Long term characterisation of electronic components

Hubert Halloin, Pierre Prat and Julien Brossard / APC - Université Paris Diderot, 10 rue Alice Domon et Léonie Duquet, Paris
hubert.halloin@apc.univ-paris7.fr

A low noise, low frequency test facility at APC

The expected performance of the distance measurement with eLISA (a few pm/√Hz between 1 mHz and 1 Hz) requires ultra-stable electronic devices in general. In particular, long term stability of voltage references is of crucial importance to ensure the fidelity of phase measurements with eLISA : they are, e.g., used as reference for analog to digital converters (ADC), for photodiodes bias or capacitive sensing of the inertial mass position.

Unfortunately, manufacturers usually do not characterize their electronics components around the mHz. In order to test discrete components as well as electronic boards, the APC (AstroParticle and Cosmology, Paris) laboratory is currently developing a dedicated test facility aiming at measuring their intrinsic performance at very low frequencies.

Accurate measurements on hours and days mainly require a strict regulation of the temperature and the decoupling of its effects on the device under tests and the measurement apparatus. The 35 m^2 low frequency, low noise test facility at APC is located in the basement of the building, with the following equipment :

- ✓ Precision air-conditioning system (<1°C variability)
- ✓ Faraday cage (~6 m^2)
- ✓ Filtered and monitored main power lines
- ✓ Precision voltage / temperature data logger
- ✓ Precision, programmable power supplies
- ✓ Thermal bath (<0.01 °C stability, >10^{15} Ω.cm, 15x15x20 cm^3
- ✓ Thermal chamber (~0.1°C stability, 56x48x40 cm^3)
- ✓ Temperature regulated rack for the acquisition electronics

View of the low noise, low frequency test facility at APC

The APC is also working, with the expertise of French metrology institutes, on the dissemination, over the urban optical fibre network, of an ultra-stable optical reference signal. This signal, used to lock an optical frequency comb, will allow the generation of a RF source around 1 GHz, with a relative stability at the level of 10^{-15} at 1s. Combined with the low frequency test facility, it will allow precise characterisations of clocks and frequency measurement devices.

Voltage references characterisation

As a first test case for this facility, the stability characterisation of selected voltage references has been studied :

Manufacturer	Model	Technology
Analog Devices	AD587UQ	buried zener
Analog Devices	ADR445BRZ	XFET
Analog Devices	ADR435BRZ	XFET
Maxim Integrated	MAX6126AASA50	proprietary
Linear Technology	LTC6655BHMS8-5	bandgap
Maxim Integrated	MAX6350CSA+	buried zener
Linear Technology	LT1021BCN8-5	buried zener
Apex Microtechnology	VRE305AD	buried zener

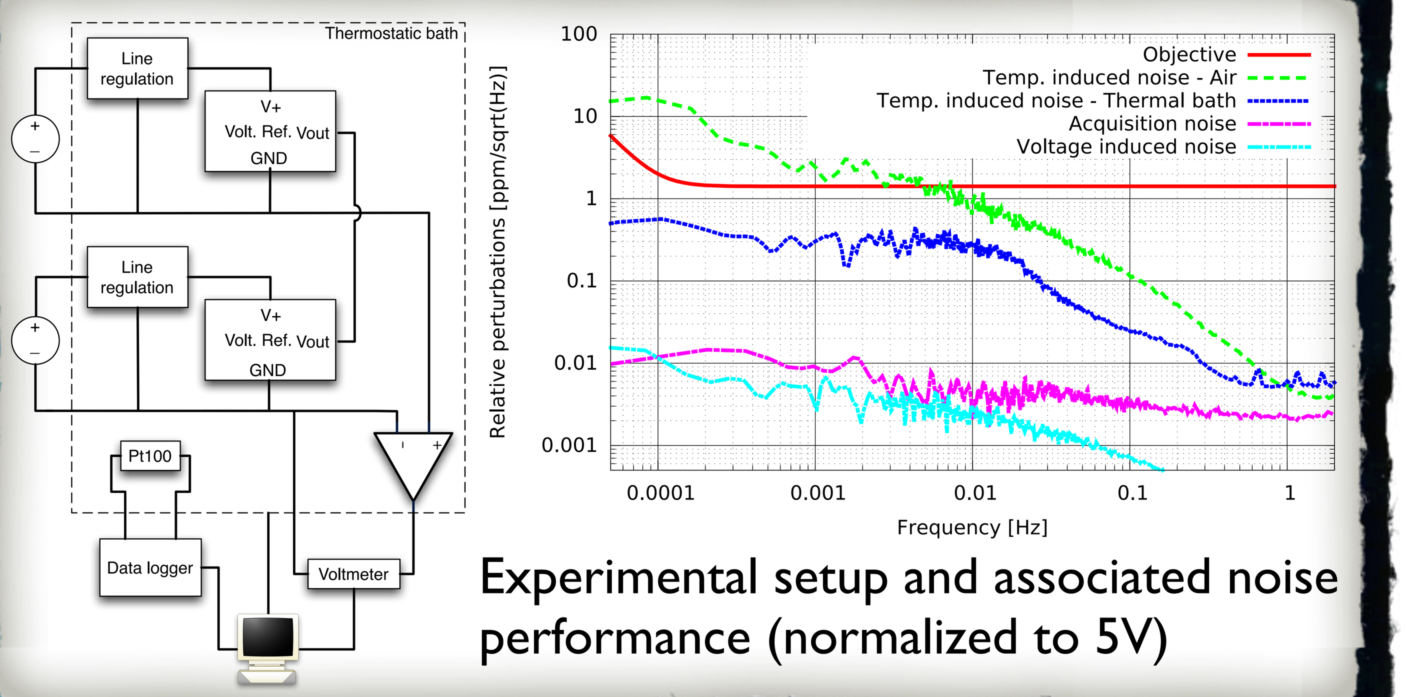
Models of tested voltage references together with the implemented technology.

