Wideband capacitive Energy Harvester Based On Mechanical Frequency-Up Conversion

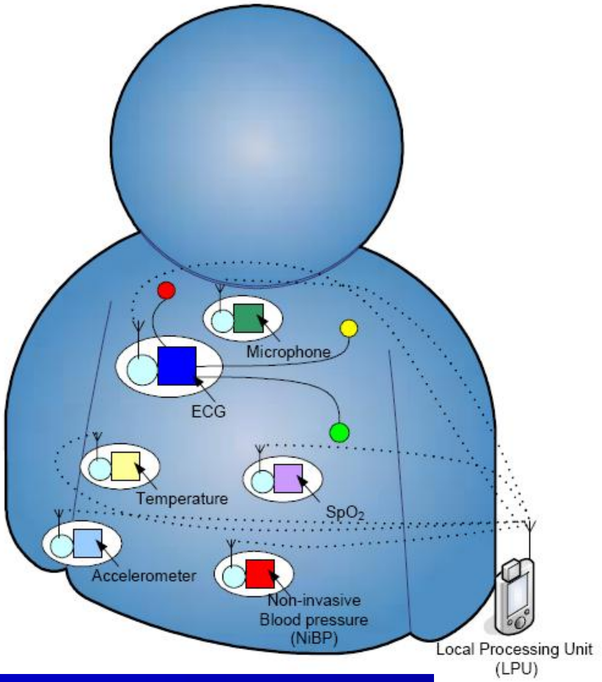
Salar Chamanian

University of Tabriz

outline

- Introduction
- Damping mode
- Bistable structure & Snap through
- Frequency up conversion system
- Conclusion
- Future work

introduction

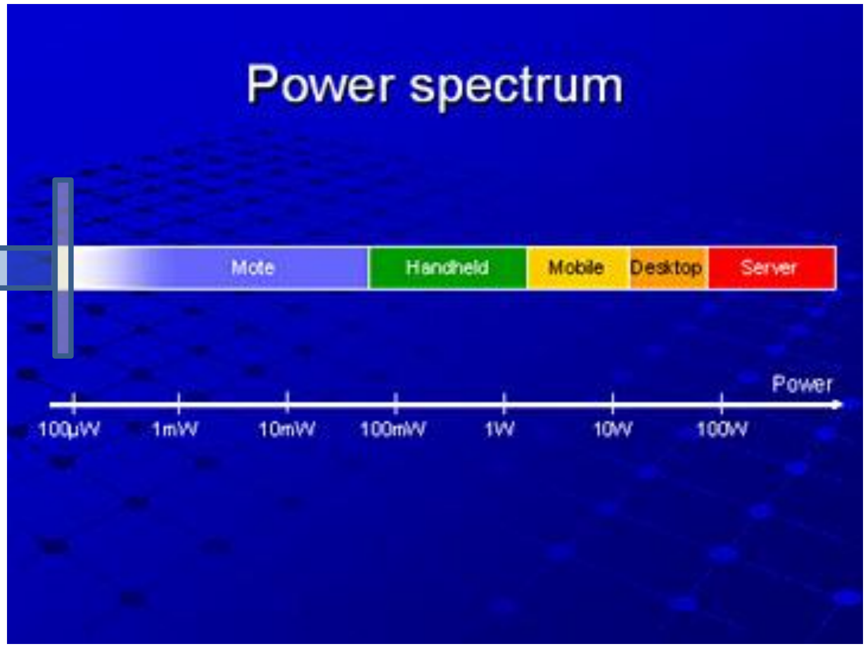


Mobile power:

Wireless sensor network(WSN)

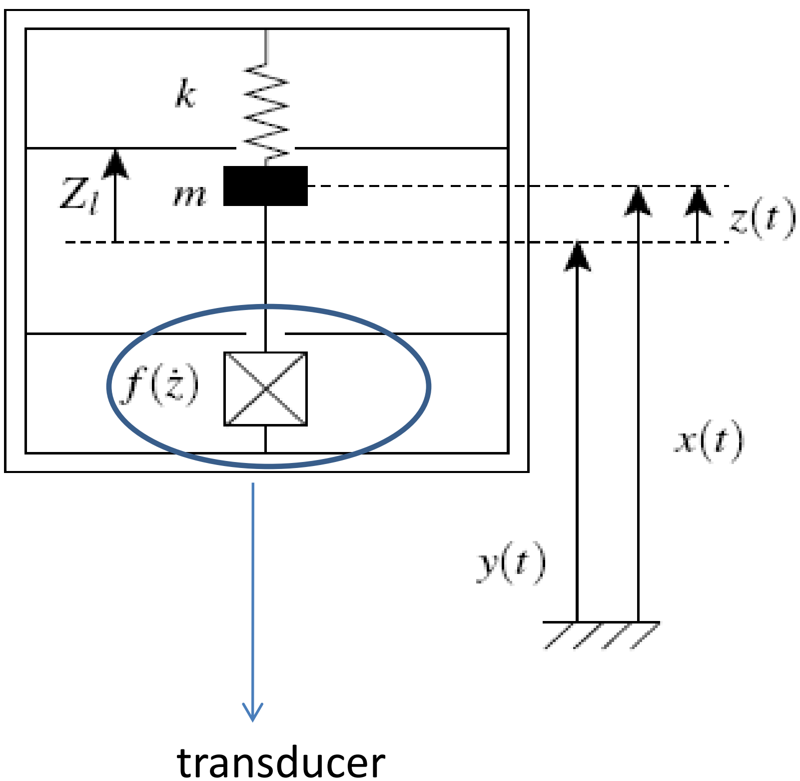
- ***Body sensor network(BSN) and medical applications***
- Structural monitoring
- Environmental monitoring
- Military applications
- Other electronics

