# Ruwai

## an open hardware seismic data recorder

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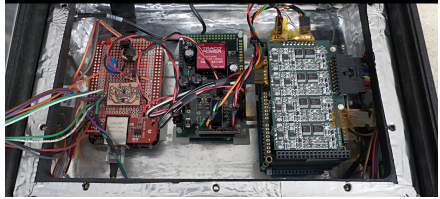
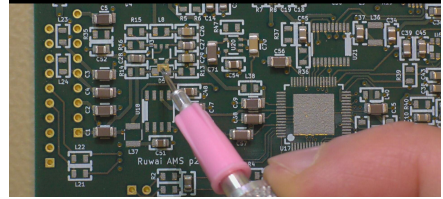
# Overview

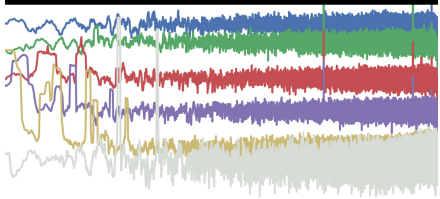
## THE RECORDER



## DIY - CONSTRUCTION




## PERFORMANCE



## USE CASE

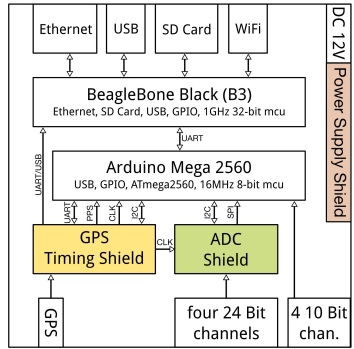
# The Ruwai Recorder

The Ruwai recorder provides 4 analog input channels with a range of +/- 2.5 Volts. Sampling rates can be selected between 100 and 1000 samples per second. Software selectable pre-amplification between 0.125 and 176 is supported. The timestamping of the data is done using a GPS-disciplined clock signal.
The power consumptions is ca. 3 Watt.

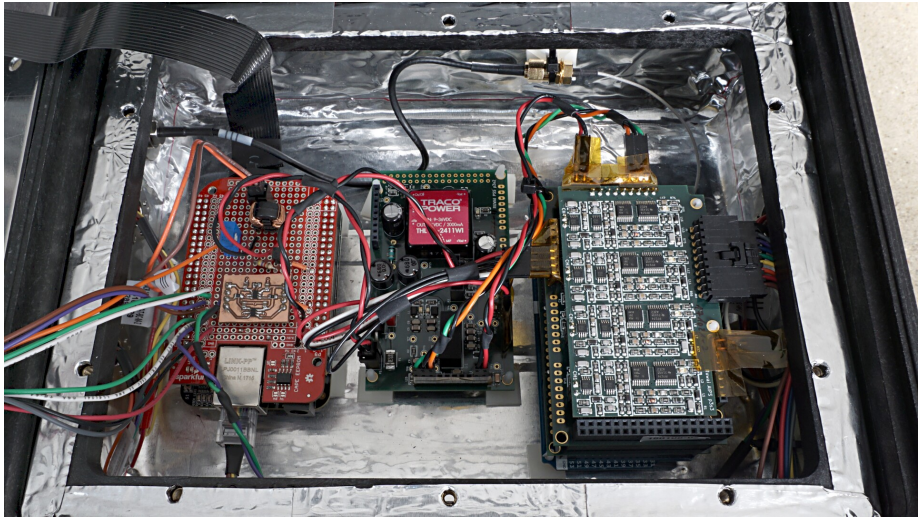
# The operational system

# Ruwai block diagram

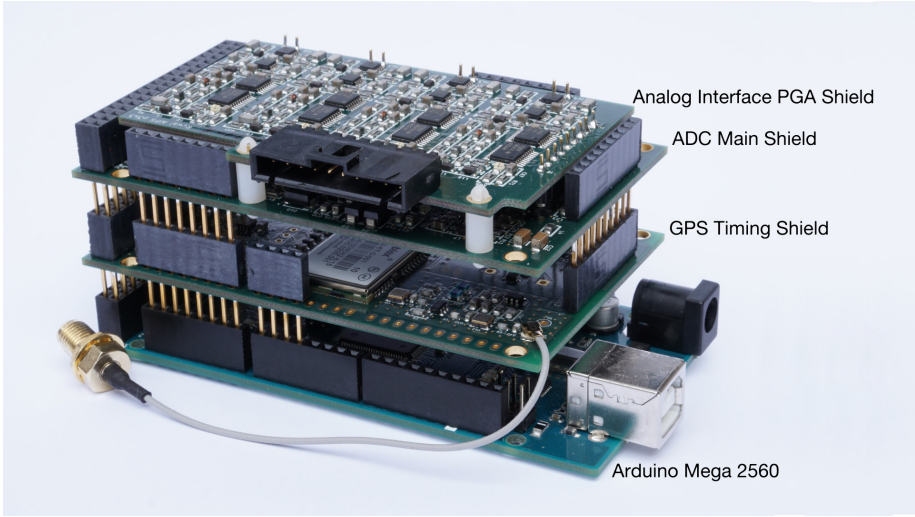
The recorder is based on the open hardware micro-controller boards BeagleBone Black and Arduino Mega 2560.
Three custom shields for the Arduino have been designed. The GPS Timing Shield for time synchronization, the ADC Shield for analog to digital conversion and the Power Supply Shield. The ADC Shield is split into a shield for the analog signal conditioning and one for the operation of the ADC.



