ADC. After reading the voltage, the capacitor is quickly discharged by making the capacitor pin as output and setting it low. The whole process takes about 200 microseconds to complete. For better results, the measurement is repeated, and the average was taken. The results are then analyzed, and the required operation performed as per the architecture (program).

b) Moisture Sensor: A moisture sensor determines the moisture content of a medium. The soil moisture sensor uses capacitance to measure the dielectric permittivity of the surrounding medium. The sensor creates s voltage proportional

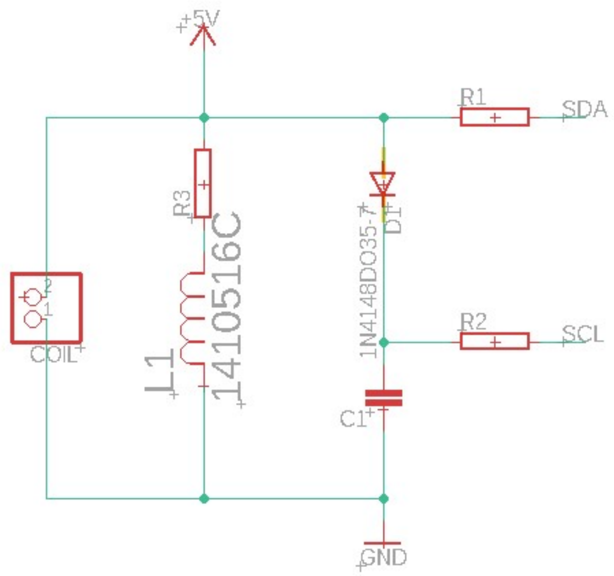

Fig. 3. Metal detection mechanism

to the dielectric permittivity and, therefore, the water content of the soil. The sensor consists of two components, i.e. the board and the part having legs. The two components are interconnected with the aid of jumper wires, and the board component is connected to the micro controller, in this case, the Arduino UNO. The circuit is associated with the Arduino using a four male header. The four male headers are labelled Vcc, ground, D0 and A0. D is for digital, and A is for analogue, which means we can get the values in both digital and analogue mode. The module also has 2 LEDs, one being the power on LED while the other works with the digital output pin.

c) Motors: Servor Motor: A servo motor is an actuator that rotates or motor that enables accurate control of the angular position, acceleration and speed. It uses a regular engine for position feedback and pairs it with a sensor. There are two main servo motor types, the AC and DC servo motor, split into position rotation servo motor, continuous rotation motor, and linear servo motor. The position rotation servo motor is used in this project. The shaft output rotates about 180 degrees. It includes physical stops located in the gear mechanism to stop turning outside these limits to guard the rotation sensor. These are the most common and most crucial servo motors and are commonly used in aircraft, robots, toys and many other applications.

2) Stepper Motor : A step motor is an electric motor whose main feature is that its shaft rotates by a fixed quantity of steps, which is moving. The internal structure of the engine produces this feature. Two main parts are a stepper engine, a rotor and a stator. The part of the engine that rotates and works is the rotor. The stator constitutes the fixed part of the rotor motor. In a step motor, the rotor is a permanent magnet. The stator comprises several bows, acting as an electromagnet when power is passed through them. On charging, the electromagnetic coil causes

Fig. 4. Moisture Sensor [5]

alignment of the rotor. The rotor is driven by a switch which ring has a running current. These motors have a sequence of bobbins, and these bobbins must be energized in a specific way to turn the motor. The motor takes a step when each spiral is energized, and the sequence of energy is constantly moving the engine to turn.

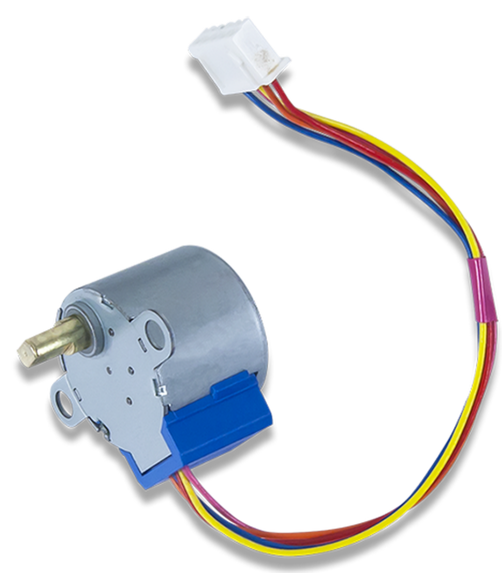

Fig. 5. Stepper Motor [6]

