Programació d'Arquitectures Encastades
Analog to Digital Converters

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Real Time Operating Systems

1. Quantization
2. Nyquist
3. Calibration
4. TI ADCs

Physical measurements

Real world physical magnitudes (temperature, pressure, light, etc) are continuous and have an infinite resolution.
-> *Continuous*: it may have signals on any possible frequency. Another way of saying it is the data in the time domain doesn't has holes.

-> *Infinite resolution:* while every instrument shows these magnitude with a certain finite number of decimals, in reality (above quantum limits) they are infinite.

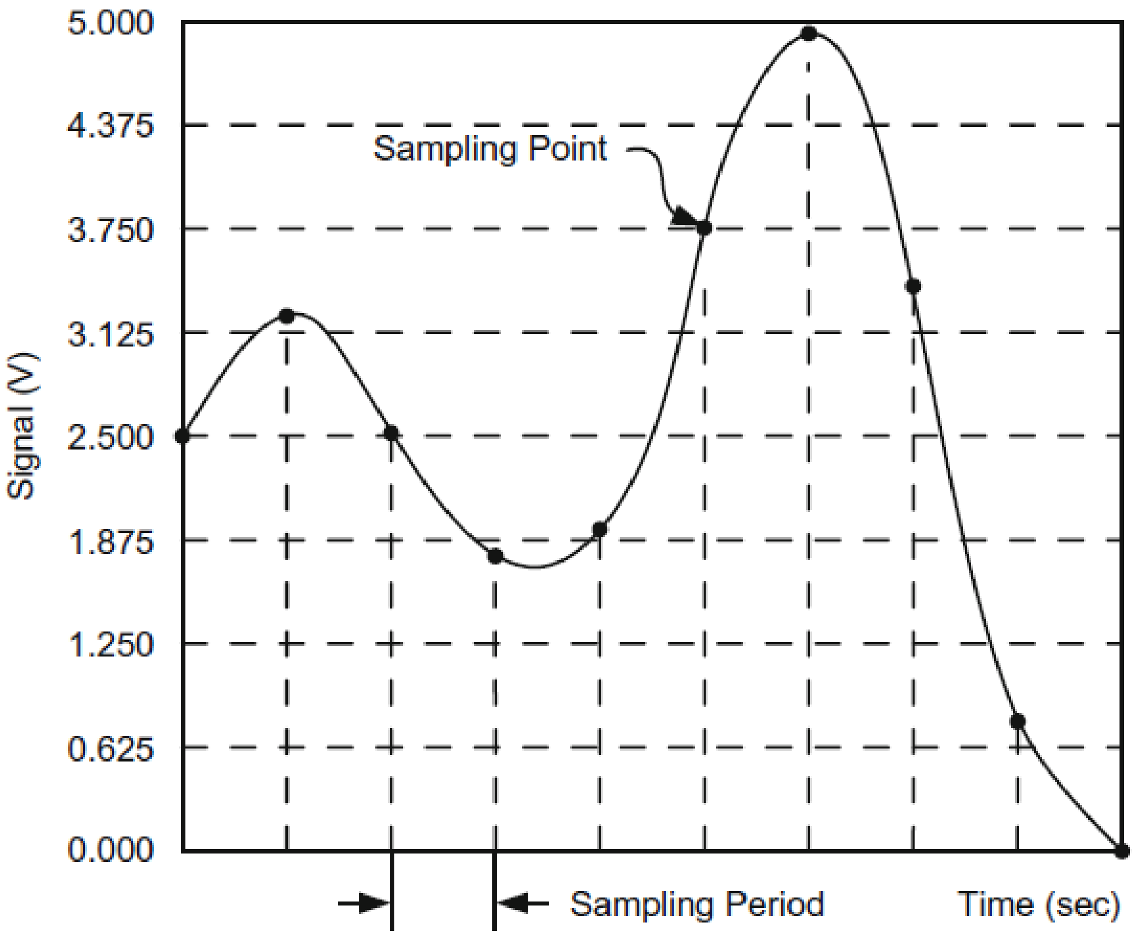
For instance, the temperature, at a given place and time, may be 25.285723 ºC. But, our thermometer may only show 25.3 ºC.

