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Efficient Energy Harvesting Systems - IOT Applications

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Abstract: ***The effectiveness of IOT (Internet of things) for industrial perspective can be discovered when devices are connected interactively with each other for better and immediate solutions for their business. Being aware of the finite availability of fossil fuels, Energy Harvesting is a smart solution for industries. When ambient energy available in the environment is converted into electrical energy the process is called Energy Harvesting. Energy harvesting system is a combination of several subsystems working together out of which power generation has a key role i. e driving IOT devices. Various sources like Solar, Piezoelectric, RF and Thermal are used to design energy harvesting system for low power applications. Some sources are dependent directly on environmental conditions in such case hybrid energy harvesting system is advantageous.***

Keywords: IOT, Energy Harvesting Systems (EHS), ambient energy, Solar, Piezoelectric, RF, Heat, hybrid energy harvesting system

1. Introduction

The interaction of the global machine networks is possible because of IOT (internet of things). It is an emerging technology also known as internet of the industries. IoT is has an important role as lot of industries are showing the interest in it as it is the future of technology. For the support system of the customers as per their requirements, smart and profitable business, other different systems, to perform analytics for business, IOT has never ending importance as the devices are connected together globally to interact with each other. In order to be ahead of the world industries are getting used to this new era for better solutions in the competitive environment.

2. Theory

When the energy is transferred from one form to another i. e ambient energy will give rise to electrical energy this phenomenon is called Energy Harvesting. Over the wide range of sources available in the environment many methods and attempts are made for making it available. When many subsytems are working with the aim of power generation to run devices that such a system is called an energy harvesting system. We have seen energy being used from solar, radio frequency, heat and even mechanically for devices which require less power are efficiently performing over the decade. Free energy is abundantly available in the environment which are mostly wasted and it is not completely consumed in the world. Environment has many sources which gives rise to energy like Solar Energy: Energy harnessed from the light of the Sun. Kinetic Energy: Energy generated from mechanical vibrational.

- Thermal Energy: temperature differences in materials generates this energy
- Radio - frequency (RF) Energy: Energy given by ambient RF waves

A. Energy Harvesting

Highest efficiency is desired in the process of conversion of ambient energy into electrical energy. Some sources have the ability to harness large amounts of electrical power (in the kW or MW range), known as macro - energy harvesting, while some sources only have the ability to harness small amounts of electrical power (in the uW or mW range), known as micro - energy harvesting. Macro - energy harvesting systems are advantageous because they generate large amounts of power; however, they require large, heavy, and often expensive equipment to handle the large voltages. They also require external connections to the power grid to sustain operations. In contrast, micro - energy harvesting systems require small, lightweight, relatively inexpensive equipment to harness small amounts of power. An especially attractive feature of these systems is that they require no connections to the electric grid; their small footprint design allows them to serve as standalone, self - sustaining systems, which is ideal for self powered applications. [8]

3. System Design

LT spice is the simulation tool used which is known for its good performance as SPICE simulation software, It has many macro models for a majority of amplifiers, Analog Devices switching regulators, amplifiers, gives liberty to devices for general circuit simulation. It serves good as schematic capture and waveform viewer with enhancements and models for easing the simulation of analog circuits.

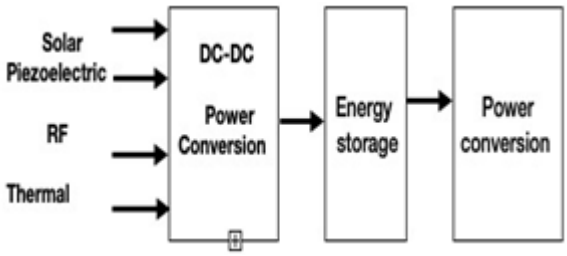

Figure 1: Proposed Energy Harvesting System

LT spice has a waveform viewer to show the results of the simulation, an enhanced SPICE type analog electronic circuit simulator. It supports AC, DC, DC transfer function, Circuit simulation analysis based on transient, schematic capture to enter an electronic schematic for an electronic circuit, noise,, DC operating point can be performed and plotted and also fourier analysis. Efficiency reports can also be generated by calculating the heat dissipation of components. It has enhancements and models to speed the simulation of switched - mode power supplies in DC - to - DC converters.

Radio frequency electronics, power electronics, audio electronics, digital electronics, are the users in this field. The figure 1 shows the system with Solar, Piezoelectric, Thermal and RF used in the harvesting system proposed.

A. Solar Energy Harvesting System

For implementing solar energy harvester, linear technology's LTC 3105 was selected. The LTC 3105 is a high efficiency step - up DC/DC converter that can operate from input voltages as low as 225mV. A 250mV start - up capability and integrated maximum power point controller enable operation directly from low voltage, high impedance alternative power sources such as photovoltaic or solar cells. Gains in the increasing manner were achieved from last many past in the device performance substances like photovoltaics which are organic called as OPV, solar cells which are known as DSSC, crystalline silicons, etc. Ambient PV cells power the IOT devices. Using photovoltaic cells electrical energy is obtained from solar energy.