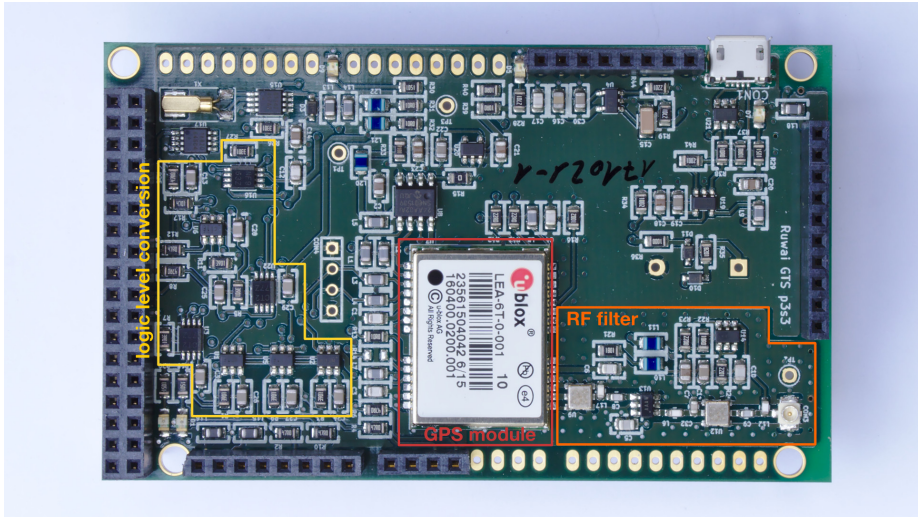
# The Ruwai internals



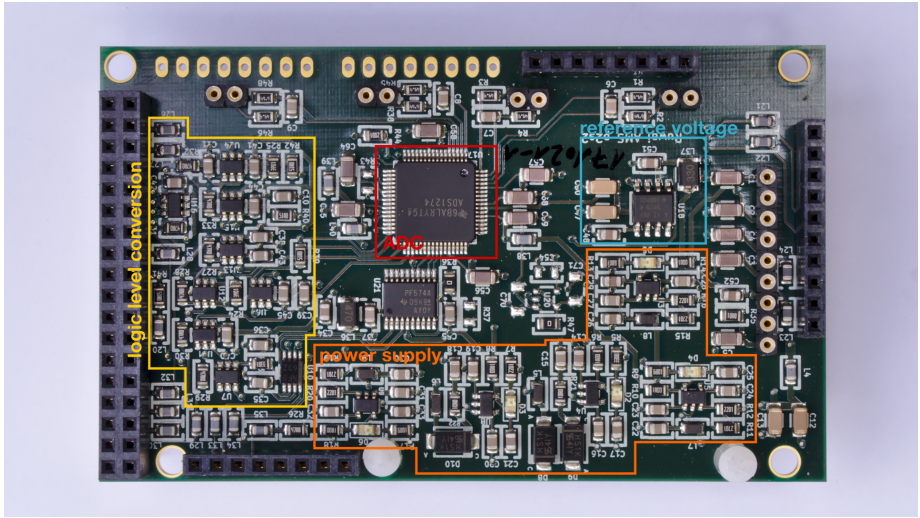
# The Arduino Shields



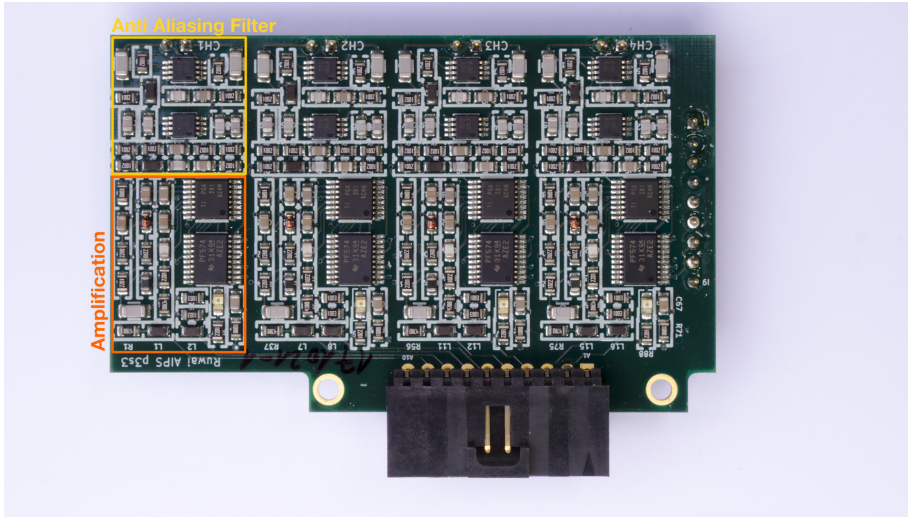
# The GPS Timing Shield



# The ADC Main Shield



# The Analog Interface PGA Shield



# DIY-Construction

The design of the Ruwai recorder aims towards the construction using simple tools. The main requirement is the possibility to build a complete system in a standard workshop and with free software only.

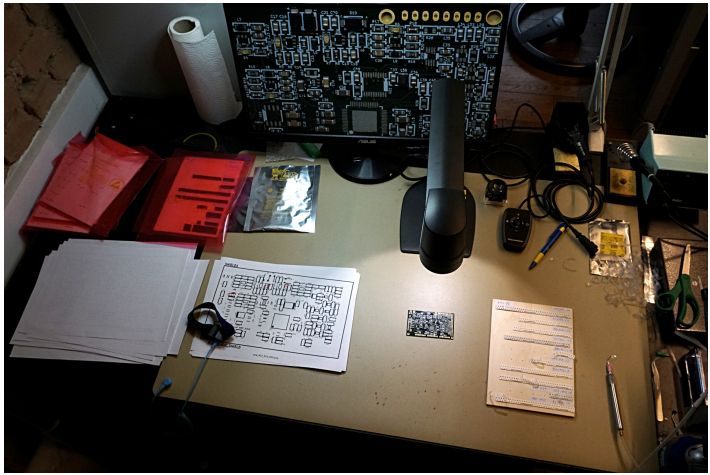
