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# DEVELOPMENT OF A MICROCONTROLLER- BASED VACUUM CLEANER

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## Abstract
*This research project deals with the design and construction of an automatic vacuum cleaner. A cleaner which is capable of efficient floor/dust cleaning and capable of avoiding obstacles is achieved in this project. Today, many people lead busy lives, busy with their work and not getting sufficient time to clean the house. The automatic vacuum cleaner helps to clean the floor. This is done by simply pressing a switch and the cleaner does the work. The cleaner cuts down the labour used in factories and homes for cleaning the floor. The automatic vacuum cleaner has many advantages and applications which are highlighted in this paper. The circuit design consists of; Arduino Mega2560 board, HC-SR04 ultrasonic sensors, L298N motor Regulator IC LM7805T, rechargeable 12V 18Ah Gel battery for power supply and other necessary circuit components. The vacuum unit consists of an intake of nozzle, intake port, vacuum chamber and the suction fans. The locomotion unit consists of; two 12V 62rpm geared motors, two drive wheels, one swivel front wheel and other assembly. The microcontroller as the central and intelligent component makes the logical decisions. The microcontroller sends signal to turn ON the suction fans, when the start push button is pressed. The microcontroller also tells the motor driver which direction it should rotate the motors based on the outputs of the three ultrasonic sensors (sensors serve as eyes to the machine, to sense obstacles within a 30cm radius). The developed cleaner will be useful for the household and industrial applications. The cleaner has eliminated the risk of dust cleaning and the physical labour associated with it.*

***Keywords***: *Arduino, ultrasonic sensor, motor driver, automatic vacuum cleaner, geared motor.*

## INTRODUCTION
An automated cleaning robot, as the name indicates is used for autonomous cleaning of the house, work or public spaces. They find their applications in-floor

cleaning, pool cleaning, lawn mowing, board cleaning and window cleaning. The modern robotics is a science of intelligent control and connection between perception and action (Gangadharaswam 2019).

Floor Cleaning has always been an integral part of the daily health and hygiene routine, be it a household or an industry. Floor cleaning is mainly of two types- Dry cleaning, which mainly involves removal of dust and particulate matter and wet cleaning, which involves cleaning of the surface with the use of water and other floor disinfectants to clean the floor of liquid waste (Kumar et al. 2019).

In our world today, most systems are fully automated; some are semi-automatic while some systems still rely fully on human intervention for successful operation. Technology has come in various ways to make the life of man easier. Cleaning is one of the most important tasks in everyday human activity and it has always been a time-consuming process. In Africa, one of the major role a married woman has to play is keeping the home clean. What would you expect a career woman to do? Sweep the floor every morning? It will be a trivial task, combining her career life and her as a wife in the family. The same goes for a person who is single or even a disabled person. There is need for intervention. As it is said, “ideas rule the world”. An automatically operated vacuum cleaner will help remove the labour intensive and the tiring task of floor cleaning. It is the best possible, technical solution for this daunting task of floor cleaning (Amadi 2022).

Nowadays, people lead a busy life. People in urbans have abnormal long working hours. In such a situation an individual will always find ways of saving time. For career oriented women, it's hard to handle home together with work. For a disabled person it is even more difficult to keep immediate surrounding clean. For individuals with respiratory illness or dust allergy, cleaning dusty areas will be derogatory for their health. The design and construction of a vacuum cleaner is the best technical solution to these problems.

In conclusion the importance of this research is to design an automatic vacuum cleaner that is capable of cleaning the floor without human labour and provides a means of effective dust cleaning. The cleaner is fully autonomous and equipped with a unique obstacle avoidance technique.

The limitations of this research work are that the cleaner is only suitable for effectively cleaning the floor and picking up dirt of a limited diameter range.

## PROBLEM STATEMENT

Nowadays, people lead a busy life. People in urban areas have abnormal long working hours. In such a situation an individual will always find ways of saving time. For career oriented women, it is hard to handle home together with work. For a disabled person. It is even more difficult to keep immediate surrounding clean. For individuals with respiratory illness or dust allergy, cleaning dusty areas will be derogatory for their health. The design and construction of a vacuum cleaner is the best technical solution to these problems. After all, technology is here to makes our lives much easier.

