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Energy Harvesting Using Piezoelectric Sensors

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***Abstract* – Technology in the present era is upgrading to bring up new and more efficient methods to produce and utilize energy without conventional resources. This project uses the concept of piezoelectricity to generate energy which is then converted into electricity. This electricity will then be used to produce the power required to charge Li ion batteries of mobile phones as well as power low voltage lighting systems such as a torch or a mini flashlight. In this project, piezoelectricity will be generated by the pressure exerted on the shoes of a person during physical activities of walking and/or running. Here, the piezoelectric sensors are placed at the peak pressure points (i.e., the forefoot and the hind foot) in the insole of the footwear, thus generating power every time a person walks or runs.**

***Keywords:* Boost converter, Energy harvesting, LED, Mobile Phones, Piezoelectricity, Smart Shoes.**

I. Introduction

Today's world is an era of harvesting renewable energy in an effort to curb the use of non-renewable energy so as to not deplete these valuable resources and preserve them for future generations [1]. Conventional methods of extracting energy for upcoming technology include the use of batteries, non-renewable and exhaustive resources. These conventional methods pose a potential threat to the environment at the time of dumping batteries because they do have a limited lifetime, as well as a considerable degree of pollution the environment [1]. However, humans are not oblivious to this problem and have an insight on how, over the years, this problem would become a major environmental issue. Therefore, various ideas have been brought forth to efficiently manage this problem. One such way is by using wasted energy instead of harvesting on new resources [2]. One method to implement this idea is the use of piezoelectricity.

A major portion of our muscular energy released for locomotive purposes and also movement of vehicles on roads, railways, runways, etc., bear mechanical strain energy. Wastage of this energy occurs during our movement from one place to another. However, this mechanical energy can be implemented in piezoelectric plates. Thus, the energy of the person or vehicle released during motion can be used to produce electricity thereby saving the energy wasted and also generating green power [3].

The class of materials used in piezoelectric plates is ferroelectric materials. These materials exhibit a property in which the molecular structure is aligned such that local charge separation occurs; thereby it creates electric dipoles that are displaced randomly. However, above the Curie temperature, there is an application of a strong electrical field. Due to this, the electric dipoles distribute themselves uniformly, relative to the electric field. This uniform distribution is maintained even after the material has cooled. This process of orienting the dipoles is called polling and after the material has cooled, the material is said to be poled. The material then displays the effect of piezoelectricity after the process of polling is completed. [3]

II. Design and Working of Device

Piezoelectric effect works on the fact that when a mechanical stress is applied to certain ferroelectric materials an electric charge accumulates in them in response, thereby conducting electricity. This effect is reversible due to the fact that an applied electrical field can always result in a mechanical strain. The mechanical strain applied to the piezoelectric material is converted into electrical pulse form with the help of piezoelectric transducers. These alternating electrical pulses, can be directly utilized or may be captured by a storage device for further utilization. Efforts have been put in this work to harvest energy from mechanical stress using the principle of piezoelectric energy conversion.

In this present era, mobile phones are an absolute necessity. As the need increases, so does the requirement for charging the mobile phones. This perpetuum use of phones requires charging systems for phones always at one's disposal. Lighting gadgets like torches can be used in cases of emergencies such as a power cut in public places. At the same time, the idea of physical activities being executed to charge batteries for mobile phones and emergency torches can make this an e-health device, thereby encouraging users to conduct healthy physical exercise.

Principle:

The basic principle involved in this project is the conversion of human mechanical power into electrical signals. The mechanical power comes from a human walk. After that this mechanical power in terms of vibrations is fed to the piezoelectric crystals that convert these vibrations into useful electric power. This output of the transducer is amplified, rectified and regulated to a value sufficient enough to charge a mobile phone battery and provide emergency light [4]. The input energy for this device is purely a mechanical energy that comes from human's motion and gets converted into the required signals via piezoelectric harvesting system. The charging time of the mobile phone and the intensity of torch light depend on the frequency and amplitude of vibration provided to the crystal. So, if the speed of human motion is increased the output of the device can be enhanced.

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Fig.1: Piezoelectric sensor

Block Diagram:

In this project, piezoelectric effect is implemented in shoes. Piezoelectric plates are placed in the soles of the shoes and by virtue of the pressure exerted on the forefoot and hind foot, electricity is produced. This electricity can be then used to power cellular phones as well as emergency flashlights that require low power [4] Fig.2 shows the block diagram of the device.