low power nodes



Inertial generator

sinusoidal force: $F\sin(\omega t)$

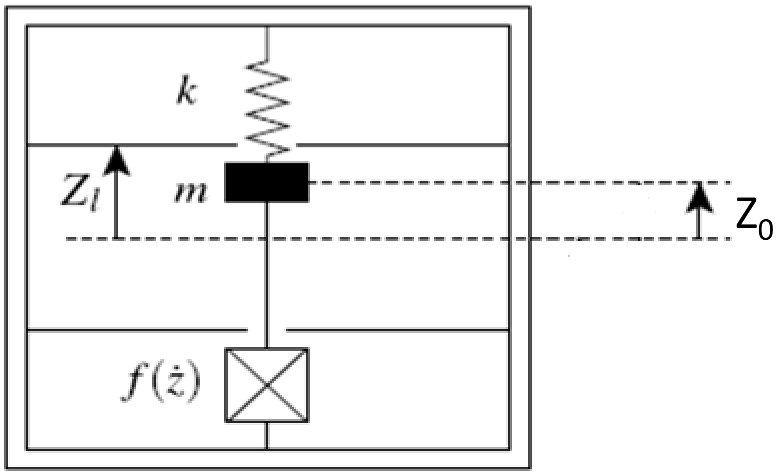


$$P_{out} \propto m\omega^3 Y^2$$

m : mass proof
ω : source frequency
Y : amplitude of vibration source
X : oscillation amplitude

- Power would be largest when system is close to resonance $\omega = \omega_n$
- Maximum flow to electrical domain $\zeta_e = \zeta_m$
- Z_l movement limitation

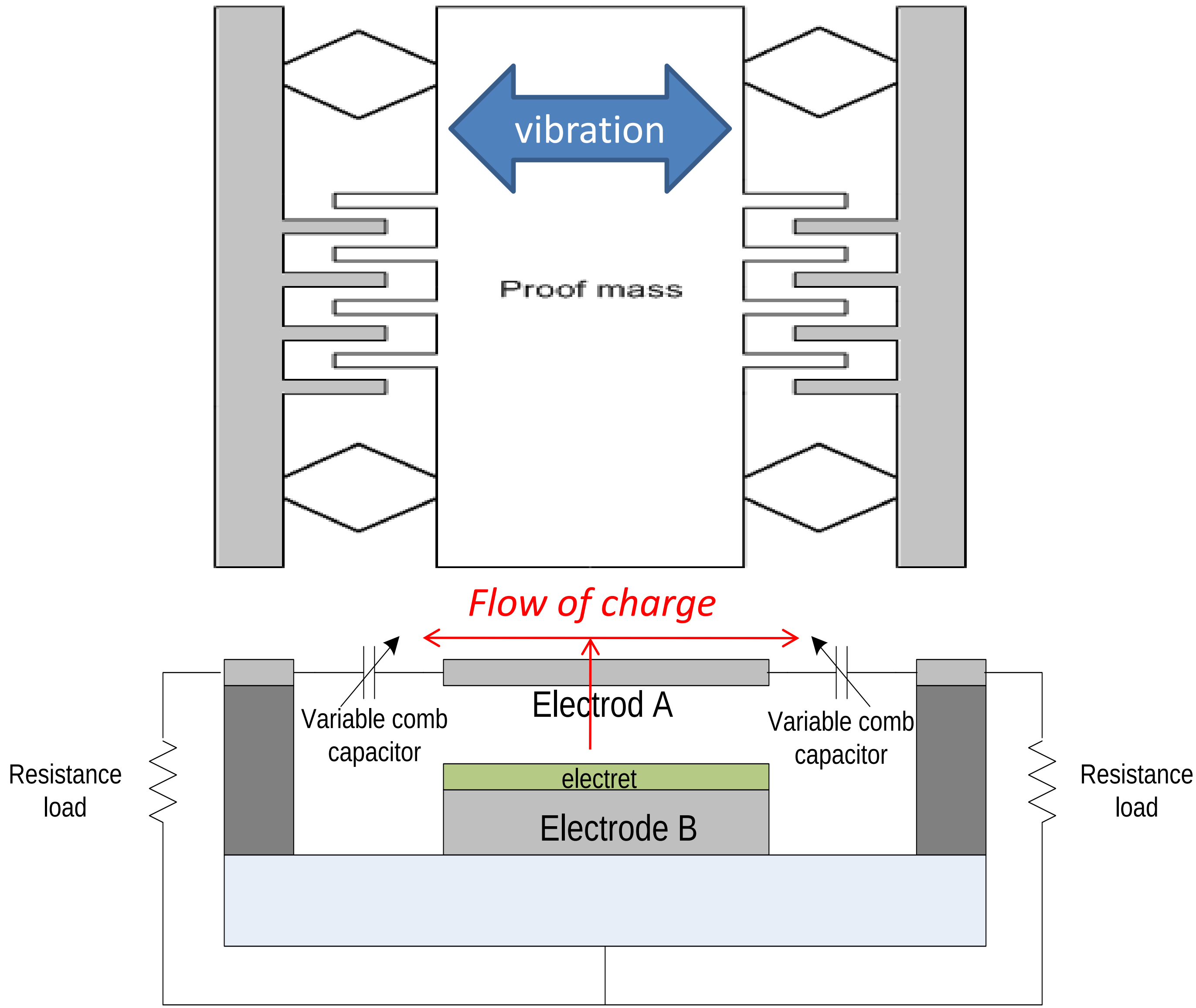
Initial displacement: Z_0

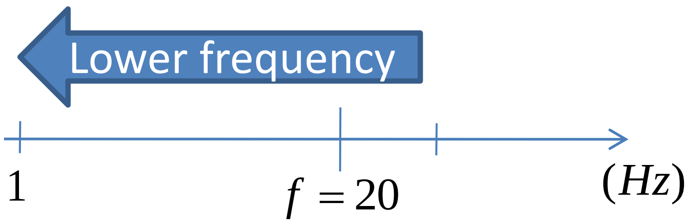


$$P_{out} \propto m{Z_0}^2{\omega_n}^3$$

- There is no frequency match problem
- $\zeta = \zeta_e + \zeta_m$
maximum power: larger ζ_e & lower ζ_m
- Maximum power delivery to electrical load