-> Measurements are **quantized** (finite resolution)

Furthermore, this value will change over time. But the value displayed by our thermometer may for example only change every second (1 Hz). Hence, we are not able to see any fluctuation of the temperature faster than this

-> **Discrete** data (sampling frequency limit)

Physical measurements



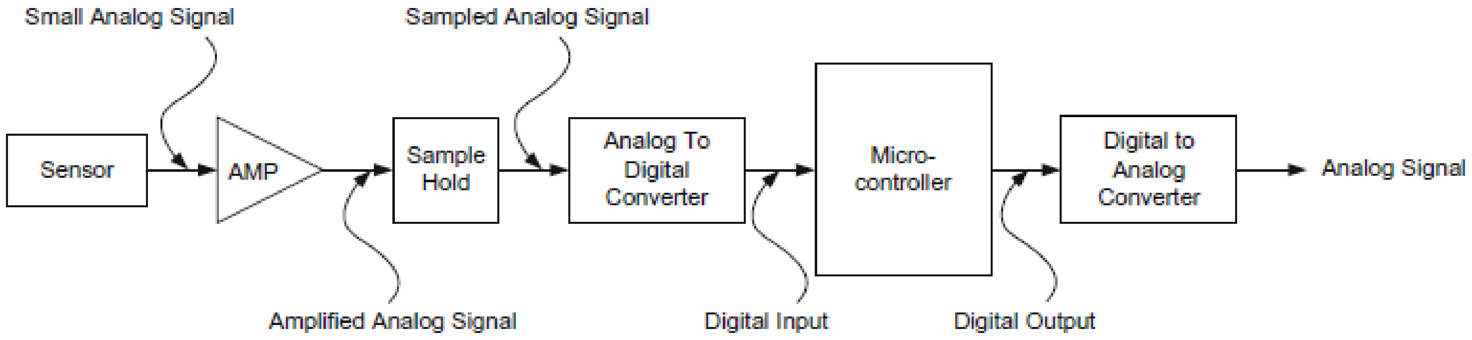
Values are quantized in magnitude and discrete in time

Acquisition chain

Every real-world measurement starts with a sensor: a sensor is any transducer that changes its electrical behavior depending on some physical environment magnitude.

For instance, a resistive temperature sensor is an element that changes its electrical resistance depending on the external temperature it is exposed.

After this element, we usually have some electronics to adapt this electrical "analog signal" and finally we find the analog to digital converter (ADC).



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Analog to digital converters

