ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 3, March 2016

Wideband Energy Harvesting Using MEMS for WSN Applications

V Amirtha Raj

Associate Professor, Department of EEE, Sree Narayana Institute of Technology, Adoor, India

ABSTRACT: The scavenging energy from radiations can be harvested by operating wireless sensor networks along with ultra-low power electronic devices for various applications. With the advancement in wireless communication technologies, inexpensive and ultra-low power wireless sensors can be applied to monitoring important parameters. The finite life span of the batteries which power the sensing system becomes a bottleneck as it is expensive to periodically replace these batteries resulting decrease in the life span of the sensing system. Thus, the energy harvesting technology is an attractive and promising solution to make the system monitoring self-sustainable. Due to advanced developments in the MEMS switches, it is desirable to use MEMS switches. MEMS switches offer lower insertion loss and higher isolation, zero power consumption, small size and weight and very low intermodulation distortion. RF-MEMS components are mainly used as inductors, tunable capacitors, switches, in VCOs, and resonators MEMS switches for wireless applications include transmit/receive duplexers, band-mode selection, time delay for phased-array antennas, and reconfigurable antennas. By integrating RF MEMS in the entire system, it will enhance the entire operation of the harvester. The size and cost will be reduced to great extent

KEYWORDS: Energy harvester, Smart AntennaMEMS, Wireless Sensor Networks.

I.INTRODUCTION

A wirelessly powered wireless terminal and sensor nodes from scavenging energy has been the dream of many researchers. With the advancement in wireless communication technologies, inexpensive and ultra-low power wireless sensors have been developed and can be applied to monitoring important parameters.The conventional wireless sensor networks are powered by using batteries. However, the finite life span of the batteries which power the sensing system becomes a bottleneck as it is expensive to periodically replace these batteries. Identifying the running out of the battery, deterioration of WSN etc. is difficult to monitor. Thus, the energy harvesting technology is an attractive and promising solution to make the system monitoring self-sustainable. Due to wide and tremendous increase in usage of wireless technologies, energy transmitted by broadcast stations, cellular stations and Wi-Fi access points can be harvested by operating ultra-low power electronic devices and sensors. It can be accomplished by having antennas, rectifier circuits for conversion of RF signals into DC, super capacitor, boost converters and necessary power management circuits.RF-MEMS components are mainly used as inductors, tunable capacitors, switches, in VCOs, and resonators. Popular MEMS switches for wireless applications include transmit/receive duplexers, band-mode selection, time delay for phased-array antennas, and reconfigurable antennas. The efficiency of energy harvester developed in [1] can be improved by modifying the components based on MEMS devices. In addition to the improvement of efficiency the power consumption within the devices are reduced to great extent. RF MEMS technology promises to enable on-chip switches with zero standby power consumption, nano-Joule-level switching power; high quality inductors, capacitors and varactors; highly stable (quartz-like) oscillators; and high performance filters operating in the tens of megahertz-to several gigahertz frequency ranges. The availability of such an arsenal of first rate RF and microwave components will provide designers with the elements they have long hoped for to create novel and simple (but powerful) reconfigurable systems. These MEMS based components and devices are more flexible and compatible with the 'smart' antenna.This integrated system improves the overall performance of the system. The overall system including smart antenna, energy convertor circuits along with WSN module is shown in figure. The entire system is split into two, i.e. Energy harvester circuit and Wireless sensor and control network. The design of energy harvester initiates from antenna and ends in the useable power for the WSN and the second part is the conventional WSN module.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 3, March 2016

The recurring demand for ever more flexible and sophisticated, yet lightweight and low power wireless systems, has generated the need for a technology that can drastically reduce manufacturing costs, size, weight, and improve performance. With the potential to enable wide operational bandwidths, eliminate off-chip passive components, make interconnect losses negligible, and produce almost ideal switches and resonators in the context of a planar fabrication process compatible with existing IC and MMIC processes, RF MEMS is widely believed to be just that technology.
The overall system is composed of converter circuits, which includes tuned rectifier circuits connected to Antenna circuit, super-capacitor, power gating circuit, boost converter etc.

