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A Review on Drive Energy Harvesting from Vibrations using poly-Vinylidene fluoride (PVDF) Piezoelectric Materials

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Abstract: The use of piezoelectric materials to transform mechanical energy into electrical energy is not a recent idea. In action, however, piezoelectric electrical generators remain limited to a very low power domain, typically within or below the mill watt range. This is mainly due to the mechanical properties of piezoelectric materials: they accept very high stresses but their strains are very small, making it difficult to use large quantities of material. Another argument concerns the high mechanical frequencies required for the efficient use of these materials: ambient mechanical vibrations usually remain within the range of 0.1–1 kHz, while piezoelectric materials that operate up to hundreds of kilohertz. A dramatic reduction in the consumption of integrated circuits linked to the development of mobile electronic devices has been achieved in recent years, enabling the use of ambient energy instead of batteries. The emphasis here is on the transformation of ambient mechanical vibrations into electrical energy. This paper compares the output of a vibration-powered electrical generator using PZT piezoelectric ceramics connected with two different electrical circuits. A new approach to piezoelectric power conversion based on nonlinear voltage processing is proposed and implemented using a different circuit. Theoretical predictions and experimental results show that the new technique can increase the power harvested by a factor of up to 4 compared to the standard technique. In particular, the problem of power optimization is examined in the case of broadband, random vibrations.

Keywords: Energy harvesting. Energy scavenging, Power optimization, piezoelectric materials, Vibrations, PZT

INTRODUCTION

The use of piezoelectric materials to transform mechanical energy into electrical energy is not a recent idea. Piezoelectric technology has been used for several years to create a spark when the crystal is squeezed, but lately the opposite effect is causing more interest. Vibration and movement can now produce power to drive wireless links and electronics. Decreased power consumption of silicon devices creates more opportunities to replace batteries and provide' free' electricity. The use of piezoelectric materials to transform mechanical energy into electrical energy is not a recent idea. In action, however, piezoelectric electrical generators remain limited to a very low power domain, typically within or below the mill watt range. This is mainly due to the mechanical properties of piezoelectric materials: they accept very high stresses but their strains are very small, making it difficult to use large quantities of material [1].

Another argument concerns the high mechanical frequencies required for the efficient use of these materials: ambient mechanical vibrations usually remain within the range of 0.1–1 kHz, while piezoelectric materials that operate up to hundreds of kilohertz.For example, the Green Micro gym in Portland, Oregon, uses technology to collect the energy generated by runners on special exercise machines. The electricity generated helps the gym reduce energy bills by 60 per cent. In the same way, Club Watt in Rotterdam uses piezoelectric technology under the dance floor in Holland. When people dance, the vibrations give the building strength.The demand for energy harvesting for devices will quadruple over the next four years, according to market research. The deployment of energy harvesting will grow at a compound annual growth rate (CAGR) of nearly 38 % over the next few years, resulting in annual shipments of energy harvesting enabled devices of 235.4 million units by 2015 from a base of 53 million this year, with a tremendous diversity of consumer and industrial applications. This shipment would translate into a global annual revenue of $9.5 billion in 2015 from energy harvesting [1]enabled devices, estimated by the Clean

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Technology Market Intelligence Company. Devices in settings with thousands of sensors working diligently to provide information on temperature, humidity, protection, machine health, structural health, and many other types of data are becoming increasingly common. Battery replacement is a major technical and cost issue in many of these applications. Viable energy harvesting technology exists today and developers are becoming increasingly aware of how to apply it to ever more innovative goods.

At the moment, the energy harvesting industry is going through a galvanizing phase in which manufacturers, device integrators and end users all realize that a common approach in terms of standardization and initial market push would lead to an effective consumer adoption curve. The research analysis shows that the energy harvesting consumer market will account for approximately 42% of all unit shipments by 2015. Main applications in this field include mobile phones, laptop computers, remote controls, portable lighting and the growing demand for kinetic energy driven wristwatches. Nonetheless, industrial applications will represent the majority of the energy harvesting industry, the desire for energy harvesting is pushing further research into new piezo-electric structures, devices and applications[2]. The three are tightly coupled with a new material that opens up new technologies that need new system designs.One of the key aspects of vibrational energy harvesting is how it can be closely incorporated into the equipment. The knee brace has built-in piezoelectric materials to produce enough current to drive prosthetic limbs, or even a pair of night vision goggles used by soldiers. Just a minute's walk produces enough energy to power a mobile phone for 30 minutes[3][4].

