State-of-the-art Digital Seismograph

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(Session S14B-01   Location MCW 3007)

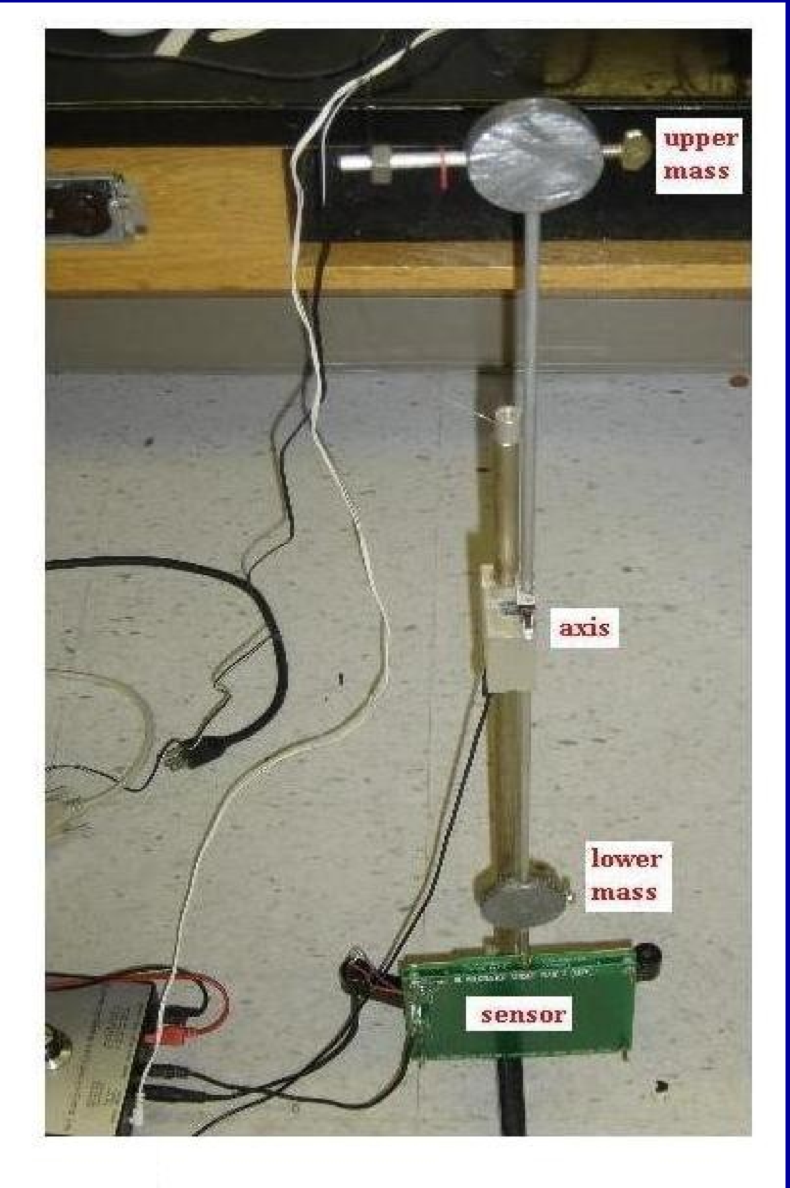
VolksMeter -- a seismometer / tiltmeter
that evolved out of fundamental physics research

The Instrument is being exhibited at this conference

Business Partners:

Les LaZar, Zoltech Corp. (Mechanical)
Larry Cochrane, Webtronics (Electronics & Software)

One Example of Pendulum research spanning nearly two decades – Compound pendulum used to study Internal friction

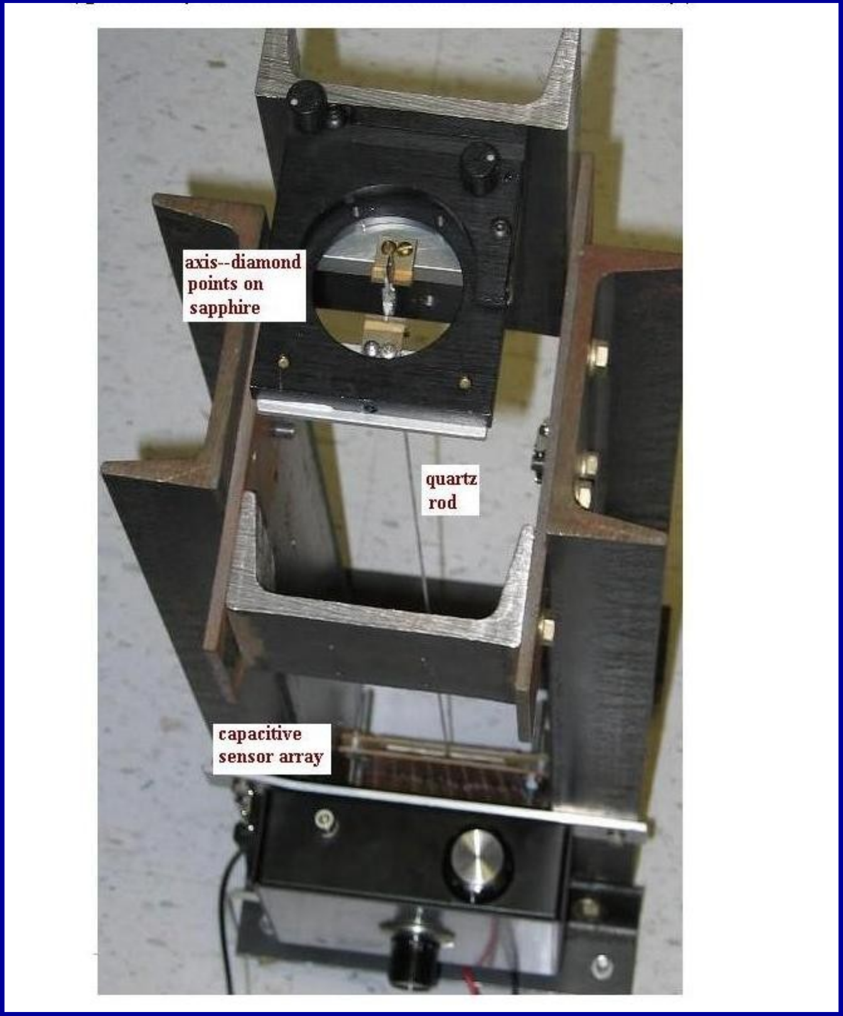


These studies discovered that Internal friction limits the performance of seismometers at low frequencies:

Some relevant publications:

(1) "**Friction at the mesoscale**", Contemp. Phys. Vol. 45, No. 6 (2004)
(2) *Vibration and Shock Handbook*, Chapters 20 & 21 on "Damping Theory" & "Experimental Techniques", ed. C. W. de Silva, CRC (2005),
(3) McGraw-Hill *Encyclopedia of Science & Technology*, articles on "Chaos (Math. Methods in Phys.)" & "Anharmonic Oscillator".

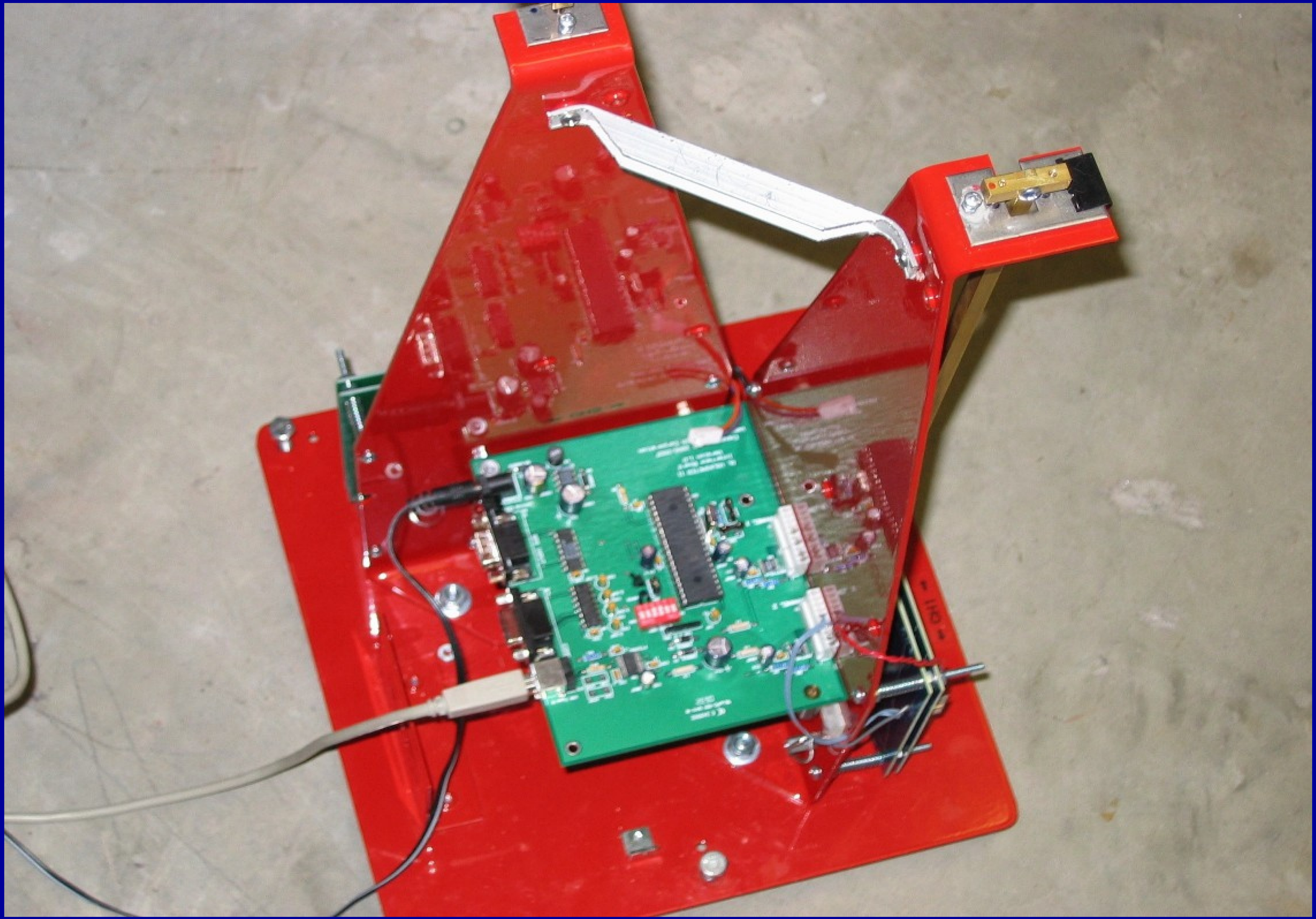
Second example of a pendulum used in physics research (generically similar to instruments used in late 19th century)



Simple pendulum used to study diurnal (non-tidal) signals continuously over an 18-month interval

Early work was by George Darwin, Son of famous English biologist in Collaboration with physics great, Lord Kelvin

