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Design of Prototype for Metal Detecting Arduino Mobile Robot using Wireless Sensor Network Powered by Solar Energy

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ABSTRACT

In today's modern technology world, there are several types of mobile robots which use different types of renewable energy systems. The advancement of modern technologies is increasing energy demand volume and is aimed at adopting alternative sources of energy. Renewable energy systems, such as solar power are the better choice to use in moving mobile robots. Robots are the fast-growing technology and communication mode to human in daily lives. Therefore, researchers have integrated solar power as an alternative energy source on mobile robots, which will solve the depletion of fossil fuels. Thus, a four wheels' metal detection solar powered mobile robot was designed in these studies. The mobile robot is implemented using solar panels, Arduino Uno, metal detector sensor and solar power. The Android Uno was implemented in the development of this mobile robot as its primary brain and to communicate with all its components. In these studies, solar power metal detecting mobile robot is developed to detect the metal and the mobile robot is powered by solar energy and the robot control via wireless sensors network controller. Studies were also done on solar panel testing with various atmospheres and temperatures to accustom the product. The automated robot and the proposed design are compared in terms of the mobile robot's accessibility, metal detecting accuracy and stability of power source. The findings demonstrate that the mobile robot's proposed design can deliver faster metal detection with a more precise, easier in turning and highly dependable power supply.

1. Introduction

The convenience of being able to manage a device from a distance has led to the increasing adoption of remote-controlled applications in our daily lives, such as robotic cars and machine arms. In situations when humans have difficulty to access, such as when handling radioactive materials, putting out fires in confined spaces, moving through narrow spaces, explosives, to perform such

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tasks, it is more efficient to use a smaller robotic vehicle or arms that can be controlled remotely [1-3]. This will ensure that human health and safety is not at risk. By transmitting a specific signal to the appropriate device through a receiver or transmitting chip, like a Bluetooth device, microcontroller, sensors a remotely controlled robotic vehicle can be instructed [2]. The number of Android-based applications has increased dramatically and among them is the Bluetooth module control app, which is useful for controlling robots [4,5].

To create a metal and obstacle detection system, sensors such as Bluetooth module sensors, metal detecting sensors and ultrasonic sensors have been used since the 1980s [6]. Sensors are devices that convert various forms of electricity into electrical energy [7-9]. The sensors serve as gateways between the environment and various devices related to technology [10-12]. The environment can be any physical setting, including airports, industries, hospitals, shopping centres and technological gadgets like cellphones, robots, tablets and smart clocks [13]. There has been an increasing trend towards renewable energy as a response to the energy issue [14].

As we humans approach the year 2000, solar energy is a topic that is being talked about more than any other. The primary benefit of solar power is that it is an endless source of free, pollution-free energy that is accessible everywhere [15]. Solar power is the electromagnetic radiation that the sun emits and radiates to all of us on earth over a distance of 149,668,992 kilometres and at a speed of 299,273.6 kilometres per second [16]. The effectiveness of the current solar collectors and the technology of collecting sunlight that uses solar cells to produce electricity [17]. Three physical elements and three key engineering considerations impact the efficiency of solar cells [18,19]. The energy of sunlight that exceeds the energy amount of gap can only donate energy equal to the energy gap; the excess energy dissipates. The voltage that is generated is only around two-thirds of the energy gap and the extra energy is once more dissipated [20].

Metal detectors have been used for metal detection purposes [2,21]. Numerous foreign things, including bullets, metal shards in the eye, coins ingested and other foreign objects, as well as medical equipment, have been located using them. Rapid metal item detection could be beneficial for diagnosis or treatment. Land mines, weapons, archaeology, treasure hunting and geophysical prospecting are some applications for metal detectors [22]. In addition, metal detectors are utilised in the construction industry to find pipelines, wires and hidden steel reinforcing bars in walls and floors, as well as foreign bodies (metal pieces) in food [23]. The most popular robots used in metal detecting are remote control robots, which can detect metals and transmit data to smartphones or tablets using Arduino Uno [24,25]. Through mounted sensors, the robot identifies metal in its route and transmits the information to smart devices [26].

In this study, a solar-powered metal-detecting remote-controlled mobile robot is developed so that it can detect metal while being controlled *via* a wireless sensor network. Studies were also carried out on solar panel testing with different atmospheres and temperatures to accustom the product. The purpose of this approach is to determine the solar panels' maximum output. The battery charging circuit component of the studies that makes use of the time for battery charging and recharging is also included. The automated robot is compared with the suggested design in terms of the mobile robot's accessibility, dependability of the power source and precision of metal identification. The findings demonstrate that the mobile robot's suggested design may provide fast and accurate metal detection, easier turning and a very reliable power source.

