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Deep-Sea Temperature Sensor. In-Situ Readings from ROV

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In-situ display temperature sensor PINT
(disPlay of IN-situ Temperature)

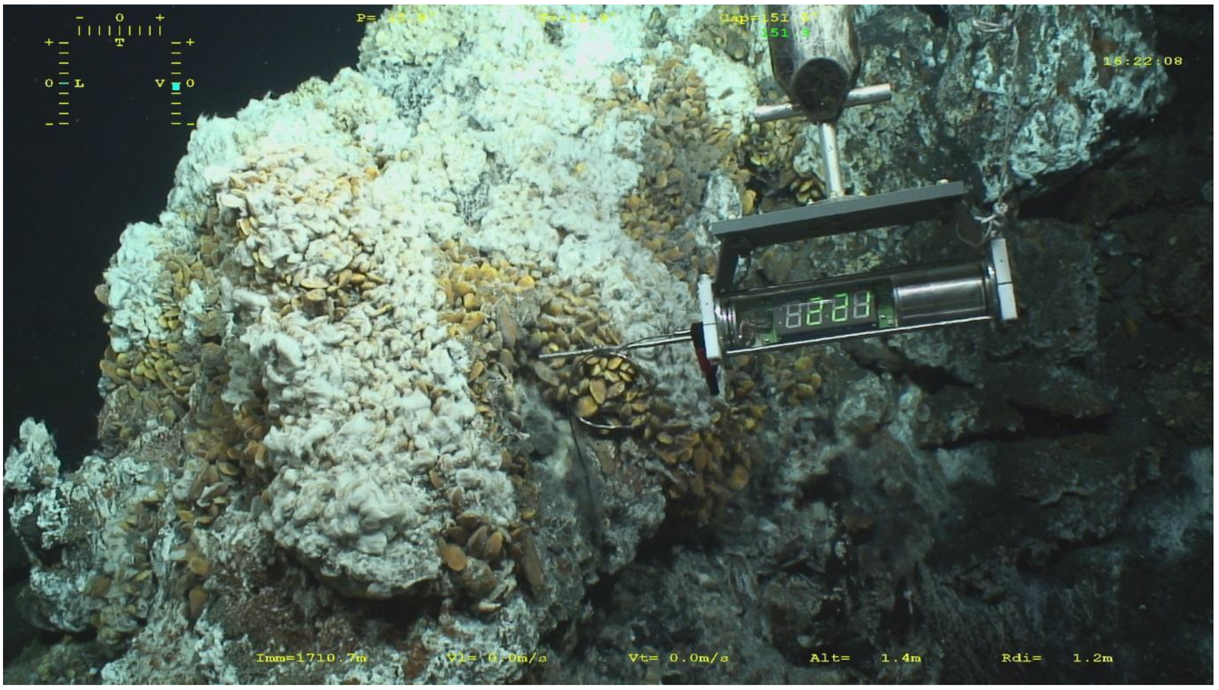

Figure 1 : PINT measuring during the 2018 Momarasat campaign

Context

One of the most recurrent questions that scientists from the French Institute for Exploration of the Sea (IFREMER) ask, is that when sampling fluids from deep sea hydrothermal sources, how can they be sure of obtaining an accurate fluid temperature reading at the cannula's end when the sampler is triggered.

Currently there are temperature probes directly connected to the ROV (Remote Operated Vehicle), but to position them correctly they must be clamped onto the cannula. This works if the sampler is left in the ROV arm throughout the dive. However, if numerous samplings are programmed, each sampler will have to be stored incrementally.

It is possible to unplug the filled sampler cable from the ROV and to connect another one. But it makes the handling complicated and requires a costly wet-mate connector.

A solution could be by using an optical or infrared connection. However, when the water is turbid or if the cannula is in the hydrothermal source moire, the communication could be lost.

