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DEVELOPMENT OF MULTI-CONTROLLED FLOOR VACUUM CLEANER USING RF ENERGY HARVESTING

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ABSTRACT

This paper investigated Multi-Controlled Floor Vacuum Cleaner power by Radio Frequency Energy Harvesting. Eco-friendly technology brings advance to this new era of technology. The energy consumption of electric is not environmentally friendly. To overcome the problem, implementing Radio Frequency Harvesting Energy to convert in to electric and power up electronic appliances. There are many automatic cleaner robot selling in the market nowadays. However the mostly use of infrared had a limitation in coverage; the robotic using Wi-Fi has a wider coverage. The uses of application also brings the coverage wider which can connect wherever the place have Wi-Fi connection or mobile data available. This benefits can brings more convenient to user can connect wherever they are. This project is started with an objective of develop a multi controlled floor vacuum cleaner using Wi-Fi. In order to make the system smart, ESP8266 Wi-Fi module used to have the internet connection. The prototype of project is developed by using Arduino Uno act as the main controller, L293D motor driver, and ultrasonic sensor. Besides that, Arduino IDE was used to write the program of the robot while Blynk apps use as a controller server. Through the project, this integrated design has performance for cleaning purpose in terms of user-friendly, convenient and eco-friendly.

Keywords: vacuum cleaner, RF energy harvesting, eco-friendly.

INTRODUCTION

A definition of a wireless communication is the transmission of information or emits electrical power from a point to another or more point in distance without the uses of medium or wires [1]. The wireless technologies is uses radio waves which is an electromagnetic radiation with wavelengths in the electromagnetic spectrum. The radio waves can transfer by various types of devices and techniques in different frequencies as low as 3 kHz to 300 GHz. A domestic robot is created as a service robot that used for convenience human, education or entertainment. Robotic floor cleaner was created around since 1996 for the purpose of household chores which cleaning and mopping floor automatically. It can save human effort and time to use the traditional sweeping tools. The robotic toys is a remote controlled robots which can entertain and relieve boredom. With the development of technology, the robotic can be control through mobile devices to replace joystick.

Wireless remote control is built by component of an electronic device to control a device from a distance. Wireless remote control also give a convenience to allow human to control or operate a device without get near to it or unable to reach. In this project, robotic floor cleaner is develop with multifunction which can move automatically and manually. Parents can allow their children to control as a robotic car besides to carry on some household chores. For the activation and motion, Wi-Fi module is chosen because it is suitable to be used to control the robotic floor cleaner. Wi-Fi has a wide coverages compare to others wireless system such as Bluetooth with small coverage and cannot radio wave cannot pass through the walls.

To complete the multi-function robotic vacuum cleaner, ultrasonic sensor, Arduino Uno and motor driver are used in this project. Ultrasonic sensor is able to detect and measure the object or walls in front of the robot to prevent it from colliding. The Arduino based robot can be controlled wirelessly connected with ESP8266 Wi-Fi module and enabled smart phone to control. The input of the robot such as motion of robot from mobile device and the response of ultrasonic sensor is control by the Arduino Uno. It also control the output which is the motor driver to carry move of robot and the cleaning parts.

The Radio Frequency is flow through surrounding us that produce by the wireless communication such as GSM, 3G, 4G and so on to transfer data. The energy consumption is to replacing the uses of batteries by using the RF energy harvesting. The concept use to capture the RF energy surrounding convert into the DC energy. This is one of the new technology with recycle purpose such as solar, wind energy and so on which without harmful and can save the environment.

Device control system

Automatic floor cleaning is not a new project of remote robot anymore. In this project, the Development of RF Energy Harvesting in Multi Controlled Floor Vacuum Cleaner using Wi-Fi which focused on the wireless technology. The operation and concept of Wi-Fi module, ultrasonic sensor, and Arduino Uno will be study and apply to this project in order to develop and wireless technology that with a remote control of the robot. It is too expensive for the existing products in the market. This robot not only help man detect obstacles or object to clean but can allow children to learn cleaning [2]. This robot can be control manually or move automatically depends on the user's need.

