Applications of open hardware Gwyscope controller for adaptive and high-speed SPM measurements

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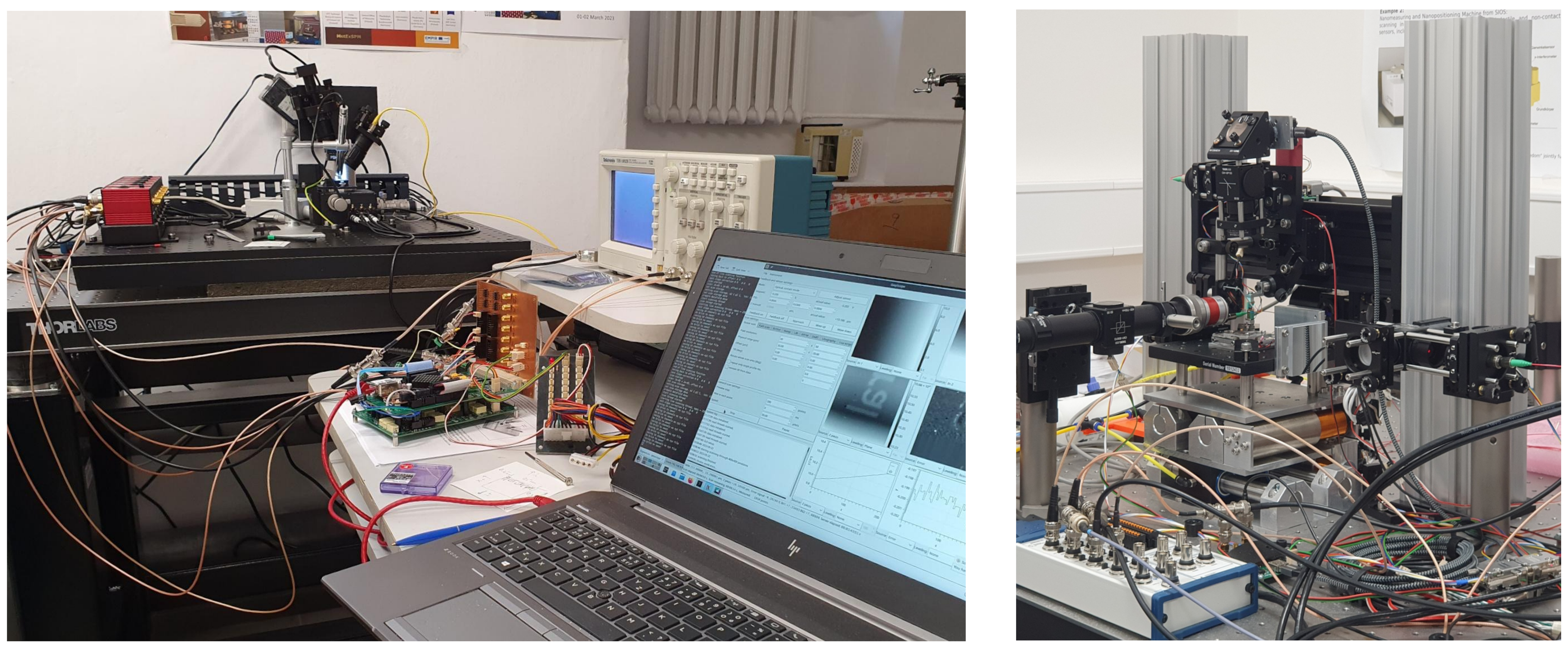
Motivation

Scanning Probe Microscopy (SPM) controllers have certain limits when used with custom built systems. Here we present a core component of a custom built SPM controller, the Digital Signal Processor, that overcomes some of these limitations. It is a low cost, open hardware system that extends the SPM performance when going to high speed, adaptive sampling, large area measurements or interfacing to other devices.

Architecture

A. Red Pitaya STEMlab 125-14 board

The core of the DSP is a low cost electronics board Red Pitaya STEMLab 125-14 which is an open-source software measurement tool based on Xilinx Zynq 7010 FPGA featuring 17 600 LUTs, 28k logic cells, 80 DSP slices and dual core ARM® Cortex™A9. The board is equipped with dual ADC (LTC2145-14) and dual DAC (AD9767). The input and output bandwidths are 50 MHz and are DC coupled. A custom built FPGA image developed in Xilinx Vivado using Verilog is used for the feedback control.

