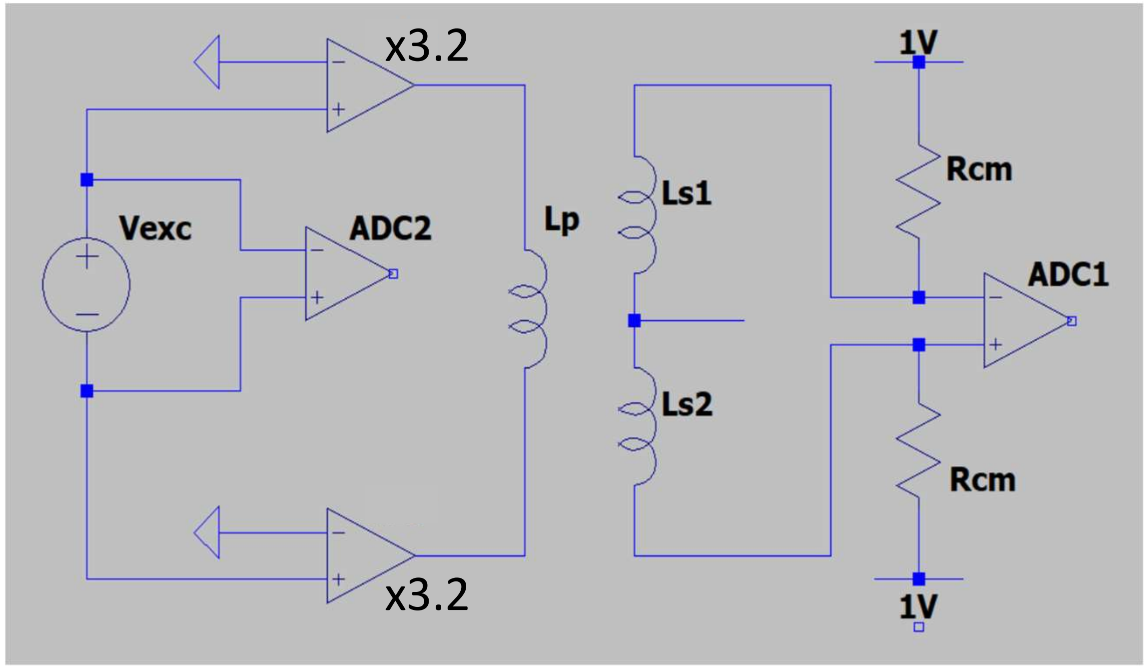
Adopted configuration

- 4-wire LVDT with sensitivity ~ 105mV/V/mm @ f_excitation = 5kHz, FS = ±5mm
- Differential analog gain x3.2 on the excitation (I verified that its noise is negligible)
- Excitation settings on PGA970:
  - Amplitude = 300mV;
  - Frequency = 5kHz
  - Waveform gain = 1.67 V/V

⇒ The resulting amplitude on the primary inductor of the LVDT is about 1,6V (verified with oscilloscope)

- Demodulator settings on PGA970:
  - V_CM enabled = 1V
  - ADC gain = 1V/V
  - BPF at 5kHz with BW = 500Hz
  - LPF BW = 500Hz
  - T_rate = 128us
  - DAC_SIN_NDS1 = 0
  - DAC_SIN_NDS2 = WAVEFORM_TABLE_LEN

