Vibrations to Power Portable Electronics and Micro Sensors

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Abstract: The use of portable electronics and small monitoring sensors have increased significantly in the last two decades. But the lack of maintenance free and portable power supplies has limited the potential applications of those components. With a passive self-tuning system, it would be possible to efficiently use a vibrational energy harvester to power those electronics. In the author's opinion the clamped-clamped beam with a sliding-mass system could be the tuning mechanism that will bring out the potential of energy harvesting from vibrations.

Introduction

Energy harvesting is a process to harvest one form of energy in the surroundings and converting it into another type of energy. The most common energy harvesters that we are used to are solar cells which can convert the energy in sunlight to electricity, and wind turbines which can convert the energy in wind movement into electricity. But to power portable electronics or Micro-Electro-mechanical sensors (MEMS), the harvester needs to be small and sufficient and work in shifting environments. MEMS are sensors used in wearable electronics and in applications where the user needs to monitor a condition of a part or space. Such as in skyscrapers and bridges where you need feedback concerning temperature, corrosion or even fatigue. A direct power supply is not always available or convenient to power those sensors. A more robust and efficient way, instead of the traditional way with batteries, is of great interest. Nonthe least out of an environmental aspect. An energy source that can be found almost everywhere, where the construction of the harvesters can be made small and does not require any maintenance, are vibrations. You can find vibrations in human movement, an operating machine and/or in infrastructure.

Theory

To convert the vibrational movement into electricity you need a transducer. The transducer takes advantage of the displacement of the inertial mass of the system and in return damping the movement of the inertial mass, see Figure 1. Most common types of transducers are piezoelectric, electromagnetic and electrostatic. Each makes use of the displacement in different ways to generate electricity.

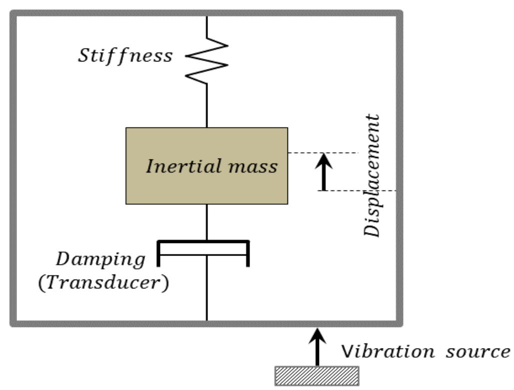

Figure 1. Schematic diagram of the linear, spring-mass-damping system

The maximum power that can be harvested in a vibration energy harvester occurs when the system inertial mass vibrates at the same frequency as the vibration it is exposed to. Also known as when the system is in resonance. Therefore tuning the systems natural frequency to match the operating environments is of great importance for the efficiency of the system. Tuning the natural frequency of the system can be achieved manually, passively and actively. Manual techniques are usually the easiest way since it mostly implicates changing the physical properties of the system, for example the spring stiffness. Active tuning is also known as active self-tuning were the tuning is automatically induced. The main setback of active self-tuning is that the tuning technique is consuming energy making it not as efficient as passive self-tuning. In passive self-tuning, the tuning is implemented automatically without any power consumption.

An analytical and numerical work has been performed on a passive self-tuning system [1]. A system with great potential to increase efficiency and usability of energy harvesting from vibrations. The system is based on a steel beam, fixed in its both ends, also known as the clamped-clamped beam. With a sliding-mass able to slide along the beam length, a schematic illustration can be seen in Figure 2.

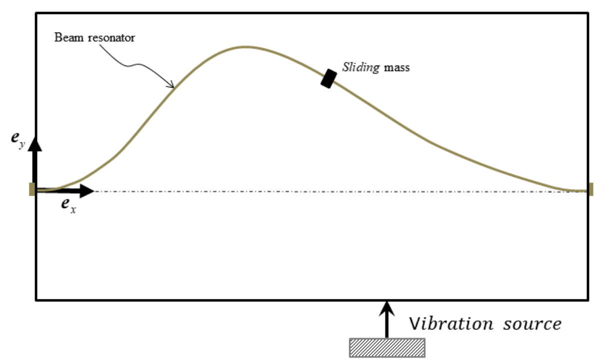

Figure 2. A clamped-clamped beam resonator carrying a sliding proof-mass.

When the system is exposed to vertical vibrations the sliding mass tends to move to the position of the beam that tunes the beam with sliding-mass systems natural frequency to match the subjected frequency. Experiments made by Lindsay M. Miller [2], could show successful results with the passive self-tuning capabilities of the clamped-clamped beam with a sliding-mass system.

Results and Conclusion

To gain and increase understanding of the behavior of the clamped-clamped beam with a sliding mass system, an analytical model of the system was produced. With the help of the analytical model it was possible to plot the frequency range of the system. Figure 3 shows the frequencies for the characteristics of a reference steel beam given in Table 1.

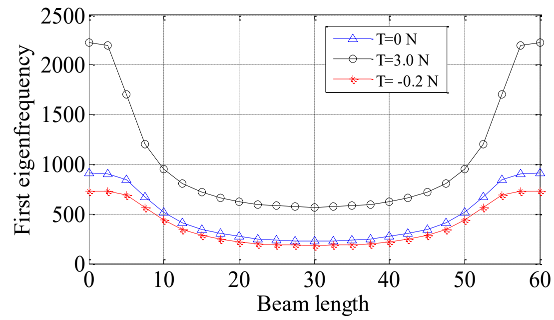

Figure 3. Frequency range in terms of sliding-mass position for a beam without any preload, with 3N pretension and 0.2N precompression.

Table 1. Characteristics of the reference steel beam.

Parameter	Value	Unit
Beam length	$L = 0.060$	m
Beam width	$b = 0.003$	m
Beam thickness	$h = 0.0001$	m
Beam mass	$m_b = 0.14$	g
Proof mass	$m = 0.8$	g

We also found that with different levels of preload we could alter the frequency range of which the system could resonate in. Improving the broadband properties of the system. It was also discovered that with pretension on the beam we could decrease the time the system needed to reach resonance. It was possible to notice that we can cover a wide frequency range with this system. Also, with small effort we could adapt the system to cover the frequency range of our application. This passive self-adapting tuning system could be modified to be used in numerous application and with most transducers depending on the application.

References

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[2] L.M. Miller, P. Pillatsch, E. Halvorsen, P.K. Wright, E.M. Yeatman, A.S. Holmes, Experimental passive self-tuning behavior of a beam resonator with sliding proof mass, J. Sound Vib. 332 (2013) 7142–7152. doi:10.1016/j.jsv.2013.08.023.