Mitigation of nonlinear vibrations with a digital piezoelectric tuned vibration absorber

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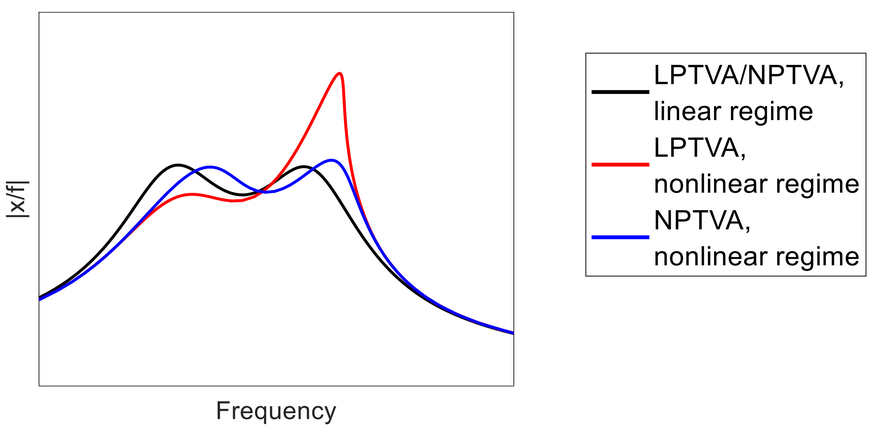
This work presents an experimental realization of a digital piezoelectric vibration absorber. A piezoelectric transducer coupled to a structure may convert a part of its mechanical energy into electrical energy. This energy can then be dissipated through an impedance, often called shunt circuit. Depending on the complexity of the circuit and on the required parameters for its physical constituents, its practical realization may be uneasy. A solution to circumvent these issues altogether is to use a digital impedance. Owing to the flexibility offered by the digital processing unit, almost any impedance can be synthesized, including nonlinear ones with arbitrary functional forms. In this work, the digital impedance is used to realize a linear or nonlinear piezoelectric tuned vibration absorber to mitigate the resonance of a nonlinear structure. The superior performance of the nonlinear absorber over its linear counterpart is demonstrated. Various nonlinear functional forms are also tested in the absorber and illustrate the relevance of a principle of similarity (i.e. the same functional form should be used in the absorber as that in the host structure) for performance.

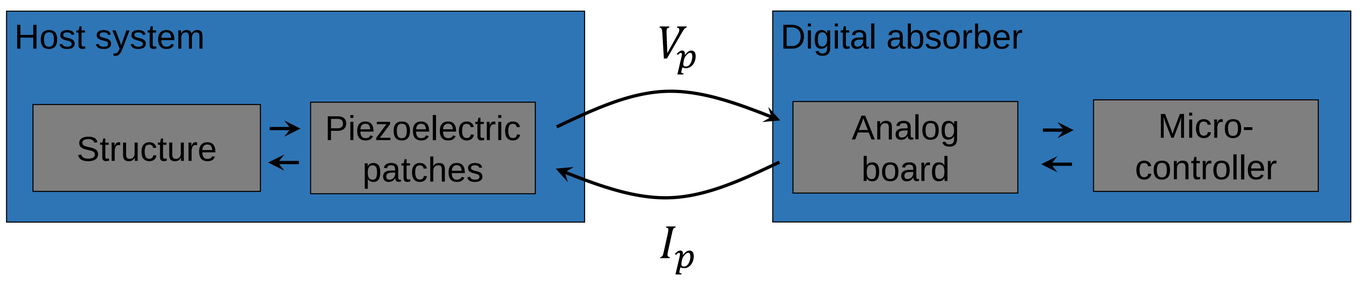
The NPTVA

A nonlinear piezoelectric tuned vibration absorber (NPTVA) [1] is a linear PTVA to which is purposely added a nonlinear element such that equal peaks remain enforced in nonlinear regimes of motion, thereby maintaining its vibration mitigation performance.

