‘Powering IoT’

Real Vibrations Simulation Tools

USER MANUAL

Francesco Cottone

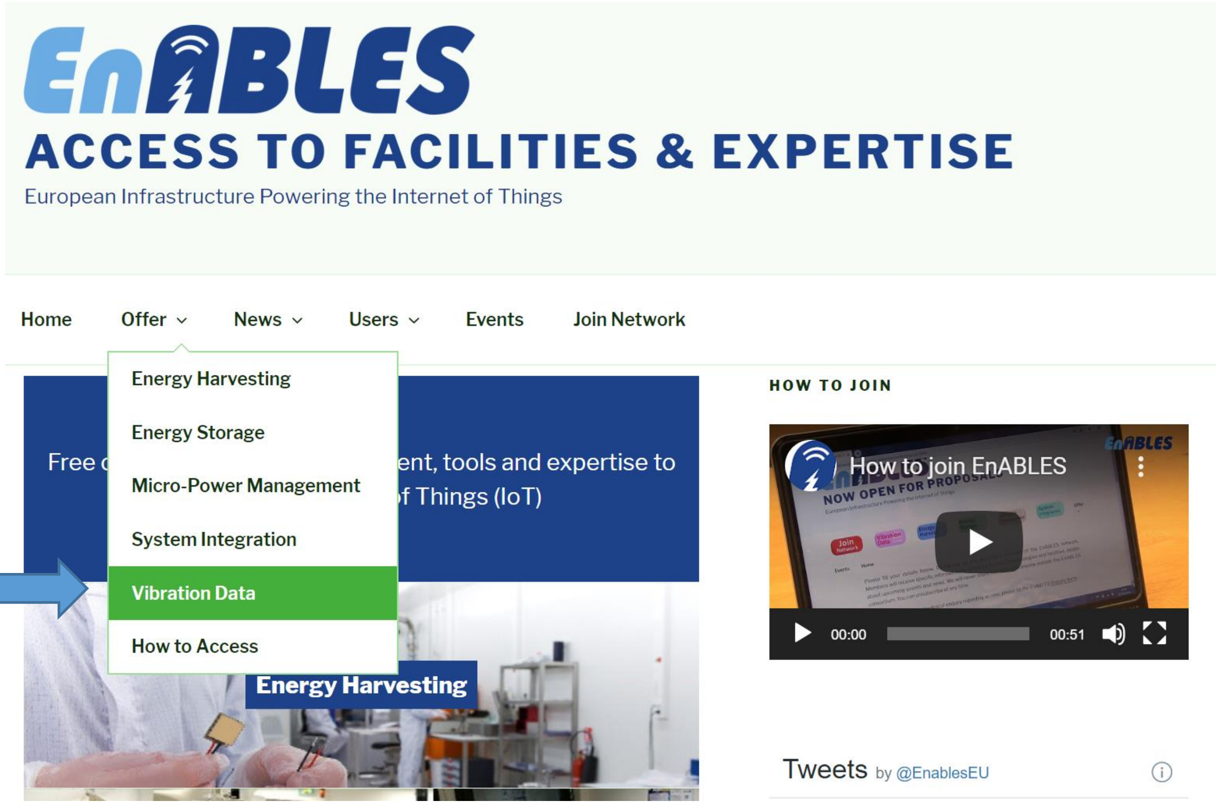
NiPS Lab– Dep. Physics ang Geology,

University of Perugia, Italy

UNIVERSITÀ DEGLI STUDI DI PERUGIA

How to access to Vibration Database

- Users are required to register from the EnABLES website https://www.enables-project.eu/ and agree to a usage agreement.
- Users are not required to register to view basic information about the dataset, but to download raw data a login is required.
- Once registered, users are able to log in, to access data and to download as much time series data as required without restrictions.



