FABRICATION OF ELECTRICAL POWER GENERATION FROM VIBRATION

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Abstract - A system is proposed to convert ambient mechanical vibration into electrical energy for use in powering autonomous low power electronic systems. The energy is transduced through the use of a variable capacitor. Using micro electromechanical systems (MEMS) technology, such a device has been designed for the system. A low-power controller IC has been fabricated in a 0.6- m CMOS process and has been tested and measured for losses. Based on the tests, the system is expected to produce 8 W of usable power. In addition to the fabricated programmable controller, an ultra low-power delay locked loop (DLL)-based system capable of autonomously achieving a steady-state lock to the vibration frequency is described.

Key Words: Delay-locked-loop, low-power design, low-power dissipation, mixed signal, performance tradeoffs

1.INTRODUCTION

The "law of conservation of energy" states that energy cannot be created nor be destroyed. Under the consideration of this law the technological giants have discovered numerous sources to extract energy from them and use it as a source of power for conventional use. The sound or noise in other terms is present all around us. So why not use it to satisfy our needs of energy. In our basic applications we see sound be converted in the electrical signals to travel over the media for communication purposes. For example the sound energy is converted into electrical signals using diaphragm present in the microphone and these signals then reach to the speakers and then converted back to sound. The electrical current generated by a microphone is very small and referred to as MIC-level; this signal is typically measured in millivolts. Application of sound energy as the source of electricity can be much beneficial for the human existence as compared to other sources. This is because the sound is present in the environment as a noise which forms an essential part of the environmental pollution. The concentration of noise to use it for power generation can lead to discovery of another hidden source of energy which can act as a boon to non-renewable sources such as coal, crude oil etc. Sound basically is mechanical wave that is an oscillation of pressure transmitted through some medium (like air or water), composed of frequencies which are within the range of hearing. Thus, considering sound as the wave we can imagine it as the flow of energy from one point to another with the help of a medium as air.

The basic idea is that sound is mechanical wave. When sound travels through any medium then it disturbs the particles of that particular medium and these disturbances caused by the sound can be used to produce electricity

2.Mechanism for Piezoelectricity

Many materials, both natural and synthetic, exhibit piezoelectricity. Crystals which acquire a charge when compressed, twisted or distorted are said to be piezoelectric. This provides a convenient transducer effect between electrical and mechanical oscillations. The generation of an electric charge in certain non conducting materials, such as quartz crystals and ceramics, when they are subjected to mechanical stress (such as pressure or vibration), or the generation of vibrations in such materials when they are subjected to an electric field. Piezoelectric materials exposed to a fairly constant electric field tend to vibrate at a precise frequency with very little variation. The nature of the piezoelectric effect is closely related to the occurrence of electric dipole moments in solids. Of decisive importance for the piezoelectric effect is the change of polarization P when applying a mechanical stress. This might either be caused by a re-configuration of the dipole-inducing surrounding or by re-orientation of molecular dipole moments under the influence of the external stress. Piezoelectricity may then manifest in a variation of the polarization strength, its direction or both, withthe details depending on (i) the orientation of P within the crystal, (ii) crystal symmetry and (iii) the applied mechanical stress. The change in P appears as a variation of surface charge density upon the crystal faces, i.e. as a variation of the electrical field extending between the faces caused by a change in dipole density in the bulk. For example, a 1 cm3 cube of quartz with 2 kN (500 lbf) of correctly applied force can produce a voltage of 12500 V . There is a magnetic analog where ferromagnetic material respond mechanically to magnetic fields. This effect, called magnetostriction, is responsible for the familiar hum of transformers and other AC devices containing iron cores. Piezoelectric materials also show the opposite effect, called converse piezoelectric effect, where the application of an electrical field creates mechanical deformation in the crystal. Piezoelectric materials exhibit both a direct and a reverse piezoelectric effect. Fig. 1 indicates conversion of vibration/ mechanical energy into electrical energy and vice versa. The direct effect produces an electrical charge when a mechanical vibration or shock is applied to the material, while the reverse effect creates a mechanical vibration or shock when electricity is applied. Any spatially separated charge will result in an electric field, and therefore an electric potential. In a piezoelectric device, mechanical stress, instead of an externally applied voltage, causesthe charge separation in the individual atoms of the material. Fig. 2 indicates generation of piezoelectricity For polar crystals, for which $P \neq 0$ holds without applying a mechanical load, the piezoelectric effect manifests itself by changing the magnitude or the direction of P or both. For the non-polar, but piezoelectric crystals, on the other hand, a polarization P different from zero is only elicited by applying a mechanical load. For them the stress can be imagined to transform the material from anon-polar crystal class (P =0) to a polar one , having $P \neq 0$. Fig. 3 shows mechanism of piezoelectric effect in quartz.

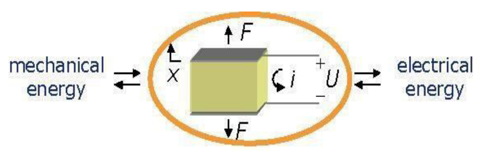

Fig. 1: Conversion of vibration/ mechanical energy into electrical energy and vice versa.