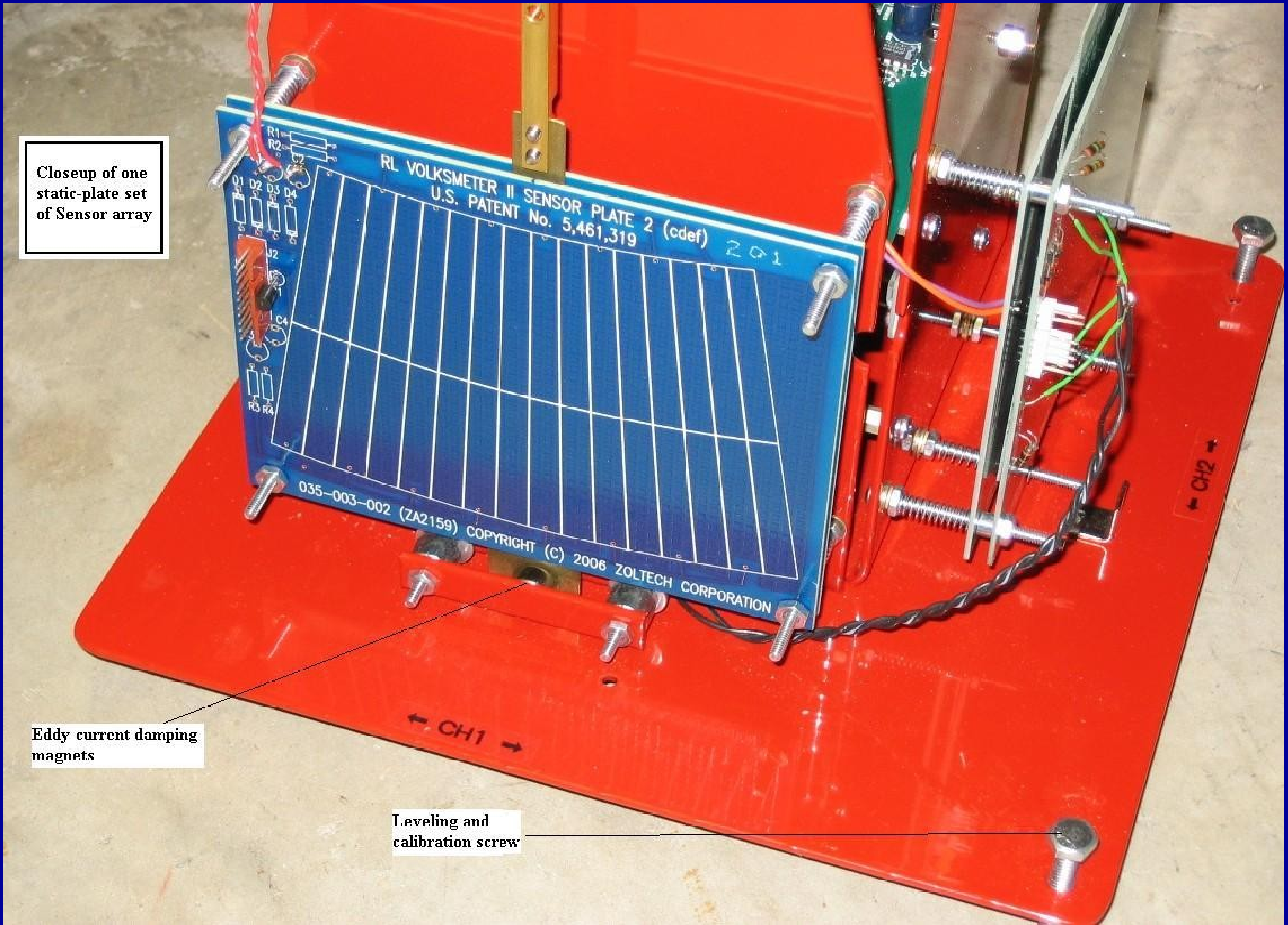
Top view of the two-pendulum VolksMeter



Close-up photograph of a Sensor

The patented symmetric differential capacitive (SDC) sensor, operating on the basis of area-variation, rather than gap-spacing-variation, is one form of the first fully-differential capacitive sensor

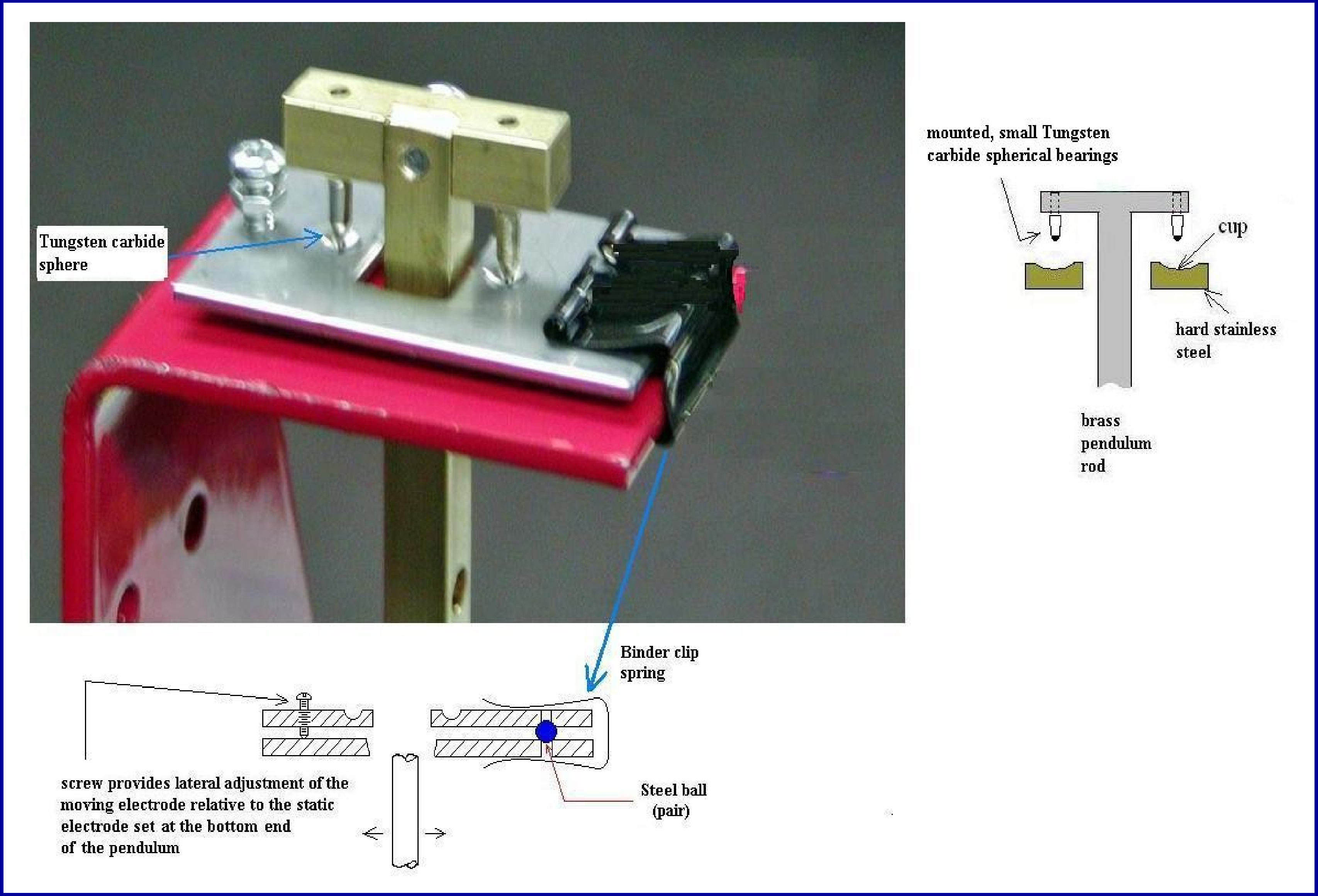
Resolution: 0.4 nrad (0.1 nm), Dynamic range > 130 dB



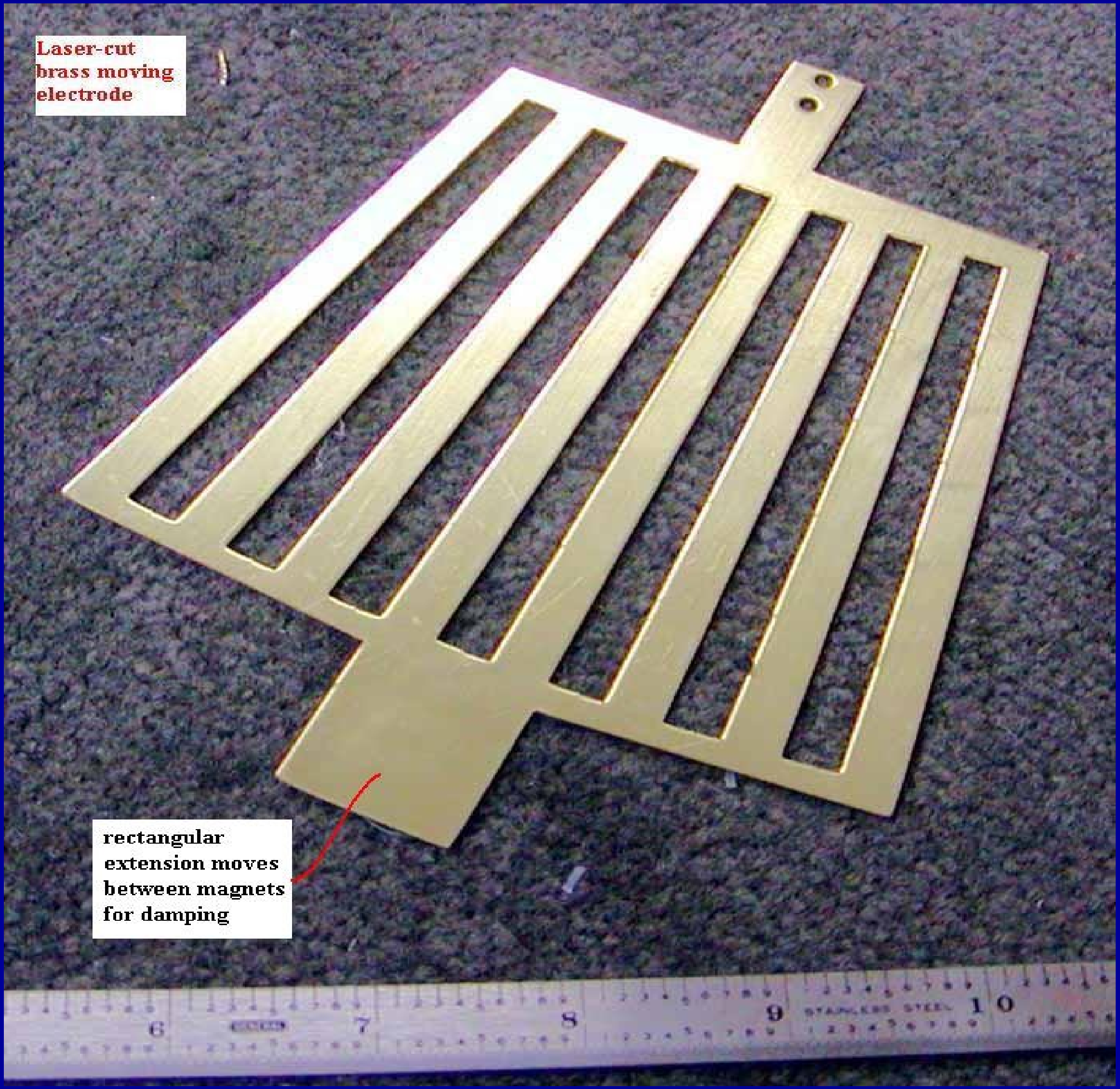
Why was a simple compound pendulum chosen?

- Superior mechanical stability.
- Simple construction.
- Simple precision calibration.
- Easy to use.
- Reduced mechanical sensitivity, previously unacceptable, overcome by latest electronics technology [SDC sensor plus capacitance to digital converter (CDC)].

