Vibration harvesting: EM energy conversion

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Vision

Small scale resonant generators harvesting ambient vibrations in the 60-250 Hz frequency range by using an electromagnetic conversion from the mechanical to electrical domain

Vibration Source	Peak Acc. (m/s^2)	Frequency of Peak (Hz)
Base of 5 HP 3-axis machine tool with 36" bed	10	70
Kitchen blender casing	6.4	121
Clothes dryer	3.5	121
Door frame just after door closes	3	125
Small microwave oven	2.25	121
HVAC vents in office building	0.2 – 1.5	60
Wooden deck with people walking	1.3	385
Breadmaker	1.03	121
External windows (size 2 ft X 3 ft) next to a busy street	0.7	100
Notebook computer while CD is being read	0.6	75
Washing Machine	0.5	109
Second story floor of a wood frame office building	0.2	100
Refrigerator	0.1	240

S. Roundy, Energy Scavenging for wireless sensor nodes with a focus on vibration to electricity conversion

Table 1: Characterization of harvestable vibrations

Goals

Power	Size	Mass	Frequency	Life time
> 40 μW	16 cm^3	0.1 kg	20-250 Hz	10+ yrs

Maximize power output:

- Maximize translation amplification due to resonance
- Maximize change in flux

What EM architecture is best suited to the above goals for small input accelerations of less than 1g?

Methods

POWER CONVERSION: The voltage generated from electromagnetic induction is equal to the number of coil turns, N, and the change in magnetic flux, ϕ, through those coils.

$$V = -N\frac{\partial \phi}{\partial t}$$

A change in flux can be achieved by using the amplification of the input vibration by the beam suspension and a magnetic circuit. There are three major magnetic circuit types: open; variable reluctance; and voice coil.

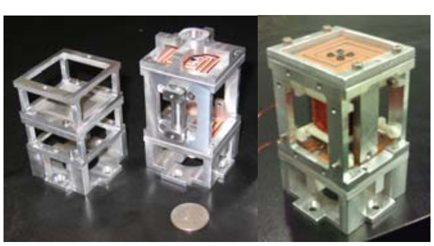

Figure 1: (left to right) Open, pole switching, and voice coil partially assembled test platforms.

Open circuit systems are basically a magnet translating relative to a set of coils. This is an inefficient but common conversion scheme. It is more effective to use iron to conduct the flux through sets of coils as in classic motor and generator design.

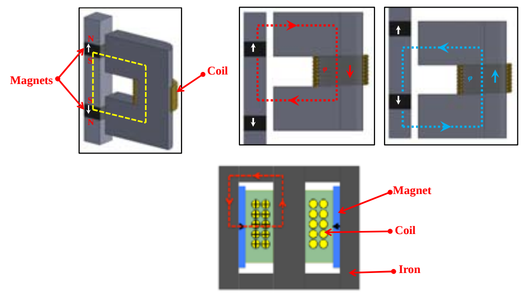

Figure 2: (top) Pole switching circuit schematic, and (bottom) x-section voice coil circuit schematic at the extremes of their translation amplitudes.

A change in flux arises in the pole switching circuit because the flux loops in opposite directions. In the voice coil circuit, the change in flux is a result of the changing area between the coil and magnetic circuit.

Findings

Parameter	Value
N [coil turns]	500
f [Hz]	35-40
signal	*sinusoidal*

For large test platforms of shown at lower left:

Open circuit: The undefined flux path makes an analytic model difficult. There is a trade off between and greater amount of magnetic material and more coil turns. Experimental results yielded **5-10 mW**.

Pole switching circuit: Modeling suggests a power potential of **100 mW**, but cogging forces limit experimental results to **1 mW** at the moment.

Voice coil circuit: Modeling suggests a power potential of **40 mW**, and experimental evaluation is ongoing.

The high power potential of the pole switching architecture seems attractive, but it is very difficult to get near the theoretical output. Thus the most attractive design will usually be either the open circuit or voice coil options depending on the application.

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