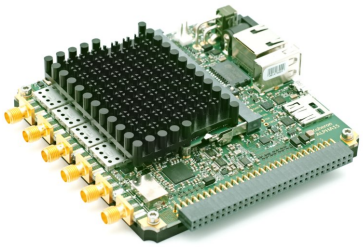


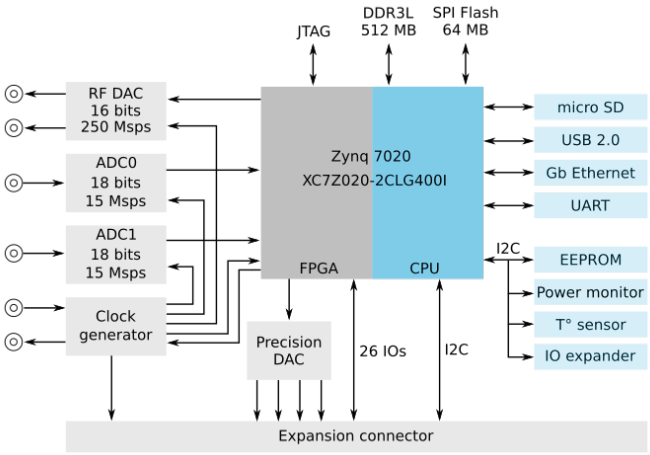
The ALPHA15 is a programmable board built around a Zynq 7020 SoC. It features two 18-bit 15 Msps ADCs with high dynamic range, low noise front-ends. The high input impedance (up to 1 MΩ) is easy to drive and allows to directly interface sensors. Two input ranges are selectionnable: 2 Vpp (± 1 V) or 8 Vpp (± 4 V). Thanks to the very low flicker noise corner frequency (below 50 Hz) the ALPHA15 excels in high oversampling applications. The ALPHA15 also features a dual-channel 16-bit 250 Msps low latency DAC and a 4-channel 16-bit precision DAC. The high speed data converters are clocked by a dual PLL, ultra-low jitter clock generator. The board comes with a comprehensive, open source, FPGA / Linux reference design.

Specifications

	ALPHA15-1M
Programmable logic, processor and memory	
System On Chip	Zynq 7020 XC7Z020-2CLG400I
Memory	512 MB of DDR3L SDRAM
Processor	ARM dual-core CPU (Cortex-A9)
18-bit ADC	
Number of channels	2
Resolution	18-bit
Sampling rate	15 Msps
Coupling	DC
Input impedance	1 MΩ
Flicker noise corner frequency	50 Hz
Input range	2 V_{pp} or 8 V_{pp}
Crosstalk	< 120 dB
Input-referred voltage noise 10 kHz, 50 Ω input, 2 V range	7 nV/√Hz
Input-referred voltage noise 10 kHz, 50 Ω input, 8 V range	18 nV/√Hz
Total harmonic distortion 2 kHz, -3 dBFS, 8 V range	-105 dB
Effective number of bits 2 kHz, -3 dBFS, 8 V range	15 bits
RF DAC	

Number of channels	2
Resolution	16-bit
Sampling rate	250 Msps
Coupling	DC
Output impedance	50 Ω
Output range	1 V_{pp}
Ultra-low jitter clock for RF ADC, DAC and FPGA	
Clock generator	Dual loop PLL, 100-fs RMS jitter (12 kHz to 20 MHz)
On-board VCXO phase noise 10 kHz carrier offset	160 dBc/Hz
Reference clock inputs	FPGA, external clock or internal crystal oscillator
On-board TCXO	10 MHz, 280 ppb
External frequency reference range	10 MHz ± 100 Hz
Precision analog monitoring and control	
Precision DAC	4 channels, 16-bit
Voltage reference	2.5 V and 4.096 V, low-drift (3 ppm/°C)
Temperature sensor	±0.2 °C accuracy
Other	
Connectivity	10/100/1000 Ethernet, USB 2.0, USB-UART
General purpose I/O	26 FPGA I/Os
Operating temperature	-10 °C to 50 °C
Outside dimensions	113 mm x 108 mm x 27 mm
Weight	123 g
Software	
OS	Ubuntu 22.04

