CLOUD-BASED MEASUREMENT SYSTEM FOR LONG-TERM DATA ACQUISITION OF TEMPERATURE AND HUMIDITY DATA IN A TIMBER RESEARCH FACILITY

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Cloud-based measurement system for long-term data acquisition of temperature and humidity data in a timber research facility

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Abstract

To evaluate new products and techniques in civil engineering, climate change which highly effects the properties of building materials, needs to be taken into consideration during long- and short-term testing. For a research facility seated in Asa (Småland, Sweden), a measurement system for temperature and relative humidity (RH) values was developed. The system consists of four temperature and RH probes, placed in different locations, and a data acquisition system (DAQ). Data from the probes is acquired continuously and stored into a cloud-based service which provides fast and easy access to the logged climate data.

Participants

The project is led by professors Erik Serrano and Per Johan Gustafsson from the Department of Structural Mechanics at the University of Lund and professor Sigurdur Ormarsson and lector Johan Vessby from the Department of Building Technology at Linné University. The electrical measurement system to acquire climate data and the corresponding software program were designed by research engineer Michael Lempart (Department of Structural Mechanics,LTH) with the help of Artur Grabowski (Department of Structural Mechanics,LTH) and Bertil Enqvist (Department of Building Technology, LNU).

Contents

1 Introduction

The experimental verification and testing of new types of timber structural elements and joints is of high value for research and development. Timber elements and joints need to fulfill several technical specifications like carrying capacity, stability, acoustical performance, stiffness and vibration damping. Another critical aspect when it comes to the development of new components is the evaluation of climate change effects influencing the material under long-term loading. Most of the testing and research is done under short-time and in most cases in a controlled climate environment. Because of the lag of time and available research facilities, long-term testing is rarely done. In the 90s, the University of Lund, built a unique research facility in Asa, Sweden, containing 60 load rigs with a load capacity of up to 50kN. The project gained financial help from the European Union. The facility has been used to examine carrying capacity and deformation of different material under long-term and under the effects of climate change. The facility was used by the University of Lund and also by other institutes and companies, for research on wood-based elements, joints and products including paper products. Wood as a hygroscopic material takes on moisture from the surrounding environment. The exchange of moisture between wood and air depends on the relative humidity (RH) and temperature of the air and the amount of water in the wood. Many physical and mechanical properties of wood depend upon the moisture content, the gradient of the moisture content and its rate of change [1]. Therefore, continuously monitoring of temperature and relative humidity is crucial when testing timber materials.

2 Materials

For continuously monitoring the temperature and RH values in the Asa research facility, four sensors of type HMP110$^{\text{TM}}$ (Vaisala, Finland) are used. The HMP110$^{\text{TM}}$ is supplied with +6.5VDC by an external switching mode power supply (SMPS) and the output of the sensor is fed into a data acquisition system (DAQ) of type USB-6002$^{\text{TM}}$ (National Instruments, Austin, Texas) (Figure 1).
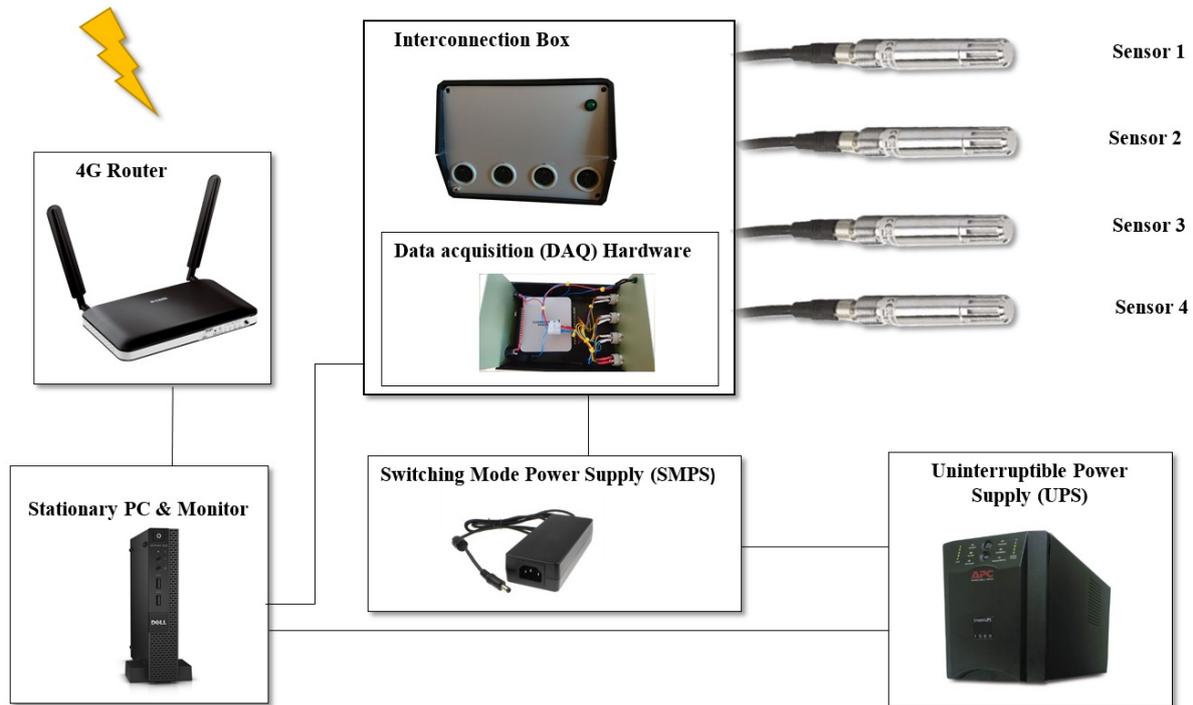
Figure 1: Blockdiagram of the measurement system. Voltage signals from the four HMP110$^{\text{TM}}$ probes are sent to an interconnection box containing the data acquisition hardware. Processed data is saved to a pc and copied into a cloud based service

The probe signals are routed to an interface box containing the DAQ hardware. With a software programmed in Labiew, data is read from the DAQ, sent to a stationary computer, and the acquired voltage levels are changed into appropriate temperature and relative humidity values. Measured data is continuously written and saved into a Labview measurement file (lvm). Once a day, all data from the lvm file is copied to the cloud-based Dropbox$^{\text{TM}}$ (Dropbox Inc., USA) service. With that, data can easily be accessed for review and post-processing purposes from any PC or mobile device with an active network connection. The USB-6002$^{\text{TM}}$ is connected to a stationary computer which simultaneously serves as a supply voltage for the DAQ via a universal serial bus (USB). An uninterruptable power supply (UPS) is connected to the stationary computer and to the SMPS of the HMP110$^{\text{TM}}$ probes to provide backup power in case of power loss or unexpected variation in the three-phase network of the facility.

