European Partnership on Metrology
Call 2022 – Digital Transformation, Health, Integrated European Metrology, Normative and Research Potential

Selected Research Topic number: **SRT-r01**
Version: 1.0

Title: Towards a true 8-digit digitiser

Abstract

The development of a digitiser with a state-of-the-art analogue-to-digital converter (ADC), operating in the range from DC to 100 kHz, is needed to meet the demands for linearity, noise, and overall accuracy of current applications in NMIs and research, which cannot be met using currently available digital multimeters (DMMs), digitizers or ADCs. Research on the key techniques and technologies of electronic measuring devices and their components is needed to build research capability to meet this challenge.

Keywords

Analogue-to-Digital Converter, digital multimeter, sampling, linearity, low noise, modelling, custom amplifiers, component behaviour, ultra-quiet power supply, time jitter

Background to the Metrological Challenges

Analog to digital conversion is arguably the most widely used measurement technology worldwide, employed in almost all communication technologies, smart sensors, measuring devices and instrumentation regardless of the application area. High accuracy ADCs are traditionally deployed in applications in the instrumentation and research area, but they are increasingly in demand in the power generation, medical (MRI, digital radiography, CT, ultrasonography), industrial and consumer (audio) markets as well.

Currently the reference for DC and low frequency (up to ~ 100 kHz) electrical metrology are Josephson based sources (JVS, PJVS, JAWS). DMM based digitisers available on the market, as well as commercially available integrated circuit ADCs, are not sufficiently accurate in terms of linearity, stability, signal noise and distortion to disseminate traceability from signals generated by these quantum standards. Commercially available digitisers, though improved over recent years, are still not developed for state-of-the-art stability and accuracy, mainly due to compromises that are made to ensure wide applicability and the technical limitations of their components. Furthermore, their hardware design is closed, and uncertainty components and data post processing are unknown, all limiting their use for applications needed by NMIs and DIs.

A number of issues need to be addressed to lay the foundation for the development of a digitiser with state-of-the-art ADC. Firstly, detailed digital models of metrology grade ADC architectures should be developed in order to compare their limitations and determine approaches to overcome their deficiencies to address state-of-the-art metrology needs. Then, the necessary metrological tools to assess designs for custom amplifiers for front-end circuitry that meets the required performance criteria should be developed along with the methods for the metrological characterisation of linear components and electronic switches. Furthermore, the development of an electrically quiet and stable power supply and a precision timing solution appropriate for metrology grade ADCs as well as the methods to measure their performances are required. Taken altogether, these steps should result in building the necessary technological and research capacity at NMIs/DIs for the development of a state-of-the-art digitiser in the future.

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 research capabilities to enable the development of a digitiser with a state-of-the-art ADC operating from DC to 100 kHz.

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The specific objectives are

1. To identify possible novel metrology grade ADC architectures for the DC to 100 kHz frequency band and develop comprehensive digital models covering integrating ADC (IADC), Sigma-Delta (ΔΣ) and possible novel/mixed designs and including first and second order error mechanisms. This includes comparing the limitations of the ADC architectures and identifying approaches to mitigate and/or compensate non-ideal behaviour by means of simulations.
2. To assess possible designs for custom amplifiers (composite operational amplifiers) for integrator and front-end digitiser circuitry with zero drift, extremely high gain, low noise and error below 1 ppm, and to develop the metrological tools to evaluate their performance. Additionally, to identify metrological methods for characterisation of linear components for their stability, tracking and nonlinear behaviour down to and below -120 dB THD (resistors, capacitors) and electronic switches for their injection currents and transients' stability.
3. To design and develop an ultra-quiet and stable low noise power supply, supplied from the mains but with negligible line interference noise, and applicable for all voltage and current spans needed by the metrology grade ADC architectures identified in objective 1.
4. To develop a precision (< 50 ps jitter) timing solution for the ADC architectures identified in objective 1, with a galvanically isolated external trigger, lock-in and internal clock frequency output, and to develop the metrological tools to evaluate its performance.
5. To facilitate the take up and long term operation of the capabilities, technology and measurement infrastructure developed in the project by the measurement supply chain (NMIs/DIs, calibration and testing laboratories), and end users (e.g. electrical power generators, manufacturers of medical imaging devices, ADC and DMM industry). The approach should be discussed within the consortium and with other EURAMET NMIs/DIs, EURAMET TCs or EMNs, to ensure that a coordinated and optimised approach to the development of traceability in this field is developed for Europe as a whole.

Joint Research Proposals submitted against this SRT should identify

- the particular metrology needs of stakeholders in the region,
- the research capabilities that should be developed (as clear technical objectives),
- the area for which the capabilities will be built (Green Deal, Digital Transformation, Health, Integrated European Metrology, Industry, Normative or Fundamental Metrology) and in which future main call the developed research capabilities are planned to be employed,
- the impact the developed research capabilities will have on the industrial competitiveness and societal needs of the region,
- how the research capability will be sustained and further developed after the project ends.

The development of the research potential should be to a level that would enable participation in other TPs.

Proposers should note that the programme funds the activity of researchers to develop the capability, not the required infrastructure and capital equipment, which must be provided from other sources.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 0.5 M€ and has defined an upper limit of 0.9 M€ for this project.

EURAMET also expects the EU Contribution to the external funded beneficiaries to not exceed 20 % of the total EU Contribution across all selected projects in this TP.

Any industrial beneficiaries that will receive significant benefit from the results of the proposed project are expected to be beneficiaries without receiving funding or associated 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,
- Provide a lasting improvement in the European metrological capability and infrastructure beyond the lifetime of the project,
- Facilitate improved industrial capability or improved quality of life for European citizens in terms of personal health or protection of the environment,

- Transfer knowledge to the instrumentation manufacturing and ICT sectors and the metrology community.

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 the Partnership 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.