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Assembly instructions

Hands-on seismology: constructing a school seismometer

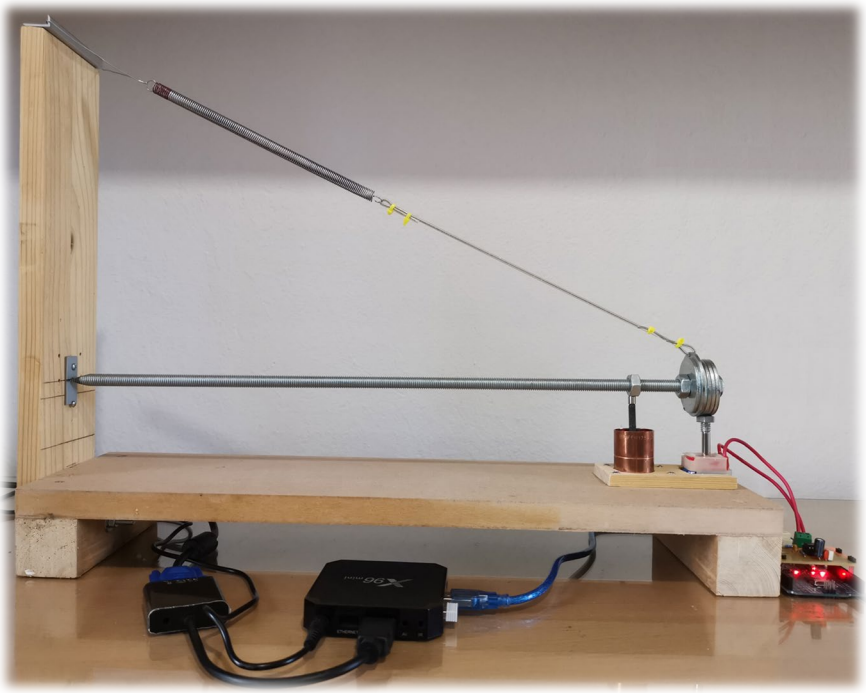
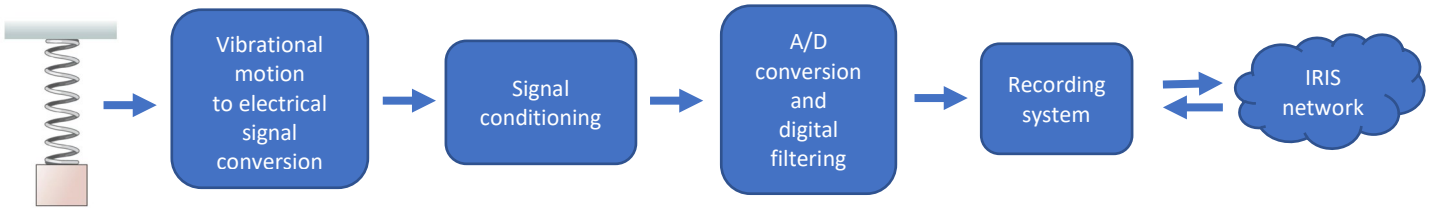


Image courtesy of Vasilis (Bill) Nousis

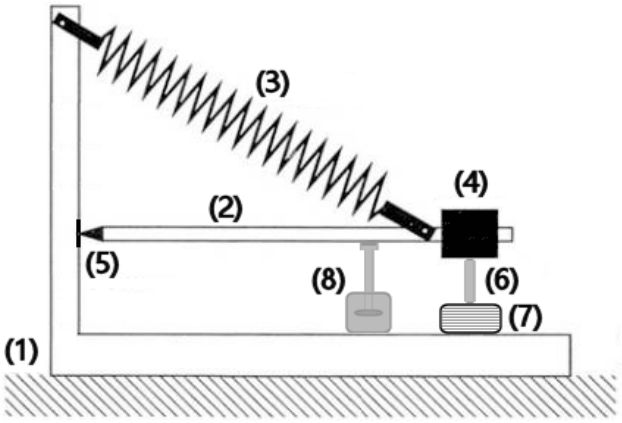
A seismometer is a ground-motion detection sensor coupled to an appropriate recording system. It can be used to record, display, archive, and analyse seismic data.



