# Noise Measurements On Chemical Batteries

## Gerhard Hoffmann

## Contents



## Goals

This is part 2 of a series of articles on the state of the art in low-noise power supplies, batteries, references and regulators. Part 1 dealt with the design of a pre-amplifier that makes it possible to measure the very small noise voltages involved. [GHF LONO]

It was felt necessary to disclose all the details of the materials used so that everybody can buy that stuff and either use it or challenge the results. That someone has a certain golden but unspecified reference behind the walls of his institute does not help much. The statistical base is already thin enough.

I do not think that the manufactures care much about these results on the noise behaviour; these results are of interest only to a small in-group, that what counts for their customers is how long their LED lamp will last with a battery set.

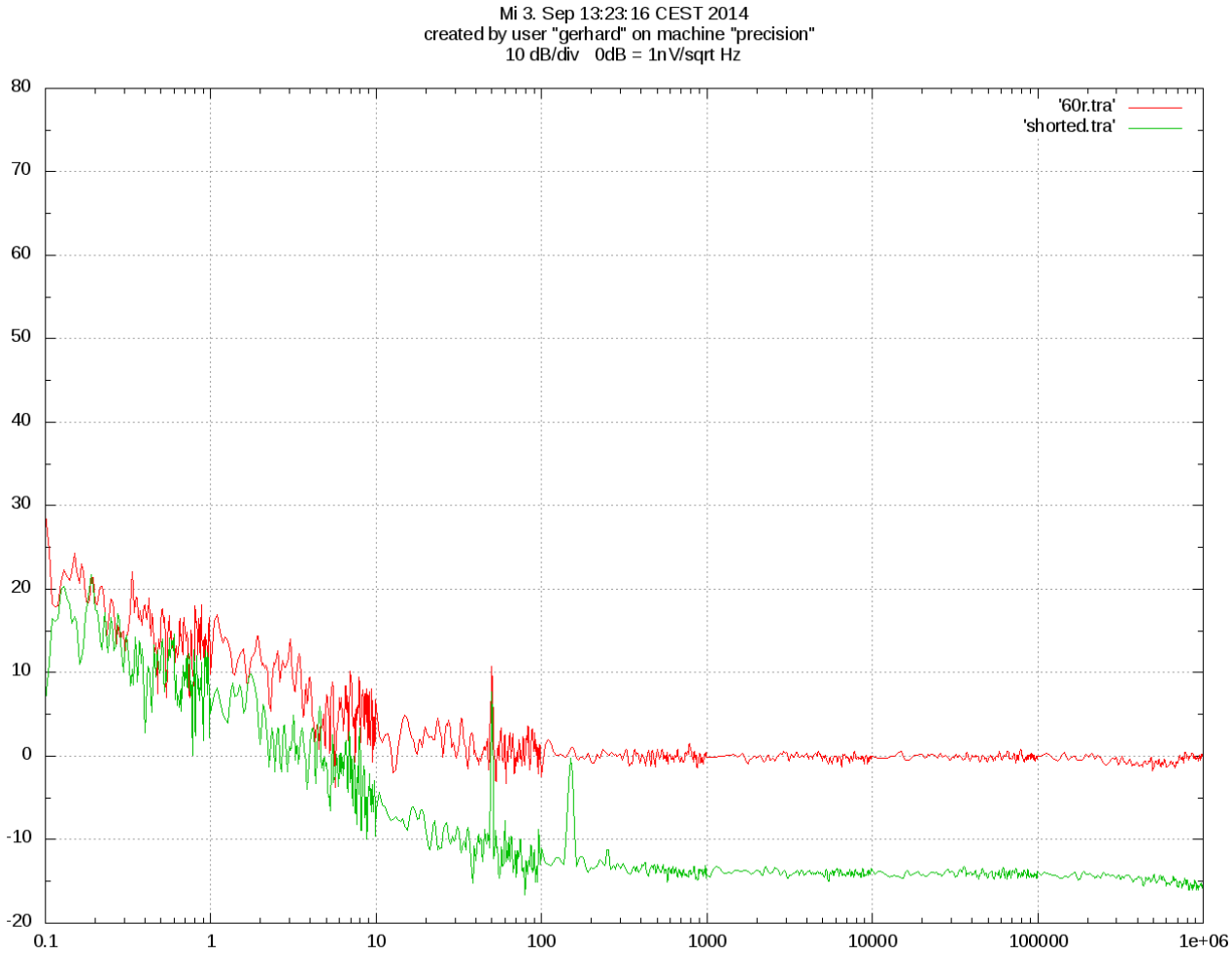
## Test Environment

I used an Agilent 89441A vector signal analyzer as a Fourier analyzer. The low frequency unit is sufficient for these tests. The high frequency unit enables 10 MHz to 2.6 GHz. Since I wanted logarithmic plots over 7 decades and since these cannot be produced from a single FFT of reasonable size, I put the 89441A on the LAN and let it do FFTs over 0..1 Hz, 0.. 10 Hz and so on until 0..1MHz. Data were collected on a PC and the interesting parts of all FFTs were combined. The result was plotted with gnuplot on a logarithmic frequency scale. There is one single C program that connects all that together and that also prepares plots from multiple measurements. A single

plot from 0.1 Hz with 200 averages takes about 500 seconds.

