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Design of Wireless Sensor Networks (WSN) in Energy Conversion Module Based On Multiplier Circuits

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Abstract:- This paper presents the design of wireless sensor network (WSN) in energy conversion module based on multiplier circuit. This energy conversion module can function as an AC to DC converter that not only rectifies the input AC signal but also elevates the DC voltage level. Here, we are using two type of multiplier circuits namely single stage multiplier circuits and multistage multiplier circuits to design the wireless sensor networks. Mathematical analysis also presented for the single and multistage multiplier circuits. Efficiency and multistage voltage output are the two parameters use to analysis the performance of the designed WSN based on multiplier circuits. Simulation results show the relationship between output voltage and RF power of the WSN system with different level of multipliers stage. Results shows that the efficiency analysis of the WSN with the different multiplier stages. Graphical results show that the efficiency of the system goes on increases with the increase in the multipliers stages. Results show the effectiveness of the designed system.

Keywords: **- Wireless sensor Network (WSN), Single stage Multiplier circuits (SSMC), Multistage multiplier circuits (MSMC).**

I. INTRODUCTION

Wireless Sensor network [1] is one of the leading technologies for data communication for number of applications. It has enormous applications in every field like defense, agriculture, environment monitoring, medical applications etc. The use of this unutilized energy as a power source will not only reduce the battery replacement cost, but also enable a long period operation in WSNs. The energy generated from an energy harvester varies in time and space. Therefore the use of RF energy harvesters [1]-[4] also requires a change in both the hardware and the software of wireless sensor nodes. Since WSNs can be applied to many types of applications such as environment and habitat monitoring, healthcare applications, and industrial process monitoring and control [5]-[12]. Placing a large number of spatially distributed low-cost sensor nodes will increase the amount and reliability of the sensor data.

In recent years the use of wireless devices is growing in many applications like mobile phones and sensor networks [3]. This increase in wireless applications has generated an increasing use of batteries. Many researchers are working on extending the battery life by reducing the consumption of the devices. We have chosen to recycle ambient energy like in Micro-electromechanical Systems (MEMS) [4]. The charging of mobile devices is convenient because the user can do it easily, like for mobile phones. But for other applications, like wireless sensor nodes which are located in difficult to access environments, the charging of the batteries remain a major problem. This problem increases when the number of devices is large and are distributed in a wide area or located in inaccessible places. The research on RF energy harvesting provides reasonable techniques of overcoming these problems.

This paper presents the design of wireless sensor network (WSN) in energy conversion module based on multiplier circuit. This energy conversion module can function as an AC to DC converter that not only rectifies the input AC signal but also elevates the DC voltage level. Here, we are using two types of multiplier circuit's namely single stage multiplier circuits and multistage multiplier circuits to design the wireless sensor networks. Mathematical analysis also presented for the single and multistage multiplier circuits. Efficiency and multistage voltage output are the two parameters use to analysis the performance of the designed WSN based on multiplier circuits.

The rest of the paper is organized as follows. In section II, basic of wireless sensor network with energy harvesting circuit is explained. In Section III, explain the single stage multiplier circuit in wireless sensor network. In Section IV, explain the multistage multiplier circuit in wireless sensor network. In Section V, simulation results are explained. Finally, conclusions are drawn in Section VI.

II. WIRELESS SENSOR NETWORKS (WSN)

Wireless Sensor Network is a network, which consists of spatially distributed sensor nodes to monitor physical or environmental conditions, such as temperature, light, vibration, motion or pollutants [2]. Many numbers of motes in working fashion constitute a network and this network route the important events under test. The block diagram in fig. 1 of the motes and understand a small function of the WSN.

From the above fig.1 we can now understand the architecture of WSN node. The node consists of four major and interconnected blocks. The blocks are looking so simple but it has many majorities of 'important and critical' applications. The unit is so popular because of its capacity of handling lots of important real world applications. The Unit

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sense the physical quantity and the electrical signals are fed to microcontroller unit. This microcontroller unit has the much intelligent software which is used for data manipulation, processing, routing, and controlling power by running power efficient algorithms and many more applications.