2. Methodology

The designed metal detector robot with solar power charging module's system framework is depicted in Figure 1. In this study, several devices have been used to interact with one another, including solar panels, battery cells, comparator, Bluetooth sensor Module android Uno, Non-Contact Metal Detector Sensor Module, motor controller module and servo motor. Solar energy is used to power the input and through a charging module, it is stored in a lead-acid battery. The design and charging module are divided into two major 12V and 6V circuits. Robot vehicles are controlled by an Android Uno app using Bluetooth module. The L298N Motor control module, an integrated monolithic circuit in a 15 lead Multi watt and PowerSO20 packaging, is used for controlling the motor. Two separate DC motors can be controlled at once by the L298N motor driver. The metal detector is a non-contact metal detection sensor module. The open-source Arduino Uno microcontroller board is used and the microcontroller contains six analogue inputs, fourteen digital input pins, one USB port, one ICSP header, one reset button and 16MHz quartz crystal [18]. A DC motor is a rotating electrical device that uses direct current to generate mechanical energy to turn the wheel. The Arduino board (pins 10, 11, 12 and 13) is connected to the DC motor, which powers the metal detector, using the motor driver board. The robot is used to detect metal components in its way and transmit the data to a communication device through Bluetooth sensor module.

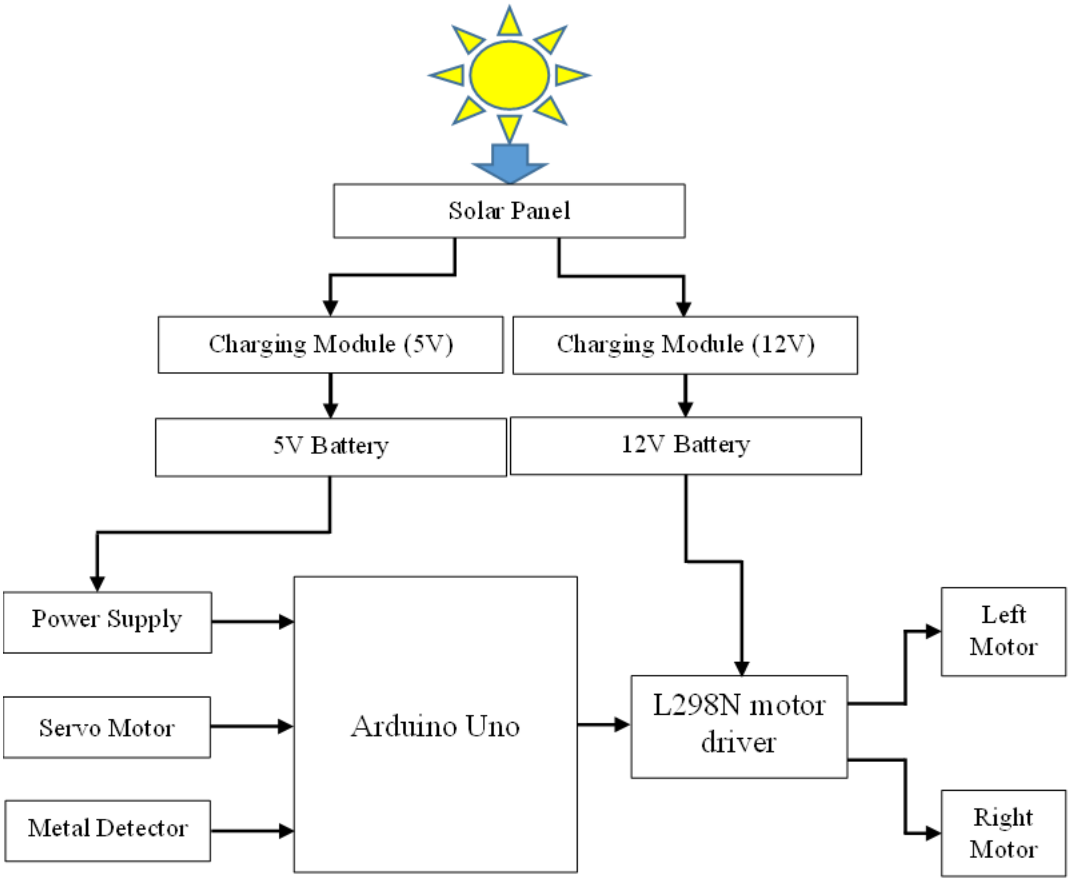

Fig. 1. Structure of metal detecting robot

3. Proposed Design

3.1 Battery Charging Module Circuit Diagram

The battery charging module systems for 12V and 6V are depicted in Figures 2 and 3, respectively. Solar cells charge battery modules to provide the circuit with power. The optimal solar panel can generate about 19V and 300mA, respectively. When temperatures are maximum, the highest voltage is generated. Voltage decreases with increasing loading and ultimately the panel output current reaches a saturation level that depends on the intensity of