EMPIR Call 2018 – Health, SI Broader Scope, Normative and Research Potential

Selected Research Topic number: **SRT-n07**
Version: 1.0

Title: Traceable measurement methods for the characterisation of Analog-to-Digital Converters

Abstract

There is an increasing demand for dynamic measurements and digitisation in industry and research applications. Analog-to-Digital Converters (ADCs) play a key role here. Industry has been able to develop and produce converters whose characteristics are able to cover a wide range of metrological and industrial needs and metrological research has developed quantum standards for the calibration of the digital converters at the highest level and directly traceable to the SI. However, there is a need to develop standards that include traceable methods for the characterisation of analog-to-digital converters for calibration and testing laboratories and for industrial applications.

Keywords

Digitisation, digital converters, digital sampling, uncertainty, SI, quantum standards, algorithms, data processing

Background to the Metrological Challenges

Recent industrial research and development in precision integrated circuits and measurement equipment has brought about a step change in the sampling rates and potential accuracy available. The characteristics of the ADC to be used in any equipment must be established during the design process, and suitability for the given application must be tested before its integration.

There have been various standardised methods for ADC characterisation, and much work has been done to harmonise them to give comparable results, namely IEC and IEEE standards. However, traceability, which is especially important for time varying signals, has not been included in the standards so far and this is limiting further progress in the field. One of the reasons for the lack of standards for traceable characterisation methods of ADCs is the lack of precision arbitrary waveform generators. To develop traceability of sampled electrical measurement, several research projects to build primary level measurement standards have been carried out, of which the latest, EMRP SIB59 Q-wave developed a prototype arbitrary waveform generator with a potential to be used as a transfer standard for ADC calibrations at the 10^{-6} level for certain parameters. With further development and investigation a fairly simple and easy-to-use traceable instrument producing multi-tone signals could be brought to industrial laboratories for ADC characterisation. It also creates an opportunity to start developing traceable measurement methods leading ultimately to new documentary standards.

To characterise an ADC parameter, different algorithms can be used. The algorithm selected will depend on the parameters to be obtained and on the sampling conditions. However, there is no single best algorithm for all types of signals and sampling conditions. Due to their complexity, the errors of most of those algorithms have not been properly evaluated and their uncertainty contribution is not known. Consequently, there is a need to study, evaluate and characterise those algorithms.

The uncertainty estimation is very complex and benefits from use of the Monte Carlo method. Specific tools to facilitate this activity are not yet available and will be necessary for the future application of the standards. Existing data processing toolboxes are not validated and only the quantum wave toolbox developed in the EMRP SIB59 Q-wave project provides an uncertainty estimation.

To satisfy the semiconductor industry requirements, the end-users of ADC for instrumentation, the testing laboratories etc., there is a need to develop traceable measurement methods for the characterisation of ADCs. Traceable reference standards should be made available, measurement procedures should be defined, the most convenient algorithms for data processing to evaluate the required parameters should be selected and validated, and tools to perform the required complex uncertainty estimation should be developed.

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Objectives

Proposers should address the objectives stated below, which are based on the PRT submissions. Proposers may identify amendments to the objectives or choose to address a subset of them in order to maximise the overall impact, or address budgetary or scientific / technical constraints, but the reasons for this should be clearly stated in the protocol.

The JRP shall focus on the development of traceable methods for the characterisation of Analog-to-Digital Converters (ADC) in order to provide substantial technical information for future revisions of relevant standards by IEC and IEEE.

The specific objectives are

1. To define the requirements of reference instruments (waveform generators, clock circuitry etc.) to enable the reliable characterisation of ADCs, and the evaluation and modification, as necessary, of available measurement equipment. A key requirement of a characterised parameter will be its direct or indirect traceability to the SI.
2. To establish and validate procedures for traceable characterisation of ADCs, addressing a selected representative set of parameters where traceability is a critical issue (Frequency response, noise, gain, harmonic distortion, spurious free dynamic range, etc.), and including uncertainty estimation which will be the basis for standards development or modification.
3. To evaluate, compare (including data processing resources) and validate the currently available algorithms for data processing, suitable for characterisation of ADCs.
4. To develop validated specific data processing tools to facilitate uncertainty estimation of the ADC characterisation.
5. To contribute to the standards development work of the European and International Standards Developing Organisations (particularly with IEC TC 85 “Committee on Measuring equipment for electrical and electromagnetic quantities” and IEC SC47A “Integrated circuits”) to ensure that the outputs of the project are aligned with their needs, communicated quickly to those developing the standards and to those who will use them, and in a form that can be incorporated into the standards at the earliest opportunity.

The proposed research shall be justified by clear reference to the measurement needs within strategic documents published by the relevant Regulatory body or Standards Developing Organisation or by a letter signed by the convenor of the respective TC/WG. EURAMET encourages proposals that include representatives from industry, regulators and standardisation bodies actively participating in the projects. The proposal must name a “Chief Stakeholder”, not a member of the consortium, but a representative of the user community that will benefit from the proposed work. The “Chief Stakeholder” should write a letter of support explaining how their organisation will make use of the outcomes from the research, be consulted regularly by the consortium during the project to ensure that the planned outcomes are still relevant, and be prepared to report to EURAMET on the benefits they have gained from the project.

Proposers should establish the current state of the art, and explain how their proposed research goes beyond this.

In particular, proposers should outline the achievements of the EMRP project SIB59 Q-wave and how their proposal will build on it.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 0.6 M€, and has defined an upper limit of 0.8 M€ for this project.

EURAMET also expects the EU Contribution to the external funded partners to not exceed 30 % of the total EU Contribution across all selected projects in this TP.

Any industrial partners that will receive significant benefit from the results of the proposed project are expected to be unfunded partners.

Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the “end user” community, describing how the project partners will engage with relevant communities during the project to facilitate knowledge transfer and accelerate the uptake of project outputs. Evidence of support from the “end user” community (e.g. letters of support) is also encouraged.

You should detail how your JRP results are going to:

- Address the SRT objectives and deliver solutions to the documented needs,
- Feed into the development of urgent documentary standards through appropriate standards bodies,
- Transfer knowledge to the semi-conductor industry, the end-users of ADC for instrumentation, and testing laboratories.

You should detail other impacts of your proposed JRP as specified in the document “Guide 4: Writing Joint Research Projects (JRPs)”

You should also detail how your approach to realising the objectives will further the aim of EMPIR to develop a coherent approach at the European level in the field of metrology and include the best available contributions from across the metrology community. Specifically, the opportunities for:

- improvement of the efficiency of use of available resources to better meet metrological needs and to assure the traceability of national standards
- the metrology capacity of EURAMET Member States whose metrology programmes are at an early stage of development to be increased
- organisations other than NMIs and DIs to be involved in the work

Time-scale

The project should be of up to 3 years duration.