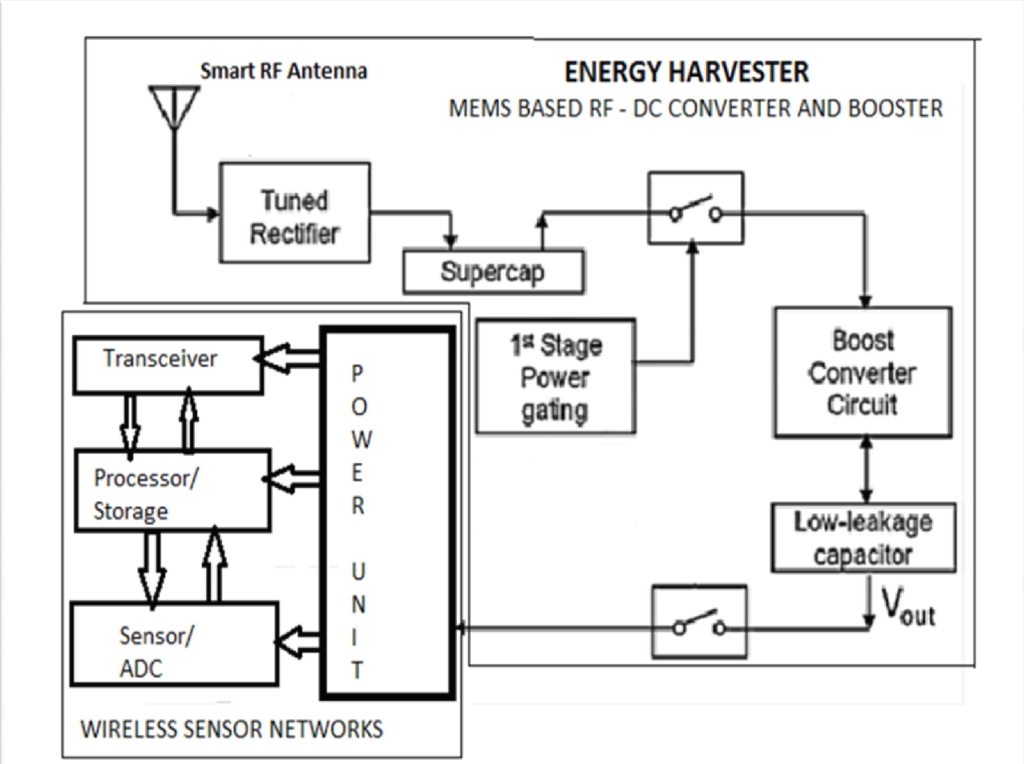

Fig: Block diagram of MEMS based Energy Harvesting for WSN applications

The output thus obtained can be directly or converted in to require form may be used to power ultra-low power electronic devices and sensors. The signal can also be transmitted in to the wireless sensors, processed for low power programmable applications etc. With the advancement in wireless communication technologies, inexpensive and ultra-low power wireless sensors can be developed. Hence the harvested energy can be utilized for wireless sensing applications.

II.ENERGY HARVESTING SYSTEM

The harvesting system is designed to drive a low power wireless sensor node by accumulating energy from ambient RF radiations Some of the key challenges in converting this scavenging energy into useful energy include a) low power density and voltage levels which is insufficient for conventional rectification process b) In order to achieve higher voltages at the output of rectifier the high output impedance should be maintained (much higher than practical loads) c) use of boost converters leads to low input resistance and the power requirements for continuous operation is much higher d) the use of multiple rectifiers along with separate antennas would occupy large area and hence increase the cost. These problems has been overcome by a) the accumulate-and-use topology b) using a power sensor so that it search for a band with a maximum energy and dynamically tune the matching network c) using variable components instead of fixed components in the design of the tuned rectifier

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 3, March 2016

Some modification in the entire system results to improve the overall efficiency and speed of the system. It can be incorporated by a broadband matching circuit in such a way that efficiency over the range not compromised. 1) By adjusting the length of T_{off}, by Auto-Z_{in}-adjust circuit, the effective Z_{in} of DC-DC converter can be controlled. Hence the efficiency of tuned rectifier is improved. 2) The efficiency of boost converter can be improved by using Maximum Power Point Tracking (MPPT) for adjusting the operating point. 3) Since the transmission consumes the major portion of power developed, the transmitting section can be made to sleep mode till the sensor node is ready to output the measured data by an adaptive duty cycle determination method. The system consists of a high gain antenna attached to a tuned rectifier.

A critical requirement of many miniature systems is the ability to sense and/or transmit electromagnetic energy for communications or remote sensing. In addition the single multiband antenna can be developed by using a power sensor, so that it search for a band with a maximum energy and dynamically tune the matching network. This can be accomplished using radio-frequency (RF), microwave, or millimeter-wave antennas that can be fabricated monolithically with other electrical/mechanical components to yield a new class of reconfigurable antennas capable of multi-band operation, adaptive beam forming, jamming/interference mitigation, polarization diversity, low-observability, and direction of arrival estimation. By combining low-loss, high-isolation RF MEMS switches with resonant micro-strip or fractal radiators, physically reconfigured antennas and their feed structures in order to provide frequency band and polarization diversity is obtained. The MEMS micro-relays are used to alternately connect or isolate sub-structures on the planar antenna element, creating a geometrically distinct radiator for each combination of switch positions. In addition, MEMS phase-shifters can be used in conjunction with multiple antenna elements to realize monolithic low-cost electronically steerable arrays (ESAs). These ESAs will facilitate future integration with active devices and signal processors to realize ‘smart’ antenna systems capable of autonomous frequency-band and radiation pattern adaptation. RF MEMS used in conjunction with fractal antenna structures as the basis of a new re-configurable antenna approach. The use of RF MEMS switches permits the overall fractal pattern to be dynamically “shattered” into subsets. This property may permit the spectral isolation of impinging RF energy through binary search algorithms. This agility offers enabling benefits for alterations in antenna performance to accommodate changes in mission, environment; tolerance to defects and faults; and enabling new algorithmic approaches and direct digital synthesis.

