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International Journal of Advancements in Technology

Research Article

Implementation of a Wearable Wireless Charging System

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ABSTRACT

Wireless charging systems have seen a rapid rise in medical devices, mobile sensing, consumer electronics, electric vehicles, and other applications due to their high operational flexibility. For elderly persons whose wearable health device batteries might run out but who might forget to recharge them, this project offered wireless charging capabilities for wearable heart rate monitor medical devices. Unlike current expensive and difficult to operate project in the market that delivered power wirelessly to implantable biomedical device, this project is a fast charging technology, low cost and easy to operate wireless charging system. The wireless power transmitter works on the basis that it detects the wireless power receiver and, if the latter is within communication range, the transmitter is enabled; otherwise, it is in sleep mode. The LCD screen of the receiver displays the voltage that it is supplied with. The wearable device will receive power when a voltage of 5V is detected. The Arduino Uno was powered by the battery's 9V supply during project implementation, which also powered the transmitter coil in the transmitter part. The electromagnetic field that was radiated was captured by the receiver coil in the receiver portion, and it was then converted to DC (Direct Current) voltage so that the heart rate monitoring device could be charged. The implemented design worked effectively based on result of performance test obtained.

Keywords: Energy Harvesting; Wireless Charging System; Inductive Charging; Wireless Power Transfer System; Wearable

INTRODUCTION

By 2050, the elderly are projected to make up more than 30% of the population in 64 nations, according to the USA [1].Wearable devices like activity trackers, smart phones, pedometers, smart watches, wearable sensor vests, belts, and heart rate measurement devices have become common, but some elderly people have chosen not to wear them due to personal preferences or other health issues [2-7]. One drawback of wearable technology is its propensity for rapid battery drain. While having a low power consumption is important for wearable technology, the majority of wearables on the market today still require frequent battery recharges [8], but elderly people may forget to charge the battery. In addition, the conventional wired method of charging has many drawbacks, including the effects on operational safety risks and the prevention of mobility and mobilization on a large scale [9]. To overcome this barrier, a wireless capabilities system must be created .While eliminating the restrictions of cables, wireless power transfer has the capacity to do the same task as a wired charger [10]. For a complete charge to take as little as 30 minutes, some authors presented quick battery charging techniques. In wireless charging occurs in the typical vest storage location, and delivered power wirelessly to an implantable biomedical device, but the current fast charging technologies are expensive and difficult to operate [11,12]. This project is a low-cost and simple to use wireless charging system for elderly people's heart rate wearable monitoring device [13].

MATERIALS

There are two main systems of this project: The hardware system and the software system. The coil that sends power wirelessly to the receiver coil is known as the transmitter coil. The wireless charger's transmitter module transforms the delivered power into electromagnetic waves, which are then transmitted using a tank circuit consisting of capacitors and inductors. This mode can

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Received: 31-Aug-2023, Manuscript No. IJOAT-23-26424; **Editor assigned:** 04-Sep-2023, PreQC No. IJOAT-23-26424 (PQ); **Reviewed:** 18-Sep-2023, QC No. IJOAT-23-26424; **Revised:** 25-Sep-2023, Manuscript No. IJOAT-23-26424 (R); **Published:** 02-Oct-2023, DOI: 10.35248/0976-4860.23.14.258.

Citation: Aina TS, Akinte OO, Iyaomolere B (2023) Implementation of a Wearable Wireless Charging System. Int J Adv Technol. 14:258.

conserve energy by using a high charging efficiency strategy of up to 75% [14,15]. The receiver coil is responsible for receiving the power that is transmitted wirelessly by the transmitter coil. The receiver module used is capable of receiving an input of 5V 1Å and transmitting up to a maximum of 5W, with a transmission range of 0-8 mm. The Arduino Uno is used to receive and process data from the receiver module, display the results on the LCD, and power the load if the voltage falls between 0.5 and 5V. The LED indicator turns on when electrical energy is successfully transmitted. In order to provide more power to the receiver in this project, an Arduino Uno was used with a 9V battery at the transmitter side. To ensure that the receiver was receiving a regulated 5V power supply, the 9V power was routed into the Arduino's DC barrel connector using a 9V battery clip with a jack [16,17]. The wearable device in the actual setup of this project is represented by a green LED and a 300 Ω (ohm) resistor. In the simulation, the device was substituted by an LED. The Arduino Uno was programmed using the Arduino IDE (Integrated Development Environment), which has code guidelines for C and C++ languages [18,19].

