American J. of Engineering and Applied Sciences 1 (1): 12-15, 2008
ISSN 1941-7020

Development of Wireless Electric Concept Powering Electrical Appliances

Hanita Daud, Noorhana Yahya, Azizuddin A. Aziz and Mohd Fadzzrul Jusoh
Department of Electrical and Electronics Engineering,
Universiti Teknologi PETRONAS, Bandar Seri Iskandar, 31750 Tronoh, Perak, Malaysia

Abstract: This study presents a concept of harvesting and transferring energy to a low power electrical appliances using wireless technology where interconnecting wires are not available. This study was a ground work for the future alternative energy supply especially to the areas where supplying direct energy is a challenge such as in deep sea exploration as well as to the area where power interruption is a problem. Research was carried out to study how the waste signal and energy in the air could be collected and converted into useful energy which later could be used to supply power to electrical appliances. The approach of this research started by simulation work using PSPICE full edition that was performed to develop the design and later was used as guidelines in developing the prototype. We then harvested the Radio Frequency (RF) signal that was available in air by using RF energy harvesting circuit. This circuit harvested the energy and converted them into electricity. It was accomplished by using an antenna to capture the RF energy and a voltage doublers circuit to convert and magnify the AC input signal to larger DC output. For a start we managed to capture a 3V voltage which was stored in a rechargeable battery. The energy in this rechargeable battery was then utilized to power up low-powered electrical appliances. Germanium and Silicon diodes have been used to harvest and amplify the voltage so that a better and higher output can be achieved.

Key words: Radio frequency (RF), voltage doublers, charge-pump circuit, energy harvesting circuit

INTRODUCTION

Wireless technology has become a popular means of transmitting signals and it has a great influence in our daily life, ranging from the use of satellite in space to the use of cellphones. This technology has provided us a convenient way to communicate practically with anybody, anywhere and anytime.

Recently, there are efforts and researches being conducted by industries and universities to develop a technique to supply power to the electrical and electronics equipments using wireless power transmission technology. Although the concept is still not being introduced widely to the market, but this technology will give a high impact in our daily life once it is commercially available.

This interesting wireless electric concept may be used as an alternative energy supply especially to the current situation where the production of energy is dependant on oil and gas industry which price is fluctuating daily. It may also be used as an alternative electric energy supply to the area that is prone to power interruption or for deep sea exploration where powering huge equipments has always been a challenge and still depending on the supply from the vessel.

Wireless energy transfer is a process that takes place in any system where electrical energy is transmitted from a power source to an electrical load, without involving wires. Wireless transmission is ideal in cases where instantaneous or continuous energy transfer is needed, but interconnecting wires are inconvenient, hazardous, or impossible [1]. Though the physics of both are related, this is different from wireless transmission for the purpose of transferring images such for television broadcasting, where the percentage of the received power is only important if it becomes too low to successfully recover the signal. With wireless energy transfer, the efficiency is a more critical parameter and this creates important differences in these technologies [2].

MATERIALS AND METHODS

Radio Frequencies (RF): The use of Radio Frequencies (RF) for communication is wireless related

Corresponding Author: Hanita Daud, Department of Electrical and Electronics Engineering, Universiti Teknologi PETRONAS, Perak, Malaysia

technology and is one of the general classes of energy carrying waves defined in the electromagnetic spectrum. These radio waves do not interfere with each other because each RF transmission has been specified to operate at certain frequency range. This research premise deals with RF that is not being used by other applications. The designed prototype will use 915 MHz because it falls under Industrial-Scientific-Medical (ISM) RF band range (902-928 MHz), made available by Federal Communication Commission (FCC), USA for low power and short distance transmission. This frequency is not being used by other applications thus no permission is needed from the authority [5,6].

Energy harvesting: Since there are a number of applications in our daily life that use RF signal to transmit data, the amount of electromagnetic energy available around us is tremendous. Most of the energy is emitted by radio and television broadcasting. This energy is not being fully utilized and left unused in the air. Thus a technique called RF energy harvesting emerges. Energy harvesting is a technique used to collect or harvest energy in any medium and to be converted into other means [3]. In this case, RF energy harvesting circuit will collect unused RF energy in the air and convert it into electricity. It harvests RF energy from a specific range of frequency [4] instead of wide range of frequency, where in the developed system the receiver is designed to harvest energy from RF signal of 915MHz.