The own noise of the 89441A is quite high, especially in the 1/f region. The 10 MHz input bandwidth takes its toll here. It took a lot of external gain to swamp it. I used a purpose-built pre-amplifier with 20/40/60/80 dB gain, bandwidth of 0.1 Hz to 1 MHz and 220 pV/sqrt Hz voltage noise density which is about -195dBV/sqrt Hz. It features a 30 Hz 1/f noise corner and is based on 10 pairs of Analog Devices ADA4898-2 input amplifiers in parallel that are averaged. Exactly this way to low voltage noise makes the amplifier unsuitable for measuring current noise. The amplifier has an optional built-in input short after the input coupling capacitor and an alternate 60 Ohm input termination to provide an easy way to check the 1 nV/sqrt Hz reference level. [GHF LONO]

F. Walls e.a. from NIST built a system with cross correlation that was usable to -205 dBV. But it turned out that even NiCd batteries have a high 1/f corner under load, so we still can see all interesting things. Results at 1 MHz are less interesting since this frequency is easy to filter. With a second preamplifier we could also use the cross correlation on the 89441A and gain some 25 dB of extra resolution. [Walls 1133]




Green trace: voltage noise of amplifier with input shorted.

Red trace: noise of a 60 Ohms thin film resistor connected across amplifier input. The flat part can be used as a 1 nV/sqrt Hz calibration line.

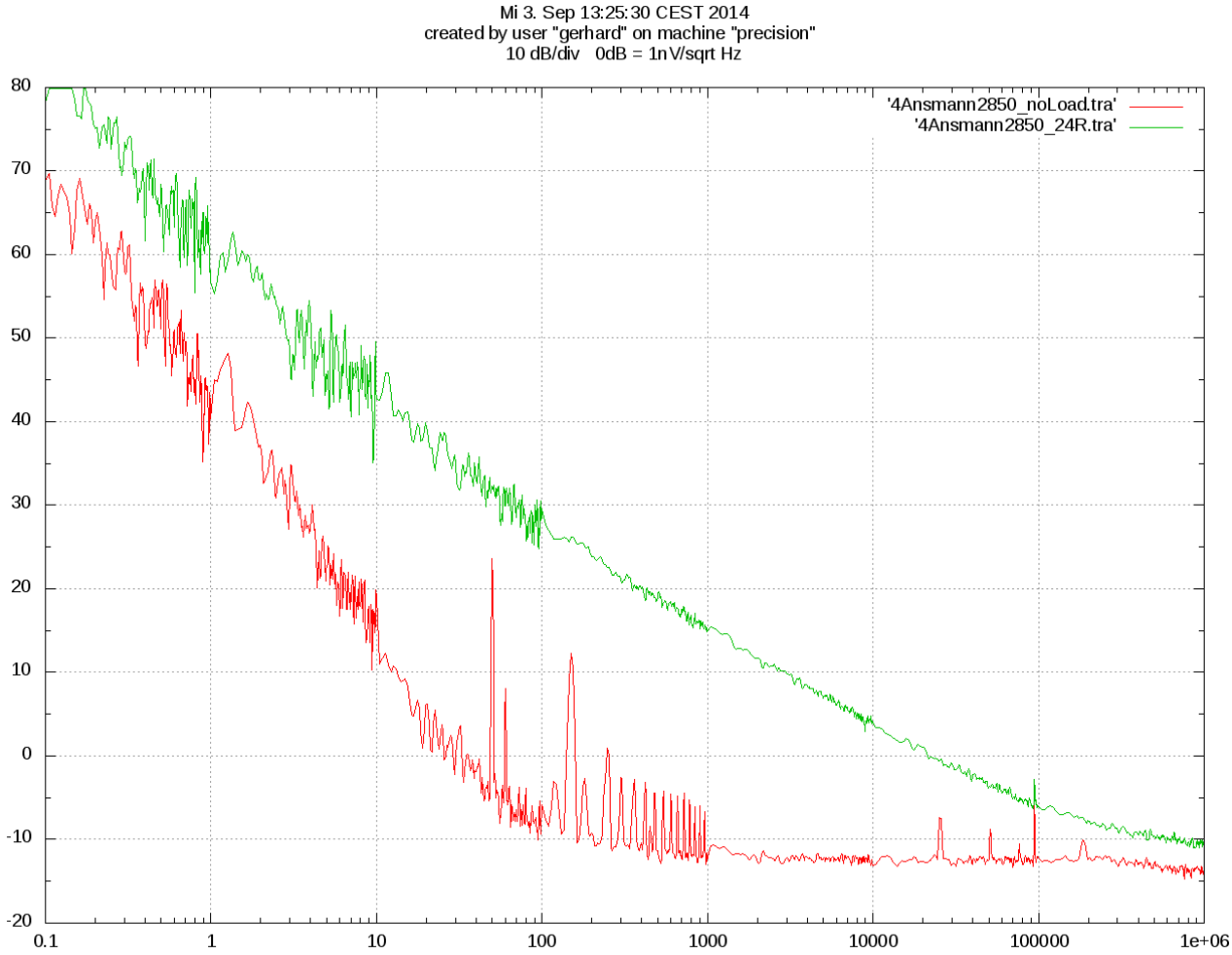
The thermal noise of the 60 Ohm resistor is abt. 13 dB louder than the amplifier with input shorted, so the amplifier input noise is 13 dB below 1.0 nV/sqrt Hz or about 220 pV/sqrt Hz.

## Ansmann NiMH Accumulators

Abt. 5.4V  4 pcs. Size AA, 2850mAh
This, and the cheaper 2500mAh version are very popular in Europe.


