Measurement Standards Laboratory of New Zealand

Report on the Humidity Response of Core Transport Technologies Data Loggers

Report No. Humidity/2024/616, 12 April 2024

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Description

Humidity data loggers manufactured by Core Transport Technologies, New Zealand.

Identification

The data loggers are identified with their associated MAC address.

Logger 1. 2C:DC:78:04:95:77
Logger 2. 2C:DC:78:04:97:1F
Logger 3. 2C:DC:78:04:97:2D
Logger 4. C6:7D:81:A4:1A:8E
Logger 5. DC:E1:E4:3E:DE:52
Logger 6. E8:BE:D9:15:15:1C
Logger 7. FB:C4:03:BB:3B:50

Client

Core Transport Technologies NZ Limited, 105 Trafalgar Street, 2nd Floor, Nelson, New Zealand

Date of Measurements

1 to 14 February 2024.

Method

The loggers were fitted to a minichamber through which conditioned air of known humidity and temperature was passed at a nominal flow-rate of 35 L/min by a Thunder Scientific TS2900 humidity generator.

Conditions of Measurements

The logger was fully immersed in the conditioned air at the time of calibration. The ambient air temperature in the laboratory was maintained at (20 ± 1) °C.

Results

The data loggers underwent exposure to three distinct relative humidity levels (10 %rh, 50 %rh, and 90 %rh (see **Note 1**)) across a range of temperatures (–10 °C, 10 °C, and 40 °C). At each temperature the humidity was stepped up and down. This is commonly done to gauge the extent of sensor hysteresis.

Typically, the calibration procedure at MSL involves maintaining a constant humidity level for 50 minutes at each measurement point, which proves adequate for achieving stability. However, due to the slightly different setup involving a larger minichamber, this duration was extended to 300 minutes. Alongside the calibration of Core TT data loggers, the air was monitored using two Vaisala

HMP7 hygrometers and an RS473 chilled mirror hygrometer. This was done to check the humidity level inside the minichamber.

Figure 1 displays a portion of the raw calibration data for logger FB:C4:03:BB:3B:50, alongside an uncalibrated Vaisala HMP7 hygrometer and the air produced by the TS2900 generator. The temperature is denoted by the dashed line. The response of the HMP 7 hygrometer is what is typically observed and expected for a dielectric-based hygrometer.

Upon initial calibration runs, it became evident that the allocated time was insufficient for the humidity loggers to stabilise. Consequently, the duration was further extended to 720 minutes (12 hours). It's worth noting that the TS2900 humidity generator couldn't operate for such an extended period at temperatures below 0 °C, restricting this prolonged calibration to 10 °C and 40 °C.

Notably, it's evident that even after 12 hours at a constant humidity level, the logger under test has not yet stabilised, while the Vaisala hygrometer has clearly reached equilibrium. The relative humidity measurement of the logger also depends on temperature and responds faster at higher temperature.

The substantial discrepancy between the Vaisala hygrometer and the TS2900 generator at approximately 30 hours arises because the Vaisala hygrometer measures humidity relative to dew, whereas the air from the TS2900 generator is with respect to frost for temperatures below 0 °C. Specifically, a relative humidity of 90 %rh at –10 °C with respect to frost corresponds to 82 %rh with respect to dew. It is expected that, likewise, the logger under test measures the humidity relative to dew for temperatures below 0 °C.

