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A SCALABLE PIEZOELECTRIC IMPULSE-EXCITED GENERATOR FOR RANDOM LOW FREQUENCY EXCITATION

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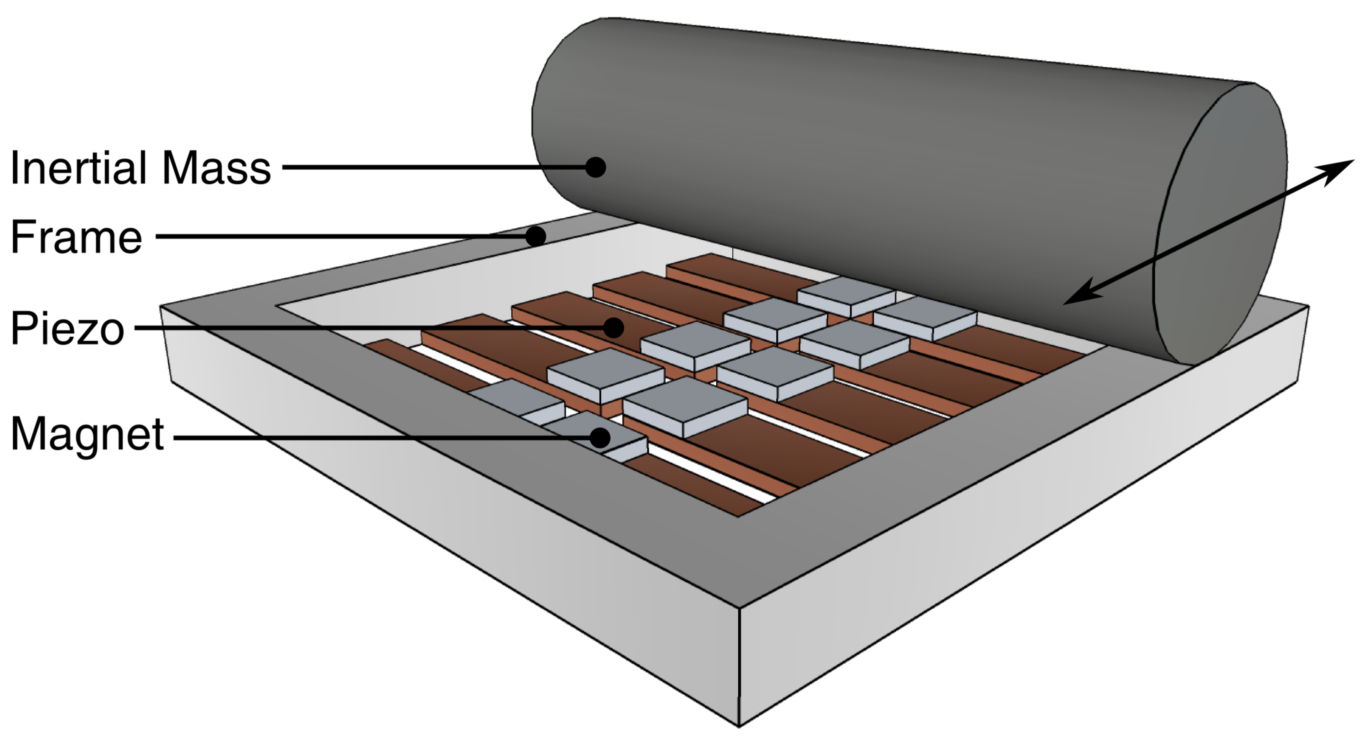
Introduction

- Random, low frequency motion is typical for human movements
- The excitation amplitudes are usually much larger than the displacement limit Z_L
- For these conditions resonant energy harvesters are not ideal
- This poster presents a non-resonant approach for low frequency, large amplitude, non-harmonic vibrations

Impulse Excitation – Prototype



- In theory the maximal power output is given as [1]:

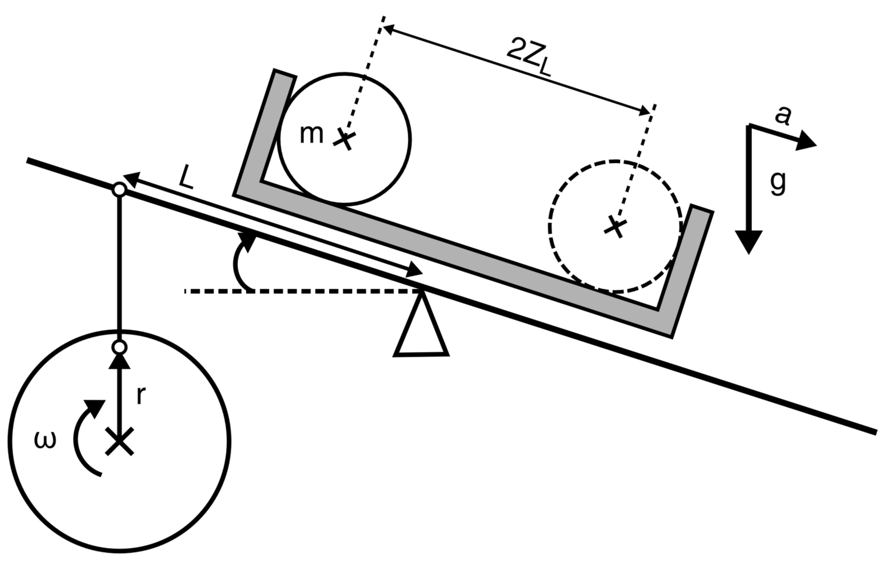
$$P_{max} = \pi f a_0 Z_L m$$

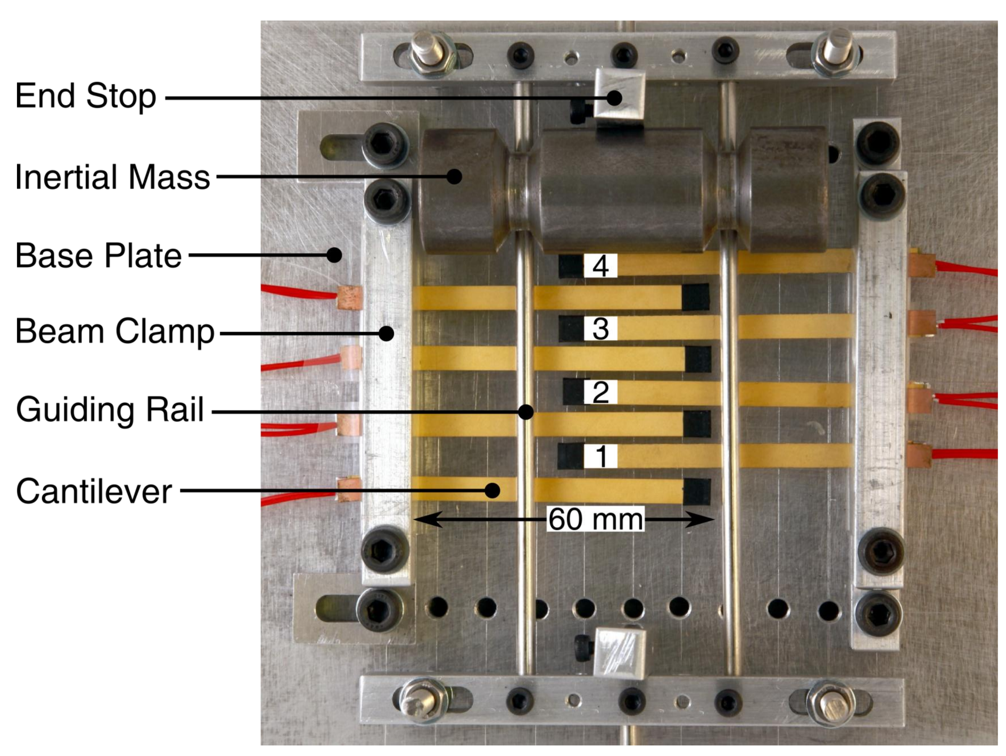
(f, excitation frequency - a_0, external acceleration - Z_L, displacement limit - m, mass)

- A larger proof mass (steel cylinder) increases the power output
- A series of piezoelectric bimorphs constitutes a distributed transduction mechanism
- A permanent magnet, bonded to the tip, snaps to the proof mass as it passes and actuates the beams
- The electromechanical coupling is improved because the beams are left to vibrate at their natural frequency after release
- The maximal power output is lower compared to a tuned resonant device, but operation over a large bandwidth can be achieved
- Perpendicular directions of travel and transducer actuation, segmented transduction and a rolling proof mass are novelties compared to other impulse-excited designs [2], [3]

Measurement Setup

- Frequencies from 0.33 Hz to 2 Hz on a rocking table
- $a(t) = a_0 \sin(\omega t)$
- Impedance matched resistive load of 120 kΩ
- 30 nF capacitance for each single beam