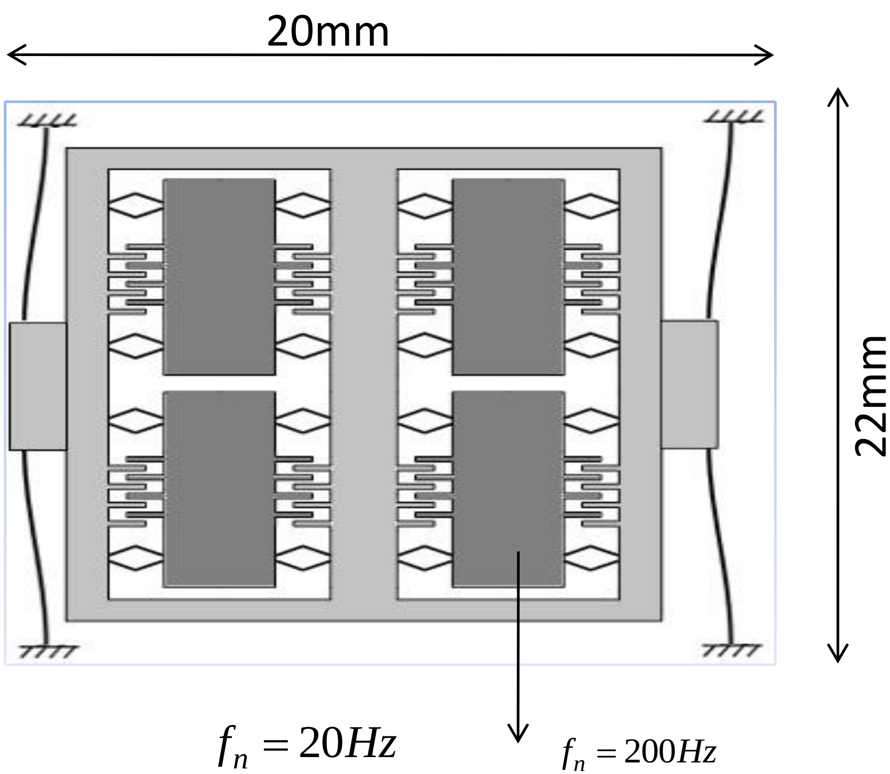
Electrostatic transducer
: Electret capacitive convertor

