

The hidden challenges faced in room sensor design

Room sensors are an integral yet often underappreciated part of HVAC systems. Few people know how much planning and work goes into creating a device that can measure the correct temperature – down to tenths of a degree – for different external conditions. Dr. Sebastian Eberle, Head of Development Environmental Sensing Technology and Yoram Mottas, Systems Engineer for Sensor Development at Belimo talk about the challenges faced in this application, and how the company uses innovative solutions to address these issues to deliver fast and accurate room sensors.

Demanding working conditions

Humans only feel comfortable in a narrow environmental window. It cannot be too hot or too cold – incredibly, many people can distinguish ± 0.5 °C changes in temperature – and the relative humidity must be just right (Figure 1). This puts a lot of pressure on HVAC systems and, with most high performance sensor elements offering a precision of ± 0.2 °C, this leaves just a ± 0.3 °C error margin for designing a room sensor device that can meet the comfort requirements and comply with industry standards.

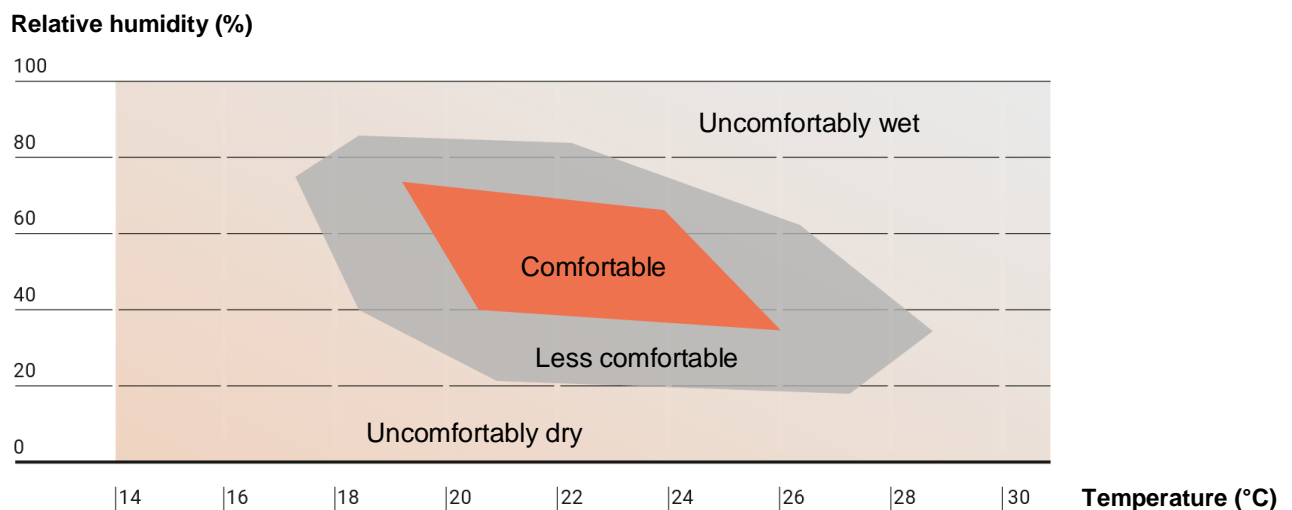


Figure 1: The temperature and humidity window that humans feel comfortable in. (Illustration by Prof. Dr.-Ing. Wolfram Frank, Chair of Fluid Mechanics and Professor Emeritus at the Faculty of Natural Sciences and Technology, Siegen University, Germany)

Measuring the temperature with such accuracy is hard on its own, but is further complicated by external factors that can affect the temperature readings, such as air flow, humidity, heat sources and voltage variations across the world. In addition, the measured value needs to represent the temperature of the middle

of a room, while the sensor is mounted on a wall. This introduces further complications as the manufacturers of the sensor have little control over how it is installed, meaning the device needs to be designed in a way that this additional parameter does not affect the readings.

