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METEO-P/H: Measuring ambient pressure and relative humidity on the ExoMars 2020 landing site

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Abstract

Finnish Meteorological Institute (FMI) has designed and is in the process of building and testing a pressure and humidity measurement device for the ExoMars 2020 lander. The ExoMars 2020 mission consists of the Russian Roscosmos Surface Platform (SP) and the European Space Agency (ESA) Rover. The Surface Platform will perform the Entry, Descent and Landing for the lander combo and start stationary science operations after landing, while the Rover will drive off the SP to explore the landing site surroundings and soil.[1] The FMI measurement device is installed on the Surface Platform to give continuous measurements from a stationary location. The METEO-P pressure device and METEO-H humidity device are part of the METEO meteorological science package, which also includes a thermometer and an anemometer from IKI, Russia, as well as the RDM Radiation and dust sensors, and the AMR magnetic field sensors from INTA, Spain.

1. Introduction

Finnish Meteorological Institute has an extensive history in providing pressure and humidity measurement devices for Mars landers. FMI's pressure device development started for the Russian led Mars 96 mission, which failed during launch. After Mars 96 FMI has provided a pressure measurement device for most of the successful and unsuccessful Mars surface missions: Mars Polar Lander, Beagle-2, Mars Phoenix, Curiosity and ExoMars 2016 Schiaparelli. FMI's humidity devices were also flown on Curiosity and Schiaparelli. Curiosity's pressure and humidity measurement device continues to provide science observations to this day.

2. METEO-P pressure device

The METEO-P pressure device is based on capacitive Barocap® pressure sensors by Vaisala Inc., Finland. Vaisala originally developed the micromachined silicon sensors for weather balloons. The Barocap® sensors for Mars landers are further optimized for the Martian surface 4-12 hPa pressure range.

METEO-P consists of two pressure transducers each containing 8 measurement channels. Each transducer contains 2-3 Barocap® pressure sensors, 2 capacitive Thermocap® temperature sensors and 3-4 constant reference channels.

During pressure measurement, frequency signals are read from the capacitive transducer sensor and constant channels. The actual calibrated pressure readings are obtained through data analysis on ground.

The pressure device is installed inside the ExoMars SP warm compartment and has access to the outside ambient pressure through a dedicated tube. METEO-P connects to the METEO Central Electronics Unit and METEO-H through connectors mounted on the METEO-P circuit board. The METEO CEU acts as the higher level controlling computer for all METEO devices.

METEO-P specifications:

- Approximate mass 100 g
- Accuracy: ± 20 Pa from 1-400 Pa and ± 10 Pa from 400-1200 Pa
- Resolution: ≤ 0.5 Pa
- Operational temperature range: -45°C to +55°C
- Response time:≤ 1 s

3. METEO-H humidity device

The METEO-H humidity device is built around the capacitive Vaisala Humicap®sensor technology. A similar measurement circuit is used as with the Barocaps®.

METEO-H has a single humidity transducer with 2 Humicap®sensors, 2 capacitive Thermocap® temperature sensors and 4 constant reference channels. Humidity readings are obtained through on ground data analysis from the transducer capacitive channel frequencies.

As the Humicaps® are substantially sensitive to temperature change, there is a resistive PT1000 temperature sensor integrated on each of the sensors for calibration purposes. The PT1000s are measured by the measurement controller. Also, a heating resistor is integrated on each of the Humicap® chips for regenerating the sensor from chemical contaminants or frost.

The METEO-H device is attached, along with other meteorological devices, on the deployable mast outside the ExoMars Surface Platform. There is a connector mounted on the METEO-H mechanics that is used to interface the METEO-H through cabling to the measurement controller integrated on the METEO-P board.

METEO-H specifications:

- Approximate mass 45 g
- Measurement range: 0-100% RH in temperatures from -83°C to -3°C
- Accuracy: $\pm$10%RH in temperatures greater than -70°C, and $\pm$20%RH in -83°C to -70°C
- Resolution: $\leq$ 1% over a Mars temperature range of -83°C to -3°C
- Operational temperature range: -128°C to +50°C (calibration down to -80°C only)
- Response time:$\leq$ 30 min for temperatures above -70°C

4. Measurement controller

The METEO-P/H measurement controller is integrated on the METEO-P printed circuit board. The controller is based on a commercial automotive microcontroller unit (MCU), the Freescale MC9S12XEP100, that was custom qualified[2] for use on Mars lander missions. The measurement controller derives most of its design from the DREAMS-P/H pressure and humidity measurement controller that flew on the ExoMars 2016 Schiaparelli lander, which was destroyed during a failed landing. Earlier FMI Mars devices were controlled by space grade Field Programmable Gate Array (FPGA) chips. The approach of using a commercial MCU enabled more autonomy for the controller and leaner development process.

The METEO-P/H controller communicates with the METEO Central Electonics Unit (CEU) through a RS-422 serial interface to receive telecommands and transmit scientific and status telemetry. The controller distributes power to the two pressure transducers on METEO-P and the single humidity transducer on METEO-H using switches on the METEO-P board. Also, METEO-H humidity sensors are regenerated by power delivered through a switch driven with Pulse Width Modulation (PWM) signal.

A PT1000 measurement circuit for measuring the METEO-H humidity sensor temperature is implemented using operational amplifiers and the MCU internal ADC module.

5. Summary and Conclusions

METEO-P/H continues the in-situ studies of Martian atmospheric pressure and humidity. Continuous data sets of these parameters are of great importance in Martian atmospheric science. The measurement device utilizes well-established technology from past missions, while improving the design based on lessons learned.

In parallel with the ExoMars 2020 METEO-P/H project, FMI is building another pressure and humidity measurement device for the NASA Mars 2020 rover. Both of these missions are scheduled to launch towards Mars during the 2020 launch window. If both missions are successful, this opens up interesting science possibilities as two FMI pressure and humidity device sets would for the first time measure simultaneously on the surface of Mars in a meteorological mini-network. Even a third observation point would be added if the NASA Curiosity rover is still operational at the time of ESA's ExoMars 2020 and NASA's Mars 2020 landings.

References

[1] ESA website ExoMars mission (2020)

[2] T. Nikkanen (1,2), W. Schmidt (1), A.-M. Harri (1), M. Genzer (1), M. Hieta (1,2), H. Haukka (1) and O. Kemppinen: Space qualification of an automotive microcontroller for the DREAMS-P/H pressure and humidity instrument on board the ExoMars 2016 Schiaparelli lander. European Planetary Science Congress 2015. EPSC Abstracts, Vol. 10, EPSC2015-465.