Details of a pendulum axis



Moving electrode of SDC sensor



Example calibration data

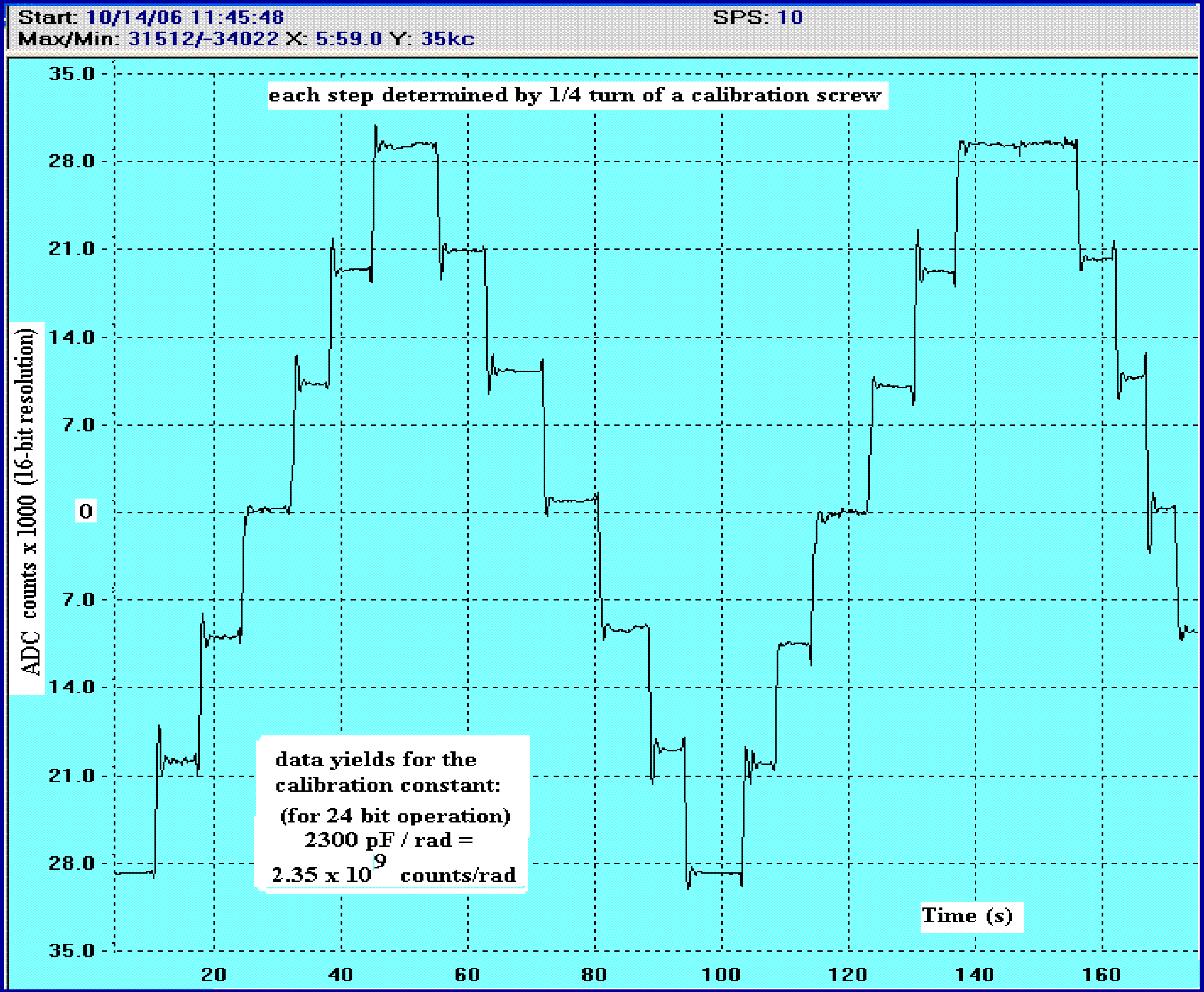
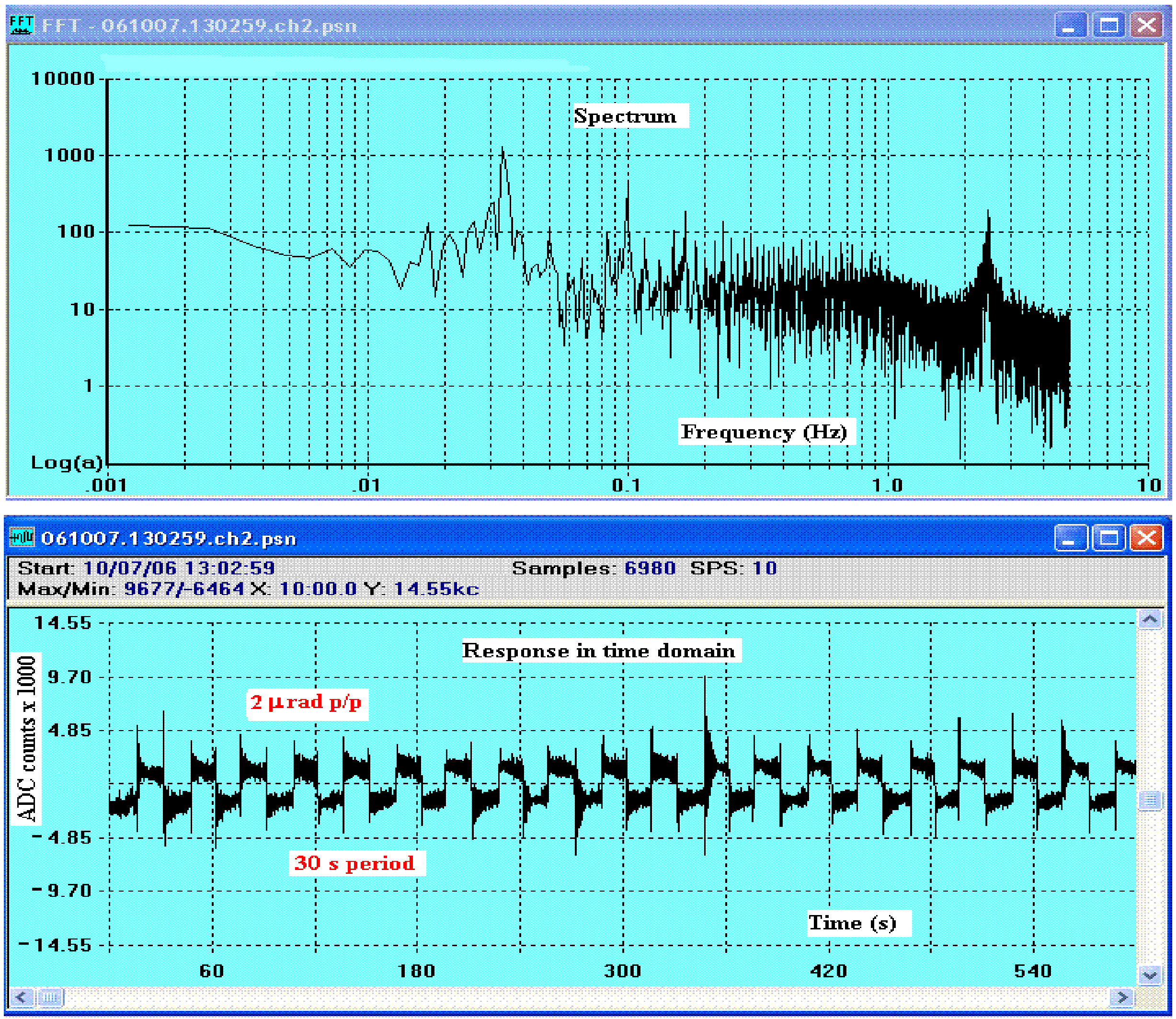


Illustration of d.c. response

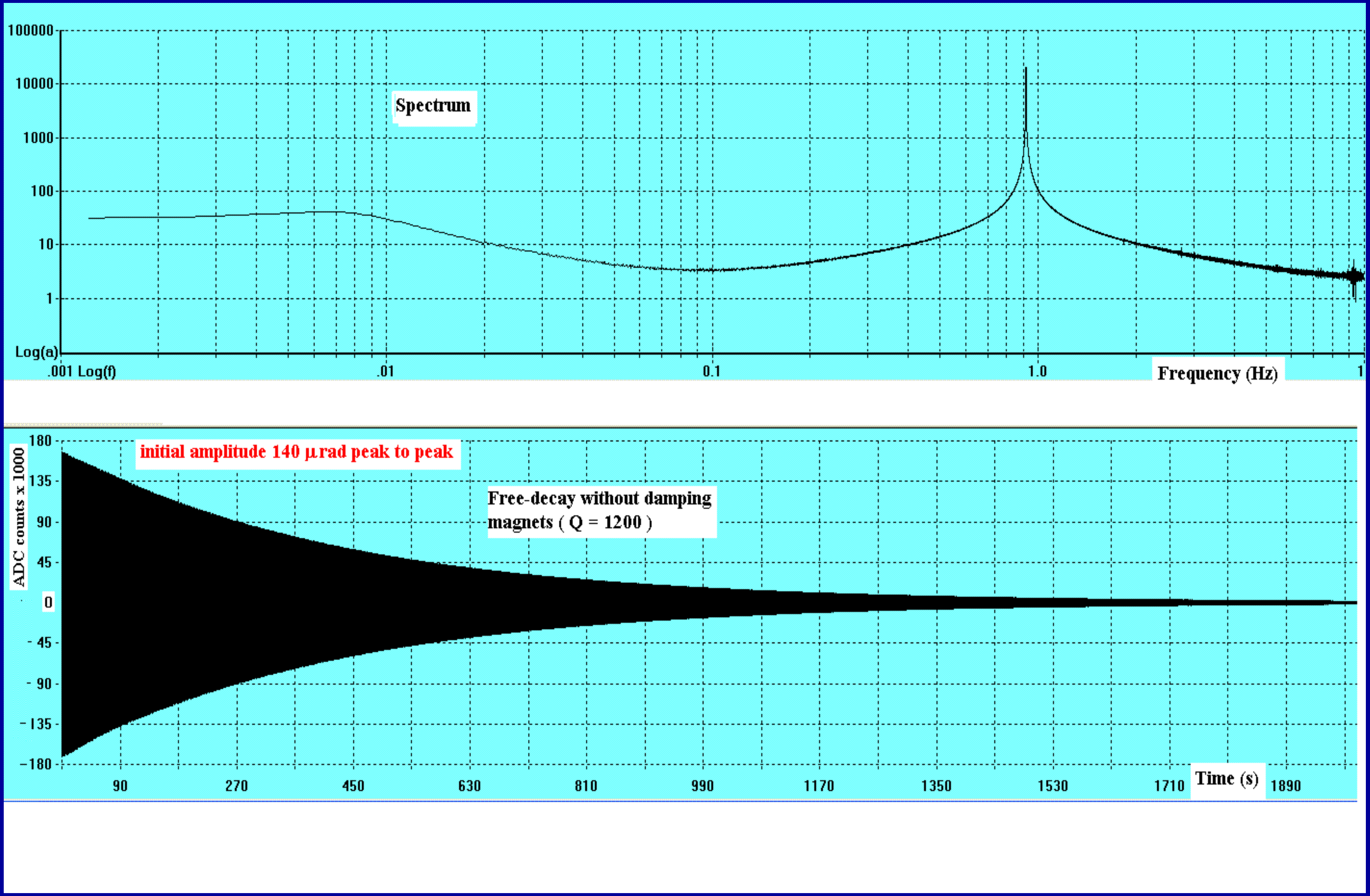
Response to body-weight deformation of concrete slab on which instruments rests

(square wave generated by stepping back & forth on opposite sides of the instrument)