The tuned rectifier without the power gating circuit cannot drive a commercial low power DC/DC boost converter. In order to store sufficient energy, a super capacitor followed by an appropriate power gating circuit is used at the output of the rectifying circuit. Since the efficiency of the boost converter varies with the input voltage, the super-capacitor operating voltage range is decided such that it maximizes the combined efficiency of RF–DC and the boost converter stage. To maximize the overall efficiency, the startup component which is wasted every cycle of intermittent operation should be made insignificant. This can be achieved by increasing the voltage across the super-capacitor or its capacitance value. The instantaneous efficiency of RF–DC section is defined as the ratio of rate of change of energy stored in super-capacitor and the input power. Due to advanced developments in the MEMS switches, it is desirable to use MEMS switches as a power gating and leakage management circuits. In comparison with other types of switches, MEMS switches offer lower insertion loss and higher isolation, zero power consumption, small size and weight and very low intermodulation distortion. Hence it will enhance the entire operation of the harvester.

III. WIRELESS SENSOR NETWORKS

Wireless Sensor Networks (WSNs) is the term that is used for wireless sensor and control networks that use batteries or Energy Harvesting techniques to power the device. With the availability of low cost integrated circuits to perform the sensing, signal processing, communication, and data collection functions, coupled with the adaptability that wireless networks can move away from fixed, hard-wired network installations.

Wireless sensor networks have recently come within reach of practical applications due to new technological developments, particularly in the area of miniaturization and device communication. These developments have enabled the creation of small devices consisting of a microcontroller, a radio front-end, a power supply and one or more sensors capable of sensing the environment. A number of such devices can together form a wireless sensor network. The development of so-called Networked Intelligent Devices (NIDs), are cooperating devices that share knowledge and

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 3, March 2016

negotiate about tasks and observations. The combination of NIDs with wireless sensor has resulted in numerous applications and most promising. The drawback to moving toward a wireless network installation has been the poor reliability and limited useful life of batteries needed to supply the energy to the sensor, radio, processor, and other electronic elements of the system. This limitation can be eliminated through the use of Energy Harvesting techniques which lasts the life of the wireless sensor. The output of each WSN can be monitored and the fault if any occurred can be easily identified and can be repaired.

.

IV. WSN APPLICATIONS

The applications for WSNs are varied, typically involving some kind of monitoring, tracking, or controlling. Specific applications include habitat monitoring, object tracking, nuclear reactor control, fire detection, and traffic monitoring

Military: Wireless sensors have become an excellent tool for military applications involving intrusion detection, perimeter monitoring, and information gathering and smart logistics support in an unknown deployed area. Military situation awareness, Sensing intruders on bases, detection of enemy units movements on land/sea, chemical /biological threats and offering logistics in urban warfare. Battlefield surveillance, command control, communications, computing, intelligence, surveillance, reconnaissance, and targeting systems.

Other applications include sensor-based personal health monitor, location detection with sensor networks and movement detection. Some traditional surveillance tasks can be taken over by unmanned surveillance systems. Typical tasks include support for securing compounds in hostile environments including protection of weapon storage depots and health monitoring, protection of provision routes, protection of forces in harbors, and monitoring activities of enemy troops.

a) *Environmental monitoring:* A number of WSNs have been deployed for environmental monitoring.
b) *Vehicle Detection:* Wireless sensor networks can use a range of sensors to detect the presence of vehicles ranging from motorcycles to train cars.
c) *Greenhouse Monitoring:* Wireless sensor networks are also used to control the temperature and humidity levels inside commercial greenhouses. Some wireless sensor networks are easy to install, they are also easy to move as the needs of the application change.
d) *Windrow Composting:* Composting is the aerobic decomposition of biodegradable organic matter to produce compost, a nutrient-rich mulch of organic soil produced using food, wood, manure, and/or other organic material. One of the primary methods of composting involves using windrows.
e) *Flare Stack Monitoring:* Landfill managers need to accurately monitor methane gas production, removal, venting, and burning. Knowledge of both methane flow and temperature at the flare stack can define when methane is released into the environment instead of combusted. To accurately determine methane production levels and flow, a pressure transducer can detect both pressure and vacuum present within the methane production system.
f) *Area monitoring:* Area monitoring is a common application of WSNs. In area monitoring, the WSN is deployed over a region where some phenomenon is to be monitored.
g) *Landfill Ground Well Level Monitoring and Pump Counter:* Wireless sensor networks can be used to measure and monitor the water levels within all ground wells in the landfill site and monitor leach ate accumulation and removal. A wireless device and submersible pressure transmitter monitors the leach ate level. The sensor information is wirelessly transmitted to a central data logging system to store the level data, perform calculations, or notify personnel when a service vehicle is needed at a specific well.
h) *Medical/ Health:* Monitoring people's locations and health conditions.

