

User Guide

Revision 2.4

March 2026

# Home Health Box

Version 2.0

Sensor and Sampling Platform for Indoor Air Quality



**ACCESS SENSOR  
TECHNOLOGIES**

Sampling made simple.®

# Notices

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Revision:

Revision 2.4, March 2026

Published by:

Access Sensor Technologies LLC Fort Collins, CO

Technical Support:

<https://www.accsensors.com>

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## Safety Notices

Air pollutant measurements from the Home Health Box are for research and informational purposes only. The Home Health Box is not a safety alarm. Always keep regular home smoke and carbon monoxide alarms installed and operational.

Do not use this product in any manner not specified by the manufacturer. The protective features of this product must not be impaired if it is used in a manner not specified in the operation instructions.

**Do Not Remove Instrument Cover**

There are no operator-serviceable parts inside. Refer servicing to Access Sensor Technologies.

**In Case of Damage**

Instruments that appear damaged or defective should be made inoperative and secured against unintended operation until they can be repaired by qualified service personnel.

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# Abbreviations

Abbreviations used throughout this manual are defined below in alphabetical order:

AE	auxiliary electrode
AST	Access Sensor Technologies
BC	black carbon
CO	carbon monoxide
CO <sub>2</sub>	carbon dioxide
CS	cross section
GUI	graphical user interface
HHB	Home Health Box
ID	inner diameter (when referring to an O-ring)
ID	identifier (when referring to samples and sample media)
ISB	Individual Sensor Board
MCE	mixed cellulose ester
MO <sub>x</sub>	metal oxide
NO	nitric oxide
NO <sub>2</sub>	nitrogen dioxide
NO <sub>x</sub>	nitrogen oxides
O <sub>3</sub>	ozone
OD	outer diameter
PM	particulate matter
PM <sub>2.5</sub>	refers to a particle size fraction, defined by the U.S. EPA, that generally consists of particles with aerodynamic diameters smaller than 2.5 μm; often called “fine particulate matter”
PM <sub>10</sub>	refers to a particle size fraction, defined by the U.S. EPA, that generally consists of particles with aerodynamic diameters smaller than 10 μm
PTFE	polytetrafluoroethylene (Teflon™)
PVC	polyvinyl chloride
RPM	revolutions per minute
RTC	real-time clock
S/N	serial number
tVOCs	total volatile organic compounds
UPAS	Ultrasonic Personal Air Sampler
UTC	Coordinated Universal Time
VOC	volatile organic compound
WE	working electrode
XRF	X-ray fluorescence

# 1 Overview and Basic Operation

Access Sensor Technologies' Home Health Box (HHB) is a small, quiet, self-contained, portable platform that allows users to collect high-quality indoor air samples. The HHB can be configured with up to two particulate matter (PM) samplers and up to two gas samplers, all of which operate using our virtually-silent ultrasonic pumping technology. The HHB collects PM by sampling air through a size-selective inlet and user-supplied filter at a constant volumetric flow rate. Similarly, the HHB collects gas-phase pollutants by sampling air through a user-supplied sorbent tube/cartridge at a constant volumetric flow rate. All sample flow rates are monitored, using internal mass flow sensors, and adjusted continuously to maintain the target volumetric flow rates regardless of changes in ambient environmental conditions (pressure/temperature/RH) or changes in the pressure drop across the sample medium. The HHB is also equipped with an optical PM sensor and a nondispersive infrared (NDIR) carbon dioxide (CO<sub>2</sub>) sensor. Additionally, the HHB can be configured with optional electrochemical sensors for NO<sub>2</sub>, NO, CO, and O<sub>3</sub>.

To learn more about the development of the Home Health Box, see: Tryner, J., Phillips, M., Quinn, C., Neymark, G., Wilson, A., Jathar, S.H., Carter, E., Volckens, J. Design and testing of a low-cost sensor and sampling platform for indoor air quality, *Building and Environment*, 2021, 206, 108398, <https://doi.org/10.1016/j.buildenv.2021.108398>.

The HHB system consists of two components:

- A hardware component to be placed in an indoor environment.
- A software component for programming HHB samples.

This User Guide describes both the hardware and the software components. It explains how to prepare and program the HHB for sampling and then retrieve the sample data.



**CAUTION: The Home Health Box is designed for indoor use only. The HHB enclosure is not waterproof. Shield the HHB from water, water spray, precipitation, etc.**

There are no user-serviceable parts inside the HHB. Refer servicing to Access Sensor Technologies.