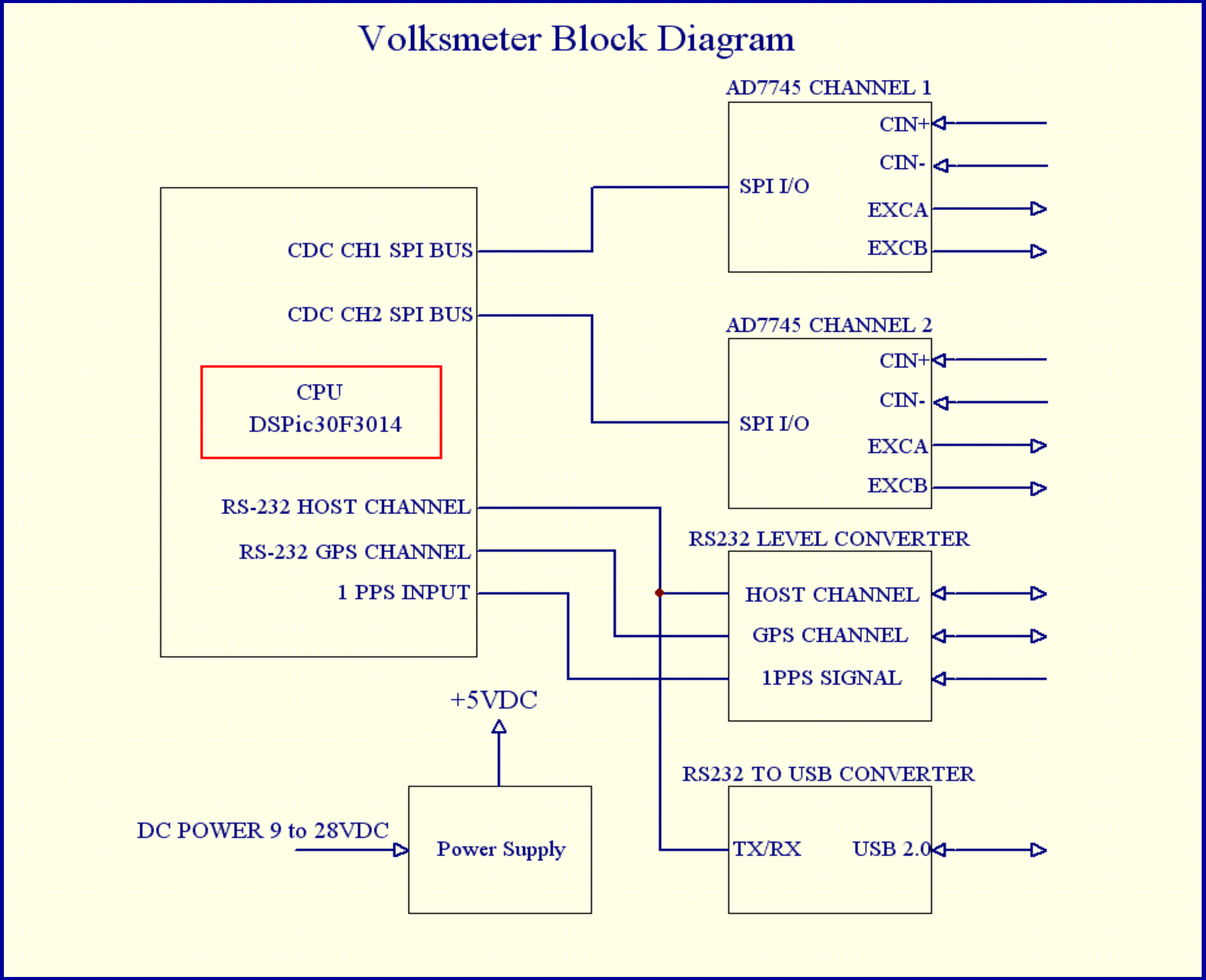


Pendulum free-decay without damping magnets

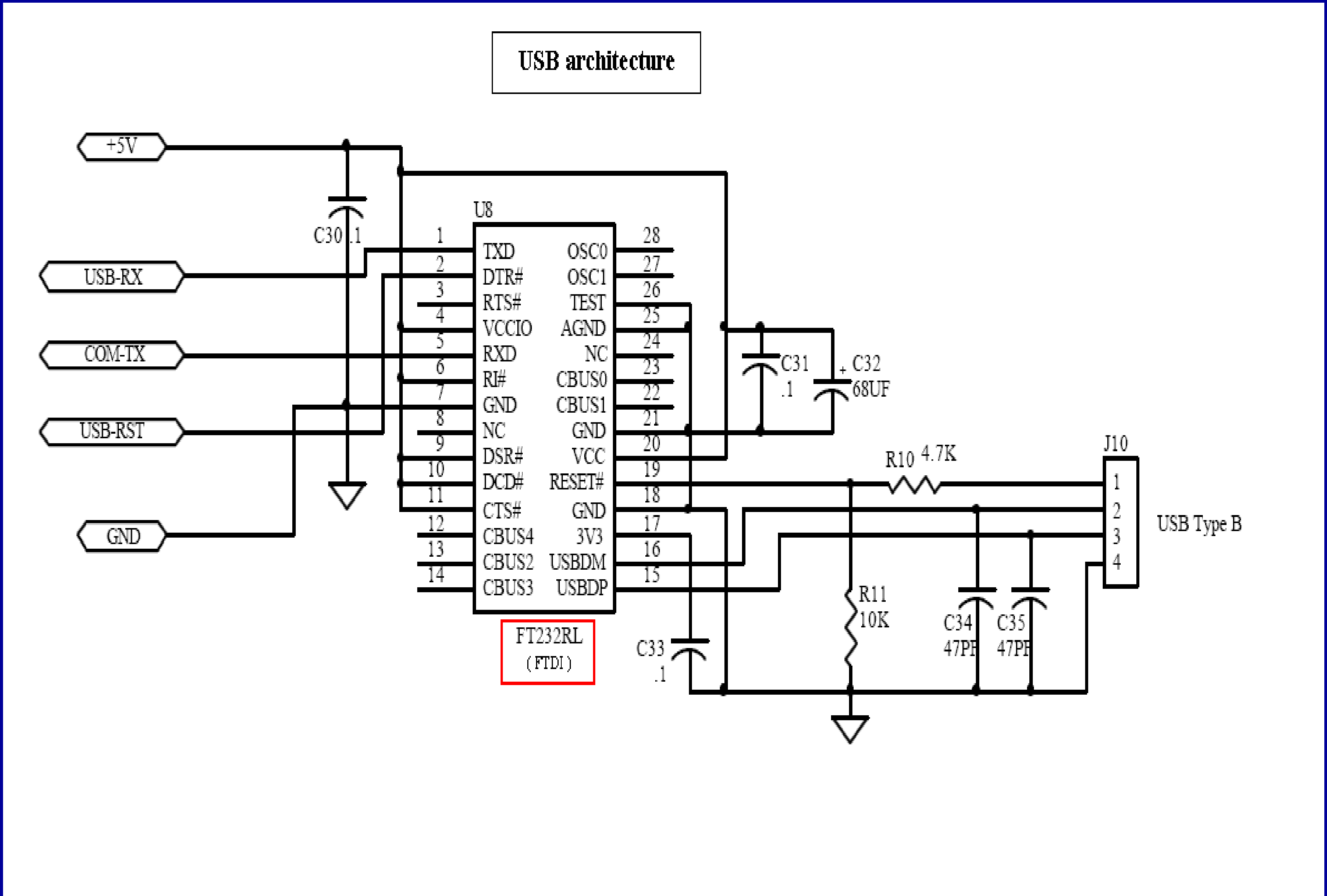
(illustrates sensor linearity—harmonic distortion below 60 dB)