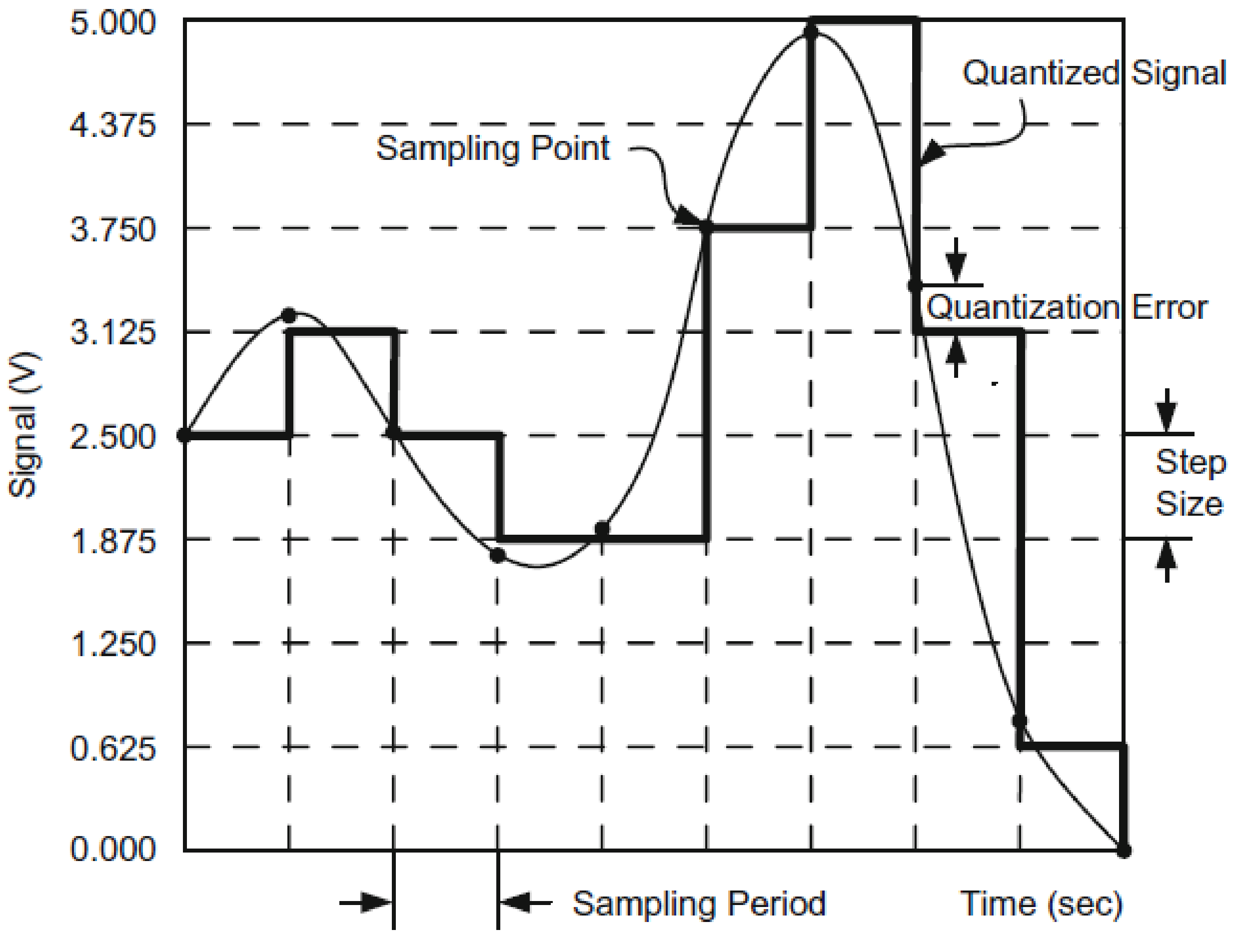
Analog to digital converters (ADC) are the electronic devices responsible to transform the continuous analog values to discrete digital counts.

Key parameters:

- Resolution: number of bits used to represent the analog input. Equivalent to the word size of the ADC digital output.
- Full scale range: analog input voltage range. Also called reference voltage.
- Sampling frequency: frequency at which it generates a new output data.
- Integration period: Conceptually, since the output is discrete, we see the "mean" value of the integration period and not only the value corresponding at an infinitesimal point of the input.