Voltage doublers: Basically, the receiver circuit consists of an antenna, a converter and an amplifier circuit. Antenna is used to capture the RF energy in the air and the converter converts the AC input to DC. Then, an amplifier amplifies the DC output before supplying to any appliances.

Voltage doublers is a circuit that is able to convert input in AC to larger output in DC (rectifier)[3]. Increasing stage of this voltage doublers will increase the output voltage. The output voltage V_{out} can be calculated using the expression in (1):

$$V_{out} = \frac{nV_o.R_L}{nR_o + R_L} = \frac{V_o}{\frac{R_o}{R_L} + \frac{1}{n}} \quad (1)$$

where, V_o is the open circuit voltage, R_o is the internal resistance, R_L is the load resistance and n is the number of stages.

However, there is a limitation to the number of maximum stages that it can support due to the voltage drop effect. When there is an output current, there is

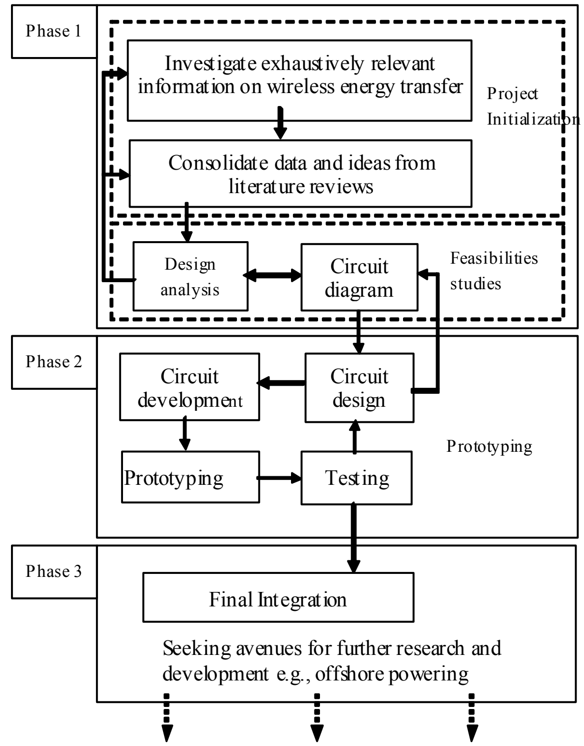

Fig. 1: Development phases

also an AC current flowing through the capacitors, resulting in a voltage drop and a lower input voltage for subsequent stages [7]. The expression for the voltage drop, ΔU is shown in (2):

$$\Delta U = \frac{I}{fC}\left(\frac{2}{3}n^2 + \frac{1}{2}n^2 - \frac{1}{6}n\right) \quad (2)$$

where I is the output current, f is the input frequency, C is the capacitor and n is the number of stages.

Methodology: The development of the prototype adopts the methodology flow as shown in Fig. 1. Development phases in Fig. 1 are self- explanatory. Project initialization and feasibilities studies as in phase1 were conducted using PSPICE full edition. The results were used in phase 2 for developing the prototype and testing.

RESULTS

Simulation (PSPICE): Design analysis and circuit design were conducted using PSPICE full edition. Voltage doublers circuit was constructed from the single stage to 7th-stage to test if properties of voltage

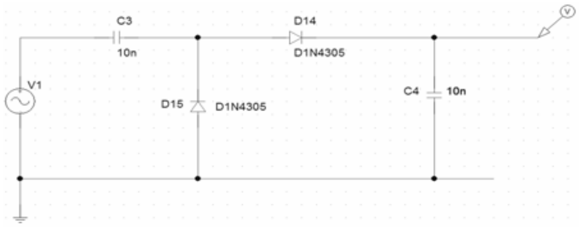

Fig. 2: Single stage voltage doublers

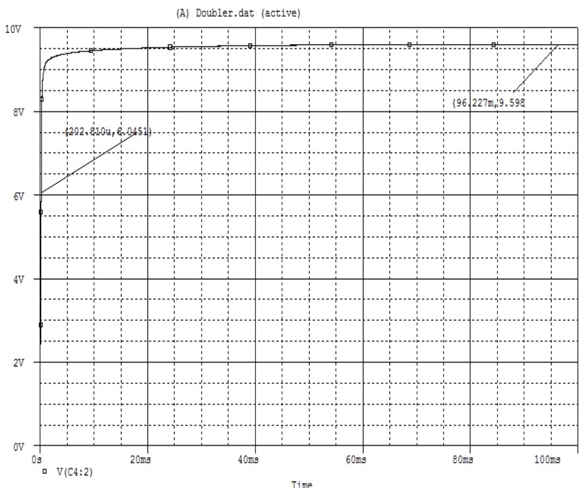

Fig. 3: Output of Single stage voltage doublers

doublers were uphold every time the stage was increased. The antenna was replaced by AC source because the output of the antenna was also in AC form. Input voltage was set at 5V. Figure 2 shows the single stage voltage doublers circuit.

