teaching experimental sciences with Freeduc-CD

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Freduc-CD

- a bootable CD-ROM
- about 40 educational applications, and documents to make them easily usable.
- a factory to output new thematic releases of Freeduc-CD
- easy to localise for various languages

Freeduc-sciences

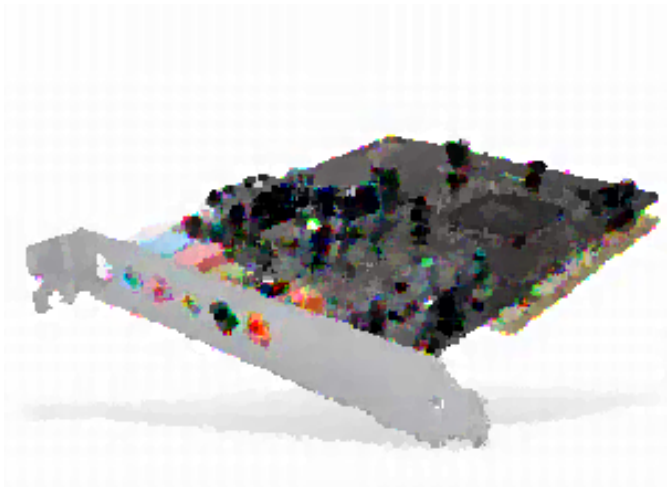
This particular release will be targetted to students in scientific areas, especially in experimental scientific fields (biology, chemistry, physics, astronomy, etc.)
It comes with out-of-the-box facilities to deal with data collection and interpretation.

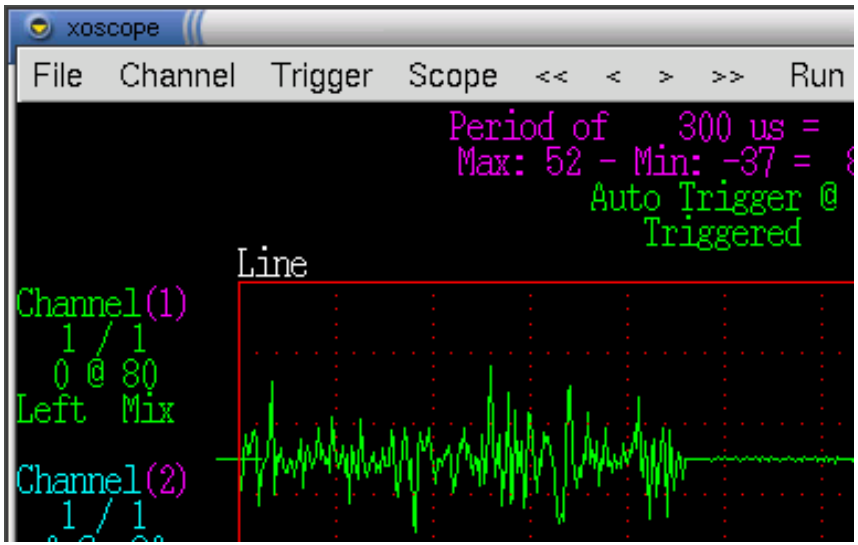
Communication with captors

To deal with physical measurements, any computer has to be able to input analogic data, and sample them regularly.

The soundcard

Most personal computers are already shipped with analog input interfaces for sound signals. However these interfaces most often suppress the continuous composant of the signal, making them poorly usable for many experimental purposes. They are readily usable with some programs like Xoscope.