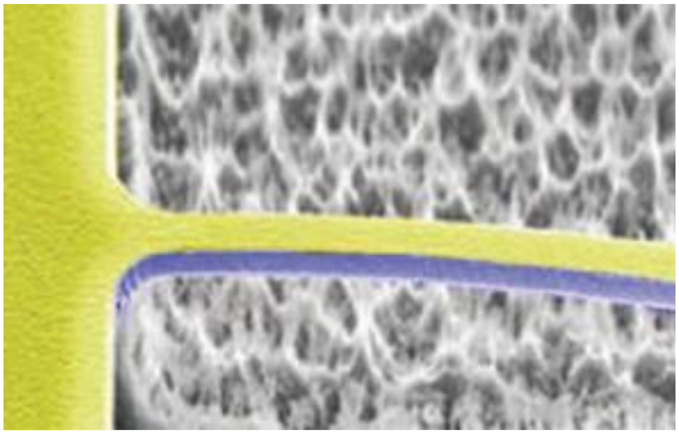

Figure 1: A PMN-PT piezoelectric cantilever

DRIVE ENERGY HARVESTING FROM VIBRATIONS

A new piezoelectric material called polyvinylidene fluoride (PVDF) was used to create a plastic micro belt that vibrates and generates power. This can be made small enough to be able to use breathing as a means of generating power for machines. Researchers at the University of Wisconsin-Madison have designed low-voltage, near-Nano-scale electromechanical devices that could lead to improvements in the energy harvesting, sensing and actuation of Nano positioning devices. An advanced piezoelectric material using lead magnesium niobate-leaded titanate (PMN-PT) exhibits a "giant" piezoelectric response that can produce much greater mechanical displacement with the same amount of electrical field as typical piezoelectric materials. These can also serve as actuators and sensors. For example, they use electricity to deliver an ultrasound wave that penetrates deeply into the body and returns data capable of displaying a high-quality 3D image. At present, the major limitation of these advanced materials is their incorporation into very small-scale devices. The PMN-PT single-crystal piezoelectric material. "The properties of a single crystal on silicon are as strong as a bulk single crystal." Devices made from this giant piezoelectric "hyperactive MEMS" material have the ability to give researchers a high level of active control.

Piezoelectric materials have been developed on a flexible rubber substrate suitable for implantable or wearable energy harvesting systems. Typically, the crystallization of these materials requires high temperatures to achieve the best efficiency, rendering them incompatible with temperature-sensitive plastics and rubbers. This research overcomes the limitations by applying a scalable and parallel process for the transfer of crystalline piezoelectric' nanothick' ribbon of zirconate titanate lead from host substrates to wider flexible rubbers. This opens up a number of new ways of including power generation in devices that vibrate and move and can even be inserted into the body.

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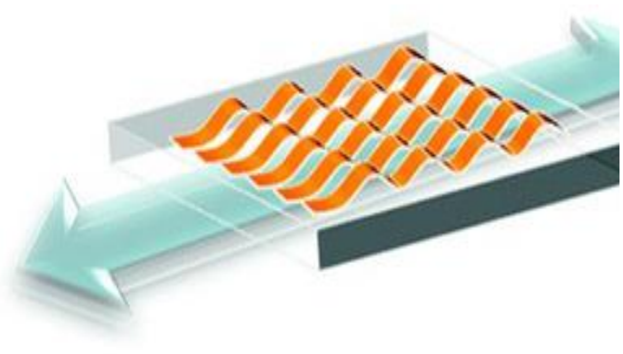

Figure 2: Piezoelectric material deposited on a flexible substrate for energy harvesting.

The emphasis is also on boosting the power generated by these flexible piezoelectric materials. A new approach that greatly enhances piezoelectric power generation by adding a p-type polymer layer on a piezoelectric semiconductor thin film. The resulting piezoelectric power generator demonstrated an 18-fold increase in the output voltage and tripled the current compared to the traditional material, with an overall output power density of over 0.88 W / cm3 and an average power conversion [5]efficiency of up to 18%. This high power generation allowed red, green, and blue light emitting diodes to turn on after only ten bends of the generator.

Three forms of piezoelectric devices have been tested for their power generation capability: the widely used monolithic piezoceramic lead-zirconate-titanate (PZT) material, the biomorphic Quick Pack (QP) actuator, and the NASA-developed Macro Fibre Composite (MFC). The MFC actuator is assembled using piezofibers surrounded by an epoxy matrix and protected by a Kapton membrane. It makes it extremely versatile, as well as resilient in terms of damage and environmental conditions and more effective in the conversion of electricity. The Fast Pack actuator is a biomorphic piezoelectric[6] device that uses monolithic piezoceramic material embedded in an epoxy matrix. This is far less versatile than the MFC, but the epoxy layer makes it more robust than the raw monolithic material. Both the Fast Pack and the PZT monolithic piezoceramic material is capable of recharging the batteries. Nevertheless, PZT is more efficient in the random vibration condition that is normally experienced when dealing with ambient vibration[7]. The Macro-Fibber composite was not well suited for power harvesting, as it was designed to be a high voltage actuator with very low current output. Modern piezoelectric materials for the construction of an energy harvesting cantilever device. The V22BL is a hermetically sealed, analog piezoelectric crystal for energy harvesting that operates with vibrations as low as 26 Hz to 110 Hz. The trick to extracting vibration energy[8] from any piezoelectric material is to fully understand the vibration environment, and the best way to do this is to calculate vibration using an accelerometer. The optimum resonance point is different for different materials, and it is important to determine the system requirements for choosing the appropriate technology.