Block diagram



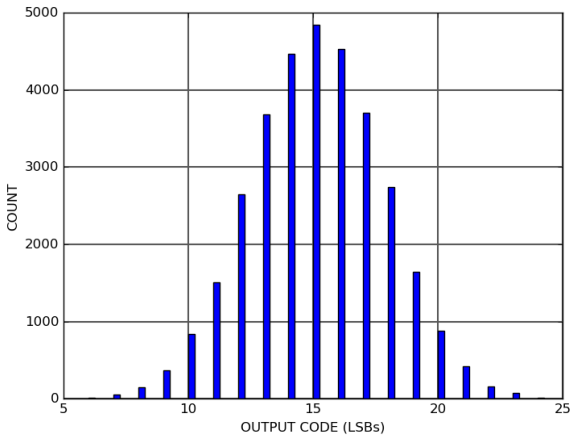
ALPHA15 block diagram

Characterisation

Transition noise

Transition noise is measured with 50 Ω terminated inputs.

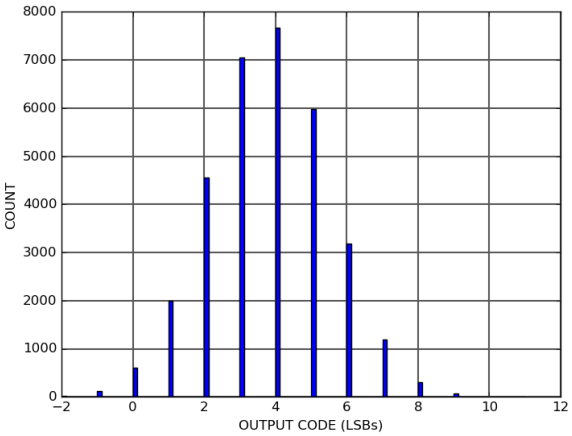
Range 2 V



ALPHA15 Transition noise histogram range 2 V

Transition noise is 2.7 LSB_{rms}, corresponding to an input voltage noise of $ v_{\rm in}$ = 21 μV_{rms}. Given that the full-scale range (FSR) is 2.048 V, the effective resolution is $ \log_{2} \left(\frac{\mathrm{FSR}}{v_{\rm in}} \right) $ = 16.6 bits.

Range 8 V



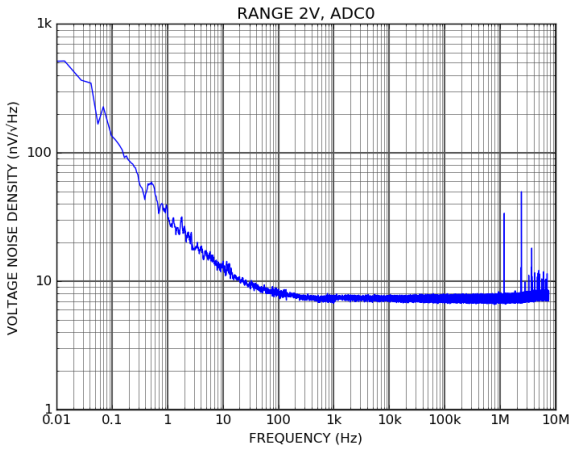
ALPHA15 Transition noise histogram range 8 V

Transition noise is 1.67 LSB_{rms}, corresponding to an input voltage noise of $ v_{\rm in}$ = 52 μV_{rms}. Given that the FSR is 8.192 V, the effective resolution is 17.3 bits.