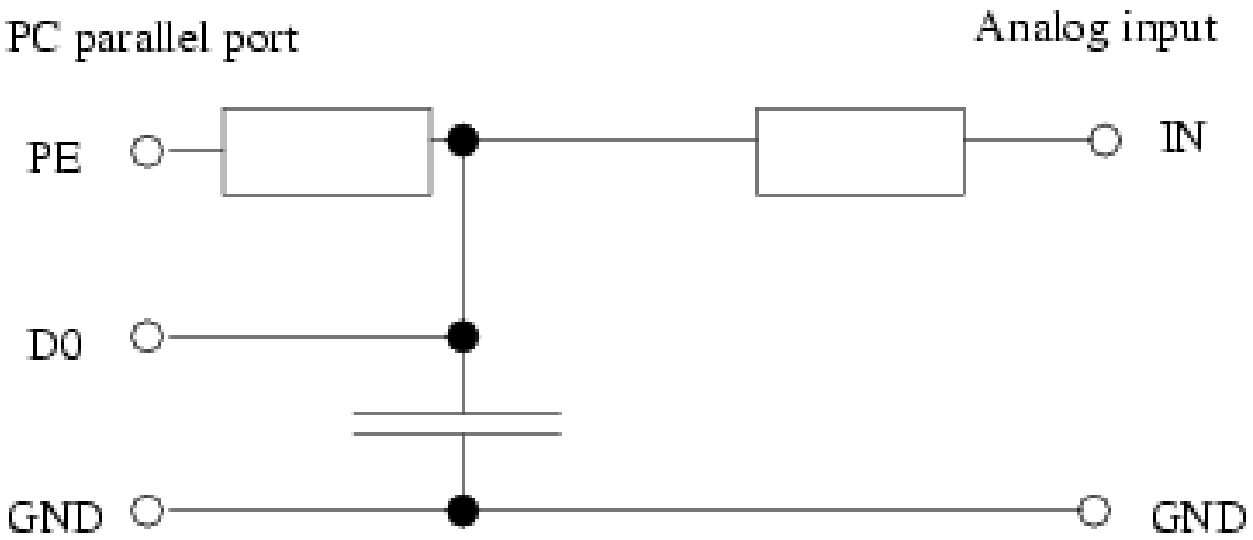


The library Comedi

For current measurements we need more specific interfaces, so-called analogic-digital acquisition devices. The library COMEDI (`http://www.comedi.org/`) is a free software which makes easy to develop software using acquisition devices, since they are callable via a normalised Application Programming Interface (API).

Inexpensive interfaces

I have developed a most inexpensive interface, based on three discrete components. The price is lower than 5 Euros. However this interface has poor features : input resistance near 10 $k\Omega$, at most 10 samples by second, accuracy about 5% with a non real-time kernel.



USBDUX

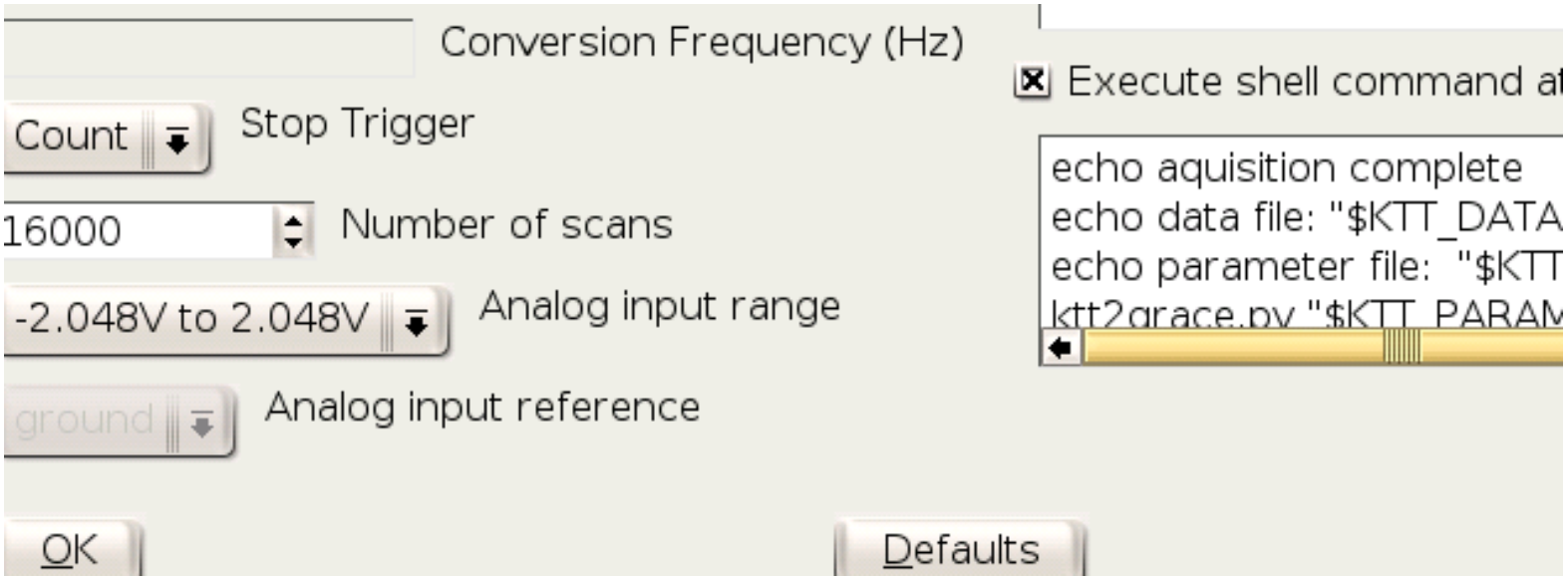
The acquisition device USBDUX, manufactured for the needs of the University of Stirling is one of the cheapest acquisition devices shipped with kernel modules making it compatible with the library Comedi. See `http://www.linux-usb-daq.co.uk/`.

Ktimetrace

Ktimetrace is a simple graphic front-end, making easy to manage the acquisition devices. It allows to :

- program the device (channels being used, sampling frequency, etc.)
- launch the acquisition and save the data
- invoke other programs to manage the data further.