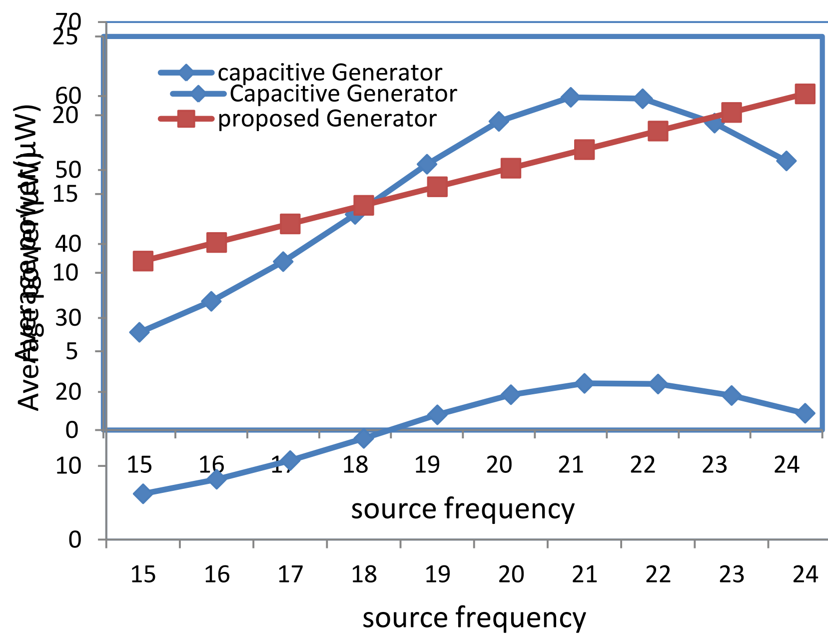




Source frequency

Average Output Power

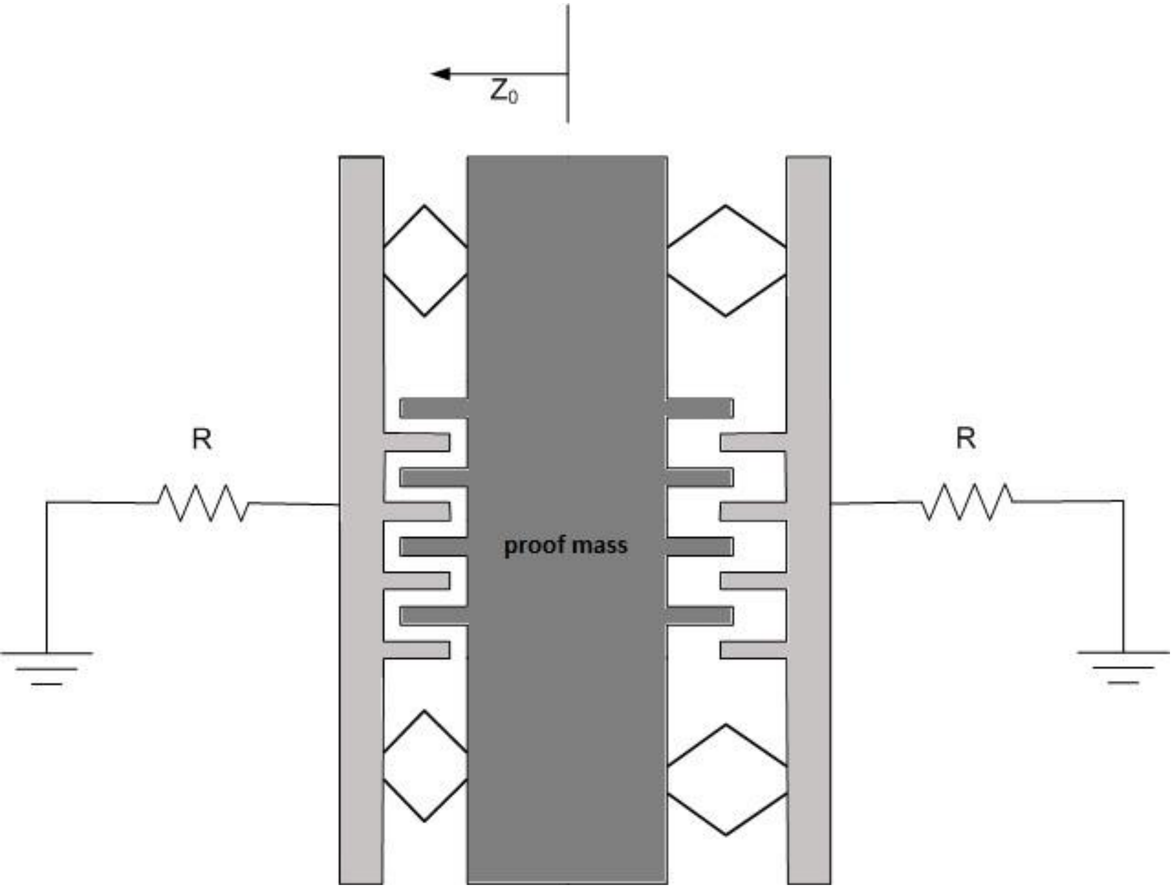




Work in damping mode

Damping mode of capacitive generator

initial displacement is applied



Dynamic equation:

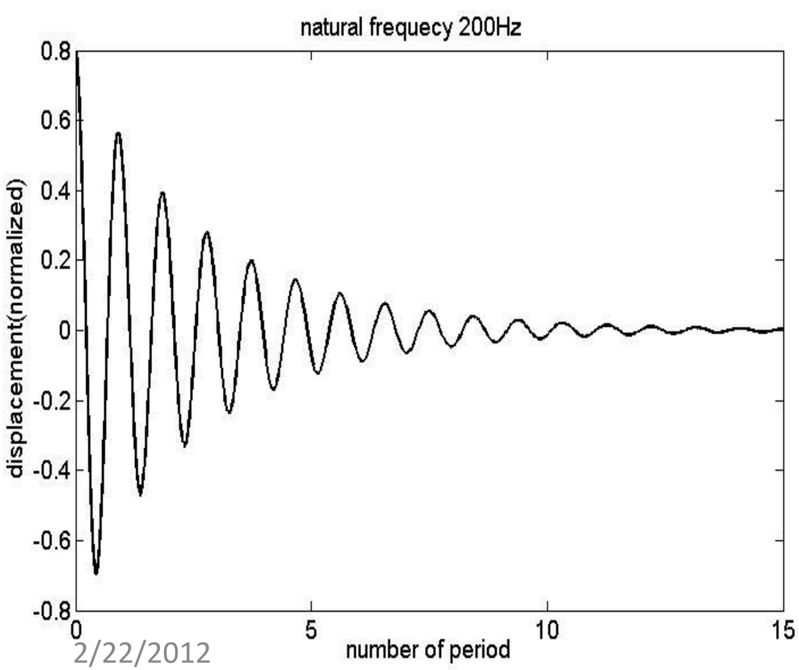
$$m\ddot{z}(t) + d\dot{z}(t) + kz(t) = F_E$$
$$z(0) = Z_0$$

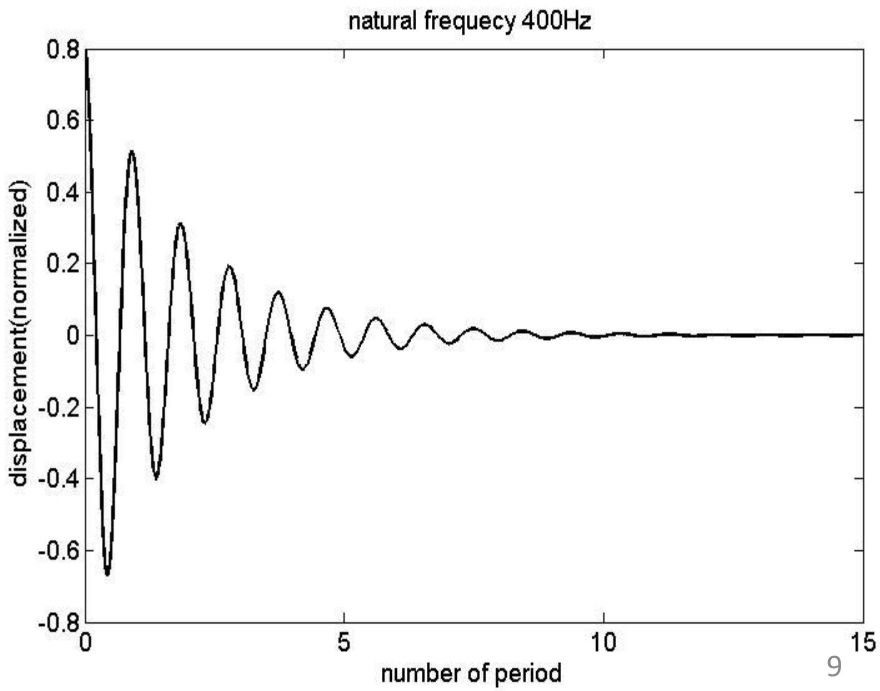
$$R\dot{q}_{C1} = V_{C1}(q_1, z) + V_{Electret}$$
$$R\dot{q}_{C2} = V_{C2}(q_2, z) + V_{Electret}$$