[3] designed Internet of Things controlling electrical appliances in university with Arduino and an

android app. The purpose of this project 8 was control device like fans, light and projector in university with the help of an application in an android phone to save electricity. This project had implement wireless technology which is an application Blynk as a phone-based control. This application can be configured and connected to the Arduino and setup through Wi-Fi. Blynk provides a user-friendly platform for users to control devices and end up with output. The researchers had found that Bluetooth for automation is not very cost efficient and a java based automation system does not consider the case when server is down. These applications can remote monitoring, controlling cloud-based storage and analytics. Blynk has few widgets and tools can customized from the toolbar. The researcher mention that the application can allows us to create an interface that link with the internet connected hardware. All the data can be stored on the Blynk Server that can import or export by user for further analysis. This application consists an authentication of users done through a code sent to emails at the time of configuration. The authentication token generated and shared with other users to authorize access is one of the benefits of this feature. Switch construct on the application represent the real-time switches in university can control from a distance and save on time and energy consumption and very user friendly that can be used by everyone. This project interact via Wi-Fi makes things become more beneficial as can control the appliances from a distance. [4] designed to solve a problem which a wireless robotic vehicles had a limited distance of control whereby using a Global System for Mobile Communication (GSM) and Radio Frequency (RF) based remoted control system. The robot is designed when user calling to the phone which link to the robot can automatic answer the call and control robot using phone by the user during the phone call. The researcher mentions that the Infrared (IR) and Radio Frequency (RF) communication systems is normally used for wireless remote control systems before the development of GSM. An infrared remote controller robotic car was able to move but the IR remote control is uncontrollable when having an object block the line-of-sight of the controller and uncontrollable from far distance. Researcher also investigate that a robotic car with IR remote control system used two Pulse Width Modulation (PWM) channels of ATmega8 microcontroller to control the speed and direction of the car. The speed control of the car can be successful but having a problem for car which unable to make a turn and a small range can control and line-of-sight alignment.

[5] proposed a prototype to remotely control an unmanned vehicle using DTMF decoder (MT8870) technology without using microcontroller. The output of the decoder was connected directly to an L293D motor driver IC to run two DC motors. The uses of this technology has a benefit that reduced circuit complexity and the program for microcontroller, but the weakness of a microcontroller is does not have a password protection system and sensors. The remote control is a DTMF matrix form keypad that inputs a digital signal into the microcontroller. The transmitter circuit consists an encoder IC that read the bit instruction from microcontroller. The RF transmitter within a frequency of 434 MHz which is a carrier frequency of the RF module send the code with its address bits to the receiver circuit. In this project, can determine that makes a call to the mobile phone stacked with a robotic car act as a remote. When there is no network, RF remote can act as an alternative control. In end of this study, this project shows that a significant device in case of gain data from remote areas where direct interference with men is difficult so it become a quite crucial topic related to the studies.

RADIO FREQUENCY ENERGY HARVESTING

Radio Frequency energy harvesting in wireless communication network is a new technologies which can recharge to storage from external radio frequency sources in circumstance ambience. This technology is wireless power transmit where also harvest the electromagnetic radiation sources. A powerful radio frequency signals can improve the power transmit and interference. Through this process require hardware consists of rectenna circuit which construct by antenna and rectifying circuitry and practical circuit to complete energy harvesting [6]. [7] Investigate the ambient of radio frequency energy harvesting skills with some measurement of the power density. This study had using Wireless Power Transmission (WPT) with the aid of increasing number of devices for utilization. The energy that used to supply for the wireless sensor is from radio frequency broadcasting stations such as Wi-Fi, radar, GSM or TV that give energy for wireless sensor nodes are effective where natural source such as solar and wind is unreachable. The change of the density in dBm/m² is refer to the frequency and time in result of 680MHz to 3.5GHz band.

This investigation had studied about recover the RF energy with two systems which is broadband system without matching circuit and second one is narrow band system with a matching circuit. Purpose of this system used an Omni-directional to increase the DC power and to recover back the original signals. This project used the Advance Design System (ADS) software to simulate the RF/DC converter which is used for double up the voltage using the harmonic-balance method. The impedance of parallel RC circuit can adapted a wide frequency range and connected the antenna directly to rectifier to avoid losses. The Figure 2.8 below shows the schema of the RF/DC converter and impedance of rectifier drawn with Advance Design System.

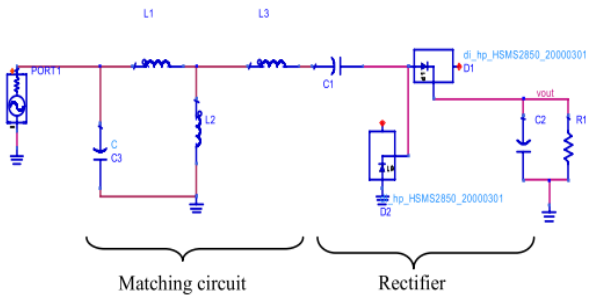

Figure-1. RF/DC Converter Schema.

