Wireless optical controls of LIGO static suspensions actuators

Maria Paola Clarizia
University of Sannio

Mentor: Riccardo De Salvo
Calum Torrie

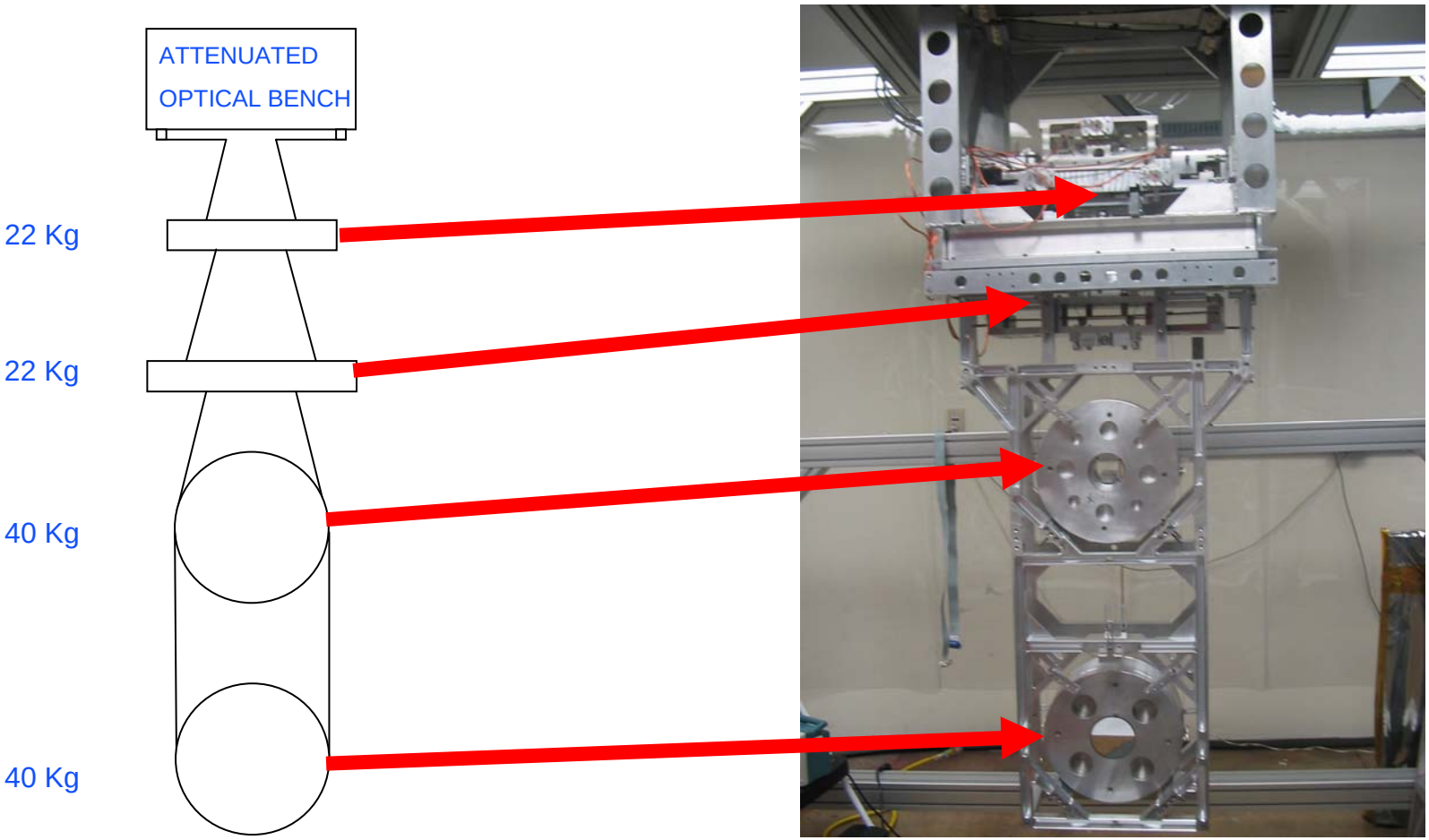
The aim of this project

A wireless control of a stepper motor to be used to balance the MIRROR suspension system of Advanced LIGO