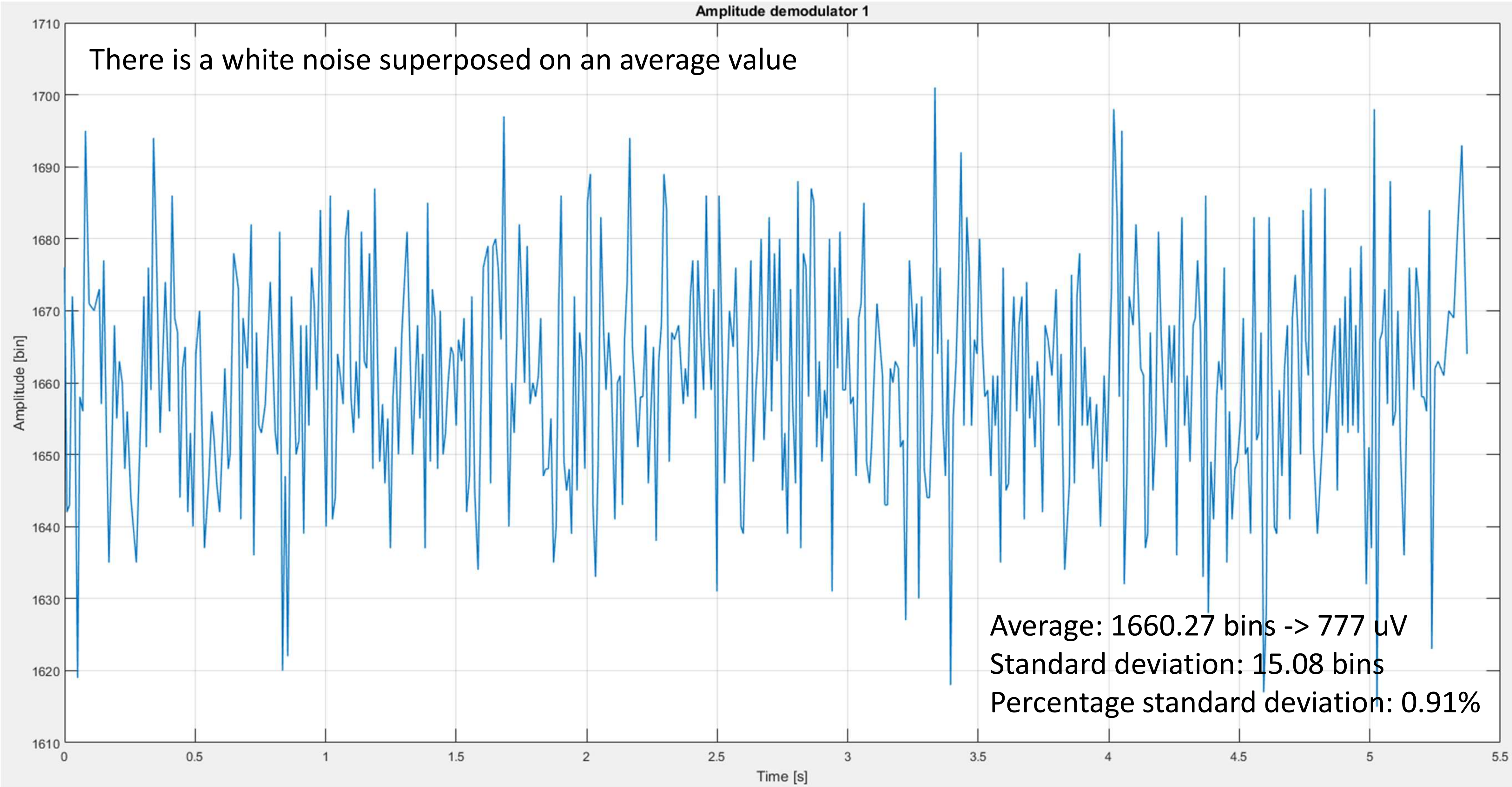


Measurements

- Every 128us the PGA microcontroller enters an interrupt and saves demod 1 data (24-bit amplitude, 32-bits sine and cosine). Those data are transferred serially to an external uC using the COMBUF
- I read a complete data set from the COMBUF every 10ms (limited by the communication protocol between uC and PC), while data packets between a communication and the subsequent one are lost (so I read 1/80 packets).
- Then I place the LVDT at different fixed positions using a micrometric positioner and I read data for a long time interval to analize their statistics over time.
- In the following I propose a measurement done when the LVDT is close to the central position, so the voltage amplitude at the demodulator input tends to 0.