METHODOLOGY

The design for this project is based on the architecture shown in figure below. The 9V battery in the power supply powered Arduino Uno. Arduino supplied 5V to the transmitter and the receiver coil in the receiver section converted the electromagnetic field to DC voltage, which can be used to charge the heart rate medical device. The transmitter operates based on the principle of detecting the wireless power receiver within communication range, and enabling itself accordingly. The LCD screen displays the voltage supplied by the receiver, and when the voltage reaches 5V, power is supplied to the wearable device (Figure 1 and 2).

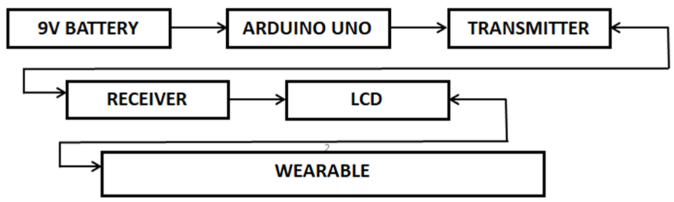

Figure 1: Block diagram of Wearable Wireless Charging System

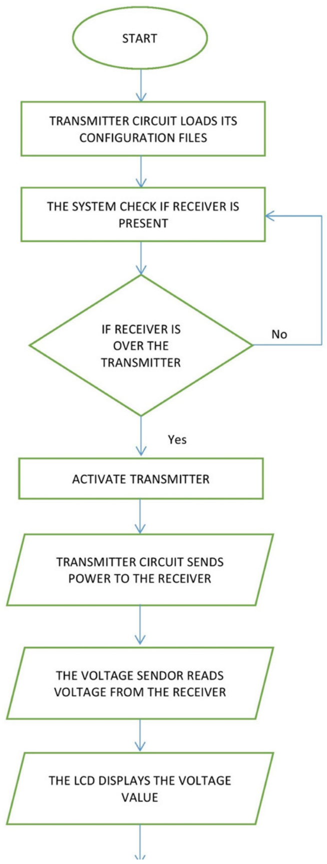

Figure 2: Wearable wireless charging system the flow chart

Simulation and implementation

The simulation of this project was designed and carried out using the Proteus 8 professional simulation environment, and the waveforms observed were analyzed. The simulation did not take into account the impact of distance between the transmitter and receiver, which is important to determine the maximum range for inductive power transfer during the actual implementation and testing of the circuit. The simulation demonstrated the feasibility of the project's real implementation. Figure 3 depicts the complete circuit diagram simulation (Figure 3).

Figure 4 present the waveform generated after simulation, showing the pulse width modulation signals, which are square waves of 60Hz and 180 degrees out of phase. The peak to peak voltage is approximately 5V. The signals presented in figure 4.2 are two, one in Red which is the output from 555 timers and another one in Blue which is from H-Bridge inverter. It is noticeable that the two signals are synchronized in phase, and the output VPP (Peak to Peak Voltage) at the inverter is 12V, while the 555 timer produces only 5V (Figure 4-6).

Measurement and testing

A table with the measurement results is provided in this section. Table 1 shows a transmitter that is powered by a variable DC source at 5V. The findings of an experiment in which the coils were positioned at various distances and the voltage was determined using a variable DC supply from the Electronics lab at Bedford College in England are shown in Table 2. The observed voltage readings corresponded to the distances, which varied from 0 to 8 mm (Table 1-3).