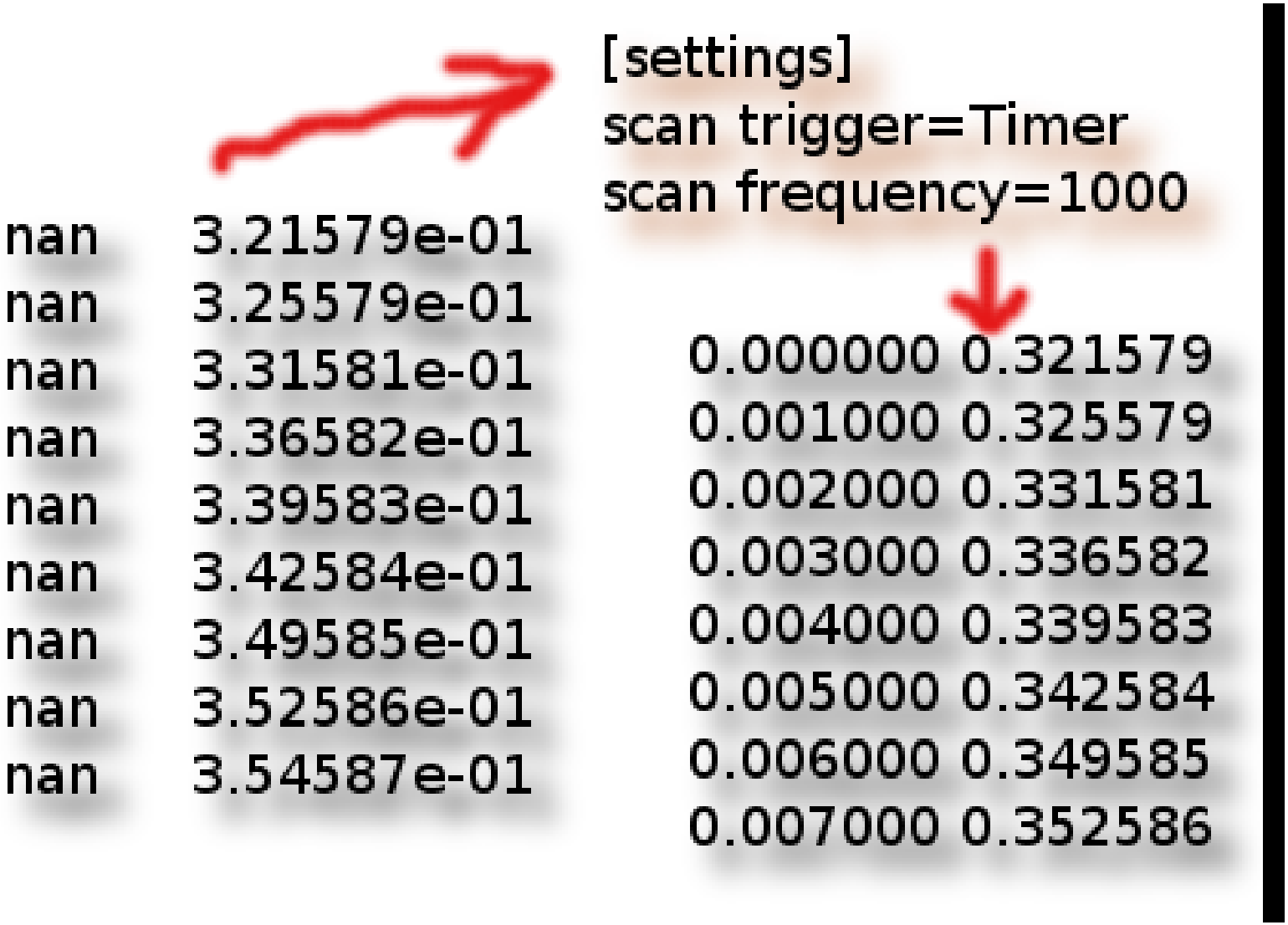
Ktimetrace


Conversion Frequency (Hz)
Execute shell command at
Count
Stop Trigger
echo aquisition complete
echo data file: "$KTT_DATA
echo parameter file: "$KTT
16000
Number of scans
-2.048V to 2.048V
Analog input range
ground
Analog input reference
OK
Defaults

Ktt2grace

Ktimetrace outputs no timecode in the data files, but it outputs an auxiliary file with all the settings. Ktt2grace is a utility to add the relevant timecode informations and format the data to be fed as an input for other data standard plotting programs like Grace.