Until now, the common technique consists in pinpointing the targeted temperature in the plume with the ROV's probe, estimating its situation, exchanging the probe for the sampler and positioning its cannula at the targeted location to take the sample. Unfortunately, as the plume moves and the temperature gradient changes quickly, it is hard to be sure to sample accurately.
To address these issues, the Ifremer R&D department has worked to design a system that meets user requirements.

In order to be able to fill several samplers in the course of a single dive, the R&D team decided to associate a temperature sensor to each sampler.

As the precision and reactivity of the PT100 probe currently used on Ifremer's subsea vectors (HOV Nautile, ROV Victor 6000, HROV Ariane) have been proven, it was decided to adopt this sensor.

The main parts of the work concerned the probe's signal processing and the transmission of the temperature signal to the user.

Concerning the communication between the sensor and the user, the R&D team chose a real-time display protected by a transparent tubular housing, with the temperature displayed directly on a screen fixed to the sampler, showing the temperature at the end of the probe which corresponds to the tip of the cannula. This resolves the cable issue between the sensor and the ROV.

In order to display the information even in poor visibility zones, the screen is wide (12 cm x 4 cm) and away from the probe via a 800 mm flexible stainless steel sleeve. This enables the display to be read through the Nautile porthole, or by using a ROV camera.

Housing

As the system could be deployed up to a maximum depth of 6,000 meters, the hydrostatic pressure forces must be evenly distributed. This is why the electronic board and the display are mounted within a tube, closed off with two cylindrical endcaps.

The screen must be visible from the outside, so the tube must be transparent. The use of glass, which has good mechanical characteristics, was not an option because it is not safe to use in a manned submersible. In case of rupture, fragmented glass could cause damage to the vehicle and personnel. To replace glass we used an equivalent transparent plastic tube which required a far thicker wall because of the poor mechanical resistance of plastic.

To stabilize the pressure, it is possible to fill the tube with dielectric oil, which still allows the electronics to function normally even under high hydrostatic pressure.

This solution, while appealing, needs an additional membrane to balance the variation of the volume of oil, depending on temperature and pressure. This membrane requires space, which is not compatible with the equipment compactness specifications. Moreover, the batteries produce heat that could modify the volume of oil.

We opted to fill the tube with a transparent epoxy resin. However, over-moulded batteries, which could dilate, are impossible to replace in case of failure.

Therefore, the design team chose the solution to over-mould one side of a transparent PMMA tube, including the endcap, the acquisition system and the screen, and to position the batteries inside a pressure resistant cylindrical aluminium shell, placed inside the non-moulded side of the tube. This side is closed off by a removable endcap, allowing access for battery replacement.
The whole sensor is compact and protected by three rods, which close off the endcaps.