In this section, input and output voltage at different distance away from the transmitter and input as well as output current at different distance away from the transmitter was measured. To measure the voltage, the coils were positioned at different distances, and the voltage recorded using a multimeter for each distance. The measurement of the current was carried out by positioning the coils at various distances and recording the current at each distance from multimeter. Other laboratory equipment's are used:

- Digital oscilloscope
- DC bench PSU
- Function generator
- Multimeter

The test involves assessing the transmitter's output voltage at different distances using the testing equipment. This test's goal is to establish the output voltage at various load circumstances and distances. The DC voltage input and output was measured using this testing equipment. The data extracted was used to determine input power, output power, and system efficiency. The voltage produced in the receiving coil was determined by analyzing the data. To ascertain whether there is any energy loss or gain in the environment, it is also possible to measure the strength of the magnetic force lines at greater distances from the coil. To carry out the voltage test, both a multimeter and an oscilloscope were utilized. During this phase, the waveform of the output voltage was displayed by the oscilloscope while the transmitter is supplied with 5V from a DC variable power supply. The electrical circuit's DC voltages change quickly, rather than slowly over minutes. The oscilloscope identified electromagnetic noise, measure voltage changes over time, and display a graph to depict the voltage's progression. The oscilloscope was enabled to achieve this Figure 7 and 8.