Red: 4 cells in series, no additional load

Green: 4 cells in series, loaded with 24 Ohms, i.e. 200 mA

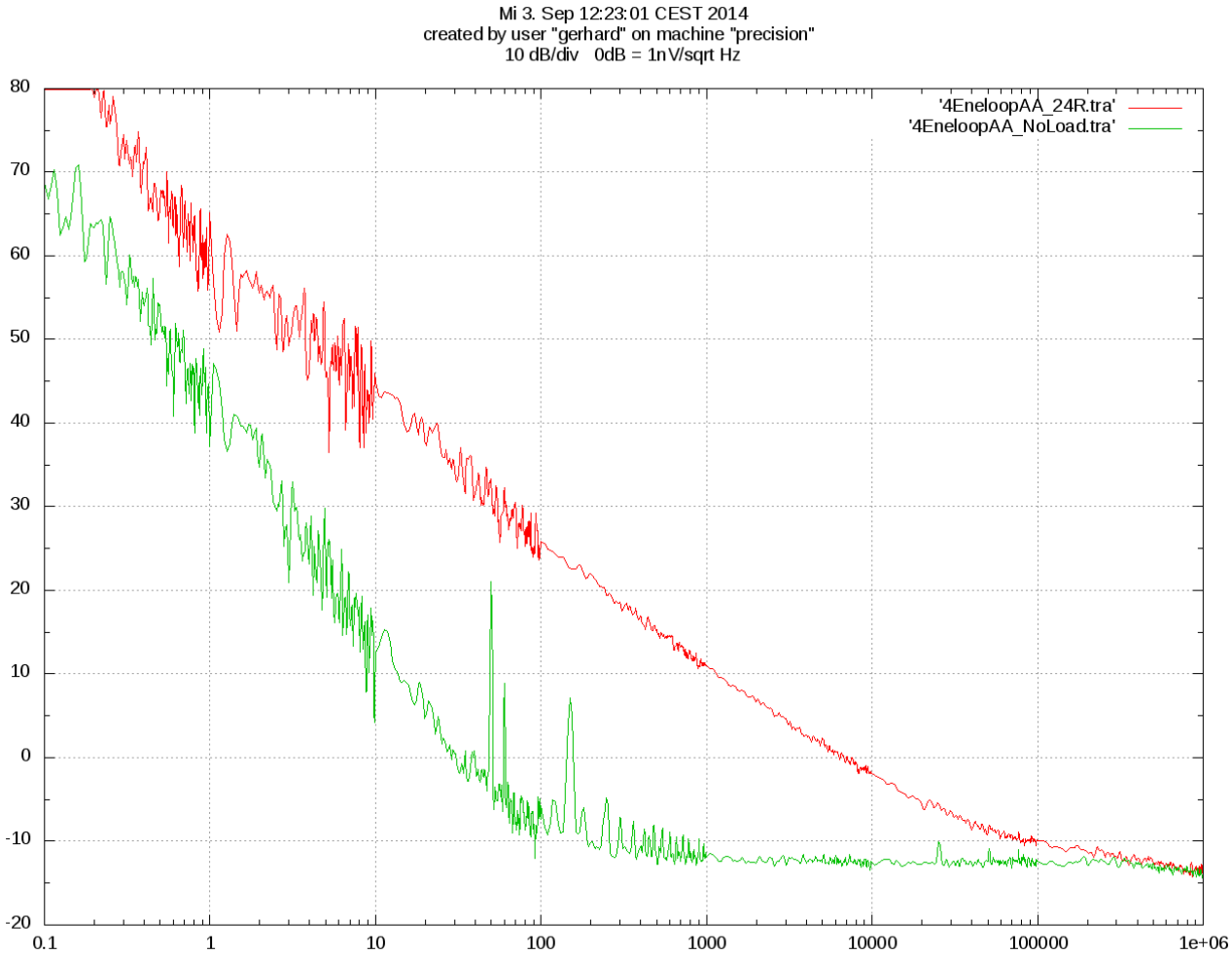


## Sanyo Eneloop

4 Sanyo Eneloops AA in series.

Green: 4 Cells without additional dc load

Red: 4 cells with 24 Ohms load i.e. about 200 mA

## Panasonic / Sanyo Cadnica

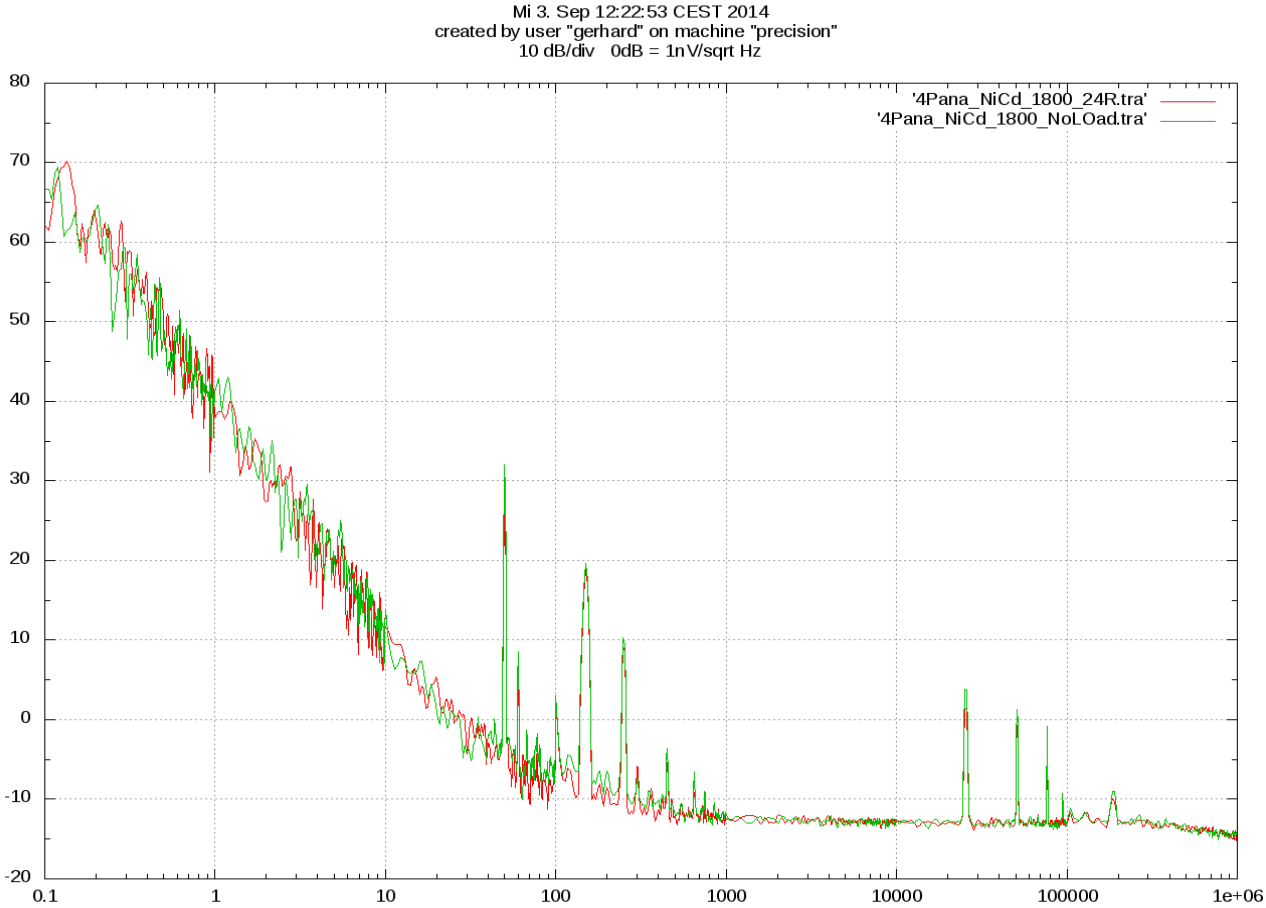

4 Sanyo/ Panasonic KR-1800SCE Cadnica NiCd batteries in series.

