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## **SPECIFICATION SHEET**

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**SUPPLY, INSTALLATION AND COMMISSIONING OF A SEMICONDUCTOR PARAMETER ANALYZER SYSTEM FOR OPTOELECTRONIC NEUROMORPHIC DEVICE CHARACTERIZATION FOR A LABORATORY OF THE CATALAN INSTITUT OF PHOTONIC SCIENCES**

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## CLAUSE 1. Object of the contract

The objective of this procurement is the supply, installation, calibration, and commissioning of a semiconductor parameter analyzer system designed for advanced current-voltage (I-V), capacitance-voltage (C-V), and ultra-fast pulsed current-voltage (pulsed I-V) characterization. The system shall support testing and development of optoelectronic neuromorphic devices such as photonic synapses, memristors, and electro-optical threshold switches. The system must be modular and expandable, with clear provisions for adding future instrumentation.

Applicable Common Procurement Vocabulary (CPV) code: **38300000-8 – Measuring instruments**.

This procurement follows best practices for EU-funded public tenders, ensuring open competition, transparency, equal treatment, and technological neutrality per Directive 2014/24/EU on public procurement.

## CLAUSE 2. Needs to satisfy

The analyzer will enable the operando study of neuromorphic devices. It must:

- Perform quasi-static and dynamic electrical tests.
- Resolve sub-picoampere signals.
- Deliver nanosecond-resolved pulsed excitations.
- Execute capacitance measurements over a broad frequency spectrum.
- Support upgradeability with spare rack slots and modular architecture.

All components must be Conformité Européenne (CE) marked, and compliant with:

- International Electrotechnical Commission (IEC) 61010-1 – Safety requirements for electrical equipment
- IEC 61326-1 – Electromagnetic compatibility requirements
- Restriction of Hazardous Substances (RoHS) Directive 2011/65/EU
- International Organization for Standardization (ISO) 17025 – Calibration and testing laboratory competence

## CLAUSE 3. Technical requirements

The system must consist of a modular architecture comprising:

- **Mainframe chassis:**
  - Support for at least 9 instrument slots
  - Integrated ground unit supporting up to 2.6 A (triaxial) and 9.5 A (binding posts)
  - USB, Ethernet, GPIB, HDMI, and DisplayPort connectivity
  - Touchscreen interface (≥15.6" FHD) and solid-state internal storage
- **Source Measure Units (SMUs):**
  - Voltage range: ±210 V, 4-quadrant operation
  - Current range: 10 aA to ±1 A
  - Measurement resolution: 10 aA with preamplifier
  - Accuracy: 0.035% to 0.1% depending on range (e.g., ±1 pA ±0.05% at 1 nA range)
  - Low noise input: <100 fA on 1 μA range
  - Load capacitance: up to 100 μF for high-current operation