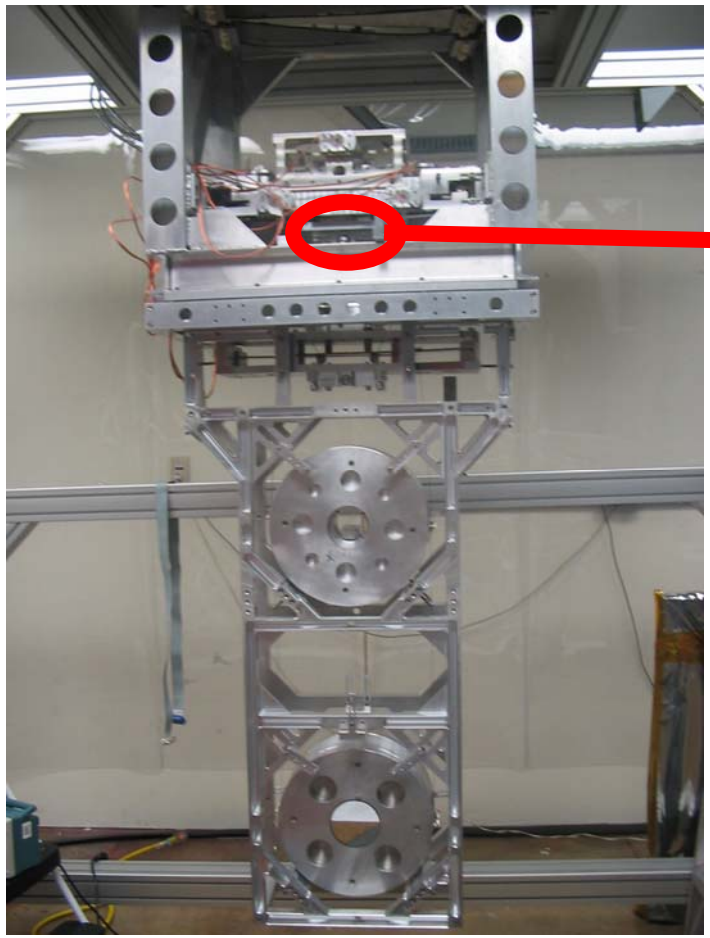
Seismic noise

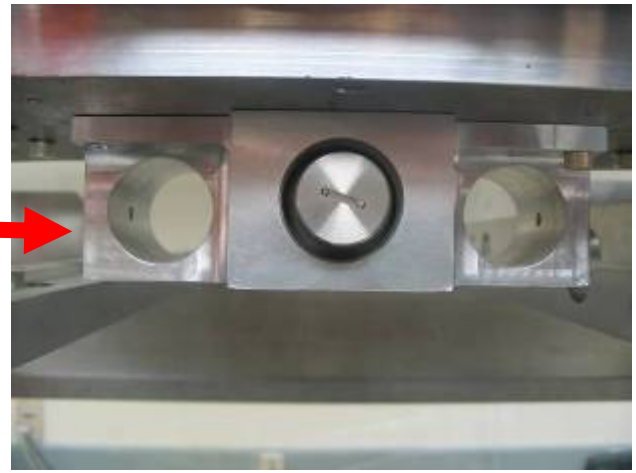
- At very low frequencies, seismic motions may dominate the detectors' noise, degrading their sensitivity
- The suspension system provides an isolation of the mirrors from the ground motion
- For Advanced LIGO a quadrupole pendulum mirror suspension is used

The suspension system



The tuning mass





THE

TUNING

MASS

PROBLEM: no tuning is possible once the vacuum chamber is close

SOLUTION: remote control of the mass to adjust the pitch of the mirror

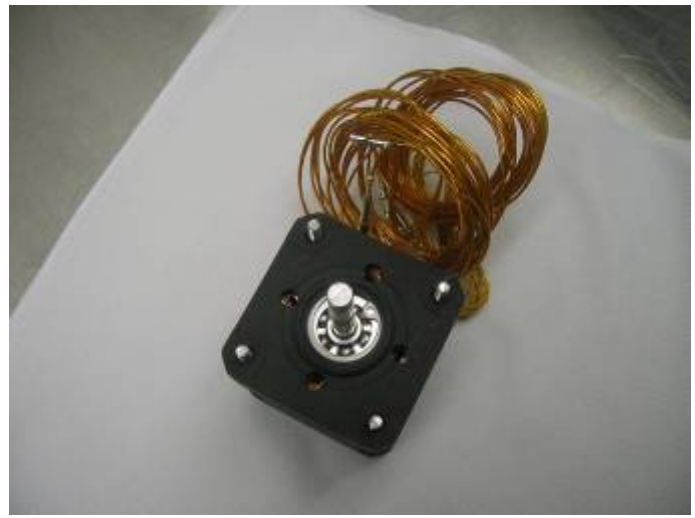
METHOD: a stepping motor,which will move its own mass by means of a threaded shaft

The idea

A wireless circuit to control the motor, in order to eliminate mechanical and electrical perturbations on the suspended masses, as well as an excessive load of outgas on vacuum.

What is a stepping motor?