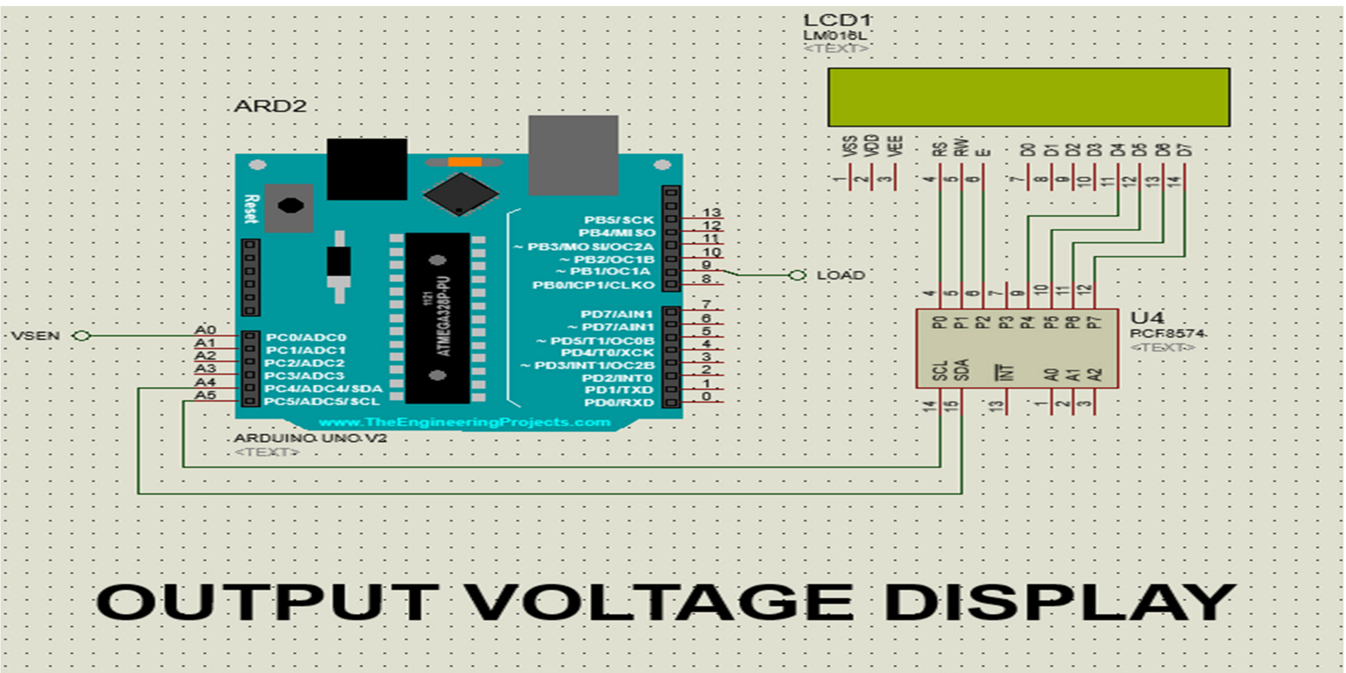

Figure 3: Complete circuit diagram simulation

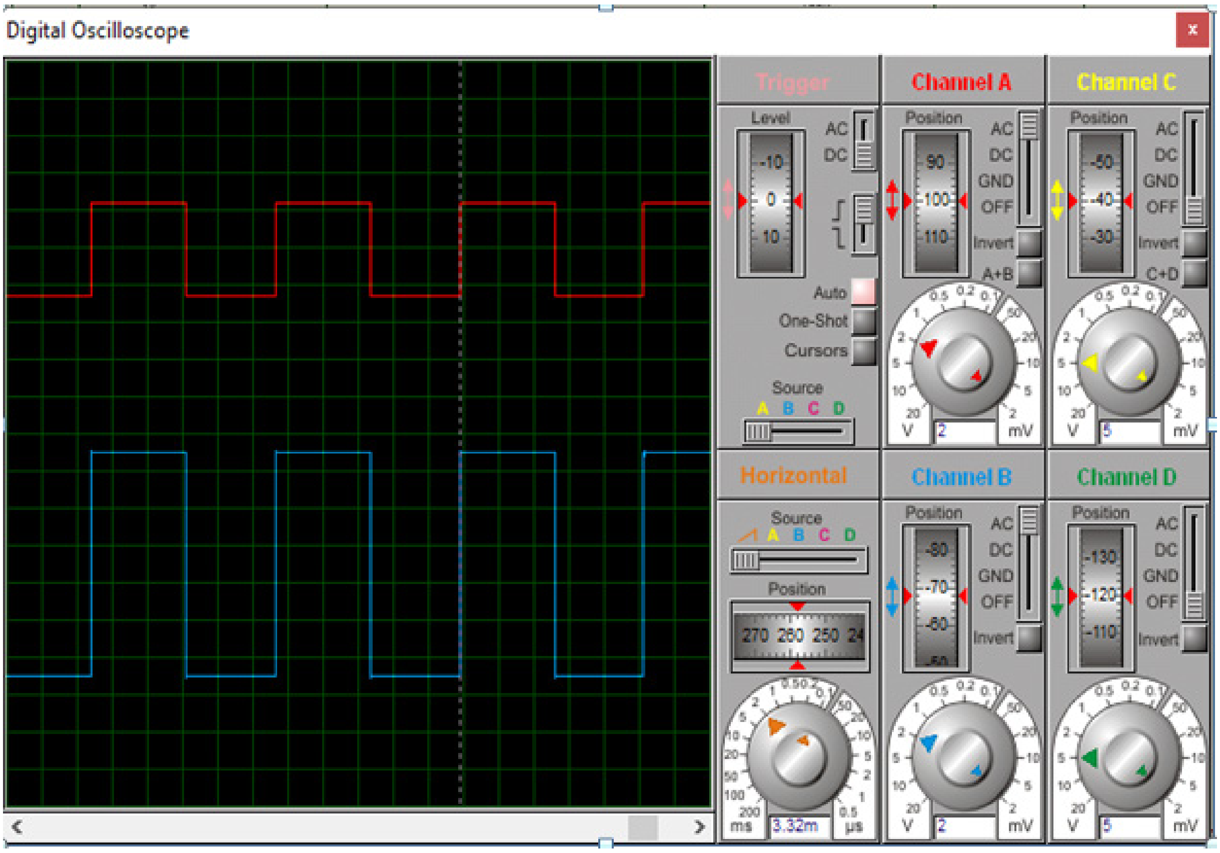

Figure 4: Waveform of simulated circuit.