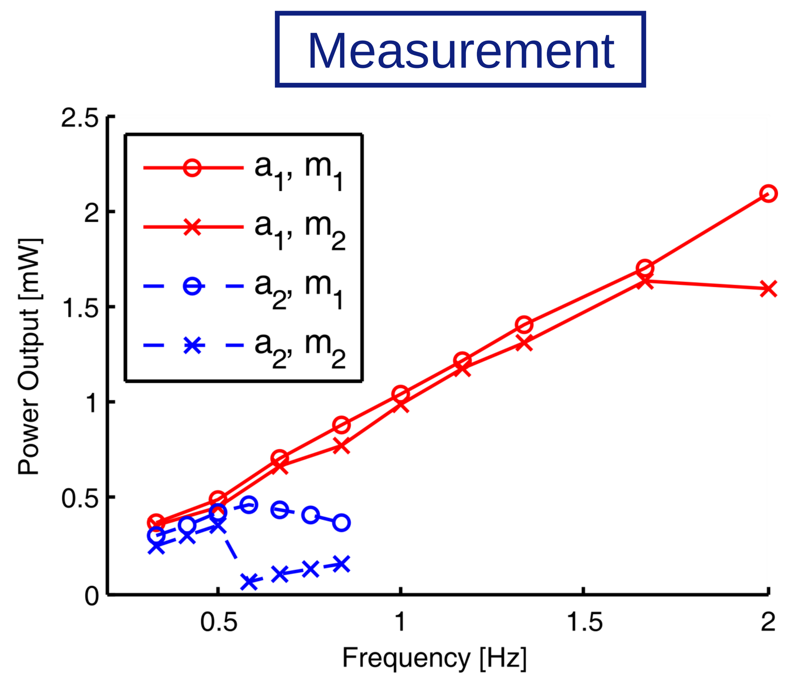


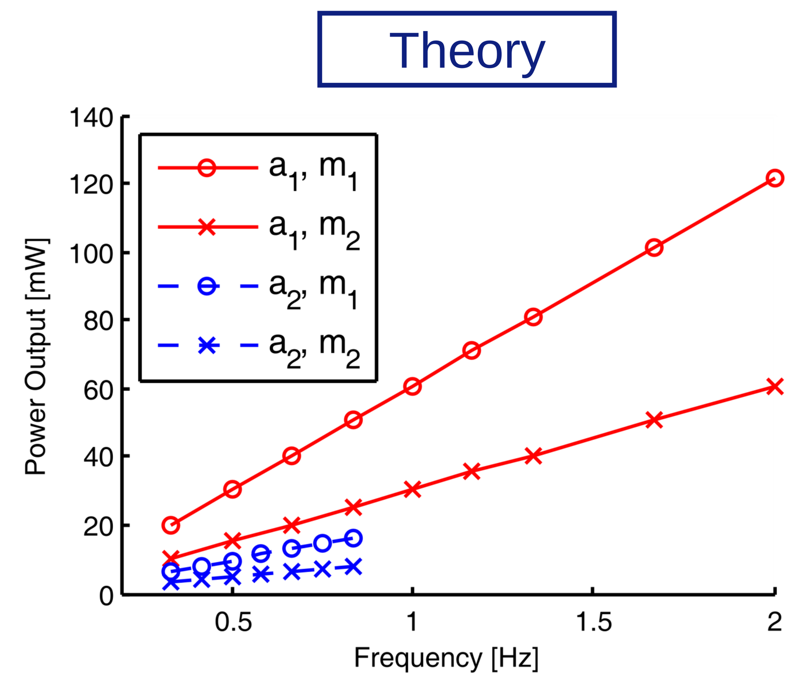


4 Configurations with:

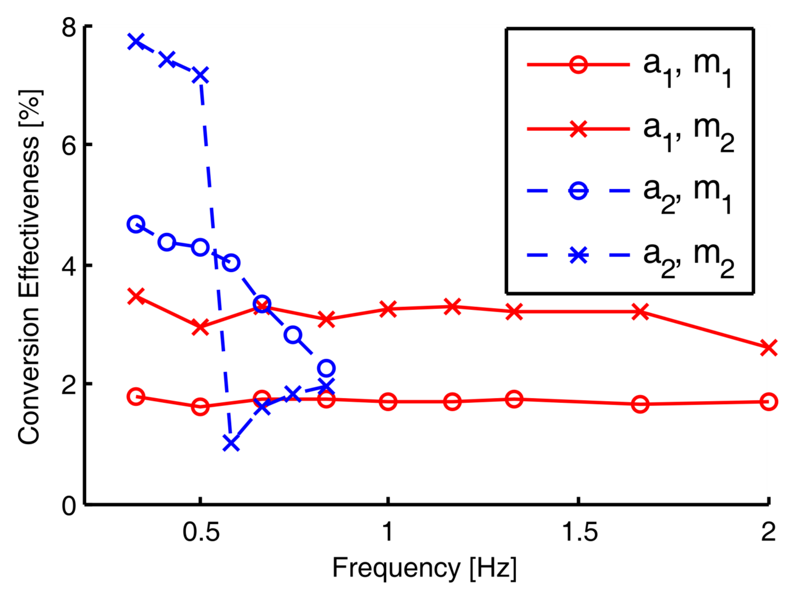
- **$a_1 = 2.72\ m/s^2$**
- **$a_2 = 0.873\ m/s^2$**
- **$m_1 = 285\ g$**
- **$m_2 = 143\ g$**