i) *Physical world:* Monitor and control the physical world: deployment of densely distributed sensor/actuator networks for a wide range of biological and environmental monitoring applications, from marine to soil and atmospheric contexts; observation of biological, environmental, and artificial systems; environmental monitoring of water and soil, tagging small animals unobtrusively, and tagging small and lightweight objects in a factory or hospital setting.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 3, March 2016

V.CONCLUSION

Thus highly efficient wirelessly powered wireless terminal can be accomplished as shown in the figure. With advanced developments for faster, smaller, highly tunable and cheaper communication systems that consume less power and have wider bandwidths for increased data rates, MEMS devices found a new field of applications. Structures such as low loss and high isolation MEMS switches, reconfigurable antennas, filters and tuners, high –Q passives and resonators, low loss planar waveguide components and low loss phase shifters are a few examples of revolutionary components. Comprising all above, the more efficient, small size, and low cost energy harvester can be developed. Overall the device can be made in miniaturized size by making the components as small as possible, so that it can be mounted anywhere and everywhere. The device can be combined with some physical sensors like heat, light, motion, EM field etc., thereby the power unit can be energized and the system became more efficient in addition to other physical sensing applications. Magnetic field energy harvester can also be included for WSN applications by proper design of converter circuits in the required form.

REFERENCES

[1] Gaurav Singh, Rahul Ponnaganti, T V Prabhakar, K J Vinoy, "A tuned rectifier for RF energy harvesting from ambient radiations", *International Journal Of Electronics and communications,*2013,564-569

[2] Christos G. Christodoulou, "RF - MEMS and its Applications to Microwave Systems, Antennas and Wireless Communications", *IEEE Xplore*, June 2009.

[3] Brown WC "The history of power transmission by radio waves", *IEEE Trans Microw Theory Tech* 1984, 1230-42

[4] Zlatoljub D. Milosavljevic, "RF MEMS Switches", *Microwave Review* June 2004.

[5] Sheng Yuan, QianXu, Yi Huang, Chaoyun Song, "Magnetic Field Energy Harvesting Under Overhead Power Lines", *IEEE Transactions on Power Electronics*, May 2016

[6] Gadriel M Rebeiz, "RF MEMS Switches: Status of the Technology", *The 12th International Conference on Solid State Sensors, Actuators and Microsystems*, Boston, June 8-12,2003

[7] Indu, Sunita Dixit , "Wireless Sensor Networks: Issues & Challenges", *International Journal of Computer Science and Mobile Computing* Vol. 3, Issue. 6, June 2014, pg.681 – 685

[8] VivekKatiyar, Narottam Chand, Naveen Chauhan, "Recent advances and future trends in Wireless Sensor Networks", *International Journal Of Applied Engineering Research,* Volume 1, No 3, 2010

[9] Jose, Nithin, Nirmal John, Prashuk Jain, PrashantRaja, T. V Prabhakar, and K. J. Vinoy. "RF powered integrated system for IoT applications", 2015 IEEE *13th International New Circuits and Systems Conference (NEWCAS),* 2015.

[10] Jusoh, M., M. F. Jamlos, N. M. Nawawi, A. Alomainy, M. R. Kamarudin, and M. R. Hamid. "Switchable parasitic antenna using PIN Diode- and MEMS-switches", *IEEE International RF and Microwave Conference (RFM)*, 2013

[11] Agrawal, Sachin, Sunil Kumar Pandey, Jawar Singh, and Manoj S. Parihar. "Realization of efficient RF energy harvesting circuits employing different matching technique", *Fifteenth International Symposium on Quality Electronic Design*, 2014

[12] Nishimoto, Hiroshi, Yoshihiro Kawahara, and TohruAsami. "Prototype implementation of ambient RF energy harvesting wireless sensor networks",

[13] IEEE Sensors, 2010van Dijk, Gert J. A., and Marinus G. Maris. "Wireless sensor network for mobile surveillance systems", *Unmanned/Unattended Sensorsand Sensor Networks,* 2004

[14] MoharamHabibnejadKorayem. "Determination the Effects of Structural Parameters on Pull DownVoltage of RF MEMS Switches", 2007 *Asia-Pacific MicrowaveConference,* 12/2007