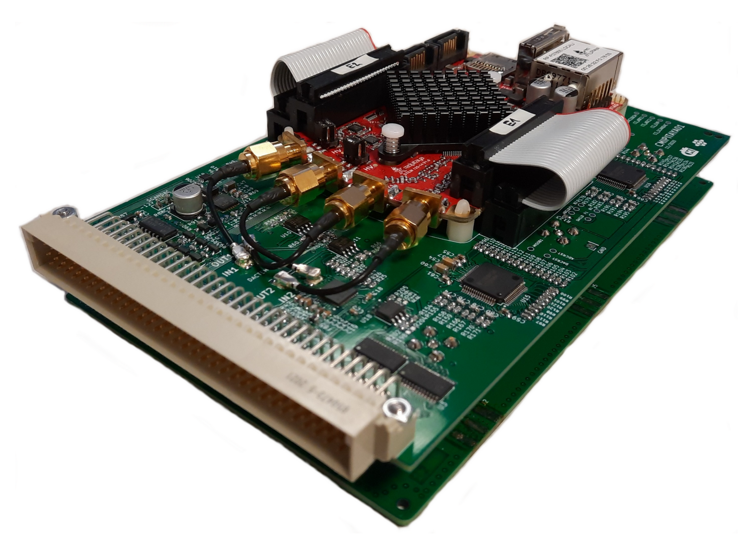


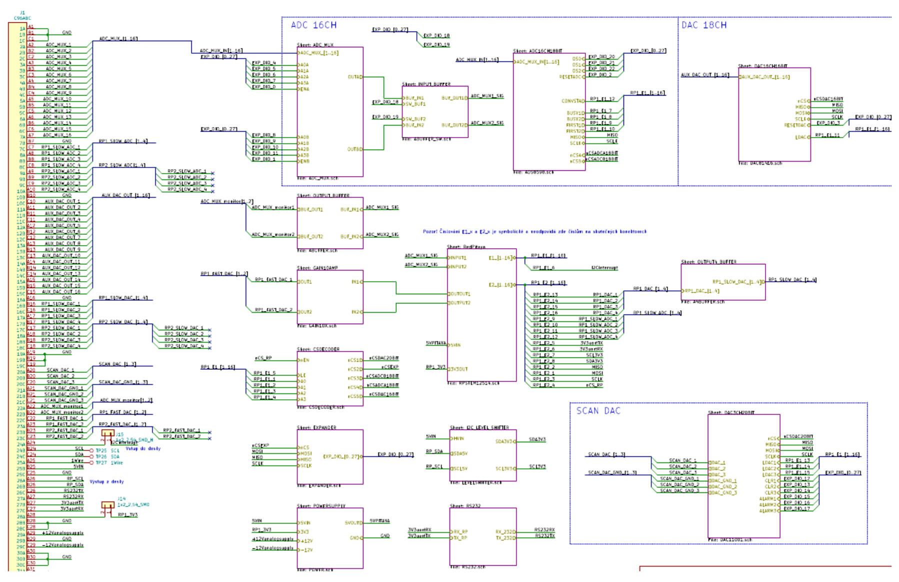
Picture on the left shows how Gwyscope is used to control a custom built SPM system such as Thorlabs EDU-AFM kit. Photo of CMI's custom built large range SPM is shown on the right.