Natural frequency	200 Hz	400Hz
Allowable displacement	150 µm	70 µm
Area	9×8 mm^2	7×5mm^2
Ratio of initial displacement	0.8	0.8

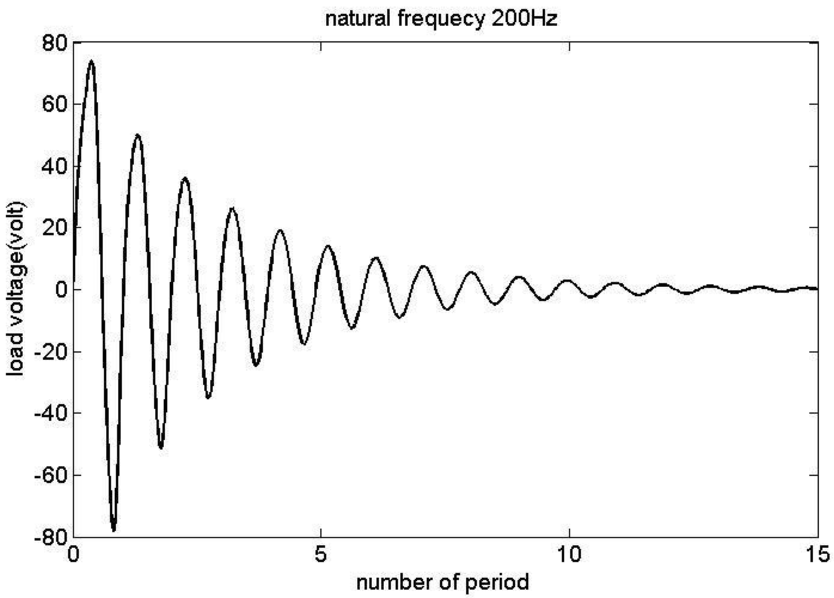
electrical damping >> mechanical damping

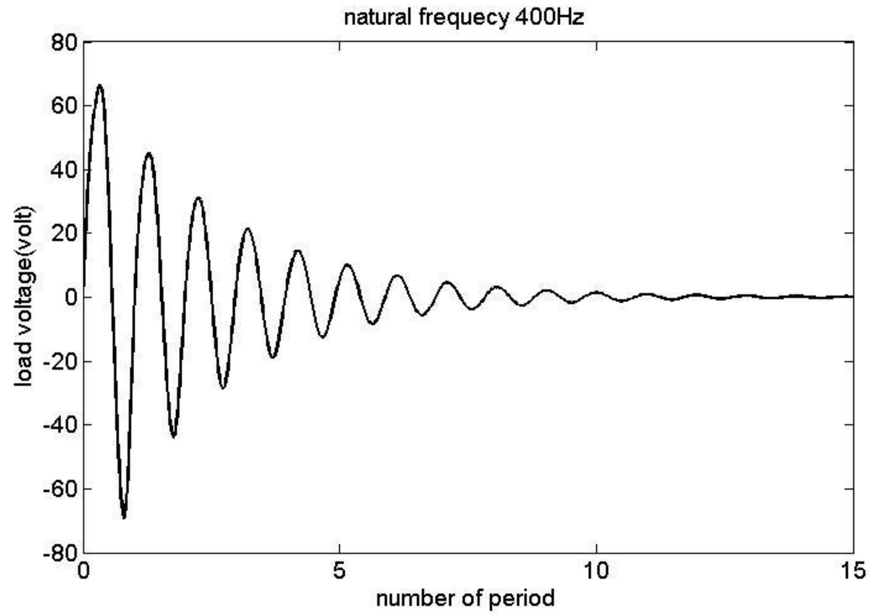
Electrical damping causes most of damping and converts to electrical power