The piezoelectric crystals are used as the voltage source which generates alternating voltage and is followed by a rectifier to convert the alternating to direct voltage. Then the output from the rectifier is given to the rechargeable battery. The output terminals of the battery are connected to 7805 IC for giving the constant supply of 5V. This 5V supply is given to the different application purpose like lightning of high power LED and for charging mobile phones. For high power application 7805 IC is connected to boost converter as boost converter require constant voltage level. As the output we get 11 V of supply. Therefore, this is a suitable method to be used for the charging of mobile phones and gadgets such as flashlights in case of emergencies. [4]

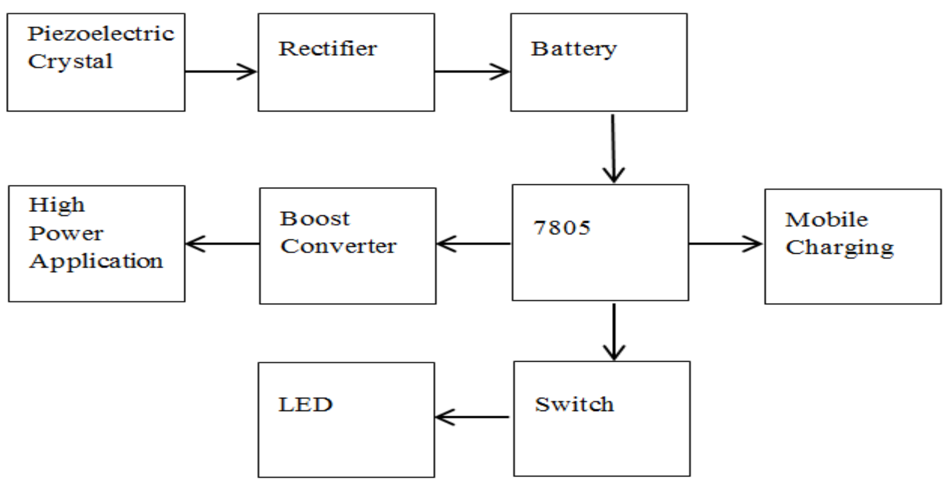

Fig.2: Proposed device block diagram.

Working:

In the existing device a large number of piezoelectric sensors are connected in series and parallel, and are mounted on the sole of the shoe [2]. The working of the device depends on the movement of the human. As a person walks, mechanical stresses are induced in his feet which are transmitted to the piezoelectric sensors which are embedded inside the shoe. This vibrational energy is then converted into electrical energy by the transducer [4]. The output is then fed to the harvesting circuit which consist of rectifier (DC conversion) and boost converter. The bridge rectifier converts the AC output into the required DC output. Fig. 3 shows the bridge rectifier circuit. Then the output from the rectifier is given to the rechargeable battery. The terminals of the battery are connected to 7805 IC for giving the constant supply of 5V. This 5V supply is given to the different application purpose like lightning of high power LED and for charging mobile phones. Further for high power applications 7805 IC is connected to boost converter. In normal walking condition for a 60 Kg man the piezoelectric sensor produces a voltage of 1.5V-2V.

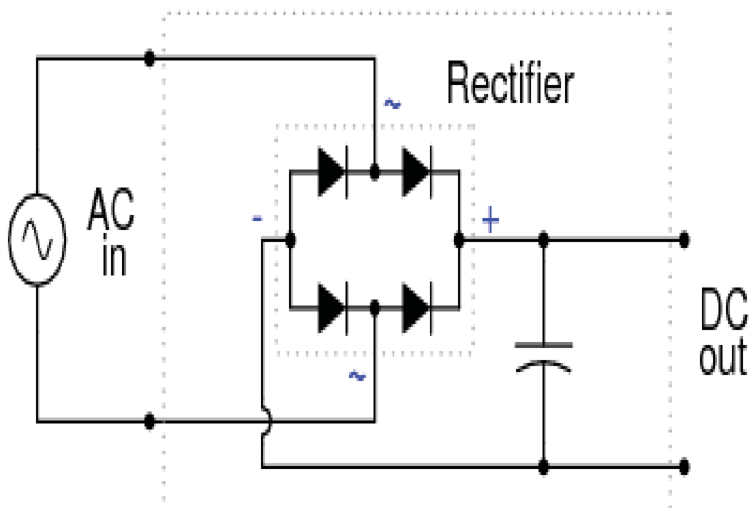

Fig.3: Rectifier Circuit.

