High voltage synthetic inductor in piezoelectric shunt to damp flexible vibrating structures

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ABSTRACT

Using resonant piezoelectric shunts is a well-established solution to mitigate vibrations in flexible structures. However, very large inductance values are required in the shunt such that electrical resonance matches one of the mechanical resonance frequencies. As it is impractical to design a common wire wound inductor coil with such a very large inductance and a low resistance as well. Therefore, the large inductance is often realized as a synthetic inductor. i.e. an active electronic circuit which mimics the electrical impedance of an inductor. A synthetic inductor consists of one or more operational amplifiers and a number of passive resistors and capacitors.

The operational amplifiers considered in literature are often of the standard low-voltage type [1], which are only suitable if the piezo also generates a low voltage. However, if a mechanical structure vibrates significantly, the voltage over the piezo's electrodes can reach several hundred volts. Standard operational amplifiers typically function for output voltage ranges up to about 30V. State-of-the-art high-voltage operational amplifiers exist up to output ranges around 100V [2].

In the field of analogue electronics, several techniques are known to boost the output voltage range of an amplifier. The most straightforward technique is the "bridge amplifier configuration", where two similar amplifiers are driven antiphase. The load is connected between the two amplifier outputs, effectively doubling the output voltage range.

Another, less common technique is the "output voltage boost configuration", where the positive and negative power supply voltages of the main amplifier are delivered by supply boost amplifiers. By selecting the proper boost amplifier supplies and gain factors it is possible to create a set of power supply voltages for the main amplifier, of which the average tracks the desired output signal, effectively doubling the output voltage range in an alternative way.

Employing a combination of both techniques, it is possible to quadruple the output voltage range. A new circuit has been designed and built, employing 6 high-voltage operational amplifiers, successfully synthesizing an inductor for a voltage range up to 400V. The circuit is then experimentally used as a shunt to mitigate the vibrations of a small flexible cantilever beam.

REFERENCES

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