2.1 HMP110™ temperature and humidity probe

The HMP110™ is a temperature and humidity probe with high accuracy and good stability. The probe can easily be combined with third party vendors and has a low power consumption. HMP110™ series probes consist of an IP65 rated stainless steel probe with a HUMICAP 180R sensor for higher accuracy. Temperature and humidity values can be read from two analog output channels with a range between 0...2.5 VDC. The probe is provided with a +5V input voltage. For the temperature, a Pt1000 RTD sensor (Class F0.1 IEC 60751) working in the range between -40...80 °C is used. The humidity HUMICAP 180R sensor is capacitive thin-film polymer sensor consisting of a substrate on which a thin film of polymer is deposited between two conductive electrodes (Figure 2).
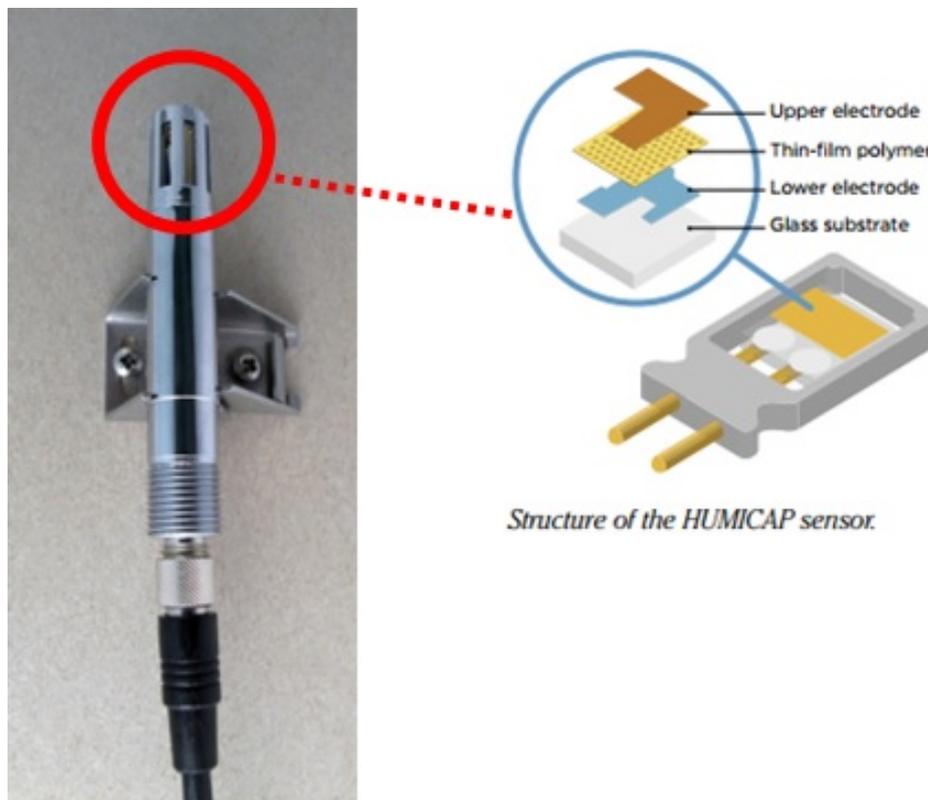
Figure 2: left: HMP110™ temperature and humidity probe. right: Layers of the HUMICAP 180R humidity sensor. The polymer film absorbs or releases water vapor. With changing dielectric properties, the changing capacitance is converted into a corresponding humidity value

The sensing surface is coated with a porous metal electrode to protect it from contamination and exposure to condensation. As the RH of the air rises or falls, the thin-film polymer either absorbs or releases water vapor. With the change of RH around the sensor the dielectric properties of the polymer film change, and so does the capacitance of the sensor. The instruments electronics measure the capacitance of the sensor and convert it into a RH value [1, 2, 3, 4, 5].