d) Arduino Uno: : Arduino is a microcontroller with a single-board designed to make the application more reachable, interactive objects, and environment. The hardware features an open-source hardware board designed with an 8-bit AVR or 32-bit Atmel ARM. Current models include a USB interface, six analogue input pins and 14 digital I/O pins to enable the user to connect various boards. The UNO Arduino board is an ATmega 328-based microcontroller. It includes 14 digital I/O pins in which 6 PWM outputs, a ceramic 16 MHz resonator, an ICSP header, a USB interface, 6 Analog IPs, a power jack and a reset button can be used, which includes all the requisite microcontroller support. They are easily connected to a USB cable or AC-to-DC adapter or battery to get started. To begin with, The board of Arduino UNO vary from each other. It is programmed with the Atmega16U2 as a USB to serial conversion device.

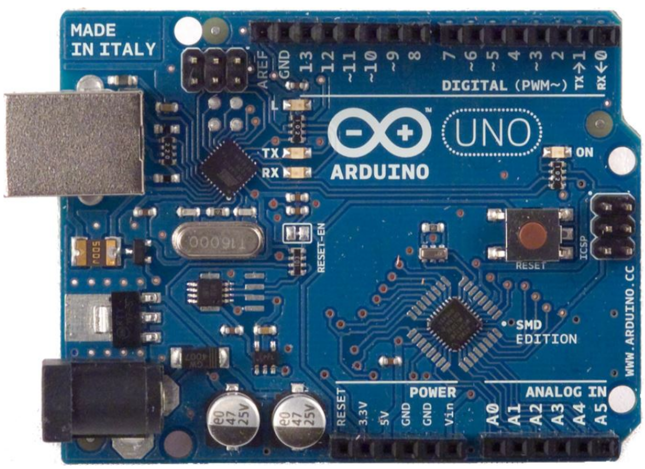

Fig. 6. Arduino Uno [7]

e) Field Programmable Gate Array(FPGA): The FPGA used in this project best fits the application of this project, which is the XC7Z010-1CLG400C from Xilinx. It is commonly used in commercial products (e.g., Zybo boards) and readily available. It was chosen since it contains 400 pins which should be the least for a fully functional FPGA. It has a built-in 12bit ADC for analogue signal processing, converting the analogue signals into equivalent values from 0 to 4095. The coil is used to detect any metal in the waste; whenever metal is detected, a distortion in the coil's magnetic field and thus the magnitude of current flow is altered, which is measured through a built-in analogue to digital converter (ADC) of the FPGA.

VII. Description of Embodiment

A. Schematics

The schematics here is the complete representation of the electrical components and connections. It focuses on the components and how they relate to each other. Looking at the General structure of the schematic, we see that it is done in a distributed representation. In the schematics, we have the following: There is a circuit for metal detection (described above), powered by the primary 5V power source, then Two motors which are meant rotation of the flaps, powered an extra

Fig. 7. FPGA [8]

powerful motor since most times the motors are too powerful so cannot be given a power supply less $9V$. So the power should be around $12V$. Also, we have the Ultrasonic sensor, which has the Echo, Trigger, Ground and connected to the main 5V supply, for detecting objects on arrival. Furthermore, we have the Arduino, which receives pulses/signals from the moisture sensor and motors and then converts them to digital signals before sending them to the FPGA. In addition, we have the brain of the Operations, which is the FPGA. The FPGA receives all the signals, synthesizes these signals and then releases an output based on what input was sent.

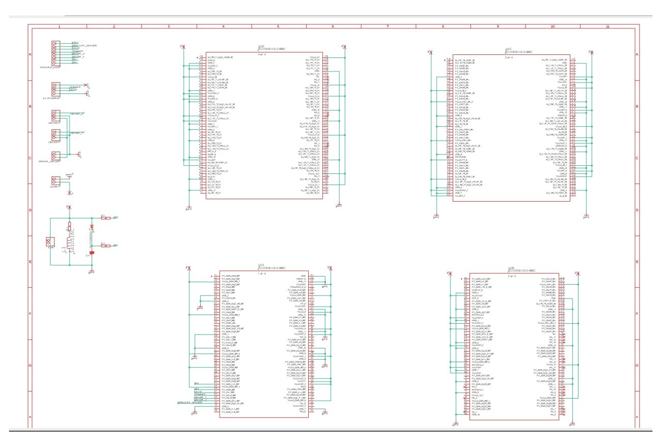

Fig. 8. Overall Schematics

B. PCB(Printed Circuit Board) Design

The PCB is a mechanically supported and electrically connected electronic component via conductive pathways, tracks or traces of signals, laminated in a non-conductive substrate

