National Institute of Technology Rourkela

Defence Seminar

Seminar Title	: Performance Improvement of Piezoelectric Energy Harvester and Its Application in Self-powered Sensor System
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Abstract

: Vibration-based energy harvesters, including sensors, have been widely deployed in condition monitoring of industrial machinery to automobile devices due to the advancement of wireless sensor networks to enhance the service life of equipment, which involves multiple sensor integration and a completely autonomous process. One of the aspects in designing such a complete system for different applications using communication modules, sensors, data acquisition, and the processor is power supply requirement.Conventional battery-powered systems require regular maintenance, have limited life cycles, and contain hazardous chemical components. One promising solution to overcome these issues is to use auxiliary or renewable energy sources. This leads to the development of energy harvesting techniques, which can utilize different sources of energy available near the sensor nodes, such as solar energy, vibration energy, and wind energy. Vibration energy is mostly wasted and a ubiquitous source of energy.

This thesis aims to design a vibration-based piezoelectric energy harvester with high quality factor in terms of energy harvesting capability and develop a self-powered system using improved piezoelectric energy harvester with efficient power conditioning circuits, to power up the sensors and sensor interfacing circuits. Firstly, a macro-scale piezo harvester incorporating a through hole is analytically verified, followed by simulation and experimental demonstration. With the proposed geometrical modification to the harvester, the resonant frequency is reduced, and power is increased significantly thereby, the harvester performance is enhanced compared to the conventional harvester under experimental environmental conditions. Secondly, the MEMS piezoelectric energy harvester is designed using an optimized hole length to cantilever length ratio using the rectangular hole and is fabricated in the PiezoMUMPs process. With the application of 1 g acceleration, the optimized hole harvester configuration produces power of 625 nW with a normalized power density of 24.1 W/mm3/g2. The lay-out of MEMS device using IISc PiezoMEMS process has also been carried out and the device is under fabrication process. The through-hole effect is verified in micro-scale, and the hole's shape and the harvester's structural modification is also carried out. Due to the low volume of MEMS devices, the output power is significantly lower, and it can drive low-power sensors when embedded with low power management ASICs. However, it can be utilized to charge rechargeable batteries or super-capacitors. Next, a self-generating meander based MEMS piezoelectric accelerometer using PiezoMUMPs process is designed to overcome the limitations of other type of accelerometers, such as their reliance on external power supplies. The mathematical analysis along with simulation is carried out to validate and finally, the device is fabricated. The proposed meander architecture utilizes low volume and exhibits improved dynamic characteristics in terms of higher voltage sensitivity, lower resonant frequencies and better structural stability with respect to reported literature. Further, a self-powered accelerometer system with low power regulator based circuit topology using the SSHI technique is proposed, where a circular hole is made on a commercial macro-scale piezoelectric energy harvester and is experimentally validated. The effect of through-hole on charging time, harvested energy, frequency of operation and average charging power has thoroughly been analyzed. The open circuit voltage and average charging power are increased by 25 % and 89.40 %, respectively, for circular hole-based harvester compared to conventional harvester configuration. The accelerometer is driven continuously for 8 minutes and 25 seconds with the proposed self-powered topology. The complete fabricated PCB prototype is tested on a commercial vehicle to validate the self-powered accelerometer system. Finally, a self-powered tire pressure monitoring system is proposed, where a novel switching circuit is integrated with a self-powered circuit topology and piezoelectric energy harvester. The implementation of the piezoelectric harvester with rotational motion is characterized by its frequency of operation and harvesting capability is explored. The proposed method works more efficiently and monitors the tire pressure at a fixed interval, indicating red or green LED status according to pressure levels. The complete system is assembled on a customized fabricated PCB and is tested on a commercial vehicle to validate the proposed methodology.