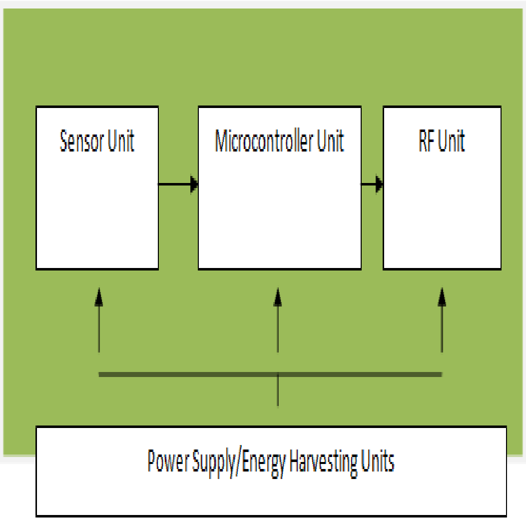

Fig.1 WSN Architecture

In fact, the intelligence of the WSN system depends on micro-controller software only. For Communication the microcontroller opens the RF Transceiver port and communication happens with other nodes. That's all facts are not as simple as we discussed. Actually each unit needs special attention for designing any system. Similarly the microcontroller also needs intelligent software so that it can manage the data manipulation, processing and transmit or receive only the important and useful data.

Small size dusts and motes are the WSN devices which make much application easy to use and reliable and cost effective. The WSN motes are based on battery. Once the battery deplete, the motes become useless. The time duration for which the mote can run without any problem is known as 'life time' of the mote. So we can analyze that we have to all about worry about its power supply for energy considerations. That is one of the major problems, which is too much costly in large area application such as in agriculture, forests, volcanos etc. This problem is not only costly but also very difficult to deploy new nodes.

So we need a technique by which without touching the node we can recharge the low battery nodes. The only way is to use the energy harvesting techniques. Many researches are researching for that major energy problem. The energy consumed by a network node can be divided between the various parts and tasks it has to perform. A number of authors have shown the structure of a general sensor network node [8] [9]. The power requirement depends on the energy requirement for particular element and it's totally depends on application.

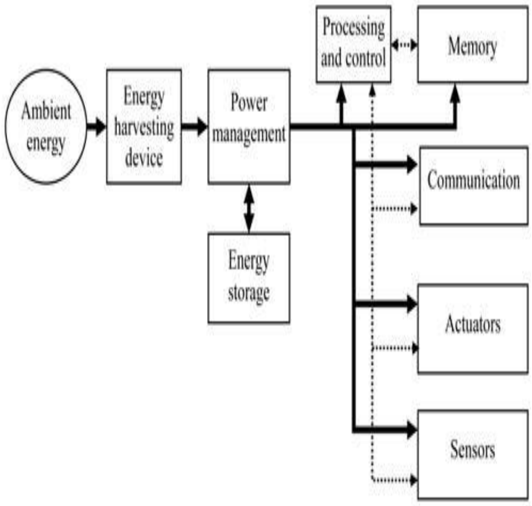

Fig. 2 WSN architecture with Energy Harvester circuit

III. SINGLE STAGE VOLTAGE MULTIPLIER

Adjacent figure represents a single stage voltage multiplier circuit. The circuit is also called as a voltage doubler because in theory, the voltage that is arrived on the output is approximately twice that at the input. The circuit consists of two sections; each comprises a diode and a capacitor for rectification. The RF input signal is rectified in the positive half of the input cycle, followed by the negative half of the input cycle. But, the voltage stored on the input capacitor during one half-cycle is transferred to the output capacitor during the next half cycle of the input signal. Thus, the voltage on output capacitor is roughly two times the peak voltage of the RF source minus the turn-on voltage of the diode.