the sun. The diode, which is positioned between the solar cell and the circuit diagram, protects against overcurrent and prevents battery discharge. The battery charging circuit can be divided into several different categories, such as a voltage divider, a transistor acting as a switch, an LED acting as an output indicator, a Zener diode parallel with 500 ohms of resistor acting as a reference voltage and a voltage divider's output voltage and the reference voltage are compared by an integrator circuit using an LM324 comparator. The transistor circuit operates when the battery is charging and the comparator voltage drops below 8.47 volts. The transistor automatically turns OFF and the LED turns on when the battery is fully charged. The same idea applies to both circuits and all the components are the same with the exception of the voltage divider resistors.

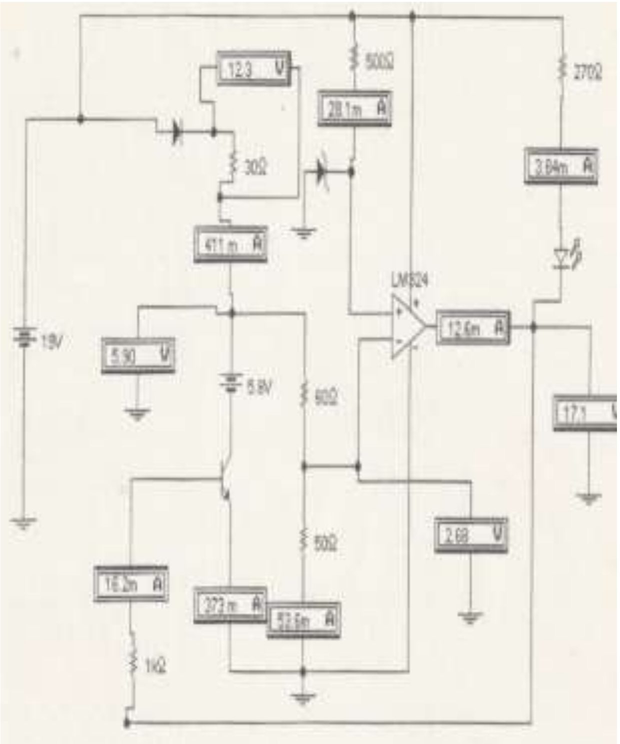

Fig. 2. 6V battery charging circuit diagram

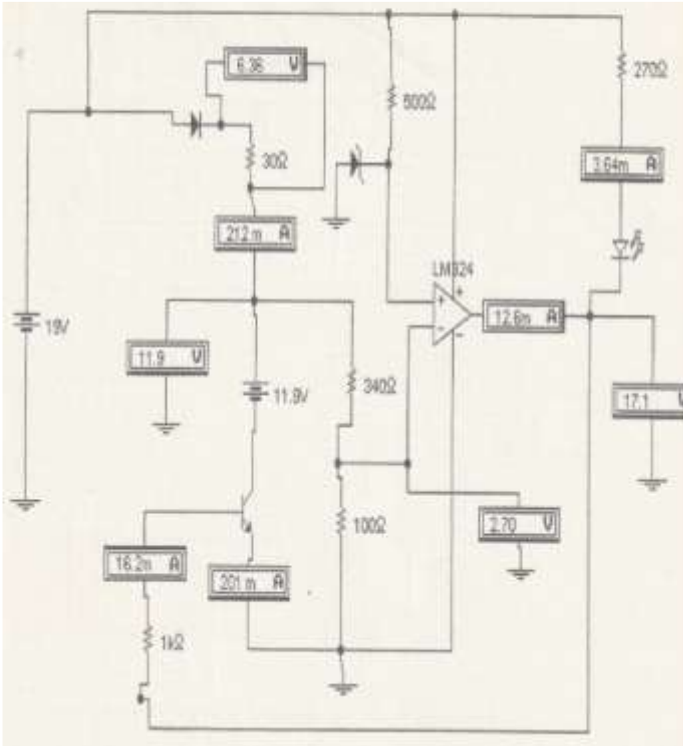

Fig. 3. 12V battery charging circuit diagram

3.2 Circuit Diagram Layout

The metal detector mobile robot's parts are shown in Figure 4. They consist of a battery pack, a copper winding or non-contact metal detector module, an Arduino Uno, HC-06 Bluetooth module and DC motors. A microcontroller board called the Arduino Uno is based on the ATmega328. The main purpose of the HC-06 Bluetooth module is to transmit data over short distances using UHF radio waves in the ISM bands, between 2.402 GHz and 2.480 GHz, between mobile robot and mobile devices. In this study, the model motor driver shield used to control the motion of the vehicle is the L298N control module. This module consists of a high-voltage and high-current dual full-bridge. The metal detector used is an LC metal detector non-contact metal induction detection sensor module. In the system, two distinct power sources were employed: a 9V source to power the motor drive and a 6V source to power the microcontroller module. To ensure a smooth and stable performance, the four-wheel metal detector robot was equipped with two DC motors on each of the front and rear wheels.