2.1.1   Probe installation and placing

The HMP110[TM] probes are placed in four different spots inside the research facility. Three of them are placed on the main floor and one is located on the loft indicated by the red triangle in Figure 3. Positioning the probes near windows or doors should be avoided as this could affect the accuracy of the measurements. Cables containing signals for temperature, humidity, power and GND are rooted from the probes to an interface box containing the USB-6002[TM] data acquisition system.
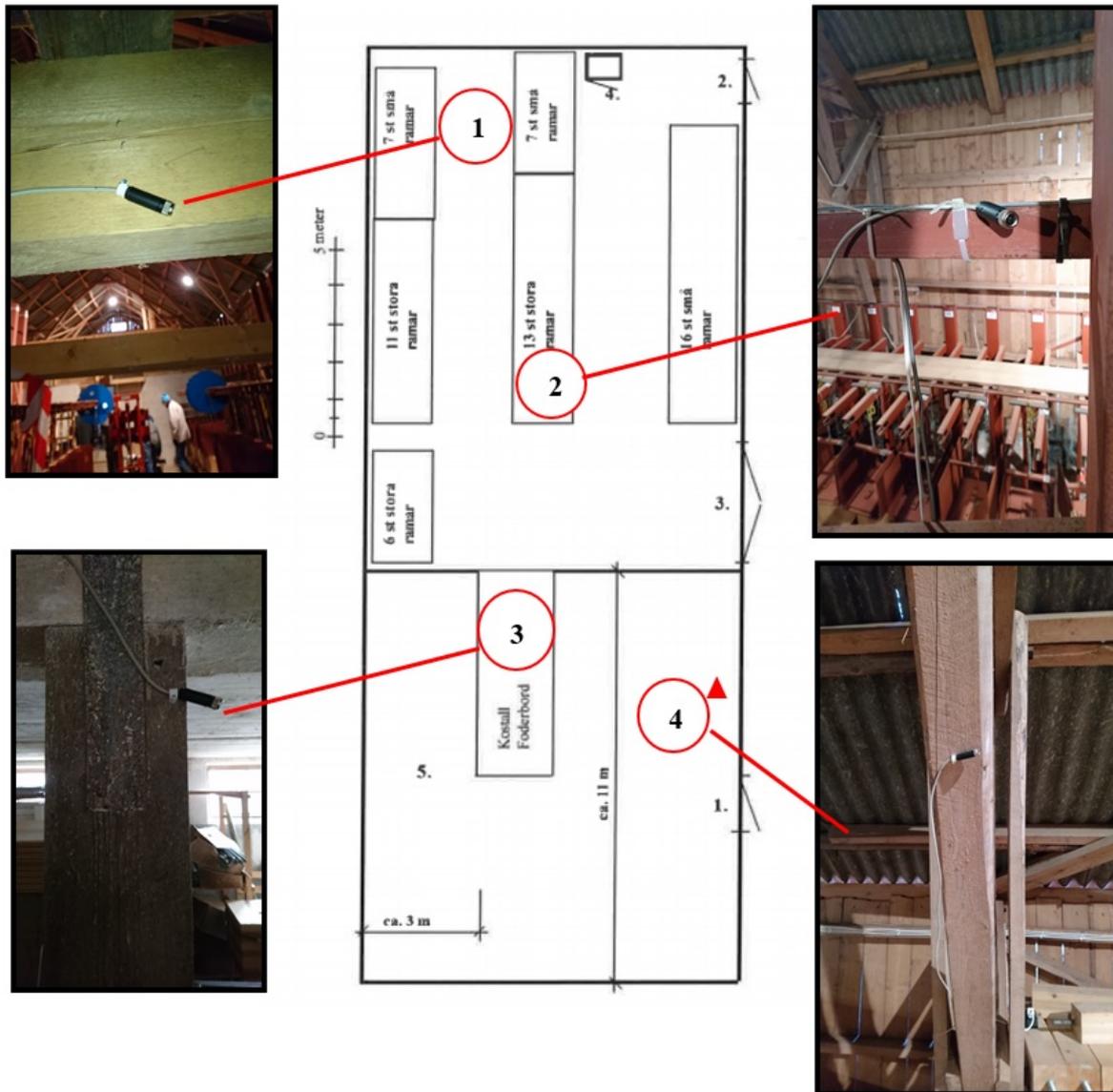
Figure 3: Placement of the HMP110[TM] probes. A total of four probes are place inside the test facility. The probe positions are highlighted on the drawing where the triangle indicates a position on the upper floor

2.1.2 Probe field calibration

For field calibration of the HMP110[TM] probes, a Model 2500TM (Thunder Scientific, Albuquerque, USA) Benchtop Humidity Generator is used. One of this calibration devices can be found at the Division of Building Materials at Lund University, Sweden. The system supplies known humidity values for instrument calibration following the 'two-pressure' principle, where two chambers are maintained at the same temperature Figure 4. In the first chamber, called the saturator, air is saturated with water vapor at high pressure. The air then is led through to the test chamber, which is contained at a lower pressure. As the air reduces in pressure, its relative humidity drops as well. A known humidity is then generated by controlling the pressure ratio Pc/Ps utilizing the enhancement factor ratio fs/fc and the effective degree of saturation es/ec. The relative humidity (RH) is calculated from the measurements of pressure and temperature with the Equation 1:

$$RH[\%] \equiv \frac{fs}{fc} \times \frac{es}{ec} \times \frac{pc}{ps} \tag{1}$$

,where fs and fc are the enhancement factors, es and ec the saturation vapor pressures (SVP) and Pc and Ps the absolute pressures in the chambers. Set points for humidity and temperature set point values are input by the operating user. Humidity is produced with a resolution of 0.02% and an uncertainty of $\pm 0.05\%$.

Important to notice is that the probes must be re-calibrated after changing the humidity sensor.
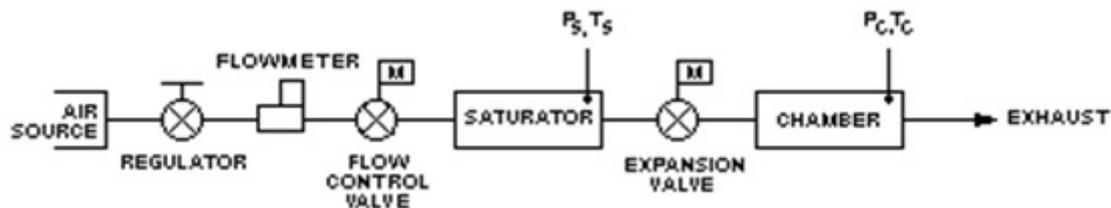
Figure 4: Block diagram of the Model 2500 humidity generator. Air from a source is regulated and flows into the saturator chamber where it is saturated with high pressure water vapor. The air is then guided through a low pressure chamber. By controlling the pressure ratio a known humidity value can be generated