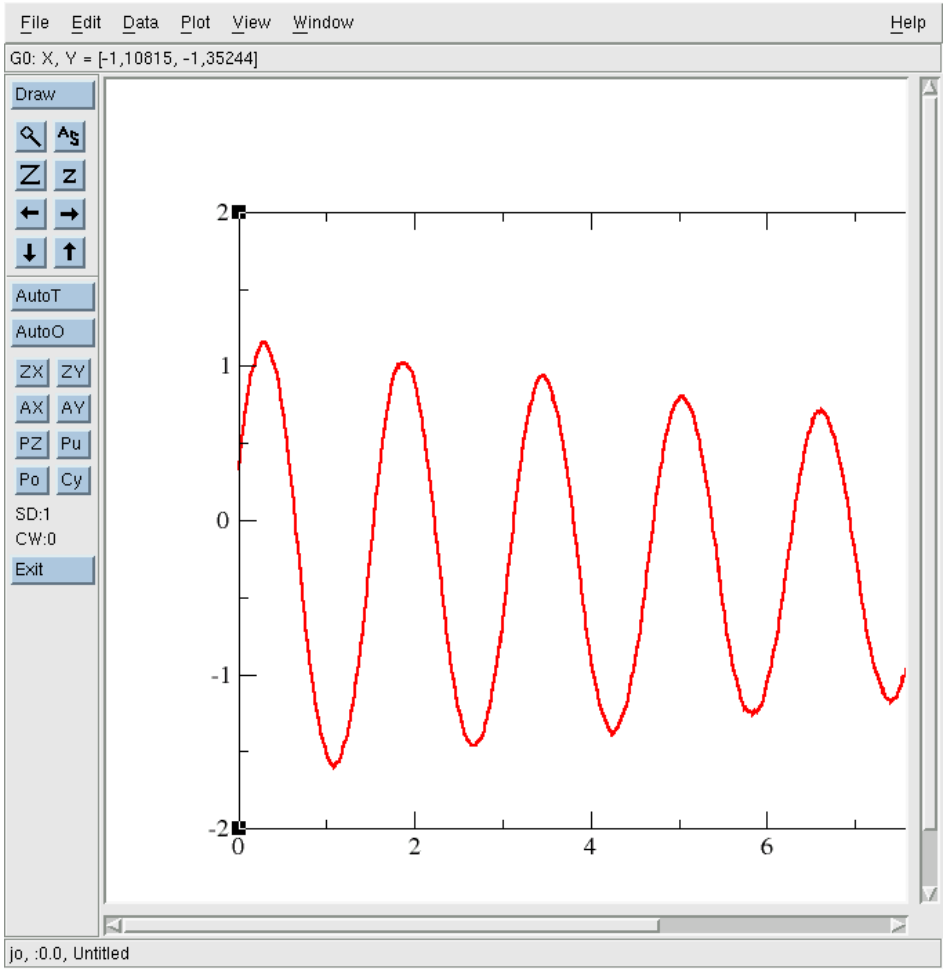
Ktt2grace


[settings]
scan trigger=Timer
scan frequency=1000
nan 3.21579e-01
nan 3.25579e-01
nan 3.31581e-01
nan 3.36582e-01
nan 3.39583e-01
nan 3.42584e-01
nan 3.49585e-01
nan 3.52586e-01
nan 3.54587e-01
0.000000 0.321579
0.001000 0.325579
0.002000 0.331581
0.003000 0.336582
0.004000 0.339583
0.005000 0.342584
0.006000 0.349585
0.007000 0.352586

Grace

Grace and its graphic front-end, Xmgrace, are mature programs dedicated at data plotting. They are primarily targetted at PhD, students, professors and research laboratories. Their features allow the users to make professional-class plots for publications in scientific reviews. I have written a some internationalisation code and made a localisation to French in order to make this application accessible by younger students.