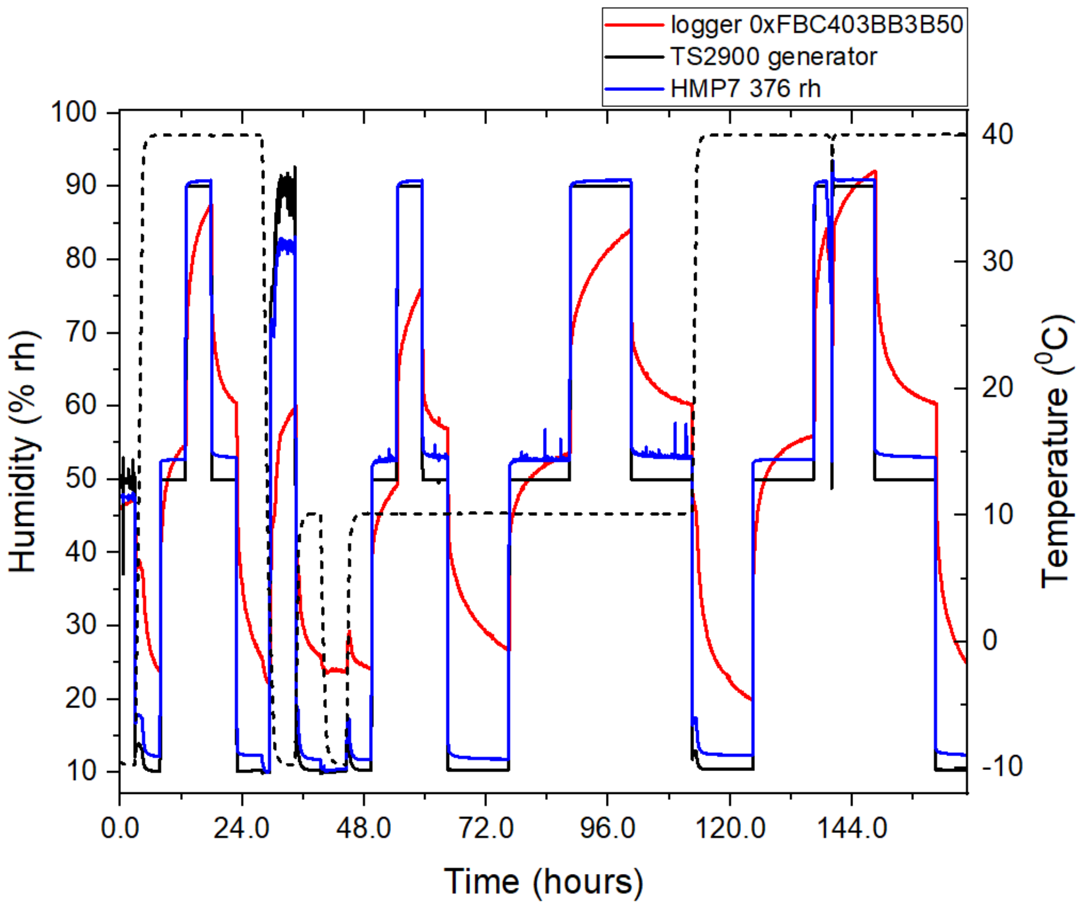

Figure 1. Comparison of the relative humidity response of logger FB:C4:03:BB:3B:50 (red) and a Vaisala HMP7 hygrometer (blue). The dotted line indicates the air temperature and the solid black line the humidity of the supplied air.