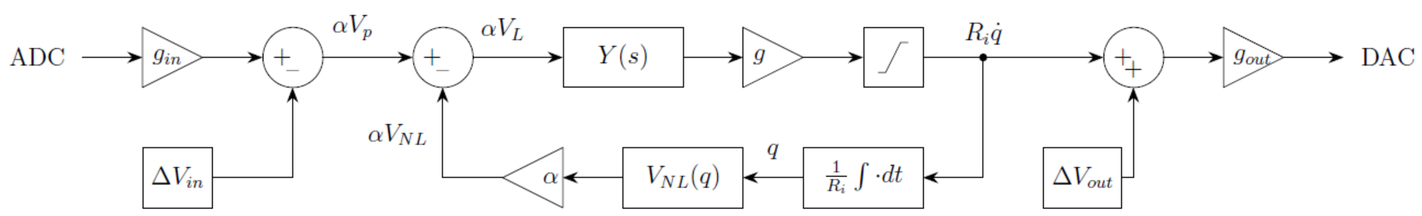


Digital absorber

The digital absorber [2] is composed of a microcontroller unit driving a current source and enables the implementation of virtually any impedance.



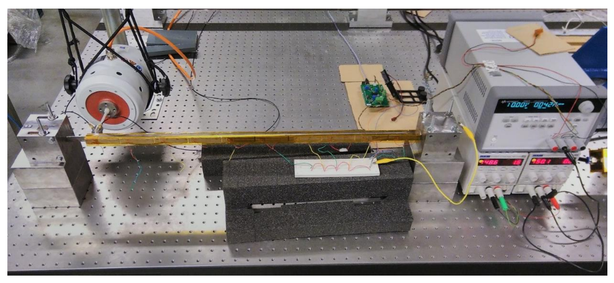
Shunt circuit synthesis

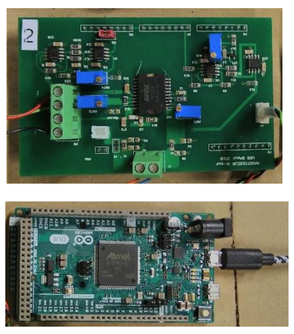


System under study

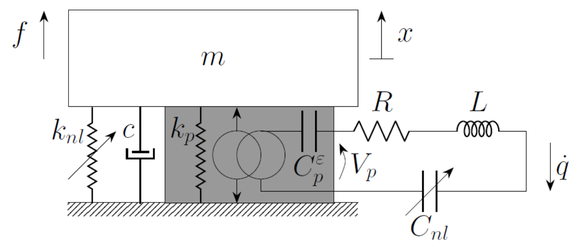
The experimental setup consists of a beam with a hardening nonlinear behavior covered with piezoelectric patches [3] coupled to the digital absorber.

Experimental setup





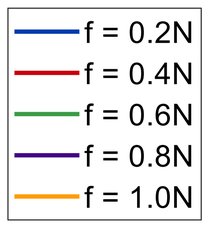
1-dof model



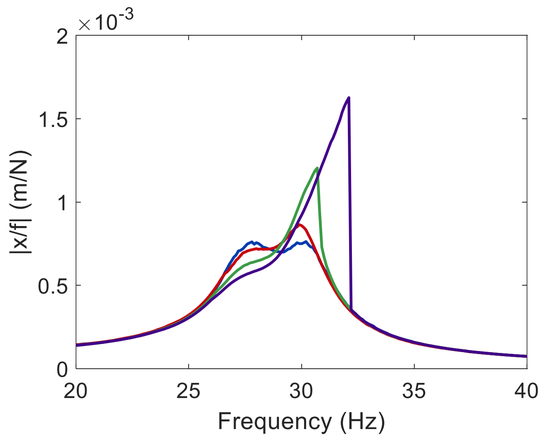
$$\begin{cases} m\ddot{x} + c\dot{x} + k_{oc}x + k_3x^3 - \theta q = f \\ L\ddot{q} + R\dot{q} + \dfrac{1}{C_p^\varepsilon}q + C_n\text{sign}(q)|q|^n - \theta x = 0 \end{cases}$$