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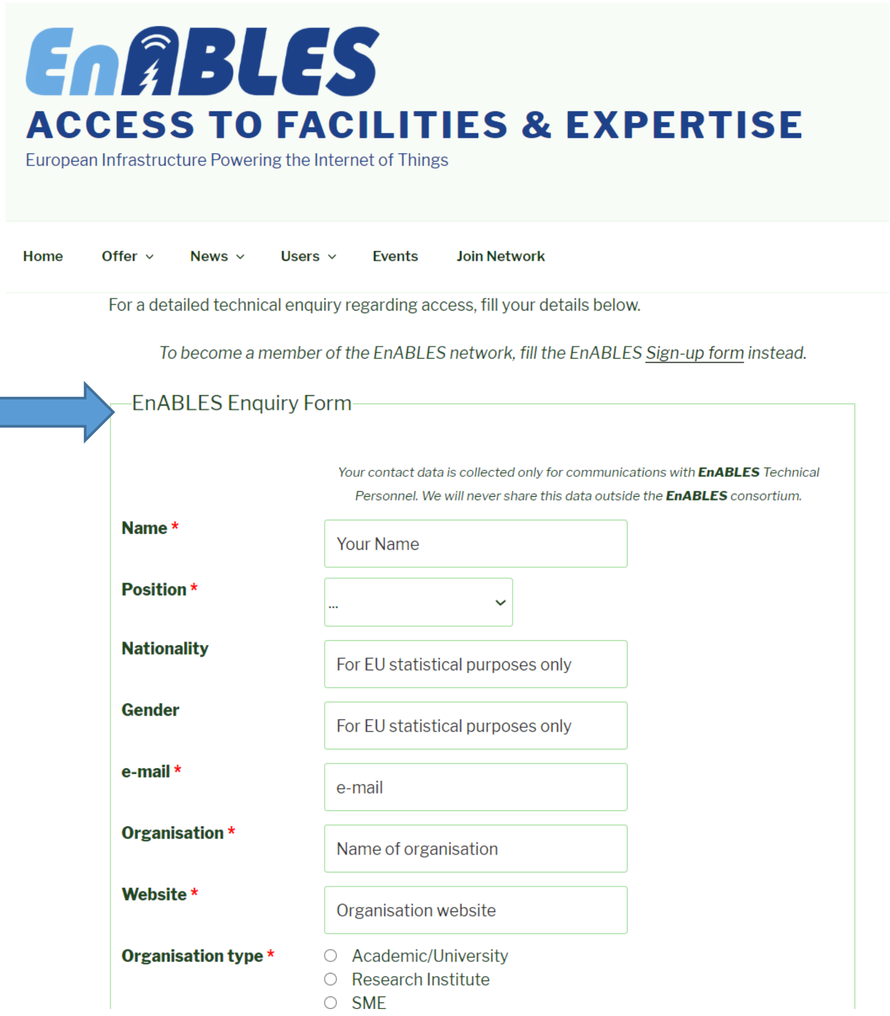


How to access to Vibration Database

- From the access webpage the users can choose the vibrations database developed by University of Southampton or Real Vibrations Database from University of Perugia.

- Now there is the direct link to the simulation tools totally free-of-charge for the EnABLES users.

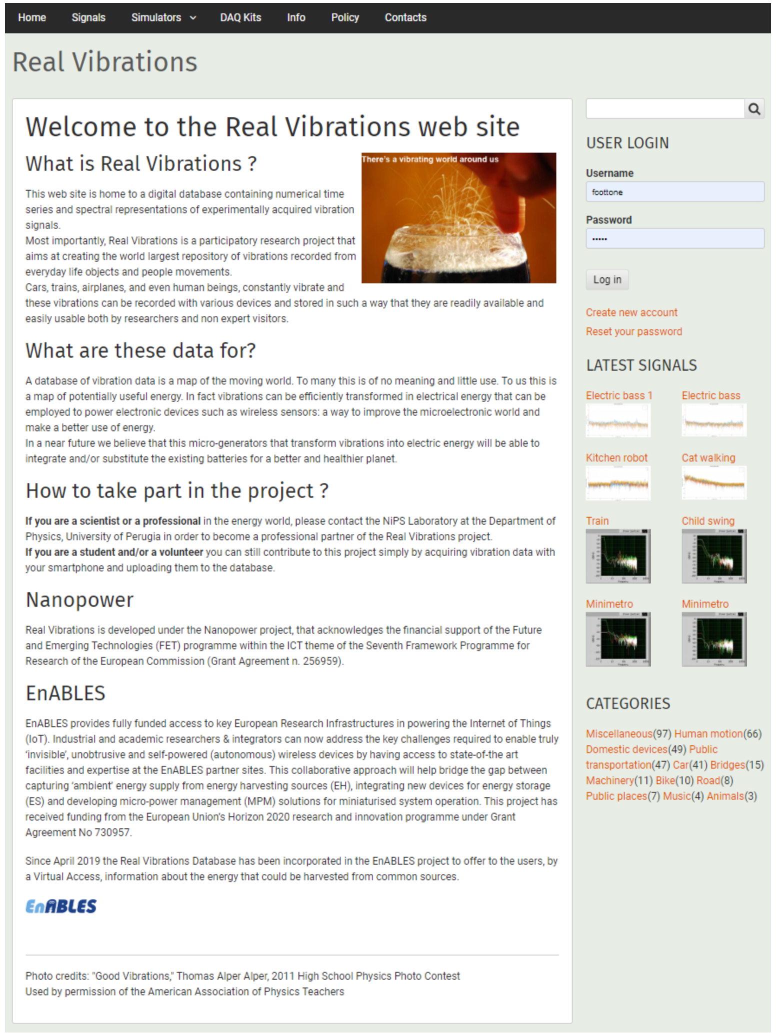
- Currently, two main simulators are available: the general transduction-independent vibration energy harvester and piezoelectric vibration harvester. However, thi toolset is under development so that new tools will be available soon!