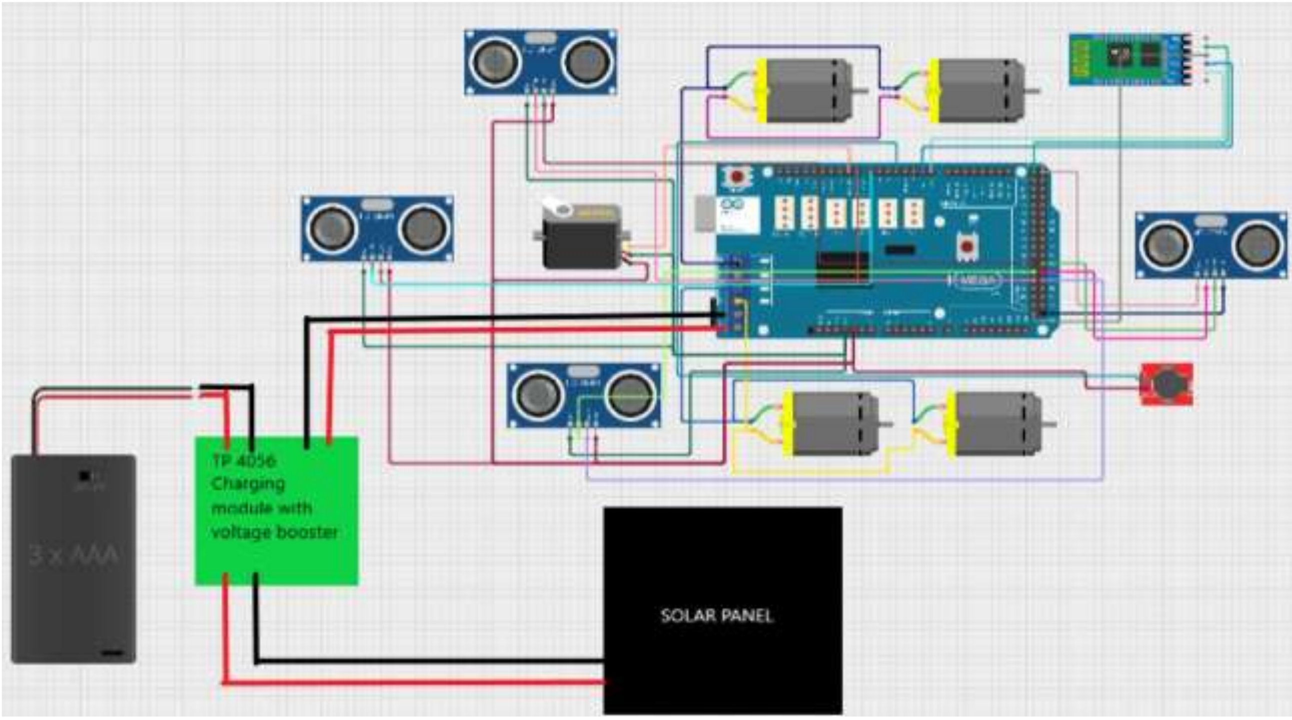

Fig. 4. Metal detector robot circuit diagram

3.3 Chassis and Prototype Design

Figure 5 depicts how the chassis plate structure for the metal detector robot was developed using a medium-density fibreboard that can accommodate the Arduino Uno, motor controller module, battery pack, solar panel and metal detector sensor or module. The central components and cables are covered by the 5mm thickest robot chassis. To sustain the entire robot as well as to accommodate the numerous components employed. The chassis plates have a maximum width and height of 170mm and 285mm, respectively.

