International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2015): 78.96 | Impact Factor (2015): 6.391

A Vibration Based Piezo Electric Energy Scavenging Interface with Feedback Monitoring

Elsa Sneha Thomas[1], **Mariam Shema Thomas**[2]

[1]Assistant Professor, Department of Applied Electronics and Instrumentation Engineering, Mount Zion College of Engineering, Kadammanitta, Kerala, India

[2]M Tech, Department of Electronics and Communication Engineering, Sree Buddha College of Engineering for Women, Elavumthitta, Kerala, India

Abstract: ***The increasing utilization of portable, implantable and wireless systems in medical, industrial and military applications increases the need for compact and efficient energy harvesting devices to be used for powering these systems. Energy harvesters that generate energy from ambient sources such as heat, light and vibration reduces the dependence of these devices on external power supplies and batteries. Due to the availability, vibration is particularly important. Some vibration sources in the environment are vehicle motion, human movements and seismic vibrations. Using piezoelectric, electrostatic and electromagnetic transduction, the efficiency of these systems is proportional with the value of the vibration frequency. Based on these observations, in this paper we present a self supplied energy generator, which includes MEMS harvester hybridly integrated with its power management circuitry for autonomous charging of an energy reservoir. This is a piezo electric vibration based energy harvester using power management IC with feedback monitoring. The system is completely self-supplied by the harvester vibration energy, and has no dependence on a previously charged energy reservoir.***

Keywords: Piezo electric, Electrostatic, Electromagnetic transduction, Wireless system, Energy harvesting, MEMS harvester

1. Introduction

Energy has been essential in building up modern society. Some energy can be seen, but most does not have a visible form. Energy is defined in several ways such as mechanical, electrical and chemical. All of these definitions are based on where energy is stored. Energy is stored everywhere. Heat, electricity, dynamic, chemical, photo and biomass forms of energy are all stored differently but these can be converted from one to the other. Among many types of energy, electricity is the most common used form for modern devices because it is easy to convert to other types. The energy obtained from the vibration is converted to electrical energy [1].

The MEMS harvester is fabricated with a recently developed process technology [5], which involves aligned solder bonding and thinning of bulk PZT ceramics on silicon. Fabrication flexibility and device performance over existing thin film deposition methods are the advantages of this technology. The harvester is packaged with a Si bottom cap and a Si glass top cap, both incorporating a recess for free movement of the harvester proof mass. The leads from the harvester are fed to the top glass substrate through vertical low glass resistivity Si vias. The CMOS chip is wire bonded on this top cap, and the connections between surface mount device (SMD) components and the chip is routed through 1um thick aluminium interconnects on the glass. [1]

The power-management IC utilizes the TSMC 0.18μm technology. The power management in the system is achieved by three sub circuits; MOS switches and an active diode for low drop out rectification, a shunt pass system to increase the harvesting efficiency, a trickle battery charger. In order to limit the overall power consumption, a supply independent bias is used to act as a current mirror to the comparators in the system [6]. The vibration on piezo generates a sinusoidal voltage at its terminals. The ac voltage is then rectified using ac-dc converters. A dc- dc converter is introducing to boost the rectified voltage; the rectified dc voltages are increased using step up converter. However, step up ratio is varied by varying the switching speed of the dc-dc converter. A feedback circuitry is introduced here to increase the efficiency of the system. The feedback circuitry includes a microcontroller. The microcontroller is used to monitor the feedback signal of output voltage. According to the feedback the switching pulses are generated from the microcontroller. The low power microcontroller has the operating range between 1.8v-5.5 v. So, the power generated from the piezo is sufficient to power the microcontroller. The step up ratio of the dc–dc converter is adjusted by varying the pulse frequency of the microcontroller. The feedback signal ensures efficient regulation of the output voltage and output filters are attached for further regulations.

The increased dc voltages are stored in capacitor. The output is sensed using the voltage sensor. The feedback signal is then fed to control station to stabilize the output voltage generated. This piezo energy harvester is a low power generator used in wireless sensor nodes. The integration is a small scale, so combination of more piezo energy harvester will create sufficient power for supplying the devices.

2. Related Works

In this section, we briefly review some recent works on piezo electric energy harvesting. In [2], R.Elfrink,et al., describes the characterization of piezo electric MEMS vibration energy harvesters based on aluminum nitride and making use of a wafer level vacuum packaging. He considers the package of

MEMS harvester to be essential for reliability as it prevents excessive mass displacements and protects the silicon beam from external influences. However the package introduces additional parasitic damping due to squeeze film effect. For this reason, it is relevant to implement a vacuum packaging approaching his work; he determined the contributions of different damping by considering the harvester as damped mass spring system .He was able to achieve higher power at lower acceleration and completely prevents parasitic fluid damping.