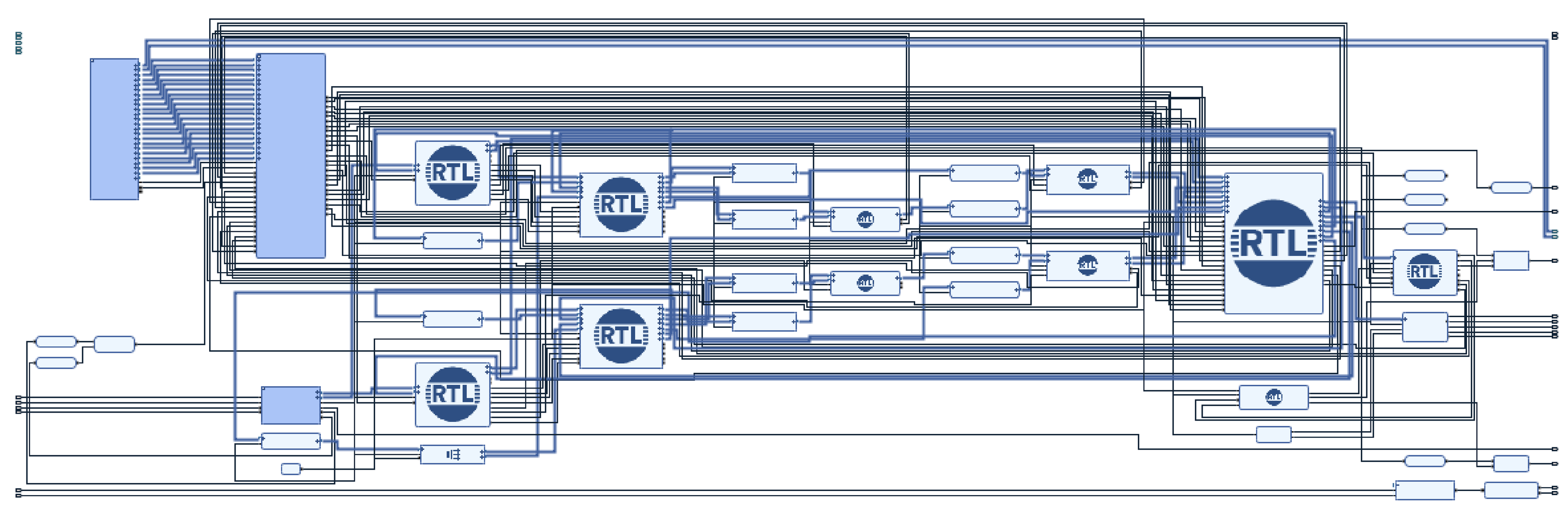
B. Additional AD and DA converters

The Red Pitaya board is mounted on additional boards with AD and DA converters connected via SPI to provide higher bit depth data for scanners and to get higher bit depth data from the sensors than what Red Pitaya offers. These converters are:

- 3x DAC11001A - single channel, 20-bit DAC, 1-LSB DNL
- 1x DAC81416 - 16-channel, 16-bit DAC
- 2x ADS8598H - 8-channel, 18-bit ADC







C. Client-server interface

The board boots from a SD card into Ubuntu Linux. A server is running on it, which can be accessed using Ethernet and can be used for controlling whole SPM scanning process, using both simple functions and scripting using Lua language. All the data are passed together with x,y positions and timestamp, making the system ideal for adaptive scanning. Data are passed in GwyObjects form to a client (see https://libgwyscan.sf.net).