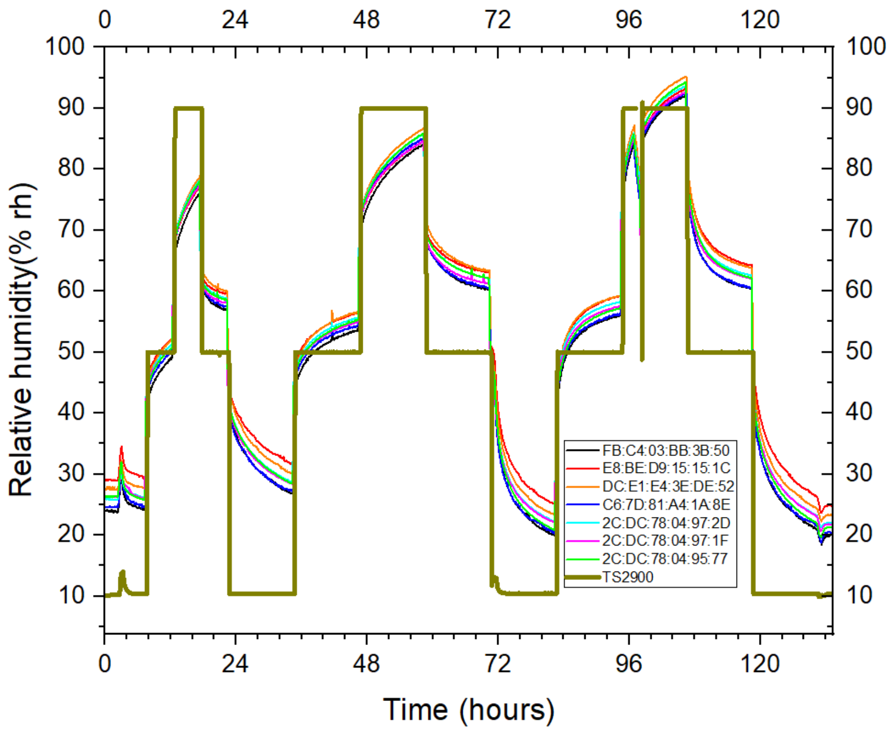

Figure 2. Measurements made by the different data loggers of the relative humidity of the air supplied by the TS2900 humidity generator.

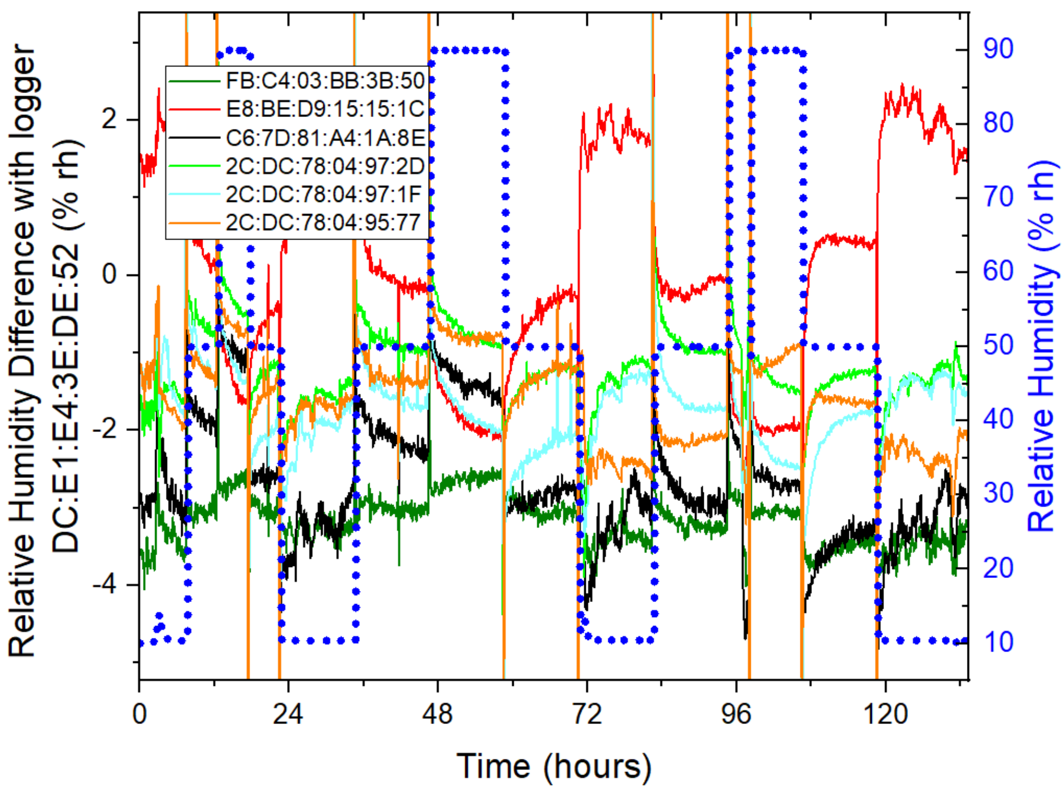

Figure 3. The difference in measured relative humidity between the each loggers and logger DC:E1:E4:3E:DE:52. The blue dotted line is the relative humidity supplied by the TS 2900 generator.