E.E.Aktakka,R. L. Peterson, and K.Najafi in [5] presents the micro fabrication and testing of a CMOS compatible high performance piezo electric inertial power generator. It offers fabrication flexibility and device performance over existing thin film deposition methods. They successfully demonstrated a new process for bulk PZT MEMS integration and PZT thinning. C.Peters,et al., in [7] introduces, a fully CMOS integrated active AC/DC converter for energy harvesting applications. The rectifier is realized in a standard 0.35 µm CMOS process without special process options. It works as a full wave rectifier and can be separated into two stages-one passive and one active. Measurements in combination with an electromagnetic harvester shows a significant increase in the achievable output voltage and power compared to a common, discrete Schottky diode rectifier. The measured efficiency of the rectifier is over 95%. Measurements show a negligible temperature influence on the output voltage between −40 °C and +125 °.In [4],D Kwon and G.A.Rincon Mora, deals with the problem of rectifying unpredictably small AC signals whose peak voltages fall below the rectified output level targeted requires low loss and no threshold rectifiers targeted. A bias flip rectifier circuit that can improve the power extraction capability from piezo electric harvesters over conventional full bridge rectifiers and voltage doublers is introduced by Y.K.Ramadass and A.P.Chandrakasan in [3].

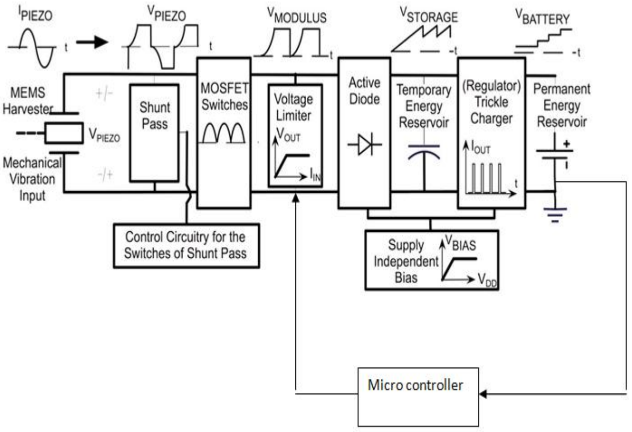

Figure 1: Overall view of the power management and the feedback circuitry

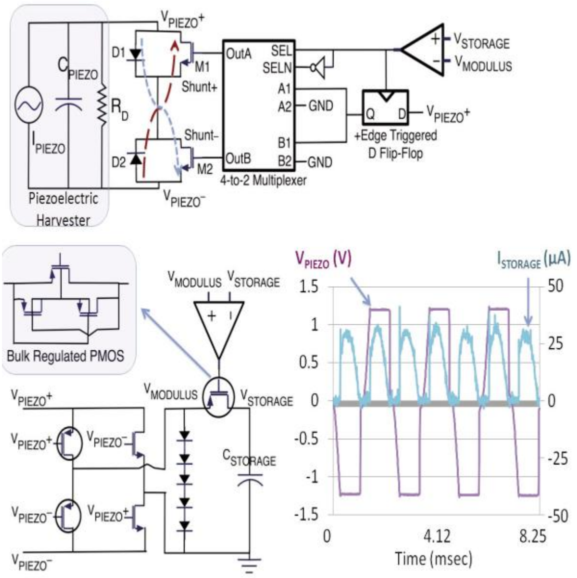

Figure 2: Active rectification is used to allow low drop-out and the shunt-pass to increase the power extraction from the harvester

3. Shunt Pass

A parallel shunt system is placed across the inputs from the piezoelectric harvester, in order to increase the harvesting efficiency. When the harvester's output current, I PIEZO, changes polarity, the harvester power starts to be wasted to discharge and recharge its self-capacitance (C PIEZO) in reverse polarization. In order to partially avoid this situation, the charge on C PIEZO is shunted to zero whenever I PIEZO crosses zero in either direction. This condition is verified by checking when V MODULUS drops down V STORAGE. Because of the Schottky diodes (D1, D2) used in the shunt path, no tuning for precise timing control is necessary to drive M1 and M2.Instead of that, one of these gates remains on during the whole recharging period of C PIEZO.

4. MOSFET Switches

The rectification of the piezoelectric output is achieved by incorporating two parts. First, four CMOS switches output the modulus of VPIEZO by converting the negative half cycles into positive ones (VMODULUS). Second, an active diode rectifies this voltage to store the charge on a temporary energy reservoir (VSTORAGE), which is also used as the power supply of the active circuitry (VDD). The PMOS gate used in the active diode is bulk-regulated in order to connect its n-well to the highest potential available for minimum leakage. This two-stage active rectification scheme minimizes the voltage drop on the path between VPIEZO and VSTORAGE, although there is a minimum input threshold requirement to drive the initial CMOS switches. Also, between these two stages, a voltage limiter implemented with a series of on-chip diodes, is used to protect the circuit against possible peaks from the harvester.