2.2 USB-6002^{TM}

The USB-6002^{TM} provides eight analog input channels with 16 bits of resolution and a 50 kS/s sample rate, 13 digital I/O lines, one basic counter for edge counting, and two analog output channels. The USB bus powered DAQ system is housed inside an interconnection box shown. Through connectors J1 to J4, the four HMP110^{TM} probes are connected to the analog inputs of the USB-6002^{TM} (Figure 5). A LED in combination with the current limiting resistor R1 indicates that voltage is supplied to the probes. Measured voltages from the DAQ are processed and displayed by the Labview Software.
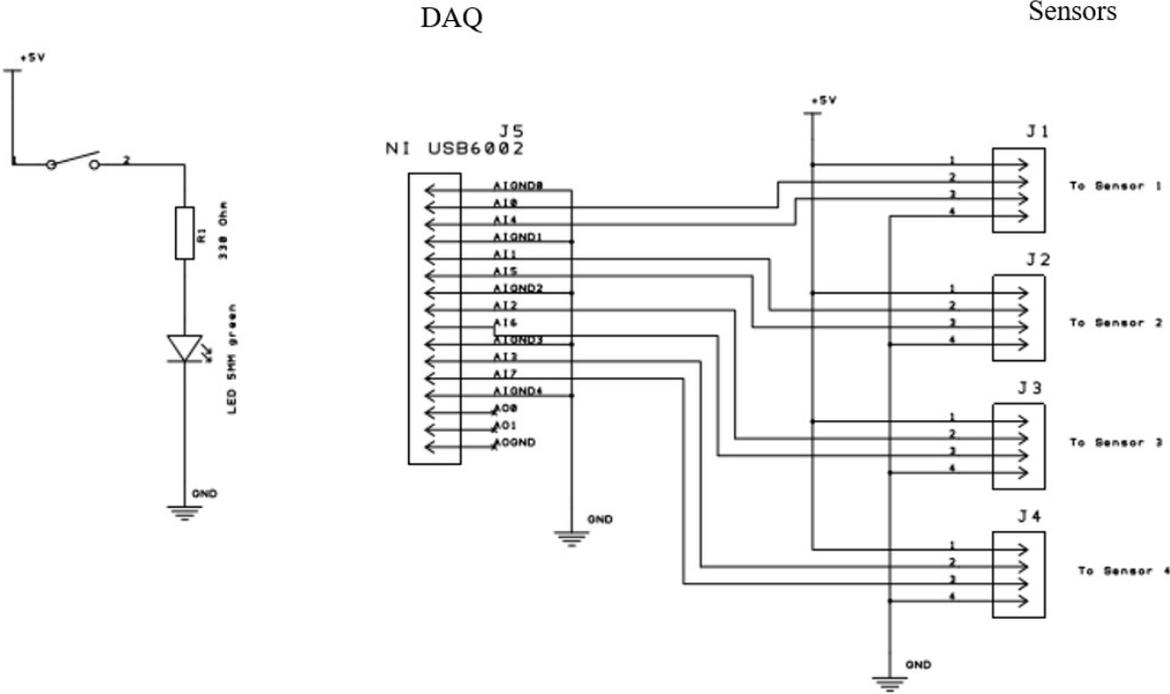
Figure 5: Electrical wiring diagram of the HMP110 signals and the data acquisition system. The four HMP110TM probes are connected to the USB 6002 National Instruments DAQ. An LED at the indicates that the 5V DC from the power supply unit are applied

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2.3 Labview Software

The monitoring system software written in the visual programming language Labview is used to acquire data from the four temperature and humidity sensors and displays the acquired data in real time on the front panel of the graphical user interface (GUI).

2.3.1 Front Panel

The front panel is based on a tab container control and consists of two tabs called 'Temperature/RH Monitor' and 'Settings'. The monitor tab uses thermometers, gauges and textboxes to show temperatures and humidity values based on the acquired voltages from the USB-6002™ DAQ. Two graphs are used to plot the values for temperature and humidity against time. The 'Settings' tab is used to make changes to data acquisition configurations, like sampling rate, sampling mode and channel choice (Figure 6). All settings are saved to a '.ini' configuration file inside the programs execution directory.
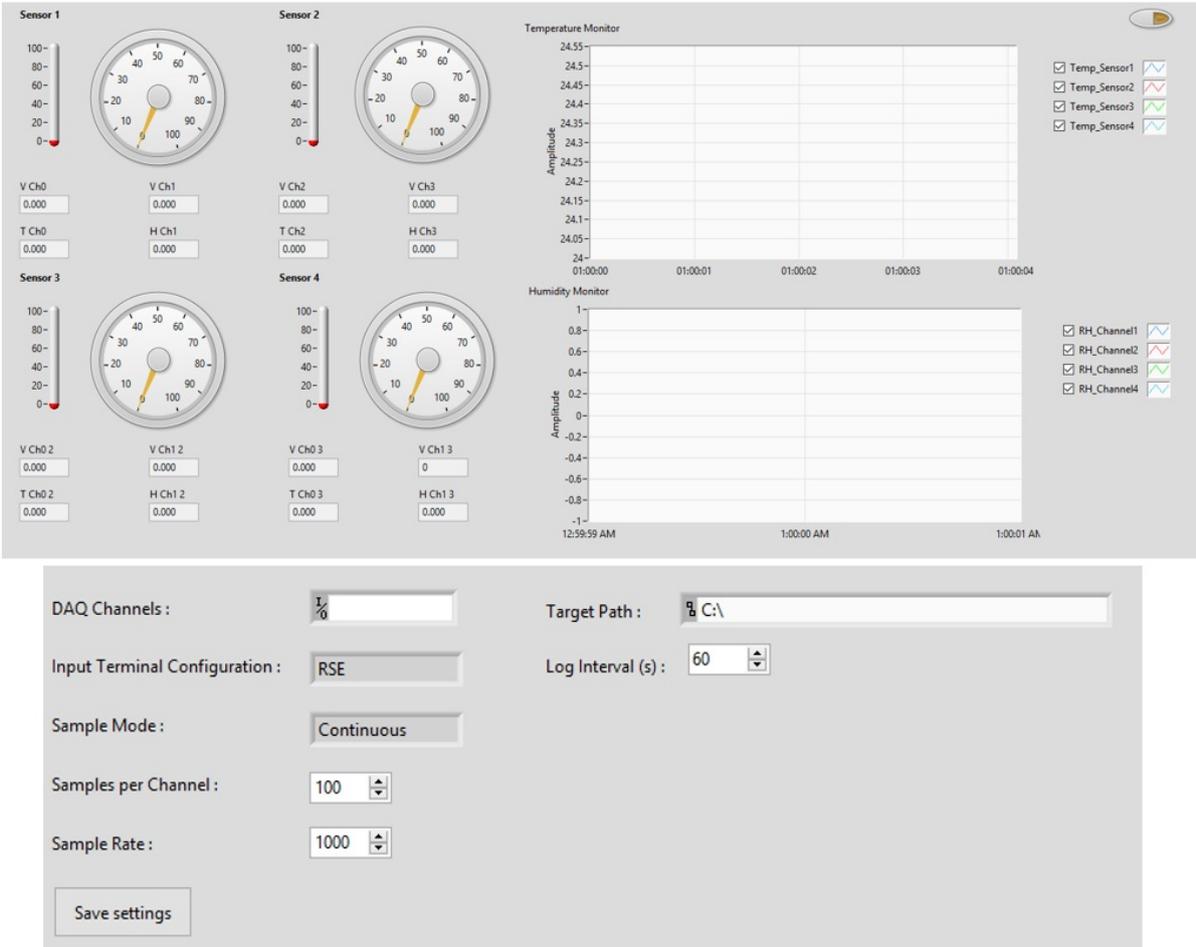
Figure 6: Graphical user interface (GUI) of monitoring software. The GUI is used to start/stop measurements and to change some data acquisition settings