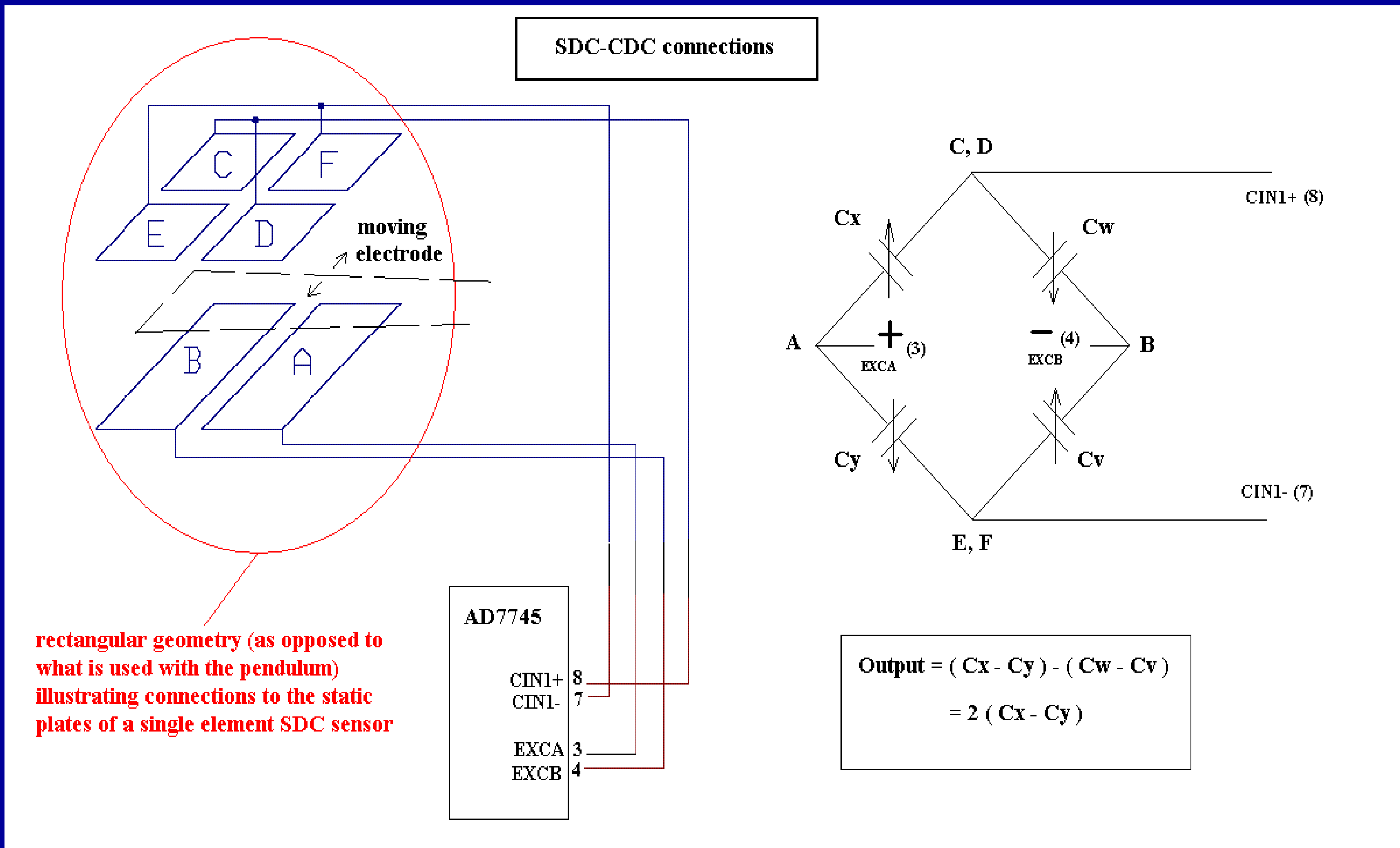
Digital electronics CPU architecture



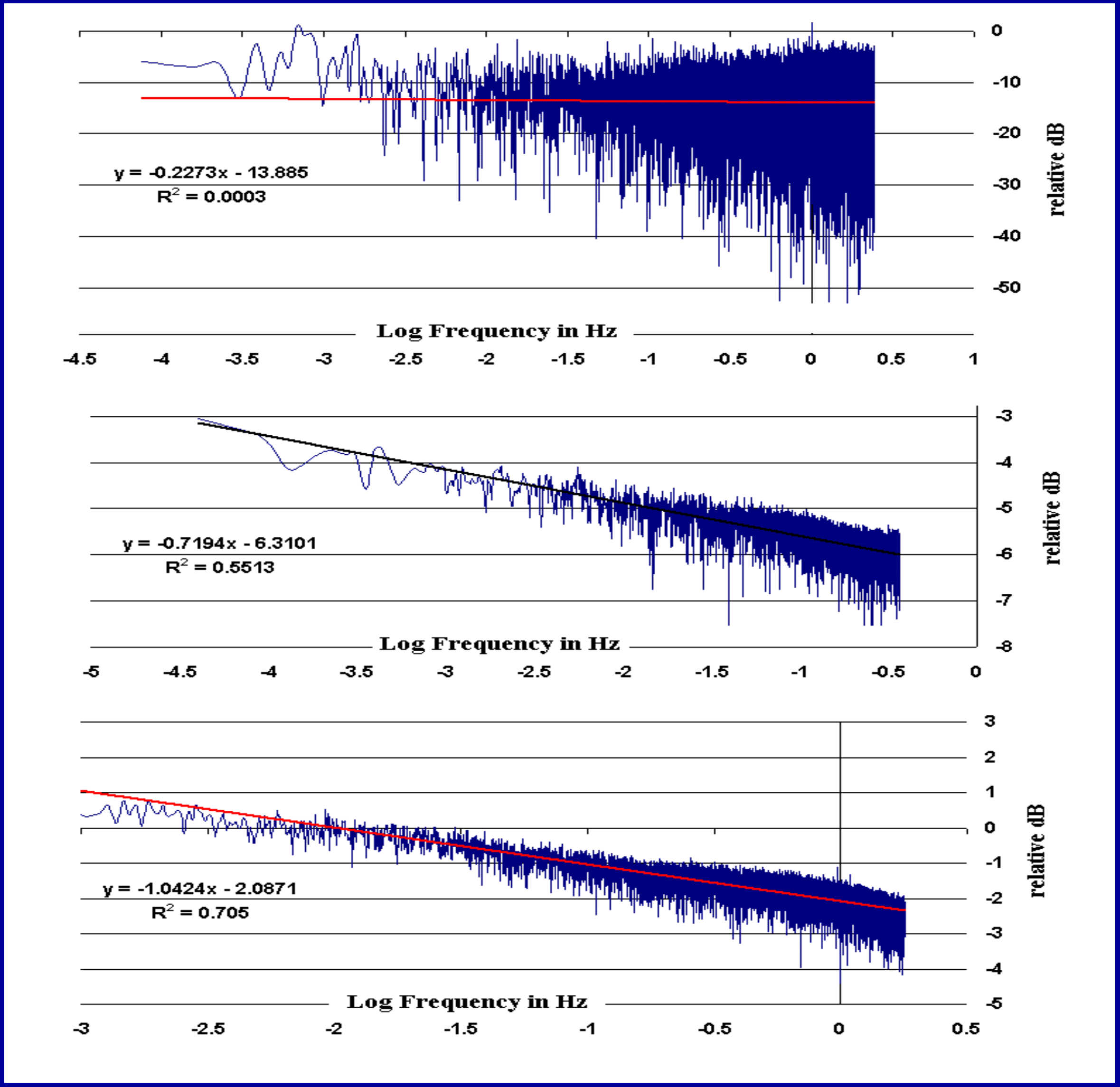
UART for USB ‘plug and play’ computer operation



Example connection--Fully-differential sensor (Peters patent U.S. 5,461,319) to the Capacitance-to-Digital-Converter (Analog Devices AD7745)



One key advantage of digital electronics

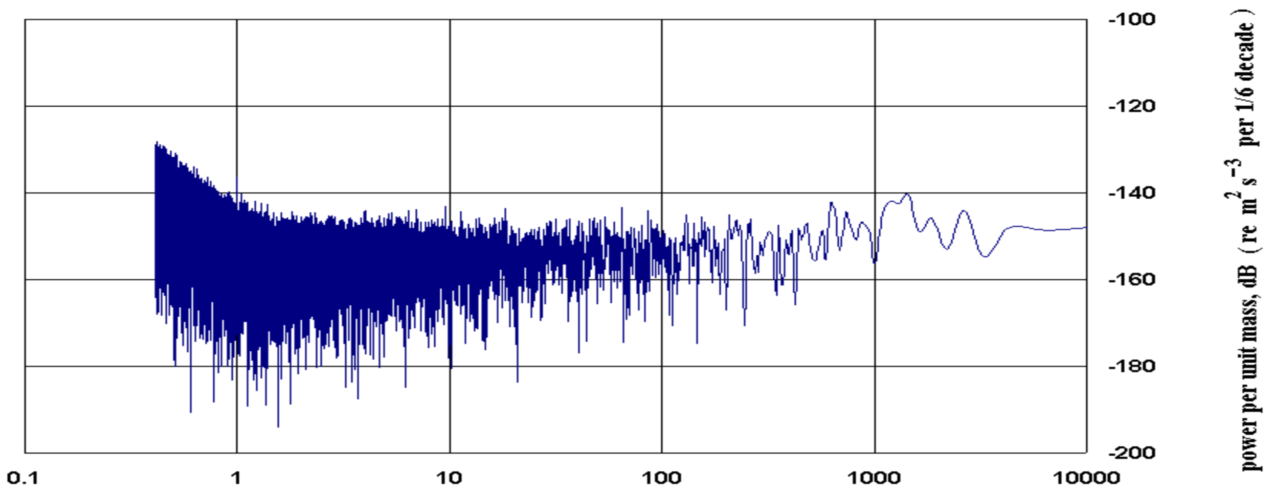


VolksMeter with fully-digital electronics
($1 / f^{0.23}$)

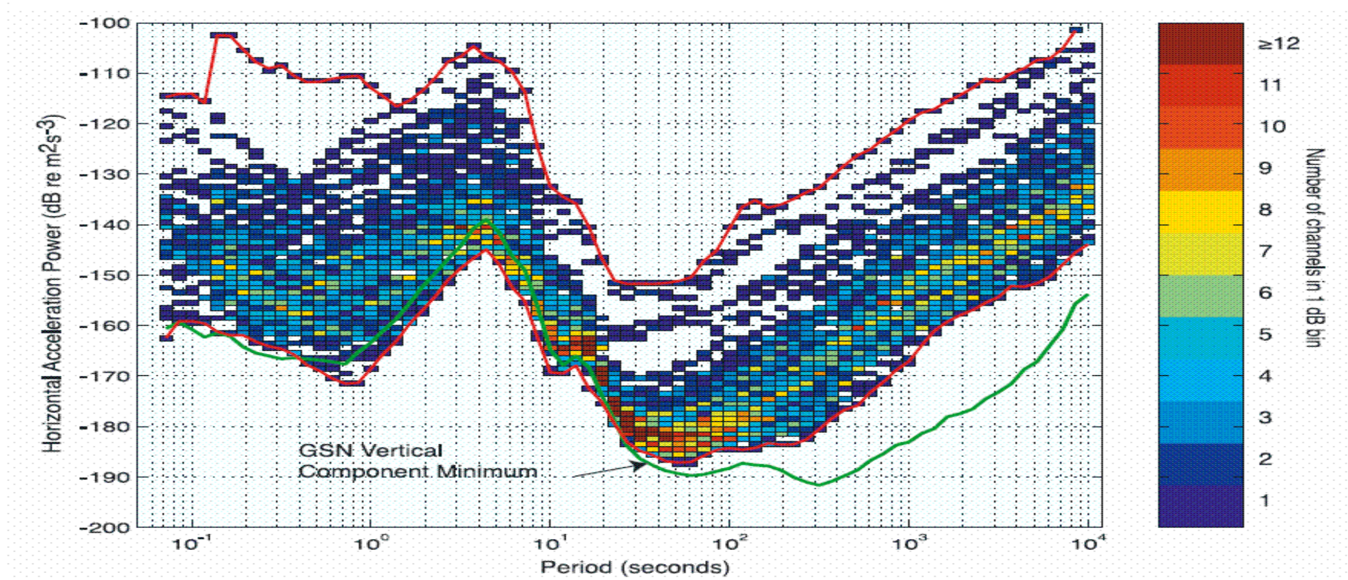
SDC sensor with synchronous detection
($1 / f^{0.72}$)

SDC sensor without synchronous detection
(classic 1 / f)

VolksMeter Noise compared to earth background



VolksMeter's Instrument Equivalent Noise Power Spectral Density



From Fig. 7, horizontal component only, J. Berger & P. Davis, J. Geophys. Res. Vol. 109, B11307 (2004).

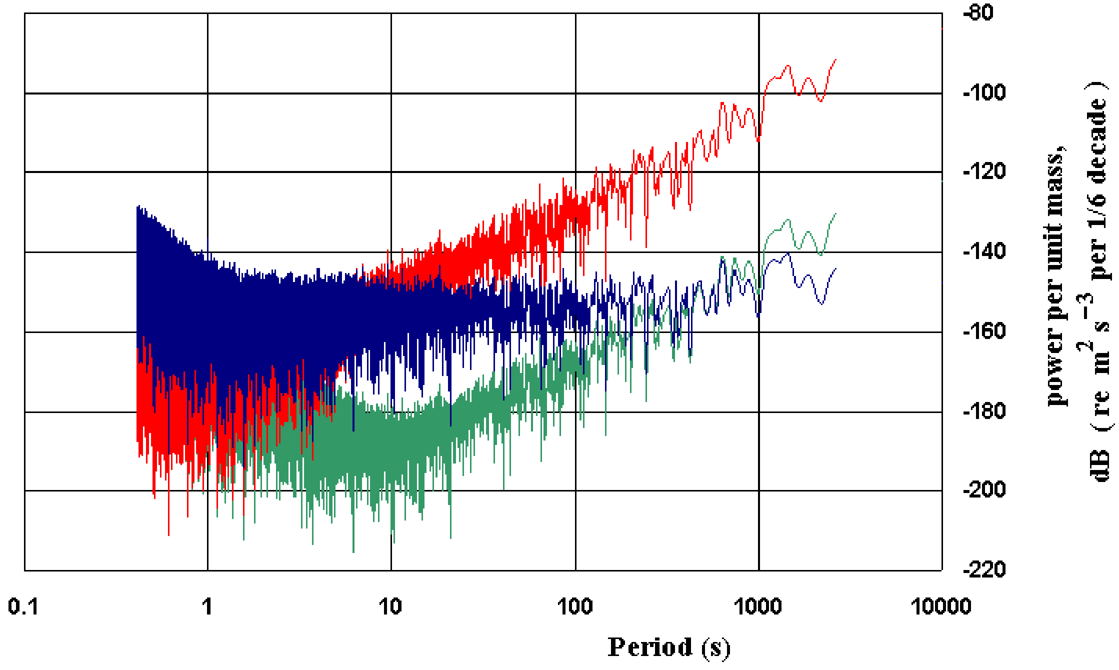
Advantage of a position sensor over a conventional velocity sensor at low frequencies

Influence of Sensor and Pendulum characteristics on Instrument Equivalent Noise Power Spectral Density

blue: present Volksmeter configuration using a position sensor

red: if the Volksmeter used a velocity sensor

green: if the pendulum's period were 10 s and used a velocity sensor ⟶ 40 dB SNR increase for T > 10 s

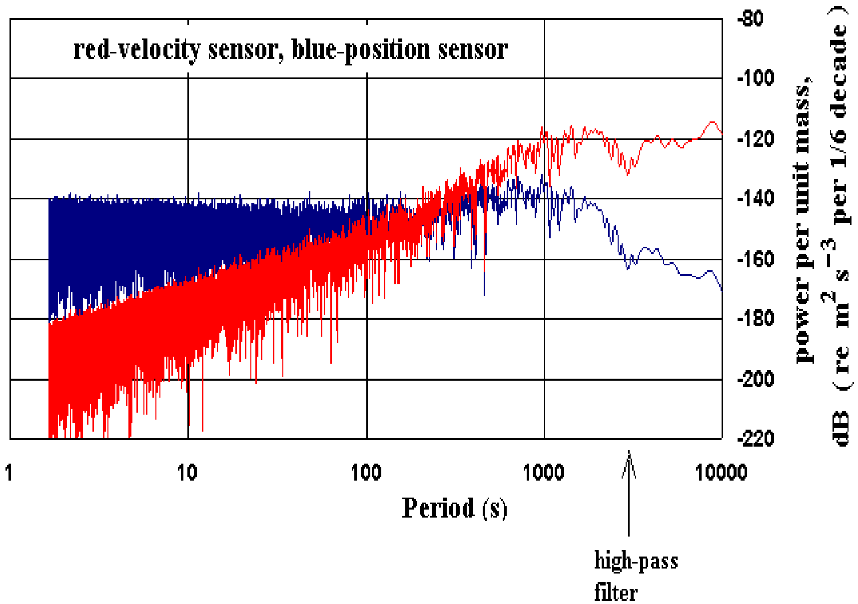


Position sensor also takes advantage of a pendulum's tilt response at low frequencies

