FlexCryo : a new flexible solution for temperature control and measurement down to 50 mK

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Context

- Lot of instrumentations for each experiment (difficulties to manage communications and synchronize data)
- Needs devices easily integrated to avoid multiple interconnections
- Severe environmental constraints in industrial application
- Systems such as pulse tube cryocoolers generate fast temperature variations. It can be useful to observe these variations, or regulate these for example

FlexCryo objectives

- Flexibility, reliability, reconfigurability according to the needs of the experiment
- Accurate measurements for cryogenic applications
- Electromagnetic immunity as far as possible due to low level measurements
- Communication with PC (Labview for example) or PLC (Siemens, Schneider…)
- Possibility to implement automated cycle not depending on an external PC

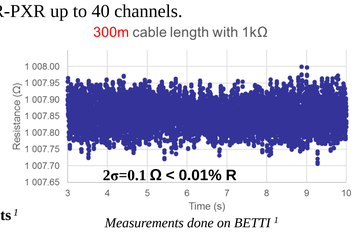
CABTR

- 8 independent channels sampled simultaneously for resistive sensors up to 100 kΩ. 4 leads 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
- Excitation power ≤25 nW for R>400 Ω

CABTR-PA
8 Channels

- Can be integrated into the FlexCryo (16 channels max) or used alone. In this case, two housings are available. CABTR-PA for 8 channels, or CABTR-PXR up to 40 channels.

CABTR-PXR
Up to 40 channels
Used for **ITER Magnets** [1]



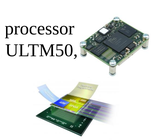
Measurements done on BETTI [1]

Lakeshore Sensors (example)	Resistance (Ω)	Sensitivity (Ω/K)	Temperature (K)	Equivalent accuracy T° (mK)
CX-1030	574.2	-97.344	4.2	±0.6
CX-1050	3507.2	-1120.8	4.2	±0.3
CX-1070	5979.4	-2225.3	4.2	±0.3

CABTR
Service des basses Températures

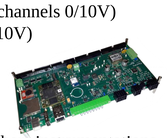
FlexCPU

- Processor card with an embedded FPGA and ARM processor
- Used to acquire and process all data from CABTR, ULTM50, MCSubK…



- Available :
  - ✓ 4 analog inputs (2 channels 4/20 mA and 2 channels 0/10V)
  - ✓ 2 analog outputs (2 channels 4/20 mA or 0/10V)
  - ✓ 8 digital inputs
  - ✓ 8 digital outputs

FlexCPU

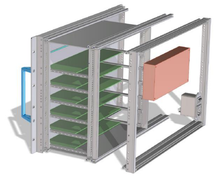


- Analog and digital I/O can be used to control others instrumentations.

FlexCryo information : flexcryo@cea.fr
CABTR information : cabtr-info@cea.fr
CABTR Website : http://cabtr.cea.fr

FlexCryo

- 19'' Metallic case for an easy integration into an electronic cabinet and for EMC reinforcements
- 5 slots available + 1 dedicated for the FlexCPU card
- Local touchscreen
- Windows software provided to configure and monitor data. Communication through Ethernet



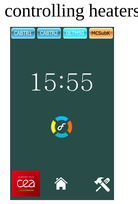
- Modbus TCP Fieldbus available to communicate with PLC, Labview…

- WIFI and Bluetooth communication soon available
- No predefined configuration. Configuration possible:

Card	Description	Nb max of cards	Channel max possible
ULTM50	0.05 K to 300 K	2	8
CABTR	>1K	2	16
MCSubK	Heaters subK	2	20

- **Embedded processor offers the possibility to implement any algorithm to control a CryoCooler cycle for example**

- The Windows application FlexCC is self adaptive depending on the hardware configuration
- FlexCC allows controlling heaters from any temperature, tune PID, make measurements and monitor data.

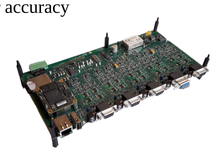


Local Display on FlexCryo

Windows application with data logger

MCSubK

- 10 heaters – 4 wires configuration for better accuracy
- Dedicated for sub Kelvin applications
- 2 ranges : 2 mA and 50 mA (up to 1W max)

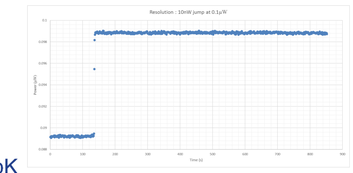


MCSubK
Exists also in standalone packaging

- Able to reach very low power better than the µW with a high resolution
  → Useful for thermal switch for example
- PID implemented for each channel, cycle at 100 ms

	40 mW (10 kΩ)	0.5 W (10 kΩ)
Mesured power stability	0.005%	0.04%

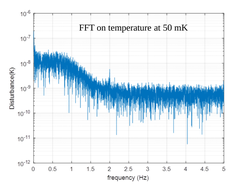
MCSubK



ULTM50

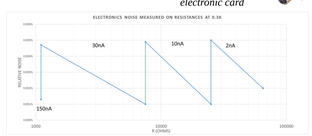
- 4 independent channels sampled simultaneously for resistive sensors up to 100 kΩ. 4 leads connections
- Current excitation with 4 ranges : 2 nA, 10 nA, 30 nA, 150 nA
- Synchronous detection to minimize 1/f electronic noise (e.g Flicker noise)
- Bandwidth up to 6 Hz with a data rate at 20 Hz
- Designed for sub kelvin applications down to 50 mK and "space compatible" (SPICA/SAFARI[3] and X-IFU)

Experiment results [2]
Sensor type GR-200A-30
dR/dT at 50 mK= 5.2 MΩ/K
Temperature : 50 mK
ΔF=1 Hz
data rate : 200 ms



ULTM50
Service des basses Températures

ULTM50
electronic card



→ **Stability : 0.37 µK rms** (k=1)

Example of FlexCryo application: Athena X-IFU project

- The FlexCryo will be used for the X-IFU cooler, for ground qualification
- In addition, for temperature more than 1 K, CABTR-PXR will be used

IFU
ATHENA X-ray Integral Field Unit

References [1]: J.-M. Poncet, J. Manzagol, A. Attard, "Design, Test, and Validation of Thermometric Chains for ITER Magnets", *IEEE Transactions on Applied Superconductivity (2016)*
[2] J.M Duval, A. Attard "Experimental results of ADR cooling tuned for operation at 50 mK or higher temperature*", submitted to Advances in cryogenic engineering 2019*
[3] J.M Duval, L Duband and A Attard « Qualification campaign of the 50 mK hybrid sorption-ADR cooler for SPICA/SAFARI", 2015 *IOP Conf. Ser.: Mater. Sci. Eng.* **101** 012010

ACKNOWLEDGEMENTS
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