Block diagram of a seismometer

Image courtesy of Vasilis (Bill) Nousis

Our seismometer, which is capable of recording local earthquakes greater than a magnitude of 3 and teleseisms greater than a magnitude of 6 on the Richter scale. is, by design, a combination of the well-known AS-1 and TC-1 school seismometers.



Schematic diagram of the seismometer

Image courtesy of Vasilis (Bill) Nousis

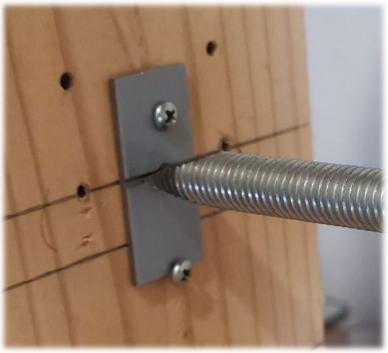
Materials

- wooden frame (1)
- threaded metal rod (2) 8 mm in diameter and approximately 50 cm long, ending in a knife edge (the boom)
- suitable spring (3)
- some weights (large metal washers) (4)
- joint to support the metal rod on the wooden base (5)
- bar-shaped neodymium magnet (6)
- magnetic coil (7)
- electromagnetic braking system (8) consisting of a piece of copper tube, a metal screw, and a neodymium magnetic disk

Instructions

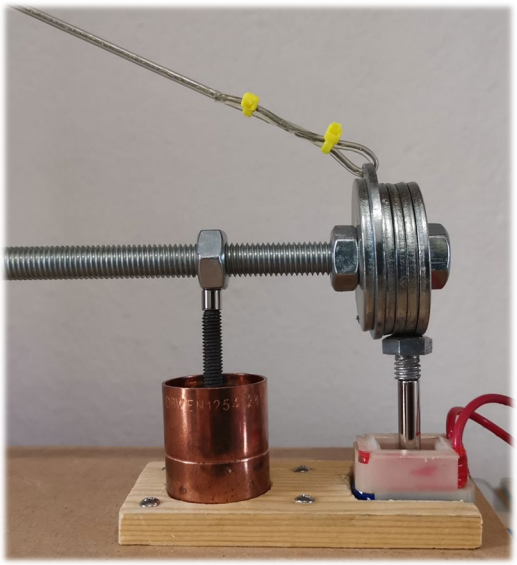
The ground-motion detection sensor

The threaded metal rod (the boom) is held horizontally and supported on a metal base by its one knife-shaped edge. For the joint (7), we use a small metal (iron) plate, into which a thin groove is carved with a file. The knife-shaped edge of the boom rests in this groove.



The joint

Image courtesy of Vasilis (Bill) Nousis



The other end of the boom

Image courtesy of Vasilis (Bill) Nousis

The other edge of the boom is suspended by a spring from a fixed point on the wooden frame of the seismometer, and some weights (metal washers) are attached to it.

The selection of the weights (4), the vertical position of the joint (5), and the type of spring (3) must be determined experimentally based on the following requirements:

1. the boom must be balanced horizontally;
2. the frequency of free oscillations of the boom must be in the order of 1 Hz.

Boom motion to electrical-signal conversion

By means of an iron bolt, the bar-shaped neodymium magnet (6) is attached to the iron washers (weights) of the boom, so that the lower pole of the magnet just enters the top of the magnetic coil.

Seismic waves force the boom to oscillate with the same frequency. Thus, the bar-shaped magnet oscillates inside the coil (7) and a voltage is created across the ends of the coil, due to the phenomenon of electromagnetic induction.