Figure 3 shows the output of the single stage voltage doublers circuit in Fig. 2. With an input of 5V supply we obtain an output of 9.6V. Figure 4 shows the 7th-stage voltage doublers circuit. Figure 5 shows that the output voltage that can be obtained from the 7th - stage voltage doublers circuit is 67V.

From the simulation, it can be concluded that the output of voltage doublers circuit is:

$$V_{out} \approx 0.95\,(n)\,(2V_{in})$$

where, n is the number of stages and V_{in} is the input voltage. Three tests were also being conducted to find out the best capacitor values to be used as stage capacitor and output capacitor. The first two tests were conducted by comparing the output voltage when stage capacitors having equal values and different values. The third test was to compare the output voltage when output capacitors values are varied. At the end of the tests we have concluded that for stage capacitor, same capacitor value is used for each and every stage because they have the same charging time. Different capacitors values will have various charging times which some of them are slower than the others. For the output capacitor, it is recommended to have a lower value of capacitor which will give better output response in term of the rise time. Table 1 shows that the rise time decreases as the capacitor size increases. From the simulation results, we have met our objectives and we use these results as guidelines to build the prototype.

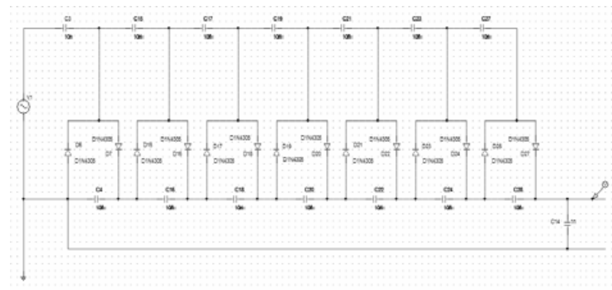

Fig. 4: 7th-stage voltage doublers

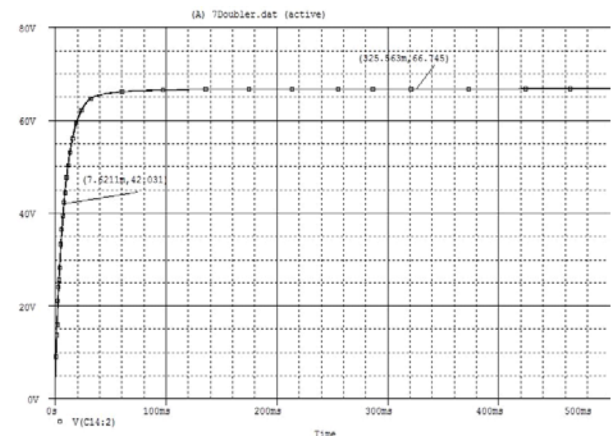

Fig. 5: Output of 7th-stage voltage doublers

Table 1: Rise time for different capacitor size

Stage capacitor value	Output voltage (V)	Rise time sec
1 nF	63.50	19.04 m
22 nF	67.05	6.5 m
47 nF	67.16	3.7 m
100 nF	67.19	2.5 m

DISCUSSION

Receiver development: The development of the receiver starts with the use of Germanium Diode (1N34), 100nF and 1 μF capacitors. Outputs produced were not as expected for voltage doublers (Table 2).