2.3.2 Blockdiagram overview

On startup of the monitoring system software, configuration settings needed for data acquisition are loaded from the 'config.ini' file (Figure 7).
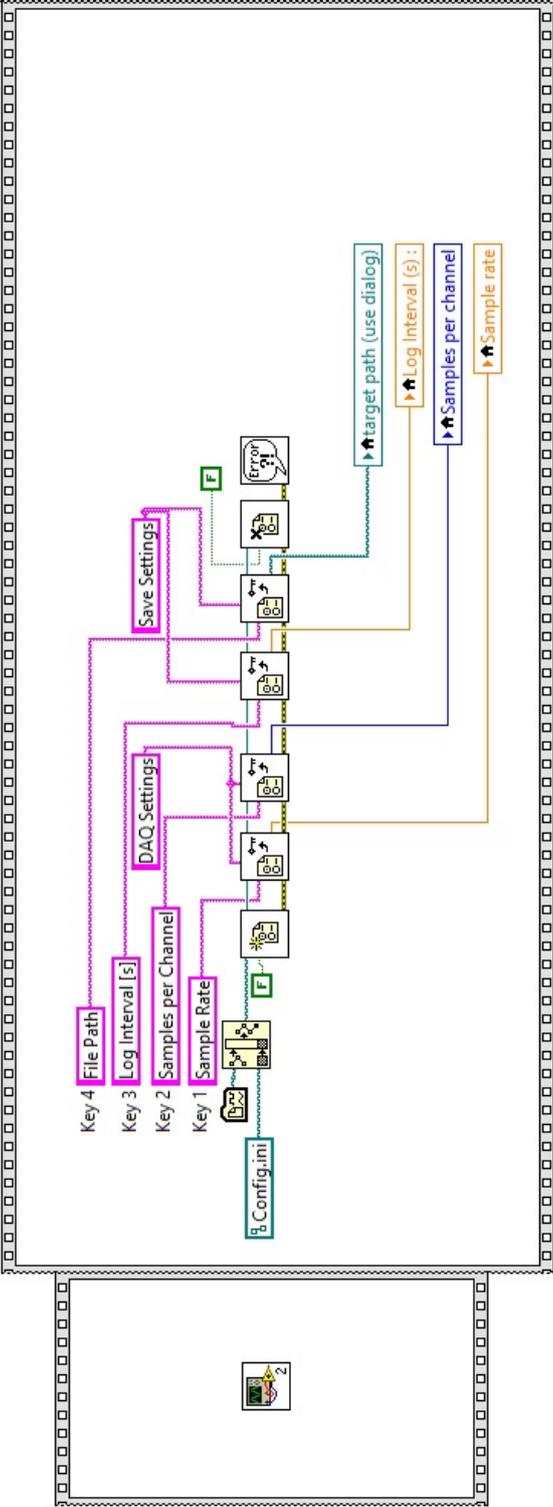
Figure 7: Loading of the acquisition settings from config.ini. The diagram shows the data flow to load configurations from the .ini settings file into the system software

Before data can be collected from the probes, parts of the user interface like start and stop buttons must be initialized and settings needed for data acquisition are set. Trough the 'Settings' tab of the user interface front panel, acquisition settings can be changed and saved to the configuration file. When the user presses the start button, data is acquired from the analog channels of the USB-6002™ (Figure 8).
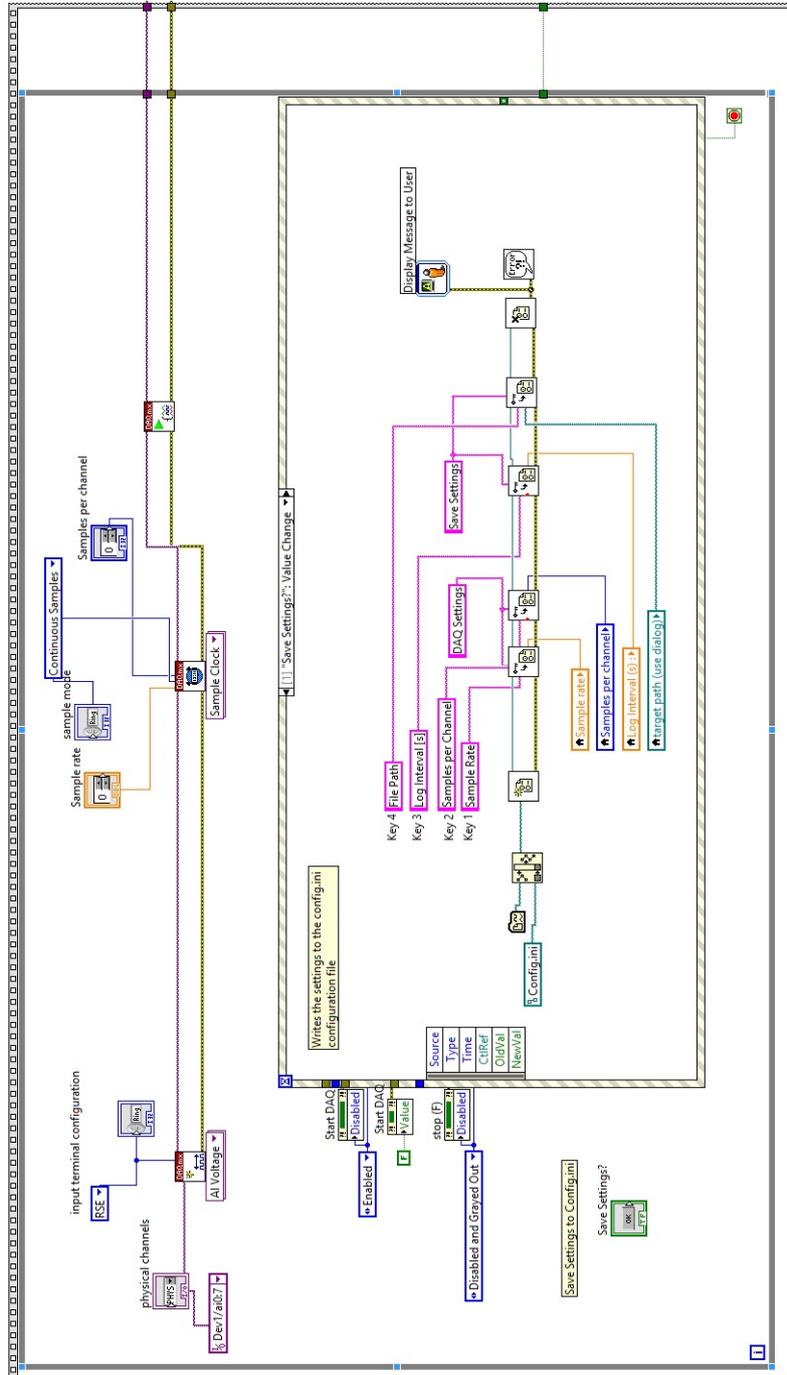
Figure 8: Software and GUI initialization. Data flow of the initialization progress at software start