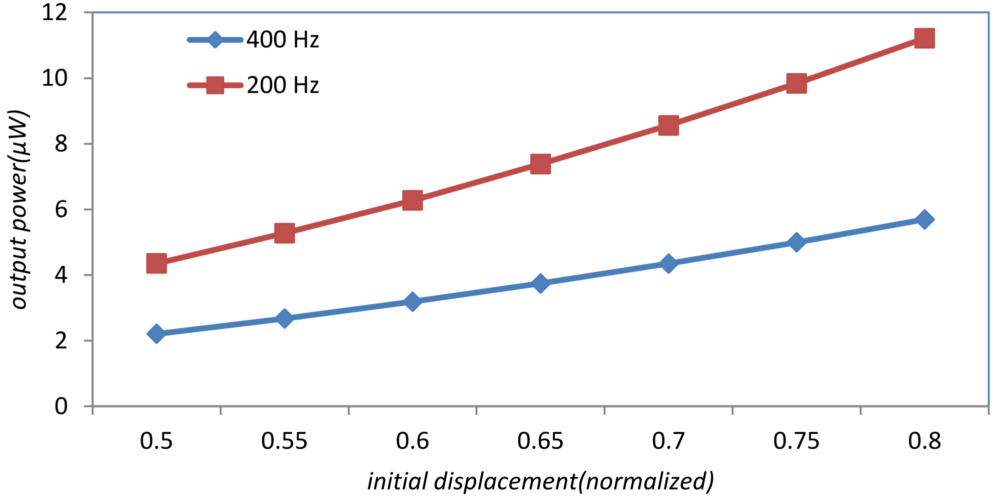


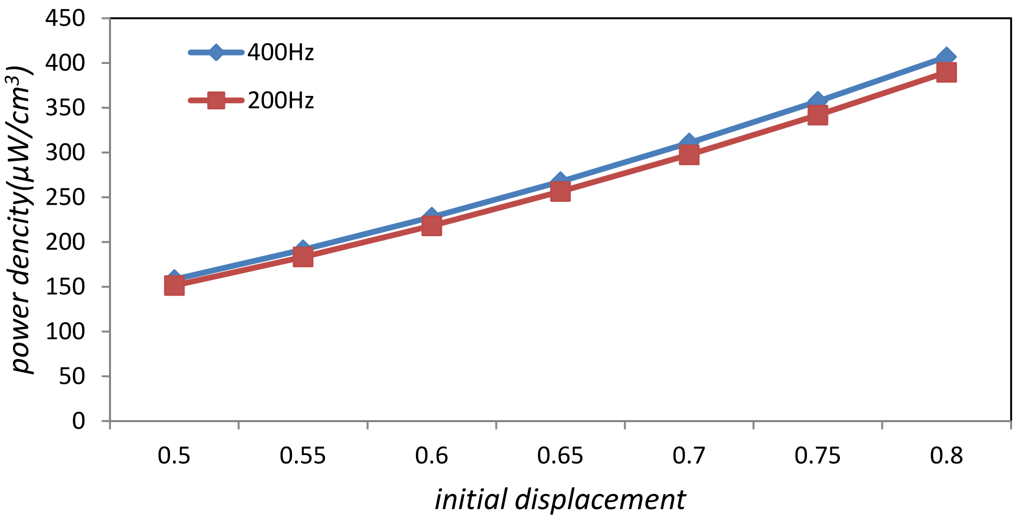
voltage level on external load (resistance load)





Average power in 0.05s (20Hz)

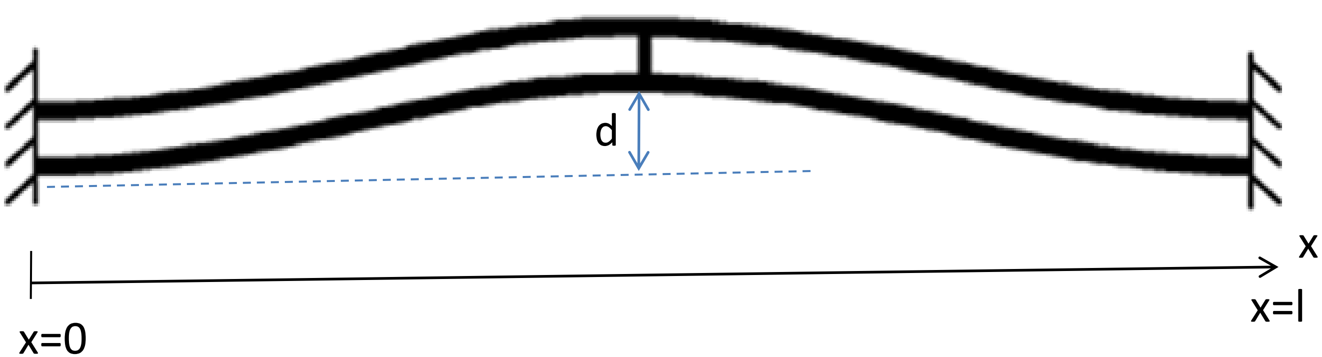




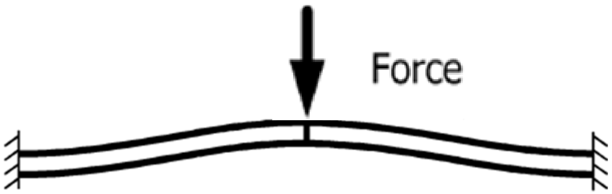
Bistable structure and ***Snap through***

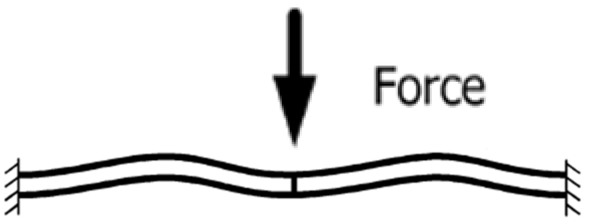
Centrally clamped parallel beam mechanism

