Mechanical Energy Storage for Energy Harvesting

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One Problem of Energy Harvesting.

When doing energy harvesting, one main problem arise:

- You can never harvest energy and directly use it to drive a load, since, usually, you do not harvest too much.

This problem is easily solved this way:

- storing every little amount of harvested energy and than using it to drive a load.

As a matter of fact, usually, the storage is a capacitor.

Capacitors as Batteries.
Pros and cons.

- Pros:
  - Straightforward solution;
  - It works: circuits driven this way already exist.
- Cons:
  - Some harvested energy is loss due to an extra heating of the system and to self-discharging of the capacitor itself

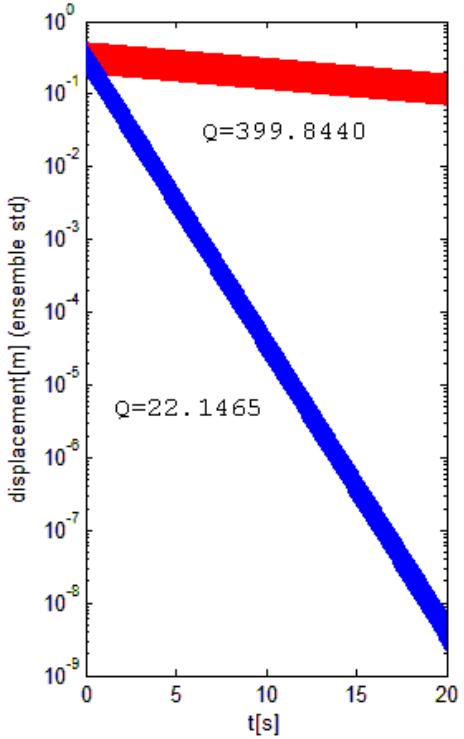
Piezoelectric Oscillators as Batteries(1).

Pros and cons.

From now on we suppose to harvest mechanical energy with piezoelectric oscillators.
Since we use oscillators as harvesters, why not using them also as batteries?

- Pros:
  - No capacitor needed;
  - No extra energy loss due to thermodynamic or electrical effects.
- Cons:
  - What does it means "oscillators as batteries"?
  - Does it work?

Piezoelectric Oscillators as Batteries(2).



Red line= displacement std without load.
Blue line= displacement std with load.

Main purpose:

- A load must be driven for some time only with piezoelectric oscillators.

Initial hypothesis:

1. A lot of oscillators with a very low mechanical damping (γ).
2. Noise limited in time.
3. Oscillators in a steady state at $t = 0s$.
4. An oscillator plugged into a load will dampen very fast.

Piezoelectric Oscillators as Batteries(3).

- 2 and 3 $\Rightarrow$when noise ends each oscillator has a certain amount of mechanical energy E.
- 1 $\Rightarrow$ for oscillators unplugged into the load, energy E is "constant" in time, i. e. the oscillator is storing E like a battery. The slow mechanical damping $\equiv$ self-discharging of the battery.
- 4 $\Rightarrow$ a plugged oscillator convert fast E into electrical energy that can be used to drive a load with low power for a short time.

Algorithms for plugging oscillators into the load so to have high averaged power for long times are needed.

Criteria for Oscillators-Sum Algorithms.

Oscillators-sum algorithms generation. As starting point, you must:

- Define exactly what you know about plugging timing (t_l) and number of oscillators plugged (n_l).
- Chose between time and ensemble averages so to avoid strong dependencies in initial boundary conditions.
- Impose constrains regarding system's output so that unknown parameters can be calculated.

The two set of t_ls and n_ls obtained with this procedure represents an oscillators-sum algorithm. Its usefulness must be tested with both simulations and measurements.

