A new device for cryogenic temperature measurements

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Introduction

- Rising of the number of thermometry channels in large installations
- Needs devices easily integrated in automated installations without fieldbus gateway
- Severe environmental constraints in industrial applications in terms of distance between sensor and instrumentation and electromagnetic perturbations
- Systems such as pulse tube cryo-cooler generate fast temperature variations. It can be useful to observe or regulate these variations for example

Objectives

- Fast acquisition to have a bandwidth in the same order of magnitude as best sensors’ thermal response time (CernoxTm from Lakeshore and CCS from Temati)
- Reliable and accurate measurements for cryogenic applications
- Electromagnetic immunity as far as possible for industrial environments
- Communication with PLC through fieldbus

Measuring principle

- 8 independent channels sampled simultaneously for resistive sensors up to 100Ω. 4 lead connections
- Synchronous detection to minimize electronic noise in industrial environments and to remove thermal EMF offsets
- Current or voltage excitation depending on the resistance value to avoid self-heating offsets
- Bandwidth up to 100Hz. Can be reduced according to needs
- Madapt functionality

<table>
<thead>
<tr>
<th>Madapt</th>
<th>LVL 1</th>
<th>LVL 2</th>
<th>LVL 6</th>
<th>LVL 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fmioz (Hz)</td>
<td>500</td>
<td>500</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Bandwidth (Hz)</td>
<td>100</td>
<td>10</td>
<td>1.7</td>
<td>0.5</td>
</tr>
<tr>
<td>Measurements</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

- Excitation power 25mW for R=400Ω

Functionalities

- Local storage for fast acquisitions. About 60000 points for each channel (resistance and temperature)
- Local temperature conversion based on Chebyshev polynomials (Lakeshore compatible), table of R-T points, Temati files...
- Profinet IO and Modbus TCP available for process automatisation. Temperature and resistance can be communicated with PLC without additional analog gateway
- Metallic case for EMC reinforcements:
  - Criterias A reached for IEC 61000-4-4 lv4 - 2kV on signal lines (Fast transient Immunity)
- Diagnostic tool available in option to evaluate CABTR calibration and detect failures. It produces the results in the form of a report.
- Windows software provided to configure and monitor data. Communication through Ethernet
- Web server available for easy configuration through Ethernet with just a web browser
- External trigger input to control acquisition

Performance

- Example of electronic accuracy (equivalent temperature using Lakeshore’s sensors given with typical values for sensitivity):

<table>
<thead>
<tr>
<th>Lakeshore Sensors (example)</th>
<th>Resistance (Ω)</th>
<th>Sensitivity (Ω/K)</th>
<th>Temperature (K)</th>
<th>Equivalent accuracy (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CX-1030</td>
<td>574.2</td>
<td>0.0124</td>
<td>4.2</td>
<td>±0.026</td>
</tr>
<tr>
<td>CX-1050</td>
<td>3597.2</td>
<td>-1120.6</td>
<td>4.2</td>
<td>±0.13</td>
</tr>
<tr>
<td>CX-1070</td>
<td>5879.4</td>
<td>-2202.5</td>
<td>4.2</td>
<td>±0.13</td>
</tr>
</tbody>
</table>

- Measurements have been done with 300m cable length and a 1kΩ resistance:
  - With Madapt Lvl7 precision has reached 0.001%. Equivalent temperature noise stays below 50µK (with CX-1050 or CCS with Tp ≤ 500 mK).
  - Accuracy is better than 0.05% with Madapt Lvl7. Parasitic capacitance of cable can affected measurement when fast measurement mode is active. (Madapt < Lvl8)
- CABTR will be used for ITER Magnets

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