The printed circuit boards (PCB) have been designed using the free software KiCad. The PCBs can be produced by prototype manufacturers using the KiCad design files.

Software tools have been developed to support the management and ordering of the electronic components needed for the Ruwai recorder.

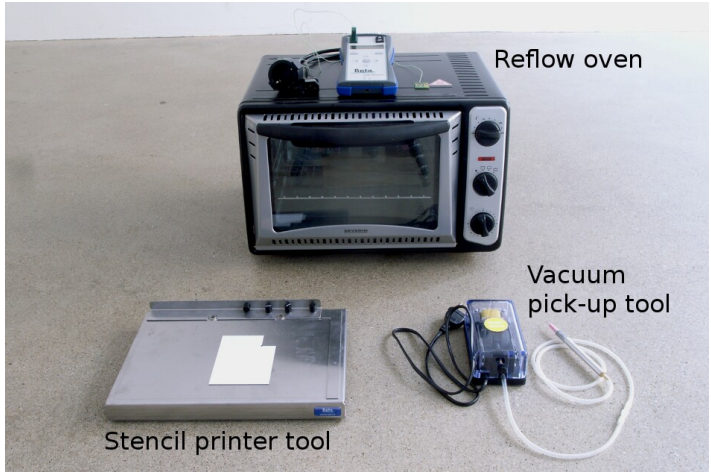
For the assembly of the surface mount devices, simple tools for the preparation of the electronic components and for visual guidance of the component location are used.

A low-cost approach using an oven with a temperature controller is used for the reflow soldering of the surface mount devices.