$$\textit{Initial shape :}\ \frac{d}{2}(1-\cos(\frac{2x\pi}{l}))$$

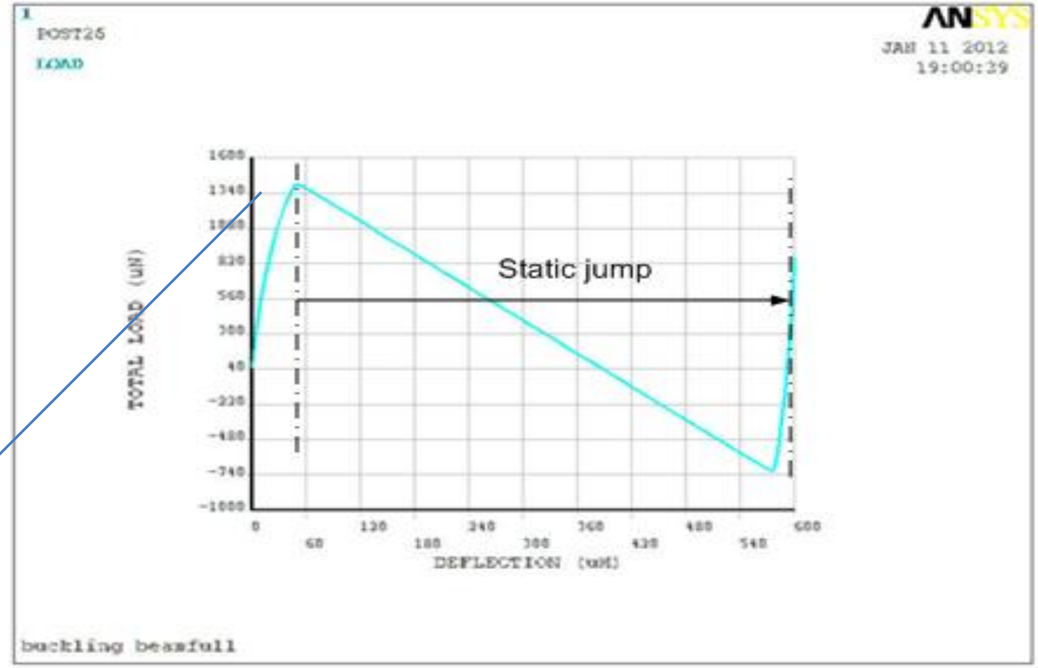


There is no stress in initial shape



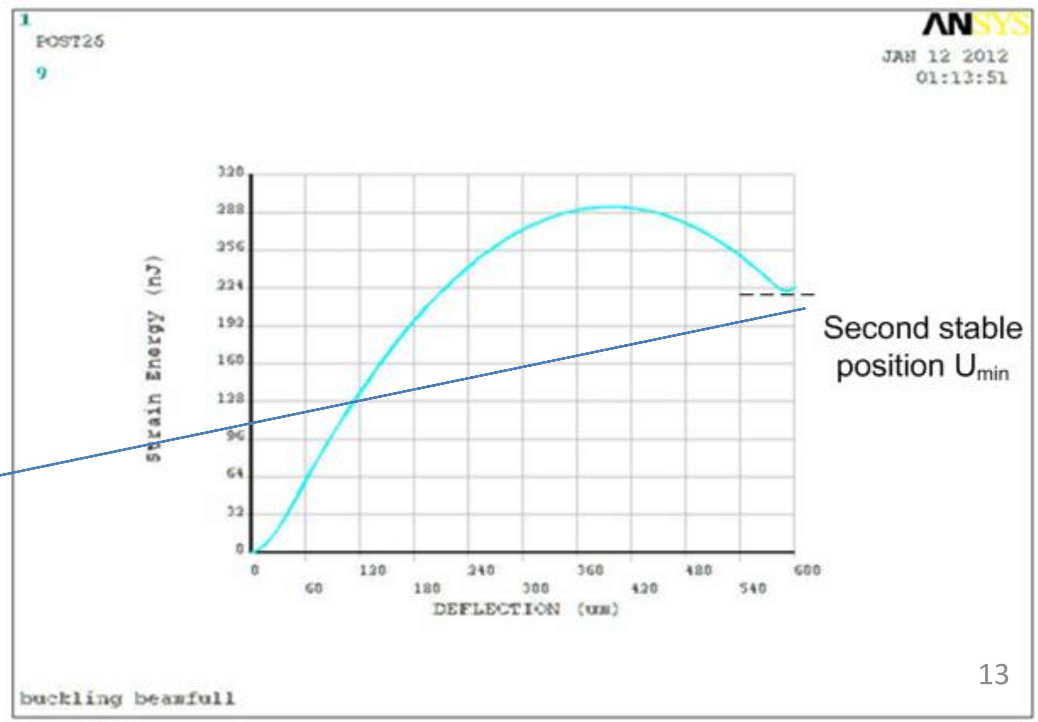


$$F_{\max} = 1516\frac{EId}{l^3} = 1340\mu N$$



Snap through to second stable position

Large acceleration

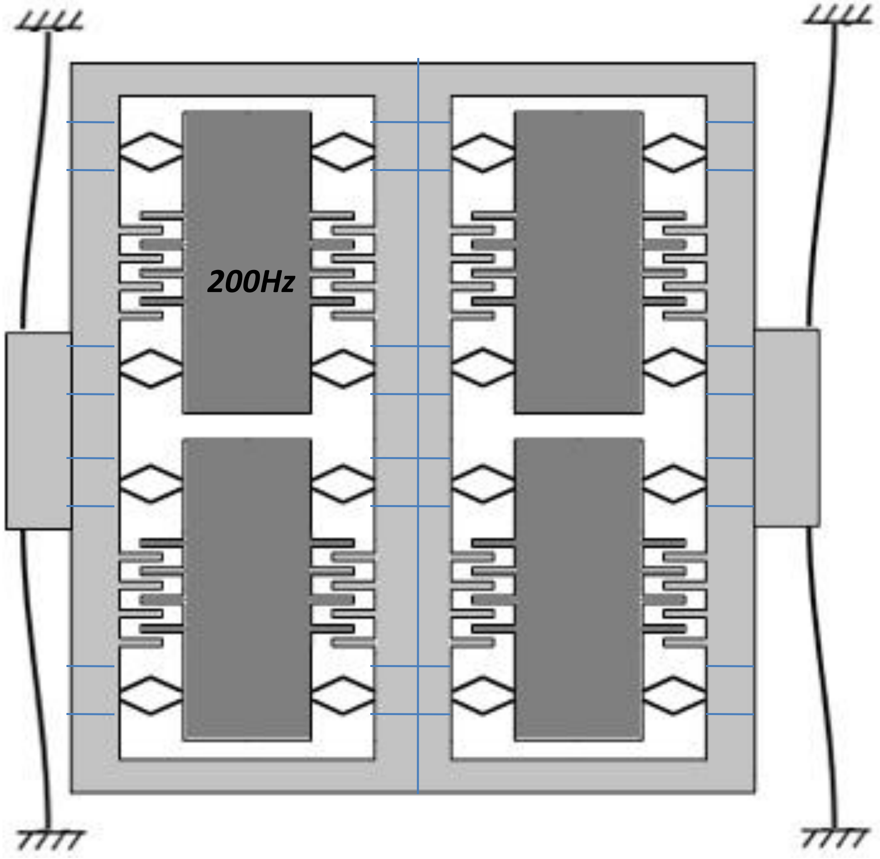


Frequency up conversion systems

In same occupied area with 20Hz electret generator

Total system is composed of :