Advantage of Position sensing at Low Frequencies

[Plots of Instrument Equivalent Noise Power Spectral Density (true power)]

Volksmeter pendulum, natural frequency = 0.918 Hz



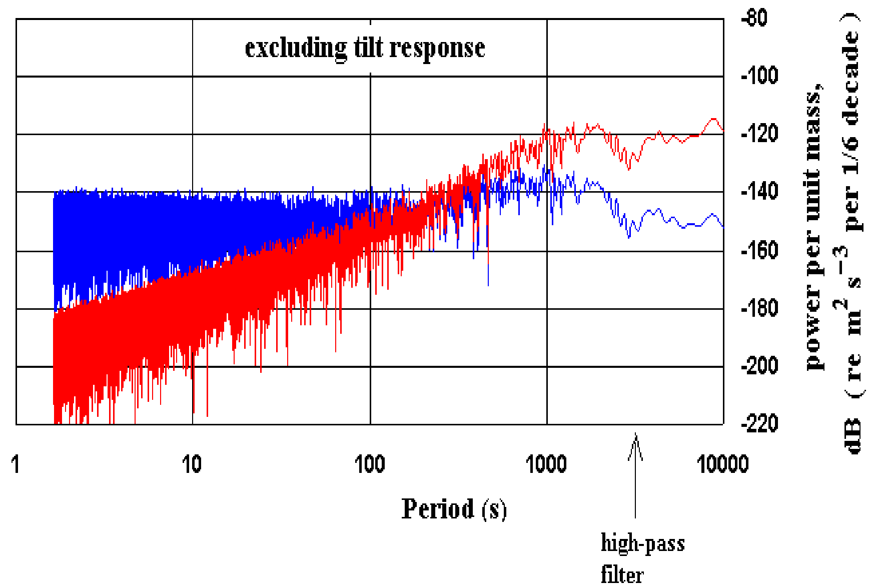
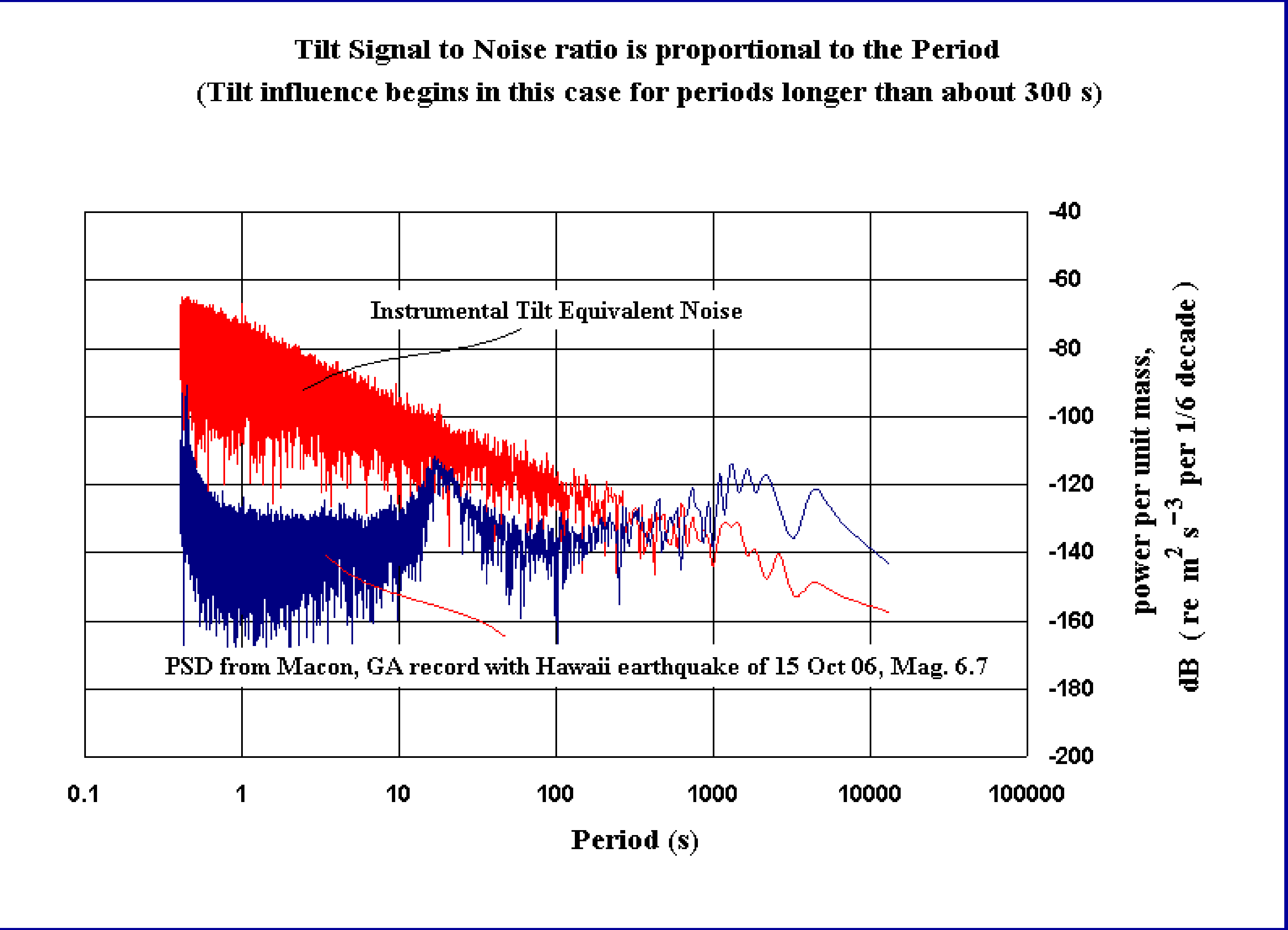
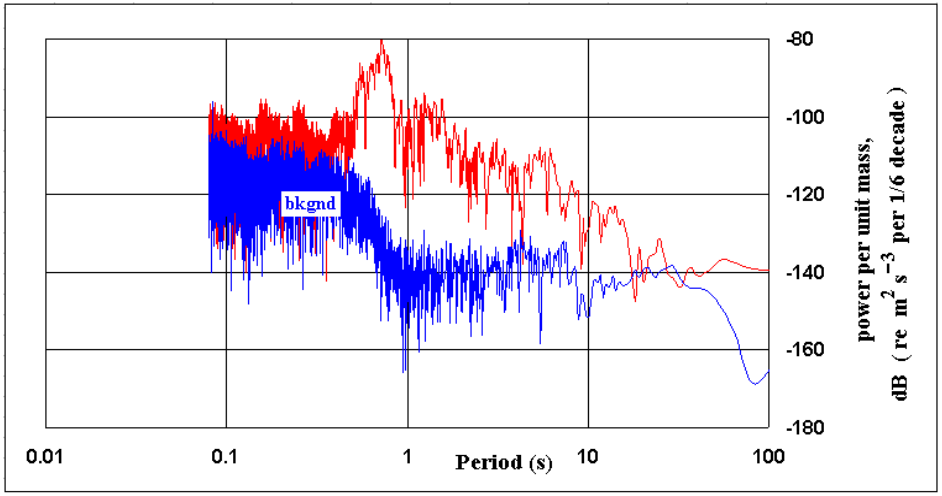


Illustration of how the tilt response becomes increasingly significant as frequency decreases

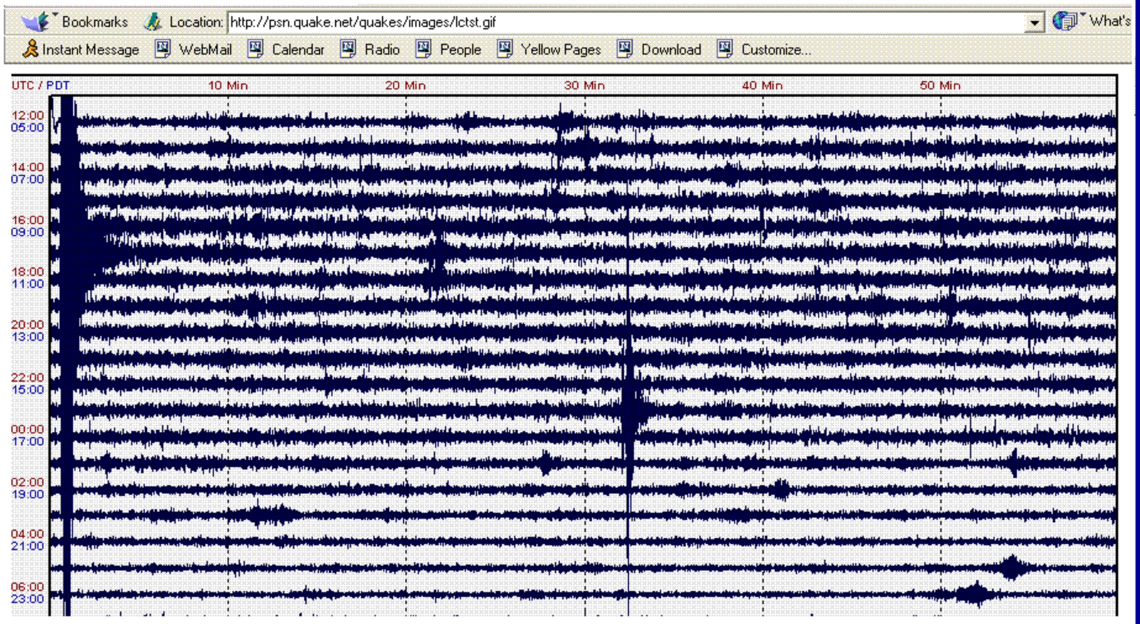
[Tilt response of horizontal seismometers treated by P. W. Rodgers, "The response of the horizontal pendulum seismometer to Rayleigh and Love Waves, tilt, and free oscillations of the earth", Bull. Seis. Soc. Amer., v. 58, no. 4, pp. 1385-1406 (1968).]