## Configuration options and specifications

### Particulate matter sampling channels

Quantity	The HHB can be configured with 0, 1, or 2 PM sampling channels.
Flow rate	1 or 2 L min <sup>-1</sup> (depending on the size-selective inlet used; size-selective inlets are interchangeable, and the flow rate is adjustable)
Flow rate accuracy	± 4% of setpoint (actively controlled)
Available inlets	PM <sub>2.5</sub> @ 1 L min <sup>-1</sup> , PM <sub>2.5</sub> @ 2 L min <sup>-1</sup> , Respirable @ 2 L min <sup>-1</sup> , PM <sub>10</sub> @ 2 L min <sup>-1</sup>
Filter size	37 mm (default) or 25 mm
Max. back pressure	7.0" H <sub>2</sub> O @ 1 L min <sup>-1</sup> , 4.5" H <sub>2</sub> O @ 2 L min <sup>-1</sup>

### Gas sampling channels

Quantity	The HHB can be configured with 0, 1, or 2 gas sampling channels.
Flow rate	3 to 30 mL min <sup>-1</sup> ; user programmable
Flow rate accuracy	± 4% of setpoint (actively controlled)
Compatible sorbent media	¼" OD × 3.5" long (6.35-mm OD × 89-mm long) thermal desorption tubes Waters™ Sep-Pak® cartridges Common glass sorbent tubes (e.g., 6- to 10-mm in diameter)
Max. back pressure	34" H <sub>2</sub> O

### Pollutant sensors

Baseline sensor package	Particulate matter: Sensirion SEN55 (laser light scattering) Carbon dioxide: Sensirion SCD30 (non-dispersive infrared; NDIR) tVOCs and NO <sub>x</sub> (qualitative relative levels): Sensirion SGP41 (MOx)
Electrochemical sensors for additional pollutants (optional)	Up to four Alphasense B-series sensors Carbon monoxide: CO-B4 Nitrogen dioxide: NO2-B43F Contact us if you would like to purchase electrochemical sensors for other pollutants (e.g., NO, O <sub>3</sub> ) for inclusion in your HHB

### Power

Power supply	15 W, 5 V USB Type-C®
Line power	The HHB can run indefinitely when plugged into a wall outlet.
Battery	Li-ion; 24 W-h; battery life will depend on the sample configuration, filter media, sorbent media, and local air density; 8-h runtime on battery when collecting two filter samples on MTL PT37P-PF03 PTFE membrane filters at 2 L min <sup>-1</sup> and two gas samples on Markes Carbopack X SafeLok™ thermal desorption tubes at 30 mL min <sup>-1</sup> with PM sensor, CO <sub>2</sub> sensor, and one Alphasense B-series electrochemical sensor running in a location with air density = 1.0 g L <sup>-1</sup> .
Charging time	When the HHB is not running, the battery will charge fully in 2 hours using the provided 15 W, 5 V USB Type-C® wall adapter.

## Size, weight, and noise

Exterior size	213 mm × 132 mm × 107 mm, excluding size-selective inlets
Weight	Up to 1.5 kg; depends upon configuration and sample media installed
Noise	< 50 dB at 25 cm distance

## Data logging

Memory type	microSD™ card
Data logging interval	5, 15, 30, or 60 s; default = 30 s

## Operating conditions

Temperature	Operating = -20 to 60 °C; Charging = 0 to 45 °C; Storage = -20 to 50 °C
Relative humidity	Up to 95% at 40 °C (non-condensing)
Altitude	2,500 ft (760 m) below sea level to 20,000 ft (6,100 m) above sea level; all sample flow rates will be adjusted automatically for variations in air density within this altitude range.

## Included accessories and replacement parts

The HHB comes with a kit containing the following items. Contact [support@accsensors.com](mailto:support@accsensors.com) if you are missing any of these items.

Description	Qty	Replacement part specifications
Power supply	1	15 W, 5 V USB Type-C® adapter
USB Type-C® to USB Type-C® cable	1	Anker A8753, 60 W
Sorbent inlet blocks	2	For ¼" (6.35 mm) diameter media
microSD™ card	1	SanDisk Industrial 8 GB SDSDQAF3-008G-I
Filter socket O-ring	2	35-mm ID × 1-mm CS, Buna-N
Sorbent inlet block O-ring	2	6-mm ID × 1-mm CS, Viton™
microSD™ card O-ring	1	23-mm ID × 1-mm CS, Buna-N
Replacement sorbent cover screws	2	M3 × 0.5 mm, 6-mm long
T8 security Torx® driver	1	Wiha 36271
Sorbent cover plugs	4	Nylon locking panel plugs, for 5/16" diameter hole and 0.016" to 0.062" panel thickness

## Additional accessories available for purchase

The following accessories are purchased separately from the Home Health Box. Contact [sales@accsensors.com](mailto:sales@accsensors.com) to purchase any of these items.