The goal was to measure the stability of these components down to a few 10^{-5} Hz, at the ppm/√Hz level, therefore updating previous studies on the same subject within the eLISA community [e.g. Fleddermann et al., 2009].

Experimental setup

A thermostatic bath was used to finely control the temperature of the DUTs and the proximity amplifier. The temperature is recorded by a Pt100 sensor at a rate of 5 Hz and the voltage is measured by a 6 ½ digits voltmeter at 50 Hz. Each acquisition is performed during at least 20 (and up to 60) hours.

When performing voltage stability measurements, the output pins of the DUTs were connected togeteher while a low noise amplifier (gain of 401) is used to measure the voltage difference between the ground pins.



Experimental setup and associated noise performance (normalized to 5V)

Measurement noises

The three following noise sources have been estimated on the $5 \cdot 10^{-5}$ - 2 Hz frequency range, and rescaled for a nominal reference voltage of 5V :

- ✓ Line regulation residual fluctuations : $\lesssim 3 \cdot 10^{-4}/\sqrt{f}$ ppm/√Hz
- ✓ Amplifier and acquisition noise (estimated by connecting the input pins of the amplifier) : $\lesssim 10^{-2}$ ppm/√Hz
- ✓ Temperature induced noise (assuming a conservative 10 ppm/K temperature dependance of the differential output voltage) : $\lesssim 0.5 / (1 + f / 0.05\ \text{Hz})$ ppm/√Hz

The measurement noise is therefore dominated by the temperature fluctuations, but well below the 1 ppm/√Hz level over the desired frequency range.

Results

First, the temperature coefficients have been measured for the different models. For this experiment, the temperature of the bath was slowly cycled (period of about 5 000 s) and correlated to the output voltage fluctuations. Direct and differential measurements have been performed with error bars at the level of about 5%.