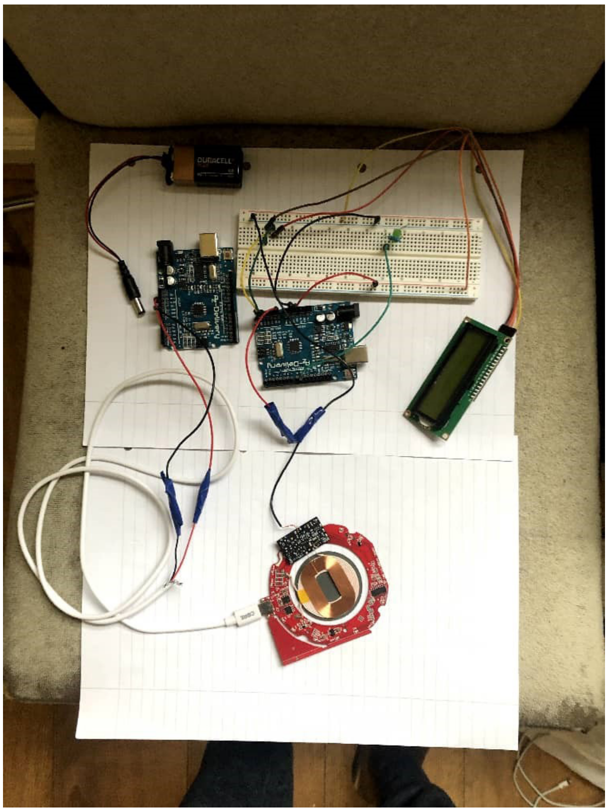

Figure 5: Implementation setup without 9V supply to Arduino board.