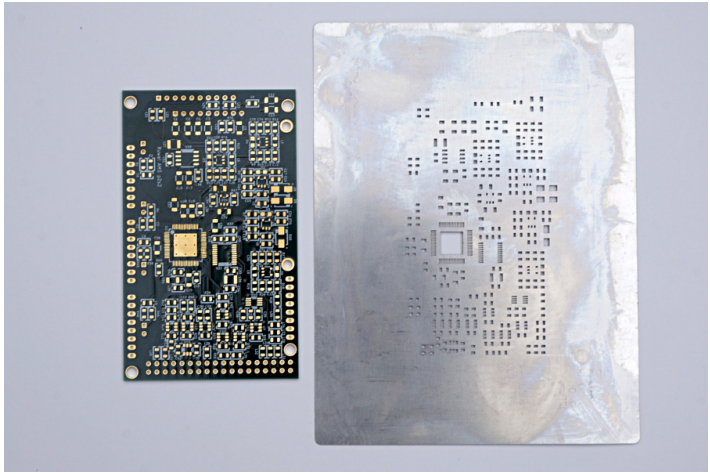
# Workplace setup



# Tools for reflow soldering

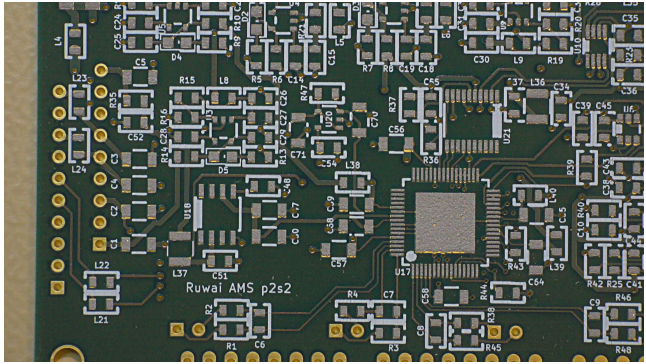


# PCB and the according SMD stencil

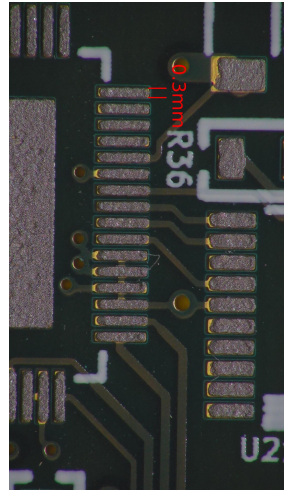


The SMD stencil is used to apply solder paste to the PCB.

# Applied solder mask

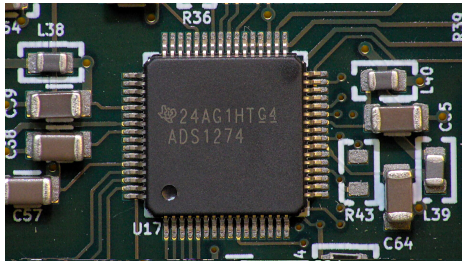



Manual application of the solder paste using the SMD stencil. Frequent cleaning of the stencil (after 2 prints) was needed for a good separation of the pads.

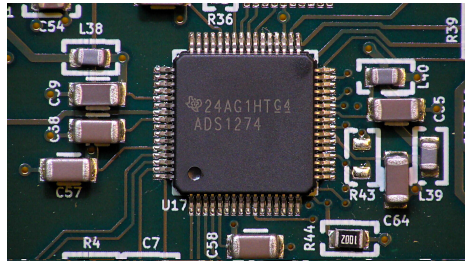


# Reflow soldering

assembled




soldered



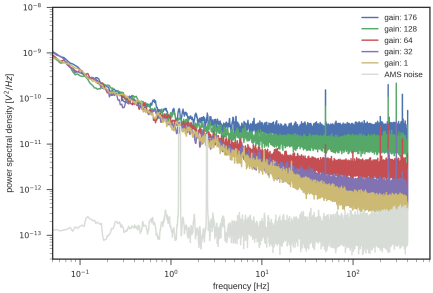

The outcome of the reflow soldering using the pizza oven was good and reproduceable.

# Performance

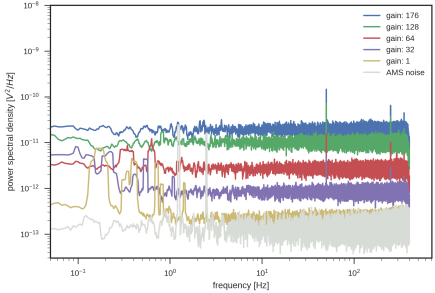
A common method to test the self-noise of ADCs is recording the output of the ADC with shorted differential inputs. Shortening the input means zero amplitude at the ADC input. In an ideal case, the output of the ADC would be zero as well. Actually, the output contains the internally created electronic noise and therefore is a measure of the quality of the ADC operation.
Based on the operation of the first prototype some changes have been applied to improve the noise characteristics. The following slides compare the performance of the first prototype to the improved second version.