Database access interface

Real Vibration Database

- The **RealVibration** database by **NiPS/UNIPG** is contains numerical time series and spectral representations of experimentally acquired vibration signals.
- Most importantly, Real Vibrations is a **participatory research project** so that under request o the administrator users can upload their recorded vibrations from everyday life.
- It includes: **cars**, **trains**, **airplanes**, and even **human beings**, recorded with various devices and readily available and easily usable both by researchers and non expert visitors.

https://realvibrations.nipslab.org/


Home Signals Simulators DAQ Kits Info Policy Contacts

Real Vibrations

Welcome to the Real Vibrations web site

What is Real Vibrations ?

This web site is home to a digital database containing numerical time series and spectral representations of experimentally acquired vibration signals.
Most importantly, Real Vibrations is a participatory research project that aims at creating the world largest repository of vibrations recorded from everyday life objects and people movements.
Cars, trains, airplanes, and even human beings, constantly vibrate and these vibrations can be recorded with various devices and stored in such a way that they are readily available and easily usable both by researchers and non expert visitors.

What are these data for?

A database of vibration data is a map of the moving world. To many this is of no meaning and little use. To us this is a map of potentially useful energy. In fact vibrations can be efficiently transformed in electrical energy that can be employed to power electronic devices such as wireless sensors: a way to improve the microelectronic world and make a better use of energy.
In a near future we believe that this micro-generators that transform vibrations into electric energy will be able to integrate and/or substitute the existing batteries for a better and healthier planet.

How to take part in the project ?

If you are a scientist or a professional in the energy world, please contact the NiPS Laboratory at the Department of Physics, University of Perugia in order to become a professional partner of the Real Vibrations project.
If you are a student and/or a volunteer you can still contribute to this project simply by acquiring vibration data with your smartphone and uploading them to the database.

Nanopower

Real Vibrations is developed under the Nanopower project, that acknowledges the financial support of the Future and Emerging Technologies (FET) programme within the ICT theme of the Seventh Framework Programme for Research of the European Commission (Grant Agreement n. 256959).

EnABLES

EnABLES provides fully funded access to key European Research Infrastructures in powering the Internet of Things (IoT). Industrial and academic researchers & integrators can now address the key challenges required to enable truly 'invisible', unobtrusive and self-powered (autonomous) wireless devices by having access to state-of-the art facilities and expertise at the EnABLES partner sites. This collaborative approach will help bridge the gap between capturing 'ambient' energy supply from energy harvesting sources (EH), integrating new devices for energy storage (ES) and developing micro-power management (MPM) solutions for miniaturised system operation. This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 730957.

Since April 2019 the Real Vibrations Database has been incorporated in the EnABLES project to offer to the users, by a Virtual Access, information about the energy that could be harvested from common sources.

Photo credits: "Good Vibrations," Thomas Alper Alper, 2011 High School Physics Photo Contest
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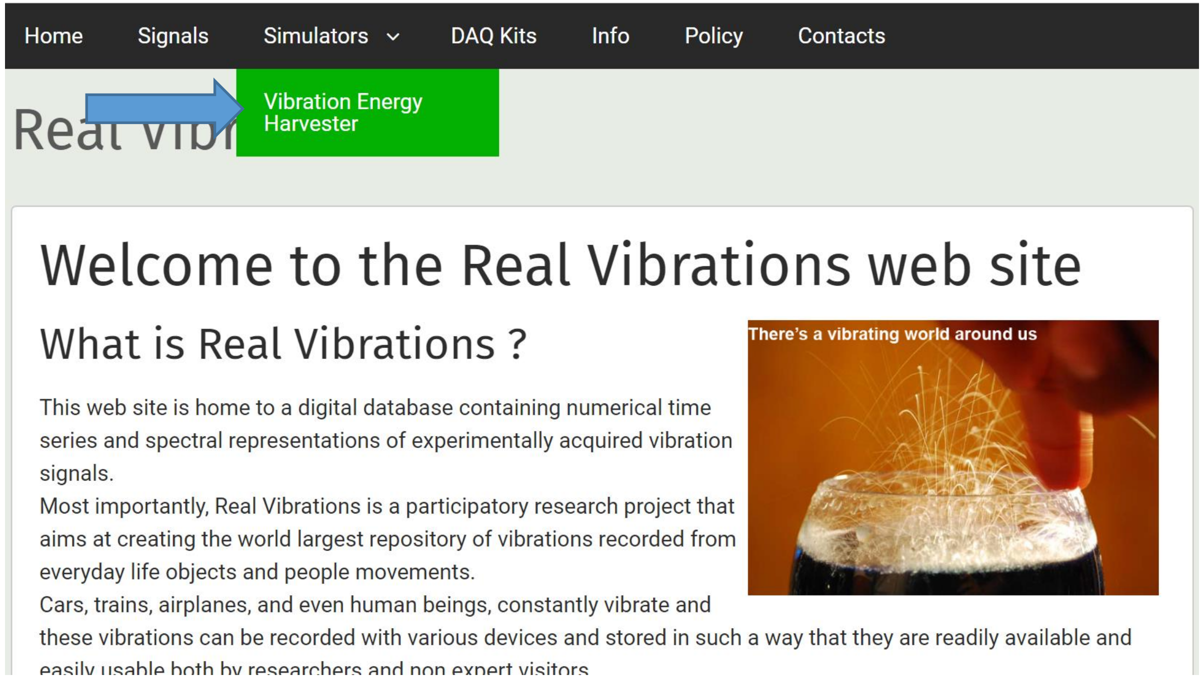
USER LOGIN
Username
Password
Log in
Create new account
Reset your password