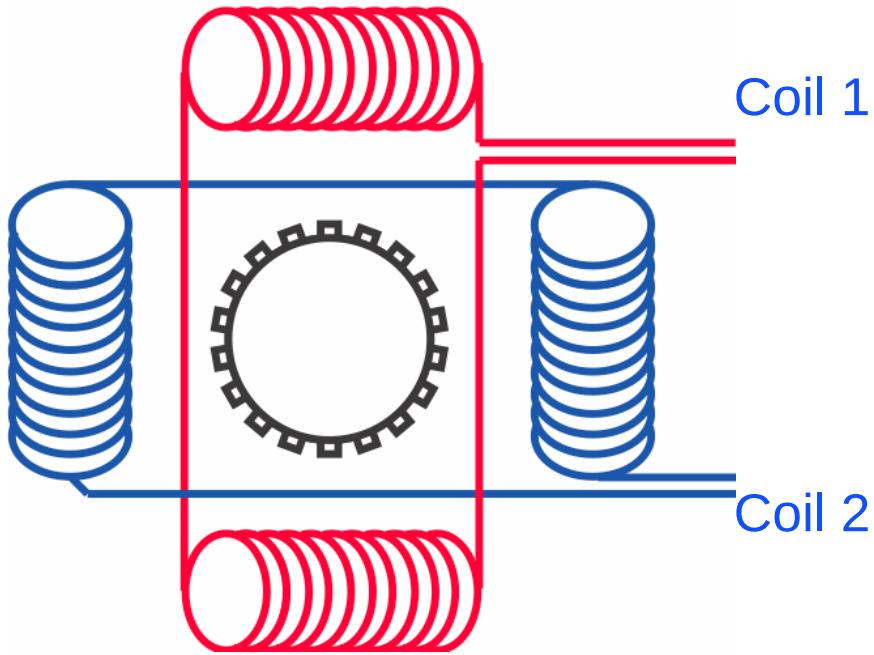
- It's an electric motor that rotates in small discrete steps (1.6^{O})
- An internal rotor containing permanent magnets is controlled by a set of stationary electromagnets that are switched electronically
- Stepping motors provide position holding torque while not in motion.



How to make steps

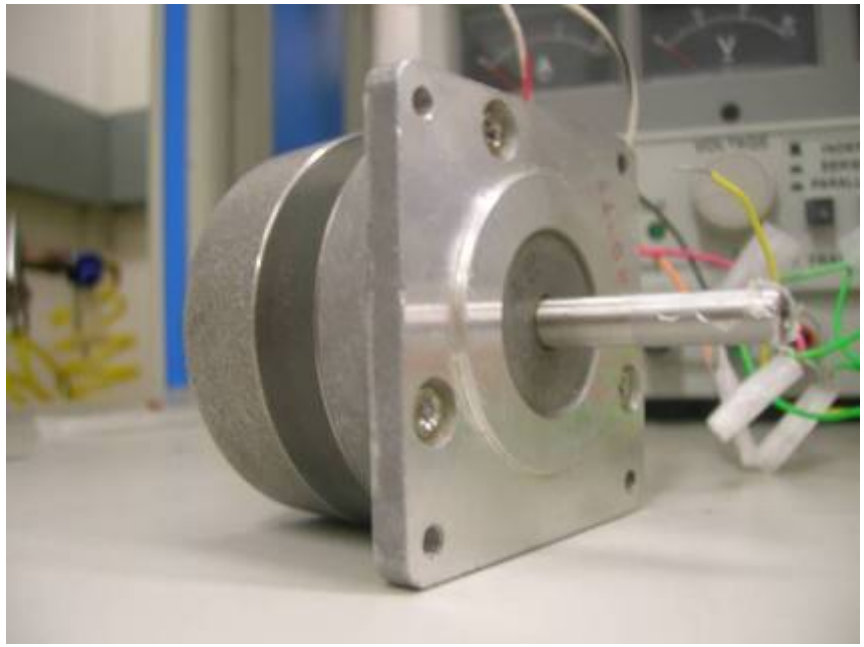
A burst of current in the two coils is required to generate a step.

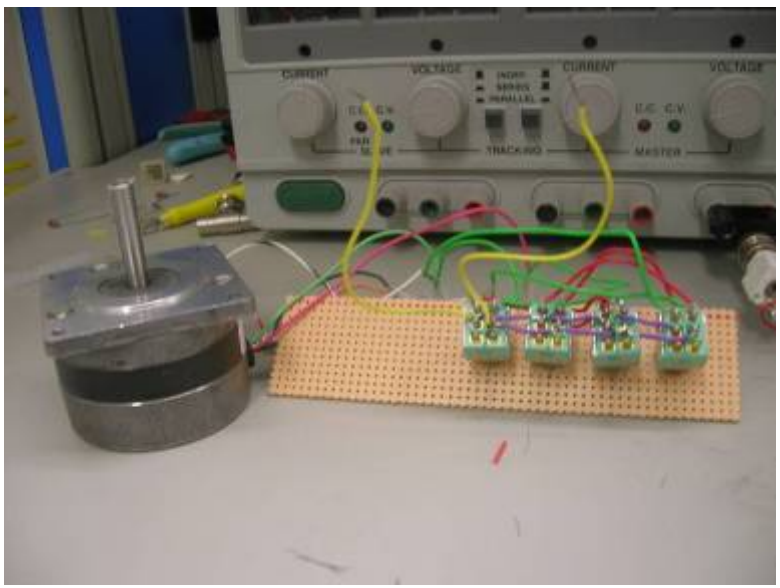
Steps	Coil 1	Coil 2
1	+ i	
2		+ i
3	- i	
4		- i