Table 2: Output voltage of 100 nF and 1 μF capacitors

No. of stages	Input voltage (V)	Output voltage (V) using 100 nF capacitor	Output voltage (V) using 1 μ F capacitor
1	3.0	7.1	9.5
2	3.0	13.2	18.6
3	3.0	13.1	25.3
4	3.0	12.6	32.7
5	3.0	12.4	36.4
6	3.0	12.3	36.9
7	3.0	12.1	35.7
8	3.0	12.1	32.3

Table 3: Summary of the output voltage from the voltage doublers circuit of 33 μF and 330 μF capacitors, 50V rating

No. of stages	Input voltage (V)	Output voltage (V) using 33 μF capacitors	Output voltage (V) using 330 μF capacitors
1	3.5	10.5	10.7
2	3.5	21.3	21.9
3	3.5	32.1	33
4	3.5	42.6	43.1
5	3.5	53.4	54.1
6	3.5	64.1	64.7
7	3.5	74.3	74.9

Germanium diodes were replaced with Schottky Diodes (1N5819) and the circuit was tested by using 1μ, 33μ and 330μF capacitors. With 1μF capacitors, the voltage doublers circuit was not able to produce the expected outputs because there was still a significant voltage drop. Then the 1μF capacitors were replaced with 33μ and 330 μF capacitors. Table 3 compares the performance of the two capacitors and it can be seen that the different in output voltage is not significant but they have achieved the required output for voltage doublers.

In conclusion, Schottky Diodes (1N5819) is a good choice for the designed system because they are able to amplify and rectify the voltage. In addition, the usage of 33μF capacitors is able to minimize the overall circuit size.

Energy harvesting test: The test was conducted by connecting a monopole antenna to the receiver (voltage doublers circuit) to replace AC power supply. The harvested energy is the ambient electromagnetic energy and it is obtained from the transmitter. The output was connected to a voltmeter to measure the possible output voltage. After the antenna and the circuit were properly grounded, the result was very promising. The circuit has managed to capture 3W of energy. In order to store the harvested energy, a rechargeable battery has been used. Rechargeable battery is well-known as a promising medium of storing energy with the least amount of self discharging problem. The stored energy in this rechargeable battery may be retrieved and used whenever needed. The energy from this battery may be connected to any low power electrical appliances such as toys, table lamps, table clock and etc as a source of power. We have achieved the result as expected and is comparable to[8].

CONCLUSION

In this study, a wireless electric concept to supply power to electrical appliances for a living room is presented. The harvesting of the energy from ambient electromagnetic energy or transmitter is the key for supplying the AC supply to the voltage doublers circuit. The Schottky diodes were used in voltage doublers circuit that amplifies the input in AC to a higher output voltage in DC. Moderate size of capacitor is also chosen to maintain the performance and to minimize the overall circuit size. The output of the circuit is stored in the rechargeable battery which later is used to power any low power electrical appliances. We hope to improve the prototype by trying to harvest larger EM energy in the coming years. This can be achieved by finding ways to combine the Germanium and Schottky diodes. Germanium diodes are better used for capturing the signal whereas Schottky diodes are rectifier diodes which are good for amplifying the input.

REFERENCES

1. Little, F.E., J.O. McSpadden, K. Chang and N. Kaya, 1998. Toward Space Solar Power: Wireless Energy Transmission Experiments Past, Present and Future. AIP Conf. Proc., 420: 1225-1233.
2. Brown, W.C., 1984. Microwave theory and techniques. IEEE Trans., 32: 1230-1242.
3. Sabate, J.A., D. Kustera and S. Sridhar, 2000. Cell-Phone Battery Charger Miniaturization. IEEE J.,
4. Marlin H. Mickie, Micheal Lovell, Leonid Mats, Lorenz Neureuter, and Dmitry Gorodetsky, October 2001. Energy Harvesting, Profiles and Potential Sources. Int. J. Parallel Distributed Syst. Networks, 150-160.
5. Clevelanf, R.F. and J.L. Ulcek, 1999. Questions and Answers about Biological Effect and Potiential Hazards of Radiofrequency Electromagnetic Field. 4th Edn. FCC Office of Engineering and Technology, OET Bulletin, Federal Communications Commission Washington, D.C. 20554.
6. Clevelanf, R.F. and J.L Ulcek, 1997. Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Field. 4th Edn. FCC Office of Engineering and Technology, OET Bulletin, Federal Communications Commission Washington, D.C. 20554.
7. Jochen Konjager, 2004. The High Voltage Page-High Voltage Sources for Multipliers Basic Circuits. November 2004; http://www.kronjaeger.com/hv/hv/src/mul/index.html.
8. Daniel W. Harrist, 2001. Wireless Battery Charging System Using Radio Frequency Energy Harvesting, MSC Dissertation, University of Pittsburgh.