LATEST SIGNALS
Electric bass 1 Electric bass
Kitchen robot Cat walking
Train Child swing
Minimetro Minimetro

CATEGORIES
Miscellaneous(97) Human motion(66) Domestic devices(49) Public transportation(47) Car(41) Bridges(15) Machinery(11) Bike(10) Road(8) Public places(7) Music(4) Animals(3)

Simulation Tools for Vibration Energy Harvesting

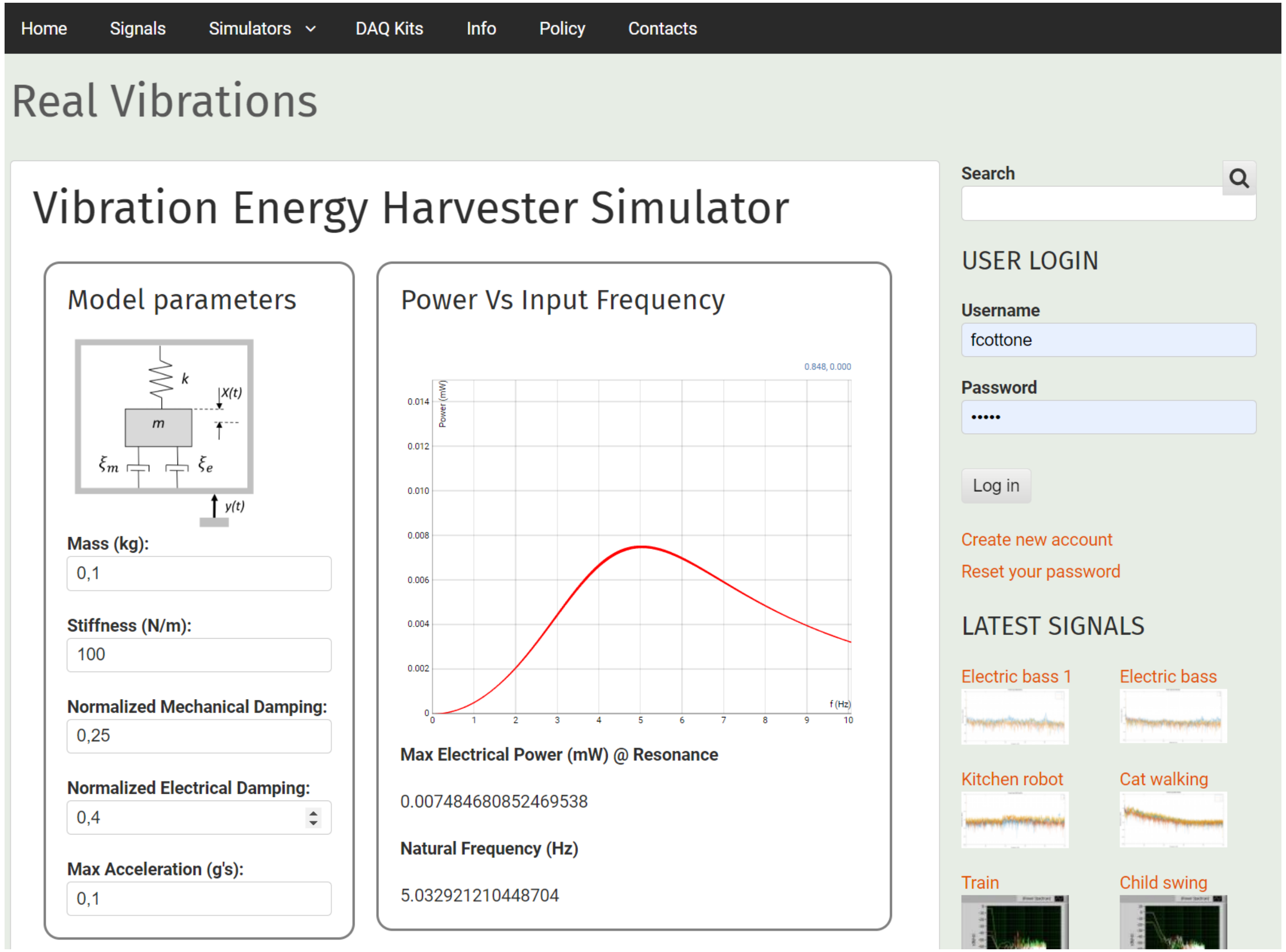
- **SIMULATION TOOLSET**
  - **Vibration Energy Harvester** https://realvibrations.nipslab.org/node/1099
  - **Piezoelectric Energy Harvester**



Simulation Tools for Vibration Energy Harvesting

https://realvibrations.nipslab.org/node/1099

- The first tool is a simulator of **transduction-independent vibration harvester** based on the theoretical model of William and Yates https://doi.org/10.1016/0924-4247(96)80118-X.
- The vibration harvester is a **spring-mass-damped resonant oscillator** in which the energy conversion is accounted by the **electrical damping.**
- The user simply provides the inertial mass m, the spring equivalent stiffness k, the normalized mechanical and electrical damping e and the maximum input acceleration.