B. Piezoelectric Energy Harvesting System

LTC3588 - 1 is used in the circuit. The LTC3558 - 1 combines a high efficiency buck converter with a low - Ioss full - wave bridge rectifier to form a complete energy harvesting provision optimised for high output impedance energy sources. [9] The output can be set at 1.8V, 2.5V, 3.3V or 3.6V using the output voltage selection pins. This could be don't programmatically with a microcontroller, if you needed to be able to change the output, but since we only want it to stay at 1.8 for low power applications volts at all times we just elected to short these pins to the 1.8V settings as shown in figure 3.

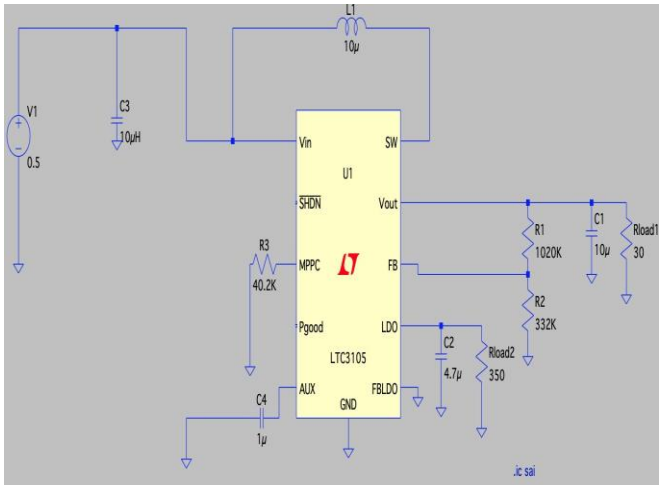

Figure 2: Piezoelectric Energy Harvesting Circuit

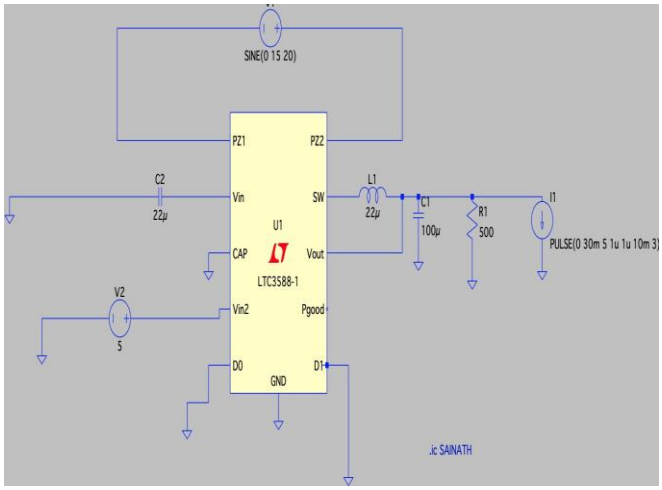

Figure 3: Piezoelectric Energy Harvesting Circuit

C. Thermal Energy Harvesting System

Thermal energy harvesting was implemented using Linear Technology's LTC3108. The LTC 3108 is a highly integrated DC/DC converter ideal for harvesting and managing surplus energy from very low input voltage sources. The stepup topology operates from input voltages as low as 20mV. LTC3108 provides a complete power management solution for wireless sensing and data acquisition. Coil craft transformers of turn ratios 1: 100 were selected upon considering factors such as low startup voltage, DC resistance and inductance of transformers.

The following circuit was used to carry out simulations using LTC 3108 with the help of LT spice:

LTC 3108 anchors selectable outputs of 2.35V, 3.3V, 4.1V or 5V. It is necessary to step down voltage to 1.8V. A step down circuit was a implemented with a DC charge of 2.7V to check the nature of the waveform.