The coil

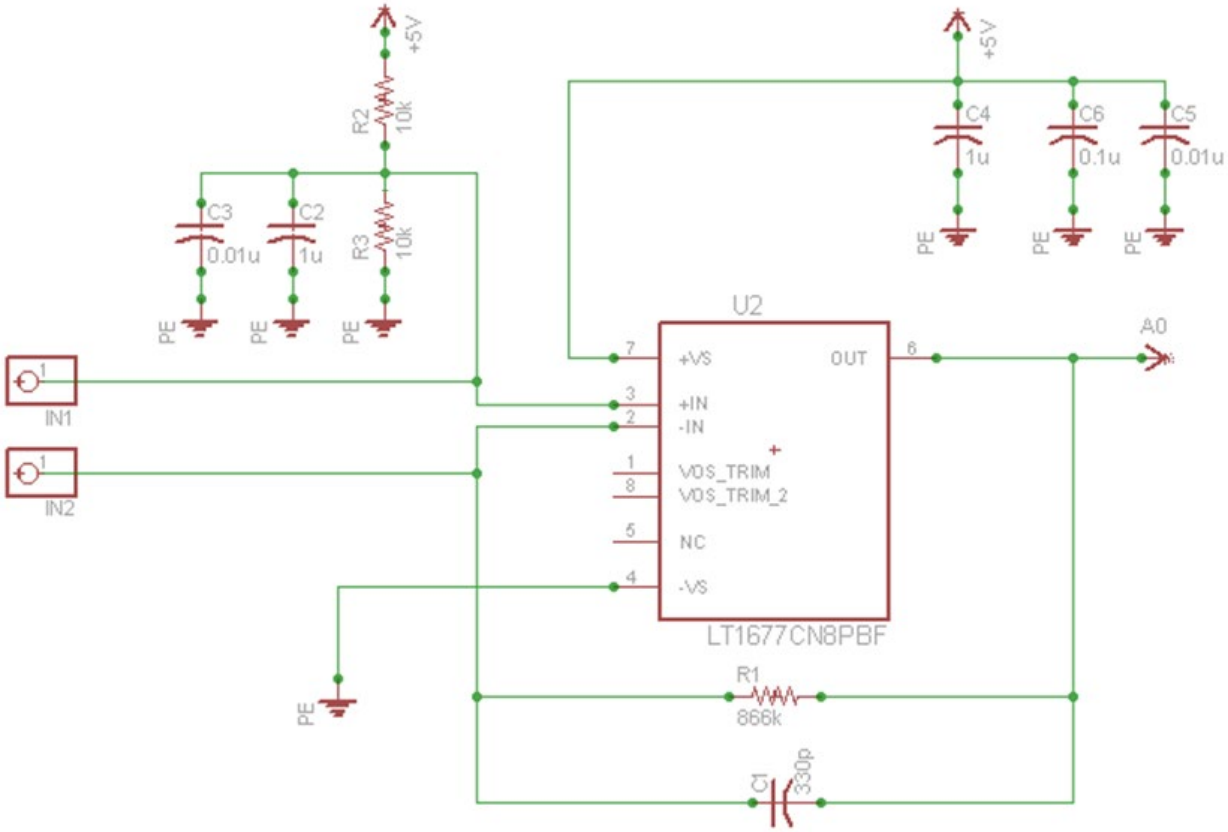
Image courtesy of Vasilis (Bill) Nousis

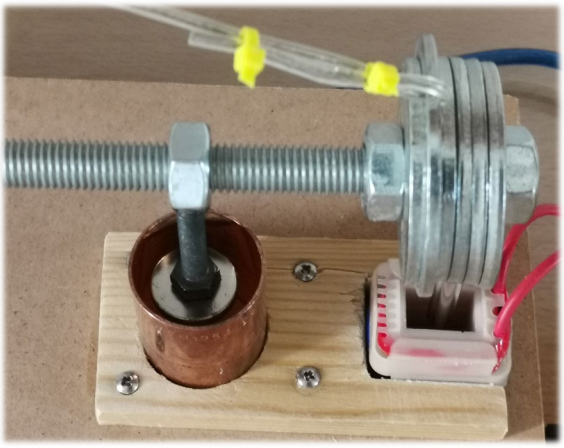
The coil must have a large number of wire turns and low resistance (around 1 kOhm). The most economical solution is to use the primary winding of a 6 V/2 W transformer. For this purpose, the iron core of the transformer must be removed, converting its primary winding into an air-core coil, so that the rod-shaped magnet can move freely inside its turns.