5. Trickle Charger

The energy stored in the temporary reservoir (C STORAGE) is dumped into a final reservoir by a trickle charger. The operation principle is, assume that the system starts with zero voltage in both reservoirs. With a vibration input, the MEMS harvester starts to supply power, and there is a start up period where CSTORAGE is charged passively. When there is enough vibration energy to charge this capacitor up to a minimum level (V0), the active circuit becomes operational, and a temporary dropout occurs in VSTORAGE. Now, CSTORAGE continues to be charged, but more efficiently with the active diode and shunt system fully operational. When VSTORAGE reaches a certain value (V2), the bulk regulated PMOS gates between the temporary and final energy reservoirs are on, and the scavenged energy is transferred to the battery through a current pulse, until VSTORAGE drops down to the level of either V1 or VBATTERY. Then, the gates are turned off, and CSTORAGE is charged again back to the level of V2. This charging scheme continues till VBATTERY is fully charged to V3 value. At this point, the gates turn off not to overcharge the battery above its rated voltage. In order to avoid the system to be locked at this stable operation point, VSTORAGE is put into scanning between V1 and V4 levels, so the system can check whether the battery needs to be recharged again. When the input vibration ends, VSTORAGE decays down to zero, and the back-flow of battery charge is prevented with a NAND gate powered by the battery. The power consumption of this NAND gate added with the leakage back to the C STORAGE results in a near-zero (<5pA) standby current draw. For testing flexibility, the battery's final charged voltage level can be adjusted by the option to use an external signal instead of internally generated V BIAS for the comparison signal V REF. Alternatively, a different set of resistors, which are used to obtain fractions of VSTORAGE, can be chosen to define the new voltage-regulation levels. The overall system is tested by a final energy reservoir at different vibration levels. The batteries used to store charge are lithium iron rechargeable battery or nickel metal hydride rechargeable battery.

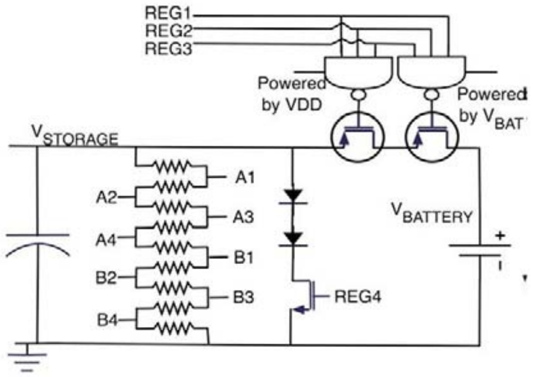

Figure 3.1

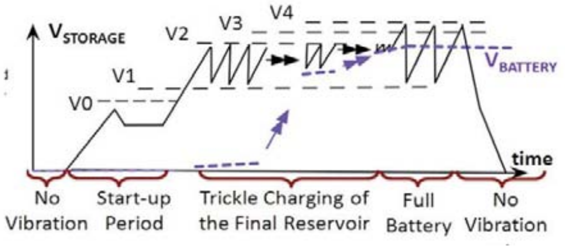

Figure 3.2

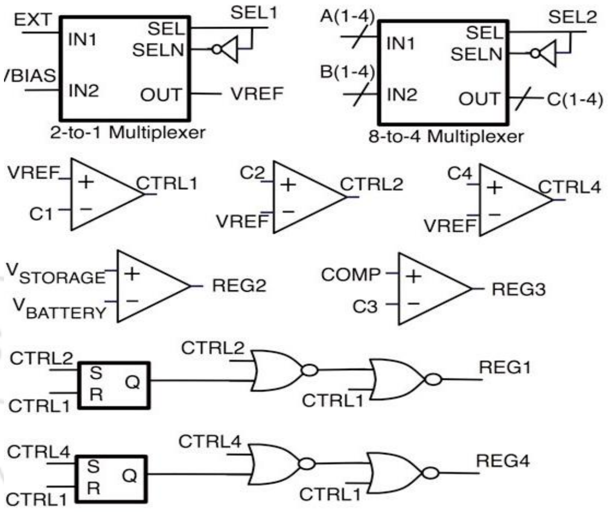

Figure 3.3

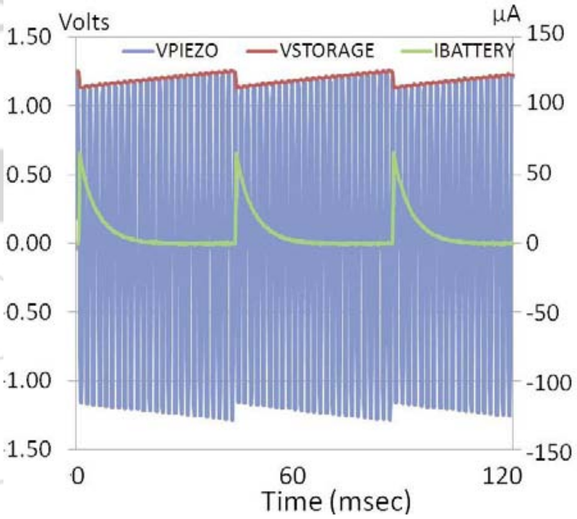

Figure 3.4

Fig.3.1, Fig.3.2, Fig.3.3, Fig.3.4 the trickle charger allows the system to charge a large energy reservoir, while it is self supplied from the temporary energy reservoir.