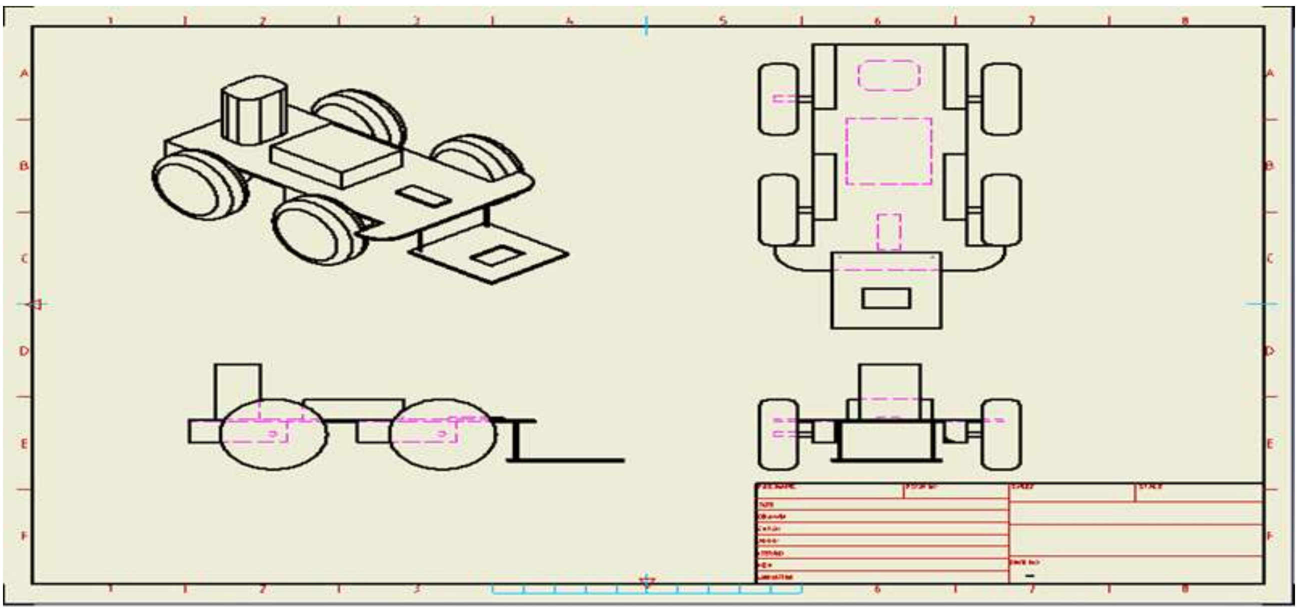

Fig. 5. Robotic vehicle chassis design

Figure 6 depicts the four-wheeled robotic frame fitted with two front and two back wheels. The plastic wheels have a connection to the servo motor and are composed of plastic. In order to prevent overloading, the robot, a plastic wheel was employed due to its lightweight. In Figure 6, a metal detecting robot with two front and two rear wheels is installed on a frame. A metal object is detected by the metal detector sensor or module in front of the mobile robot, which responds with a built to the buzzer. For an automated mobile robot, an ultrasonic sensor is positioned immediately above the mobile robot, high enough to follow the lawn's pavement without touching it. All the vital parts of the system were able to fit in with the robot's bodywork.

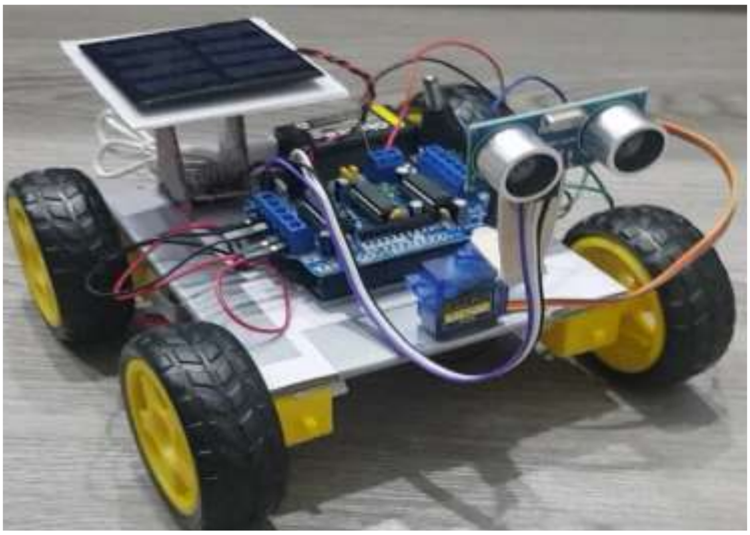

Fig. 6. Metal detecting mobile robot

4. Software Implementation

The implementation of software used to assess the movement and metal detection of the mobile robot in these studies is depicted in Figure 7. The Arduino software programming language was used to implement the system in C and C++. The programme codes implemented accordingly on the system will transfer the data to the Arduino Uno to perform the task. The mobile robot is informed which signals should be transmitted by the Arduino Uno, which keeps track of incoming signals and carries out tasks accordingly. As a result, the robot moves or navigates in a specific order based on the inputs made using a remote controller. The working flow of the mobile robot to move the robot in the forward or any direction is depicted by the flow chart in Figure 6. When the mobile robot detects the metal object via the metal detector sensor, the buzzer will sound and the Arduino will then instruct the motor to advance via a remote controller. The ultrasonic sensor sends a sound signal at a frequency of 37 kHz and then waits for the signal's matching echo.