The operation of the seismometer is based on forced oscillations. So, the ground-motion detection system, due to resonance, will have the highest sensitivity to seismic waves of a frequency limited to a small range around its natural frequency, which, as we have already said, is in the order of 1 Hz. The choice of this frequency is made so that, in addition to local earthquakes, the seismometer will be able to detect distant earthquakes. This is because the higher the frequency of seismic waves, the faster the energy they carry weakens with distance. Therefore, only low-frequency seismic waves from distant earthquakes can reach and excite the seismometer.

Signal-conditioning system

The voltage induced across the ends of the coil, due to an earthquake, is too low and needs to be amplified. The amplifier is based on the very low noise LT1677 op-amp from Analog Devices. As this op-amp is quite expensive and relatively difficult to acquire, we have tried different alternatives, getting good results with OP27, OP177, AD820, MCP6021, and MAX410, among others.





The damper

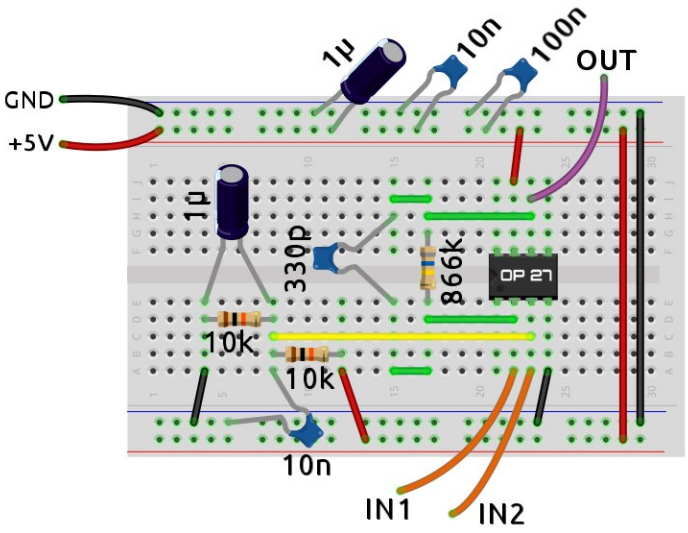
Image courtesy of Vasilis (Bill) Nousis

An important part of the seismometer is the electromagnetic braking system (the damper). If the oscillation of the boom is not damped (minimized) quickly, the recording of secondary seismic waves will be masked by the continuing oscillations of the boom due to primary waves. Thus, the arrival of the secondary waves won't be clear in the seismic data, resulting in an inability to determine the characteristics (epicentre) of an earthquake.

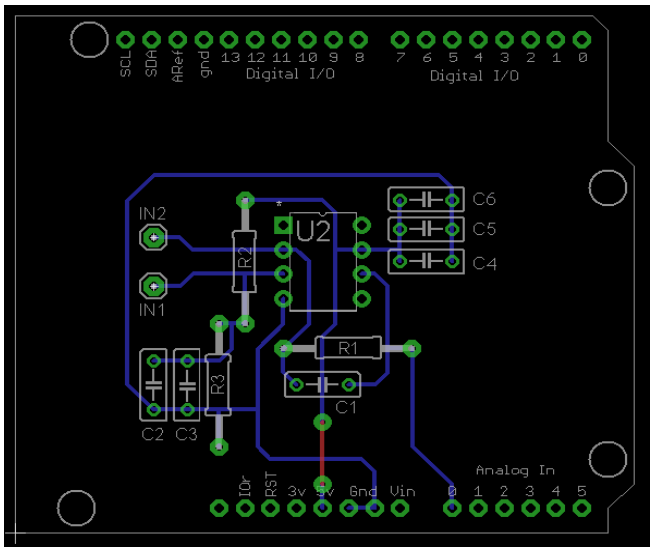
The damper consists of

1. a small piece of copper pipe about 2 cm in diameter;
2. an iron bolt, which is attached to the boom by means of a small magnetic cylinder with a small magnetic neodymium disk attached to the other end. The system is properly installed, so that the magnetic disk can move freely inside the copper pipe.