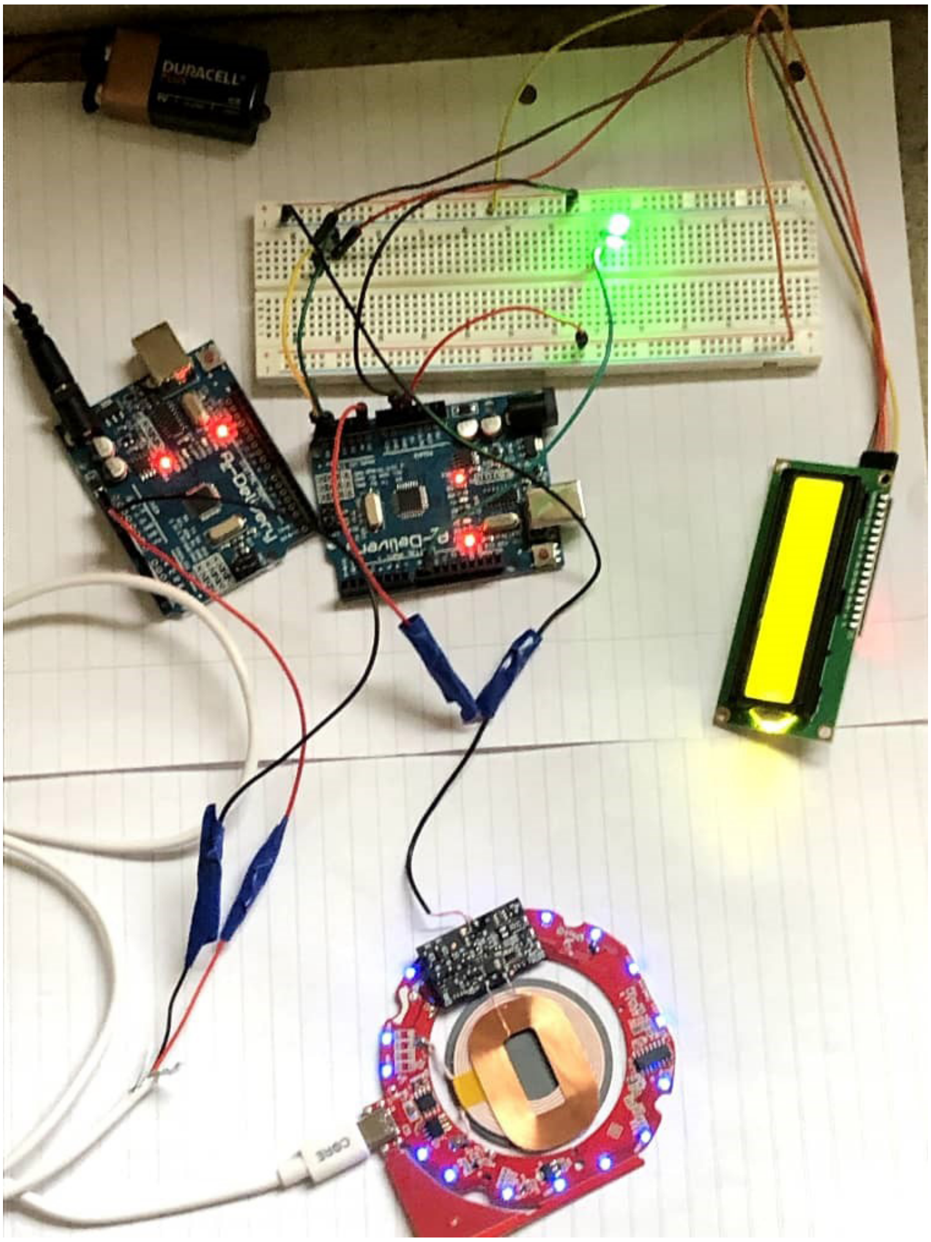

Figure 6: Implementation setup with 9V supply to Arduino board

Table 1: Transmitter powered with 5V supply from a variable DC supply.

Distance (mm)	Input voltage (V)	Input current(A)	Input power(W)
0	5	0.35	1.75
1	5	0.35	1.75
2	5	0.35	1.75
3	5	0.35	1.75
4	5	0.35	1.75
5	5	0.35	1.75
6	5	0.35	1.75
7	5	0.35	1.75
8	5	0.35	1.75

Table 2: Input voltage, output voltage, output current when transmitter coil and receiver coil are axially placed with wearable connecter.

Distance (mm)	Input voltage (V)	Output current	Output voltage (V)	Load condition
0	5	0.16	4.98	Load powered
1	5	0.23	4.89	Load powered
2	5	0.39	4.84	Load powered
3	5	0.48	3.49	Load powered
4	5	0.57	2.89	Load powered
5	5	0.61	2.5	Load powered
6	5	0.75	1.7	Load powered
7	5	0.92	1.2	Load powered
8	5	0.98	1	Load powered
9	5	0.07	0.49	Load not powered
10	5	0.03	0.35	Load not powered
11	5	0.02	0.28	Load not powered

Table 3: Input voltage, output voltage, output current, power dissipation.

Time (s)	Distance (mm)	Input voltage (V)	Output current	Output voltage (V)	Power dissipation(W)	Efficiency (%)
20	0	5	0.16	4.98	0.7968	99.6
30	1	5	0.23	4.89	1.1247	97.8
40	2	5	0.39	4.84	1.8876	96.8
50	3	5	0.48	3.49	1.6752	69.8
60	4	5	0.57	2.89	1.6473	57.8
70	5	5	0.61	2.5	1.525	50
80	6	5	0.75	1.7	1.275	34
90	7	5	0.92	1.2	1.104	24
100	8	5	0.98	1	0.98	20