Once the data has been collected, the Fast Fourier Transform extracts the frequency information. This is often directly associated with equipment, such as a 120 Hz AC engine or a 60 Hz appliance, but most applications may require some form of vibration characterization. It provides a portable vibration analysis system that can be conveniently used in many different vibration environments to collect data in hard-to-reach areas. The built-in timer allows several different types of vibration to be recorded and a simple USB interface enables the user to easily identify each vibration. This can also help make sure that the crystal is not exposed to excessive vibrations that can damage the device and shorten its useful life. Nevertheless, the power output of the piezoelectric crystal must also be interfaced with the device electronics. This is often done by a DC-DC converter that supplies a rechargeable battery. The design of this device is important as the crystal production is low to start with, as any losses and inefficiencies[9] will significantly reduce the performance of the system. Linear Technology has incorporated a low-loss, full-wave bridge rectifier with a high-efficiency buck converter designed for high-energy impedance. The LTC3588 is an ultra-low quiet current, under voltage lockout (UVLO) mode with an increasing threshold of 16 V to provide efficient energy extraction from piezoelectric transducers with high open circuit voltages.

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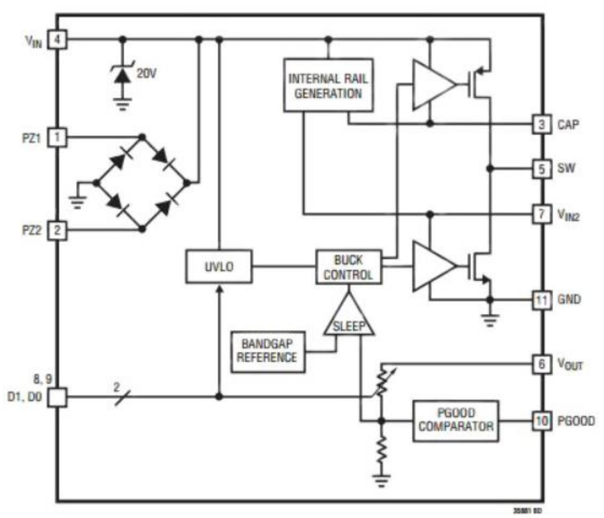

Figure 3: The Linear Technology LTC3588 for interfacing a piezoelectric vibrational transducer to storage.

Piezoelectric technologies are also used in larger systems, and even generate power from a speed bump. New Energy Technologies is still improving its commercialization technologies and has demonstrated its Motion Power devices. Piezoelectric pads mounted under the road surface to provide power for roadside displays and wireless communication links have been made in some countries. The pads are mounted at a depth of 5 cm below the surface when the road is repaired or resurfaced and the studies have shown that they do not affect the life of the pavement or decrease the performance of the vehicles. The more traffic passes and the heavier the traffic, the greater the power produced.The system was tested in 2009 under a 10 m asphalt strip to generate about 2000 Wh of electricity. The company says that 1 km of a single-lane road would generate about 200 KWh, while a four-lane highway would produce about 1 MWh of electricity, enough to power 2,500 households.Such electromagnetic energy harvesters use an oscillating magnet, which moves through a fixed coil, generating a varying amount of magnetic flux, producing a voltage. In order to maximize the power output, the harvester is mechanically tuned to the optimized resonant frequency present within the specification.

Vibrational energy harvesting is an increasingly important technique for moving equipment from trains to vehicles, as well as personal devices. This will make a significant contribution to the explosive growth of energy harvesting over the next four years, and researchers are looking at new technologies to open up new applications.Developments in piezoelectric materials offer new ways to build the materials themselves, and their incorporation into silicon systems offers even more opportunities for power supply where appropriate. As the power consumption of processors and wireless transceivers falls with the latest silicon technology, so the energy produced by vibrational energy[10] harvesters can be used more effectively. Coupled with rechargeable batteries and low-power DC-DC converters, new piezoelectric materials can provide the power needed for portable and industrial applications with higher power outputs and increased efficiency. Vibrational technology is also opening up new applications in transport, in particular road systems that provide signal and lighting control, reduce the costs of building and maintaining telematics networks with a significantly long, maintenance-free design life.