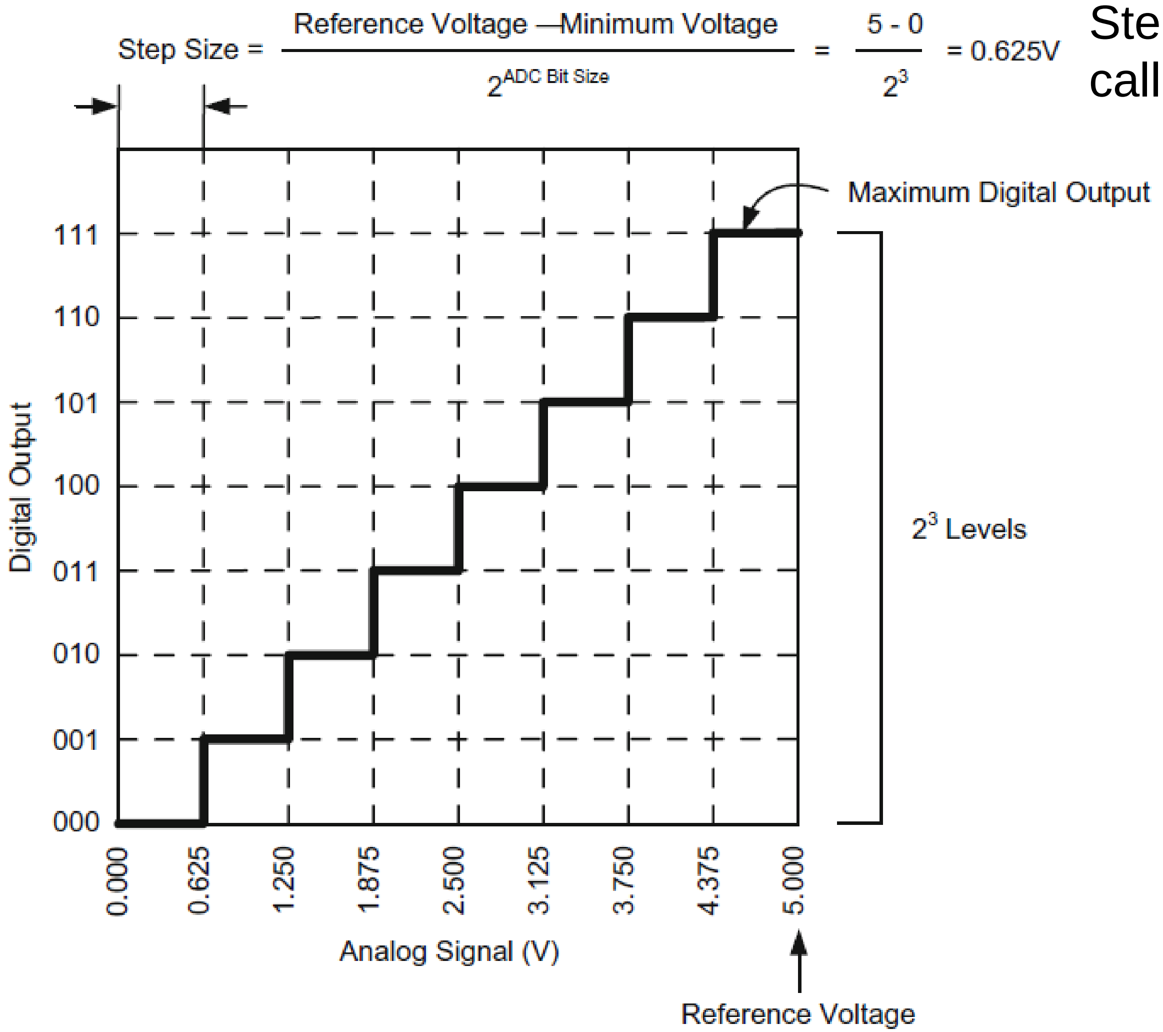
Caution! Resolution is not a real indicator of the accuracy of the ADC measurements. An ADC can state it has 32 bits resolution, but 8 of them being only noise…

ADC operation example



Quantization error is ideally in the range of +/- half the step size.