Figure 2 illustrates the response of various data loggers. The air temperature was maintained at 10 °C for the initial 72 hours, followed by an increase to 40 °C for the remaining of the displayed data. Notably, all loggers exhibit a comparable response to the supplied humidity, showcasing uniform behavior among them. For enhanced clarity, Figure 3 presents the difference between each logger and logger DC:E1:E4:3E:DE:52 using the same dataset. Throughout the measurements, all loggers consistently recorded values within a 6 %rh margin of each other. This highlights a consistent response to humidity and suggests a similar response time for each logger.

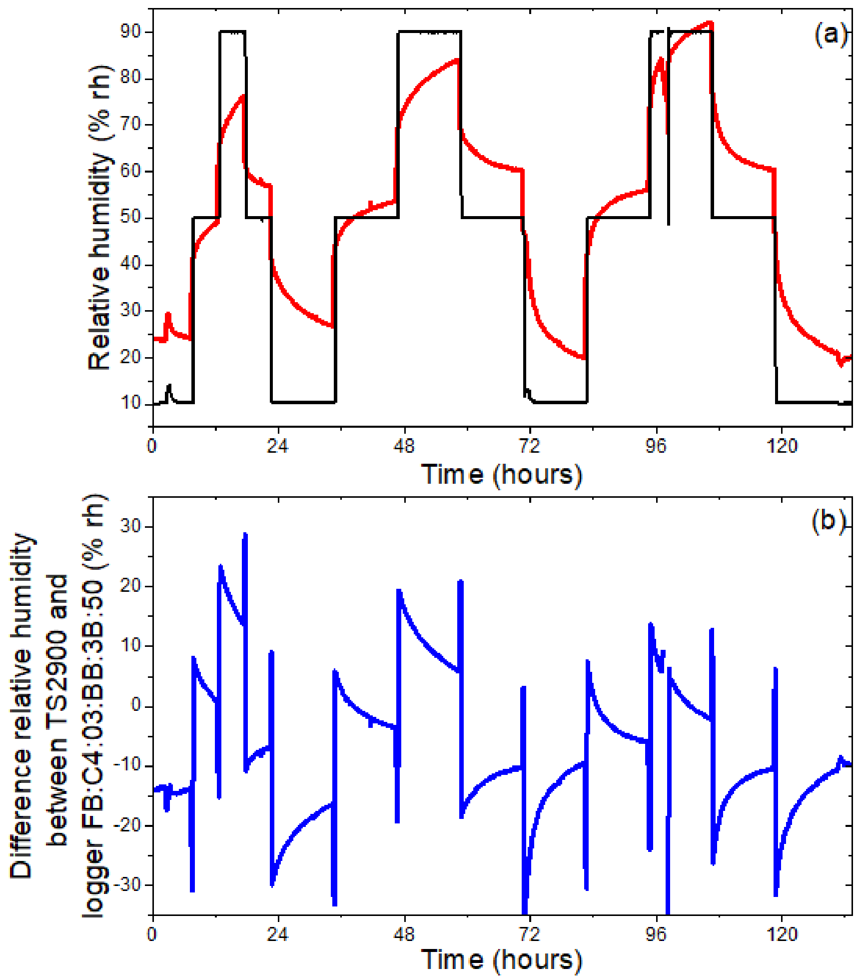

Figure 4. (a) The relative humidity generated with the ts2900 together with the response of logger FB:C4:03:BB:3B:50. (b) The difference between the generated relative humidity and the one measured with logger FB:C4:03:BB:3B:50.