CONCLUSIONS

In this paper, the study of environmentally friendly vibration energy harvesting of the conversion of vibration energy into electrical energy has become a major field of research. This demonstrated the patterns of vibration energy harvesting from ambient vibrations using electrostatic, piezoelectric and electromagnetic. The processing circuits have been studied. It may not apply to a piezoelectric vibration energy harvester designed to operate in unpredictable circumstances. Compared to energy stored in a common storage facility, there is more improvement in sustainability, maintenance-free and environmentally friendly terms. Efficient means of converting environmental noise into electrical energy. Because vibration energy harvesting is a safe, abundant, sustainable energy source, it is of great interest to research the process of energy harvesting. Potential issues to be tackled in the field of research include increasing conversion efficiency and energy harvesting and storage circuits. Apparently, one of the ways to recharge these batteries is to use electricity from the surroundings. The advantages of energy harvesting are not the replacement of batteries, but rather the alleviation of some of their drawbacks, particularly in relation to maintenance issues. This is a new alternative, sustainability and renewable energy with many potential applications.

REFERENCES

[1] A. Harb, “Energy harvesting: State-of-the-art,” *Renew. Energy*, 2011.

[2] C. R. McInnes, D. G. Gorman, and M. P. Cartmell, "Enhanced vibrational energy harvesting using nonlinear stochastic resonance," *J. Sound Vib.*, 2008.

[3] S. M.Taware and S. P. Deshmukh, "A Review of Energy Harvesting From Piezoelectric Materials," *J. Mech. Civ. Eng.*, 2013.

[4] E. Blokhina, A. El Aroudi, E. Alarcon, and D. Galayko, "Introduction to Vibration Energy Harvesting," in *Nonlinearity in Energy Harvesting Systems*, 2016.

[5] S. Boisseau, G. Despesse, and B. Ahmed, "Electrostatic Conversion for Vibration Energy Harvesting," in *Small-Scale Energy Harvesting*, 2012.

[6] I. Dakua and N. Afzulpurkar, "Piezoelectric energy generation and harvesting at the nano-scale: Materials and devices," *Nanomaterials and Nanotechnology*. 2013.

[7] L. Zuo and X. Tang, "Large-scale vibration energy harvesting," in *Journal of Intelligent Material Systems and Structures*, 2013.

[8] D. A. Wang and H. H. Ko, "Piezoelectric energy harvesting from flow-induced vibration," *J. Micromechanics Microengineering*, 2010.

[9] X. Zhang, Z. Zhang, H. Pan, W. Salman, Y. Yuan, and Y. Liu, "A portable high-efficiency electromagnetic energy harvesting system using supercapacitors for renewable energy applications in railroads," *Energy Convers. Manag.*, 2016.

[10] R. L. Harne and K. W. Wang, "A review of the recent research on vibration energy harvesting via bistable systems," *Smart Materials and Structures*. 2013.

[11] Gagandeep Singh Narula, Dr. Vishal Jain, Dr. S. V. A. V. Prasad, "Use of Ontology to Secure the Cloud: A Case Study", International Journal of Innovative Research and Advanced Studies (IJIRAS), Vol. 3 No. 8, July 2016, page no. 148 to 151 having ISSN No. 2394-4404.

[12] Gagandeep Singh Narula, Ritika Wason, Vishal Jain and Anupam Baliyan, "Ontology Mapping and Merging Aspects in Semantic Web", International Robotics & Automation Journal, having ISSN No. 2574-8092, Vol. 4, No. 1, January, 2018, page no. 01 to 05 .

[13] Gagandeep Singh Narula, Usha Yadav, Neelam Duhan and Vishal Jain, "Evolution of FOAF and SIOC in Semantic Web: A Survey", CSI-2015; 50th Golden Jubilee Annual Convention on "Digital Life", held on 02nd to 05th December, 2015 at New Delhi, published by the Springer under Big Data Analytics, Advances in Intelligent Systems and Computing having ISBN 978-981-10-6619-1 page no. 253 to 263.

[14] S. Balamurugan, K. Amarnath, J.Saravanan and S. Sangeeth Kumar, "Scheduling IoT on to the Cloud : A New Algorithm", European Journal of Applied Sciences 9 (5): 249-257, 2017.

[15] S.Balamurugan et.al., "Smart Healthcare: A New Paradigm", European Journal of Applied Sciences 9 (4), 212-218, 2017

[16] S.Balamurugan et.al., The IoT and the Next Revolutions Automating the World. IGI Global, 2019