ADC transfer function



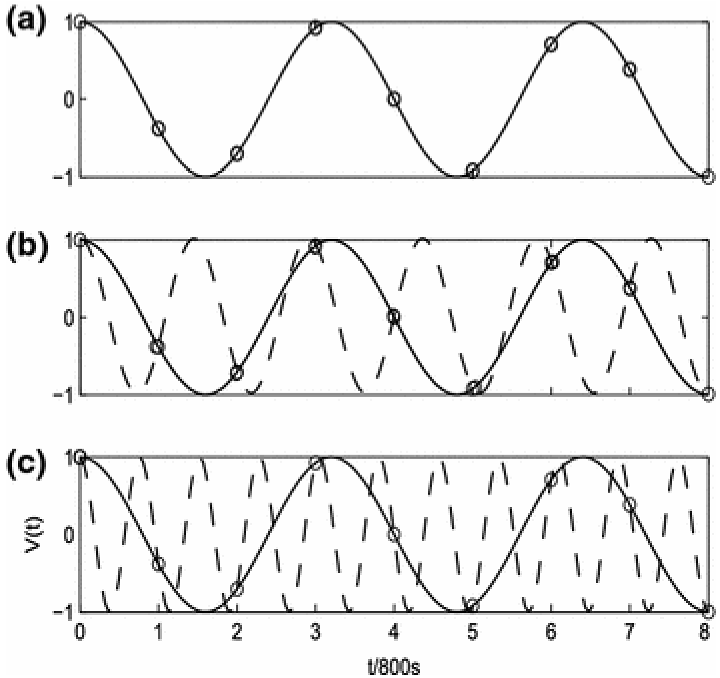
Step size is commonly called a LSB

Resolution: 3 bits
Full scale: 5 V

Aliasing

A common error is to have signals of the sampled analog signal with a frequency higher than half the sampling frequency.

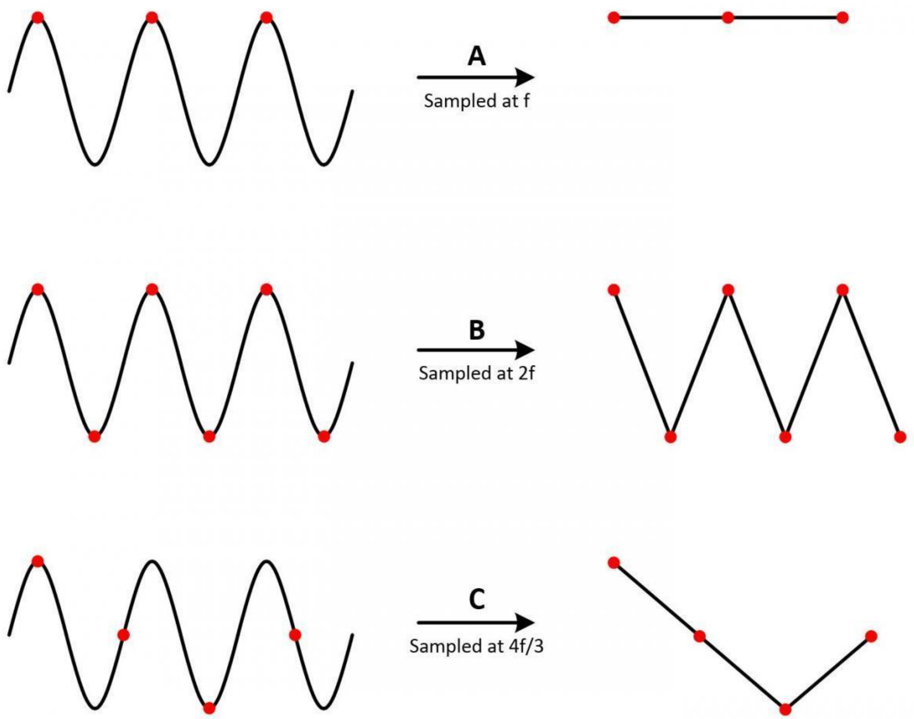
Plot a) shows the samples and the reconstructed signal with frequency f.
Plot b) shows a signal with frequency fs - f which may produce the same output.
Plot c) shows a signal with frequency fs + f