ADC input noise floor

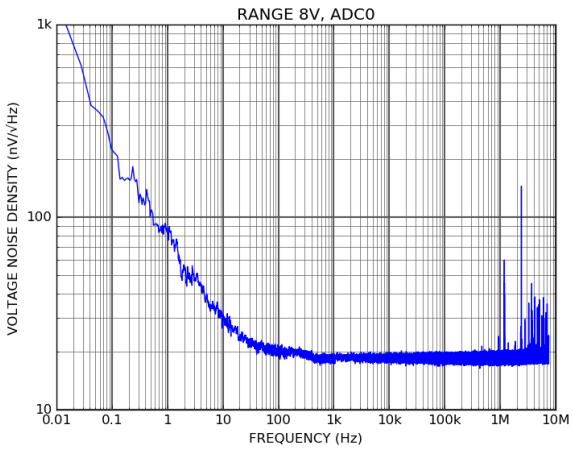
Noise floor measured with 50 Ω terminated inputs.

Range 2 V



ALPHA15 ADC input noise floor range 2 V

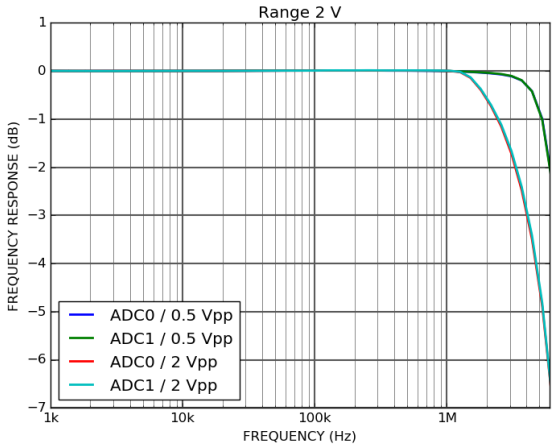
Range 8 V



ALPHA15 ADC input noise floor range 8 V

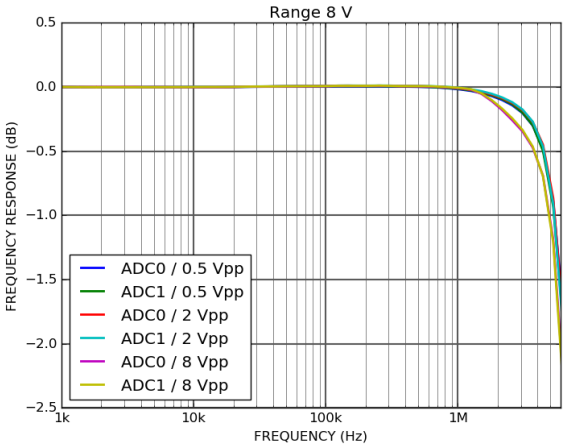
ADC front-end frequency response

Range 2 V



ALPHA15 ADC front-end frequency response range 2 V

Range 8 V

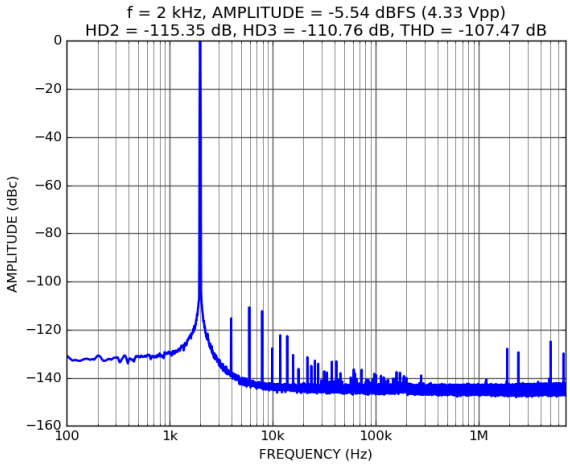


ALPHA15 ADC front-end frequency response range 8 V

ADC dynamic performances

We measured dynamic performances of the ADC using an ultra-low distortion sine wave at 2 kHz. The measurements are performed on the 8 V range.