When the MEMS harvester is connected to an optimum resistive load without any power-management circuitry, it can supply 24.1µW and 63.9µW under 0.5g and 1.0g vibration levels, respectively. The Normalized Power Density (Power / Volume / Acceleration2), and bandwidth of the generator is compared with the current state-of-the-art micro-fabricated inertial harvesters. When the harvester is connected with its power management IC, it can charge a 20mF ultra-capacitor up to 1.31V in 20min under 0.5g vibration, and in ~8min under 1.0g vibration input.

6. Micro Controller

The Microcontroller is used to monitor the feedback signal of output voltage. According to the feedback the switching pulses are generated from the microcontroller. The low power microcontroller has the operating range between 1.8V-5.5 V. So, the power generated from the piezo is sufficient to power the microcontroller. The Step up ratio of the DC –DC Converter is adjusted by varying the pulse frequency of the microcontroller. The feedback signal ensures efficient regulation of the output voltage & output filters are attached for further regulations.

7. Conclusion

In this work, a self supplied piezo electric energy harvester is designed to generate more efficient output with the use of a power management circuitry and by incorporating a feedback monitoring. With the introduction of feedback, the output voltage is monitored fluctuations can be reduced with use of filters, the step up ratio is varied by varying the switching speed of the converter and thus the efficiency of the system is increased, the output of the system will be within the range even if the input is below the normal level. Output voltage is indicated using the display. The output voltage obtained will be within a range from 2.5V to 3 V. Here we are modeling a single system. By combining more and more stages, we can get a desirable output. The feasibility of miniaturizing the device, proving that the proposed structure is a good candidate to be used in powerless micro system applications operating at low frequency vibration mediums.

8. Acknowledgment

I would like to express profound gratitude to our Head of the Department, Prof. Thomas George, for his encouragement and for providing all facilities for my work.

References

[1] Ethem Erkan Aktakka,Rebecca .L.Petersron,Khalil Najafi,"A Self Supplied Inertial Piezoelectric Energy Harvester with Power-Management IC,MI"University of Michigan,Ann Arbor*ISSSC 2011*/Session 6.

[2] R. Elfrink, et al., "First Autonomous Wireless Sensor Node Powered by a Vacuum-Packaged Piezoelectric MEMS Energy Harvester," *IEEE International Electron Devices Meeting,* pp. 543-546, Dec. 2009.

[3] Y.K. Ramadass and A.P. Chandrakasan, "An Efficient Piezoelectric Energy Harvesting Interface Circuit Using a Bias-Flip Rectifier and Shared Inductor," *ISSCC Dig. Tech. Papers*, pp. 296-297, Feb. 2009.

[4] D. Kwon and G.A. Rincon-Mora, "A Single-Inductor AC-DC Piezoelectric Energy-Harvester/Battery-Charger IC Converting ±(0.35 to 1.2V) to (2.7 to 4.5V)," *ISSCC Dig. Tech. Papers,* pp. 494-496, Feb. 2010.

[5] E.E. Aktakka, R.L. Peterson, and K. Najafi, "A CMOS Compatible Piezoelectric Vibration Energy Scavenger Based on the Integration of Bulk PZT Films on Silicon," *IEEE International Electron Devices Meeting,* Dec. 2010.

[6] E. Dallago, et al., "Active Self Supplied AC-DC Converter for Piezoelectric Energy Scavenging Systems with Supply Independent Bias," *IEEE Int. Symp. Circuits and Systems,* pp. 1448-1451, May 2008.

[7] C. Peters, et al., "A CMOS Integrated Voltage and Power Efficient AC/DC Converter for Energy Harvesting Applications," *Journal of Micromechanics and Micro engineering*, vol. 18, no. 10, pp. 104005+, Sept. 2008.

Author Profile

Elsa Sneha Thomas working as Assistant Professor in Department of Applied Electronics and Instrumentation, Mount Zion College of Engineering, Kadammanitta.

Mariam Shema Thomas, received the B-Tech degree in Electronics and Communication and M-Tech degree in Communication Engineering from M.G University, at Sree Budha College of Engineering in 2013 & 2016 respectively.