III. Simulation Result

The simulation design of the device is done using the MATLAB Simulink Software. Here boost converter using MOSFET is used for the boosting of the output. Fig.4 shows the simulation circuit of the device. MOSFET is used for boosting the voltage from 5V, generated by the layers of piezoelectric sensor to 11V. Fig.5 shows the simulation circuit for boost converter. Fig.6 shows the graph of input voltage given to the piezoelectric energy harvesting circuit. The input voltage given is 5V. Fig.7 shows the graph of output voltage obtained from the rectifier circuit. Fig.8 shows the graph of input voltage given to the boost converter which is connected to IC 7805. Fig.9 shows the graph of output voltage obtained from the boost

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converter. The output of boost converter is 15V which is used for high power application. Fig.10 shows the graph of output voltage obtained from the piezoelectric energy harvesting system.

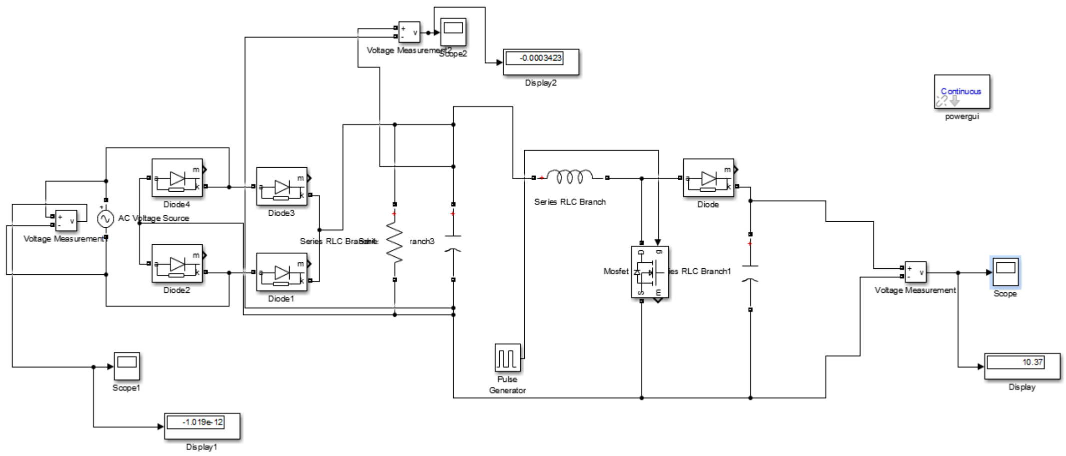

Fig.4: Piezoelectric Energy Harvesting Circuit

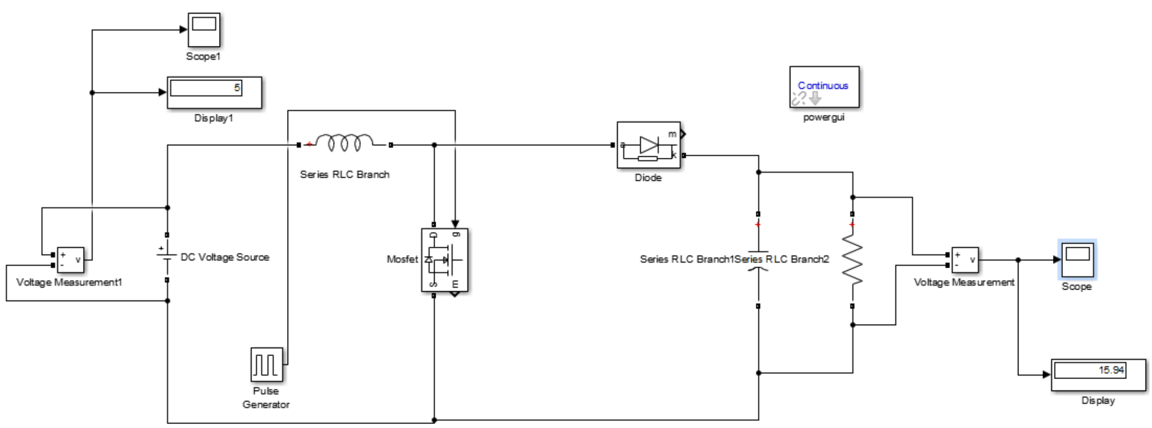

Fig.5: Boost Converter Circuit

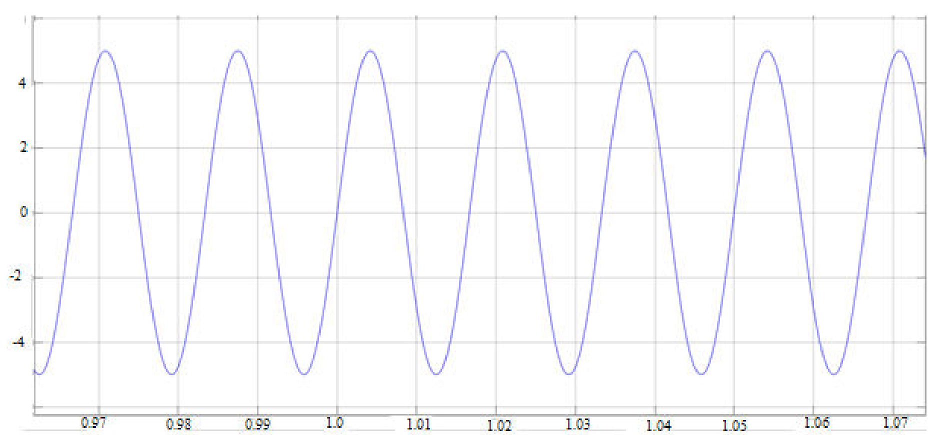

Fig.6: Input voltage to circuit.

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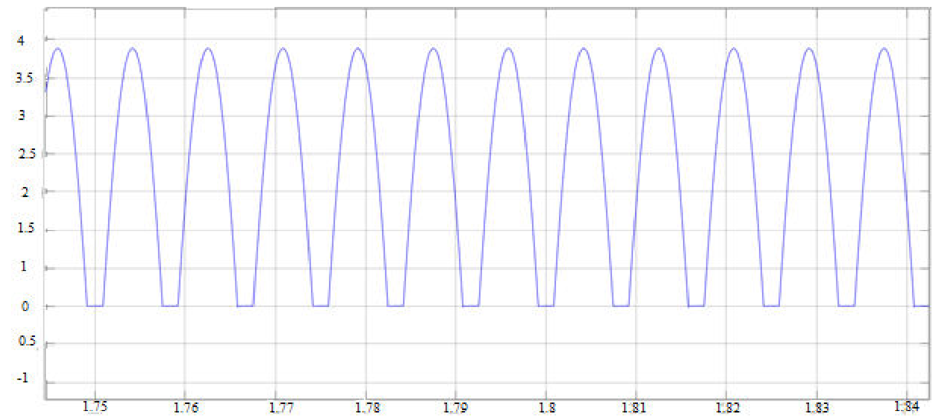

Fig.7: Output voltage from rectifier

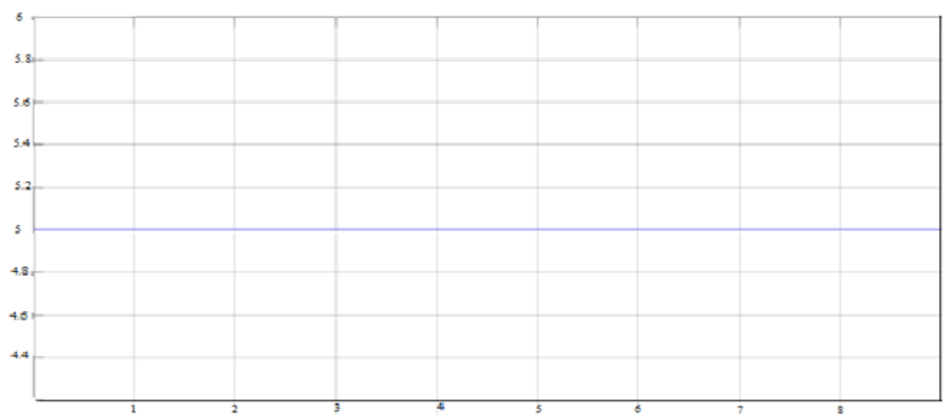

Fig.8: Input voltage for boost converter.