## METHODOLOGY

The first step of this project was to investigate the requirements for a robot vacuum cleaner. This step provided information about specifications of components required. The next step was to design and construct the main circuit board of the vacuum cleaner. Prior to this the, program was written for the microcontroller using the Arduino IDE software. After that the vacuum compartment was put together. Necessary tests were carried out to determine the efficiency of the machine. This project deployed an Arduino ATmega2560 microcontroller, three HC-SR04 ultrasonic sensors, L298N motor driver, two 12V 1500rpm suction fan, two 12V 62rpm gear motor, three drive wheels, Regulator IC 7805T, 12V 18Ah Gel battery. The vacuum unit consists of an intake nozzle, intake port, vacuum chamber and the suction fans. The vacuum chamber has three screens inserted to collect trash of various diameter.

## DESIGN OF THE CLEANER

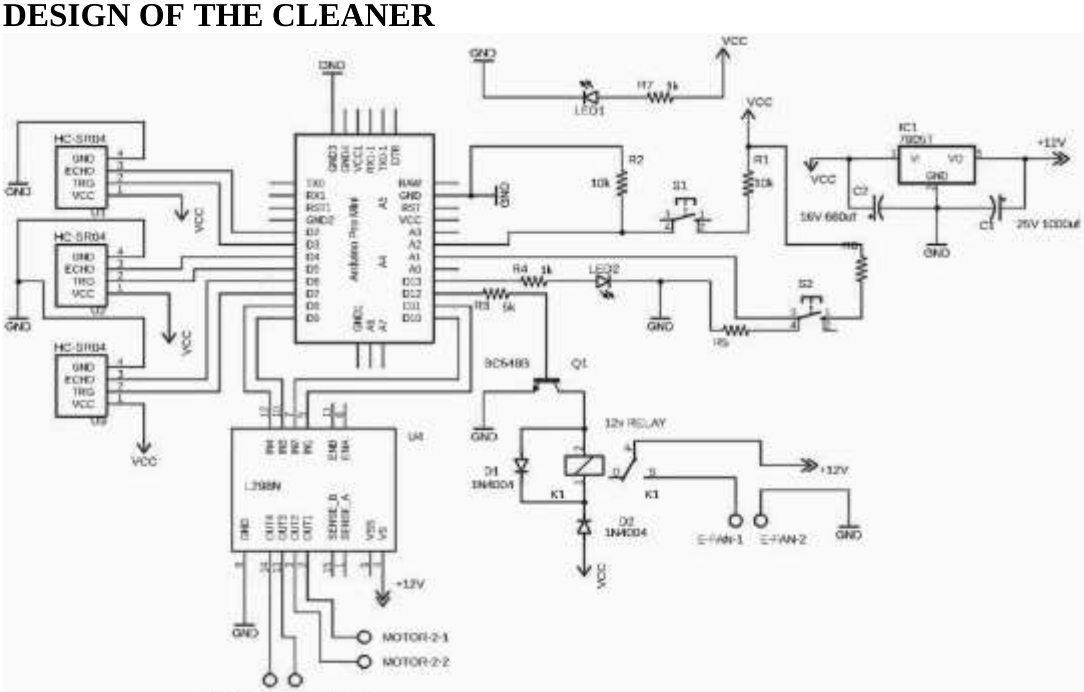


Figure 1: Schematic diagram of automatic vacuum cleaner circuit

The circuit design consists of; Arduino Mega2560 board, HC-SR04 ultrasonic sensors, L298N motor driver, Regulator IC LM7805T, rechargeable 12V 18Ah Gel battery for power supply and other necessary circuit components. The vacuum unit consists of an intake of nozzle, intake port, vacuum chamber and the suction fans.

Table 1: Component specification

| *Components* | *Specification* |
|---|---|
| *Motor driver L298N* | 15pins, maximum current 2A, 5-35V drive voltage. |
| *Arduino mega 2560* | 54 digital input/output pins |
| | 7-9V input, 800mA |
| *LM7805 regulator IC* | 7-35V input, 5V and 1A output, |
| *Red/White LED* | 3-5V, 20mA |
| *Ultrasonic sensors* | 5V operating voltage |
| *Relay* | 12V, 10A |
| *Geared motor* | 12V, 62rpm |
| *Battery* | 12V 18Ah |
| *Blower Fan* | 12V, 2.65A, 1500rpm |

**Sensor** - HC-SR04 Ultrasonic sensor is a 4-pin module, whose pin names are Vcc, Trigger, Echo and Ground respectively. This sensor is a very popular sensor used in many applications where measuring distance or sensing objects are required. The module has two eyes like projects in the front which forms the Ultrasonic transmitter and Receiver. The sensor pins are connected to the microcontroller.