How to test the motor

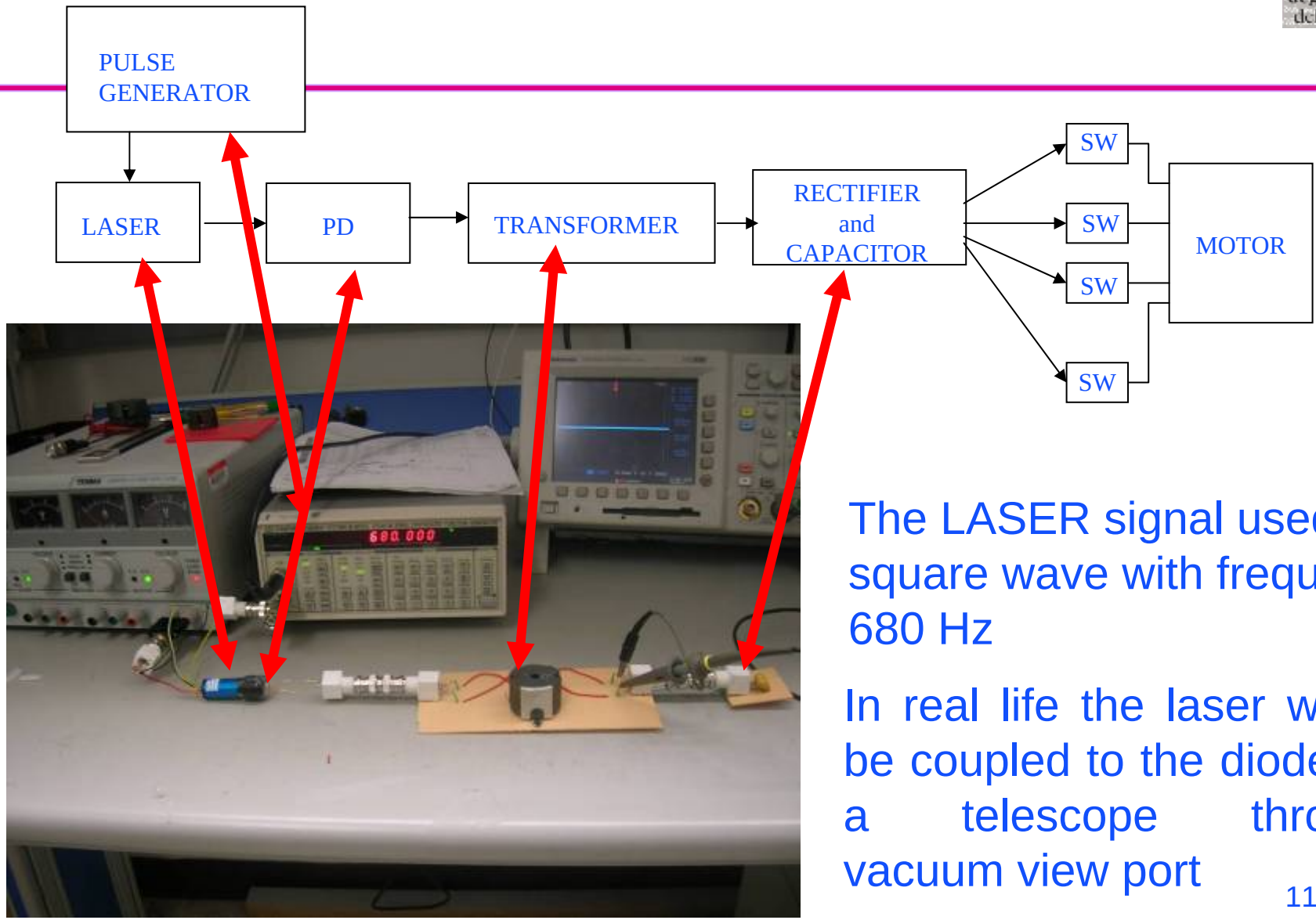
- A charge is stored on a capacitor





- A burst of current is injected in the coils by means of FET switches

The feeding circuit



The LASER signal used is a square wave with frequency 680 Hz

In real life the laser would be coupled to the diode via a telescope through vacuum view port

Some specs

The laser:

Max control freq.: DC to 300 kHz

Output power: 1 mW

Wavelength: 635 nm

The silicon detector:

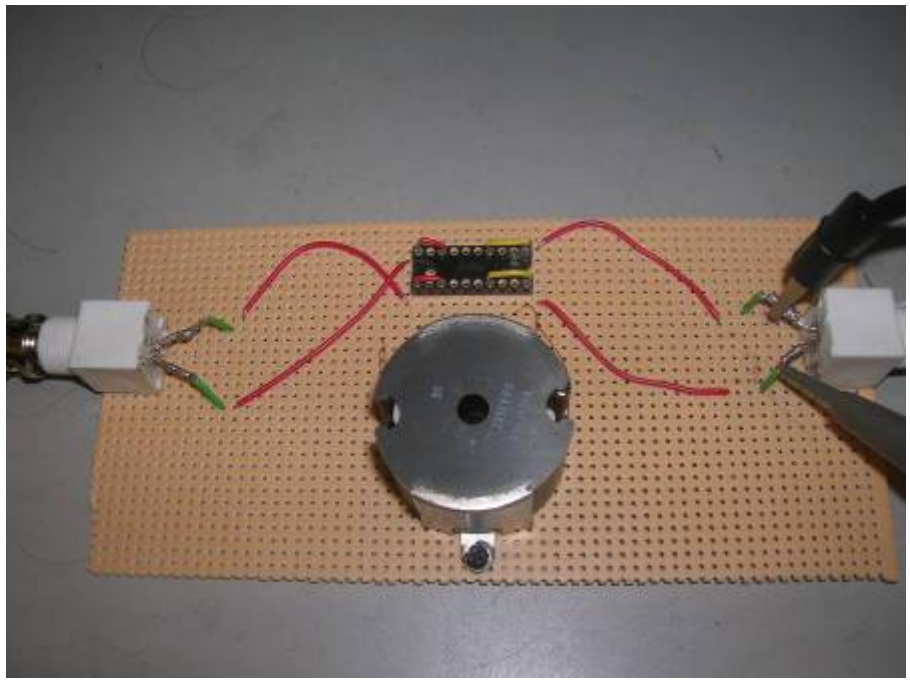
Responsitivity (at 635 nm) = 0.42 A/W

The output current of the detector is about 0.42 mA

The transformer

The main formula:

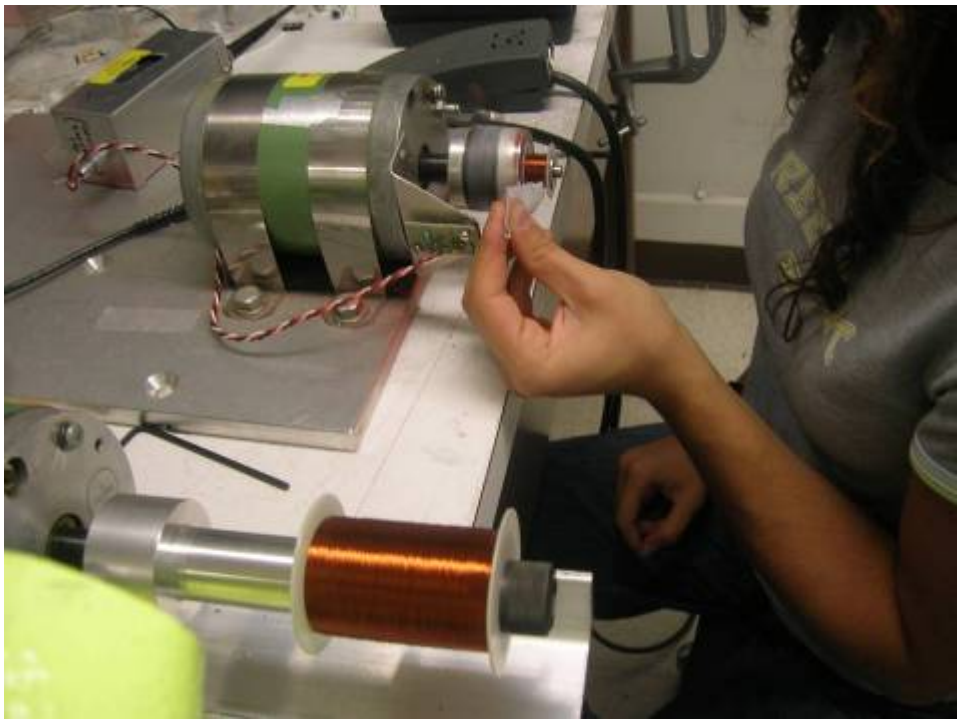
$$\frac{V_1}{V_2} = \frac{N_1}{N_2} = \frac{I_2}{I_1}$$

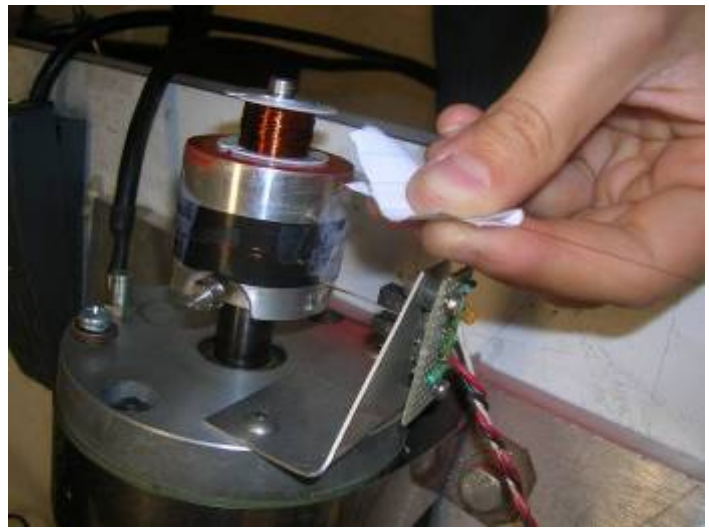


...but actually it's not so simple!!!