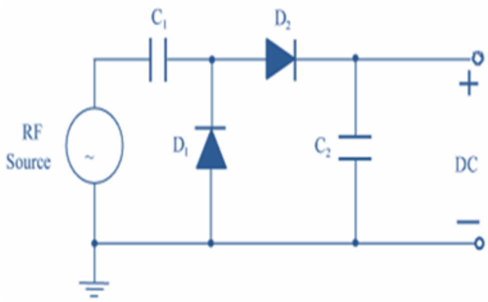

Fig. 3 Multiplier Circuit

The most interesting feature of this circuit is that when these stages are connected in series. This method behaves akin to the principle of stacking batteries in series to get more voltage at the output. The output of the first stage is not exactly pure DC voltage and it is basically an AC signal with a DC offset voltage. This is equivalent to a DC signal superimposed by ripple content. Due to this distinctive feature, succeeding stages in the circuit can get more voltage than the preceding stages. If a second stage is added on top of the first multiplier circuit, the only waveform that the second stage receives is the noise of the first stage. This noise is then doubled and added to the DC voltage of the first stage. Each independent stage with its dedicated voltage doubler circuit

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can be seen as a single battery with open circuit output voltage V_0, internal resistance R_0 with load resistance R_L, the output voltage, V_{out} is expressed as in

$$V_{out} = (V_0 / (R_0 + R_L))\ RL \quad (1)$$

When n number of these circuits are put in series and connected to a load of R_L in Equation (2) the output voltage V_{out} obtained is given by this change in RC value will make the time constant longer which in turn retains the multiplication effect of two in this design of seven stage voltage doubler.

$$V_{out} = \frac{nV_0}{nR_0 + R_L} R_L = V_0 \frac{1}{\frac{R_0}{R_L} + \frac{1}{n}} \quad (2)$$

The number of stages in the system has the greatest effect on the DC output voltage, as shown from Equations (2) and (3). As n increases, the increase in output voltage will be almost double the input voltage up to some number of stages. The capacitors are charged to the peak value of the input RF signal and discharge to the series resistance (RS) of the diode. Thus the output voltage across the capacitor of the first stage is approximately twice that of the input signal. As the signal swings from one stage to other, there is an additive resistance in the discharge path of the diode and increase of capacitance due to the stage capacitors.

$$Vout = n * [2.728 * Vrms - 0.09] \quad (3)$$

This is the final relationship between V_{out} and Vrms value, 'n' be the no. of stages.

IV. MULTI-STAGE VOLTAGE MULTIPLIER

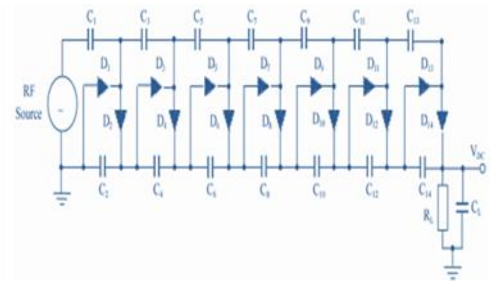

Fig. 4 Multistage Voltage Multiplier

One of the Multi-stage voltage multiplier circuit design (Fig. 4) implemented in this project is shown in above figure. It's a Schematic of 7 stage voltage multiplier. Starting on the left side, there is a RF signal source for the circuit followed by the first stage of the voltage multiplier circuit. Each stage is stacked onto the previous stage as shown in the Figure. Stacking was done from left to right for simplicity instead of conventional stacking from bottom to top.

The circuit uses eight zero bias Schottky surface-mount HSMS-285X series, HSMS-2850 diodes. The special features of these diode is that, it provides a low forward voltage, low substrate leakage and uses the non- symmetric properties of a diode that allows unidirectional flow of current under ideal conditions. The diodes are fixed and are not subject of optimization or tuning. This type of multiplier produces a DC voltage which depends on the incident RF voltage. Input to the circuit is a predefined RF source.

V. EXPERIMENTAL RESULTS

In this section, we present the design of wireless sensor network (WSN) in energy conversion module based on multiplier circuit. The simulated results at the output voltage of voltage multiplier circuit are shown graphically in following figure. From the graph analysis, the simulated values are more close to the linear graph and thus provide much better and controllable results. The reason behind this may be due to the uncertainty in series resistance value of the diode obtained from SPICE parameters in modeling.