Testing and compensating

Understanding which heat transfer mechanism – conduction, convection or radiation – is responsible for a specific phenomenon can help to point the design engineers in the right direction. This type of testing requires accurate control of the environmental parameters, using a set-up such as the one shown in Figure 2.

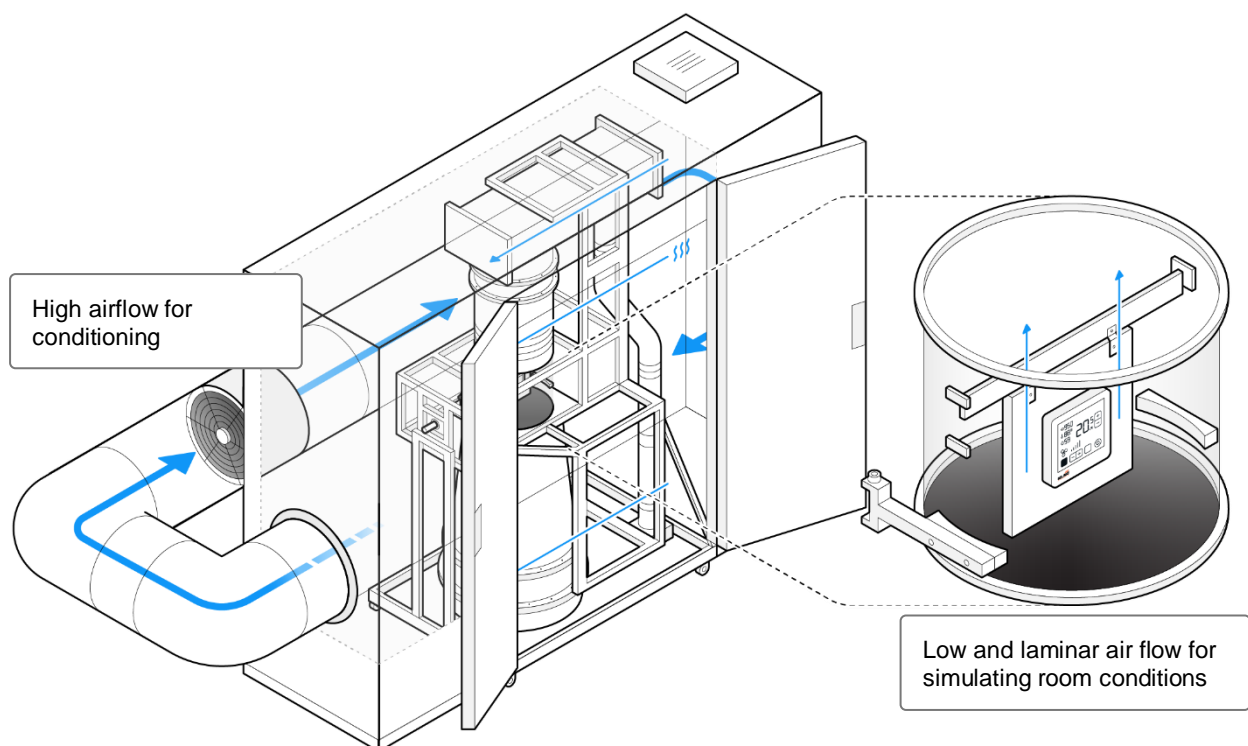


Figure 2: Visualisation of the Belimo Room Sensor test rig used to design and assess the sensor's performance under varying environmental conditions.

The test chamber holding the sensor is supplied with a constant, laminar airflow that can be precisely controlled from 0.05 m/s to 0.3 m/s, mimicking an indoor environment. This unit is then positioned in a thermally insulated housing that is able to regulate the temperature with a 0.1 °C accuracy. As the airflow inside the housing is much higher than the one inside the test chamber, the desired temperature can be reached (or changed) very quickly. This set-up also offers control of parameters such as humidity and power supply voltage, providing a powerful tool to create a detailed calibration profile and to separately assess the individual contributions of each heat exchange mechanism.