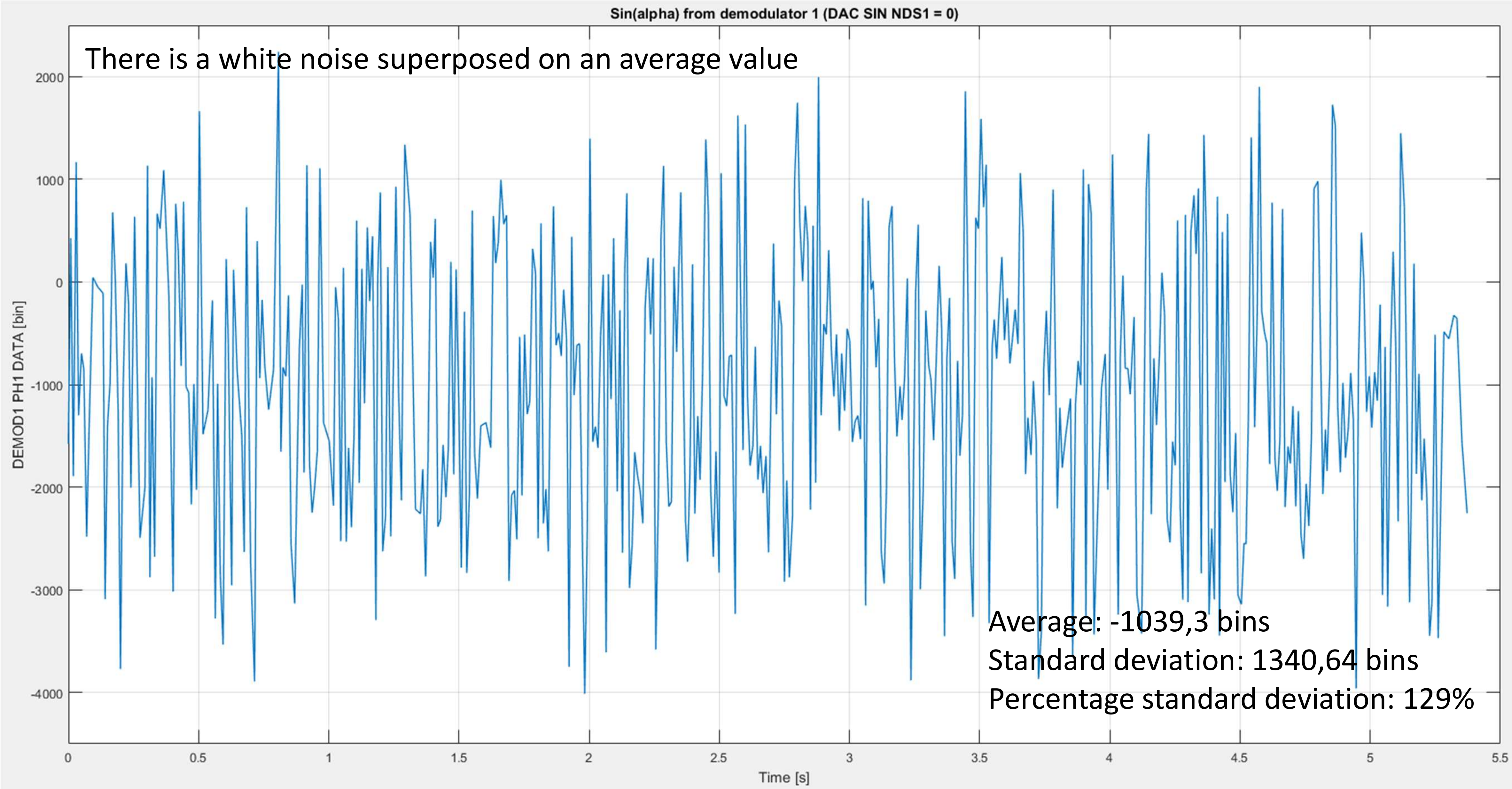
Measured amplitude

Data coming from the amplitude demodulator are expressed in bins: they are given by A[V]*2^24/2.5/pi