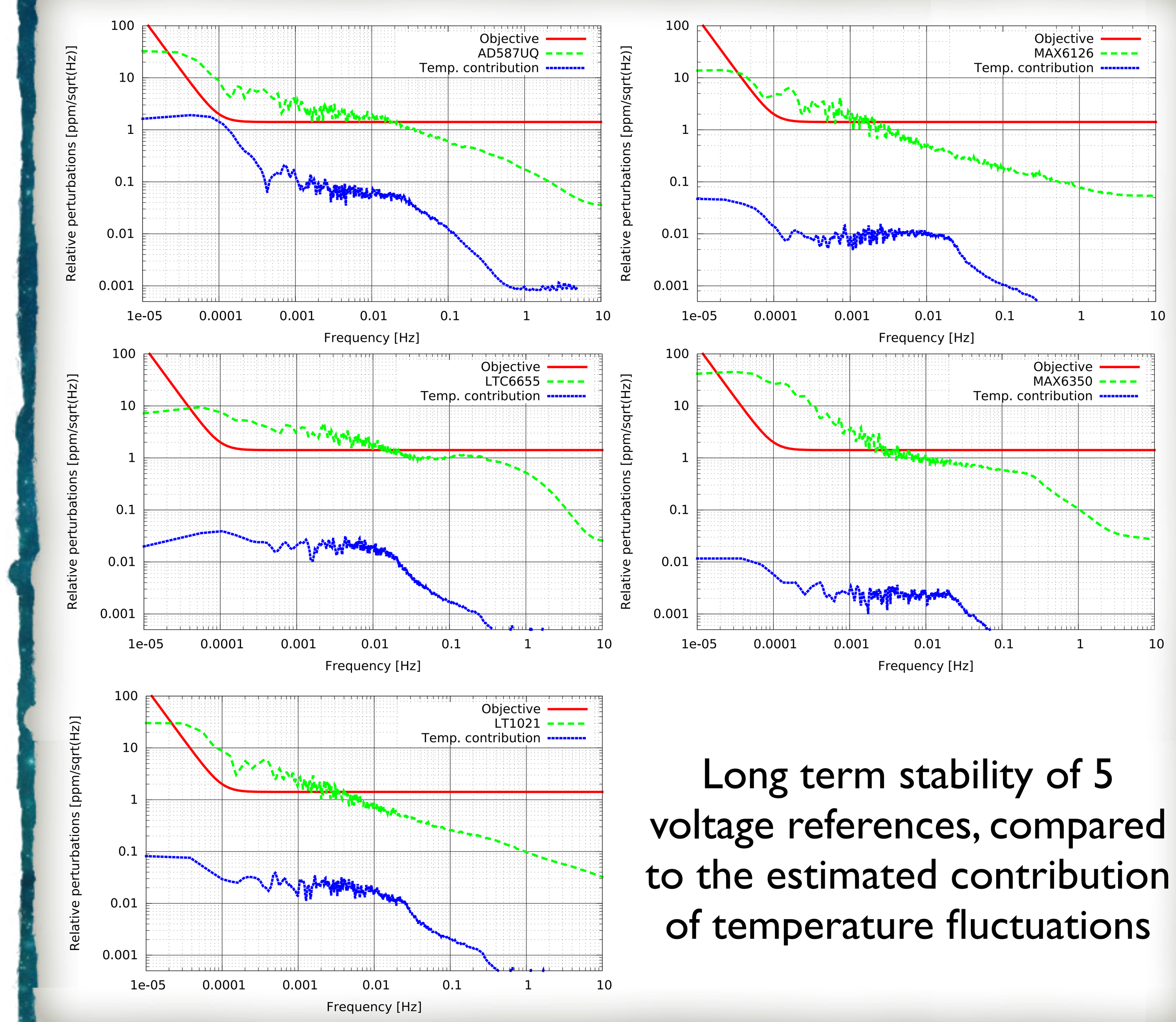
Some values exceed the manufacturer's specification, probably due to the different measurements methods (box vs. sine methods).

Model	TC [ppm/K]	δTC [ppm/K]	TC_m [ppm/K]
AD587UQ	8.30	-2.22	5
ADR445BRZ	1.9	1.72	3
ADR435BRZ	-3.1	-1.8	3
MAX6126AASA50	0.47	-0.45	3
LTC6655BHMS8-5	-2.90	0.69	2
MAX6350CSA+	0.32	0.12	1
LT1021BCN8-5	-0.18	-0.67	5
VRE305AD	2.0	-0.85	0.6

Measured temperature coefficients, individual (TC) and differential (δTC), compared to the manufacturer's specification (TC_m).

The intrinsic stability was measured for the 8 voltage references. After a first screening on 'short' acquisition times (a few hours), 5 models were selected (both XFET-based models exhibited a relatively high output noise).

Long term stability (~55 h acquisition time) was then computed, along with the estimated contribution of temperature fluctuations (dominant noise).



Long term stability of 5 voltage references, compared to the estimated contribution of temperature fluctuations

These results confirm previous studies (performed down to 10^{-4} Hz) for the 'best' identified voltage references (MAX 6126, LT1021, AD587UQ) using buried Zener. The LT6655 model exhibit similar performance, with a different technology (bandgap). However, none of them meets the eLISA requirements (factor ~3 to 5 at 0.5 mHz).

References

Halloin et al, *'Long term characterization of voltage references'*, submitted to IEEE trans. on Instr. & Meas.
Fleddermann, et al. *'Intrinsic noise and temperature coefficients of selected voltage references'*, IEEE trans. on Instr. & Meas., 2009.