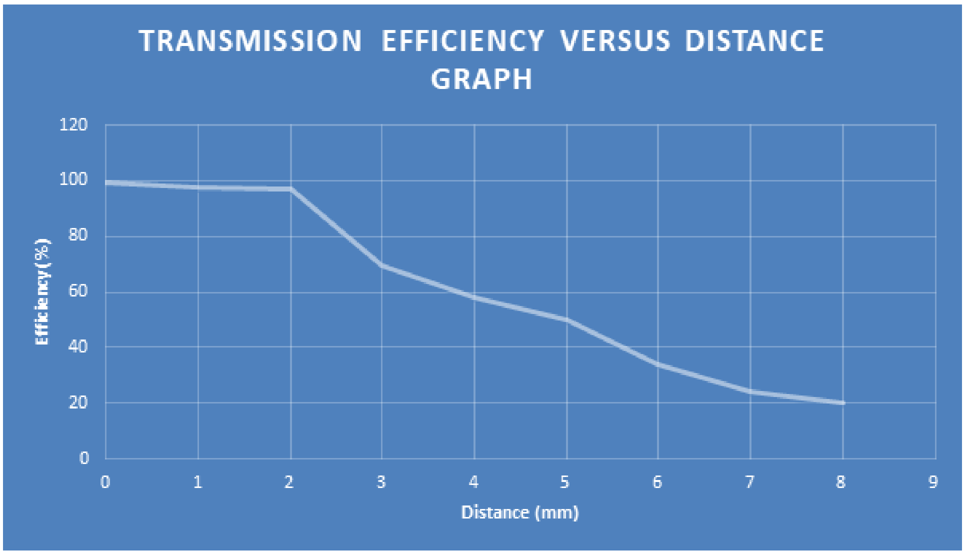

Figure 7: Transmission efficiency *versus* distance graph

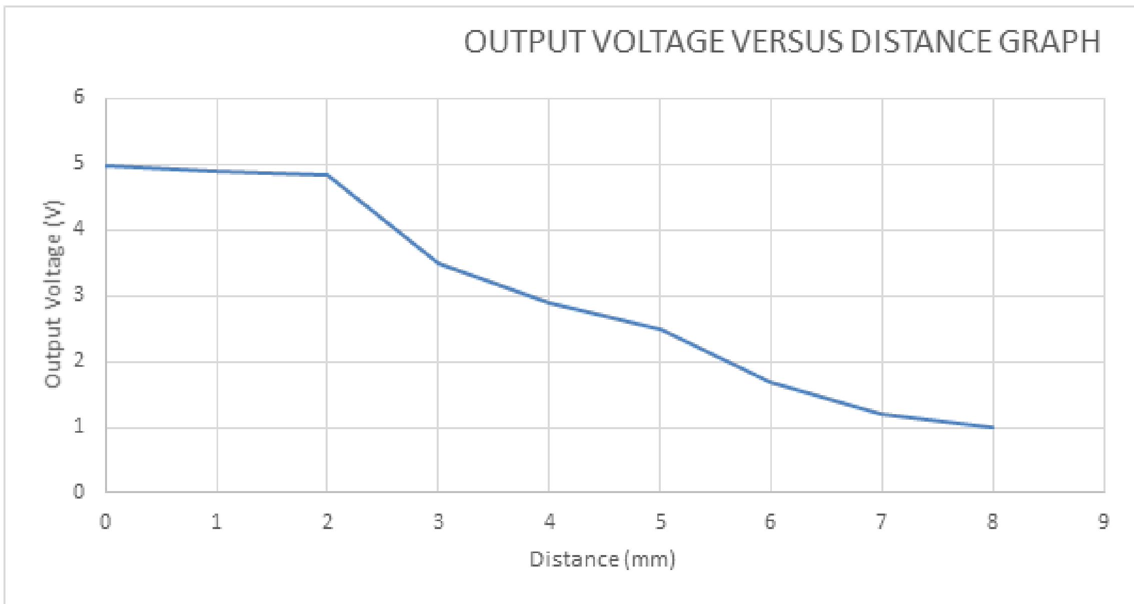

Figure 8: Output Voltage *versus* distance graph.

RESULTS

In order to simulate the transmitter, Qi-based wireless transmitters schematic diagram of 9038 model transmitter was considered which consist of oscillator, inverter and LC Tank. All these components are already embedded in the wireless transmitter purchased for the implementation of the main circuit. In the simulation stage it was assumed that the same signal coming out from the transmitter coil is received by the receiver coil by direct conduction. The experimental set-up, was based on assembly of hardware component on breadboard. The transmitter and receiver are located axially in relation to one another. A component verification test was carried out with a multi-meter to verify the working of the component. A breadboard test was carried out and the project components assembled on the breadboard to verify the working of the circuit. This project testing considered several significant ethical, health and safety issues that the project might bring up and how to adequately address them in accordance with the British Computer Society (BCS) code of conduct, particularly the code that addresses due regard for public health, privacy, security, and the well-being of others as well as the environment. The British Computer Society (BCS) code of conduct mandated that potential risks and impacts should be revealed whenever there is a conflict between strictly following the directives of the responsible authority and using professional judgement in a thoughtful, independent manner. There are some ethical concerns with inductive wireless charging. One of these is the potential health effects of being exposed to magnetic fields produced by resonant inductive coupling, but there is now little to no proof that this technique poses any health problems. The project used a Qi compatible transmitter and receiver to protect this. In addition, the presence of alternative technologies that achieve the same aim with less risk and the ratio or balance between risks and benefits, which is essentially a utilitarian concern, were taken into account. The system performed successfully. In the performance analysis it was observed that as the receiving coil moves away from the transmitting coil the strength of the magnetic flux it produces weakens. This necessitates the voltage received according to Faraday's law of induction to decrease as the two coils are separated by distance axially. This can be seen in figure 8 where the voltage decreases as the distance increases, along with the efficiency. According to the data in table 3 above, the greatest efficiency attained was around 99.9% at 0 mm. The project's goal and objective have been accomplished, despite the fact that the distance was only a few millimeters due to the input voltage and the size of the coils, according to these data and analyses.