Simulation Tools for Vibration Energy Harvesting

Theoretical model

- The Newton's motion equation for an inertial generator is the following:

$$m\ddot{z}(t) + (d_m + d_e)\dot{z}(t) + kz(t) = -m\ddot{y}(t)$$

- where, the mechanical damping ratio is related to the mechanical and electric viscous damping, with k_t^2 and R_l being respectively the electro-mechanical transduction coefficient and the resistive load,

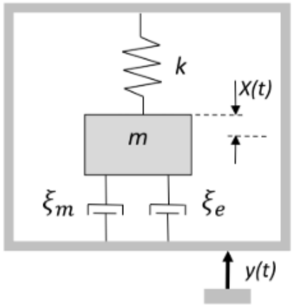
$$\zeta_m = \frac{d_m}{2m\omega_n}, \qquad \zeta_e = \frac{k_t^2}{2m\omega_n R_l}$$

- by assuming a simple Harmonic excitation of input frequency $f = \omega/2\pi$ and phase $\phi = 0$,

$$\ddot{y}(t) = Y_0 \sin(\omega t + \phi)$$

- the electrical power versus input vibration frequency is then calculated with the following expression:

$$P_e(\omega) = \frac{m\zeta_e\left(\frac{\omega}{\omega_n}\right)^3 \omega^3 Y_0^2}{\left[1-\left(\frac{\omega}{\omega_n}\right)^2\right]^2 + \left[2(\zeta_e+\zeta_m)\frac{\omega}{\omega_n}\right]^2}$$



Mass (kg):
0,1

Stiffness (N/m):
100

Normalized Mechanical Damping:
0,25

Normalized Electrical Damping:
0,4

Max Acceleration (g's):
0,1

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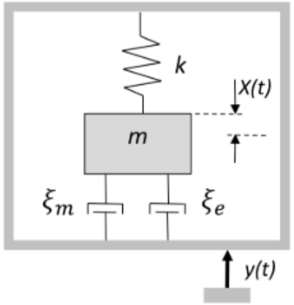
$$\ddot{y}(t) = Y_0 \ \sin(\omega t + \phi)$$

- At resonance for $\omega = \omega_n$, the maximum power is given by the following formula.

$$P_{max}(\omega_n) = \frac{1}{4} m\omega_n^3 Y_0^2 \frac{\zeta_e}{(\zeta_e + \zeta_m)}$$

- The power can be maximized when the condition is verified

$$\zeta_e = \zeta_m$$



Mass (kg): 0,1

Stiffness (N/m): 100

Normalized Mechanical Damping: 0,25

Normalized Electrical Damping: 0,4

Max Acceleration (g's): 0,1

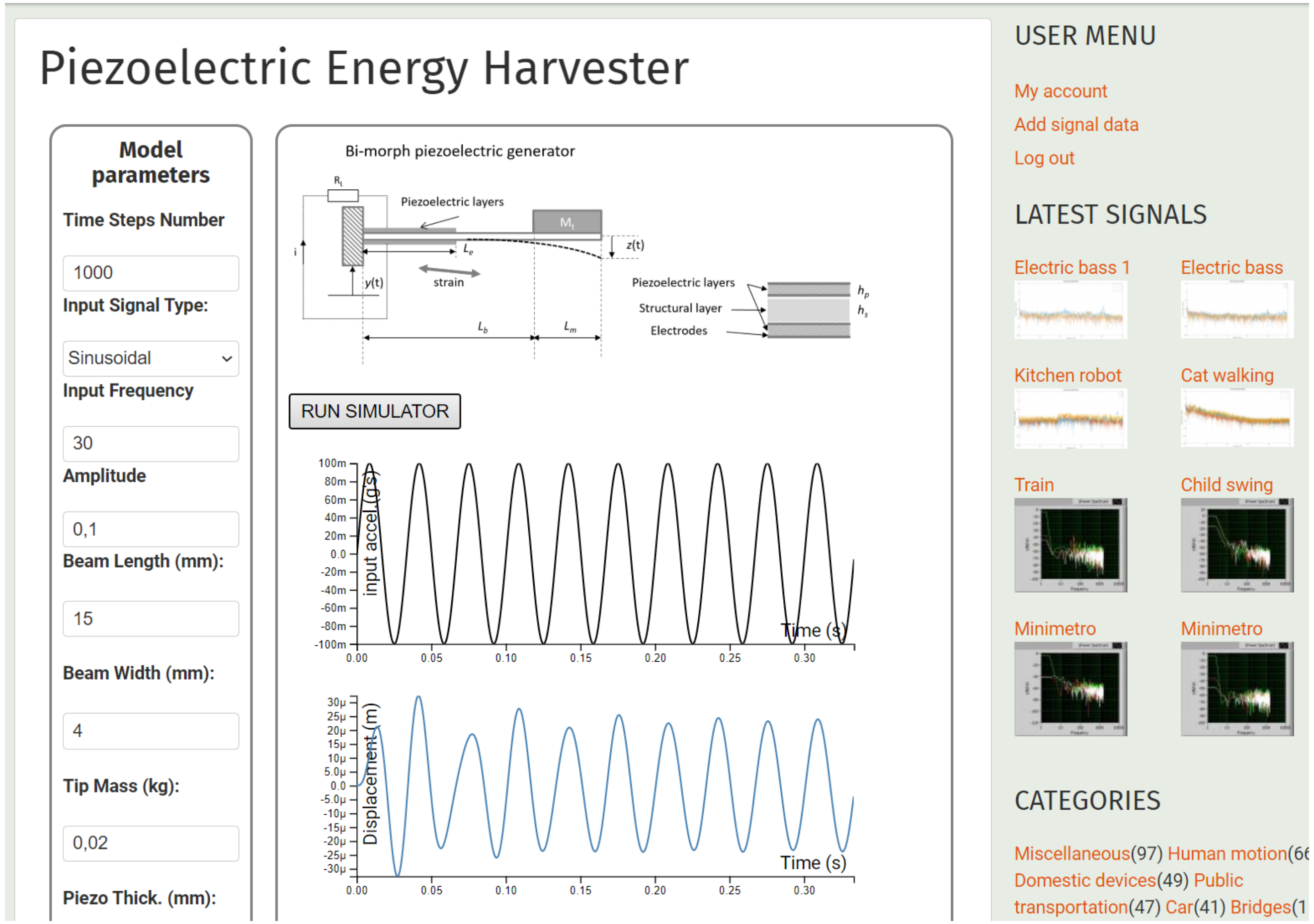
Simulation Tools for Vibration Energy Harvesting

