ENERGY HARVESTING ELECTRONICS FOR PIEZOELECTRIC ENERGY GENERATOR

Abstract

Energy Harvesting taps ambient waste energy through increasingly efficient micro-energy power generators using piezoelectric elements. As circuits such as Wireless Sensor Networks (WSN) that operates on low duty cycle and high energy efficiency become more popular, demand for using micro-energy generators to power an electronic circuit without a battery or AC-wired power source increases. The process of capturing such energy, store and manage the energy to power electronic circuits requires specially developed electronic circuits. These electronic circuits require non-conventional electronic circuitry operating at extremely high energy-power efficiency. An Energy Harvesting Circuit Module has been developed that harvest electrical energy directly from piezoelectric composites. Performance data and recorded measurement are presented. Energy efficiency of the Module exceeding 70% has been achieved at average input energy input of less than 1 micro-Joule.

Energy Harvesting Circuitry is developed for energy harvesting sources that by themselves cannot supply adequate power for any useful purpose or application such as WSN. Many of these applications do not require a lot of average power, as they need only intermittent duty cycle. Energy Harvesting Circuits are designed to be able to capture, accumulate and store energy from a variety of energy harvesting sources and efficiently and effectively manage harvested energy to power wireless sensor networks and other applications. These Circuits expands the operating range of power deployment beyond AC lines and batteries.

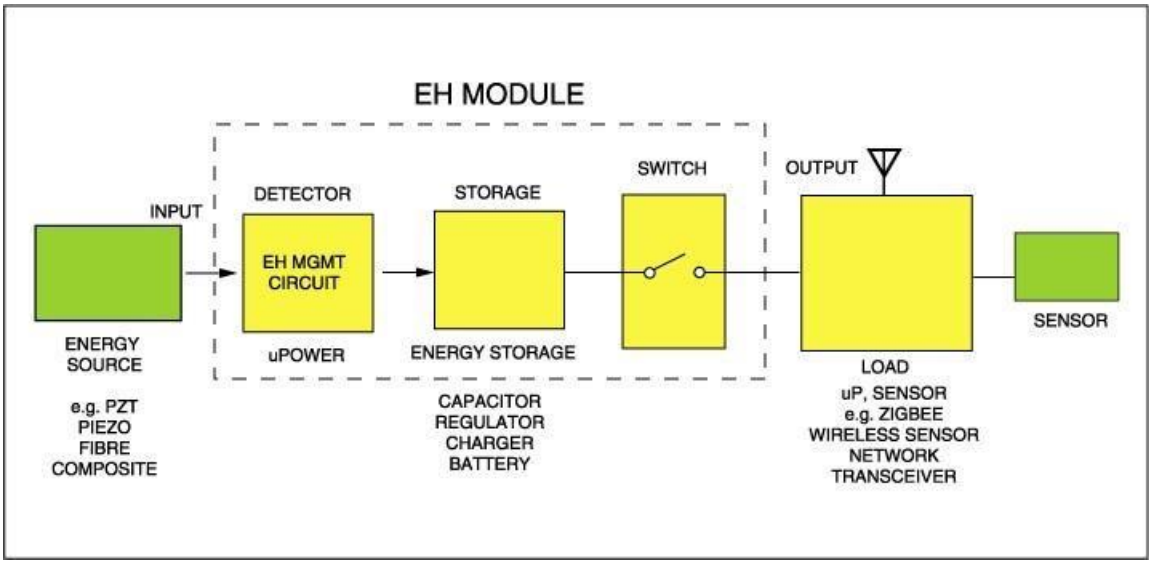
Common Energy Harvesting Sources include:
* Mechanical Energy generated by vibration, stress and strain.
* Thermal Energy captured by proximity to furnaces and heaters
* Light Energy as gathered from different light sources using photovoltaic devices
* Electro-magnetic Energy derived from inductors, coils and transformers.
* Natural resources such as wind, water flow, and solar, or human beings utilizing one or more of the above sources
* Chemical and biological energy sources that tend to occur naturally

Energy Harvesting applications are typically for power supplies used as either primary power sources or supplementary secondary power sources. Examples of Energy Harvesting applications are Extreme Life Span Power Sources, Battery eliminators, wireless sensor networks, condition-based monitoring systems, self-powered remote control switch, alternate backup power source and battery charger for rechargeable batteries. As an alternate or secondary power source, redundant power systems can be implemented to build reliability and robust systems.

An Energy Harvesting Circuit emulates the characteristics of a battery so that it can actually power an electronic circuit designed to operate with a battery. Most electronic loads require a low impedance power source that operate between two voltage levels, a high voltage representing the maximum battery voltage possible and a minimum voltage level representing voltage levels at the end of battery life.

An Energy Harvesting System consists of three major components:
* an energy generator
* an energy harvesting circuit that can capture, store and manage that energy
* a load that consumes that energy

The load energy consumption must be matched to the energy generated for the system to operate properly.



Battery output and Energy Harvesting voltage levels cycles in between two defined voltage levels, although at different rates of change. The Basic Energy Harvesting Function Block consists of rectifiers, comparators, voltage references, control logic circuitry, energy storage elements and an output switch. Together these circuits capture, accumulate and store generated energy that varies greatly in shape, magnitude and duration. The Energy Harvesting Concept is illustrated with a diagram of bathtub and water capture from rain, the magnitude of which over a period of time is uneven and sporadic, and may include a period of no rain at all. Therefore it is necessary to be able manage and monitor energy levels at very high energy efficiency, lest the energy captured are all consumed by the management and monitoring circuit itself.

A diagram of Energy Available versus Time illustrates that the energy input has energy peaks and valleys, resulting in an averaged energy level. The actual required energy to operate a load may be significantly higher than the average energy level, requiring a short energy burst. Another way to look at energy level is to look at Energy Harvesting Module voltage level, which gives an indication of the accumulated energy levels. The measured typical energy efficiency of the Energy Harvesting Module is shown in the Energy Efficiency Characteristic curve. For average input energy of 1 microjoule, the efficiency of the Module is 76%. At 10 microjoule of input energy, the energy efficiency of the Module is 95%. At 100 microjoule or higher levels of average input energy, the energy efficiency of the Module is close to 100%.

A plot of current consumption of the Energy Harvesting Module vs. its voltage level indicates many orders of magnitude of variation of current for a rather small range of voltage levels. Notice that the current levels are very low but not zero at close to zero volts. The overall behavior of this curve and the control of current vs. voltage levels along the curve are essential to the functionality and efficiency of the EH Module. Another view is to observe the current consumption vs. time, as measure in hours. This curve indicates that the captured energy can remain over several days inside the EH Module without a secondary storage such as a battery.