- Real-time source and measure operation with auto-ranging and compliance limits
- **Capacitance-Voltage Unit (CVU):**
  - Frequency range: 1 kHz to 10 MHz
  - AC drive: 10 mV to 1 V RMS, 1 mV resolution
  - DC bias:  $\pm 30$  V internal, up to  $\pm 210$  V with SMU bias tee integration
  - Accuracy: down to 0.1% for 1 nF at 100 kHz
  - Parameter support: Cp-G, Cp-D, Cs-Rs, C-t, C-f, impedance (Z), admittance (Y)
  - Open/short/load compensation and confidence check diagnostics
- **Pulse Measure Unit (PMU):**
  - Voltage:  $\pm 40$  V (80 Vp-p)
  - Current: up to  $\pm 800$  mA
  - Pulse width: 10 ns to 40 s, programmable in 10 ns steps
  - Waveform memory:  $\geq 2048$  segments
  - Accuracy:  $\pm(0.25\% + 100 \mu\text{A})$  for 10 mA range
  - Internal 14-bit digitizer for simultaneous voltage and current capture
  - Transient waveform acquisition: up to 1 MSa/channel at 200 MS/s
- **Remote Preamplifier and Switch Module (RPM):**
  - Extends PMU sensitivity down to tens of pA
  - Integrated switching between I-V, C-V, and pulsed I-V modes
  - Noise floor:  $<200$  pA on 1  $\mu\text{A}$  range,  $<1$  pA with extended integration
  - Timing alignment with system clock: skew  $<2$  ns
- **Analog-to-Digital (A/D) Conversion System:**
  - 14-bit resolution for pulsed channels, 16-bit for precision DC channels
  - Sample rate: 200 MS/s (pulsed), 1 S/s to 10 kS/s (DC logging)
  - Memory depth:  $\geq 1$  million points per channel
  - Oscilloscope-free preview of waveform segments
- **Software platform:**
  - GUI with real-time visualization and batch operation support
  - Pre-configured test libraries: I-V sweeps, C-V profiling, NBTI/PBTI stress
  - Python, SCPI scripting, waveform export and log capture
  - Trigger configuration for test synchronization and custom sequencing
  - Software to run the system and perform data analysis shall be provided with a lifetime license, including critical updates.
- **Parallel measurement and expandability:**
  - True simultaneous measurement across all installed modules
  - Independent channel control with no recabling
  - Up to 9 SMUs or combination of SMU/PMU/CVU/RPM

#### CLAUSE 4. Power distributions and safety

- Operation: 230V  $\pm 10\%$ , 50 Hz (per **UNE-EN 61010-1**, Spanish adoption of IEC 61010-1)
- CE-certified power integration with overvoltage protection
- Electrostatic Discharge (**ESD**) protected ports
- Automatic shutdown and restart safety protocol

#### CLAUSE 5. System layout and services

The proposal shall include:

- Fully annotated system diagrams
- 3D mechanical footprint drawings for lab integration
- Environmental specifications: operating range 10–40°C, 5–80% Relative Humidity (**RH**)
- Provisions for future module additions

## CLAUSE 6. Transportation, installation, start-up and training

- Terms: Delivered at Place (**DAP**) to ICFO, Castelldefels, Spain
- Full delivery with insurance and customs clearance
- On-site installation and system calibration traceable to ISO 17025, or equivalent.
- **Minimum two-day training**, covering:
  - Equipment setup and configuration
  - I-V, C-V, and pulsed I-V measurement operation
  - Software usage and data export
  - Preventive maintenance and diagnostics

## CLAUSE 7. Acceptance test

Acceptance shall be conducted onsite post-installation and shall include comprehensive benchmarking using certified reference devices and standard test methodologies compliant with **ISO 17025 or equivalent, JEDEC JESD22-A104 or equivalent, and IEC 60747-1 or equivalent.** The full test report must be signed off by both the vendor and ICFO.

### A. I-V Characterization (SMU modules)

- **Test devices** (at least):
  - High-purity silicon PN junction diode such as **1N4148** or equivalent, with documented datasheet characteristics (forward threshold voltage  $\sim 0.7$  V, reverse leakage  $< 25$  nA @  $-20$  V)
  - Certified  $100\text{ M}\Omega \pm 0.01\%$  high-precision resistor with low temperature coefficient ( $\leq 10$  ppm/ $^{\circ}\text{C}$ )
- **Procedure:**
  - Perform forward and reverse I-V sweeps from  $\pm 10$  mV to  $\pm 10$  V in logarithmic and linear steps
  - Record current resolution limits and symmetry of response
- **Acceptance criteria:**
  - Deviation from known diode characteristics  $< 0.05$  V at 1 mA forward current
  - Leakage current match within 5% of datasheet limits in reverse bias
  - Resistor test: measured current at  $\pm 10$  V within 0.01% of theoretical (100 nA)
  - Open-circuit noise (no DUT):  $< 100$  fA RMS over 1 s integration at 0 V bias
  - Measurement repeatability: coefficient of variation  $< 0.2\%$  over 10 cycles

