

Title: Small electrical current metrology for industrial applications

Abstract

The measurement of small electric currents is crucial in industrial metrology. Major applications include aerosol metrology, photometry, radiometry, and ionising radiation metrology. However, traceable low-current measurement methods are lacking for these applications and practical problems with measurement uncertainties at the point-of-use have not been adequately addressed. Therefore, advanced instrument standards, methods, and collaborative research between metrologists and point-of-use practitioners are needed to ensure accurate calibration for small currents, i.e., microamperes (μA) to femtoamperes (fA), in industrial conditions and in different applications.

Keywords

Electric current, small current, ammeter, calibration, standardisation, ionising radiation metrology, aerosol metrology, particle metrology, photometry, radiometry

Background to the Metrological Challenges

Many measurement activities, such as ionising radiation metrology, photometry, radiometry, and aerosol metrology, use methods that convert the quantity of interest into a small electric current, ranging from μA down to fA . As these applications are linked to human health, industrial efficiency and environmental protection, they are under regulatory control. But advances in legislation demand increasing accuracy in the measurement of small electrical currents.

However, the measurement of such small electrical currents poses practical challenges. Presently, traceable calibrations for small current meters either have insufficient uncertainties (typically around 1 %) or, at the lowest currents, uncertainties are not available at all. For these meters, the uncertainty at the point of use is often dominated by unknown or poorly characterised properties (e.g., linearity). Additionally, the time-structure of pulsed signals is difficult to control, which can lead to additional errors or uncertainties. Methods for robustly evaluating the measurement uncertainty under high-noise, fluctuating-background conditions are also missing.

In order to meet these needs, new portable current references and meters must be developed and existing instruments and methods optimised. These tools must then be applied to calibrations in radiation metrology, photometry, radiometry, and aerosol metrology in both laboratory and industrial conditions, in order to characterise sources of uncertainty. As this work covers such a diverse array of applications, a coordinated approach is required between National Metrology Institutes (NMIs), research institutes and end users working in the different fields of use for small electric currents.

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 traceable measurement and characterisation of small electrical currents from μA to fA for industrial applications.

The specific objectives are

1. To develop and optimise new and existing portable reference current sources and meters for use in industrial calibrations with background offset current stability better than 1 fA (10^{-15} A) per month and

gain stability in the range 1 ppm to 10 ppm per year. In addition, to develop accurate instruments and calibration methods for pA-level pulsed-current meters.

2. To use the instruments and methods developed in Objective 1 to increase the performance of small current measuring instruments in ionising radiation metrology, photometry/radiometry, and aerosol metrology applications. This will be achieved through (a) calibration/validation of measurements performed over a range of currents from fA to μ A, with target uncertainties of 0.001 % in favourable conditions, and (b) determination of the gain and offset stability, and the linearity, of measurement systems under a range of laboratory and industrial conditions.
3. To develop good practise guides and protocols, for the measurement, data processing and uncertainty estimation of small current measurements for both calibration laboratories and industrial environments, including ionising radiation, photometry, radiometry, and aerosol metrology.
4. To facilitate the take up of the technology and measurement infrastructure developed in the project by the measurement supply chain, research organisations (EMN Quantum Technologies, EMN Laboratory Medicine, EMN Pollution Monitoring, EMN Radiation Protection), standards developing organisations (CEN TC 264/WG 32, ISO TC 32/SC4/WG12, ISO/TC 85, BIPM's CCEM-CCRI-TG-LCM), and end users (e.g., environmental, health care and energy sectors).

These objectives will require large-scale approaches that are beyond the capabilities of single National Metrology Institutes and Designated Institutes. Proposers shall give priority to work that meets documented industrial needs and include measures to support transfer into industry by cooperation and by standardisation. An active involvement of industrial stakeholders is expected in order to align the project with their needs – both through project steering boards and participation in the research activities.

Proposers should establish the current state of the art and explain how their proposed project goes beyond this. In particular, proposers should outline the achievements of the EMPIR project 15SIB08 e-SI-Amp, and how their proposal will build on those.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 1.9 M€ and has defined an upper limit of 2.3 M€ for this project.

EURAMET also expects the EU Contribution to the external funded beneficiaries to not exceed 35 % 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,
- Feed into the development of urgent documentary standards through appropriate standards bodies,
- Facilitate improved industrial capability or improved quality of life for European citizens in terms of personal health, protection of the environment and the climate, or energy security,
- Transfer knowledge to the health care, environmental and energy.

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.