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Piezoelectric Energy Harvesting

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Abstract

Low power wireless devices have been increasing in applications of industrial automation monitoring with the limitation of manual battery replacement. This can be overcome by a miniaturized device that can convert natural mechanical energies to power wireless devices. During the last decade piezoelectric cantilever energy harvesters have been increasingly investigated for this application. Energy harvesting technique is proposed as the best alternative. There exists variety of energy harvesting techniques but mechanical energy harvesting happens to be the most prominent. This technique utilizes piezoelectric components where deformations produced by different means are directly converted to electrical charge via piezoelectric effect. Subsequently the electrical energy can be regulated or stored for further use.

1. Introduction

Energy harvesting is the process by which energy is derived from external sources and utilized to drive the machines directly, or the energy is captured and stored for future use. Some traditional energy harvesting schemes are solar farms, wind farms, tidal energy utilizing farms, geothermal energy farms and many more. With the advent of technology, utilization of these sources has increased by leaps and bounds.

Piezoelectric Energy Harvesting is a new and innovative step in the direction of energy harvesting. Not many researchers have been carried out till now in this field, hence it is a challenging job to extract energy from piezoelectricity. [1] [2] Through this research paper, we will describe the basic working of a piezoelectric crystal. Then later in the paper, we have proposed the idea of combining energy from a number of piezoelectric crystals to obtain higher voltages. Certain ways of implanting the crystals at different places have also been sited in the paper. Piezoelectric crystals can be utilized to obtain voltages of very small values and hence can drive low voltage devices. [3][4] Hence, Piezoelectric Energy Harvesting comes under the category of Micro scale energy harvesting scheme.

1.1 Need of Energy Harvesting

Advanced technical developments have increased the efficiency of devices in capturing trace amounts of energy from the environment and transforming them into electrical energy. In addition, advancements in microprocessor technology have increased power efficiency, effectively reducing power consumption requirements. [5] In combination, these developments have sparked interest in the engineering community to develop more and more applications that utilize energy harvesting for power.

1.2 Benefits of Energy Harvesting

Energy harvesting provides numerous benefits to the end user. Energy harvesting solutions can:

1. Reduce dependency on battery power. Harvested ambient energy may be sufficient to eliminate battery completely. The device can be powered only from by the harvester and rely on internal energy storage to smooth out variations in available ambient energy.
2. Reduce installation costs. Self-powered wireless sensors do require wires, conduits and are very easy to install.
3. Reduce maintenance costs. Energy harvesting allows for devices to function unattended and eliminates service visits to replace batteries.
4. Provide sensing and actuation capabilities in hard-to-access in hazardous environments on a continuous basis.
5. Provide long-term solutions. A reliable self-powered device will remain functional virtually as long as the ambient energy is available. Self-powered devices are perfectly suited for long-term applications looking at decades of monitoring.
6. Reduce environmental impact. Energy harvesting can eliminate the need for millions on batteries and energy costs of battery replacements.

2. Methodology

The piezoelectric effect is a special material property that exists in many single crystalline materials. Examples of such crystalline structures are Quartz, Rochelle salt, Topaz, Tourmaline, Cane sugar, Berlinite ($AlPO_4$), Bone, Tendon, Silk, Enamel, Dentin, Barium Titanate ($BaTiO_3$), Lead Titanate ($PbTiO_3$), Potassium Niobate ($KNbO_3$), Lithium Niobate ($LiNbO_3$) etc. There are two types of piezoelectric effect, direct piezoelectric effect and inverse piezoelectric effect.

The direct piezoelectric effect is derived from materials generating electric potential when mechanical stress is applied and the inverse piezoelectric effect implies materials deformation when an electric field is applied. The energy harvesting via Piezoelectricity uses direct piezoelectric effect. The phenomenon will be clear from the diagram shown in Fig.1

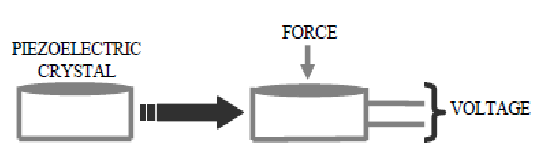

Fig: 1. Piezoelectric Effect

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3. Experimental Set-Up

Experimentation has been done on a Piezo-crystal and it is tested with a Light Emitting Diode (LED). The two terminals of the LED are connected with the two terminals of the crystal. Choice of Blue LED is being made for experimentation. Single stroke on the crystal blows blue LED with full intensity. Measured values of output voltage and current from the crystal come out to be 3.5 Volt and 100 milliamps. The only shortcoming of this using a single crystal and a LED was that both the voltage and current obtained exists instantaneously. To increase the range of voltage and current output, an assembly of 6 crystals in series and 6 such series has been put in parallel. When number of voltage sources are put in series, then the net voltage increases, while when a number of voltage sources are put in parallel, then the strength of signal, that is, current increases. This is the concept used behind the assembly. The output of parallel connection is fed to the current amplifier for signal strengthening and the output of series connection is fed to the amplifier for biasing purpose and also to the voltage amplifier. The assembly has been put under a doormat and the output obtained from amplifier has been very encouraging, which was around 6 V voltage and 1 ampere current. This magnitude of voltage and current can be certainly used to charge a battery. Fig. 2 shows the assembly used in our system.

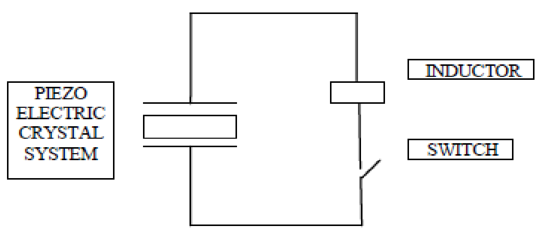

Fig: 2. Assembly Used

4. Conclusion & Scope of Further Work

Energy harvesting is a topic of substantial and increasing research attention, and motion driven devices represent a large fraction of this activity. Motion energy harvesting devices are now offered commercially by several companies, mainly for applications where machine vibration is the motion source, although body-powered applications. The paper demonstrates an arrangement for low power energy harvesting and storage device for powering small electronic gadgets. The energy absorbing ability of this arrangement is much better than battery based energy storage systems in energy harvesting. It should be noted that very little power is harvested outside of the resonance frequency and therefore the optimal frequency of the harvester has to be tuned according to the vibration frequency by some novel designs or adaptive structures. Most electronics have a minimum voltage threshold for utilization, limiting the effective utilization voltage of the super-capacitor although there is no limitation in the super-capacitor itself. So, better utilization of the stored energy can be done by using low voltage DC-DC converters.

Future work includes developing regenerative brakes for bicycle for urban use where frequent braking is required. So, whenever brakes are applied on a busy road the energy is recovered back in the super-capacitor bank instead of getting wasted in the brakes.

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