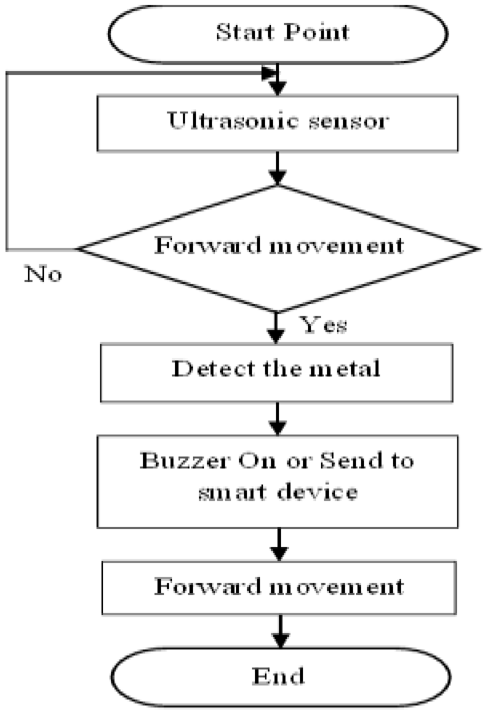

Fig. 7. Software implementation structure

5. Results and Discussion

5.1 Investigation of Solar Panel

Figure 8 depicts the input current and voltage from the solar panel measured at various temperature levels. At a temperature of 36 degrees Celsius, the measured output voltage and current of a solar panel are 19.23 volts and 0.81 amps, respectively, whereas at a temperature of 20 degrees Celsius, they are 10.55 volts and 0.21 amps. Figure 8 depicts how the potential voltage and current, which range from 36°C to 20°C, drop linearly with temperature. The voltage and current continued to drop from 18.89V to 10.55V and 0.81A to 0.21A, respectively, after that. Voltage and current both decrease with temperature, but by different percentages: 8.68% and 60%, respectively. However, depending on the weather, both the observed voltage and current will rise or fall.

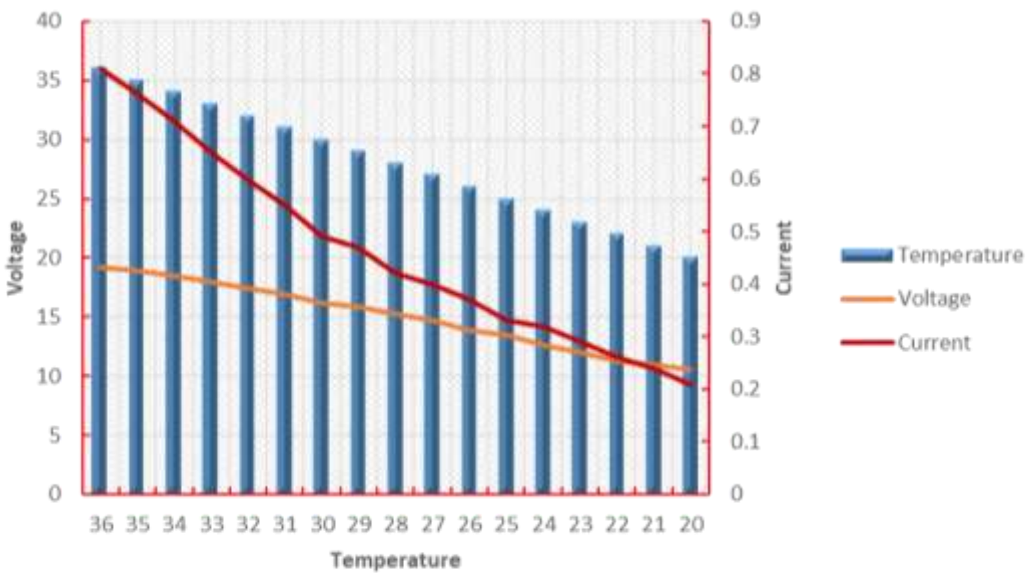

Fig. 8. Solar panel test results

5.2 Battery

Along with the alkaline main cells, there is a wide variety of rechargeable batteries available. The primary focus of this research's battery studies is to determine how long it takes solar cells to discharge to the endpoint voltage. In this investigation, lithium manganese dioxide and lead-acid batteries are employed. According to studies, these two batteries will discharge more slowly and charge more quickly. The lead-acid battery's key advantages include its demonstrated power capacity, durability, small size and light weight and reduced electrolyte leakage. In lithium manganese dioxide batteries will perform as the active cathode material. Therefore, this battery's high discharge voltage is twice as high as that of conventional dry cell batteries. Lithium manganese dioxide batteries have the advantages of being able to sustain steady voltage levels over extended periods of discharge and having a low tendency to self-discharge.