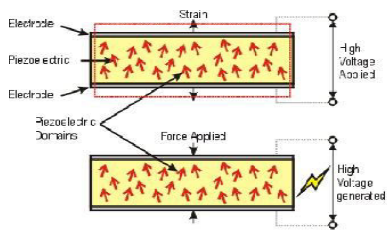

Fig. 2: Generation of piezoelectricity.

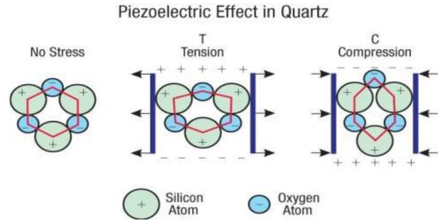

Fig. 3: Mechanism of piezoelectric effect in quartz

3.Methodology

Understanding the mechanism for energy harvesting from vibration using piezoelectric material is essential in determining a suitable design methodology, which is simplified in Figure. The mechanical energy from ambient source is produced by an electrodynamics shaker and this energy is converted to electrical energy via the piezoelectric materials and, finally, the electricity is stored . The piezoelectric ceramic plate is attached to the vibration source so that the device vibrates together with the source. The electricity is generated once the vibration source begins to vibrate. The piezoelectric ceramic plate converts vibration into electrical energy. The conversion mechanism in the active materials can generate electricity using a relative movement of the mechanical stress and the effect of deformation of the strain used in the mechanical system.

In this experiment, two types of setup for proto- type generators were used to convert the vibration into electrical energy. The first setup (the cantilever beam without a concentrated tip-mass) required a lower vibration frequency, but used a larger energy harvester. The second setup (with the concentrated tip-mass at the end of the cantilever beam) analysed the energy harvested for high frequency vibration using a medium-size energy harvester. Both setups operated at the same range of velocity, but produced different voltage outputs. A Puma vibration controller and analysis system captured the measurements. With scalable hardware and soft- ware, the vibration control and analysis system combine the simplicity of operation required for production screening with the power and versatility required for testing prototype generators . The Puma vibration control and analysis system soft- ware incorporates high quality data acquisition and signal generation hardware designed with the latest floating-point digital signal-processing technology with patented digital vibration control methods . Adaptive control permits Puma to control and adjust the speed in real time.

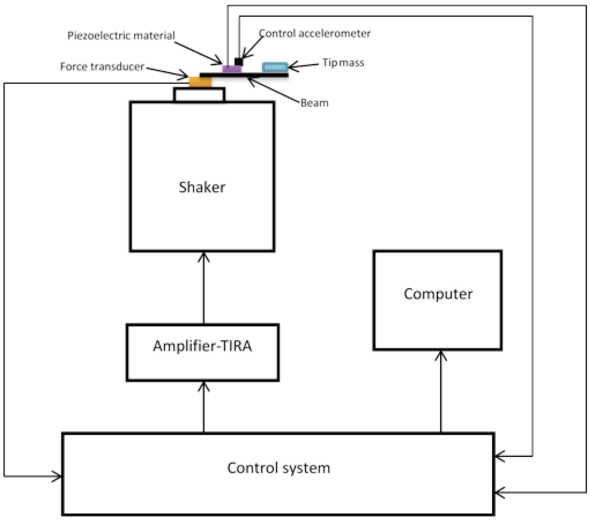

Figure : Schematic diagram for the experimental setup.

4.Application & Scope

Industrial and manufacturing units are the largest application market, for piezoelectric devices, followed by the automotive industry. There is also high demand from medical instruments as well as information in telecommunication. The global demand for piezoelectric devices was valued at the approximately US$14.8 billion in 2010. The largest material group for piezoelectric device is piezocrystal and piezopolymer due to its low weight and small size. Piezoelectric crystals are now used in buzzer, solar system also. This technique can solve the problem of electricity to road lighting system, and without the need of kilometers of electrical wire which runs along the sideof the road. It is more efficient operation techniques with cost effective device. Piezoelectric materials are capable of carrying high load and operating very high frequencies. It requires no maintenance as there are no moving parts. It acts as a capacitor and therefore requires very little power. However, protection of sensitive piezoelectric devices is required against harsh weather condition, and strong electric fields (200-500V/mm) can break down dipoles and depolarize a piezoelectric material.

CONCLUSIONS

A system has been presented to convert ambient mechanical vibration into electric energy. The conversion process has been modified through the use of C_{par} to provide for maximal energy transfer. Several controller IC optimizations for low power, in- cluding power switch sizing and C_{par} capacitance, have been performed. The controller has been verified to operate correctly and its losses have been measured. Based on predicted values of capacitance from the MEMS transducer, 8.6 microwatt of power is expected to be available for use by a load, resulting in a self-powered electronic system. An architecture for closing a loop around the system by means of energy feedback which offers more robust operation has been proposed. Under this new control scheme, it is estimated that the same system would pro-duce approximately 5.6 microwatt of useable power. The maximum energy producible can easily be increased by moving to processes designed for higher voltage operation.

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