Since NiCd is banned in Europe for most purposes, they are hard to get. I bought these at the Conrad store in Berlin-Schöneberg, the label reads “Only for use in power tools, medical, emergency and alarm systems”.

Panasonic is trying to kill its Sanyo brand, which is probably dumb since Sanyo is a good name in batteries. I got 3 with the new and one with the old name.

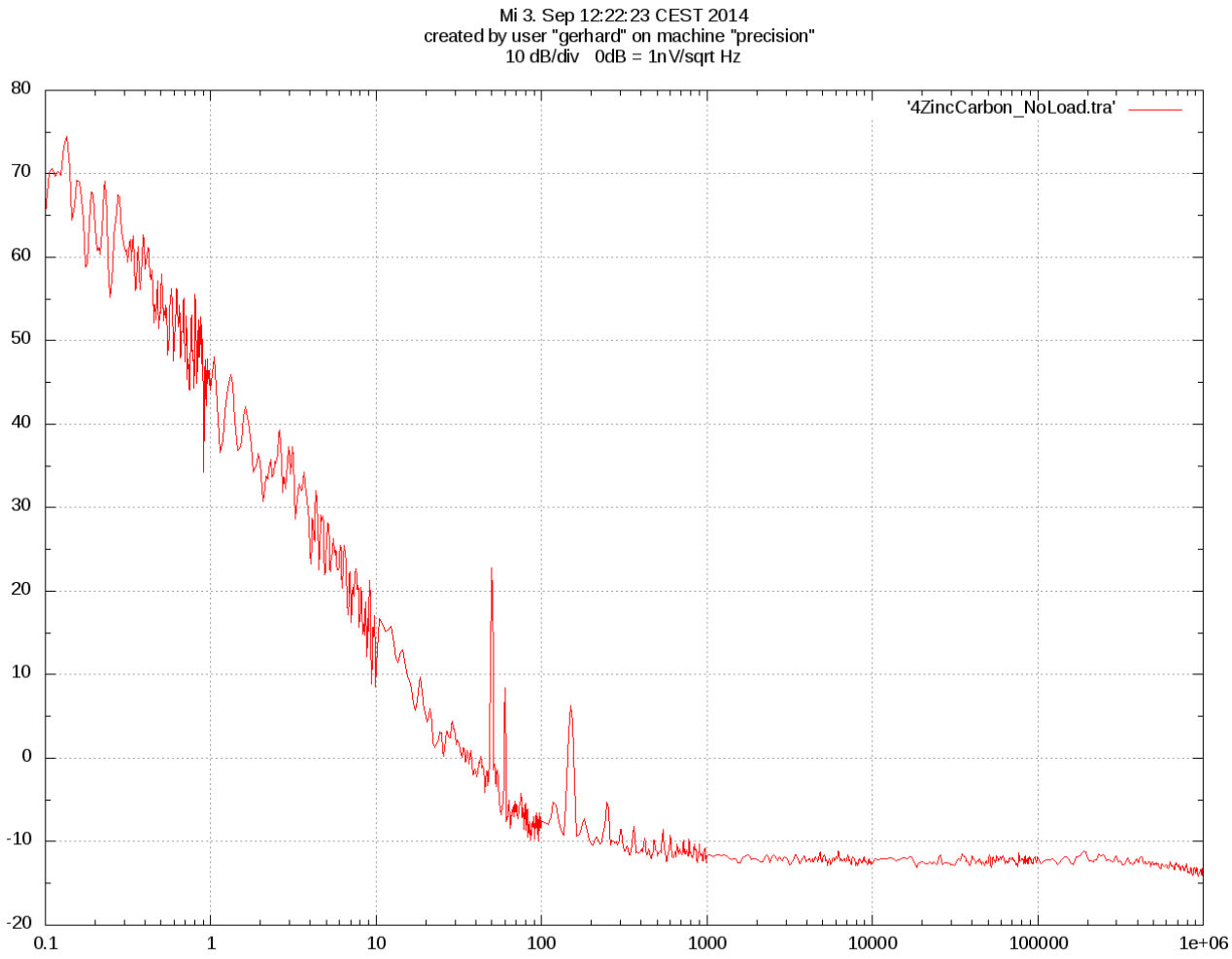
Cell size is 42 mm long * 22 mm dia.