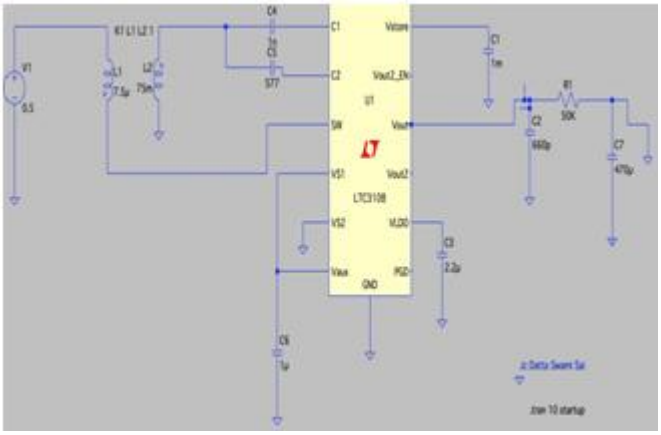

Figure 4: Thermal Energy Harvesting Circuit

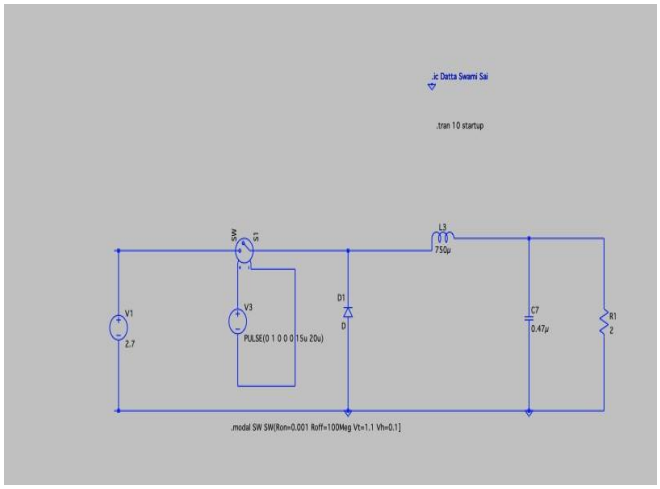

Figure 5: Circuit to step down the voltage

D. RF Energy Harvesting System

The main technological advancement that has allowed these harvesting devices to generate sufficient power is through the development of receivers which can sense broad ranges of frequencies, not just limited to television UHF signals, while capturing the highest concentration of generated waves. Schottky diode offer low forward voltage and high switching speed, and consider as an ideal component for RF energy harvesting. This circuit uses HSMS2820 schottky diode. RF signals can be captured using multiband antenna as shown in figure. It is capable of receiving 900Mhz/1800MHz/1900MHz/2.4GHz. Small patch antennas can be used at higher frequencies.

4. Analysis

Different software's are available to conduct simulations in this area such as: P Spice, LT Spice and Simulink. For this paper LT spice has been used for simulation results and its version is LT Spice IV. LT Spice provides schematic capture along with a waveform viewer with enhancements and

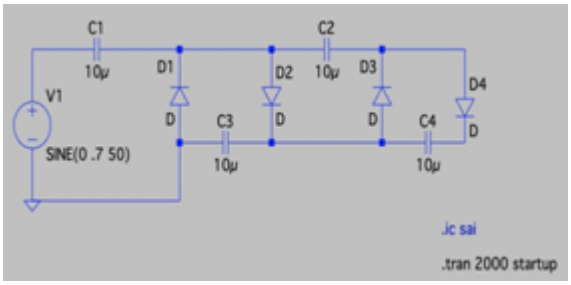

Figure 6: RF Energy Harvesting Circuit

models for speeding the simulation of switching regulators. In LT Spice IV third - party models can be imported and it is node - unlimited. Fourier analysis as well as circuit simulations based on transient AC noise and DC analysis can be plotted. Efficiency reports can be generated based on calculation of heat dissipation of components. LT Spice IV is used by many users in fields including radio frequency electronies, power electronies, digital electronies etc.

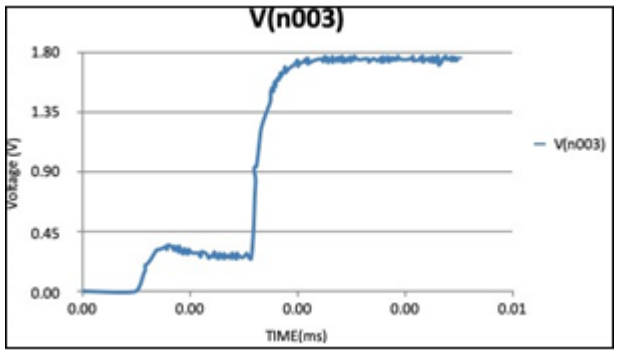

Figure 7: Output waveform of Solar Energy Harvesting

After the simulations Output voltage for Solar energy harvesting system can be seen as simulated with the help of LTpsice.

Figure 7 shows time response of output voltage. Peak value of obtained rectified output voltage is 1.8V.

5. Result and Discussions

Solar Energy Harvesting System was implemented on LTC 3105 with the output of 1.8V. Similarly Piezoelectric Energy Harvesting System was implemented using LTC3588 - 1, LTC 3108 supports Thermal Energy Harvesting System. RF Energy Harvesting System was also implemented using the components available in LTSPICE. Solar energy is considered as Uncontrollable, Predictable source while indoor light is Partly controllable and Predictable. The choice between the two can be made based upon the required output. Piezoelectric energy harvesting system is obtained from mechanical vibrations is characterized as Controllable and also Partly - predictable. Uncontrollable and Unpredictable is the thermal source. Partly controllable, with Partly - predictable is RF. These conditions should also be considered while developing a system.

