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Introduction

e majority of us have been familiar with usage of ambient renewable energies including solar, wind, ermal and biochemical energies to generate electricity. However, our environment is still full of wasted energies. Vibration [1] and acoustic energies [2] are two of the currently wasted energies. Vibration and acoustic energies are clean and renewable. But unfortunately, output power of vibration and acoustic energies are lower than solar and wind energies. is becomes a main issue for wide practical application of vibration and acoustic energies harvesting. However, vibration and acoustic energies exhibit several special advantages than solar and wind energies. Firstly, harvesting vibration and acoustic energies is not limited by weather and time. Vibration energy largely exists in motions from vehicle and airplane, human body, operating machine, etc. And, acoustic energy can be easily found in noise from tra cs, airplane engine, stadium, etc. Ubiquity of vibration and acoustic energies will provide a great number of opportunities to allow us to utilize vibration and acoustic energies. Most importantly, storage of vibration and acoustic energies over a period of time may be signi cant. is short review aims to illustrate piezoelectricity-based vibration energy harvesting, acoustic energy harvesting, and the related AC/DC circuit design.

Vibration Energy Harvesting

ere has been numerous studies focusing on the conversion of mechanical vibration energy to usable electric energy mostly using piezoelectric materials [3-5]. A piezoelectric material generates an electrical charge when mechanically deformed (i.e., direct piezoelectric e ect), or conversely, it physically deforms in the presence of an electric eld (i.e., converse piezoelectric e ect). It should be mentioned that, piezoelectricity is not the only way to scavenge vibration energy. For example, magnetic generator can also be used for vibration energy harvesting [3]. Since the predominated method for vibration energy harvesting is using piezoelectricity, this short review will only cover piezoelectricity-based vibration energy harvesting.

Many e orts in piezoelectric energy harvesting have sought to scavenge the ambient environmental vibration energy such as air ow, water ow and rain drop. Matova et al. [4] reported an air ow energy harvester using with a Helmholtz resonator combined with a piezoelectric energy converter. e resonator stores and accumulates the air ow energy converted into electrical energy harvester. e maximum power of 42.2 W was obtained when the air ow velocity is 20 m/s. Li et al. [5] experimentally proposed and tested a bioinspired piezo-leaf architecture which converts wind energy into electrical energy by wind induced uttering motion. e peak output power is approximately 600 W with the maximum power density 2 mW/cm3 for a single leaf. Erturk et al. [6] studied piezoaeroelasticity for vibration energy harvesting. e electricity is generated at the utter boundary of a piezoaeroelastic airfoil from aeroelastic vibration. An electrical power output is 10.7 mW at the linear utter speed of 9.3 m/s. Ovejas et al. [7] developed multimodal energy harvesters from wind to electrical power by piezoelectric lms. Taylor et al. [8] used piezoelectric polymers to harvest the mechanical ow energy, available in oceans and rivers, to electricity. e multielement-Eel system is capable of producing 1 W in a nominal 1 m/s water ow. Liu et al. [9] employed an array of similar PZT microcantilevers in a self-sustained ow-sensing microsystem for harvesting wind-driven vibration energy. e output voltage and power were measured as 18.1 mV and 3.3 nW at the ow velocity of 15.6 m/s with the corresponding power density 0.36 mW/cm3. Voltages generated by ceramic based piezoelectric

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been introduced by Liu and Phipps et al. and also use ampli ed acoustic wave to deform a PZT piezoelectric back plate [16-18]. e EMHR generated the power of 30 mW when incident 160 dB SPL at 2.6 kHz, Lee et al. [17] developed a Helmholtz resonator with single-layer and multilayer piezoelectric cantilever beams to harvest acoustic energy. e output power of multilayer PVDF composite cantilever is 0.19 W when incident SPL is 118 dB at 850 Hz. In addition to a Helmholtz resonator, a sonic crystal was also used to scavenge acoustic energy [18,19]. A curved polyvinylidene uoride (PVDF) piezoelectric beam was installed inside a defect region of sonic crystal to acts as a resonant cavity. e output power of sonic crystal acoustic energy harvester is ~ 35 nW with the incident SPL of 80 ~ 100 dB at 4.2 kHz. Very recently, a novel and practical acoustic energy harvesting mechanism to harvest a travelling sound at a low audible frequency (180 ~ 200Hz) was developed and studied both experimentally and numerically [20-33]. is acoustic energy harvester used a quarter-wavelength straight tube resonator with multiple piezoelectric cantilever plates installed inside the tube. e maximum output power of the acoustic energy harvester is measured as 10.129 mW when the incident sound pressure level is 112 dB.

Vibration and Acoustic Energies Harvesting Circuit Design

Overall speaking, essentials of piezoelectricity-based vibration and acoustic energies harvesting are both to apply vibration to piezoelectric transducer, and then generate a vibration deformation to create AC electrical output. In piezoelectric energy conversion, the e ciency strongly relies on the impedance of external circuit which converts AC to DC to charge a storage component (e.g., electrochemical battery). A vibrating piezoelectric element (piezoelectric oscillator) generates AC output while the battery generally require a stabilized DC because of the electronic compatibility. erefore, a high e cient AC/DC conversion external circuit needs to be considered to achieve a high e ciency electromechanical energy conversion.

 e most simple AC/DC interface circuit for piezoelectric energy harvesting system is the standard interface circuit [21,22]. In the standard energy harvesting circuit, the piezoelectric element is directly connected to a storage capacitor through a full-bridge recti er, and the external loading resistance is used to match the impedances of the piezoelectric element with the external circuit in order to maximize the harvested electrical power [23,24]. In addition to the standard energy harvesting circuit, nonlinear electronic interfaces have been developed to increase the energy harvesting e ciency of piezoelectric elements [25]. e synchronized switch harvesting on inductor (SSHI) interface circuit is one of the most improtant nonlinear electronic interfaces by adding a digital switch and an inductor to the piezoelectric element in series (S-SSHI) and parallel (P-SSHI). In both S-SSHI and P-SSHI, the piezoelectric output voltage is inversed when the switch is triggered at the maximum piezoelectric displacements measured by a displacement sensor. SSHI circuits are found to not only enhance the harvested power by 400~900%, but also broaden the system bandwidth compared with standard circuits [26]. us far, most studies focusing on the AC/DC conversions for a single piezoelectric oscillator. In order to realize an AC/DC conversion for multiple piezoelectric oscillators, the e ect of external circuits has been investigated both numerically and experimentally [33-36]. Furthermore, the size of vibration and acoustic energy harvesters may need to be minimized to more easily embedded into energy sources. us the size and volume e ect of electronic components in circuit may need to be considered [27-46] in future circuit design for vibration and acoustic energies harvesting.

Conclusion

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