The NiCd cells are unaffected by the 200 mA load current.



## 1.5V Zinc-Carbon Batteries

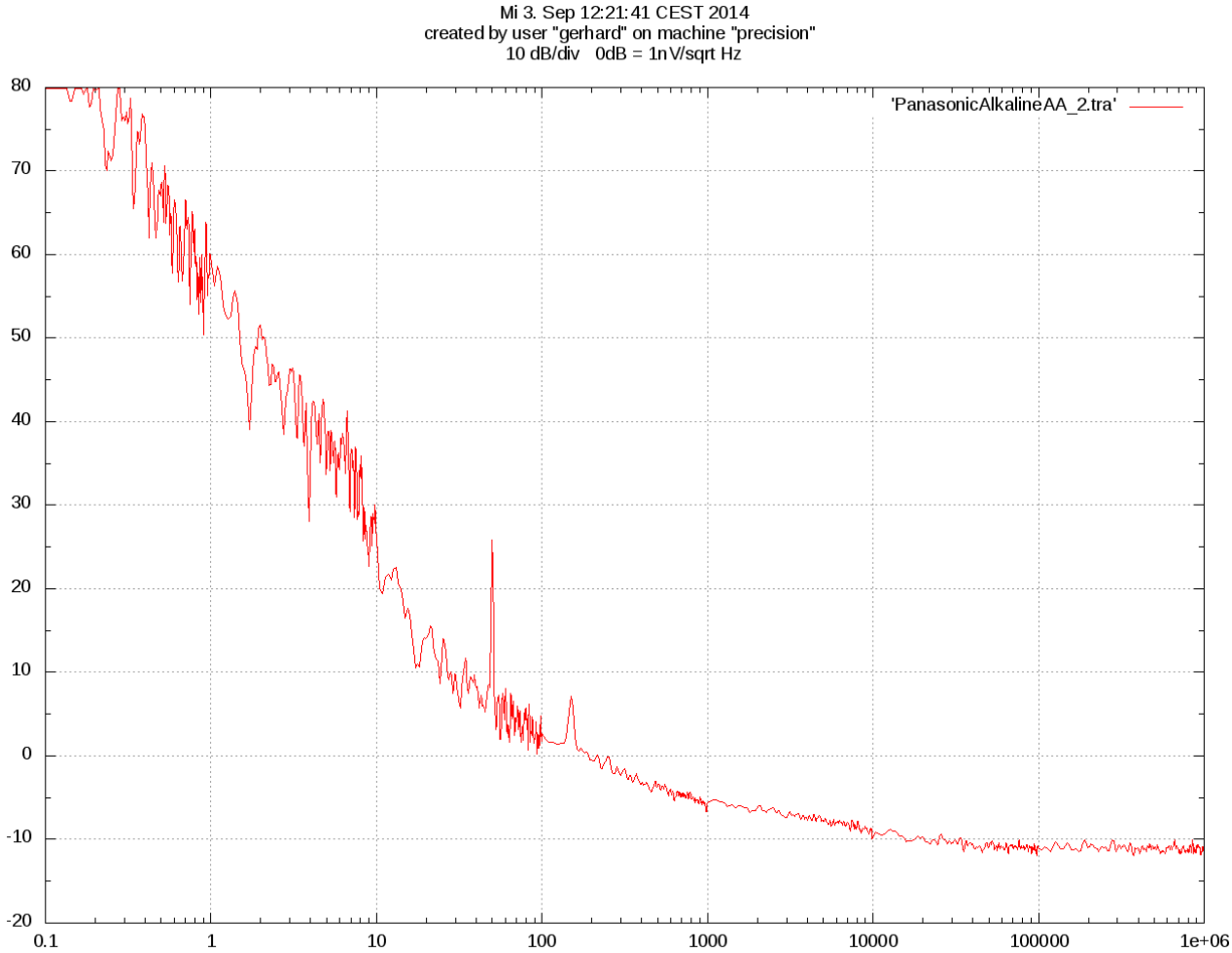
4 pcs. Aerocell AA, very cheap.
These zink carbon cells are not bad, either. I skimped on the test under DC load.



## Panasonic 1.5V Alkaline

A standard product, available everywhere.