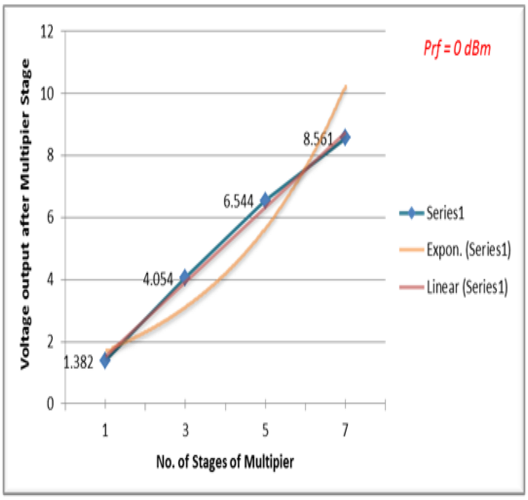

Fig.5 Voltage Multiplier o/p vs no. of stages

This resistance value of diodes in practical circuit may be lower than in the model, which provides fast discharge path, in turn rise in voltage as passes through the stages and reaches to final output. In this work, Fig. 5 has the DC output voltages obtained through simulation at 0 dBm is1.382 V. Below fig. 6 show the result of a 1, 3, 5, and 7 stages (value of 'n') voltage doubler circuit with equal capacitance values for Voltage Output (V_{out}) (in V) with reference to the Received RF power. From these results, the use of equal stage capacitance of each being 3.3 nF was hence considered for the design of the multiplier.

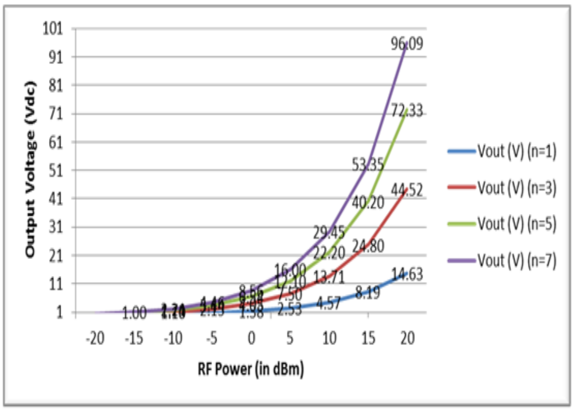

Fig. 6 O/P voltage vs RF Power

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A. Efficiency Analysis of Multiplier

When designing an antenna, two main parameters are generally evaluated: DC Voltage output (VDC) with which we dealt in the above section and secondly RF to DC energy conversion efficiency. Now we are going to calculate and analyze Efficiency of the Voltage Multiplier Circuit, defined as:

$$\eta = \frac{P_{DC\ out}}{P_{RF\ in}} = \frac{V_{out}^2}{R_{load}} \cdot \frac{4\pi Z_{air}}{|E|^2 . G . \lambda^2} \qquad (4)$$

Where R_{load} is the load resistance, Z_{air} is air characteristic impedance (120π ohms), E is electric field RMS value at receiver position, G is receiver antenna gain and λ is the wavelength. Below fig.7-11 show the result of a 1, 3, 5, and 7 stages (value of ‘n’) voltage doubler circuit for Efficiency (in %) with reference to the Received RF power, keeping output load resistance constant.

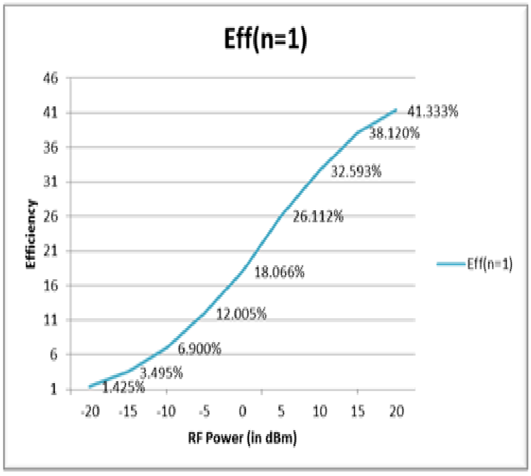

Fig.7 a 1stages (value of ‘n’) voltage doubler circuit for Efficiency (in %) with reference to the Received RF power

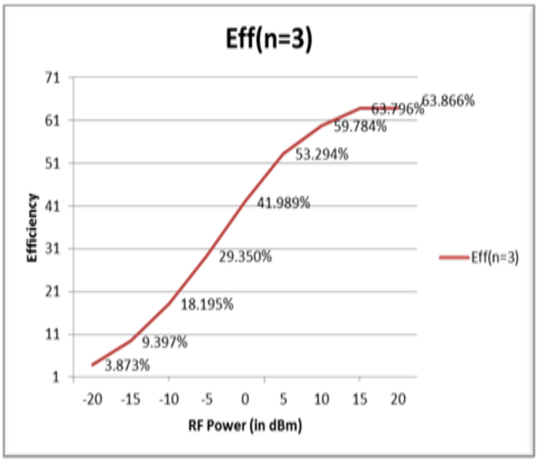

Fig.8 a 3 stages (value of ‘n’) voltage doubler circuit for Efficiency (in %) with reference to the Received RF power