Response to local earthquakes (two events, same helicord)



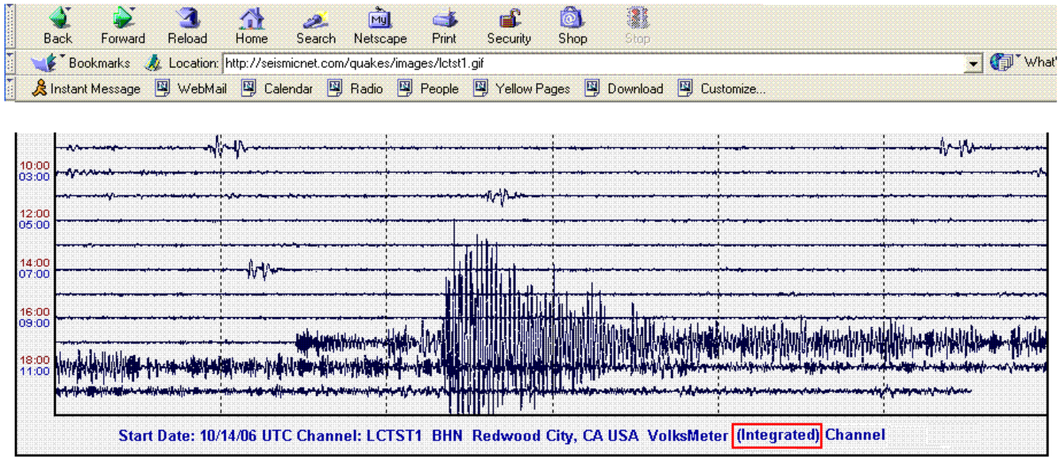
Power Spectral Density plot of first Earthquake of Mag. 4.5
(2[nd] earthquake Mag. 3.9)



Helicord records -- each event 160 km northerly distant from instrument having N-S pendulum orientation

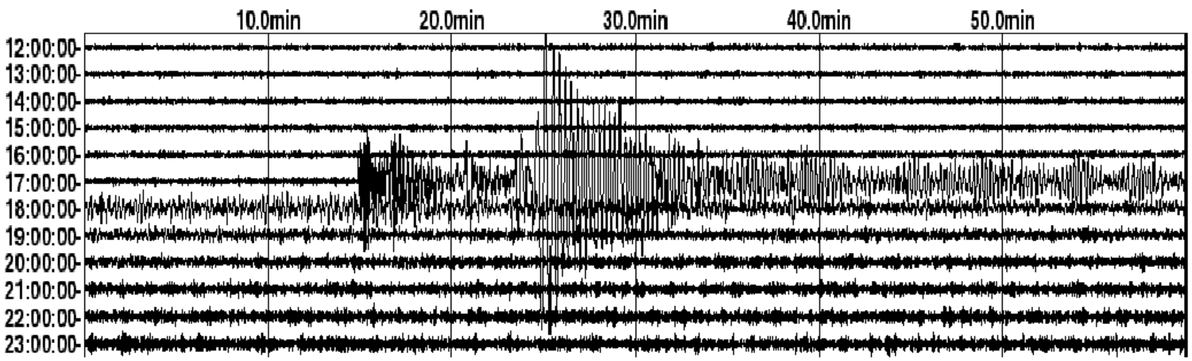
Comparison of Volksmeter teleseismic response to a commercial broadband instrument

Volksmeter record of Hawaii earthquake of 15 Oct 06, Mag 6.7, recorded in Redwood City, CA



USGS Broadband (STS-1), no filter (one of 3 display types realtime at http://jclahr.com/science/psn/cor/index.html)

Data from station COR (Corvalis, Oregon)



COR ,00/BHZ Start Date:10/15/06 Filter: None. Displacement Magnification = 5000.00 @ 1.000 Hz

Advantage of the Integrated signal for the real-time observation of teleseismic earthquakes

(Event is the Hawaii earthquake of 15 October 2006, Mag. 6.7, observed in Macon, Georgia)

Spectra: blue--clamped pendulum, red--raw position data, green--integral of position after high-pass filtering

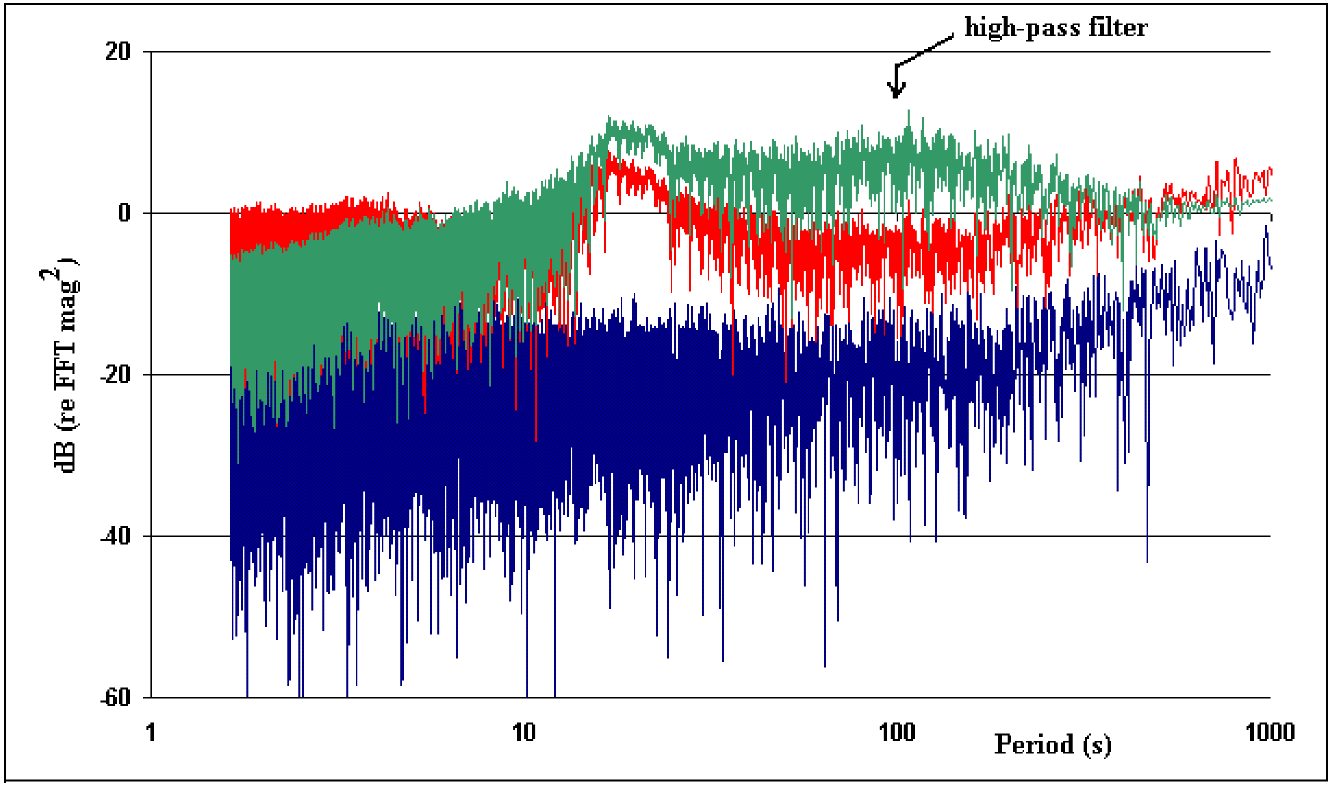
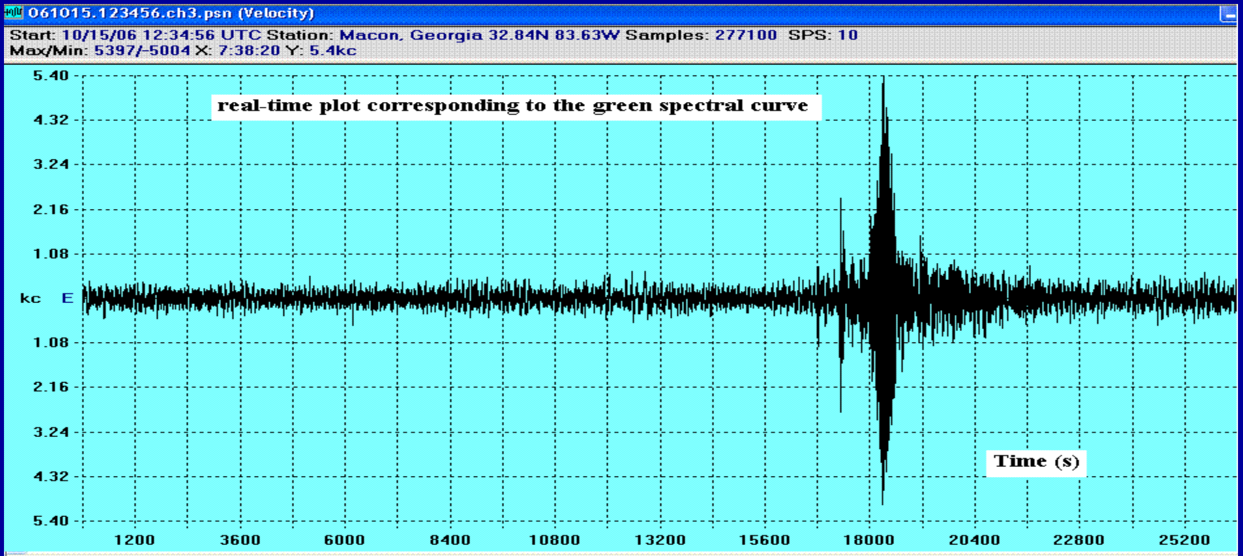