In Figure 4, again utilising the same dataset, the difference between the supplied relative humidity and logger FB:C4:03:BB:3B:50 is depicted. Even 12 hours after a humidity change, a substantial difference of up to 15 %rh continues to persist between the logger and the generator. As the 50 %rh level is approached both in increasing and decreasing humidity, the sensor's final value is expected to fall between the ascending and descending values. Typically, the stable values recorded with an increase or decrease in humidity are different, and this difference is attributed to hysteresis. Besides the hysteresis, there is also a component associated with the long response-time, which contributes to the difference. Consequently, at 50 %rh and 40 °C, the anticipated final value for this logger is situated between 56 %rh and 60 %rh. While this can offer a general idea of the anticipated correction at this humidity level, it must never be relied upon for calibration purposes under any circumstanceAs an example for the time response, in Figure 5 the response of logger FB:C4:03:BB:3B:50 to a humidity shift from 50 %rh to 10 %rh is depicted. The response characteristics are similar for other humidity steps and the other tested loggers. The response is defined by an initial rapid change from approximately ~57 %rh to ~40 %rh, followed by a much slower component. Utilising a double exponential fit for the latter allows for an estimation of the eventual stable value and the anticipated time required to reach this state. This analysis yields an estimated final value of 22 %rh, which is a significant difference with the applied humidity of 10 %rh. Similarly to before, these values should not be used for calibration purposes. From analyising the time response it can be estimated that one would need to wait around 1246 minutes to obtain a value within 1.7 %rh of the final value. As a ballpark figure, one would need to wait around one day for the logger to stablise after a change in humidity.