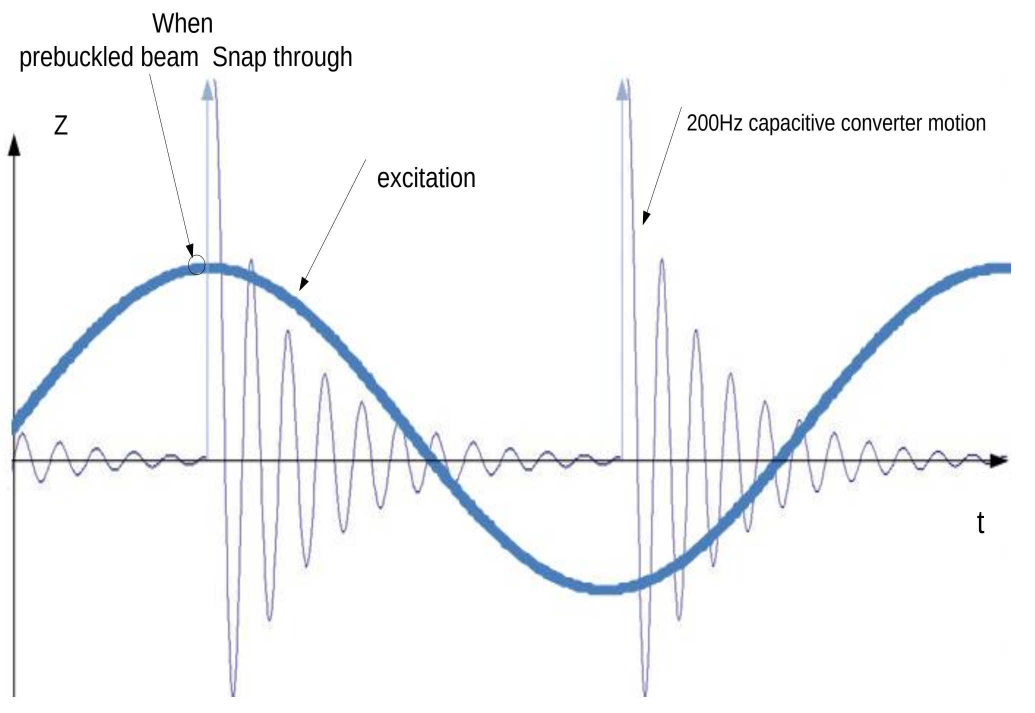
- *four 200Hz generators*
- *Precurved-beam bistable mechanism*



Excepted output

sinusoidal Vibration excitation :
with acceleration >3.65m/s^2 @ 20Hz
(the minimum acceleration is determined by the force is needed to snap through happen)

Scaled Expected Output:



Natural Frequency	200Hz	400Hz
Allowable displacement	150 µm	70 µm
Number of subsystem	4	8
Number of actuated in 1period	2	2
Ratio of Initial displacement	0.6	0.6
Sub power(µwatt)	6.28 µW	3.4 µW
Total power(µwatt)	50.24 µW	54.4 µW

4 times actuated in one period :
output power=108 µW

comparison

Output power of 400Hz is more
But for 400Hz is complicated

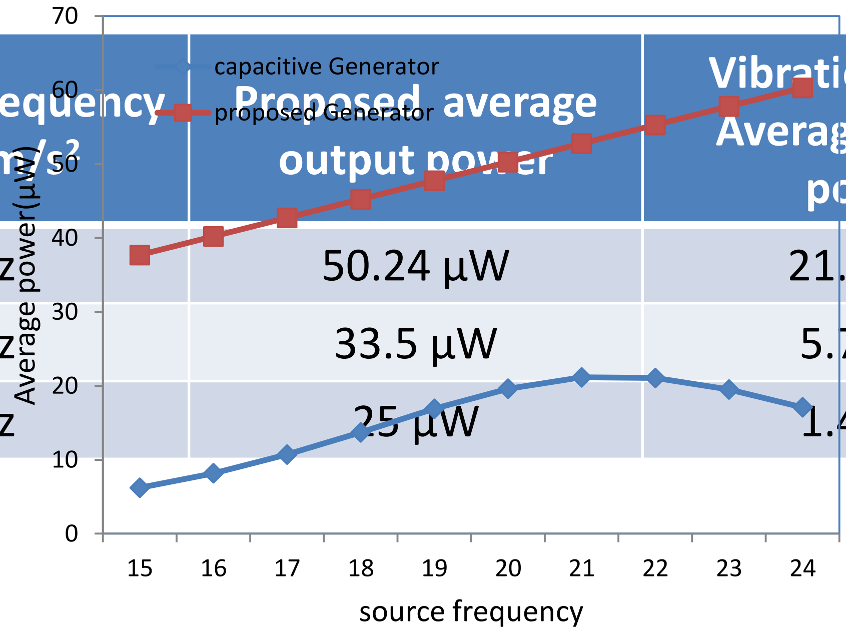
System with
natural frequency of 200Hz

Initial displacement	Average total output power(µW)
0.65	60
0.7	68.4
0.75	78.5
0.8	89.5

Comparison in lower frequency

Assumptions:
we considered acceleration magnitude is relatively constant in lower frequencies

Excitation frequency $a=3.65\ m/s^2$	Proposed average output power	Vibration driven Average output power
20 Hz	50.24 µW	21.7 µW
15 Hz	33.5 µW	5.7 µW
10 Hz	25 µW	1.4 µW



Conclusions

- We could propose a frequency up conversion for capacitive generators by using precurved bistable structure.
- There is no need to tune the external excitation to resonance frequency to obtain optimum power.
- In frequency up conversion system more power can be obtained in wideband frequency.
- For low frequency vibration sources, this structure can be used to enhance power density, for example : energy harvesting from body motions which common electrostatic generators need more large volume to adjust with source frequency.

Future works

- We must fabricate system and get experimental data and compare with expected characteristics of system.
- In order to power load circuits we need to Design power management circuit.
- We would design quadrstable mechanism for frequency up conversion to able excite system 4 times in one period of input vibration

Thank You