Having fun…

WINDING IT ALONG





The wire used is very thin (AWG 35, that is a diameter of 0.203 mm)

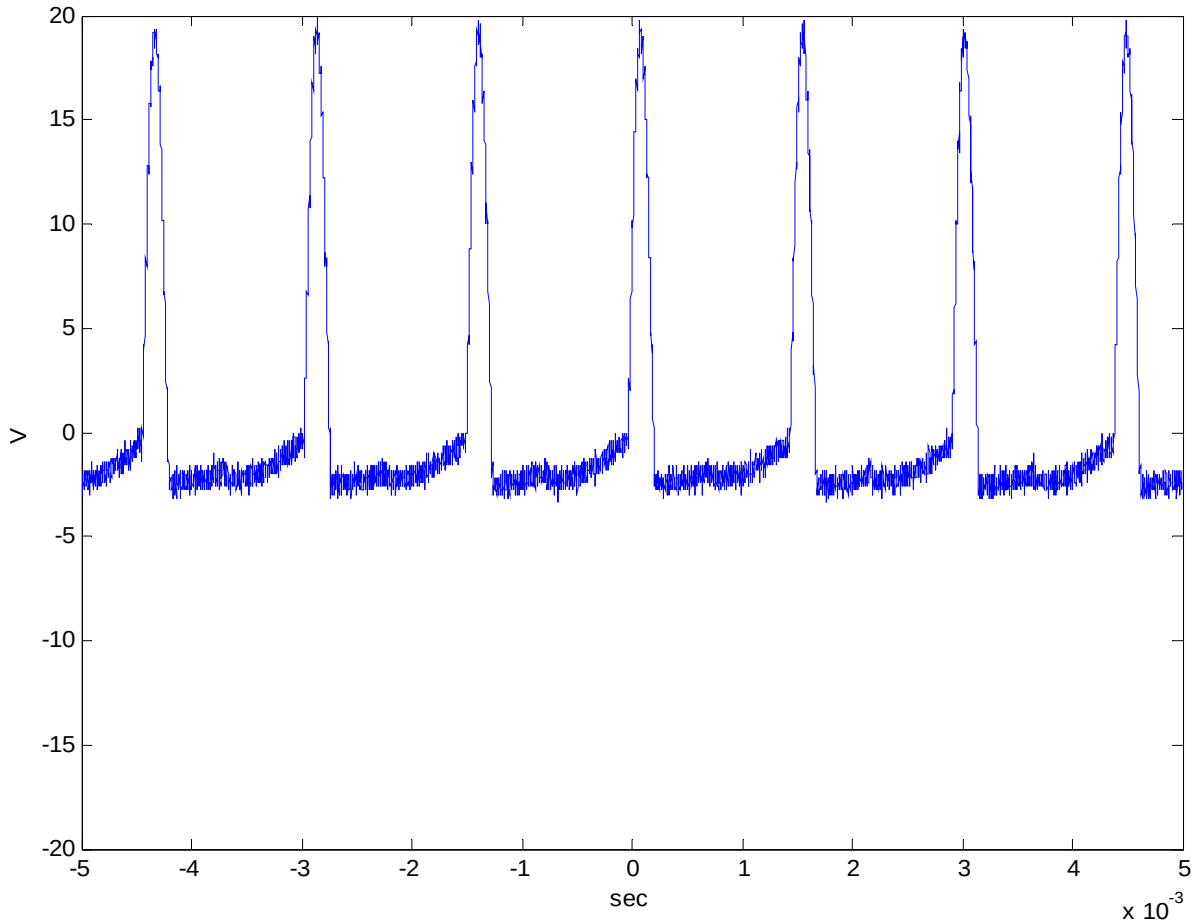
Influences on the voltage

The voltage that can be obtained on the secondary strongly depends on:

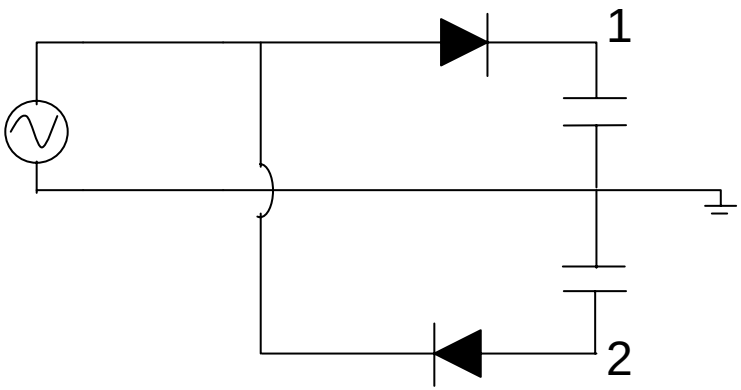
- The wire choice
- The section of the FERRITE core
- The excitation frequency