# Power Spectral Density

First prototype




Second version



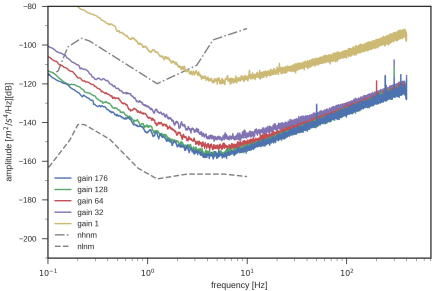

Power spectral density averaged for all 4 channels and sampling rate 800 sps. The light grey line represents the noise of channel 1 of the AMS shield only. All power spectral densities were smoothed using an 11 samples long moving average filter. The change of the operational amplifier of the anti aliasing filter improved the 1/f Noise at low frequencies significantly.

# Minimum resolvalbe ground motion

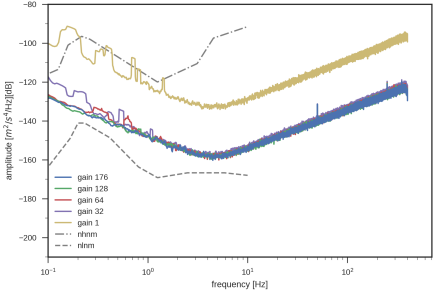
The shorted input noise of the Ruwai and the transfer function of a seismic sensor can be used to estimate the minimum resolvable ground velocity. The inverse transfer function is used to reconstruct the ground motion that would have created the signal of the shorted input noise. This signal represents the noise floor of the whole recording system. Any ground motion with an amplitude below the noise floor would not create a voltage high enough to exceed the internal noise of the Ruwai.

# Minimum noise floor

First prototype




Second version



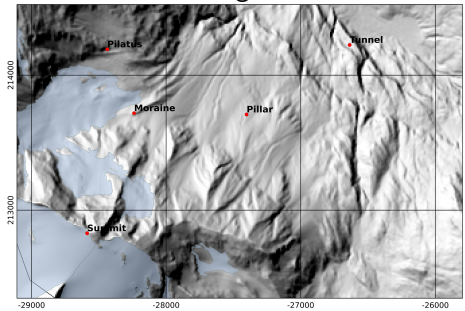

Minimum noise floor of the Ruwai system with a 4.5Hz GS-11D (81 V/m/s) sensor and a sampling rate of 800 sps.

For the second version, the increase of the gain larger than 32 doesn't lower the noise floor. This suggests, that the noise source is before the amplifier.

# Usecase SeisRockHT

Northface of Hoher Sonnblick

Monitoring stations

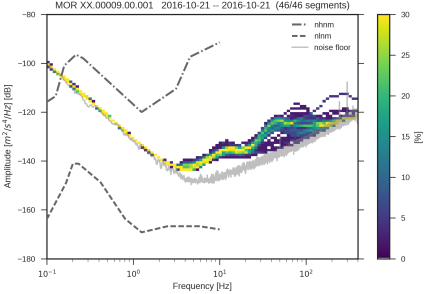



8 Ruwai recorders have been built for the SeisRockHT project. 5 units are used at the northface of Hoher Sonnblick in the Austrian Alps to monitor the rockfall activity.

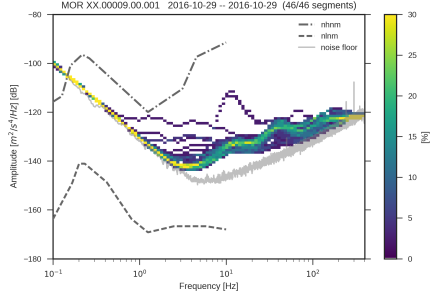
Three of the stations are powered using solar power supply and a wind turbine and 2 are connected to the mains power.

# Real-World data quality

## Normal background noise




## Earthquake sequence




The power spectral densities show, that the Ruwai recording system is suitable for the analysis of the seismicity of the north face of mount Hoher Sonnblick. In general the system is capable for seismic monitoring at sites with moderate seismic background noise.

# Usability

The deployment of the monitoring stations at Hoher Sonnblick resulted in several important improvements that are needed for good operation and maintenance of the Ruwai recorders:

- Protect the electronics using a front panel.
- Provide status information by a LCD.
- Easy access to the data using an SD-card outside the front panel.
- Sturdy and easy to use metal connectors.
- Stable recovery after frequent power loss.

These improvements mainly facilitate the maintenance during bad weather or when in a hurry. All points have been implemented in Version 2 of the Ruwai recorder.

# Contact

Further information about Ruwai can be found at `http://www.mertl-research.at/projects/ruwai/`.

The design files are available at `http://repo.or.cz/ruwai.git`.

Contact me under stefan@mertl-research.at or visit `http://www.mertl-research.at`

find out more about the generative logo at `http://www.mertl-research.at/design/generative_logo/`