Experimental Results

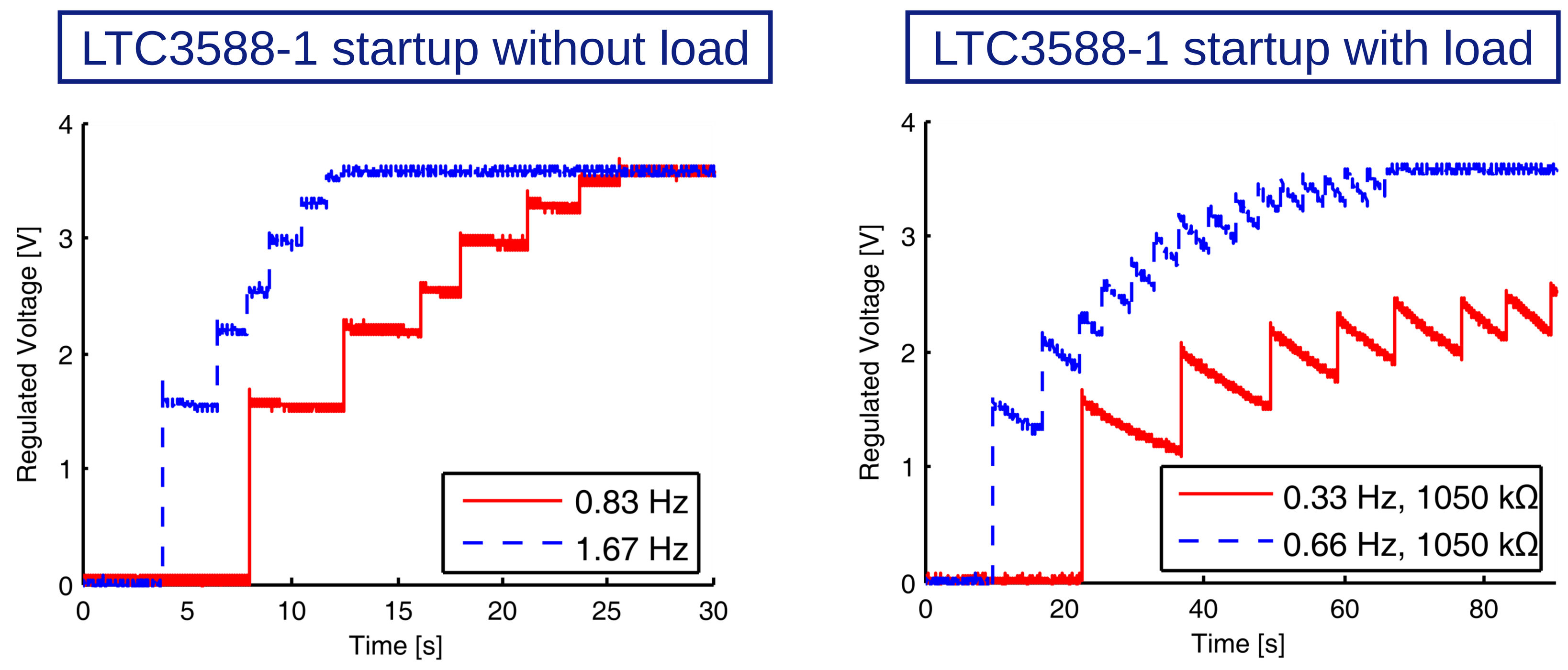




- In theory a higher proof mass and acceleration do have an advantage
- The experiments show that the transduction mechanism is not able to extract all the additional energy stored in the proof mass



- A larger acceleration extends the bandwidth for which the cylinder travels the full range (indicated by the breaking points in the lines)
- The conversion effectiveness is best when the proof mass barely reaches the end stops
- The effectiveness stays almost constant across a large frequency range



- Time to reach the target voltage depends on the excitation
- If the load current is too high, the regulator never reaches the target
- Best regulator efficiency was only around 40%

Conclusions

- Large range of frequencies (up to six fold in our experiments)
- Transduction mechanism needs to be matched to the design, but this can easily be done by changing the geometry of the beams
- Losses due to power conversion circuitry can not be neglected
- Power density of 3.8 to 13 μW per cm^3 with proof mass m_2
- Design can easily be scaled down

Acknowledgements

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References

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