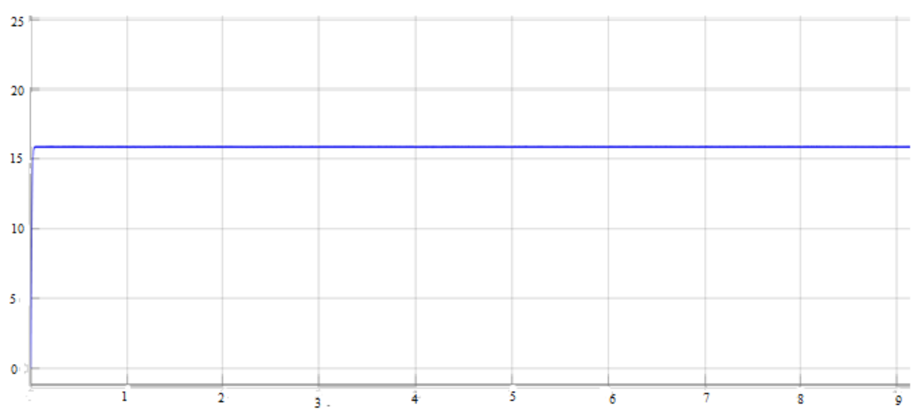

Fig.9: Output voltage from boost converter.

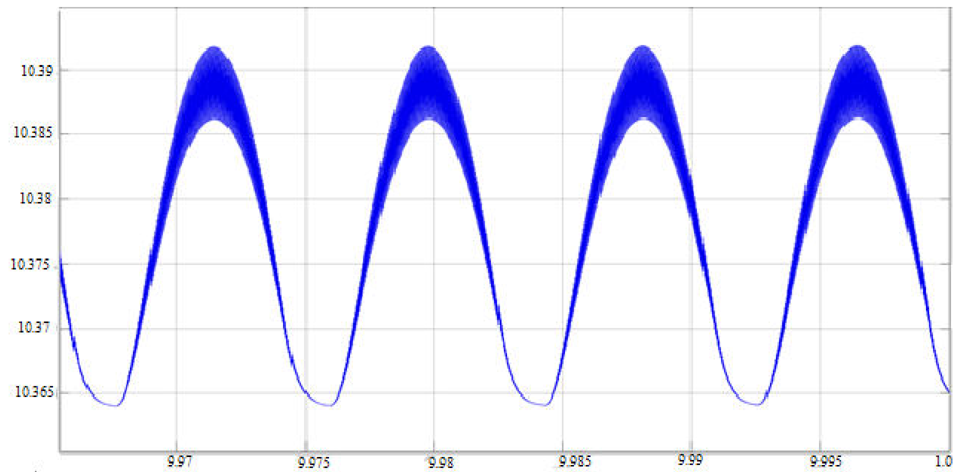

Fig.10: Overall output voltage from piezoelectric energy harvesting circuit.

IV. HARDWARE RESULT

In the hardware arrangement, piezoelectric sensors are connected in series and parallel combination in the sole of the shoe. The boost converter is used and it plays a vital role in boosting the voltage from 5V, generated by the layers of piezoelectric sensor to 12V. A rectifier circuit has been included for the conversion of AC to DC. The hardware circuit consist of an IC 7805 for providing the constant supply of 5V to boost converter. A battery is used to save the energy generated during the process and the saved energy can be used further to charge mobile phone and also to light emergency torch. Fig.11 shows the hardware setup of piezoelectric energy harvesting system. Fig.12 shows the mobile phone charging circuit. Fig.13 shows the emergency torch circuit. Mobile phone and an emergency torch is being charged by the energy which is stored in the battery.