Figure 2: Ultrasonic Sensor

Three ultrasonic sensors have been chosen to be used to serve as eyes to the device and they are placed at the front, left and right on the body of the machine also considering the viewing angles such that one doesn't interfere with the other.

**Arduino board -** The Arduino Mega 2560 is a microcontroller board based on the ATmega2560. It has 54 digital input/output pins (of which 15 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The MCU is the central component of the circuit. All components are controlled and connected to the MCU. The controller is programmed using Arduino IDE software.

Figure 3: Arduino Mega 2560

**Wheel** - It is a three-wheel system, where the front wheel is a follower and the two back – wheels are the drivers since only those two are attached to the DC geared 62rpm motors.

Figure 4: Motor Assembly Parts

**Motor** – DC geared motors have gear box pre-attached to them which is used in a variety of robotic applications. Geared motor has the ability to deliver high torque at low speeds. The gear head functions as a torque multiplier and can allow small motors to generate higher speeds. The geared motor and its assembly were fastened to the base of the machine with bolts and nuts. The motors are connected to the OUT pins of the motor driver module.

Figure 5: DC Geared Motor

Two DC geared motors are required, since two will be used for driving the wheels of the robot.

**Power** - Unlike non-robotic vacuum cleaners, it cannot be operated using power cords. So, batteries are used to power these autonomous robots. In this work a rechargeable 12V 18Ah Gel battery is used and can be charged using mains supply or solar module.

**Motor Driver** – This **L298N Motor Driver Module** is a module for driving DC and Stepper Motors. This module consists of an L298N motor driver IC and a 78M05 5V regulator. **L298N Module** can control up to 4 DC motors, or 2 DC motors with directional and speed control. The motor driver is connected to the two geared motors via it output terminal block. The input pin 1-4 is connected to the PWM pins of the microcontroller. The module is also connected directly to the battery.

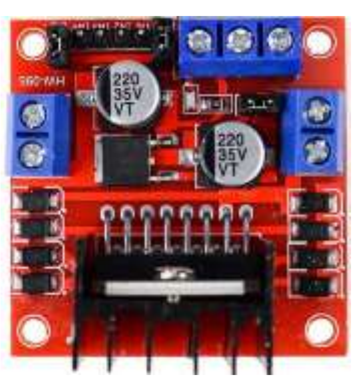


Figure 6: L298N Motor Driver

**Suction Fan**

Centrifugal blowers differ based on their airflow capacity, blower type, blower dimension and maximum operating pressure. This blower was chosen because of high speed, low amp rating and size

Figure 7: Suction Fan 12 VDC 2.65A

**System Operation**

The circuit basically consists of three ultrasonic sensors, motor driver module, two suction fans, Arduino mega MCU, LM7805 regulator IC and other basic circuit components. The circuit powered with a 12V, 18Ah battery.

When the circuit is turned ON by the switch, 12V is injected into the circuit and is regulated to 5V by the LM7805 regulator. The 5V powers ON the MCU. At this point the Red LED come ON and the white LED begins to blink.

The MCU is the brain of the system, responsible for running the program. The ultrasonic sensors act like eyes to the robot. When the start push button is pressed the MCU sends signal to the motor driver to drive the motors in a forward direction (the white LED becomes stable). The output pin from the MCU to the transistor is HIGH, voltage is supplied to the base of the BC548 transistor. The transistor actuates the relay coil by completing the circuit, which turns on the suction fans. The 1N4004 diode is connected in reverse biased across the relay coil to protect the transistor. The capacitors reduce fluctuations in the circuit. When the stop push button is pressed the robot stops moving, the fans stops working and the white LED starts to blink.

The ultrasonic sensors are placed on at the front of the robot, one on the left and the other on the right. When the cleaner is powered on it moves forward in a straight line until it meets an obstacle. By default, the robot is programmed to turn right. If there is obstacle to the right, it then turns left.