Applications and performance

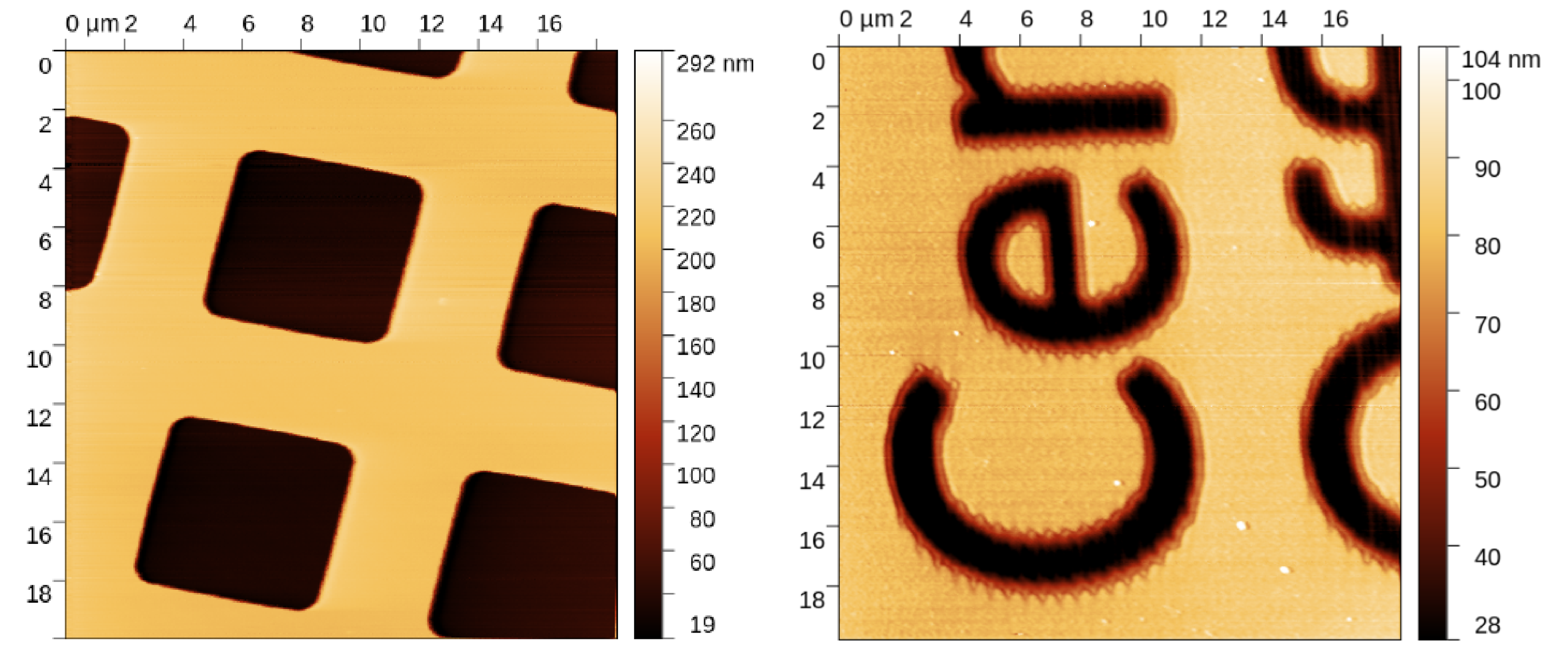
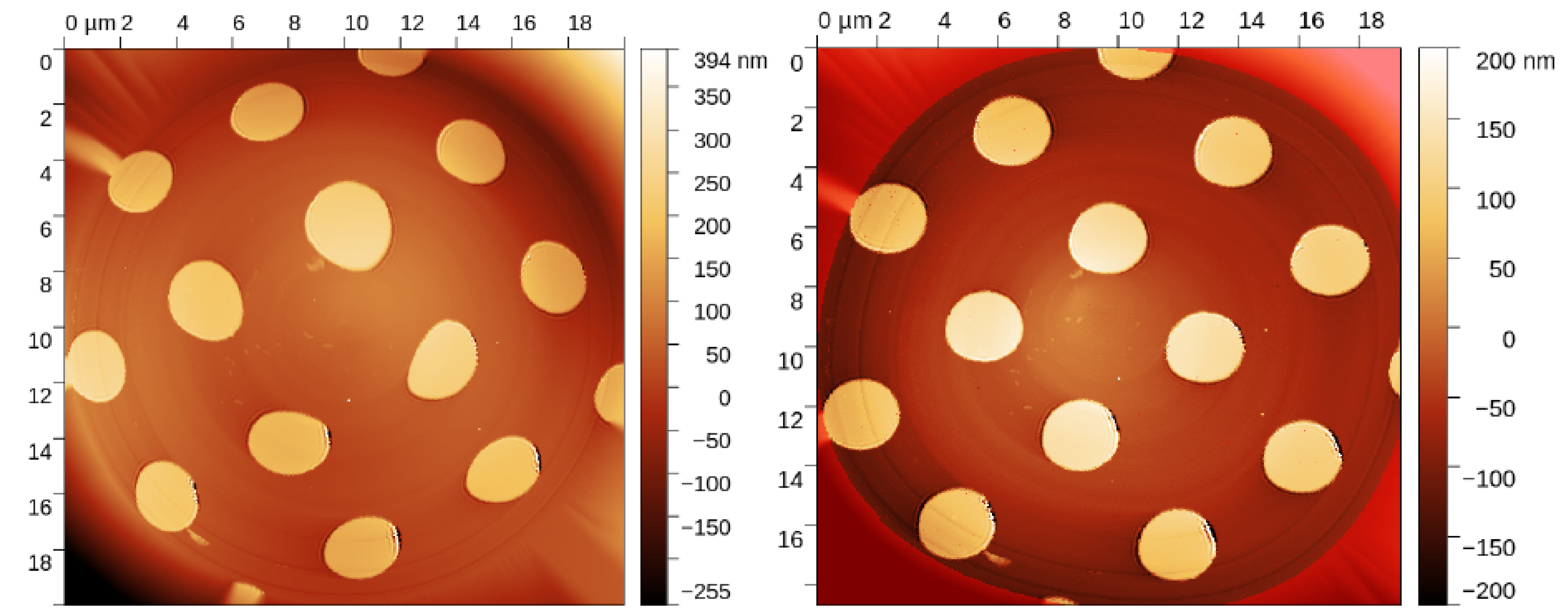
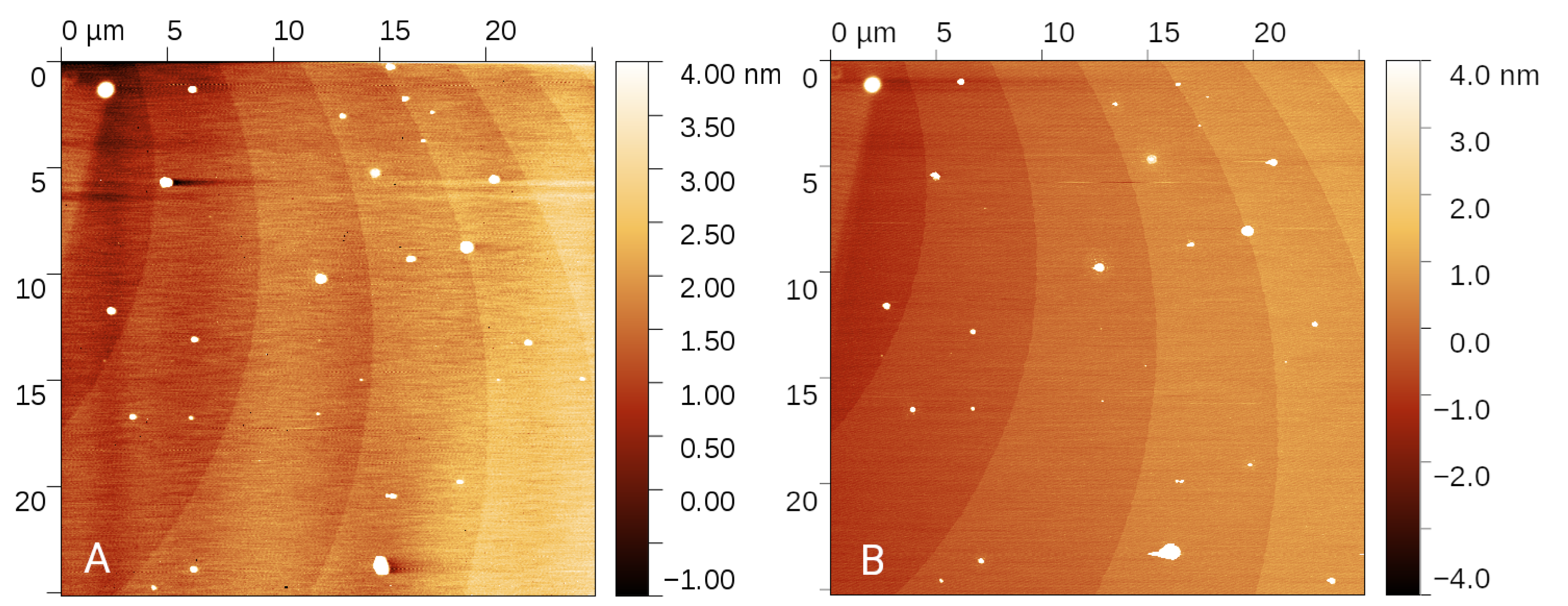


Image on the left shows topography of a BudgetSensors reference sample grating. MetExSPM sample detail is on the right. Feedback loop was affected by performance of particular AFM probe after a few hours of searching for the right location. Acquired with Gwyscope & Thorlabs EDU-AFM.



BudgetSensors reference sample dots grating. Comparison of piezo data use (left) and strain gauge data use (right) for spiral scan path. Acquired with Gwyscope & Thorlabs EDU-AFM.



Comparison of measurements on silicon steps. Acquired using a custom built setup with Gwyscope (A). The same area was measured on Bruker Dimension Icon commercial AFM (B).

Example of a measurement on MetExSPM sample using a custom built large range, high speed AFM controlled with Gwyscope.

How to get it?

The documentation for all the parts including C and FPGA codes and printed circuit boards can be found on Gwyscope's websites https://gwyscope.net/ or in a HardwareX article, see https://doi.org/10.1016/j.ohx.2023.e00451

Acknowledgment

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