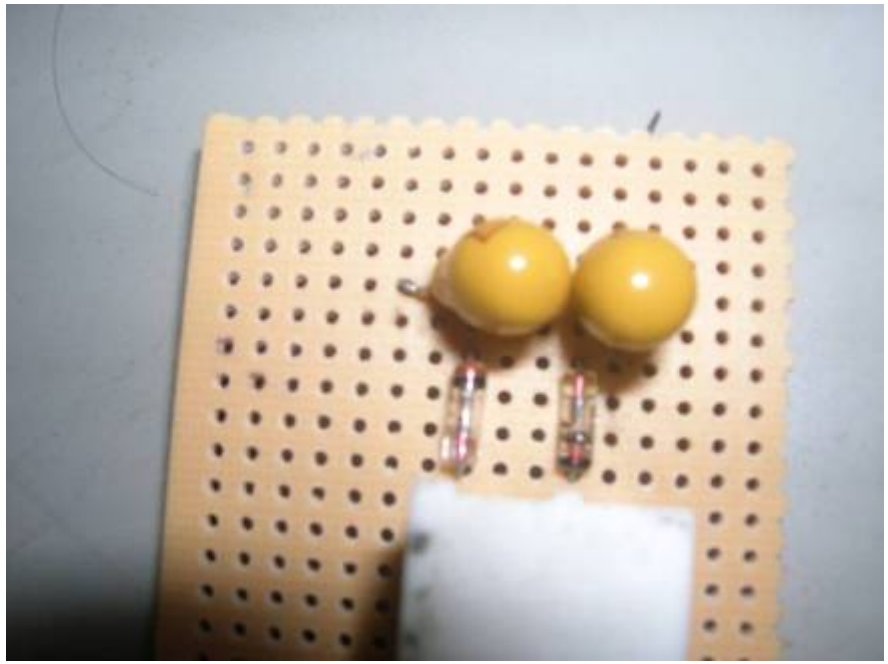
  Increasing the section of the FERRITE core, the frequency corresponding to the maximum voltage decreases

The voltage on the secondary



The rectifier

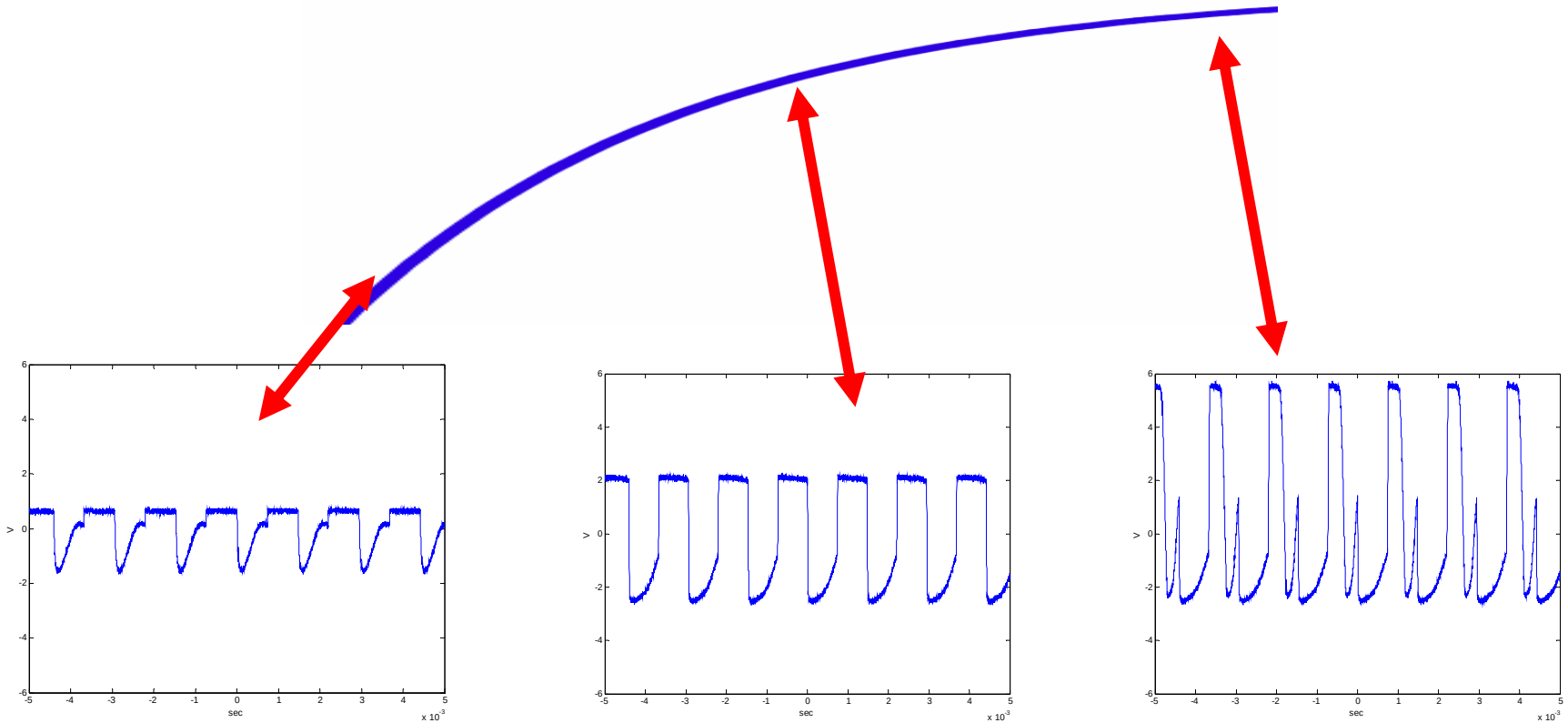




this kind of rectifier gives a DC voltage which is the peak peak voltage of the wave coming from the transformer (a SMALL voltage drop is due to the diodes).