https://realvibrations.nipslab.org/node/1100

- The second tool regards the simulation of a vibrational energy harvester based on a **piezoelectric bi-morph cantilever**.

- The web application performs a numerical integration of the dynamical equations of the piezoelectric bi-morph based on theoretical model of Roundy, S., & Wright, P. K. (2004). https://doi.org/10.1088/0964-1726/13/5/018; Cottone F. et al. (2015). https://doi.org/10.1140/epjst/e2015-02593-5

- The user can select any signal coming from the database (even stochastic). The integration is performed with modified Euler-Maruyama with predictor-corrector algorithm.



Simulation Tools for Vibration Energy Harvesting

https://realvibrations.nipslab.org/node/1100

INPUT PARAMETERS

Model parameters

Time Steps Number

1000

Input Signal Type:

Database Signal

Database Signal

Car (30 s)

Input Frequency

30

Amplitude

0,1

Beam Length (mm):

Beam Width (mm):

4

Tip Mass (kg):

0,02

Piezo Thick. (mm):

0,2

Struct. Thick. (mm):

0,1

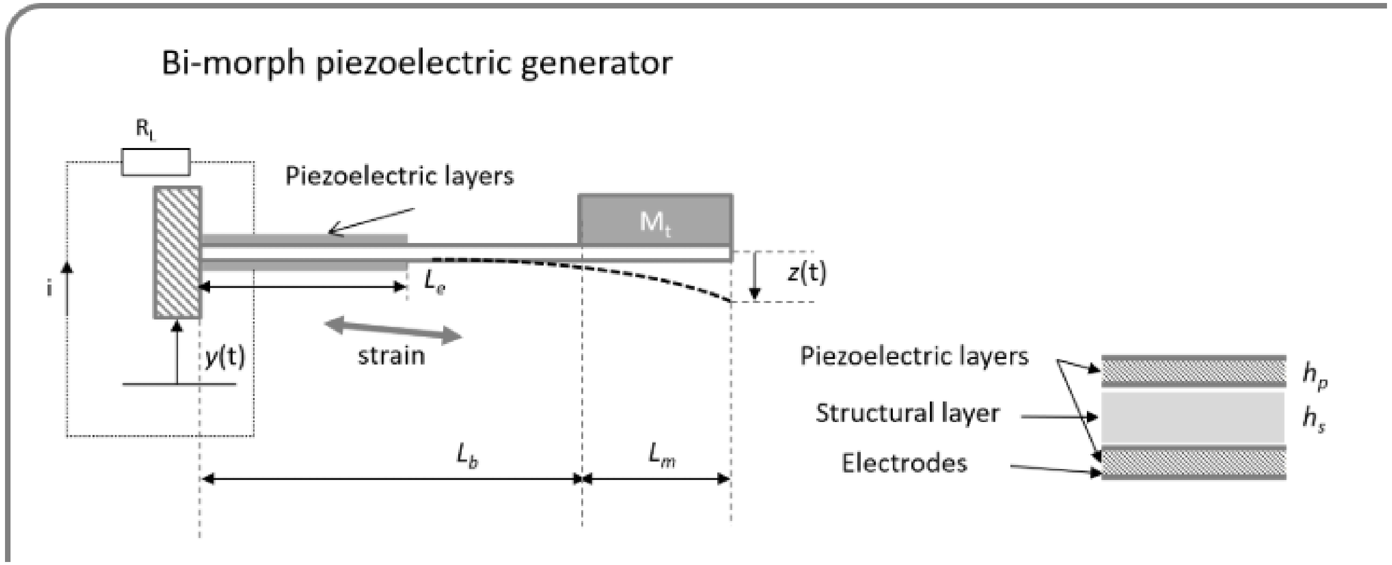
Mech. Damping Ratio:

0,03

Load Resist. (ohm):

100e3

GENERATOR MODEL



Simulation Tools for Vibration Energy Harvesting

https://realvibrations.nipslab.org/node/1100

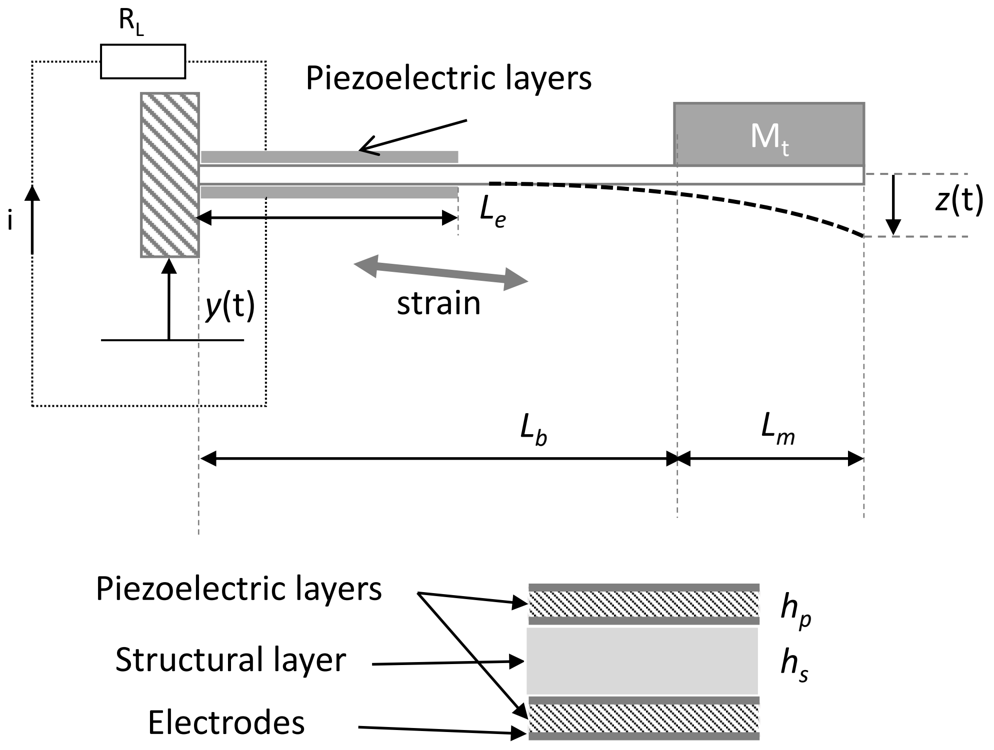
- The system of governing equations of the main model are derived from the Newton's and Kirchhoff's laws as follows :

$$m\ddot{z}(t) + 2\zeta_m\omega_n\dot{z}(t) + kz(t) + k_vV(t) = -m\ddot{y}(t)$$

$$\dot{V}(t) + \frac{1}{R_lC_p}V(t) = k_c\dot{z}(t)$$

- where the k_v, k_c and C_p represent the electro-mechanical transduction coefficient, the velocity-voltage coefficient and the equivalent capacitance of the piezoelectric beam. These parameters are derived from the particular geometry and electrical properties of the piezoelectric generator: such as beam length, width, thickness and piezoelectric constant of the material.

Bi-morph piezoelectric generator



Simulation Tools for Vibration Energy Harvesting

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- The **dependent parameters** are derived from the **input parameters** as the paper of Roundy [1] and Cottone [2].