The program was written using simple algorithm. The program begins to run when the switch is turned ON. A red LED begins to glow and the white LED begins to blink. If the start push button is pressed, the blower comes ON and 5 seconds later, the robot begins to move in a forward direction. It starts to clean. Three scenarios were considered for obstacle manoeuvre: firstly, if there is obstacle to the front, the robot turns right, moves forward, turns right and moves forward. Secondly, if there is obstacle to the right and front, but none to the left, the robot turns left, moves forward, turns left and moves forward. Lastly, if there is obstacle to the front, right and left the robot moves backwards and checks for the first and second scenarios. The program flow chart of the work is shown below:


Figure 8: Program flow chart of the system

## DESIGN CALCULATIONS

### Design Assumptions

The following assumptions where made in the analysis of the design;
Efficiency of machine 80%
Length of room = 4800 mm
Breadth of room = 4500 mm
Area of room = 2160000mm$^2$
The cleaner is used on a purely flat, plain and smooth surface.

### Determining the Speed of the Vacuum Cleaner

The higher the diameter of the wheels the lesser the speed. A smaller diameter will allow the RVC to move at a desired speed (at this point there is no specific value of desired speed in mind).
Radius of drive wheel (R) = 38.2mm
Output of gear motor = 62 RPM
Converting to linear Speed (v)
Speed (v) = $R \times \omega$

$$\omega = \frac{2\pi N}{60}$$

Where ω is angular speed in radian per second and N is number of revolution
$\omega$ = 6.493 radians/second
v = 3.82mm × 6.49 radians/second = 0.24802m/s
Speed (v) = 0.248m/s
Considering efficiency of power delivered to motor = 80%
Speed delivered or Speed of Robot ($v_r$) = $v_r$×0.8 = 0.198m/s

### Determining the Time Taken for the Cleaner to Clean a Room with Dimensions Specified

Time taken by the robot to cover the room length once (t)

$$= \frac{L}{Vr} = \frac{4800}{198.42} = 24.19\text{seconds}$$

Number of passes required for robot to cover the entire room

$$= \frac{bredth\ of\ room}{width\ of\ the\ cleaner} = \frac{4500}{262} = 17 \text{ passes approximately}$$

Total time taken for the robot to clean the entire room
= 17×24.19 = 415.48seconds

Hence it will take the robot approximately 7 minutes to clean a square area of $2160000mm^2$

**Determining the Battery Capacity**

The battery life can be determined using this expression:

Battery life = $\frac{battery\ capacity\ in\ Ah}{load\ current\ A}$

Battery capacity in Ah = 18Ah

Load current = 2×1.5A (motor current) + 2×2.65A (fan) + 0.8A (MCU) = 9.1A

Therefore, battery life = $\frac{18\text{Ah}}{9.1A}$ = 1.98 hours = 7128 seconds

**Determining the Distance Covered by the Cleaner when Battery is full.**

Speed of robot = 0.198m/s

Time of battery life = 7128 seconds

Distance covered by the robot = $speed \times time$ = $198.42 \times 7128$ = 1414337.76mm

**Determining the area of intake port**

Circumference of intake port = 168mm (measured)

Radius of the intake port (R)

= $\frac{circumference\ intake}{2\pi}$ = $\frac{168}{2\pi}$ = 26.74mm

Area of intake nozzle

= $\pi R^2$ = $2246.33mm^2$

The intake nozzle is a rectangular shape; the length of the intake port is the same as the width of the robot (262mm). Hence, the width of the nozzle required to give an area of $2246.33mm^2$ will be given as

$\frac{2246.33}{262}$ = 8.57mm

**Determining bin capacity**

The container used as bin has the shape of a cuboid. The size of the container:

Length 153mm, breadth 153mm and height 75mm. the volume of the bin is calculated using the expression below.

Volume = Length x breadth x height

= $153\ x\ 153\ x\ 75 = 1{,}755{,}675mm^3$

Volume in litres = $17.56l$

Pictorial view of the cleaner

Figure 9: Front and Rear View of Cleaner

**TESTING**

The tests carried out were done to achieve the following objectives:

1. Observe the obstacle manoeuvre technique of the robot using four different scenarios.
2. Determine the speed of the vacuum cleaner.
3. To determine the maximum weight and the size of dirt the cleaner can pick up.