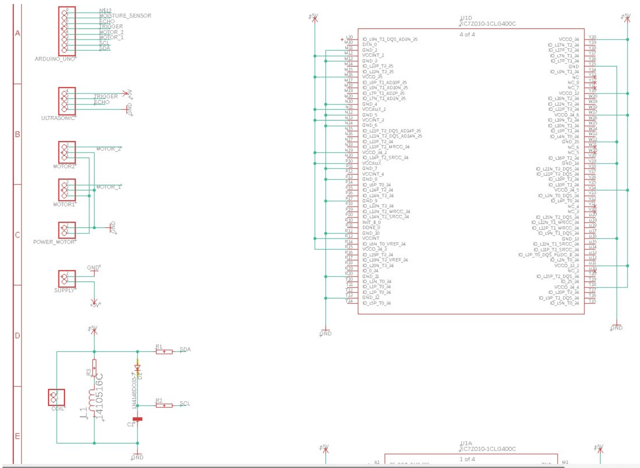

Fig. 9. Schematics 1

from a copper sheet. For the PCB design, first, we consider certain factors before trying to place these components alongside each other for later usage. First is the PCB size from below; it is seen that the PCB board is minimal ($Width = 37.69mm$ and $Height = 49.7mm$), but this feature varies depending on the functionality of the PCB. This size avoids, first of all, the waste of equipment as hardware is costly and reduces production cost. Furthermore, heating is an essential factor when it comes to PCB design. This check is carried out mainly for the respective components to avoid accidents caused by overheating in the future. This is verified using values such as the track width and trace width. This trace width computation in this PCB was computed just for the copper, and a value of $2.87mm$ was realised. Furthermore, the PCB contains just two layers: the Top layer(Red) and the bottom layer(Blue); we could also see there are 9 vias and no air wires. Therefore, the PCB can be classified under Multi-Chip-Module-Laminate. Here the conductor is through the middle of the pads to avoid loose contact. Also, for this PCB, we use the $FR4$ GT(Glass Transition Temperature) = $130 degreescelsius$ because the PCB uses just two layers.

C. VHDL Programme and implementation

So in continuation of this project, a VHDL code was developed using ModelSim to implement all the functions specified in the schematics and PCB. We implemented two functions, the range detector(ultrasonic sensor function) and the ADC converter. With the ADC converter, we were converting signals from Analog to Digital. For the Range sensor, we have four parts: the counter, which is meant to carry a count for the sensor, and then we have the Distance calculation module, which calculates the distance between the sensor and the Trigger module to generate a pulse for the sensor. This is because the sensor will wait to set a trigger from FPGA before sending the measured distance back to the FPGA. Furthermore, we have the Range Sensor module, which combines all three modules by instantiating these modules and mapping them to the ports

