# Design of a nonlinear energy sink with energy harvester

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**Abstract**

Ambient vibrations are ubiquitous, arising from sources such as human motion, machinery, structures, and ocean waves. Most of their energy lies in wide spectra of low frequencies. In machinery and structural systems, mitigating these vibrations is crucial, making low-frequency vibration reduction a prominent research area. Structural health monitoring, which uses sensors to detect and quantify ambient vibrations, faces challenges with frequent battery replacements. To address this, energy harvesting mechanisms are integrated into sensors to capture ambient vibrations and power the sensors. As a result, both vibration mitigation and energy harvesting have become significant areas of study.

Linear tuned mass dampers (TMDs) have been widely used for vibration mitigation. These secondary attachments, tuned to match the resonance frequency of primary systems, effectively reduce vibrations and harvest energy near resonance points. However, their performance deteriorates outside these frequencies. This limitation has led to the development of nonlinear energy sinks (NES), which operate over broader frequency ranges, and arrays of TMDs for multiple resonance frequencies.

Nonlinear energy sinks are secondary attachments that dissipate vibration energy through nonlinear coupling with primary systems. They mitigate vibrations across wide frequency bands and, when combined with energy harvesters, enable simultaneous vibration reduction and energy harvesting. This study examines a system integrating a nonlinear energy sink with an electromagnetic energy harvester.

The investigated system comprises a primary oscillator subjected to harmonic base excitation and a secondary NES attachment that absorbs vibration energy. An electromagnetic energy harvester is attached to the secondary mass (NES) converts mechanical energy into electrical energy through magnetic levitation in a current-carrying coil attached to the primary oscillator. The electromotive force (EMF), generated through the relative motion between the coil and the magnet, depends on the rate of change of electromagnetic flux, a nonlinear function influenced by the magnet's position, orientation, and velocity. However, many studies simplify this phenomenon by treating flux changes as linearly dependent on magnet velocity. This analysis prioritizes the accurate representation of the magnet's position and velocity to quantify energy transfer between the mechanical system and the electrical circuit.

The energy dissipation of the system is quantified both with and without the NES. Additionally, the impact of the energy harvester on the system dynamics and energy dissipation is evaluated. A parametric analysis is performed to optimize the system's performance. The findings provide insights into designing efficient linar oscillator with nonlinear energy sink (LO-NES) systems for applications requiring both vibration mitigation and energy harvesting.

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