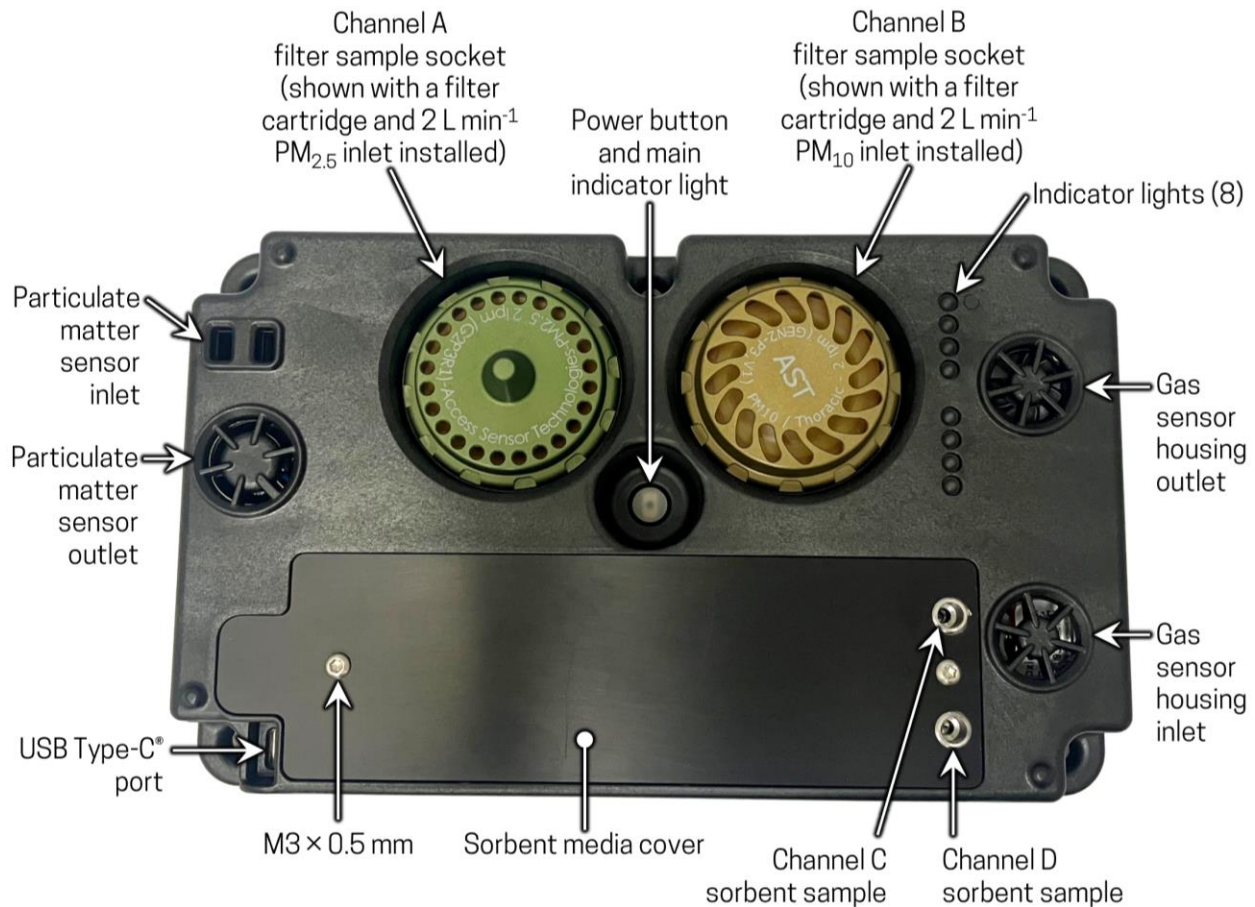
Description	Notes
Size-selective inlets PM <sub>2.5</sub> @ 1 L min <sup>-1</sup> PM <sub>2.5</sub> @ 2 L min <sup>-1</sup> Respirable PM @ 2 L min <sup>-1</sup> PM <sub>10</sub> @ 2 L min <sup>-1</sup>	A size-selective inlet is required to collect a particulate matter filter sample. All Access Sensor Technologies GEN2 inlets can be used with the HHB. The HHB v2 (manufactured in 2023 and later) <i>cannot</i> be used with GEN1 PM <sub>2.5</sub> 1 L min <sup>-1</sup> inlets.
Filter cartridges 37-mm 25-mm	A filter cartridge is required to collect a particulate matter filter sample.
Filter inlet flow check adapter	Seals over a size-selective inlet to allow the inlet of the filter sampling channel to be connected to a flow meter (can also be used to install and remove size-selective inlets)
Filter inlet tool	For installing and removing size-selective inlets
Sorbent inlet blocks; other diameters	Available upon request
Sorbent inlet block flow adapter	Inserts into the sorbent inlet block to connect the inlet of the sorbent sampling channel to a flow meter
Sorbent block lifting tool	M3 x 0.5 mm, 4-mm thread length