Grace

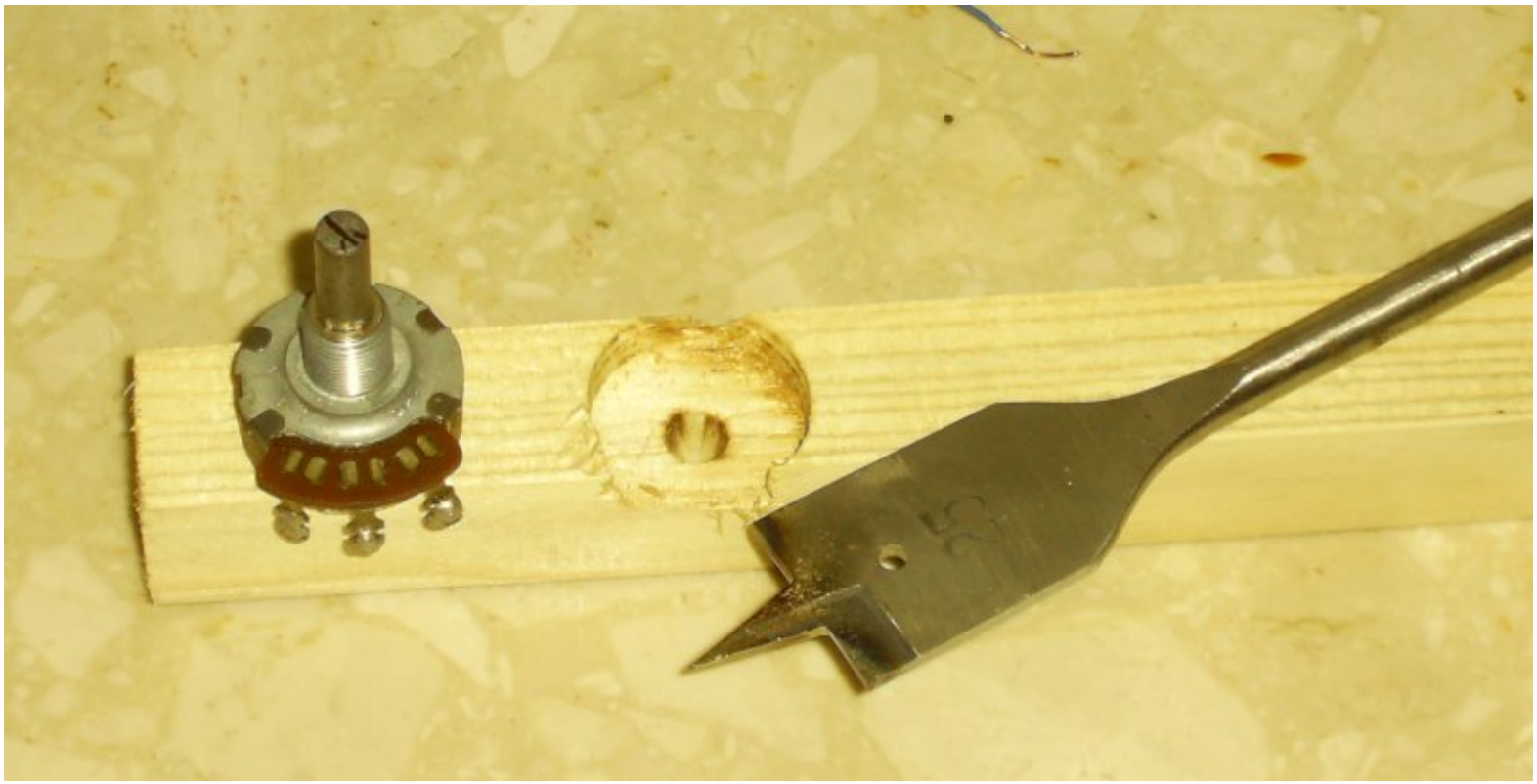

File Edit Data Plot View Window Help
G0: X, Y = [-1,10815, -1,35244]
Draw
AutoT
AutoO
ZX ZY
AX AY
PZ Pu
Po Cy
SD:1
CW:0
Exit
2
1
0
-1
-2
0
2
4
6
jo, :0.0, Untitled

Studying a pendulum

Here is a story about a little experiment about the physics of the pendulum and about solid friction.

Gathering some tools ...

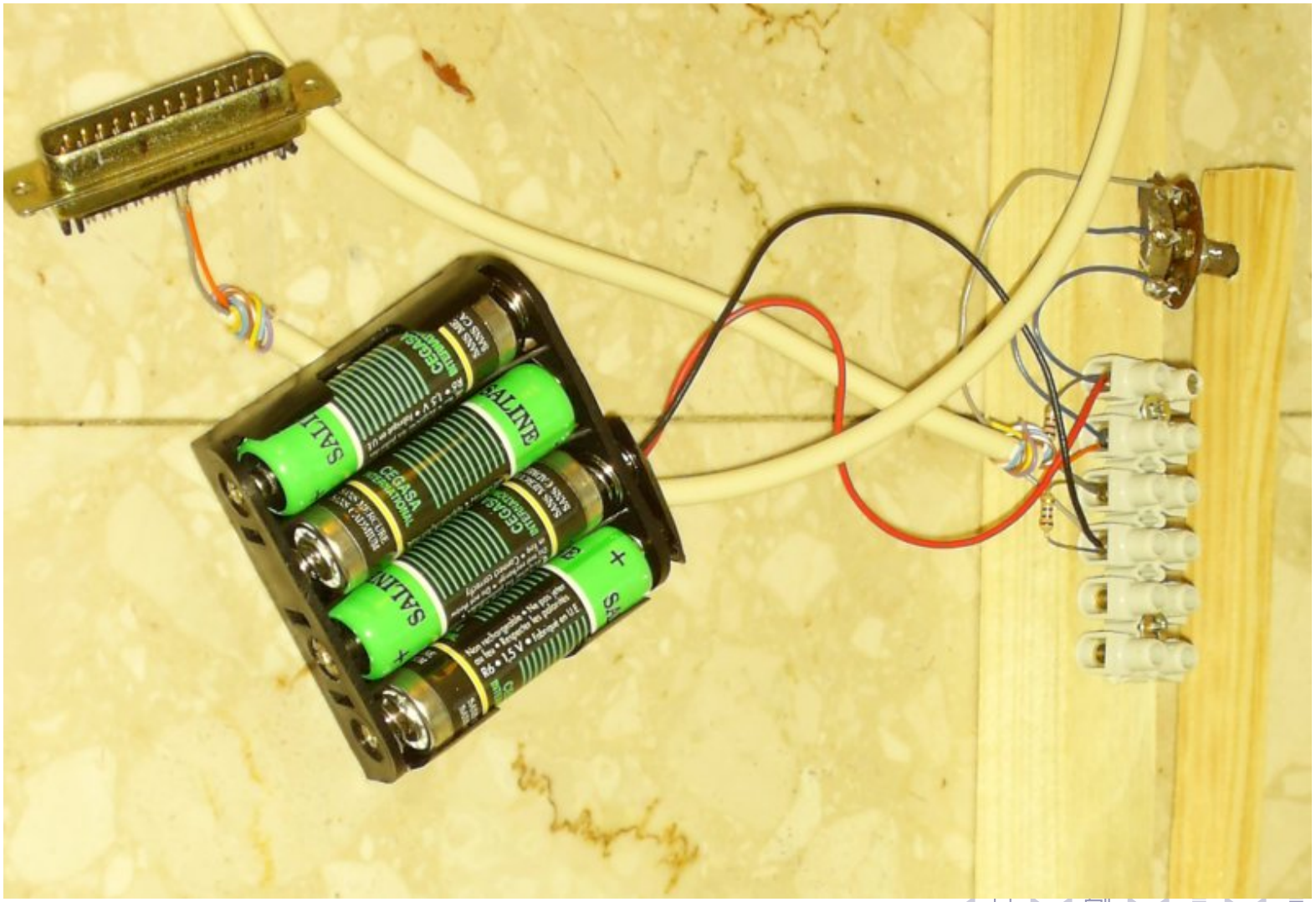
Fitting a potentiometer into a wooden stick



Wiring it all

Notice the two equal resistors, and the plug for a battery power supply.