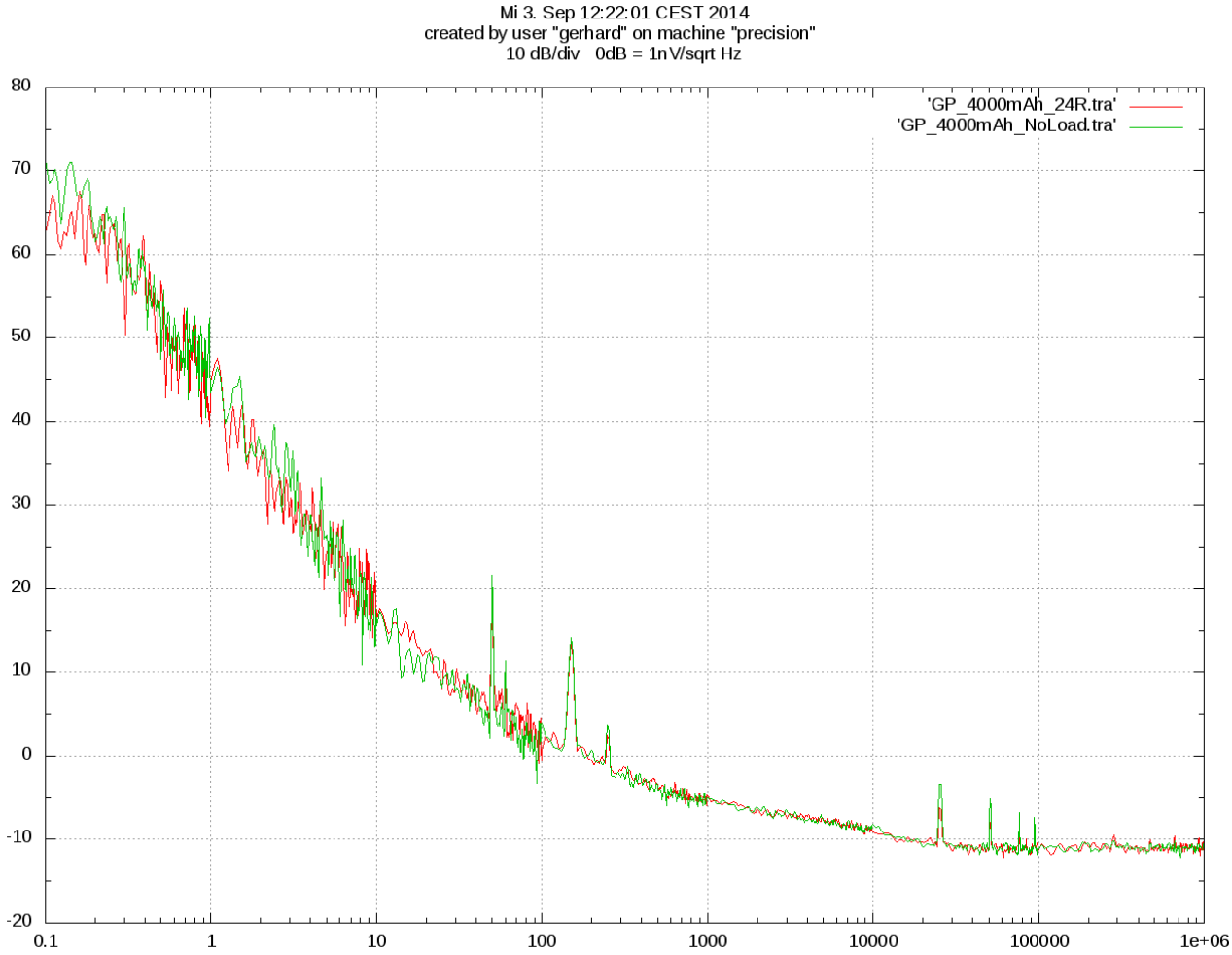

4 cells in series, no dc load



## GP NiMH 4000mAh C size

These 4000 mAh NiMH cells are still quite good under load.

Measurement is for 4 cells in series.

