tions are typically weighed in grams and not ounces as are other types of power systems); reduce the cost (cheaper) of the portable electronic device; enhance the service life of the electronic device; improved the reliability of the portable electronic device; providing a more robust design (generally the more energy encountered the more power generated) (e.g., active fibers can withstand a hammer strike without damage); reduced the maintenance and life cycle costs of owning and operating the portable electronic device; conversion of a higher percentage (up to about 70% or more) of energy from ambient mechanical sources to electrical power using piezoelectric fiber composites; improved performance over an extended life cycle; improve the overall quality of the portable electronic device; improving the operating experience for the user of the portable electronic device.

[0103] In accordance with another embodiment of the present invention, a method or integration path for the proper design and development of a self-powered electronic device is provided. The method includes the steps of determining the energy needs of the device and the particular application(s); inventorying ambient sources of mechanical energy (e.g., machines, structures, transporting means, human, device operation and handling, etc.); modeling and confirming the piezo power input; and determining and designing rectification, storage, and regulation needs.

[0104] Power is a key system parameter, so a detailed understanding of the device power requirements under various power dynamics is the first order of business. This may include, for example, voltage power up requirements, supply voltages, operating and maximum current requirements for individual components, optimum system power efficiencies, the power generating system, the power collection system, the power storage system, the power distribution system, and the like.

[0105] Another aspect that must be taken in to consideration is the space available for the power portion of the system. To save space and maximize the harvesting of as many sources of mechanical energy as possible, the ceramic fibers may be disposed/attached/embedded at various locations throughout the device. The layout of the power system should seek to save power and avoid unwanted voltage drops. Ground planes and/or shields can be used to reduce/prevent EMI and/or noise interaction.

[0106] In accordance with another embodiment of the present invention, a method **160** of self-powering a portable electronic device is provided. As shown in FIG. **10**, the method **160** may include incorporating an energy harvesting system **162** comprising piezoelectric ceramic fibers into a portable electronic device. The piezoelectric ceramic fibers may be positioned and oriented **164** at one or more mechanical energy input points. A charge is generated **166** in the piezoelectric ceramic fibers from mechanical energy input at one or more of the mechanical energy input points. Preferably, the mechanical energy is input through normal use of the portable electronic device. The charge may be collected **168** from the piezoelectric ceramic fibers using suitable electrical circuitry. The collected charge may be stored **170** in an energy storage device. The electrical energy may be conditioned (e.g., rectified) prior to storage. One or more loads of the portable electronic device may be powered **172** using the stored energy generated using the piezoelectric ceramic fibers.

[0107] In another embodiment (not shown), a belt and belt clip may comprise piezoelectric ceramic fibers and may be electrically coupled to one another. The belt clip may include an energy storage device and a male connector. Mechanical energy imparted to the belt and belt clip is collected and stored. When the electronic device is place in the belt clip, a female connector on the electronic device may connect to the male connector on the belt clip such that the electronic device is charged from the belt clip storage device.

[0108] FIG. **11** illustrates direct and converse piezoelectric effect. As illustrated, the direct effect may be a sensor application and the converse effect may be an actuator application.

[0109] FIGS. **12**A and **12**B illustrate example power generation capabilities of exemplary piezoelectric fiber composites where the power generated was stored in a capacitor. FIG. **12**A illustrates the AC voltage generated from an exemplary piezoelectric fiber composite. As illustrated, when the vibration amplitude is about 2.8 mm at about 22 Hz, a maximum output voltage of about 510 V_{p-p} may be produced. In FIG. **12**A, each square represents 50 V in the vertical direction and 1 second in the horizontal direction. FIG. **12**B illustrates how fast an exemplary capacitor may be charged. In FIG. **12**B, each square represents 10 V in the vertical direction and 1 second in the horizontal direction. Accordingly, in the illustrated embodiment, a 400 μF capacitor bank may be charged to about 50 V in about 4 seconds. This may be sufficient power to run, for example, wireless sensors, illumination devices, alarms, audio components, visual displays, vibrating components, clocks, and other functional devices.

[0110] FIG. **13**A illustrates exemplary power generation for a range of applied forces. The x-axis shows the force in Newtons and the y-axis shows the continuous power in milli-Watts. Each curve on the graph represents a PFCB with a specified thickness ratio between the piezoelectric material and the non-piezoelectric metal shims. X in FIG. **13**A represents the ratio of metal thickness to the piezoelectric thickness. As illustrated, a maximum power output of about 145 mW was measured. Additionally, maximum power was generated at an equal metal/piezo ratio or when X=1.

[0111] FIG. **13**B illustrates exemplary power generation for a range of frequencies or vibrations. As shown, much larger power may be generated at resonance. As shown, the PFCB tested had a resonance frequency of about 35 Hz. The graph shows that at such a frequency, a maximum power of about 145 mW may be produced. However, even at about 25 Hz and about 45 Hz a significant amount of power may be generated. Accordingly, a wide frequency peak may produce more power at random frequencies.

[0112] FIG. **14**A illustrates exemplary resonance frequencies for a range of thickness ratios. According to the graph, a resonance frequency may be chosen to get maximum efficiency based on a particular application. For example, if a company has a compressor that works at 27 Hz, the thickness ratio may be modified to get a resonance frequency of 27 Hz so that maximum output may be achieved.

[0113] FIG. **14**B illustrates exemplary power generation for a range of thickness ratios. As illustrated, maximum power is generated at about 33 Hz or when the thickness