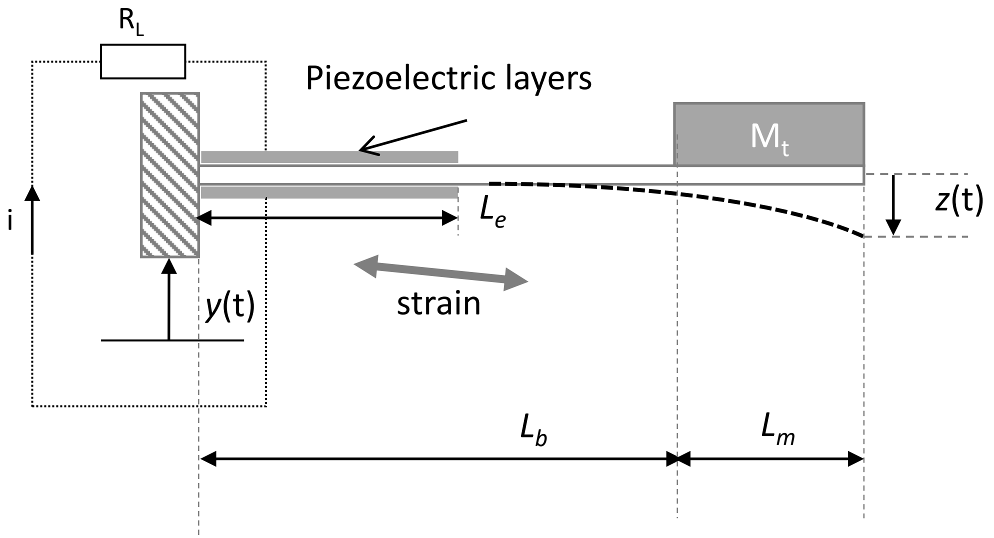
$k_v = kd_{31}/h_p k_2$ Electro-mechanical transduction coefficient

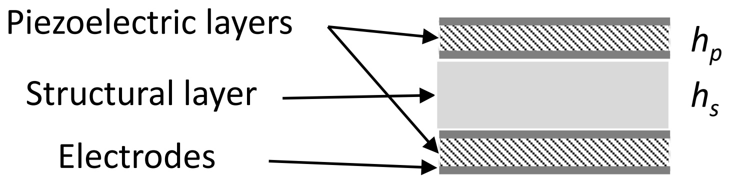
$k_c = 2h_p d_{31} E_p k_2/(ae_p)$ Voltage to velocity coefficient

$$k_1 = \frac{2I}{b(2L_b + L_m - L_e)}$$ Average strain to input force

$$k_2 = \frac{3b(2L_b + L_m - L_e)}{L_b^2\left(2L_b + \frac{3}{2}L_m\right)}$$ Average strain to vertical displacement

Bi-morph piezoelectric generator





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Simulation Tools for Vibration Energy Harvesting

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$$I = 2\left(\frac{w_b h_p^3}{12} + w_b h_p b^2\right) + \frac{1}{12}\left(\frac{E_p}{E_{sh}} w_b h_{sh}^3\right)$$ Beam area inertia moment

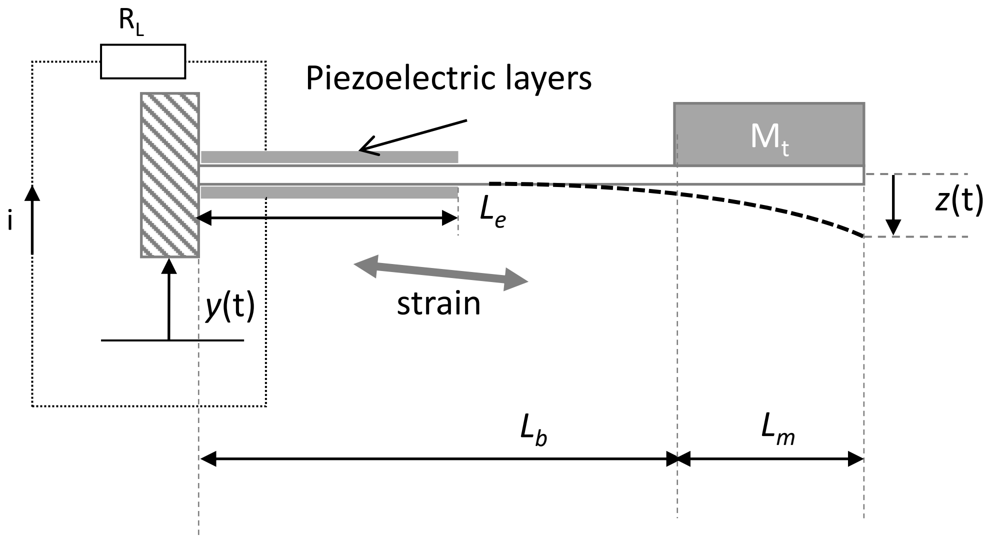
$$K = E_p k_2 k_1$$ Equivalent spring constant of the beam

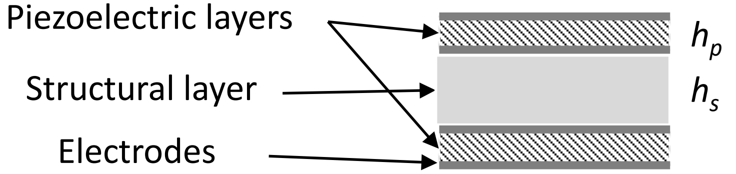
$$C_p = \frac{a^2 e_p w_b L_e}{2h_p}$$ Equivalent capacitance of piezoelectric beam

$$a = 1 \; or \; 2$$ It is equal to 1 for series and 2 for parallel connection of the bi-morph

$$b = \frac{h_p}{2} + \frac{h_{sh}}{2}$$ distance between structural and piezoelectric layer

Bi-morph piezoelectric generator





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