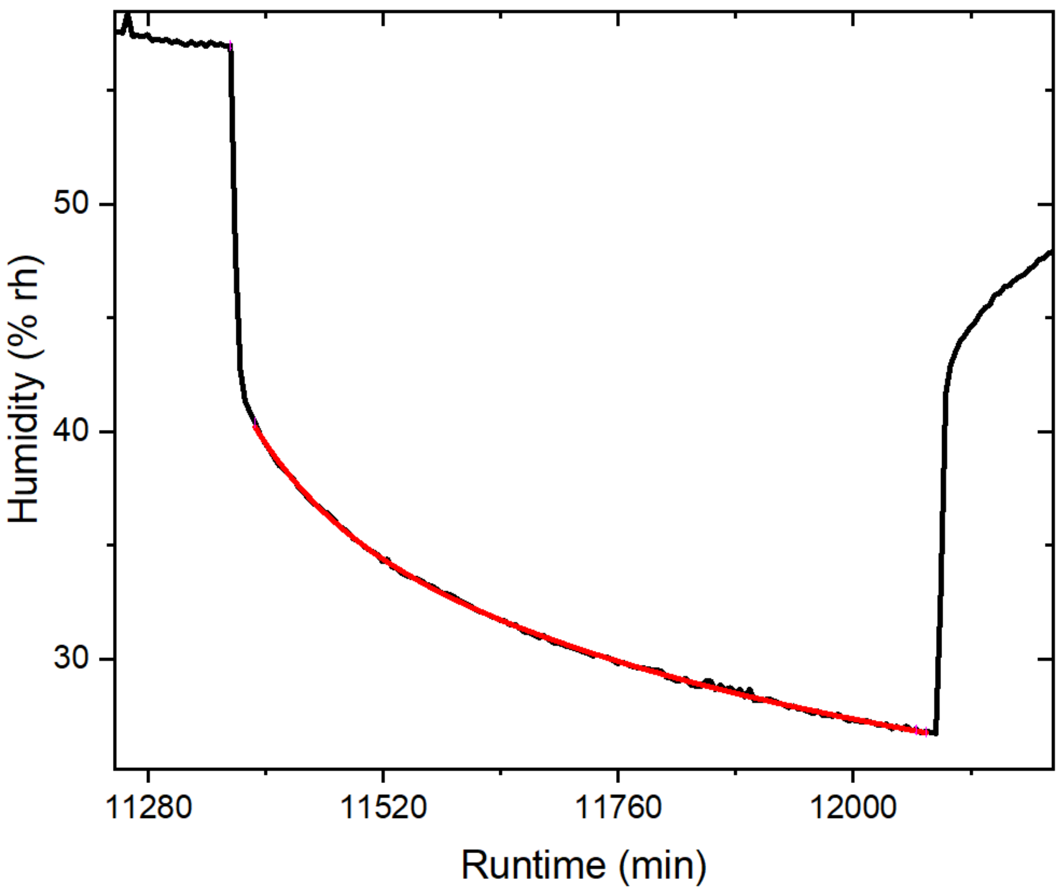

Figure 5. Example of the logger response after a change in humidity from 50 %rh to 10 %rh. The red curve is a double exponential fit to the data.

Recommendations

The observed slow response is unexpected for dielectric hygrometers and can lead to inaccuracies in measurements, especially considering that humidity fluctuates more rapidly in real-world applications than the measured time response. This sluggish response is likely not attributable to the dielectric humidity sensor component itself, but rather to factors related to the enclosure and how the sensor is mounted.

The observed response suggests that the sensor is measuring the humidity within the enclosure rather than accurately reflecting the environmental humidity, due to poor air flow and limited exchange with the surrounding air. It’s crucial to note that humid air can become trapped in dead spots within the sensor enclosure, where air flow is severely limited, thereby increasing response time. This highlights the need for improvements in the design of the loggers to enhance their performance in measuring relative humidity.

To address this issue, several changes are recommended:

- Reducing the volume of the enclosure to minimise the amount of trapped air and dead space.
- Improving air flow by removing or using a different membrane, enlarging the opening and having multiple openings.
- Altering the position of the sensor within the enclosure to optimise its exposure to the surrounding air and improve response time.

Furthermore, precautions must be taken to prevent condensation inside the enclosure, which can occur when the temperature drops below the dew point of the air within. This can happen when there is not sufficient air exchange and the temperature decreases rapidly inside the logger. This will result in erroneous measurements due to water in the liquid phase accumulating in the enclosure.

Relative humidity depends strongly on temperature, especially at high relative humidity. Therefore, it is important to measure the air temperature accurately to obtain good humidity measurements. Heat generated by other electronic components on the pcb board can influence the measured temperature and, therefore, the humidity measurements. The position of the humidity sensor and other components on the pcb board, and the way they are mounted, are important.

To ensure accurate measurments, it’s advisable to thoroughly test the sensors after assembly of the complete logger, rather than solely relying on manufacturer datasheets of the sensor component. Testing can, for example, be done by using a low-cost and easy-to-use two-flow humidity generator during development. This can aid in investigating and optimising the humidity response of the loggers. Such a generator can be purchased, constructed, or rented.

Sensirion has published a helpful design guide for humidity sensors. Most of these guidelines are valid for humidity sensors made by other manufacturers as well. This document summarises best practice for developing humidity sensors and can be downloaded at https://sensirion.com/media/documents/FC5BED84/61644655/Sensirion_Temperature_Sensors_Design_Guide_V1.pdf.

Currently, the tested loggers would require large corrections between ~6 %rh and ~15 %rh to obtain an accurate measurement of the humidity. The long response time to changes in humidity potentially restricts the usefulness of the loggers to applications where humidity changes very slowly and a very long delayed response is acceptable.

Note 1

1. In the SI, relative humidity is a quantity of dimension one, and as such is represented as a number and expressed as a decimal (e.g., 0.5) or as a percentage (e.g., 50 %). In this report we use the widely adopted convention of writing the units of relative humidity, when expressed as a percentage, as %rh (e.g., 50 %rh).