## Items not provided

Description	Notes
Flow meter	Required only for flow verification

See the section of this User Guide on [Verifying sample flow rates](#) for information on the flow meters we recommend for verifying the flow rates of HHB filter and sorbent samples. In brief, we recommend Alicat Whisper™ [MW-](#) or [MWB-Series](#) Low Pressure Drop Mass Flow Meters.

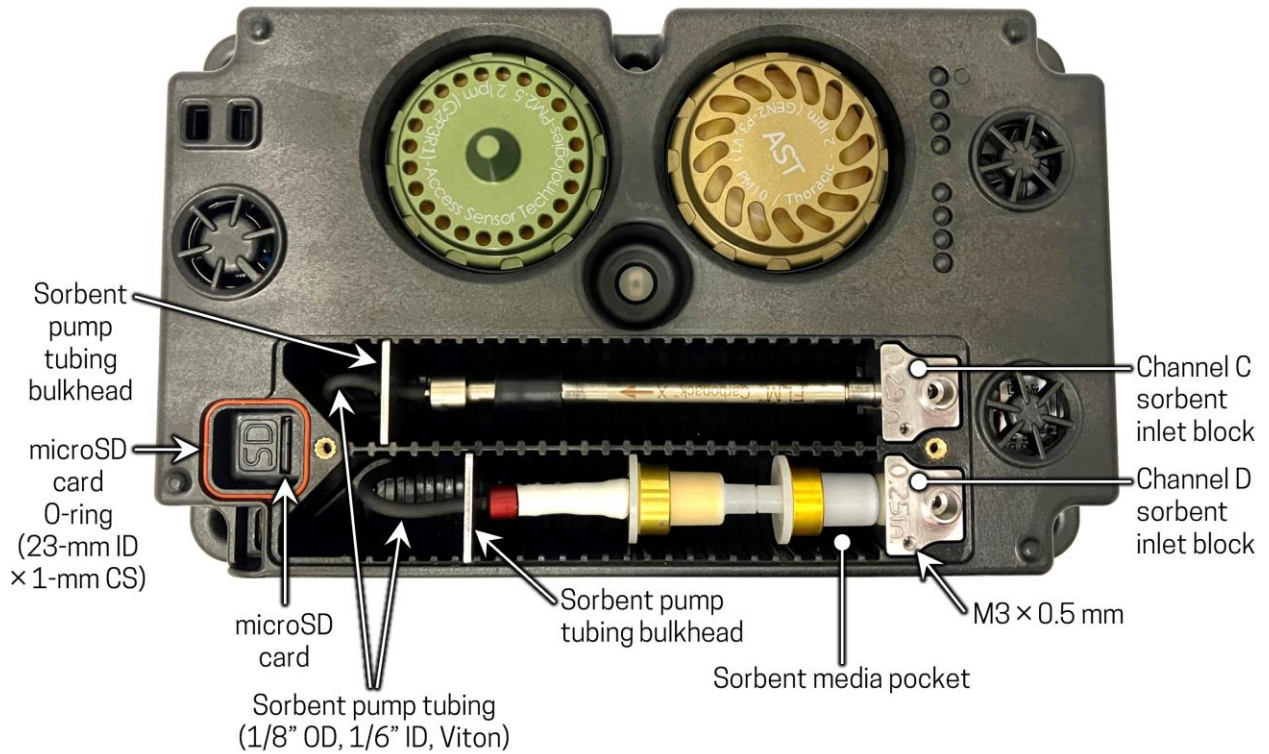
## Home Health Box at a glance



**Figure 1.** A fully-assembled Home Health Box with key components labeled. GEN2 PM<sub>2.5</sub> 2 L min<sup>-1</sup> and PM<sub>10</sub> 2 L min<sup>-1</sup> inlets are shown here as examples, but any of Access Sensor Technologies' GEN2 size-selective inlets can be installed on the HHB. The face shown here—with the filter sample, sorbent sample, PM sensor, and gas sensor housing inlets—is considered the “front” of the HHB.