The neodymium magnetic disk participates in the oscillations of the boom. Due to this movement, eddy currents are induced in the copper pipe. In this way, energy from the oscillating boom is transferred to the tube, which contributes to the rapid damping of the oscillations.

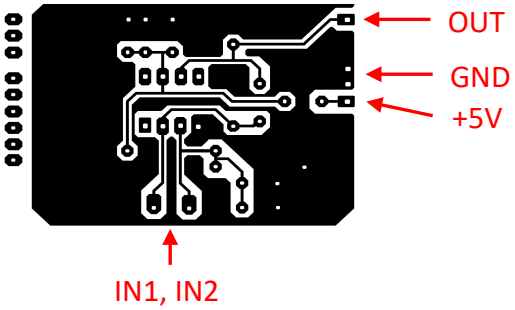


The amplifier: breadboard version



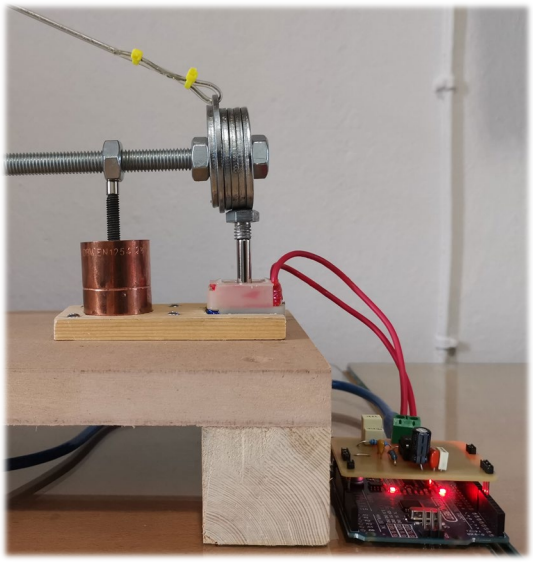
The amplifier: printed circuit board (PCB) version

OUT: To Arduino A0
GND, **+5V**: To the corresponding Arduino Pins
IN1, **IN2**: Coil connection pins



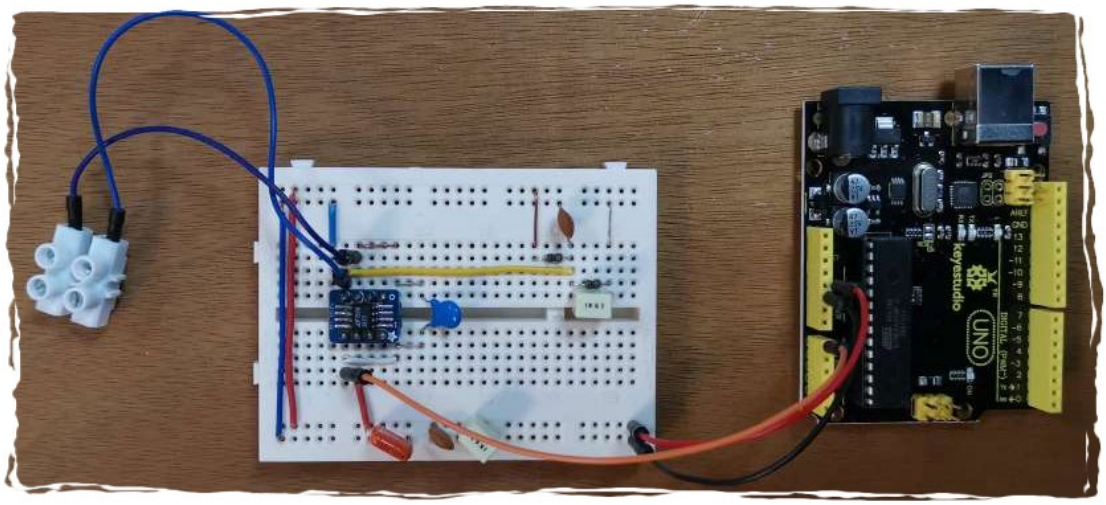
The Printed Circuit Board for the amplifier has the form of a shield board that 'piggybacks' onto the Arduino board.