Adding a battery and a DB25 connector

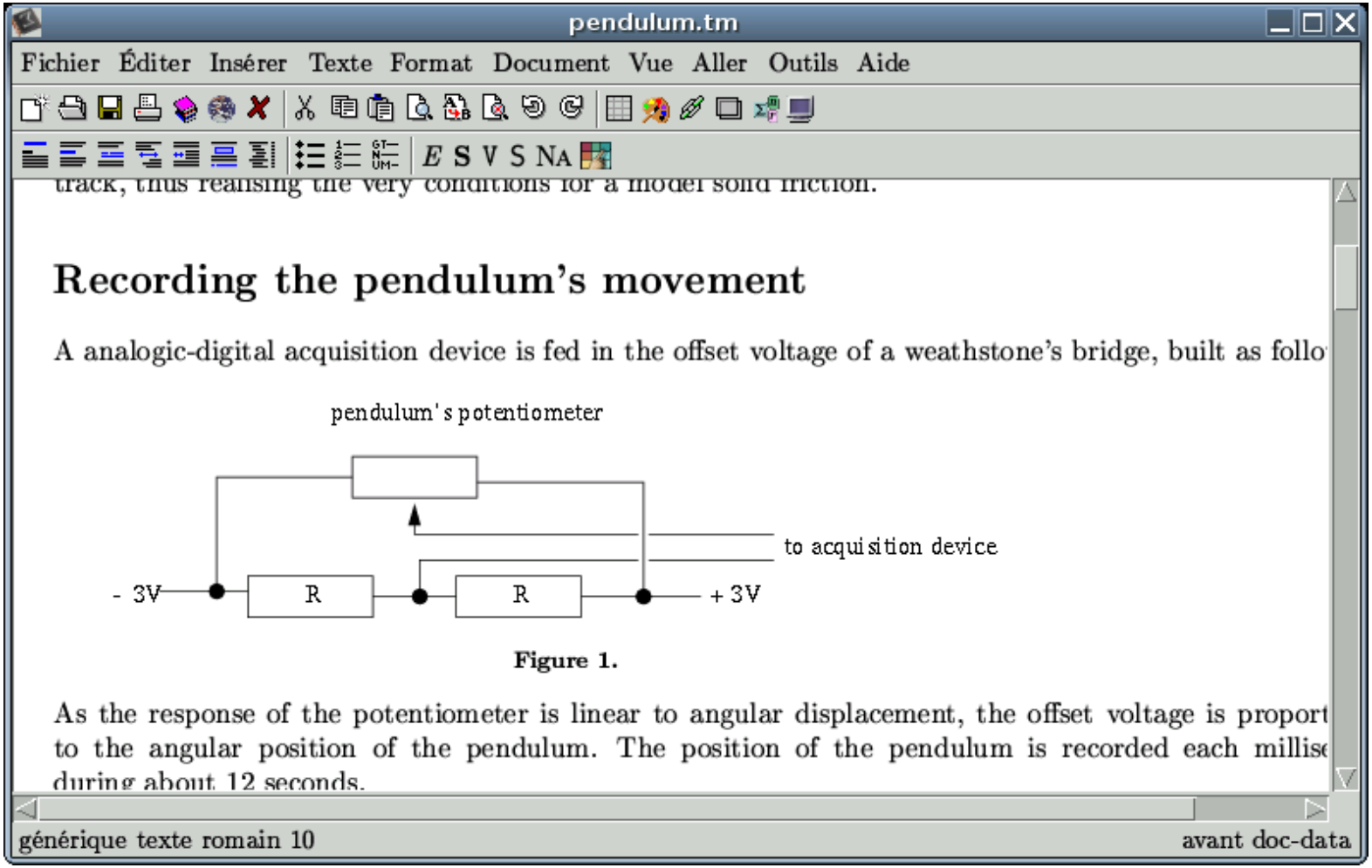


The pendulum oscillates

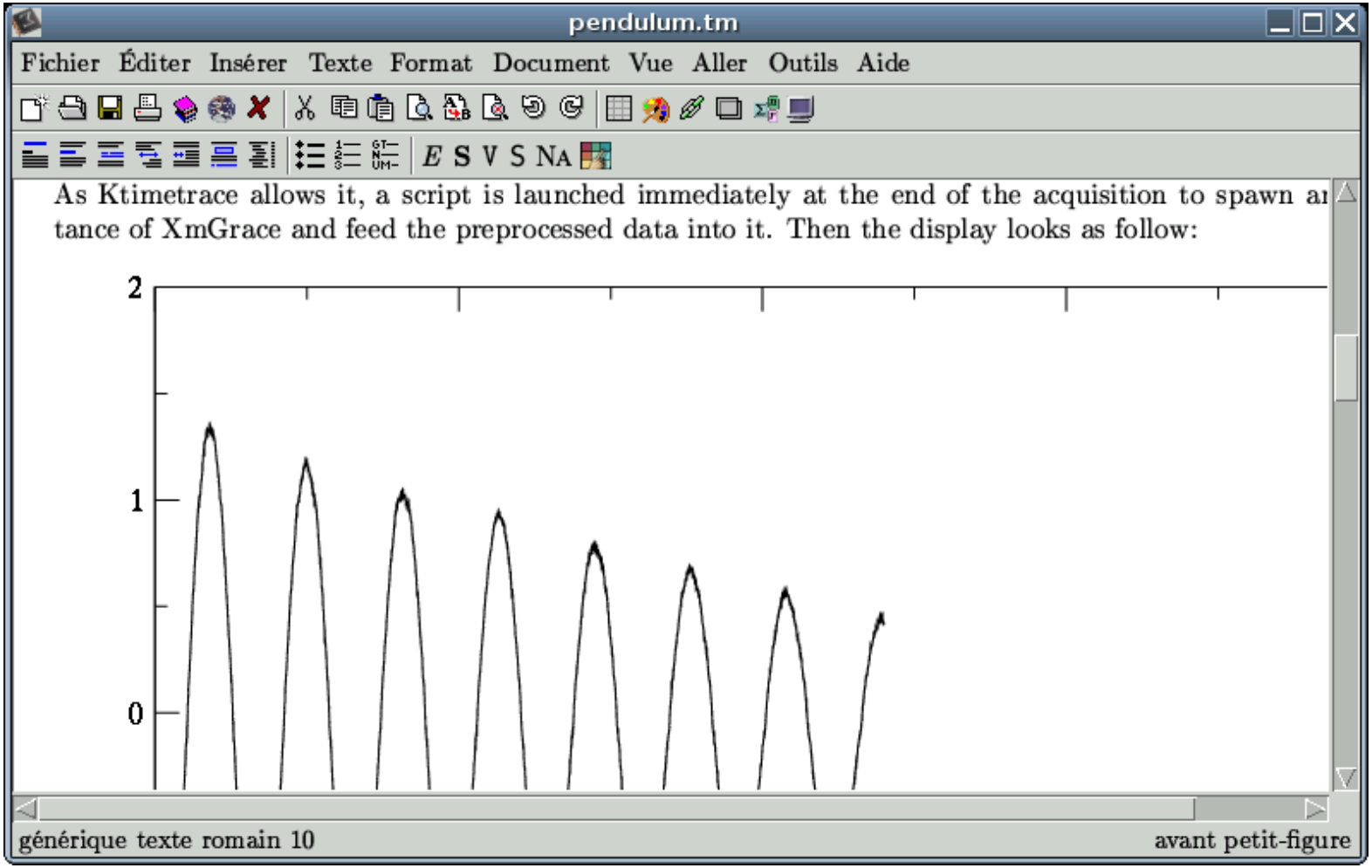
12,000 measurements are recorded

0.000000 0.321579	0.069000 0.675665	9.977000 0.239558
0.001000 0.325579	0.070000 0.683667	9.978000 0.237558
0.002000 0.331581	0.071000 0.687668	9.979000 0.233557
0.003000 0.336582	0.072000 0.687668	9.980000 0.232557
0.004000 0.339583	0.073000 0.688668	9.981000 0.232557
0.005000 0.342584	0.074000 0.692669	9.982000 0.228556
0.006000 0.349585	0.075000 0.696670	9.983000 0.227556
0.007000 0.352586	0.076000 0.701671	9.984000 0.226555
0.008000 0.354587	0.077000 0.706673	9.985000 0.226555
0.009000 0.358588	0.078000 0.710674	9.986000 0.224555
0.010000 0.363589	0.079000 0.712674	9.987000 0.224555
0.011000 0.365589	0.080000 0.718675	9.988000 0.218553
0.012000 0.374591	0.081000 0.721676	9.989000 0.218553
0.013000 0.378592	0.082000 0.722676	9.990000 0.214552
0.014000 0.390595	0.083000 0.723677	9.991000 0.215553
0.015000 0.391596	0.084000 0.728678	9.992000 0.212552
0.016000 0.393596	0.085000 0.730678	9.993000 0.213552
0.017000 0.402598	0.086000 0.735680	9.994000 0.209551

XmGrace, then TexMacs to write a structured report



See the data plotted



Then a dicussion about a model

pendulum.tm

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the amplitude decays quite linearly with time. So we can use the following model for the data, θ bein angular elongation and t being the time:

$$\theta = \theta_0 + \theta_1(1 - \frac{t}{t_{\text{null}}})\sin(2\pi\frac{t - t_0}{T})$$

θ_0 is the mean value, θ_1 is the initial amplitude, t_{null} is the date when the oscillation finishes, t_0 is a accounting for the initial phase, and T is the period of the pendulum.