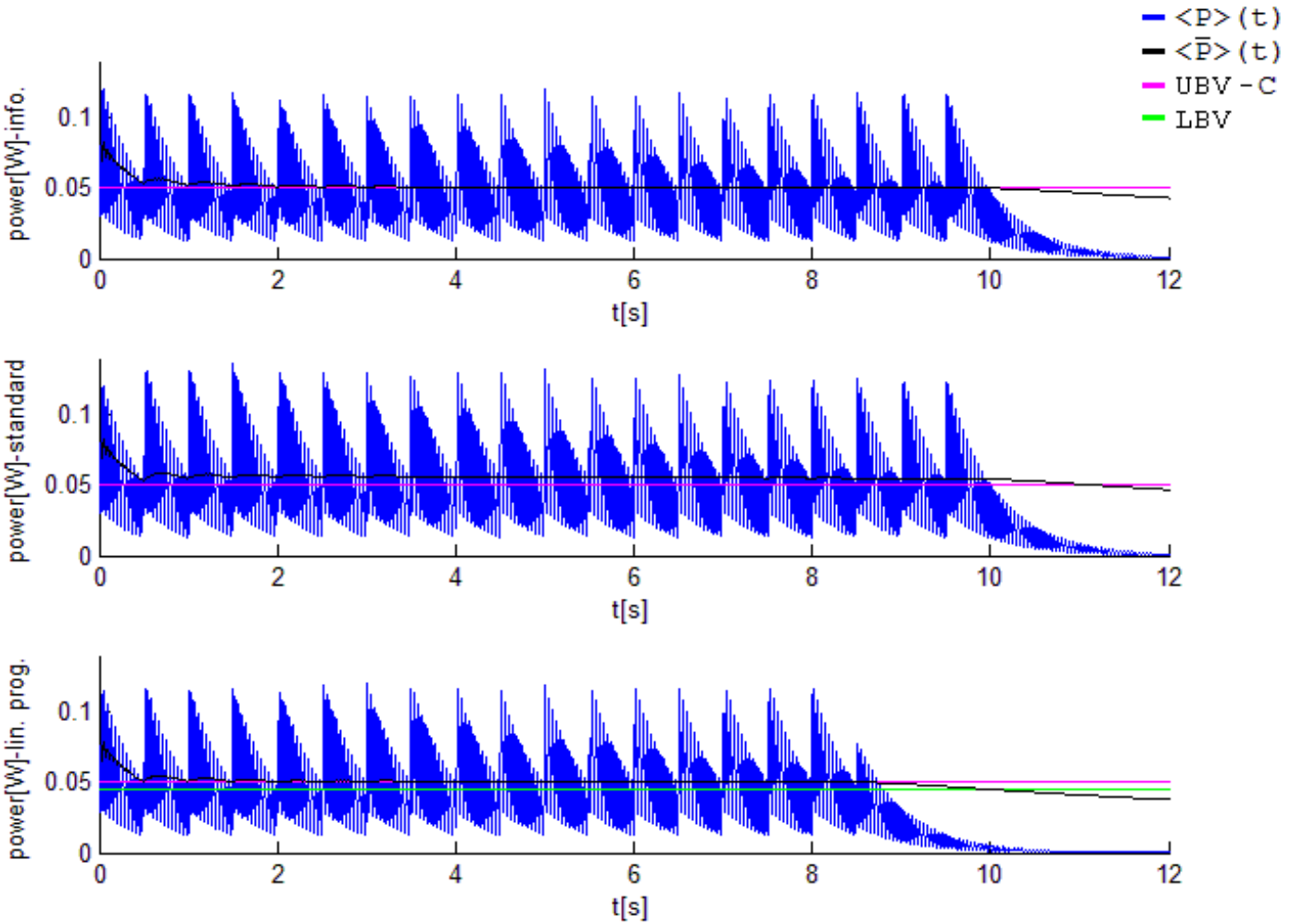
Our Choices.

- n_ls unknowns; $t_l = l\Delta t$, $l = 0,1,...s$, Δt fixed.
- Time averaged power is used $\left(\bar{P}(t) = \frac{\int_0^t P(j)dj}{t}\right)$.
- Constrains are of the form
  $\bar{P}(t_{l'}) = C$
  $\forall l' | 1 \leq l' \leq s+1$ or
  $\bar{P}(t_{l'}) \in [UBV; LBV]$
  $\forall l' | 1 \leq l' \leq s+1$

Symbol	Value
h	$0.0005s$
T	$20s$
Δt	$0.5s$
m	$0.0155Kg$
E	$5J$
ω_0	$40Hz$
γ	$0.05\ \frac{Ns}{m}$
$\frac{Kv}{m}$	$1.85\ \frac{N}{VKg}$
Kc	$1.859 * 10^2\ \frac{V}{m}$
R	$40M\Omega$
C_p	$10^{-8}F$
$C = UBV$	$0.05W$
LBV	$0.045W$

Simulations' Results(1).