Analogue-to-digital conversion and digital filtering



The electrical signal due to the very small oscillations of the boom, after its amplification, is driven to the A0 Arduino analogue input pin.

NERdaq software, developed by Chris Knudsen of New England Research Inc. to support school seismometers, will be installed in the Arduino device. The seismic data is digitized and filtered by the software. Using the technique of oversampling, the software creates a slower data flow (about 19 samples per second) but of higher active resolution. This data is then sent to the recording system.



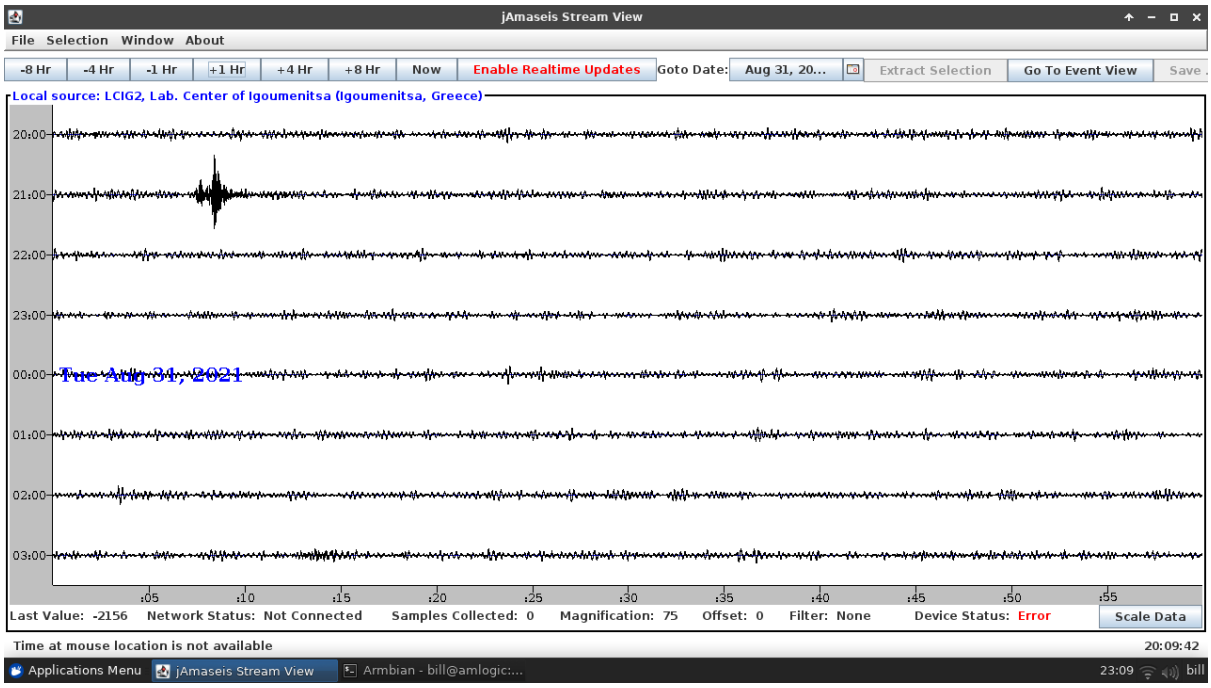
Recording system

The recording system can be any computer system capable of running jAmaSeis software. This can include a desktop or laptop (running Windows or Linux or MacOS) computer, a Raspberry Pi, or even a TV box modified to run Armbian Linux.

jAmaSeis can record, display, archive, and send the data from our seismometer to IRIS servers. With the embedded travel-time curves model, the distance from the epicentre of a recorded earthquake can be computed. By using data from three different seismometers, the exact location of the epicentre can be determined.

An additional feature of the jAmaSeis software is that it can be used without having a local seismometer connected, instead using data from a cloud (on the IRIS network) seismometer.

armbian
universal operating system
Applications Menu
17:08
bill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Further resources

PCB

NERdaq

Armbian

jAmaSeis

You can contact the author at this email address if you have problems with the assembly.