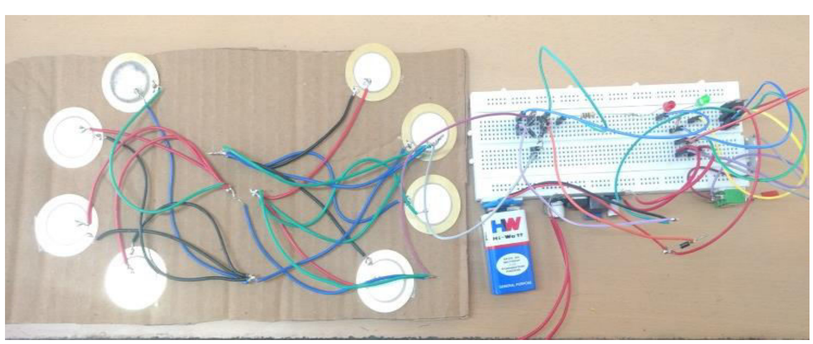

Fig.11: Hardware Setup of Piezoelectric Energy Harvesting System.

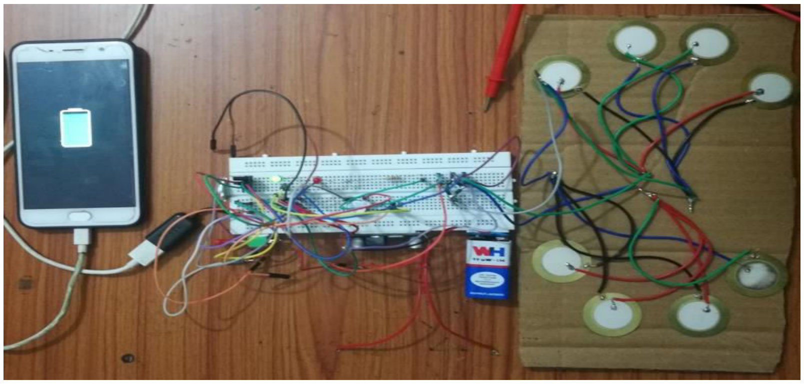

Fig.12: Mobile Phone Charging

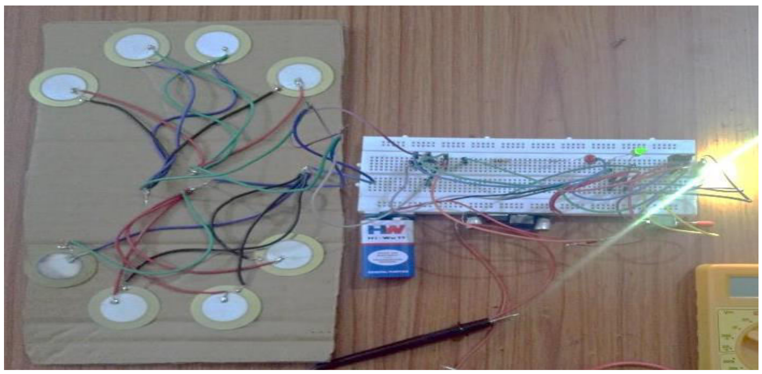

Fig.13: Emergency torch light circuit.

V. Conclusion and Future Scope

In this paper we have presented the dual working of a device which can charge a mobile phone as well as also light up the emergency torch. This type of technique can be used for many applications in areas where availability of power is less or totally absent and give power supply in real time. This device can be used anywhere and does not have any side-effect on human body. So, we conclude that the effectiveness of the device depends on walking ability of the user, i.e. how well the user is performing his morning walk or jog and also the results obtained by these piezoelectric sensors depend a lot on the weight of a person. The device is indirectly proving to be an asset for human health by encouraging a renowned fitness activity termed as walking. This can be the most beneficial and healthy input, an e-gadget can ever take making it a health promoting device.

The device is indirectly proving to be an asset for human health by encouraging a renowned fitness activity termed as walking. This can be the most beneficial and healthy input, an e-gadget can ever take making it a health promoting device. Hence, people can easily charge their mobile phone battery and use emergency torch daily by just walking more and more.

Piezoelectric materials have wide scope in future. Piezoelectric transducers can be placed under the floor in various busy areas like railway station, shopping malls, airport, school, collages, etc. and can be used as a renewable energy source for lighting system present around. It can also be placed under the floor of discos as a large amount of pressure is applied on the floors there while dancing.

Piezoelectric transducers can also be used on speed breakers. When vehicle cross the speed breaker there is enough pressure that can be used for lightning the street lights and traffic signals. These materials can be also used as sensing elements detection of pressure variations in the form of sound is the most common sensor application, e.g. piezoelectric microphones. Sound waves bend the piezoelectric material, creating a changing voltage.

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