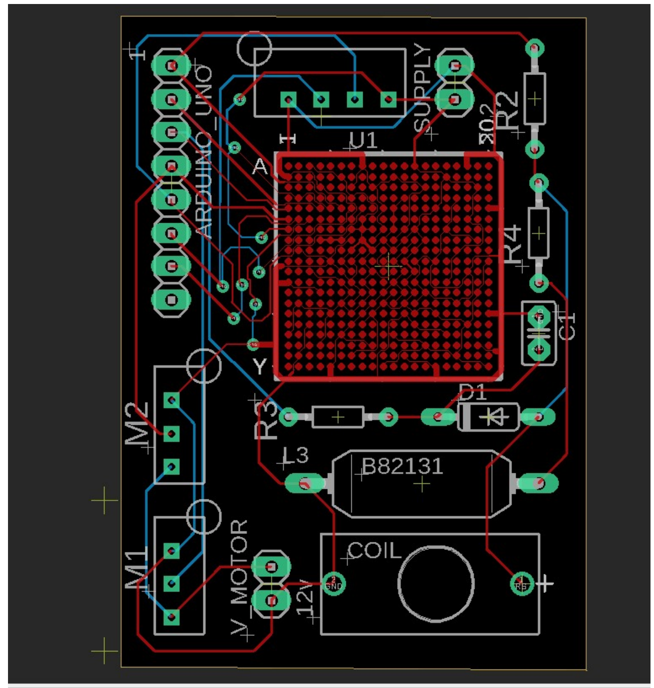

Fig. 10. PCB Design

to produce the required output. There is a summary of the VHDL, and all parts can is seen below.

```
entity Distance_calculation is
    Port ( clk : in  STD_LOGIC;
           Calculation_Reset : in  STD_LOGIC;
           pulse : in  STD_LOGIC;
           distance : out  STD_LOGIC_VECTOR (8 downto 0));
end Distance_calculation;


architecture Behavioral of Distance_calculation is
component Counter is
generic (n : POSITIVE := 10);
Port ( clk : in STD_LOGIC;
enable : in STD_LOGIC;
reset : in STD_LOGIC; -- Active Low
Counter_output : out STD_LOGIC_VECTOR(n-1 downto 0));
end component;
signal Pulse_width : STD_LOGIC_VECTOR(21 downto 0);
begin
--CounterPulse : Counter generic map(22) port map(clk, pulse, not Calculation_Reset, Pulse_width);


Distance_calculation : process(pulse)
variable Result : integer;
variable multiplier : STD_LOGIC_VECTOR(23 downto 0);
begin
if(pulse = '0') then
multiplier := Pulse_width * "11";
Result := to_integer(unsigned (multiplier (23 downto 13)));
if(Result > 458) then
distance <= "111111111";
else
distance <= STD_LOGIC_VECTOR(to_unsigned (Result, 9));
end if;
end if;
```

Fig. 11. ADC Code

VIII. Conclusion

In this paper, we developed an abstract way to automatically separate waste(A full implementation can be seen in [9] for better understanding). After stating the problem of waste disposal, a small scale solution is provided in this paper. Here we have designed just a part of the system, not fully implemented. But we tried to implement the hardware on an abstract level with the use of VHDL. So we attempted to model the system behaviour and structure. A schematic was designed as a pathway to design the PCB layout. We successfully did all this, then created a VHDL code to implement the system

```vhdl
--use UNISIM.VComponents.all;

entity Counter is
generic(n : POSITIVE := 10);
    Port ( clk : in  STD_LOGIC;
           enable : in  STD_LOGIC;
           reset : in  STD_LOGIC;
           counter_output : out  STD_LOGIC_VECTOR (n-1 downto 0));
end Counter;


architecture Behavioral of Counter is
signal count : STD_LOGIC_VECTOR(n-1 downto 0);
begin
process (clk, reset)
begin
if (reset = '0') then
count <= (others => '0');
elsif (clk'event and clk = '1') then
if (enable = '1') then
count <= count + 1;
end if;
end if;
end process;
counter_output <= count;
end Behavioral;
```

Fig. 12. Counter Code

```vhdl
entity Distance_calculation is
    Port ( clk : in  STD_LOGIC;
           Calculation_Reset : in  STD_LOGIC;
           pulse : in  STD_LOGIC;
           distance : out  STD_LOGIC_VECTOR (8 downto 0));
end Distance_calculation;

architecture Behavioral of Distance_calculation is
component Counter is
generic (n : POSITIVE := 10);
Port ( clk : in STD_LOGIC;
enable : in STD_LOGIC;
reset : in STD_LOGIC; -- Active Low
Counter_output : out STD_LOGIC_VECTOR(n-1 downto 0));
end component;
signal Pulse_width : STD_LOGIC_VECTOR(21 downto 0);
begin
--CounterPulse : Counter generic map(22) port map(clk, pulse, not Calculation_Reset, Pulse_width);


Distance_calculation : process(pulse)
variable Result : integer;
variable multiplier : STD_LOGIC_VECTOR(23 downto 0);
begin
if(pulse = '0') then
multiplier := Pulse_width * "11";
Result := to_integer(unsigned (multiplier (23 downto 13)));
if(Result > 458) then
distance <= "111111111";
else
distance <= STD_LOGIC_VECTOR(to_unsigned (Result, 9));
end if;
end if;
```