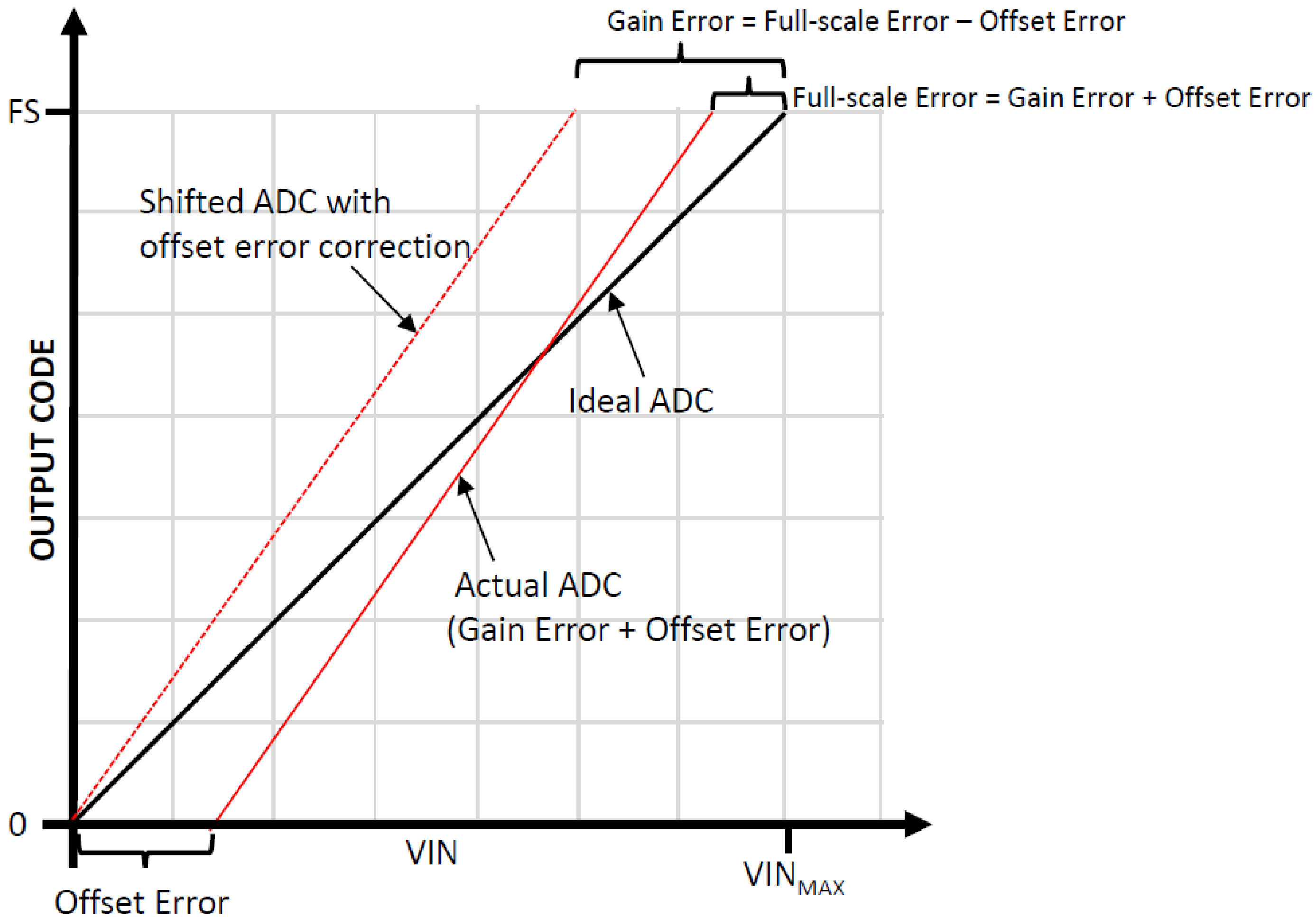
This issue is known as aliasing. It happens if the sampling frequency is to low for the signal we want to see or if we don't have an anti-aliasing filter on the electronics and an external interfering signal is appearing.

Nyquist–Shannon sampling theorem

Half of the sampling frequency ($f_s/2$) is called the Nyquist frequency. What this theorem says is that any signal below this frequency may be correctly reconstructed. Any signal above may produce aliasing.
Another way to interpret this theorem is that we need at least TWO points for any given signal to reconstruct its original frequency.