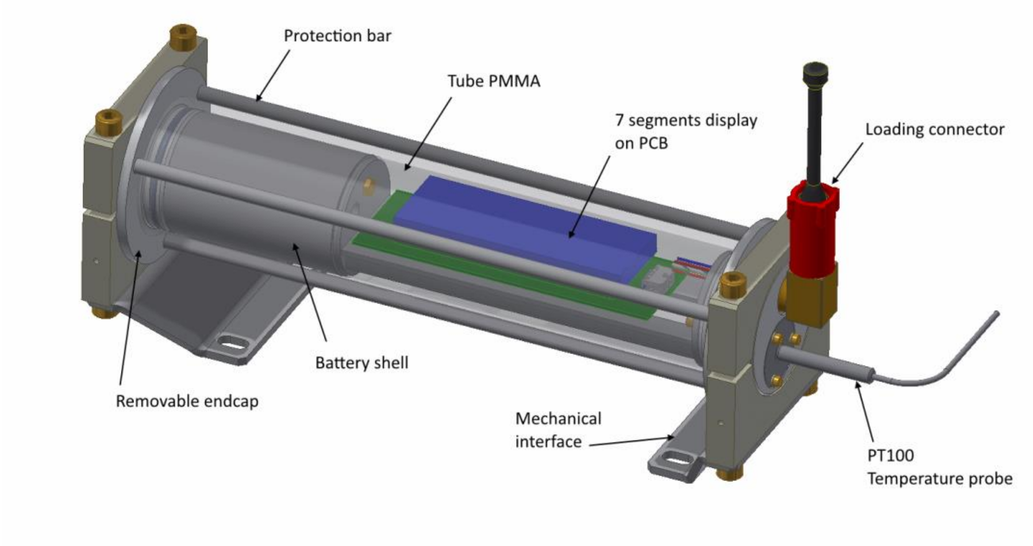

Figure 2 : Mechanical architecture – Ø 100 mm / Length 370 mm

Electronics

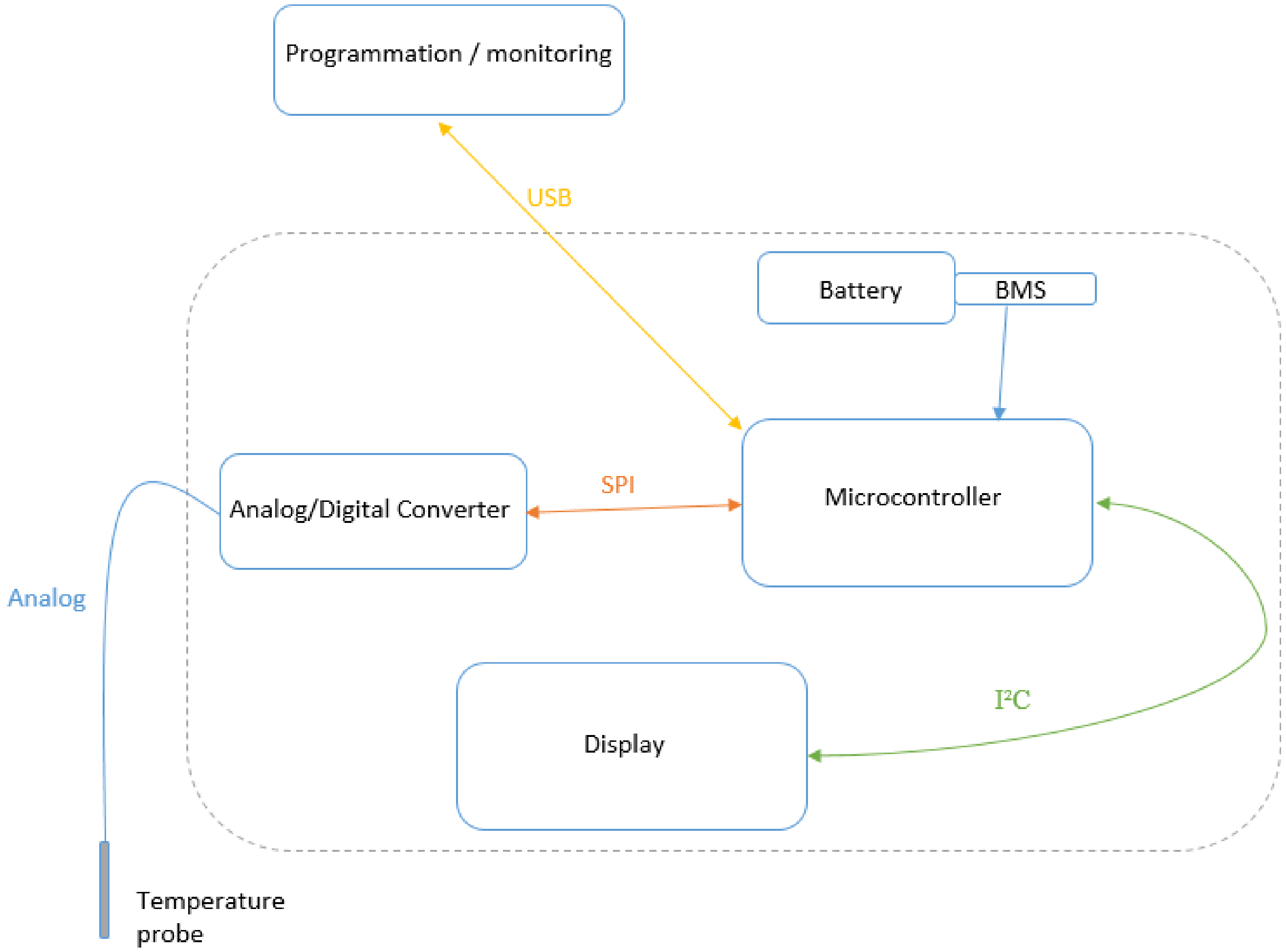

Figure 3: Electronic Architecture

The electronic architecture is built around the temperature sensor, which is the sensitive part. An RTD (Resistivity Temperature Detector) or PT100, made of platinum, was chosen thanks to its large temperature range, high precision, and linear characteristic curve.

An amplifier coupled to a PT100 is essential to step up the signal from the temperature probe. The ADC MAX 31865 was chosen as the best amplifier to automatically adjust and compensate for the resistance of the connective wires.

A compact microcontroller chip was used to provide the embedded intelligence of the system. The advantage of the Arduino Nano deck is the numerous libraries and open source drivers available built around a reliable microcontroller.

The real-time signal is displayed on an Adafuit 4 digits 7 segment display. It can communicate with the microcontroller via an I²C bus. The controller chip controls the multiplexing of all LEDs. The design team chose a green light display, for better visibility in the deep sea.
To preserve compactness, the functional blocks are welded onto a circuit board interface, integrating a power surge conditioner and inverter protector.

Sampler equipment is generally designed to work on ROVs or HOVs for between 12 and 72 hours. The energy pack must present an excellent weight/footprint/power ratio. This is indeed the case with lithium-ion technology. The Panasonic battery offers in addition a smart driver, preventing deep discharges.

Certification and tests

In order to meet IFREMER's quality requirements and to validate the sensor's pressure resistance before its first deployment, the sensor undergoes a certification test in a hyperbaric chamber.
This certification corresponds to the NF X10-812 standard and is composed of an 8-hour proof pressure test (750 bars at 4°C), then 10 cycles from 1 bar to service pressure (625 bars, in this case).