Fig. 13. Distance Calculation Code

```vhdl
entity Trigger_generator is
Port (clk : in STD_LOGIC;
Trigger : out STD_LOGIC);
end Trigger_generator;

architecture Behavioral of Trigger_generator is
component Counter is
generic(n : POSITIVE := 10);
Port ( clk : in STD_LOGIC;
enable : in STD_LOGIC;
reset : in STD_LOGIC; -- Active Low
Counter_output : out STD_LOGIC_VECTOR(n-1 downto 0));
end component;
signal resetCounter : STD_LOGIC;
signal outputCounter : STD_LOGIC_VECTOR(23 downto 0);
begin
trigg : Counter generic map(24) port map(clk, '1', resetCounter, outputCounter);
process (clk)
constant ms250 : STD_LOGIC_VECTOR(23 downto 0) := "101111101011110000100000"; --to generate 250ms pul.
constant ms250And100us : STD_LOGIC_VECTOR(23 downto 0) := "101111101100111110101000"; -- to gnerate
begin
if(outputCounter > ms250 and outputCounter < ms250And100us) then
trigger <= '1';
else
trigger <= '0';
end if;

if(outputCounter = ms250And100us or outputCounter = "XXXXXXXXXXXXXXXXXXXXXXXX") then
resetCounter <= '0';
else
resetCounter <= '1';

end if;
end process;
```

Fig. 14. Trigger Generator Code

```vhdl
entity Range_Sensor is
    Port ( fpgaclk : in  STD_LOGIC;
           pulse : in  STD_LOGIC;
           triggerOut : out  STD_LOGIC;
           meters : out  STD_LOGIC_VECTOR (3 downto 0);
           decimeters : out  STD_LOGIC_VECTOR (3 downto 0);
           centimeters : out  STD_LOGIC_VECTOR (3 downto 0);
                      motor1 : out std_logic;
                      motor2 : out std_logic);
end Range_Sensor;


architecture Behavioral of Range_Sensor is
component Distance_calculation is
Port(clk : in STD_LOGIC;
Calculation_Reset : in STD_LOGIC;
pulse : in STD_LOGIC;
distance : out STD_LOGIC_VECTOR(8 downto 0));
end component;

component trigger_generator is
Port(
clk : in STD_LOGIC;
trigger : out STD_LOGIC
);
end component;

signal distanceOut : STD_LOGIC_VECTOR(8 downto 0);
signal triggOut : STD_LOGIC;
```

Fig. 15. Global Architecture

in the direction of High-Level Synthesis with the help of an FPGA. At the moment, the only results generated were the signals seen after the code was synthesized. But in the future, we hope to implement this project on an FPGA or an Arduino fully.

References

[1] M. Alberti, "Urban Patterns and Environmental Performance: What Do We Know?" *Journal of Planning Education and Research*, vol. 19, no. 2, pp. 151–163, Dec. 1999, publisher: SAGE Publications Inc. [Online]. Available: https://doi.org/10.1177/0739456X9901900205

[2] M. Bertrand and S. Mullainathan, "Do people mean what they say? implications for subjective survey data," *American Economic Review*, vol. 91, no. 2, pp. 67–72, May 2001. [Online]. Available: https://www.aeaweb.org/articles?id=10.1257/aer.91.2.67

[3] N. R. Ambati, "Social innovation practices in sustainable waste management: Case study of successful social enterprises in ahmedabad," *International Journal of Scientific and Technology Research*, vol. 8, no. 12, pp. 1978–1985, 2019.

[4] D. Zhang, T. S. Keat, and R. M. Gersberg, "A comparison of municipal solid waste management in Berlin and Singapore," *Waste Management*, vol. 30, no. 5, pp. 921–933, May 2010. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0956053X09005194

[5] "Soil moisture - Let's Control It." [Online]. Available: https://www.letscontrolit.com/forum/viewtopic.php?t=5223

[6] "Stepper Motor - Digilent." [Online]. Available: https://store.digilentinc.com/stepper-motor/

[7] "A000073 by Arduino Corporation | Development Boards & Kits." [Online]. Available: https://www.arrow.de/products/a000073/arduino-corporation

[8] "Xilinx fpga zynq core board xc7z010 xc7z020 7000 industrielle xme0724—instrument parts & accessories— - aliexpress," https://de.aliexpress.com/i/4000715510628.html, (Accessed on 07/01/2021).

[9] A. Chandramohan, J. Mendonca, N. R. Shankar, N. U. Baheti, N. K. Krishnan, and M. S. Suma, "Automated waste segregator," in *2014 Texas Instruments India Educators' Conference (TIIEC)*, 2014, pp. 1–6.