DISCUSSION

A wireless power transmission system for wearable device to transfer wireless power using inductive coupling in the close vicinity of the transmitting and receiving coils has been implemented. The prototype circuit diagram developed and implemented showed that power can be successfully delivered wirelessly. The procedures encompasses: Definition of requirements in terms of charging efficiency and power consumed, analysis of the theoretical frame work of the project through comprehensive literature review, prototype circuit diagram design and simulation with Proteus 8 Professional software and finally implementation of the wireless charging capability system. This project is part of the wireless embedded system as it covers automatic control, energy harvesting and energy aware techniques and wireless sensor network. The authors learnt about wireless sensor networks and applied it in this project. Various electronic components has been worked with when providing a prototype design with management of the project using waterfall project management methodology skills. This project is low cost and easy to operate wireless charging system for heart rate wearable monitoring device for elderly people. The unique prototypes is Qi standard compatible, proposed algorithm and flowchart is not complex and the implementation stage provides and avenue for easy trouble shooting in case of fault. Purchasing the required hardware components and putting it all together to create the prototype are crucial steps in this project. A simple configuration, low maintenance cost, and control are a few criteria considered when choosing the hardware component kit. Other factors are compatibility with Arduino-style circuit boards and a kit with well-arranged components in a plastic container that will aid in correct storage will be taken into account. During this step, internet was surfed for ideas on how to get the project's hardware components supplied in the allotted time. From Google, the Proteus 8 Professional software will be downloaded. An online tutorial video was viewed to walk through the process of entering a circuit of moderate complexity in order to become familiar with the methods needed to operate Proteus' schematic capture module. The documentation for Arduino IDE 2.0 was checked for more information. The source code for the open-source Arduino IDE 2.0 was downloaded from the website GitHub.

CONCLUSIONS

For any wireless power technology to function, it requires a transmitter and a receiver. In the case of Inductive Coupling, the transmitter and receiver are separate coils wound on materials with high permeability to increase the efficiency of the circuit by increasing inductance. However, the efficiency of this system decreases considerably with an increase in distance between the two coils. The prototype wireless charger was implemented by placing the coils at various distances and recording the readings in a table. The circuit was designed, and components were obtained with careful consideration of their accurate rating. Component verification was done using a multi-meter to ensure proper functionality. The project was then assembled on a breadboard in stages to facilitate effective block testing and troubleshooting if needed. This project was implemented on a breadboard and tested stage by stage based on the block diagram. The Qi wireless transmitter was powered by an Arduino Uno, and the output voltage was displayed on an LCD. A 9V battery was used to energize the circuit, and multimeter readings were taken at different distances ranging from 0 mm to 8 mm. The test results indicated that wireless power transfer using this setup is feasible up to a distance of 8 mm. However, at distances greater than 8 mm, the power transferred was insufficient to power the LED. In the performance analysis it was observed that as the receiving coil moves away from the transmitting coil the strength of the magnetic flux it produces weakens. This necessitates the voltage received according to Faraday's law of induction to decrease as the two coils are separated by distance axially. This can be seen in figure 8 where the voltage decreases as the distance increases, along with the efficiency. According to the data in table 3 above, the greatest efficiency attained was around 99.9% at 0 mm. The project's goal and objective have been accomplished, despite the fact that the distance was only a few millimeters due to the input voltage and the size of the coils, according to these data and analyses.

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