The PINT sensor (disPlay of IN situ Temperature) passed the certification tests and has been deployed twice; the first time in a stand-alone operational mode during an oceanographic campaign, in the Atlantic Ocean, on hydrothermal sources at 1,700 meters deep. During this campaign, VICTOR 6000 ROV positioned PINT at several locations, in and out of the hydrothermal plume, validating the sensor and display reactivity in a quick temperature gradient.
The second campaign, PINT was associated with the sampler IBIS (IsoBaric Isothermal fluid Sampler) during a test mission in the Mediterranean Sea, with the HOV NAUTILE at 2,500 meters.

Conclusion

Two PINTs are currently in use and will promote the precision of sampling used by stand-alone equipment.

An upgrade of the PINT is scheduled for 2020 in order to miniaturize and add on a data logger.

Acknowledgments

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References

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Biographies

Jean-Romain Lagadec is a mechanical engineer at Ifremer's engineering and marine instrumentation service. He is responsible for the PINT mechanical design in the DEEPECOS project, and has also developed two deep-sea sampling systems, for fluids and fauna. His is also involved in various seafloor observatory projects.

Sébastien Prigent is an electronics engineer at Ifremer's engineering and marine instrumentation service. He is in charge of the PINT electronic architecture. His work includes developments for operational oceanography, in both coastal and seafloor fields.

Jean-Pierre Lafontaine is a development and assembly technician in the engineering and marine instrumentation team. He is a major contributor to the mechanical design phase in the DEEPECOS project, which includes the implementation monitoring and the assembly of PINT and of an additional fauna sampler. His work also includes precision machining and oceanographic systems deployment.