Suppression of delay-induced instabilities of digital piezoelectric vibration absorbers

G. Raze*, A. Paknejad†, G. Zhao†, V. Broun‡, C. Collette† and G. Kerschen*

* Space Structures and Systems Laboratory
University of Liège
Allée de la Découverte 9, 4000 Liège, Belgium

† Precision Mechatronics Laboratory
Université libre de Bruxelles
Avenue F.D.Roosevelt 50, 1050 Brussels, Belgium

‡Département ingénieur industriel
Haute École de la Province de Liège
Quai Gloesener 6, 4020 Liège, Belgium

ABSTRACT

Piezoelectric vibration absorbers constitute an attractive means of vibration mitigation. However, piezoelectric shunt circuits usually require high inductances and the performance of the absorber is very sensitive to parameter variations. Fleming et al [1] proposed the concept of synthetic impedance as an alternative solution to implement a piezoelectric shunt circuit. The resulting impedance can be arbitrary and is easily tuned, so that the aforementioned drawbacks are no longer an issue. In this work, a digital vibration absorber is used to realize a piezoelectric shunt circuit. Even though the digital absorber is designed to mimic a passive piezoelectric shunt circuit, stability issues may arise. They are caused by the combined effect of delays induced by the digital processing unit, as well as the high impedance of the piezoelectric transducer. By casting the problem as a feedback control problem, it is observed that these causes incur a shift of the zeros of the open-loop transfer function toward the right part of the complex plane. As a result, the damping of the poles of the closed-loop transfer function is gradually lowered and these poles may eventually become unstable. A remedy to this problem is to modify the coefficients of the transfer function implemented in the digital processing unit such that the open-loop zeros of the real system are the same as those of the ideal system, i.e., without delays. The proposed approach is demonstrated on a piezoelectric beam, for which a digital shunt targets the second mode. Figure 1 shows the frequency response function of the system when the piezoelectric patches are open-circuited together with the initial and improved transfer functions. By stabilizing the system, the proposed approach makes the system acts like an actual passive shunt circuit.

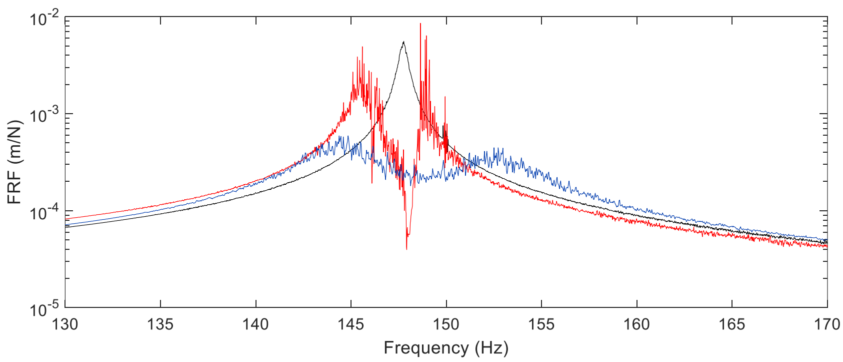

Figure 1: Frequency response function of the piezoelectric beam with open-circuited piezoelectric patches (-), initial transfer function (-) and improved transfer function (-).

REFERENCES

[1] A. J. Fleming, S. Behrens, and S. O. R. Moheimani. “Synthetic impedance for implementation of piezoelectric shunt-damping circuits.” *Electronics Letters* Vol. **36** (18), p. 1, (2000).