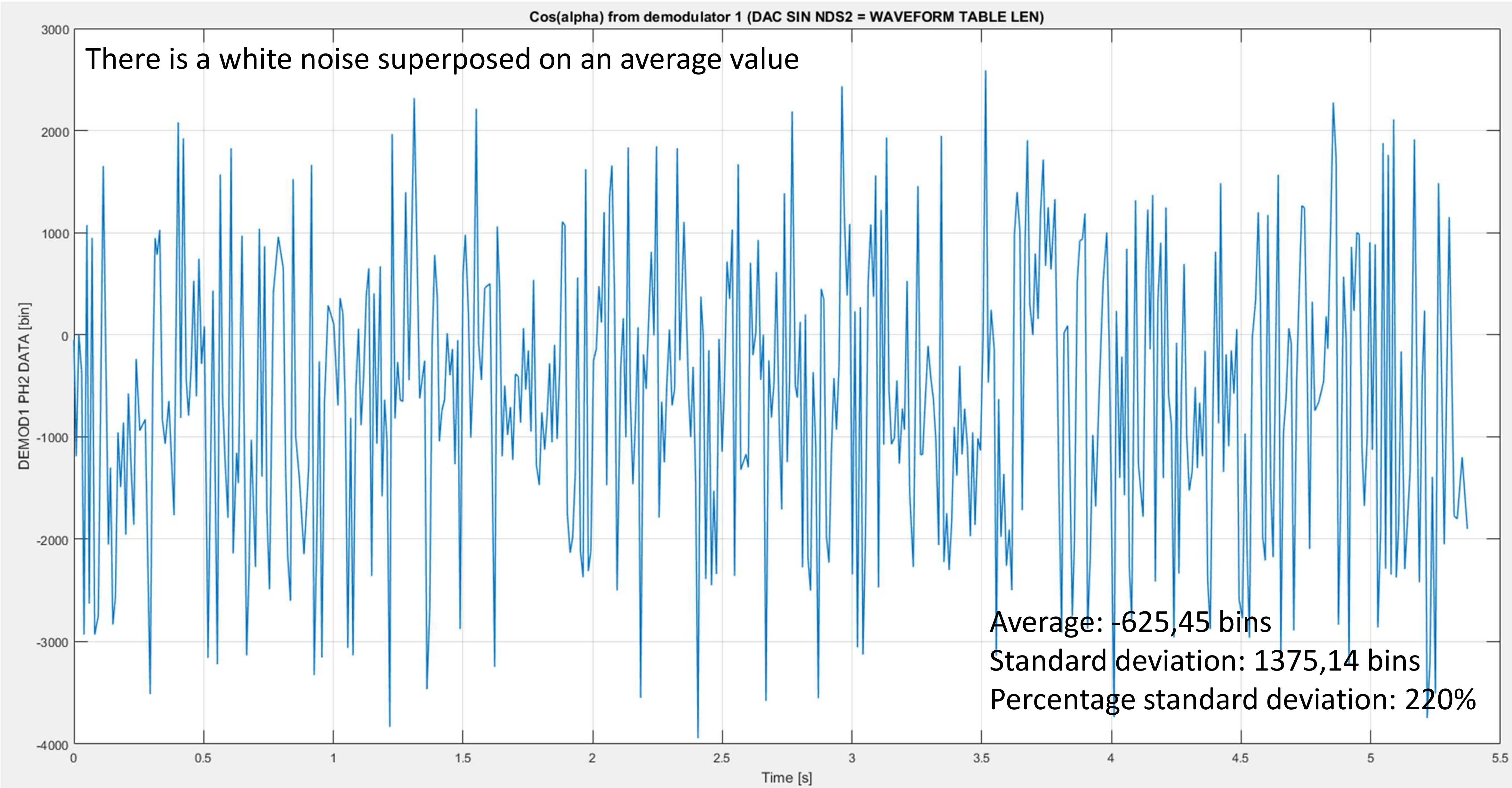
Measured sine (since DAC_SIN_NDS1 = 0 the phase demodulator measures sin(phase))