The output signal of the DAQ assistant, shown in Figure 9 is split, and the temperature and humidity values are calculated based on the output voltage of the channels. Temperature and humidity are shown in two different graphs. Data is acquired continuously and written into a Ś.lvmŠ measurement file with the help of the Write to measurement File Express Virtual Instrument (VI). The write to measurement file VI is configured so that data is written to a new file once a day. Through a shift register, the actual filename is continuously compared to the name of the previous iteration. In case of a file change event, the filenames will be different for one iteration which triggers a copy event, saving the previous file is saved into the Dropbox™ (Dropbox Inc., USA) cloud directory located in the windows explorer. Data acquisition is started and stopped using the appropriate buttons on the graphical user interface (GUI) of the application.
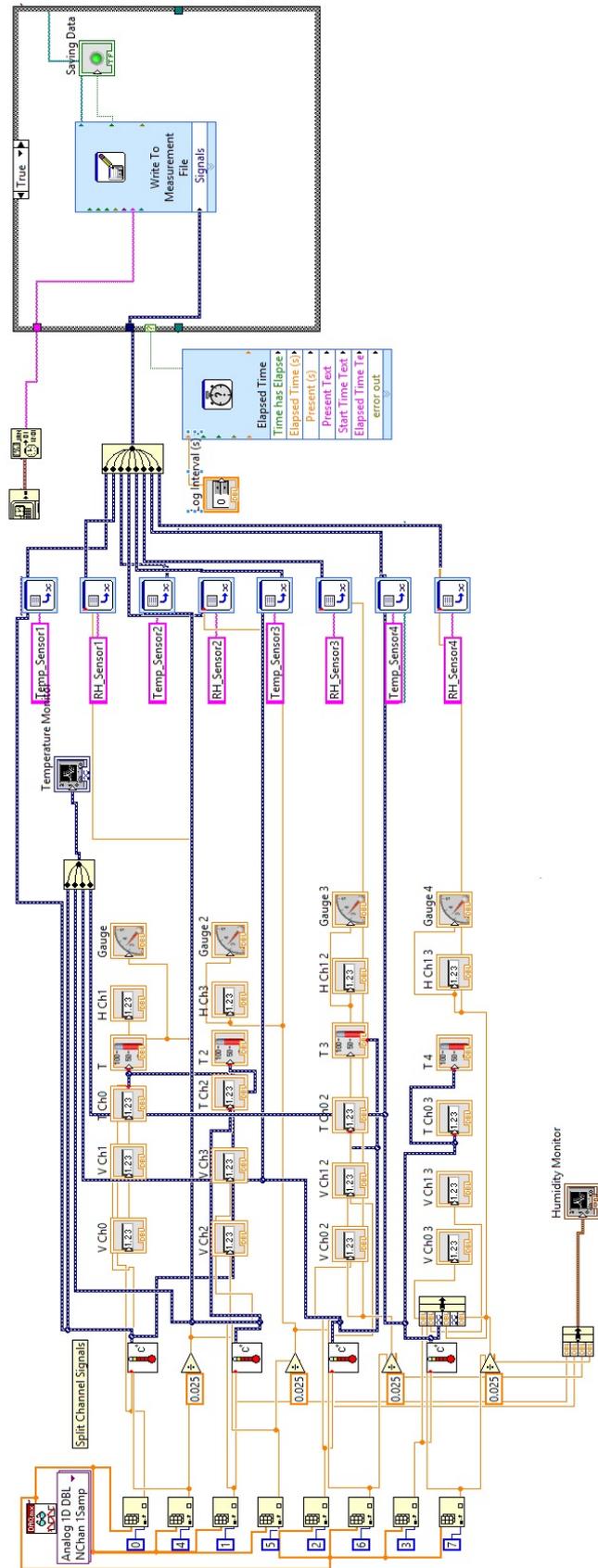
Figure 9: Data acquisition and saving of measurement data. The blockdiagram shows how data is acquired and processed by the software

3 Comments and Discussion

The developed system for acquiring temperature and relative humidity data from four HMP110™ probes is a stable and cost-effective solution which can be used for long-term monitoring in the Asa research facility. The collected data are easy to access via the build-in cloud function and data files can be modified and loaded into other software programs for post-processing. For future projects, the Labview software and the channels of the DAQ system can easily be extended and combined with other modules to be used with additional temperature and humidity probes or other types of sensors.

4 References

[1] Forrest Product Laboritory:*Wood handbook - Wood as an Engineering Material.*,United States Department of Agriculture Forest Service, Madison USA: General Technical Report FPLŰGTRŰ190 (2010)

[2] Vaisala:*HMP110 datasheet.*, Vantaa Finland (2016)

[3] Vaisala:*HMP110 User's Guide Vaisala Humidity and Temperature Probes HMP60 and HMP110 Series.*,Vantaa Finland (2016)

[4] Vaisala:*Vaisala HUMICAPő Sensor for Measuring Relative Humidity*,Vantaa Finland: Vaisala Technology Description (2016)

[5] Thunder Scientific:*Series 2500 Benchtop Two-Pressure Humidity Generator*,Albuquerque, New Mexico USA: Document Edition 4 (2003)