By using spiral antenna, value of calculated and simulated return losses in a good result which the return losses is lower than -10dB. The maximum radio frequency energy that using spiral antenna had obtained in -42dBm. Broadband system had a very low dc power harvested because the level of radio frequency energy is mismatched. The way to increase the direct current is to increase the radio frequency by using the special radio frequency source Wireless Power Transfer.

The different of sources come with various frequencies are emitting power in every directions in a scattering ambience. The change of the power density is depends on the frequency and the time in a range of band. For the narrow band system, the maximum of the power density had occur at the 1.8GHz to 1.9GHz band. Authors had shown that the possibility of harvesting the radio frequency energy surroundings. The radio frequency power density is quite low after measured in city area because of large wide band frequency. The first system had proven that the attended direct current power and for the two system has very low direct current power. The energy that harvested can be store in super capacity or battery differences. These energies are particularly low and just from the range from 10 $\mu W/cm^2$ to 1 mW/cm^2. Constant in temperature difference and heat flowing can make thermoelectric devices to operate continuously. When compared to other energy harvesting devices, these harvesting devices may be commonly inflexible and weighty, for example solar cells which are small in size. In terms to generate useful amounts of energy that can be support and used by the thermoelectric energy-harvesting devices normally require relatively large amount of energy to be collect and used.

[8] designed a circuit of dual band architecture that can capture a large amount of EM radiation in a city area produces by mobile data and Wi-Fi operating frequencies. The system purpose to increase the energy high conversation efficiency with an input power and convert into DC voltage. The amount of radio frequencies was increase nowadays because broadcast TV channels and the broad diffusion of Wi-Fi hotspots and mobile repeaters. Instead of that, electromagnetic radiation energy radiated is hard to capture because the time-dependent, the amount of users on time and the ambience. The improvement of energy optimization techniques begin from low power design and improvement into high power design skills. The architecture block for harvester is built by two energy conversion channels which are low and medium power. The both channels created to handle various power level at the frequencies range and transfer the recovered energy to hardware storage such as super capacitor. For the low power channel is fixed path by voltage comparator with a feedback to compare the rectifier voltage with the reference. The connection of the circuit of both channel is complete in LC networks configuration. A low power channel is designed to control the incoming power from -20dBm to 5dBm while medium power channel is designed to control the input power from 5dBm to 20dBm. The hardware and regulation storage has voltage step-up converter that can increase input voltage to the regulation part. The harvest part of circuit also designed to optimize the simultaneous operation at the frequencies of 936MHz which is GSM frequencies and 2.4GHz which is Wi-Fi frequencies.

The result of the harvesting system had calculate the RF to DC conversion efficiency that high possibly and the ratio between total power transfer to the load and total power at receiving antenna is injected in a matched circuit. The RF to DC energy conversion efficiency reaches a maximum conversion efficiency of 65% for incoming power of 15dBm in medium power range and 60% at 5dBm in low power range at input power. The Figure 2.12 at below shows the RF-to-DC energy conversion efficiency. The result shows that good for both channels compared between simulated and measured result. The overall result can conclude that energy harvesting circuit simple to interconnect with low power sensors for rechargeable and power system usage to get a long life and recycle system.

RESULTS AND DISCUSSIONS

Figure-2 show the schematic diagram of RF Energy Harvesting in Multi Controlled Floor Vacuum Cleaner using Wi-Fi. The connection was first tested using software before applied in breadboard to make sure the system works as expectation. The RF harvesting circuit was tested on a breadboard before solder on a strip board to make sure system works as expectation.

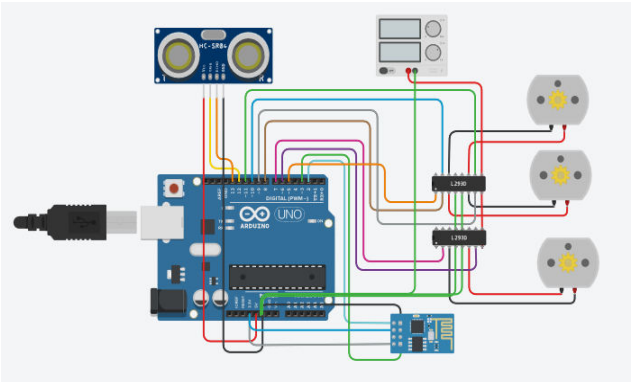

Figure-2. Connection of Multi-Controlled Floor Vacum Cleaner.