5.2.1 Lead acid battery discharging for 12V

Figure 9 depicts the voltage and current of a lead-acid battery that is discharging against time at various time intervals. At the initial and final times, the measured discharge voltage and current were 11.62V and 0.89A at their highest and 1.46V and 0.13A at their lowest values for various time intervals. Additionally, Figure 9 shows that 1.46V and 0.13A or the discharge time is 90 minutes, to discharge to the lowest values. In the meantime, the initial voltage and current or power absorbed by the load is the reason why 73.5% of the voltage and current rapidly decreased with time under 30 minutes. Finally, it discharged to the lowest voltage and current after a more gradual fall that lasted between 35 and 90 minutes. As the duration of the discharge increased, the voltage and current decreased steadily, going from 2.64V to 0.22V and 0.89A to 0.13A. When the battery load is connected to the circuit, the measured voltage and current will fall.

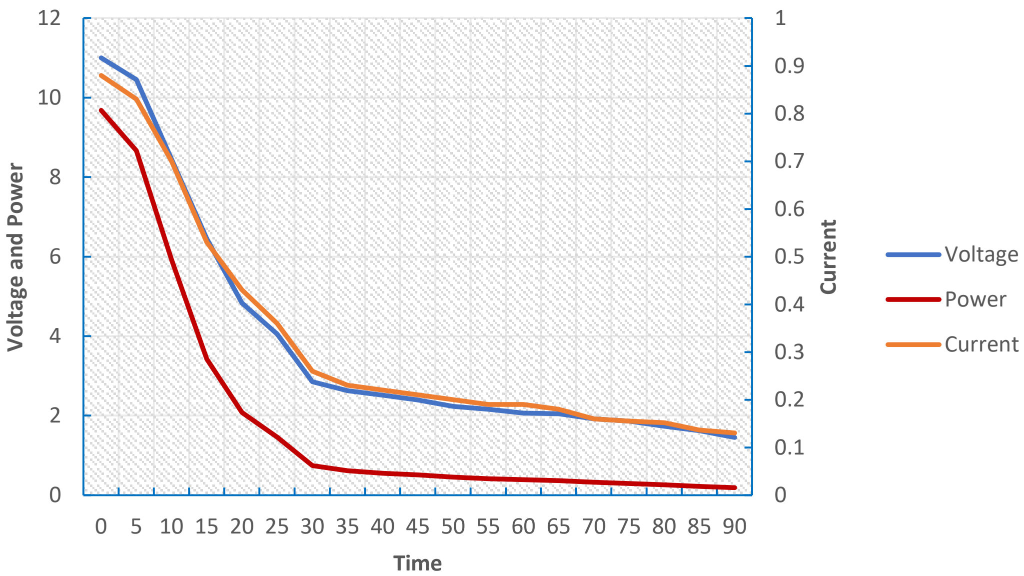

Fig. 9. Discharge of lead acid battery

5.2.2 Lithium-Manganese dioxide battery discharging for 6V

Figure 10 depicts the voltage and current of a lithium-manganese dioxide battery discharging against time at various time intervals. At the initial and end times, the measured discharge voltage and current were 5.52V and 0.84A at their greatest and 0.17V and 0.065A at their lowest values for various time intervals. Figure 10 shows that the total time of 84 minutes to discharge battery to the lowest voltage and current, which were 0.17V and 0.065A respectively. The initial power absorbed by the load is the reason why the percentage of the power that rapidly decreased with time below 45 minutes is 73.5%. However, it was seen that the shift in load was what caused the current to increase from 0.62 to 0.92 over the 45-to-51-minute period. After 51 minutes, the current value dropped quickly from 0.92A to 0.28A. Before draining to the lowest voltage and current or power, it first underwent a slower fall from 51 to 90 minutes. As the duration of the discharge increased, the voltage and current decreased steadily, going from 0.73V to 0.17V and 0.27A to 0.065A, respectively. When the load is connected to the circuit, the measured voltage and current will fall.