5   Appendix - Monitoring Software User Guide

5.1   Graphical User Interface (GUI)
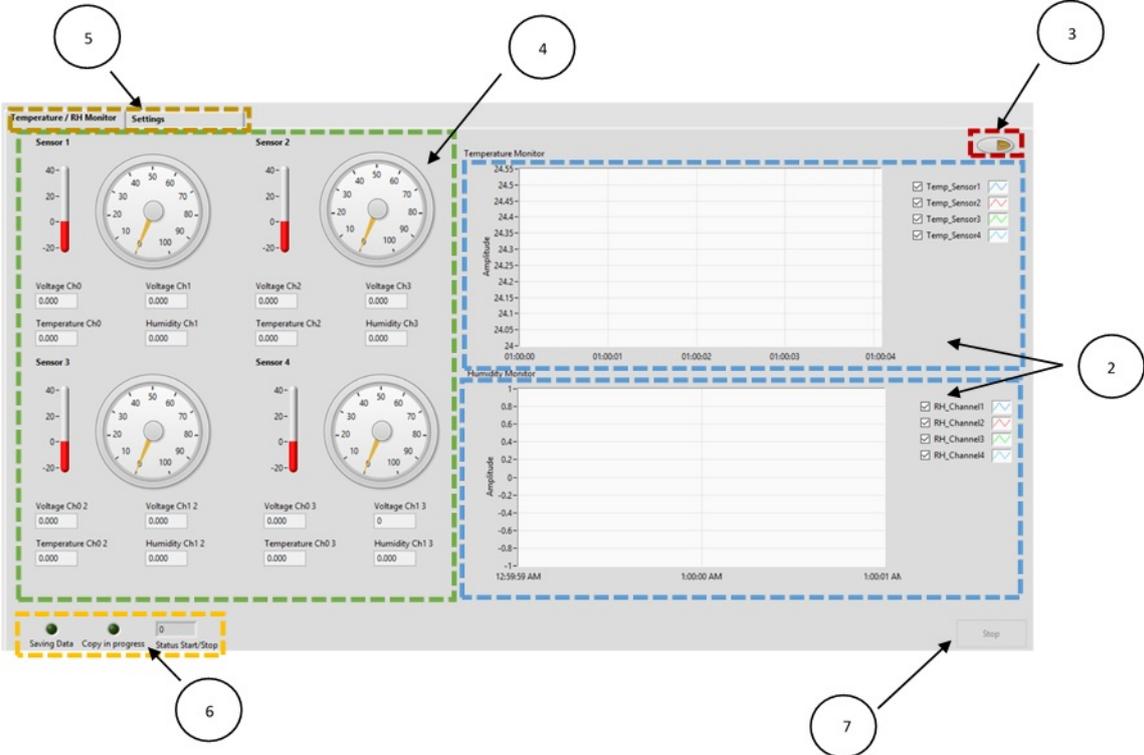
Graphical User Interface of the monitoring software

1. Main Screen

2. Temperature and humidity graphs

3. Start button

4. Temperature and humidity graphical and numerical indicators

5. Menu bar

6. Software Status indicators

7. Stop button

5.1.1   Main Screen

The main screen of the monitoring application provides grapical and numerical indicators for the measured temperature and humidity values and lets the User start and stop measurements. Temperature and humidity graphs The graphs are used to display measured temperature and humidity data.

5.1.2 Start button

When the start button is pressed, the measurement system starts data acquistion and sends measurements to the desktop application.

5.1.3 Temperature and humidity graphical and numerical indicators

This area of the main screen contains graphical and numerical indicators which display measured data.

5.1.4 Menu bar

The menu bar lets the user toggel between the Main screen and the Settings screen.

5.1.5 Software Status indicators

There are three different software status inidcators:

- Saving Data, when data is acquired and written to a measurement file.

- Copy in progress, when a measurement file is copied to the cloud base service.

- Status start/stop, inidicates the masurement state. I the indicator is boolean 0, no data is acquired. Id the the indicator is boolean 1, data acquisition is in progress.

5.1.6 Stop button

The stop button is used to cancel any ongoing data acquisition.

5.2 Settings

The settings tab of the monitoring software is used to change data acquisition settings like the DAQ channels, sample rate, samples per channels, the target path of the measurement file and the logging interval.
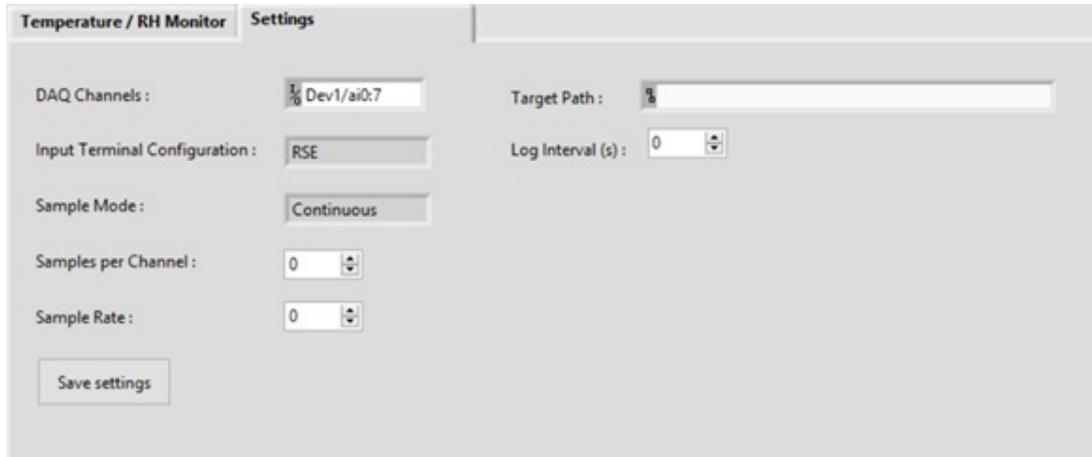
Settings tab container of the monitoring software

5.3 Data Acquisition

1. To start the monitoring software, press the Asa application icon on the windows desktop.

2. Close the upcoming start screen by pressing ok.

3. Press the start button of the application to start logging temperature and relative humidity values.

4. Press the stop button of the application cancel data logging.
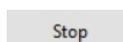
5.4   Cloud connectivity & Data Access

All measured data is saved continuously stored into a cloud based service called Dropbox. The time interval for data logging can be changed in the settings section of the monitoring software.

To get access to the temperature and humidity files, the Dropbox service needs to be installed on your operating machine. To download Dropbox, the following link can be used:

https://www.dropbox.com/downloading

The setup automatically integrates the dropbox service into Windows Explorer. Alternatively a webinterface which provides direct access to the logfiles can be used:

https://www.dropbox.com/login

As downloading a larger amount of files can be stubbornly, it is recommended to include the cloud service into Windows Explorer.