The procedures required to achieve the first objective is listed below:

i. Case 1: An obstacle is placed 600mm to the front of the vacuum cleaner. The cleaner is switched ON and the start push button is pressed.
ii. Case 2: Two obstacles were placed one to the left and the other to the front of the cleaner, at the same distance stated above. The cleaner is switched ON and the start push button is pressed.

iii. Case 3: Two obstacles were placed one to the right and the other to the front of the cleaner, at the same distance stated above. The cleaner is switched ON and the start push button is pressed.
iv. Case 4: three obstacles were placed at the same distance stated above to the left, right and front of the cleaner. The obstacles were placed in such a way that there is no way for the cleaner to pass through. The cleaner is switched ON and the start push button is pressed.

Observations made are discussed in the results section of this chapter.

The procedures required to achieve the second objective is listed below:

1. A distance of 3620mm was marked (a start and a finish line). Stopwatch was used to record time elapsed in seconds.
2. The vacuum cleaner was placed at the start line. The cleaner is switched ON and the start push button is pressed.
3. The time taken for the cleaner to reach the finish line was taken. Procedure 2 and 3 were repeated five times with the same distance. The average of the time recorded was calculated.
4. The results obtained were recorded in a table.
5. The speed of the vacuum cleaner was calculated using the expression:

$$speed\ of\ vacuum\ cleaner = \frac{distance\ travelled\ by\ the\ vacuum\ cleaner\ in\ meters}{average\ time}$$

The procedures required to achieve the third objective is listed below:

1. To determine the maximum weight and size of the dirt picked up the cleaner was switched ON and allowed to clean a dirty area.
2. After cleaning the cleaner was then switched OFF. The bin was opened and emptied. The largest size of dirt was separated.
3. The size of the dirt was measured and recorded.

## RESULTS

The following results were obtained from the first test carried out.

Case 1: the robot turned to the right as is expected, based on the program written.
Case 2: the robot turned to the right avoiding obstacles to the left and in front.
Case 3: the robot turned to the left with obstacles in front and to the right.
Case 4: the robot reversed (moved backwards), and turned to the right when there was a way out.

The following results were obtained from the second test carried out.

Table 5.1 Table showing distance covered and time measured

| *S/N* | *Distance covered (mm)* | *Time (seconds)* |
|---|---|---|
| *1* | 3620 | 21 |
| *2* | 3620 | 22 |
| *3* | 3620 | 20 |
| *4* | 3620 | 23 |
| *5* | 3620 | 23 |

The time measured is recorded to the nearest whole number

Average time = $\frac{21+22+20+23+23}{5} = 21.8s$

Speed = $\frac{3.62}{21.8} = 0.1661m/s$

The following results were obtained from the third test carried out.

These observations were made. The cleaner was able to pick up dust size particles very easily. Particles larger than the nozzle of the cleaner could not be picked up. The largest size of particle has a diameter around 8.5mm.

**DISCUSSION**

It was observed that the robot obstacle manoeuvre was perfect. The robot carried out the instruction as written in the program. It reacted positively to all the scenarios considered in the programming. More sensors can be employed to enhance the manoeuvre of obstacles. The speed calculated comes up short when compared to the speed calculated based on the speed of the gear motor. The initial speed was calculated to be 0.198m/s (speed of the motor without weight attached). The reason for the drop-in speed is as a result of the weight of the vacuum cleaner.

**CONCLUSION**

The Automatic vacuum cleaner is an essentially a compact self-controlled floor cleaning device which cleans the floor by a set of commands given from a microcontroller. Essentially, the automatic vacuum cleaner has a very discrete design in terms of the compactness and usability as very handy and easy to operate This research work offers an insight into vacuum cleaning technology. The work shows the role embedded systems play in automating devices. The practical work done is an example of how to use local materials available in the immediate environment to provide engineering solutions to technical problems. The cleaner has eliminated the risk involved in dust cleaning and the physical labour associated with it. The limitations of this research work are; the cleaner is only suitable for floor cleaning and picking up dirt of a limited size and weight range. This concept employed in this project can be used to build vehicles capable of obstacle manoeuvre. The developed cleaner will be useful for the household and industrial applications.

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