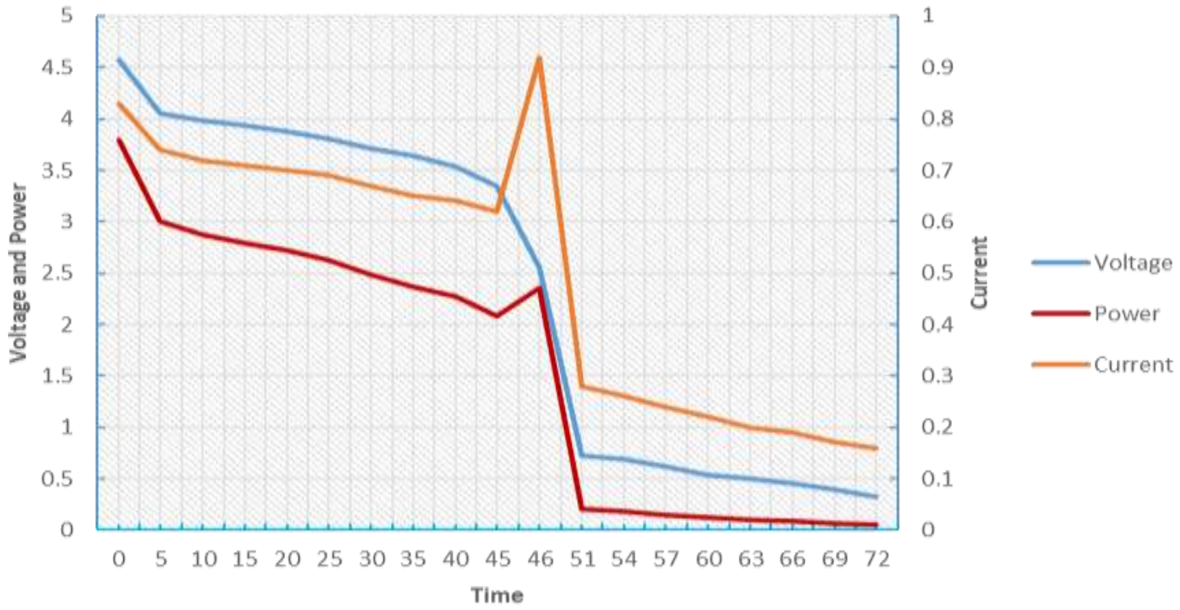

Fig. 10. Discharge of Manganese dioxide battery

5.3 Robot Input and Output Voltage

According to Table 1, the input voltage of every component was assessed using Arduino. 10.48V is the measured Arduino input voltage, while 11.1V is the recorded battery output voltage. About 13–14 V is the input voltage for motor drivers. The robot is propelled forward by motors connected to a Bluetooth control module. The remote-controlled robot is simpler to control while moving forward or backward and using Bluetooth to identify metal. By driving the left and right motors in opposition to one another, the metal-detecting remote-controlled robot can revolve on the ground. The motor will turn clockwise when the robot turns to the right. As a result, while the motor on the right wheel rotates backward, the one on the left wheel rotates forward. The motor should spin anticlockwise if the robot is turning to the left. As a result, while the motor on the right wheel rotates forward, the motor on the left wheel revolves backward. The measured voltage for the motor has the same value while it is moving in the same direction. However, when the motor rotates to the left or right, the measured voltage rises while on the other side it is zero. The motor's measured voltage can be found in either the automated or remote robots in Table 1. Compared to automated robots, remote robots have greater measured voltages than automated robots do. As a result, the robotic metal detector will move more quickly, be more stable and be simpler to manage.

Table 1
Measured voltage for Motor and Arduino

Devices Input	Measured voltage	
Arduino	10.48 V	
Motor driver	13.37 V	
	Measured voltage for Remote control robot	Measured voltage for Automated robot
Motor Driver Module	6.94 V	6.82 V
Bluetooth Module	4.97 V	4.82 V
Metal Detector	4.98 V	4.93 V
Front Motor Voltage		
Left Motor	5.46 V	5.43 V
Right Motor	5.51 V	5.46 V
Back Motor Voltage		
Left Motor	5.49 V	5.46 V
Right Motor	5.47 V	5.43 V

6. Conclusions

This study successfully developed a metal detecting robot and power management system. Using solar panels, the charge circuit for a lead-acid battery and a lithium-manganese dioxide battery is tested in the first stage. There were three primary tasks or stages completed: measuring voltage and current for solar panels at various temperatures, designing a battery charging circuit and measuring voltage and current for batteries charging over time. The solar panel has been tested with various temperatures while serving as the circuit's power source system. The charging apparatus consists of two separate batteries. As a component of battery charges, the charging circuit was created to make use of charging time and recharge the battery. Using the Arduino platform, an Android implementation and a metal detecting sensor in these experiments, a metal detecting robot was created in the second step. The robot's brain is an Arduino Uno board. It also involves the software's portable application component. The Android application receives input that determines the robot's basic movements. A level of precision and a low likelihood of failure were attained. The metal-detecting robot's effectiveness, dependability and charging time can all be improved by commissioning the power management system and Bluetooth-enabled job control. The outcomes therefore demonstrate that the suggested design power management system can give a very dependable supply of power. The examination of the remote-controlled metal detecting robot system reveals that it can readily adjust its location, stop moving and detect metal.

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