Username and password to the cloud service can be obtained from the division of structural mechanics (LTH, Lund, Sweden) or from the writer of this manual.

The dropbox folder contains four subfolders:

- Asa File Viewer, which contains a Matlab program to view the logfiles and plot the temperature and humidty data against time.

- Asa Log Files, which contains the measured data.

- Labview Program, which contains the software program written in Labview.

- Monitoring Software, which contains the deployed Windows software.

5.5 Asa File Viewer

The Asa File Viewer can be used to load single or multiply log files to view and plot logged temperature and humidity data. All data is even displayed in a table, from which values easily can be copied into a different application like Microsoft Excel or Word. The file viewer software can be found in the Dropbox folder 'Asa File Viewer' which contains a setup file. After the installation process is completed, the file viewer can be started via the Asa monitor icon on the desktop.

Asa file viewer desktop icon

After starting the application the user is prompted to choose one or multiple log files. Multiple files can be chosen by holding the **Shift** or **Ctrl** key on the keyboard and marking the wanted files with the left mouse button.
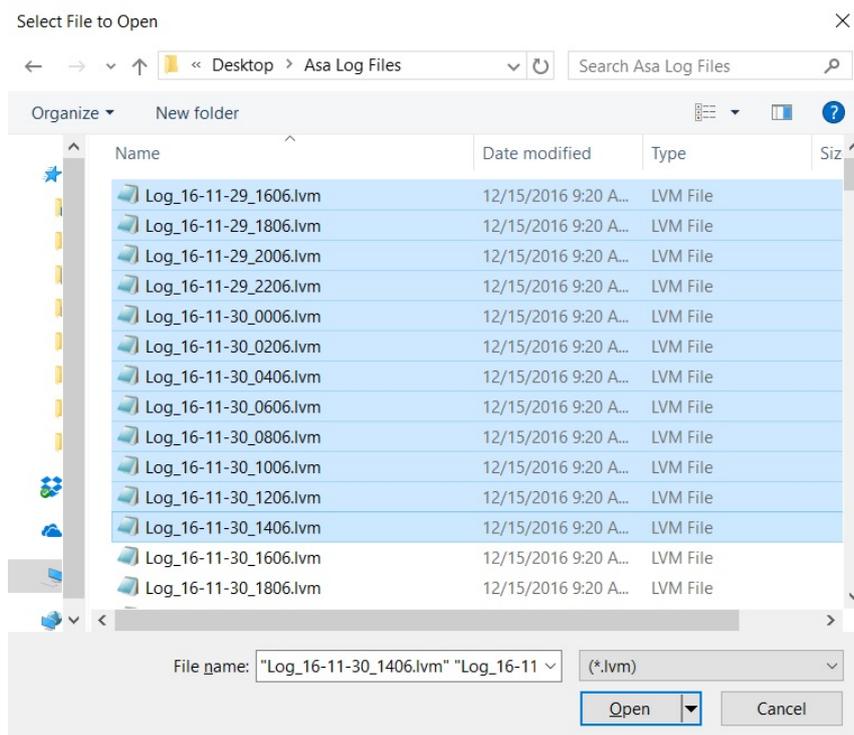
Asa file viewer open file dialog

By pressing the open button the selection is confirmed and the data files are read.

While reading the read log files, no active window or progress bar is shown on the screen. Depending on the amount of chosen files, the reading progress can take up to one minute.
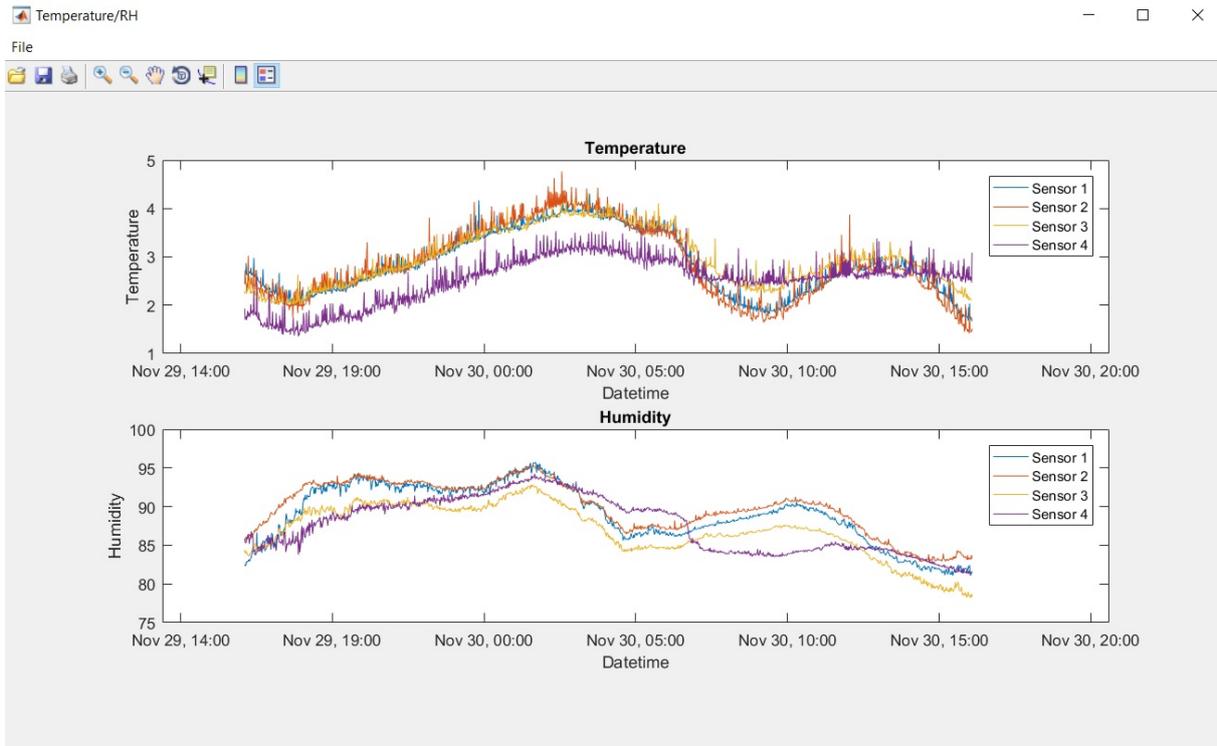
Plot of the temperature and humidity data

Data table acquired from the log files