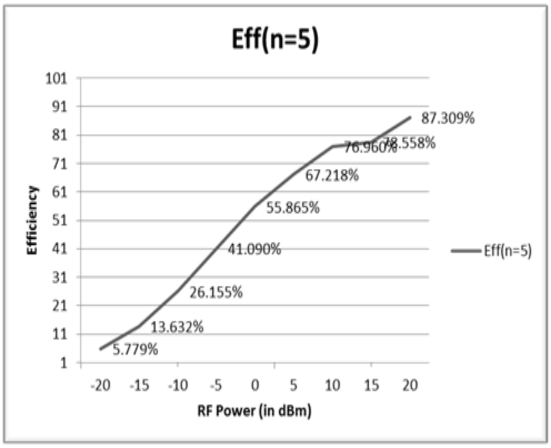

Fig. 9 a 5 stages (value of ‘n’) voltage doubler circuit for Efficiency (in %) with reference to the Received RF power.

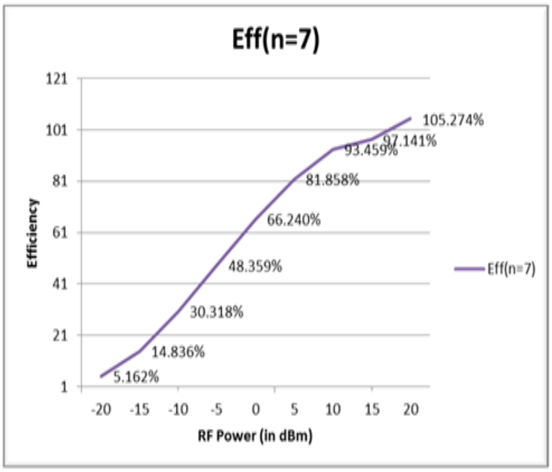

Fig. 10 a 5 stages (value of ‘n’) voltage doubler circuit for Efficiency (in %) with reference to the Received RF power.

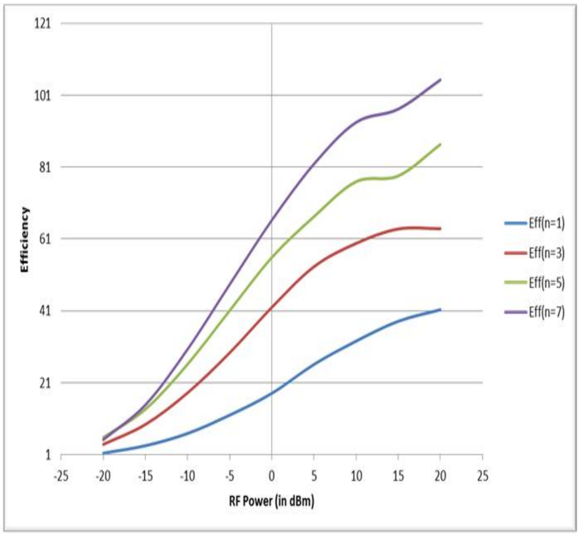

Fig. 11 stages (value of ‘n’) voltage doubler circuit for Efficiency (in %) with reference to the Received RF power

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VI. CONCLUSIONS

In this paper, we present the design of wireless sensor network (WSN) in energy conversion module based on multiplier circuit. This energy conversion module can function as an AC to DC converter that not only rectifies the input AC signal but also elevates the DC voltage level. Efficiency and multistage voltage output are the two parameters use to analysis the performance of the designed WSN based on multiplier circuits. Simulation results show the relationship between output voltage and RF power of the WSN system with different level of multipliers stage. Results shows that the efficiency analysis of the WSN with the different multiplier stages. Graphical results show that the efficiency of the system goes on increases with the increase in the multipliers stages.

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