Calibration ADC



MSP432 ADC

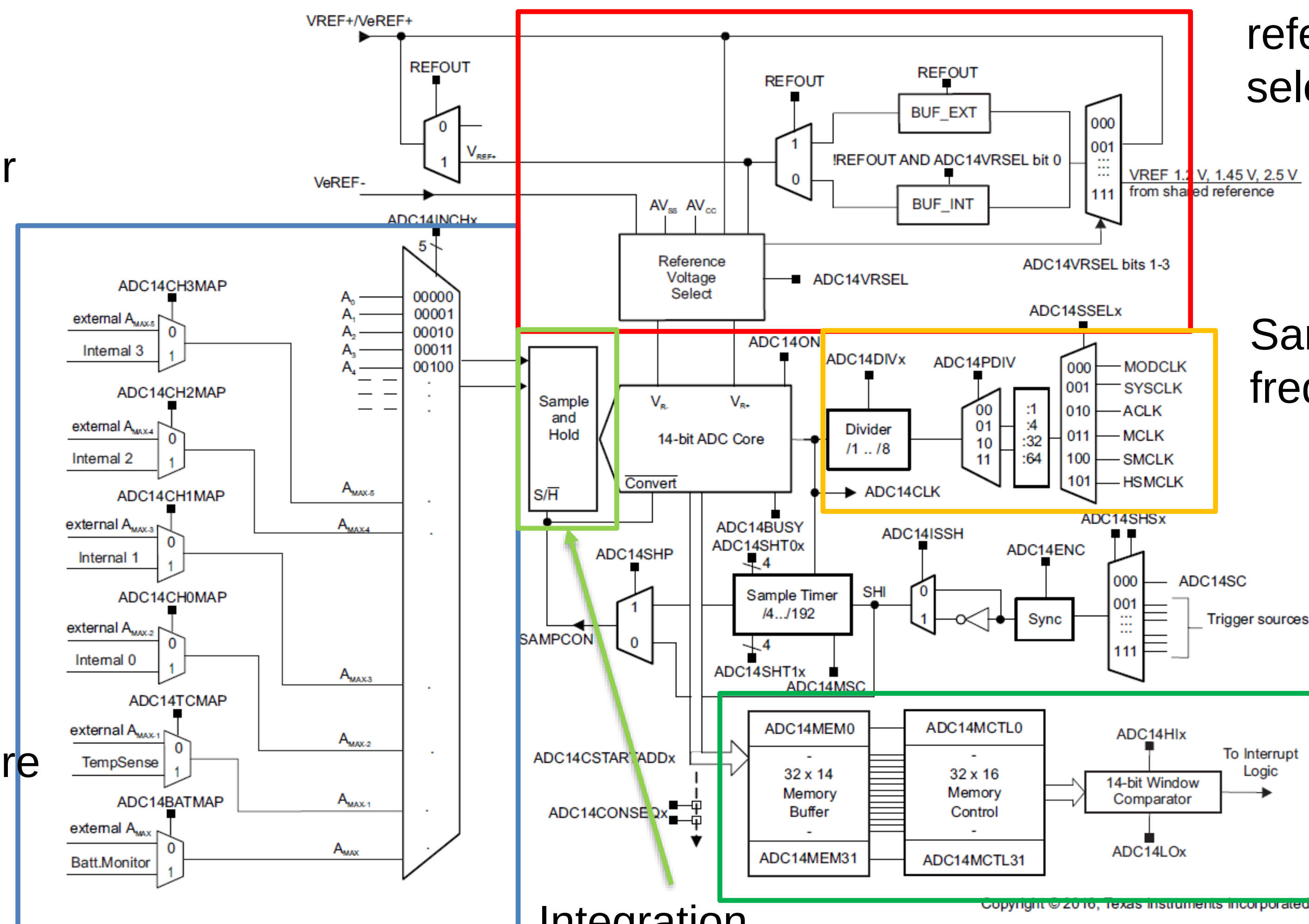
- Maximum sampling frequency: 1 Msps (1 MHz)
- Resolution: 14 bits
- Software selectable internal voltage reference (1.2 V, 1.45 V or 2.5 V) or external
- Up to 32 individual input channels
- 32 conversion storage registers and IRQs
- Conversion modes:
  - Single-channel
  - Repeat-single-channel
  - Sequence
  - Repeat-sequence