Impedance matching

The rectifier impedance changes while the capacitor charges up.



Choice of the capacitor

The generation of a MOTOR step requires a certain amount of charge.

The bigger the capacitance, the slower the charging up TIME, but the smaller the capacitance, the higher the voltage required for A motor STEP.

The capacitance has to be big enough to defeat stictions

The capacitor chosen

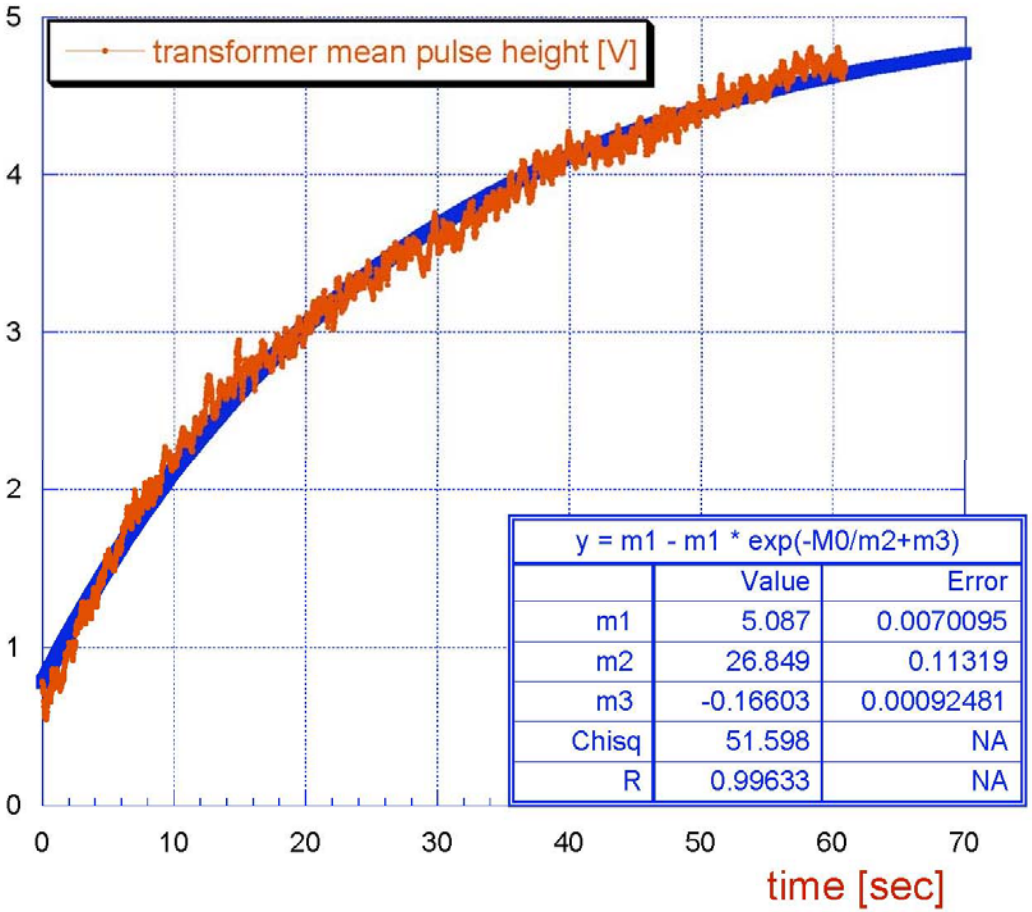
Several charge up times have been measured for different values of the capacitance and different transformers.

A capacitor of 100µF seems to be a good tradeoff!

Voltage needed: 5 V

Time of wait for one step: approximately one minute WITH 1 mW LASER POWER

The charging up curve



Further improvements

- The transformer used gives a good voltage, but it's not optimized: a higher voltage could allow a smaller capacitor or a faster charge up time to be used.
- Impedance mismatching should be taken into account
- A laser with a larger power can be used to provide a stronger signal and to lower the waiting time for one step

Next steps

Developing the FET SWITCH control circuit of the motor.

The principle is to use frequency jumps to control gates of FET switches and four bandpass filters to route the current pulses.

acknoledgements

My mentors Riccardo De Salvo and Calum Torrie

My professor Innocenzo Pinto

Dave Grimmett, Paul Russel and Peter King

Marco Tarallo

Ilaria Taurasi

Yuri, Chiara, and all the italian people (including John HONORARY ITALIAN)

United states for:

- Wonderful places
- Wonderful people
- Wonderful cookies


OREO
THAT'S IT !