The system hardware was connected according to the connection shown in Figure-4.1. The Arduino Uno power on by using USB cable. Ultrasonic sensor and ESP8266 Wi-Fi Module connected with Arduino Uno which is 5V and 3.3V respectively as a power source. An external power supply of two li-ion battery with 7.4V motors was connected directly to the motor driver so that motors could receive enough power and rotate in a normal speed. Android application was used as a control the movement and activation. Software of Android application was Blynk software which communicate with the hardware. Blynk provides different functions of widgets in the widget box. The suitable widgets had selected and place in project. The settings in joystick with the output settings to set the virtual pins to V1 to differentiate several

of widget and the button settings with the output settings to set the virtual pins to V2. The coding given in the setting required to apply in the coding Arduino IDE to run the widgets. The connection of robot to Blynk displayed in serial port. First, Arduino Uno was plugged into the USB port of the laptop to upload the coding into Arduino Uno. After the uploading process completed, the Arduino will execute the program. The ESP 8266 Wi-Fi module will be reset so that it returns to the initial condition before connect to any network access point. Next, the Wi-Fi module will be configured in order to connect to the desired access point. The connection will base on the SSID and password write in coding and connect automatically if the Wi-Fi access. The first display shows in serial monitor is Blynk from the library and the Wi-Fi name. After successful, the command will display connected to Wi-Fi, then only connect to the Blynk application.

A connection was made between ESP 8266 WiFi module, Arduino Uno, DC motor and two L292D motor driver, ultrasonic sensor and RF harvesting energy circuit. After that the Arduino code was uploaded into Arduino Uno. The project started for the specified Wi-Fi network and the rest of the action will only be executed once ESP 8266 was connected to the network. If the Wi-Fi network is not connected, a "No, Good! Reconnecting" sentence which write in the coding will be printed on the serial monitor and the system will continue to search and reconnect to the particular network. After the robot of Wi-Fi module connected to Wi-Fi, it will start connect with the application. The robot had connected to Blynk successfully and the bottom will show the connected message. The application will display connected and packet data will PC and the ping will be shows in serial monitor and ready to run. The Arduino Uno connected with components and modules were programmed by using Arduino IDE. The completed project allows user to control the robot run automatically by touch the button in Blynk. The vacuum motor will active and ultrasonic will detect object and robot will turn right to avoid crush. Besides that, user also can control and clean a specified place with the robot manually by touch the joystick so that it could give user a better user experience on the Android application.

Figure-3. Prototype of project.

The prototype of RF Energy Harvesting in Multi Controlled Floor Vacuum Cleaner using Wi-Fi was successfully implemented, the robot used in prototype works according to the control of user can work in both automatic and manual mode. This robot was designed to provide convenient for the user in home or outside because it can be control through Android application. It also friendly user and recycle which can save power by harvested and converted from natural resources. The reason to choose Wi-Fi as a communication medium is because Wi-Fi can offer a wider coverage area compare to Bluetooth and infrared so user can con troll the device in the Wi-Fi coverage area. During the robot start-up, the Wi-Fi module will scan and connect to the appropriate network by referring to the Wi-Fi SSID and password preset in the system. The module will retry if the network was failed to join the network until it is connect. User is not allowed to control the system by Android application if the system failed to connect the network since the control command will not be received by the Wi-Fi transceiver. Once connected with the application, the Blynk application can control which send the data to module and Arduino will read and process the command data. The time taken for transmit data depends on the strength of signal. If both of the signal of phone and robot's connectivity is strong, the time taken would be very fast. Meanwhile, if one or both of the signal is weak, it will be a few second delay to communicate. In this project, control manually through the Android application can helps to run in a specified place and act as a radio controlled car. The automatic mode can remote outside of home or somewhere cannot see the robot to run and clean it automatically which detect by the ultrasonic sensor. This is to avoid the robot to hit any objects or wall and run around the places. Next, the technology which is RF energy harvesting which can power up the robot. The circuit which consists of an antenna to receive the radio frequency to the next part of circuit. In this project also used two types of antenna for analysis which is directional and omni-direction antenna. Both antenna has their own specification. For omni-directional, the design can allow it to receive signal in 360 degrees horizontal but is quite poor coverage when far away from transmitter. The directional antenna only can recive the signal in a fix direction but with a more stable coverage compare to omni-directional antenna. The frequency in surrounding was not stable will affect the input of the antenna. For the prototype, project used the RF transmitter to direct supply to the circuit. While the next part of circuit consists of rectifier and capacitors to convert to DC energy. At the end of the circuit will provide a DC supply and it is connected to a battery charging board 03962A. The battery charging board will connected to the li-ion battery and battery supply to motor driver. Each charging board only can charge one battery in a time