Data coming from the phase demodulator are expressed in bins. The scale factor between bins and Volts is unknown



Measured cosine (since DAC_SIN_NDS2 = WAVEFORM TABLE LEN the phase demodulator measures cos(phase))

Data coming from the phase demodulator are expressed in bins. The scale factor between bins and Volts is unknown



It is clear that the phase measurement is much more noisy than the amplitude measurement (the noise on sine and cosine is two orders of magnitude higher than the amplitude noise).
It follows that if a calculate the amplitude as $\sqrt{\sin^2 + \cos^2}$ I get much higher noise compared with the amplitude noise

In addition, I can calculate if there is a scale factor between amplitude calculated by the amplitude demodulator and amplitude extracted starting from sine and cosine values.
This case the scale factor between amplitude and phase demodulator seems $\sqrt{1039.3^2 + 625.45^2}$/1660.27 =0.73
I do not understand why this value.
Am I doing some mistake in my considerations?

Starting from sine and cosine it is also possible to extract the phase as arctan(sin/cos)
Since sine and cosine are affected by a high percentage noise also the phase will be extremely noisy. Even worse, the arctan function is limited to angles between -90° and +90°, so the result is not correct every time the measurement is located in the second or third quadrant of the cartesian plane. In order to avoid this issue, I add 180° every time the cosine is negative (since it indicates that the measurement is located in the 2nd or 3rd quadrant).
As shown before the cosine is very noisy and in addition it has a small average value when the LVDT is located near the center position, so it continuously crosses zero and the phase results in continuous jumps of 180°, which determine a random change of sign in the position measurement.

The result is a very high noise superposed on the position measurement when the LVDT approaches it center position.
In my case the phase noise is still strong when I move the LVDT 5um away from the center, so the result is a random fluctuation of the measurement between -5um and +5um, which results in an overall noise of 10um peak-to-peak.

I also tried the same measurement at different positions of the LVDT and I noticed that the mean values of sine and cosine change (ok), while their noise keeps the same standard deviation value
Here you find a comparison between a measurement in the center (I repeated the measurement described in the previous slides) and a measurement at 4mm away from the center (that is almost the full-scale of the LVDT).

position[mm]	average Amplitude [bin]	std Amplitude [bin]	Sine [bin]	std Sine [bin]	Cosine [bin]	std Cosine [bin]	sqrt(sin^2+cos^2)	Scale factor
0	1643,547259	15,3802187	-1161,3316	1345,93	-662,638	1370,186	1337,078982	**0,813532422**
4	1456262,977	72,84242468	118114,8643	1299,33327	-1822336,58	1254,952827	1826160,382	**1,254004538**

From my measurements the scale factor changes for different amplitudes at the input of the PGA970

Conclusions

I summarize here my questions and doubts about phase demodulator:

- Phase noise is a problem in my application when the LVDT approaches the center position. I do not understand why noise is so high, since both amplitude and phase are extracted starting from the same digitalized inputs
- Is there a smart way to extract phase starting from the PGA970, which permits to improve performance? In particular, do you have any suggestion to limit noise?
- Why does the scale factor seem to change at different LVDT positions? Am I doing a mistake in data elaboration or is it normal?
- Finally, I have another question about PGA970 phase demodulation: The demodulator provides data every 128us, regardless of the frequency of the signal. Nevertheless, the datasheet indicates that two points are sampled for each period (the sine and the cosine components), so i expected the data rate to be dependent on the excitation period. Does the chip make some interpolation in between to keep the rate constant?