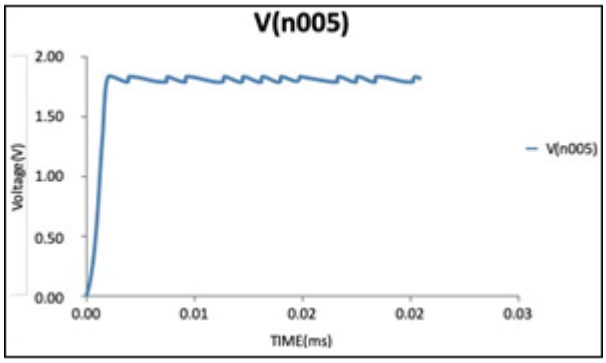

Figure 8: Output waveform of Piezoelectric Energy Harvesting

6. Conclusion

This study tells us about the proposed energy harvesting system model based upon the controlled voltage output for Solar, thermal, RF and piezoelectric energy harvester suitable for WSN. It has been designed to supply the 1.8 V and low

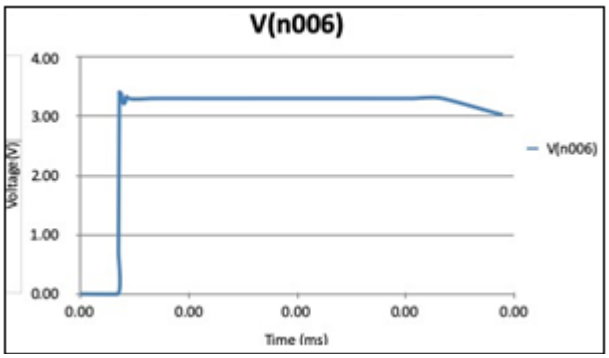

Figure 9: Output waveform of Thermal Energy Harvesting

The proposed model has been recorded with low input voltage. The various simulations has been conducted to see the behaviour of the different sources independently for the purpose of driving low power devices. Hybrid energy harvesting system is better option for industries as it will reduce the dependance on any single source. Also, many sources are largely influenced by the geographical area and the temperature condition. In such cases it is difficult for industries to continue the constant power supply. The different energy harvesting ensures availability of the desired amount of power which signifies its stable and consistent performance.

7. Future Scope

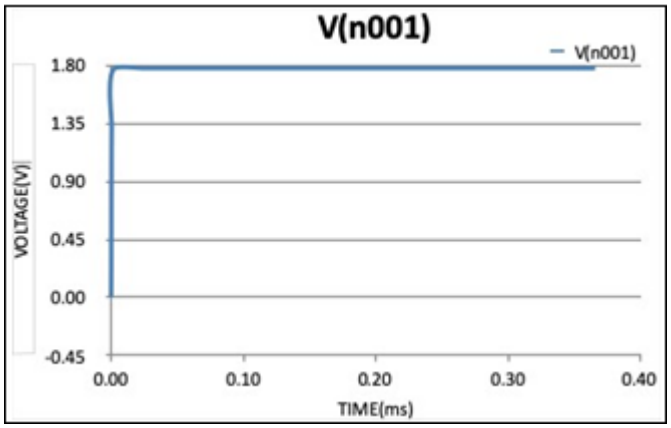

Figure 10: Step down Voltage Output

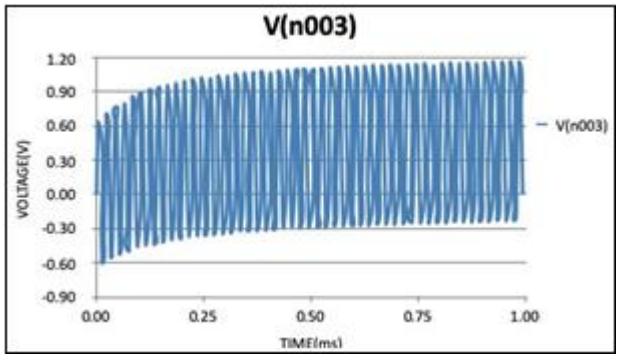

Figure 11: Output waveform of RF Energy Harvesting

Fig.9. Output waveform of Thermal Energy Harvesting Energy harvesting offers significant advantages to the development and improvement of the Internet of Things. The energy harvesting system can be developed with more compact shape. Energy is a critical component for creating an enhanced class of autonomous and mobile applications that can operate for much longer periods of time without the need for battery charges. It also drives cost savings by significantly delaying battery replacement, which often costs more than the battery itself and energy harvesting is a key element in bringing intelligence to the edge and the IoT to a world of new places and applications. Future expansion will be implementing the energy harvesting system with the modules readily available and build a better device.

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