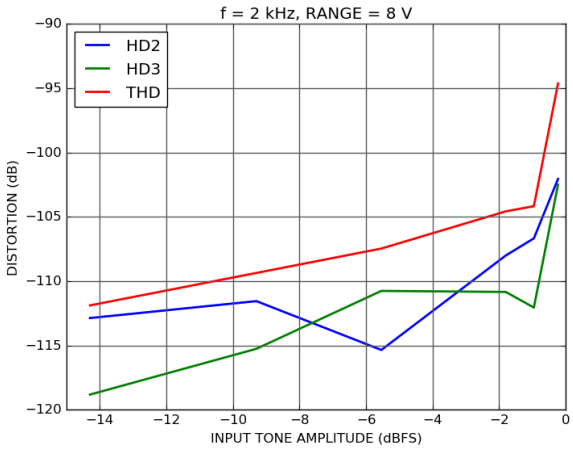
FFT of the acquisition for a 4.33 V_{pp} (-5.54 dBFS) signal:



ALPHA15 fft sine 2kHz

Distortion

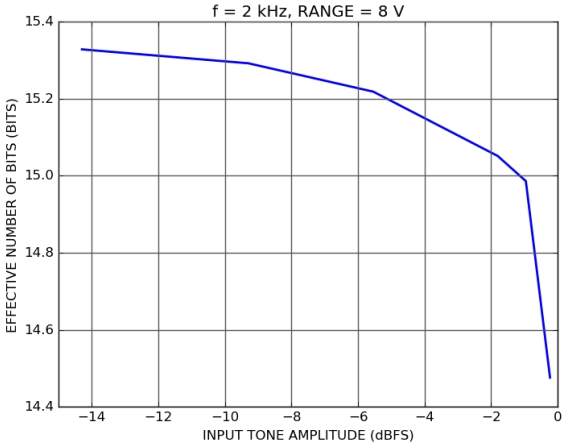
Distortion at 2 kHz versus the amplitude of the input tone. The total harmonic distortion (THD) is obtained from the rms sum of the first six harmonics.



ALPHA15 distortion

Effective number of bits (ENOB)

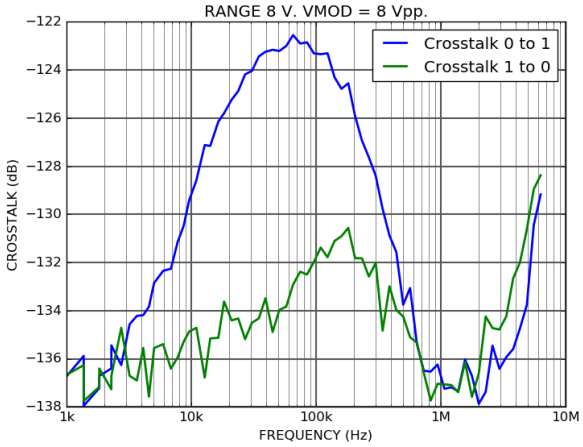
The ENOB is measured over the full Nyquist bandwidth (7.5 MHz).



ALPHA15 effective number of bits

ADC crosstalk

Measured on the 8 V range using a 8 V_{pp} sine input signal.



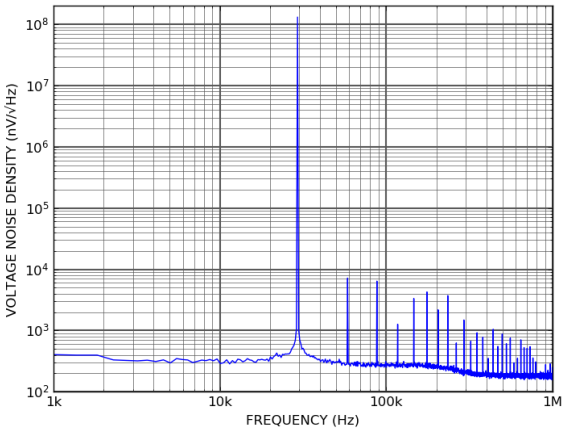
ALPHA15 crosstalk

Applications

DAC distortion measurement

We use high dynamic range and linearity of the ADC to characterize the distortion of the RF DAC output once amplified.