Then this formula is translated to Grace's particular syntax:

$$y = a0 + a1 * (1 - x/a2) * \sin(2 * 3.1416 * (x - a3)/a4)$$

When fed into the non-linear fitting system, this formula, with the five parameters (a0..a4) does not Grace to fit the data, because of numeric inability to find the match. Then we restrict the fitting regi

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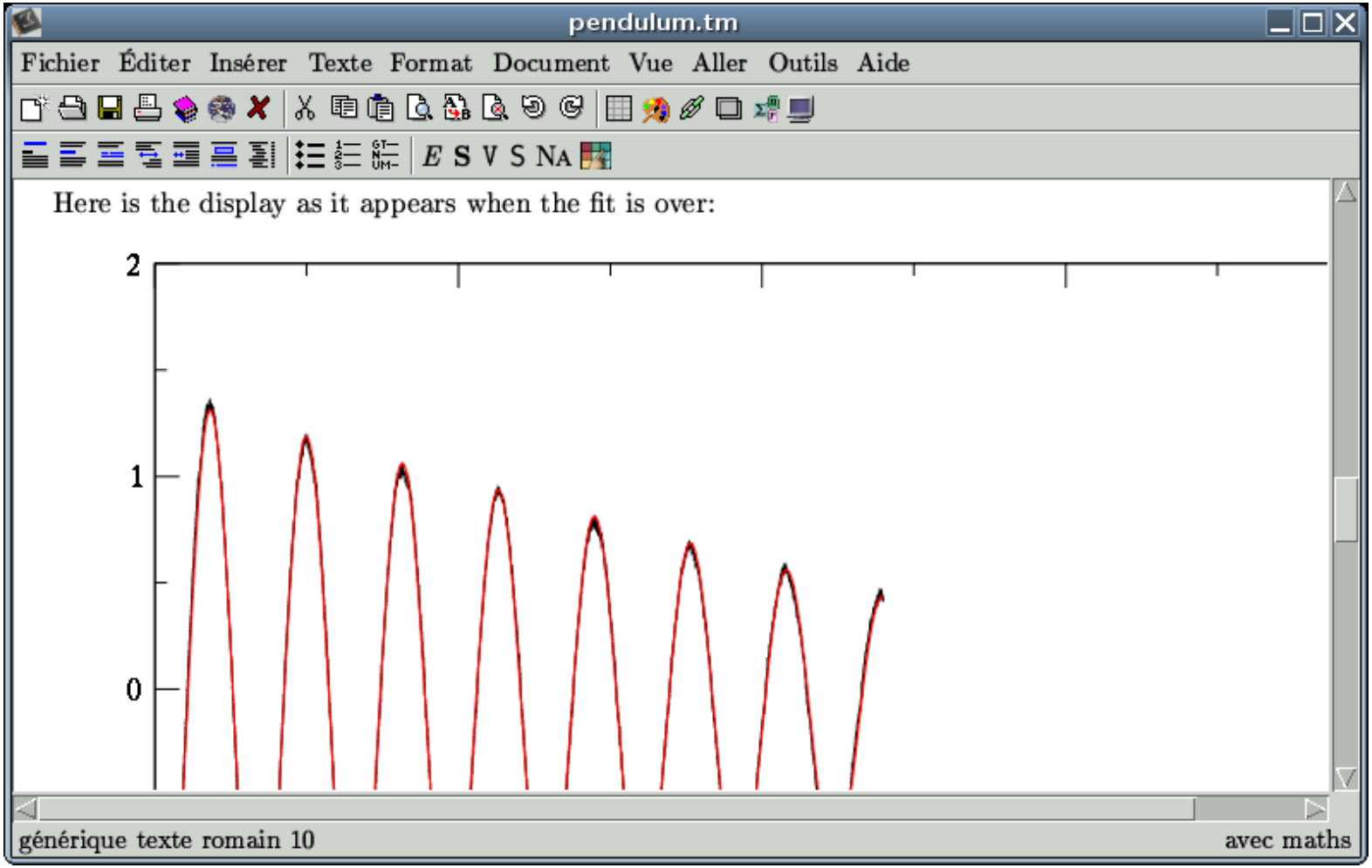
See the fit : data in black, model in red



Theoritical considerations

pendulum.tm

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raly consider the case when the phase φ is null. Then the velocity vanishes at $t = \pm\frac{T}{4}$, so

$$W = 2F \cdot s_0 \left[\sin(2\pi\frac{t}{T})\right]_{\frac{T}{4}}^{-\frac{T}{4}} = -4Fs_0$$

which is exactly the same result.

This result is strikingly simple : the amount of energy converted into heat at each period is proport to the amplitude s_0. Then, why the linear decay or the amplitude s_0 ?

Let us consider that the amplitude s_0 is now a function of time, and that in a first approximation we separate the sinusoïdal function and the amplitude decay. For the pendulum, as for other vibrators internal energy is proportional to the square of the amplitude, so we may state that this ener expressed by $E = \frac{1}{2}ks_0^2$. Let us express that the decay rate of this energy is given by the mean pow the friction force during a period: $\frac{dE}{dt} = ks_0\frac{ds_0}{dt} = -4\frac{Fs_0}{T}$. Then it comes:

$$\frac{ds_0}{dt} = -4\frac{F}{kT}$$

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