Vibration Harvesting: EM Energy Conversion

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Vision

Small scale resonant generators harvesting ambient vibrations in the 60-200 Hz frequency range by using an efficient electromagnetic circuit to convert the mechanical vibrations to electrical energy

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

Methods

BEAM STRUCTURE: Analysis of multiturn beam geometries suggests beam suspensions with a footprint on the order of 1 cm^2 can be designed to resonate in 60-200 Hz range.

Figure 1: Macro test version of multiturn beam structure

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; Pole Switching; and Variable Reluctance.

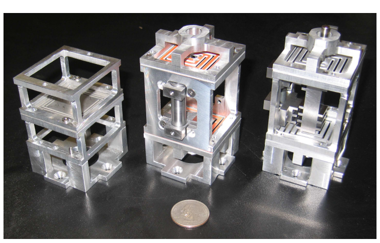

Figure 2: (left to right) Open, Pole Switching, and Variable Reluctance partially assembled test platforms.

Open circuit systems are basically a magnet translating relative to a set of coils. The flux change through the coils is roughly proportional to the proximity of the coils and magnet. 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 the pole switching and variable reluctance circuits as in classic motor and generator design.

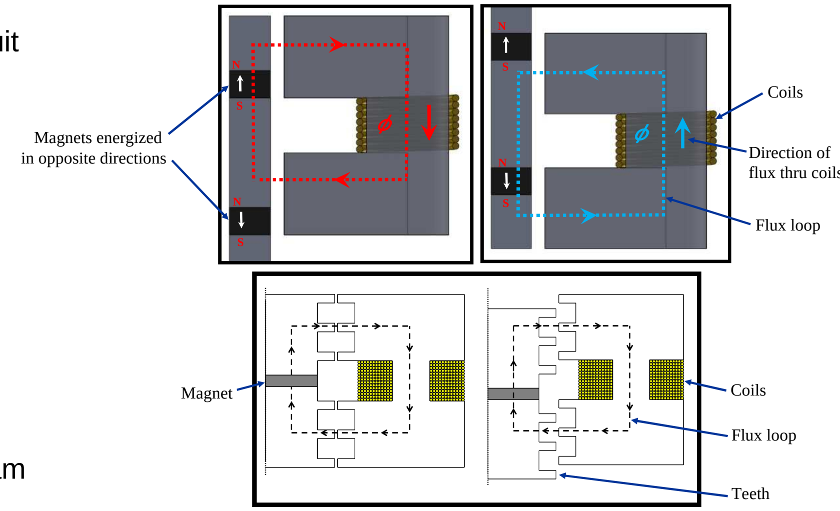

Figure 3: (top) Pole switching circuit schematic, and (bottom) variable reluctance circuit schematic at the extremes of their translation amplitudes.

A change in flux arises in the pole switching circuit because the flux loops are in opposite directions, but in the variable reluctance circuit, the change in flux is a result of the teeth aligning and misaligning.

Research Questions

[1] Can the beam suspension be made to resonate in the 60-200 Hz range with a 1 cm^2 footprint?

[2] Which magnetic circuit type is best suited for harvesting ambient mechanical vibrations?

Findings

[1] Small structures can be designed to resonate between 60 and 200 Hz.

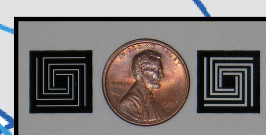

Figure 4: 10 x 10 x 0.09 mm Silicon beam structures that Resonates at 140 and 110 Hz

[2] The test platforms shown in Figure 2 are being used to evaluate the power performance of the circuit types with 500 coil turns. The OC designs generate 3-5mW. The PS design has problematic damping forces necessitating a redesign, and the VR design is being evaluated currently.

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