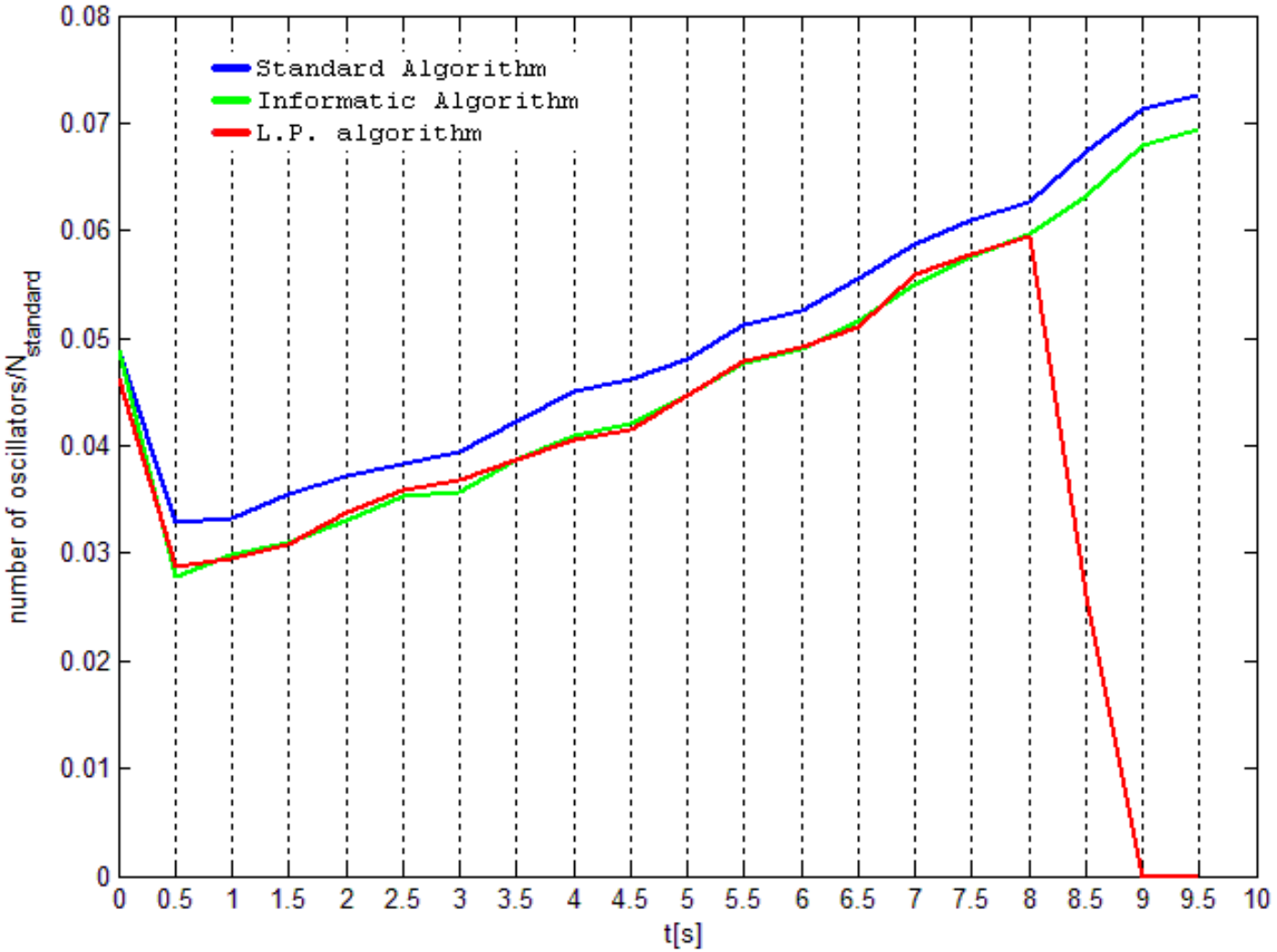
Power Issues.



Simulations' Results(2).

Economical issues.

$N_{standard} \approx 140,\ N_{info} \approx 130 = 0.929 N_{standard},\ N_{LP} \approx 106 = 0.755 N_{standard}$



Summary.

- Oscillators as energy storages instead of capacitors.
- Algorithms for plugging oscillators into a load so to have high power for a long time.
- Driving loads with only oscillators was theoretically demonstrated with simulations.

- future “to do”s
  - Develop more algorithms making different initial choices.
  - Test experimentally these theoretical results.