

An Introduction to Joule-Thief™ Vibration-Based Energy Harvesting

Abstract

AdaptivEnergy provides a high energy density energy harvesting solution that, when mated with today's low power microelectronics, provides a self-powered intelligent sensor solution. Depending on an application's environment and power needs, AdaptivEnergy's Joule-Thief™ technology can either autonomously power the application as the sole power source, act as a recharging source for its batteries, or even augment non-rechargeable batteries to extend device lifetime. This application note provides an overview of the environments in which AdaptivEnergy's vibration-based energy harvesting technology can be successfully deployed.

Introduction

AdaptivEnergy has developed energy harvesting solutions designed to convert available mechanical energy – vibrations, impacts, and force – into usable electrical energy. This technology allows an application to be self-powered in environments where batteries and wires have been the sole previous alternatives. Using locally available (and free) vibrational energy therefore makes the end application independent from the finite lifetime of batteries and the physical challenges of running power lines. The result is a longer-lasting, autonomous product with significantly lower installation and maintenance costs.

Where Joule-Thief™ Energy Harvesting Fits

The key to a maintenance-free, renewable power source for a given application lies in the application's *environment*. The thermal, light (solar), vibratory (mechanical), and electrostatic (RF) properties of a deployed low power microelectronics product all provide opportunities for long life self-powering. This application note focuses on environments where vibratory energy *by itself* provides for a self-sustaining power solution.

There are three main categories of vibration sources, as shown in Table I: Industrial, Structural, and Vehicular. Note that each category contains diverse vibration sources, although general rules of thumb typically predominate. These rules include the following:

- (1) **Industrial** applications can typically take advantage of “fixed frequency” vibrations since AC-driven motors and pumps produce vibration harmonics from their drive frequency (for example, 60Hz in the United States and 50Hz in Europe). This means that a

disproportionate amount of the mechanical energy available for harvesting occurs within a narrow range of known frequencies.

- (2) **Structural** applications typically have lower vibration amplitudes (both G level and displacement) than the other two categories. These applications also tend to be the most difficult for battery maintenance and power line service.
- (3) **Vehicular** applications tend to have more *random* vibrations than the other categories. Although nearly all vehicular applications provide significant vibration amplitudes and G levels for energy harvesting, this energy is available more through random occurrences such as bumps/rough surfaces/dynamic frequencies than through one particular frequency of interest.

Table I. Categories of vibration and recommended AdaptivEnergy Joule-Thief™ Energy Harvesting module

Category	Vibration Sources	Recommended AdaptivEnergy Joule-Thief™ Module			
		JTF-060e5 (Fixed Frequency)	JTF-120e5 (Fixed Frequency)	JTRA-e5mini (Low Freq Random)	Custom Joule-Thief™
Industrial	Motors		X		
	Compressors		X		
	Turbines		X		
	Pumps	X	X		
	Smart Grid	X	X		
	Transformers	X	X		
	Chillers	X	X		
	Fans	X			
	Conveyors			X	X
	Cutting, Dicing			X	X
Structural	Bridges				X
	Roads				X
	HVAC Systems	X			X
Vehicular	Train			X	X
	Truck			X	X
	Automobile			X	X
	Helicopter			X	X
	Other Aircraft		X		X

Of course, there are exceptions to each of the main categories – for example, variable speed motors running off AC or DC power do not exhibit the same vibrational characteristics as a fixed speed motor or pump. Aerospace applications typically produce their available mechanical energy at higher frequencies than truck-based applications. Cargo containers oftentimes display vibrations mimicking those of their transport vehicles plus can provide new vibration modes based on their structural design. Although not the subject of this application note, there are proven methods for characterizing your application environment if it is “unique” compared to those discussed herein.

Joule-Thief™ Vibration-Based Harvester Options

AdaptivEnergy presently offers four standard vibration-based energy harvesters, in addition to the high power density (HPD) product line available Q4 2009. A brief summary of these harvesters follows below:

- **JTF-060e5**
The first commercialized AdaptivEnergy Joule-Thief™ product, this module is designed for applications with a 60Hz (line frequency) vibration content. The module has wide applicability in environments such as motors, pumps, transformers, fans, etc., and is available with a rechargeable battery (recharged by the harvester) or battery-free with onboard capacitive storage.
- **JTF-050e5**
This unit is identical to the JTF-060, except it is designed for environments such as Europe that use a 50Hz line power supply. The line power supply frequency typically expresses itself in the application’s vibration profile, and therefore more energy is present in Europe at a 50Hz than a 60Hz vibration frequency.
- **JTF-120e5**
Field testing has demonstrated that many industrial applications present a higher vibrational power density at 2X the drive frequency – also known as the 2nd harmonic. Therefore, the JTF-120e5 works in very similar applications as the JTF-060e5 but is able to more efficiently harvest the 2nd harmonic energy. This module is also available with a rechargeable battery (recharged by the harvester) or battery-free with onboard capacitive storage.
- **JTRA-e5mini**
As noted previously, transportation environments present a different vibrational signature than most industrial applications. After extensive in vehicle and on vehicle

vibration and harvester technology testing, AdaptivEnergy designed the JTRA-e5mini to work effectively in a wide spectrum of transportation environments. This “Random Vibration Module” harvests energy from low frequency vibrations as well as “impact” events typically experienced in transportation applications.



Figure 1. JTRA-e5mini in “kit” form, shown with a Texas Instruments eZ430-CC2500 wireless microcontroller board solely powered by the AdaptivEnergy harvester.

For More Information:

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