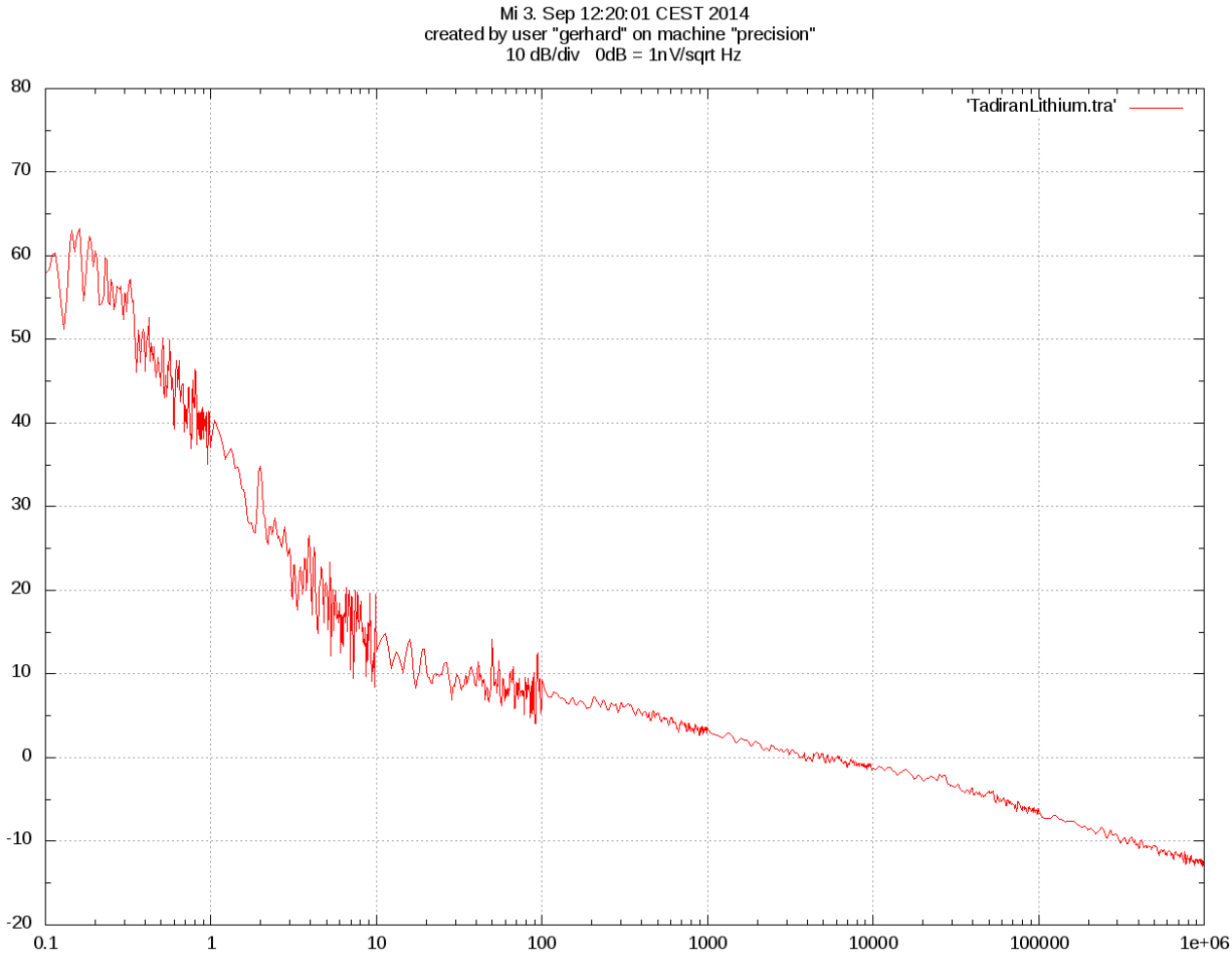
## Tadiran Lithium

Tadiran Lithium battery,
Digi-Key 439-1009-nd
mfgpn tl-5955/t

3.6V

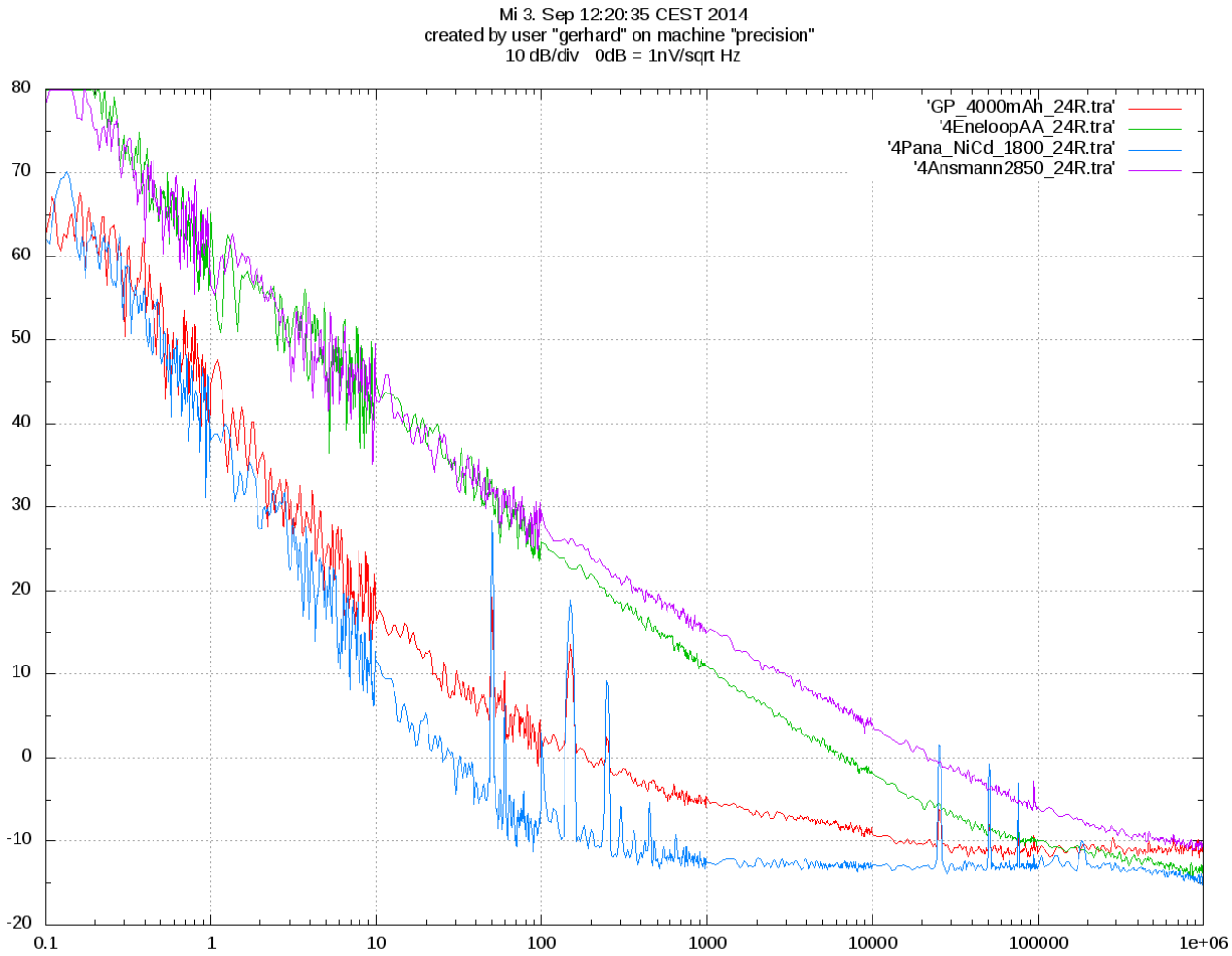
2/3 AA size

This cell looks like being constructed to deliver 1 uA forever, not too much current at a time. Probably the source resistance is not very low. It is not interesting as a low noise power supply.