Illustration of difference in the time domain—raw data vs integrated signal



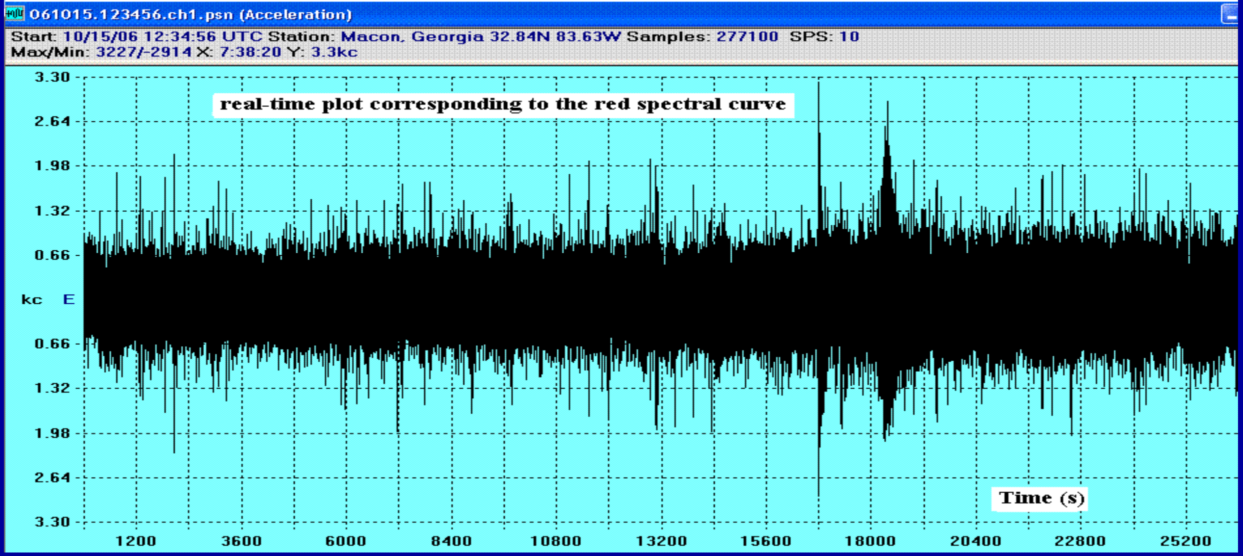
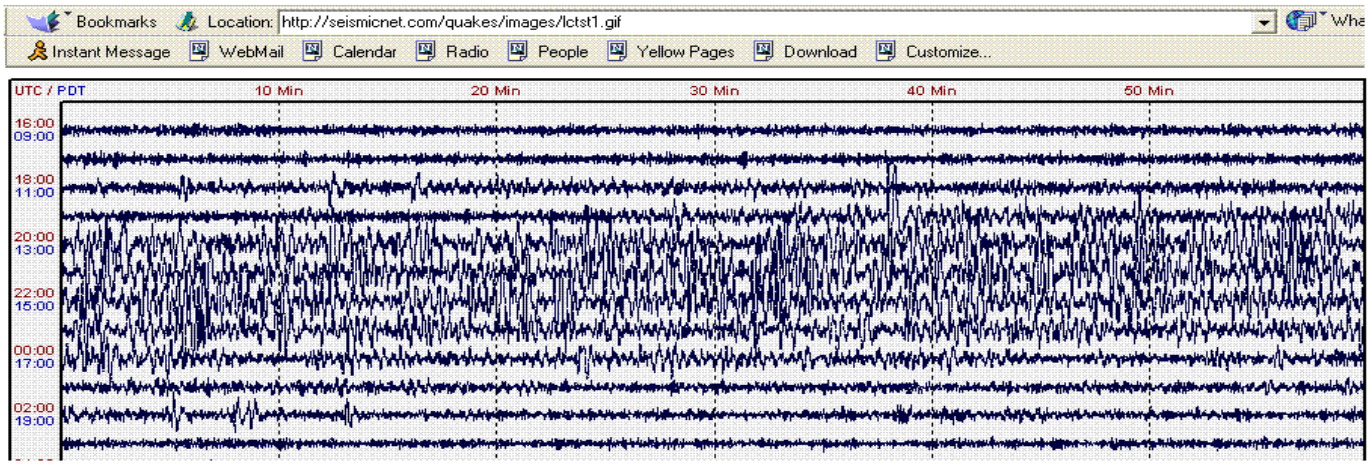
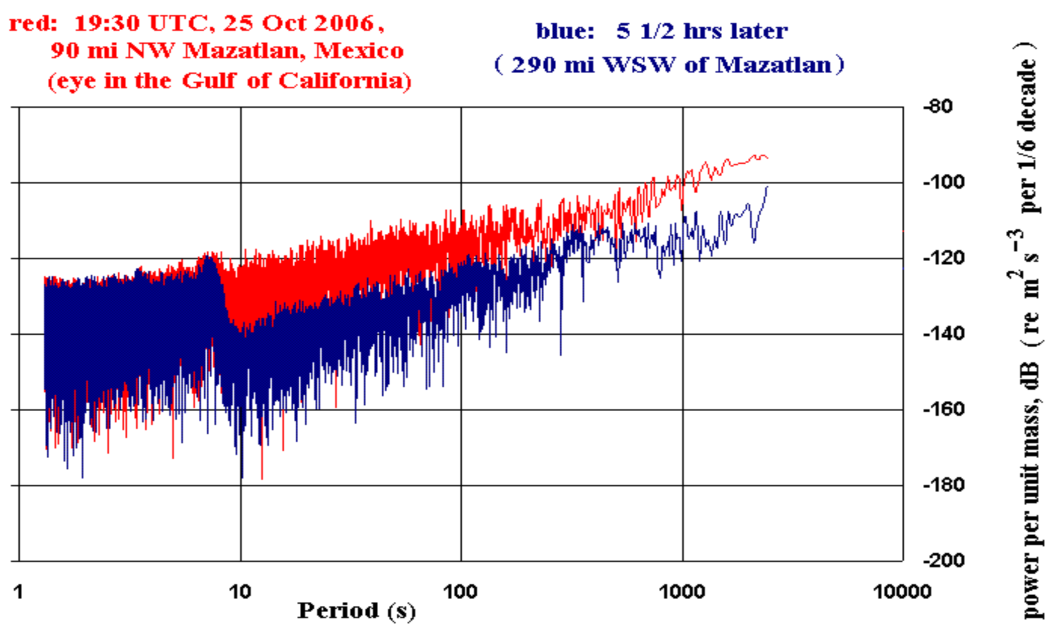


Illustration of the broadband features of the Volksmeter
(response during demise of tropical storm Paul)



Helicord record, Instrument at Redwood City, CA



Power Spectral Densities

(32K points from pair of 6 h segments)

VolksMeter Operational Attributes

Triad of features integrated in a uniquely synergetic package:

2. Latest technology (fully differential capacitive) sensor
3. Award-winning acquisition electronics
4. Powerful, user-friendly acquisition (WinSDR) and analysis (WinQuake) software (also compatible with USGS seismic recording package, “Earthworm”)

- Providing good earthquake records, both local and teleseismic, while
- Yielding a new window on the world of very-low-frequency earth motions and
- Providing means to easily generate TRUE power spectral densities)

Example of WinQuake generated figures (records following storm passage)

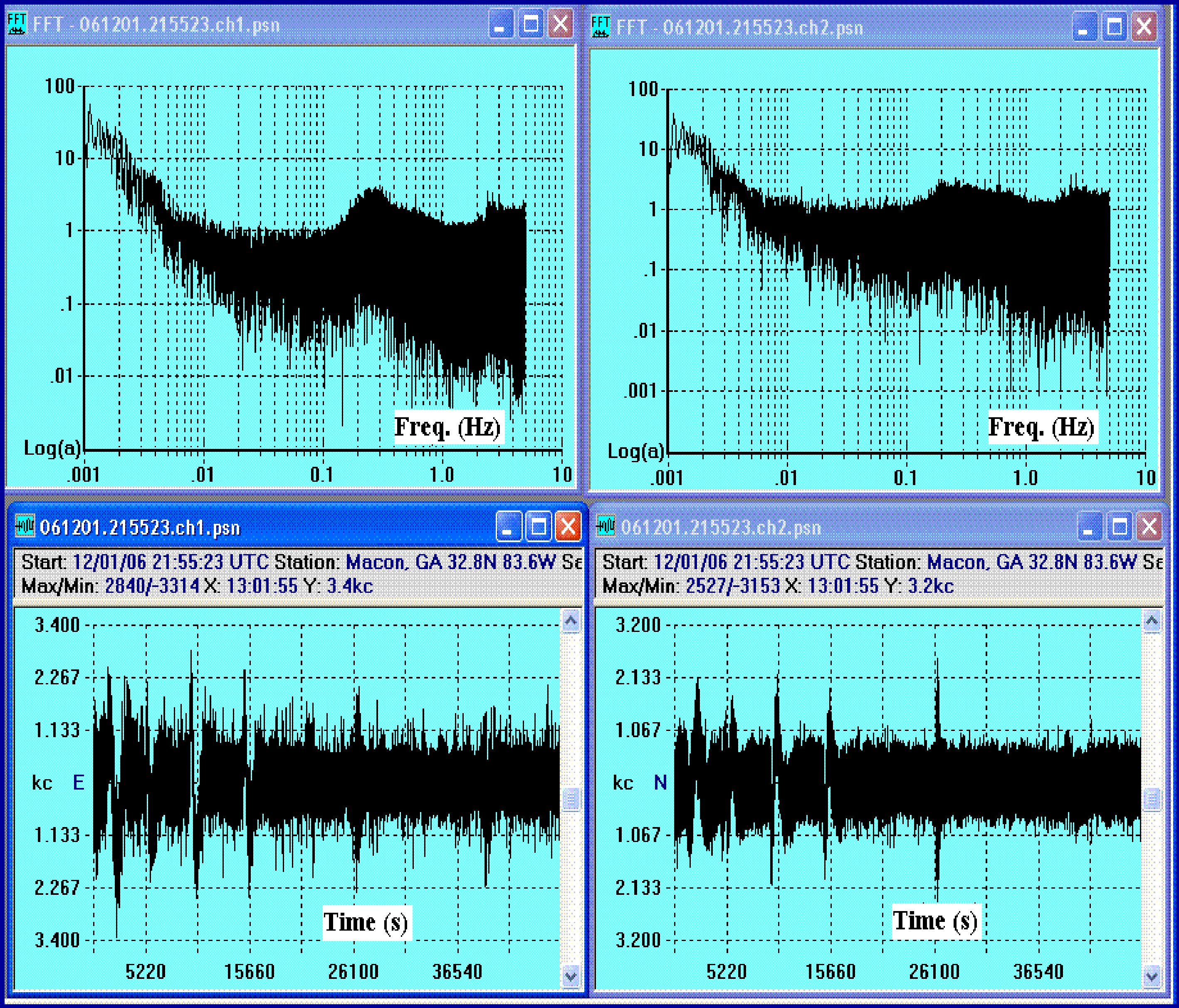


Illustration of the ease with which filtering is done (here low-pass at 0.1 Hz)

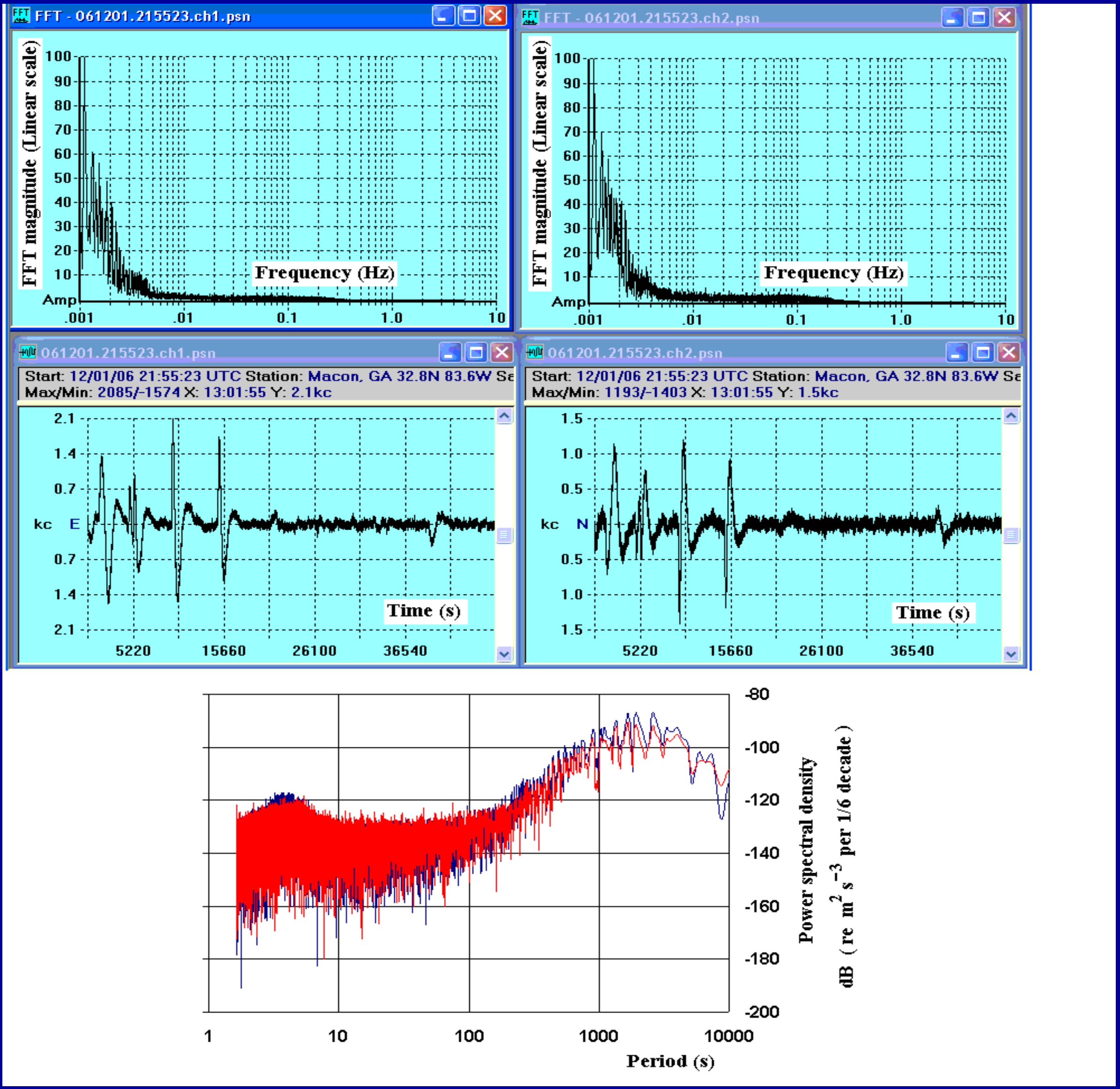


Illustration of added-versatility through easy-exportation of data to Excel