DAC output is set to full range (1 V_{pp} on 50 Ω) and amplified to 8 V_{pp} on 1 MΩ using an AMP100. The DAC outputs a 30 kHz sine wave which is acquired using the ADC on the 8 V range. Here is the measured power spectrum:



ALPHA15 DAC distortion

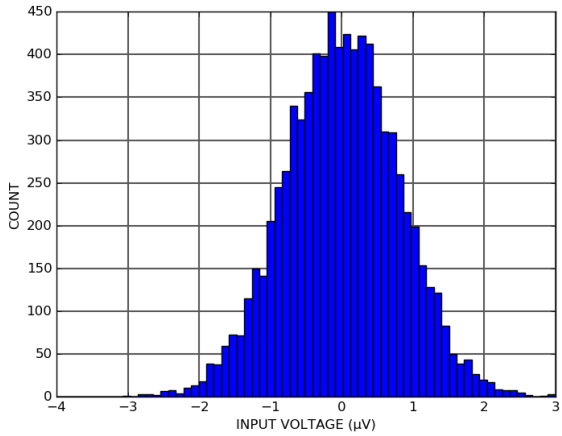
Second harmonic distortion (HD2) is -85 dB, and third harmonic distortion (HD3) is -86 dB. Total harmonic distortion (THD) using the first 16 harmonics is -81 dB.

Oversampling

Because of its high sampling frequency ($ f_{s} $ = 15 MHz) and the low flicker noise corner frequency ($ f_{c} \lesssim $ 50 Hz), the ALPHA15 is well suited for oversampling applications. The maximum oversampling ratio is about $ N_{\rm max} \sim f_{s} / (2 f_{c}) $ = 150 000, corresponding to about $ \log_{2}(N) / 2 $ = 8.5 additional bits or an overall resolution of 26.5 bits.

We use the decimator instrument with an oversampling ratio of 4096: the cascaded-integrator comb (CIC) first decimates by a factor 2048 and the finite impulse response (FIR) filter by a factor 2. The maximum signal frequency of 1.8 kHz is still well above the 1/f noise corner frequency.

We plot the histogram (using 8192 samples) of the input voltage noise. The input is terminated with 50 Ω and set to the 8 V range.



ALPHA15 Decimator input voltage noise histogram, 8 V range

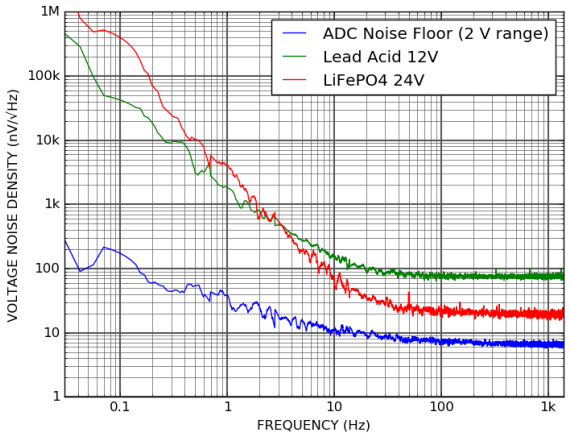
Input noise is $v_{\rm in} $ = 787 nV_{rms} in the 0.45 Hz to 1.831 kHz acquisition band. Given that the full-scale range (FSR) is 8.192 V, the effective resolution is $ \log_{2} \left(\mathrm{FSR} / v_{\rm in} \right) $ = 23.3 bits, which is a 6 bits improvement.

Battery noise measurement

The ALPHA15-1M ADC front-end offers both low input noise and a high 1 MΩ input impedance, allowing many physical systems to be directly interfaced to the board without a pre-amplifier.

Here we use this feature to directly measure the voltage noise density of a 12 V lead acid battery (SG75-12) and a 24 V LiFePO4 lithium battery (B24008).

The battery output is simply AC-coupled using a 22 µF capacitor, which combined with the 1 MΩ input impedance provides a 7.3 mHz AC cut-off frequency. The ADC is set to the 2 V input range. After waiting for the ADC input voltage to settle, we acquire low frequency data using the decimator instrument:



ALPHA15 Voltage noise spectral density of different batteries

Ordering codes

PRODUCT NUMBER	ATTRIBUTE
ALPHA15-1M	None
ALPHA15-1M-BP	Mounted baseplate