There are pros and cons brought in this project. The RF energy harvesting in multi controlled floor vacuum cleaner using Wi-Fi brought convenient to the user. The appliances can be control through an Android application without the need of moving to the

conventional switch or infrared remote. Next, this robot will clean the place and user could enjoy a clean area without works with household. This application have an own server to receive user control command. If the user's Android phone was connected to different Wi-Fi network, the control command still be able to receive by the robot. The RF energy harvesting can help user to save energy in order to charge the robot. However, through this prototype, the circuit is not stable and strong enough to receive enough radio frequencies. At the result can observed that the current produced by the circuit is quite low although has an ideal and controllable voltage. However, a single battery still needs to spend a long time to fully charge.

CONCLUSIONS

Development of a robotic vacuum cleaner that controlled remotely with wireless technology used an Android app for controlling purpose. The robotic vacuum cleaner was developed by using ESP 8266 Wi-Fi module as provide connection to the Wi-Fi network in the home and an Arduino Uno was used as a central controller which receives command and executes corresponding action according to the condition. Besides that, the L293D motor driver was used to control the direction of the motor. This motor driver can receive up to 12V DC so that developer can choose different types of motor to meet the requirement of the system. Furthermore, the motor driver can used to control the speed of the motor by PWM. Ultrasonic sensor used in this project can control the range as required by changing the value in the Arduino IDE coding. The next objective which is to implement a RF energy harvesting technologies for self-sustaining to power up robotic vacuum cleaner. The most important part was the type of antenna that receive the radio frequency will affect the input source and the power value at the end. This project had tried the omnidirectional and directional to test the output result. The circuit are next construct by simple components which is diode and capacitor. Diodes are used to do rectifier to change to DC supply while capacitor is to filter purpose. The output power will be connect to the charging board and charge to the li-ion battery. The results show that RF energy harvesting charging board is able to produces inconstant of voltage and small amount of current and it more suitable for small electronic appliances and charge to the battery.

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REFERENCES

[1] Win Adiyansyah Indra, Saravanan A/L Sukumaran, Khalil Azha Mohd Annuar and Irianto. 2019. Analysis of Handover Planning in Wideband Code Division Multiple Accesses (W-CDMA). Journal of Engineering and Applied Sciences. 14(3): 823-830.

[2] Win Adiyansyah Indra, Mohd Saad Hamid, Norfadzlia Binti Mohd Yusof, Nihanthinidevi A/P Jayraman and Herdy Rusnandi. 2019. Frequency Reuse Optimization for OFDMA Network. Journal of Engineering and Applied Sciences. 14(4): 1219-1225.

[3] Indra W. A., Aziz S. A. C., Hassim N. B. 2018. Performance of on-line microwave measurement for nickel ore. ARPN Journal of Engineering and Applied Sciences. 13(6): 2335-2339.

[4] Indra W. A., Morad F., Norfadzlia M. Y., Aziz S.A.C. 2018. GSM-based Smart Energy Meter with Arduino Uno. International Journal of Applied Engineering Research. 13(6): 3948-3953.

[5] Win Adiyansyah, Indra and Nurulhalim, Hassim. 2016. Real-Time Microwave Moisture Measurement of Nickel Ore in Conveyor Application. Journal Teknologi. 78(6): 111-115.

[6] Albasha L. *et al.* 2010. Investigation of RF signals energy harvesting. Active and Passive Electronic Components.

[7] Collado A. and Georgiadis A. 2013. Conformal hybrid solar and electromagnetic (EM) energy harvesting rectenna. IEEE Transactions on Circuits and Systems I: Regular Papers. 60(8): 2225-2234.

[8] D'Hont S. 2004. The Cutting Edge of RFID Technology and Applications for Manufacturing and Distribution. Texas Instrument TIRIS. pp. 1-13.