Informed design

The extensive data collected using the testing rig can be fed into sensor design to maximize its performance, reducing the influence of radiation and eliminating self-heating. For example, testing showed that optimizing the design of the air vents in the housing can enhance the coupling between the sensing element and the actual temperature of the room. This can be further optimized by changing the shape and position of the air flow channels within the device.

Another important consideration when designing room temperature sensors is that measurements should be unaffected by the heat generated by the electronic components inside the device itself. This requires strategies to isolate the sensor element without impacting the form factor of the overall design. One approach to achieving this is shown in the heat map in Figure 3.

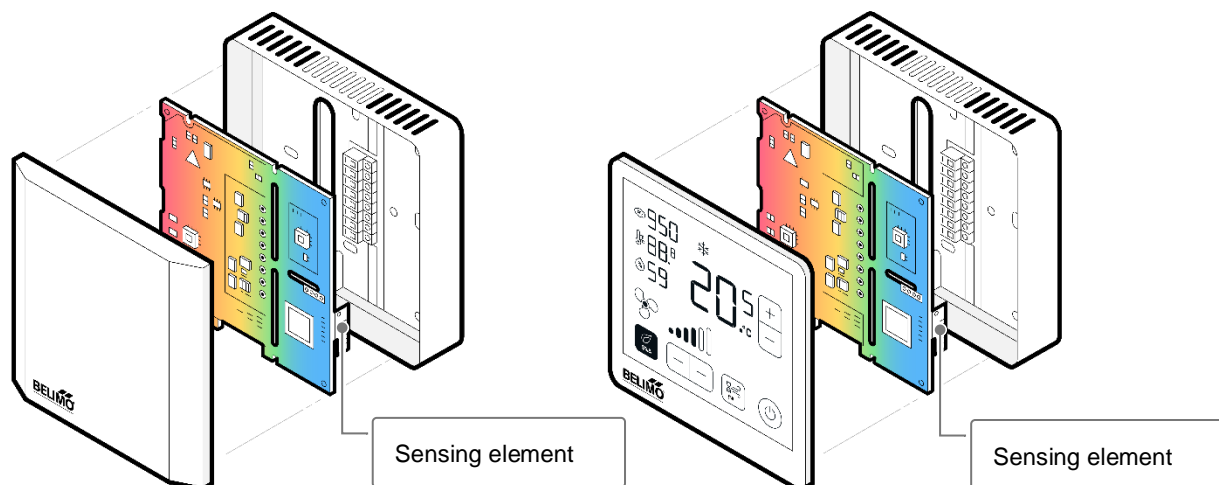


Figure 3: A heat map showing temperature variations across a sensor's PCB.

The sensor's printed circuit board (PCB) is made up by two physically separated sections connected by thin supports. The lower part contains the sensor element, while the upper part holds electronic components – such as the microcontroller and power source – that generate heat during normal operation. As can be seen, this area of the PCB gets much warmer than the portion holding the sensor element. The heat is stopped from affecting the sensor element via conduction thanks to the physical separation, small supports, and the fact that the copper ground planes of the two circuits are not connected. Since copper is a very efficient heat conductor, this detail can reduce self-heating effects significantly.

Although many problems can be addressed during the design phase, there are still external factors that are beyond a manufacturer's control – such as air flow, humidity, different heat sources and varying power supplies. The latter, for instance, is addressed by an internal real-time measurement and a compensation

algorithm. However, relying too much on compensation could render a device less sensitive and slow to react.

Summary

There are a lot of requirements when it comes to room sensors; they need to be accurate, fast and suitable for use across the globe and a multitude of applications. This requires thorough planning when designing the device to eliminate potential internal sources of error, while also compensating for unavoidable external fluctuations. This article has only addressed the difficulties related to temperature measurements, and has not even touched the monitoring and controlling of other parameters needed to ensure the comfort and safety of indoor spaces, such as humidity, CO₂ levels, particulate matter, or volatile organic compounds. Hopefully, this has helped to highlight the complexities of creating a high-performance room temperature sensor, and will give this commonly overlooked device some well-deserved appreciation.

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