EMRP Call 2012 – Open Excellence, Industry and SI Broader Scope

Selected Research Topic number: **SRT-s05**
Version: 1.0

Title: A quantum standard for sampled electrical measurements

Abstract

Sensing and measurement of electrical signals are increasingly dependent on analogue-to-digital conversion of sampled measurements. Recent R&D in precision integrated circuits and measurement equipment has brought about a step change in the sampling rates and potential accuracy available. Traceability of DC electrical metrology to quantum standards is well established but emerging measurement applications are placing new demands on the traceability for dynamic quantities. Research is required to develop quantum devices for waveform metrology at the highest level of accuracy.

Conformity with the Work Programme

This Call for JRPs conforms to the EMRP Outline 2008, section on “Grand Challenges” related to Industry & Fundamental Metrology on pages 10, 11 and 32.

Keywords

Josephson effect, quantum standard, SI, volt, digital measurement

Background to the Metrological Challenges

Sophisticated analogue to digital and digital to analogue converters are now in the market place and the trend towards higher accuracy and higher sampling rates is set to continue. Measurement across a wide range of disciplines is taking advantage of this evolution. However, established techniques based around DC and AC measurement as separate disciplines are not aligned with the needs of dynamic measurement.

The present methods for disseminating the SI volt for non-stationary or alternating waveforms are indirect and rely on the equivalence of direct and alternating current (DC and AC) via a thermal transfer device. A consequence of this is that DC and AC are seen as separate quantities and whilst DC measurements have enjoyed a quantum basis for many years, AC measurements have not. Furthermore, AC measurements are based on single frequency waveforms and the thermal transfer methods give no information on harmonic content or phase.

Recent releases from semiconductor and instrumentation manufacturers have included ultra high performance ADC prototypes having resolution up to over 30 bits and high resolution and high update rate synthesisers (16 bit resolution and update rate to over 1 Gsamples/s). These devices and instruments will impact the metrology of AC voltage at the primary level and will require the development of new techniques for their calibration. While their static or quasi-static characterisation is a task that can be performed using existing Josephson standards, the characterisation in the whole range at the maximum level of accuracy is, at the moment, very challenging.

The performance of test instrumentation described in the current BS IEC and IEEE standards [1,2] for converters can be met by commercially available instrumentation at present, but a limit is being reached for the latest generation of devices. Measurement systems based on the Josephson effect, being a quantum standard offer both high accuracy and low noise enabling them to have a specification in advance of the latest devices coming onto the market. This includes new applications for quantum devices in data converters and waveform generation. Novel methods for biasing Josephson junctions, such as the use of optoelectronic devices, need to be explored together with approaches for direct analogue to digital conversion in terms of the Josephson constant $K_J = 2e/h$. Specialised electronic circuits are required to

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interface the sensitive and accurate Josephson devices to the range of voltages and frequencies encountered in precision waveform metrology.

Scientific and Technological 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 JRP-Protocol.

The JRP shall focus on the traceability to the SI volt for analogue to digital and digital to analogue converters operating in the DC to 10 MHz range.

The specific objectives are

1. To realise a measurement system based on the Josephson effect for the dynamic calibration of analogue to digital converters.
2. To establish dissemination methods based on state of the art instrumentation and converters, as used in national measurement institutes and the next tier of users in the calibration and test sectors. This shall include techniques for both repetitive and single shot waveforms.
3. To improve digital signal processing techniques and evaluate their contribution to the measurement uncertainty.

These objectives will require large-scale approaches that are beyond the capabilities of single National Metrology Institutes and Designated Institutes. To enhance the impact of the research work, the involvement of the larger community of metrology R&D resources outside Europe is recommended. A strong industry involvement is expected in order to align the project with their needs and guarantee an efficient knowledge transfer into industry.

Proposers should establish the current state of the art, and explain how their proposed project goes beyond this. Reference should be made to the iMERA-Plus project T4 J03 JOSY.

The total eligible cost of any proposal received for this SRT is expected to be around the 2.7 M€ guideline for proposals in this call. The available budget for integral Research Excellence Grants is 42 months of effort.

Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the “end user” community. This may be through the inclusion of unfunded JRP partners or collaborators, or by including links to industrial/policy advisory committees, standards committees or other bodies. Evidence of support from the “end user” community (eg letters of support) is encouraged.

You should detail how your JRP results are going to:

- feed into the development of urgent documentary standards through appropriate standards bodies
- transfer knowledge to the instrumentation sector,
- the European electrical measurement community.

You should detail other impacts of your proposed JRP as detailed in the document “Guide 4: Writing a Joint Research Project”

You should also detail how your approach to realising the objectives will further the aim of the EMRP to develop a coherent approach at the European level in the field of metrology and includes 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 Member States and countries associated with the Seventh Framework Programme whose metrology programmes are at an early stage of development to be increased
- outside researchers & research organisations other than NMIs and DIs to be involved in the work

Time-scale

The project should be of up to 3 years duration.

Additional information

The references were provided by PRT submitters; proposers should therefore establish the relevance of any references.

[1] BS IEC 60748-4-3:2006, Semiconductor devices - Integrated circuits - Part 4-3 Interface integrated circuits - Dynamic criteria for analogue-digital converters (ADC)

[2] IEEE Standard 1241-2010 (Revision of IEEE Std 1241-2000) IEEE Standard for Terminology and Test Methods for Analog-to-Digital Converters.