Absorbers on a nonlinear structure

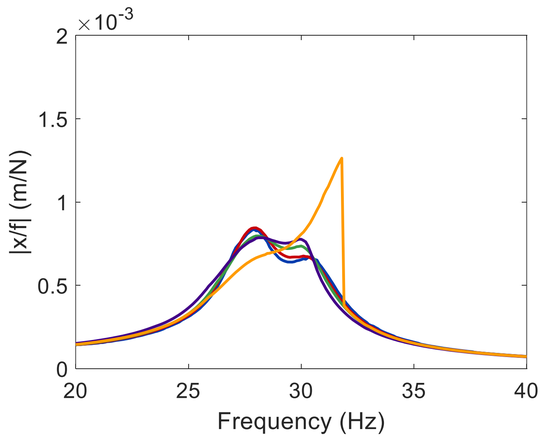
The piezoelectric patches are shunted by circuits with nonlinear capacitors having different functional forms. Clearly, the absorber obeying a principle of similarity [4] is the one which exhibits the best performance.



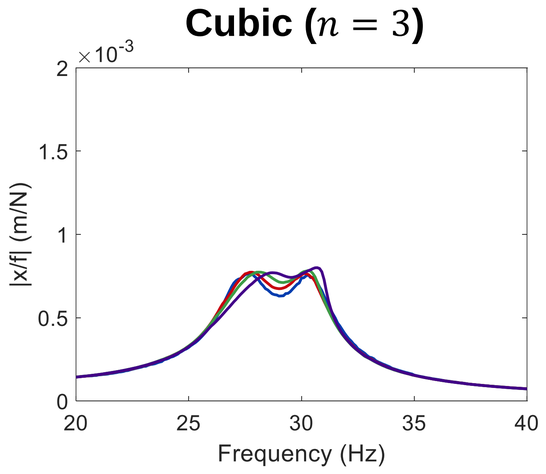
Linear ($C_n = 0$)



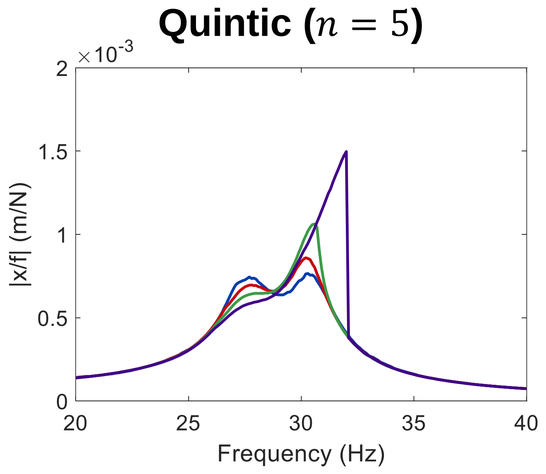
Quadratic ($n = 2$)



Cubic ($n = 3$)



Quintic ($n = 5$)



Conclusion

- Digital absorbers form a flexible framework for the implementation of nonlinear absorbers.
- Absorbers obeying a principle of similarity have the best performance.
- Adverse dynamical phenomena and saturation of the electronics may limit the performance of the absorber.

Acknowledgements

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[1] Soltani P, Kerschen G. *The nonlinear piezoelectric tuned vibration absorber*. Smart Mater Struct 2015;24:075015. doi:10.1088/0964-1726/24/7/075015.
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[3] Lossouarn B, Deü J-F, Kerschen G. *A fully passive nonlinear piezoelectric vibration absorber*. Philos Trans R Soc A Math Phys Eng Sci 2018;376:20170142. doi:10.1098/rsta.2017.0142.
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