### B. Pulsed I-V Performance (PMU modules)

- **Test devices** (at least): Fast recovery diode (e.g., 1N4937) and memristor emulator circuit with known dynamic resistance profile
- **Procedure:**
  - Generate single and burst-mode pulses from 10 ns to 1  $\mu$ s width
  - Evaluate waveform integrity and reproducibility at 10 Hz – 1 MHz repetition
- **Acceptance criteria:**
  - Rise/fall time  $< 15$  ns, pulse duration jitter  $< 200$  ps
  - Peak amplitude variation  $< 2\%$  over 20 iterations
  - Baseline return to within 1% of zero level between pulses

### C. C-V Measurement (CVU module)

- **Test devices:** NIST-traceable capacitors (100 pF, 1 nF, 10 nF, all  $\pm 0.05\%$  tolerance)
- **Procedure:**
  - Sweep frequency from 1 kHz to 10 MHz using fixed AC voltage (100 mV RMS)
  - Repeat tests under 0 V and  $\pm 30$  V DC bias
- **Acceptance criteria:**
  - Measurement accuracy within  $\pm 0.1\%$  of nominal values
  - Frequency response linearity error  $< 0.05\%$  over 2 decades
  - Repeatability: standard deviation  $< 0.2\%$  across 10 repeated measurements per device

### D. Combined-mode Validation (RPM switching)

- **Test sequence:**
  - Execute SMU, CVU, and PMU measurements sequentially through RPM module with automatic switching
- **Acceptance criteria:**
  - Mode switching time  $< 50 \mu\text{s}$
  - No signal loss or accuracy degradation during or after switching
  - Repeat of full cycle three times: measurement variation within  $\pm 0.5\%$  max spread

### E. A/D Converter Performance

- **Procedure:**
  - Apply a precision triangle waveform (e.g., 0–2 V, 100 Hz) from external calibrator
  - Digitally sample waveform at full resolution over one full cycle
- **Acceptance criteria:**
  - Integral non-linearity  $< 0.05\%$  full scale (FS)
  - Differential non-linearity  $< 0.02\%$  FS
  - No data loss or dropout during 200 MS/s acquisition

### F. System-wide Stability and Drift Test

- **Procedure:**
  - Conduct I-V and C-V tests repeatedly for 6 hours at room temperature ( $23 \pm 2^\circ\text{C}$ )
  - Use same test setup (resistor and capacitor)
- **Acceptance criteria:**
  - Drift of critical values (e.g., forward voltage, capacitance peak)  $< 0.1\%$
  - Signal-to-noise ratio (SNR) variation  $\leq \pm 3$  dB
  - Open-circuit baseline current and voltage must not deviate beyond 0.02% of range

All acceptance results must be delivered in both digital and printed form, with graphs, tabulated metrics, traceability records, and device identifiers clearly labeled. A final validation checklist shall summarize each module's conformance and repeatability.

Test results and calibration certificates must be archived under ISO 9001, or equivalent, quality procedures.

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## CLAUSE 8. Warranty and Follow-on Support

- Two-year warranty compliant
- Includes initial and end-of-warranty ISO 17025, or equivalent, re-calibration
- Service support:
  - Remote diagnosis  $\leq 48$  h
  - On-site intervention  $\leq 10$  business days
  - 10-year spare part availability
- The technical service team must be based in Europe and ideally in Spain.

## CLAUSE 9. Delivery and Installation Time

- Delivery: DAP (Castelldefels, Spain), including insurance and customs
- Includes shipment, customs, calibration, installation, and initial training
- Installation: Functional verification and ISO 17025, or equivalent, calibration
- Training: At least 2 days on-site
  - Day 1: hardware setup, safety, I-V/C-V operation
  - Day 2: advanced pulse scripting, data logging, maintenance
- Acceptance report signed by vendor and end-user upon completion

Castelldefels, on the date of its digital signature

Prof. Dr. F. Pelayo García de Arquer  
GL CO2MAP