MSP432 ADC14

Input multiplexer for 32 channels

Voltage reference selection

Sampling frequency



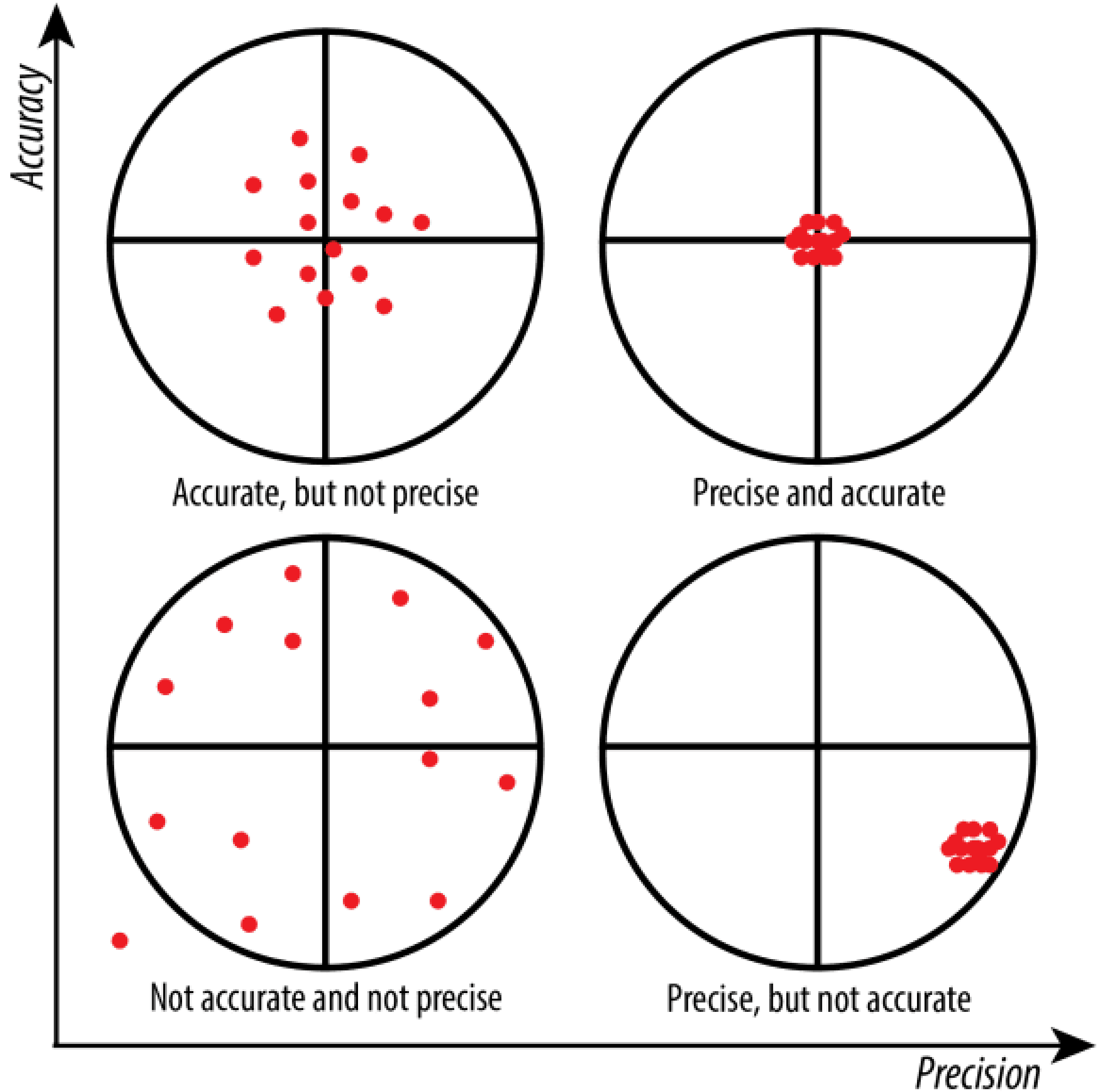
Buffering and IRQ

Temperature & battery monitoring

Integration time control

Questions?

Exactitud



Precisió

STM32CubeMX