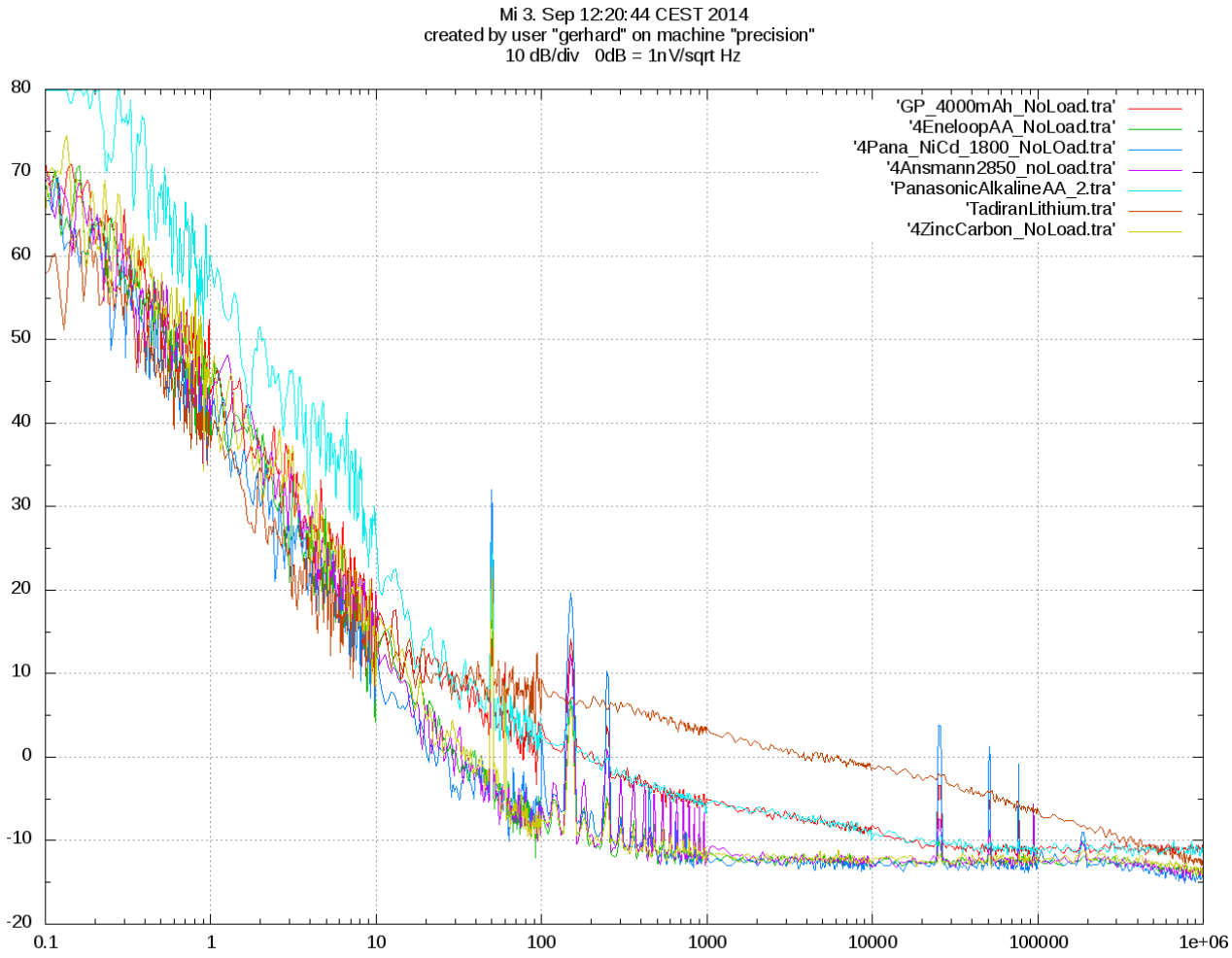



## Results At A Glance

4 Cells with 200 mA load:
There is a clear winner: the large NiCd batteries. Second is the C size NiMH. Size seems to matter. At, say, 20 mA load, the smaller cells might catch up.



Cells without DC load:




Without load, Ansmann NiMH, Eneloop NiMH, Zinc Carbon and of course the Panasonic NiCd stress the limits of the measurement system at least above 100 Hz. Using correlation, the results would probably be even better. In the 1/f region under no-load conditions, there are no real differences, except for the Alkaline.

## Document history [GHF BATT]

V1.0 2014-09-4 first published version
V1.1 2014-09-30 minor clarifications

# Literature

GHF LONO = Gerhard Hoffmann: A 220 pV/sqrt(Hz) Low Noise Preamplifier, 2013
<http://www.hoffmann-hochfrequenz.de/downloads/lono.pdf>
Walls 1133 = Boggs, Doak, Walls: Voltage Noise In Chemical Batteries,
<ts.nist.gov/timefreq/general/pdf/1133.pdf>
GHF BATT = Gerhard Hoffmann: Noise Measurements on Chemical Batteries, 2014
<www.hoffmann-hochfrequenz.de/downloads/NoiseMeasurementsOnChemicalBatteries.pdf>