**CAUTION:** There are no user-serviceable components inside the Home Health Box. Do not open the plastic enclosure (i.e., do not remove any cover besides the sorbent media cover). If the Home Health Box needs repair, return it to Access Sensor Technologies.



**Figure 2.** A photograph of the Home Health Box with the sorbent media cover removed. The thermal desorption tube in Channel C and Waters ozone scrubber/DNPH cartridge combination in Channel D are shown here as example sorbent media. No sorbent media are included with the purchase of the HHB. All sorbent media are to be supplied and installed by the user.



**Figure 3.** A photograph of the Home Health Box with the size-selective inlets, filter cartridges, sorbent media, and sorbent inlet blocks removed to show the Channel A, B, C, and D labels.



(a) Size-selective inlet PM<sub>2.5</sub> @ 1 L min<sup>-1</sup> (GEN2)



(b) Size-selective inlet PM<sub>2.5</sub> @ 2 L min<sup>-1</sup> (GEN2)



(c) Size-selective inlet Respirable PM @ 2 L min<sup>-1</sup> (GEN2)



(d) Size-selective inlet PM<sub>10</sub> @ 2 L min<sup>-1</sup> (GEN2)



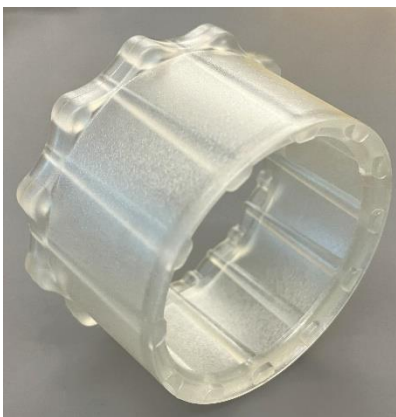
(e) Yellow 37-mm filter cartridge (GEN2)



(f) Blue 25-mm filter cartridge (GEN2)



(g) Filter inlet flow check adapter



(h) Filter inlet tool



(i) Sorbent inlet block flow adapter



(j) Sorbent block lifting tool

**Figure 4.** Home Health Box accessories.

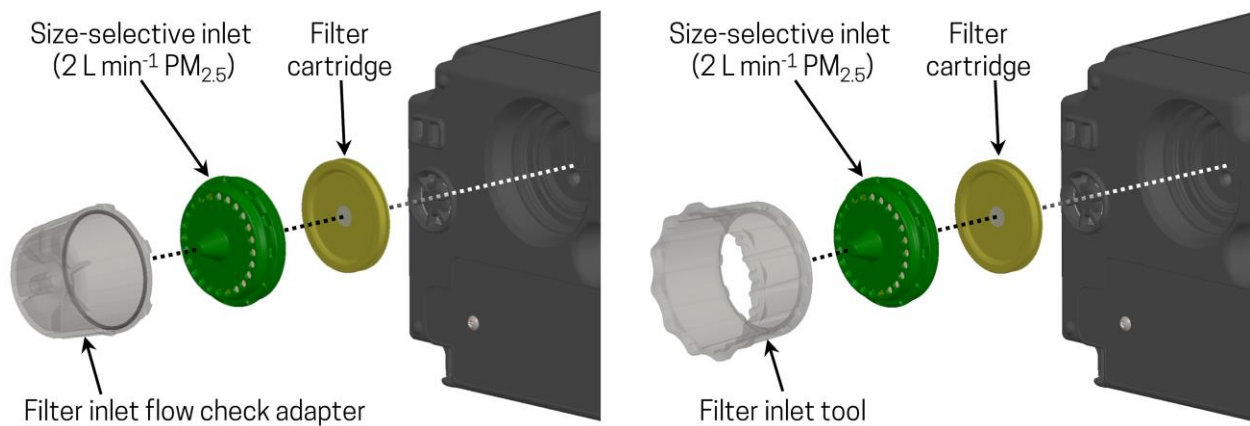


**Figure 5.** The Home Health Box is designed to be set down on a flat surface, as shown here, with the front of the box (i.e., the face with the inlets) facing the room during sampling (i.e., not facing towards a wall or up against any other vertical surface).

## Installing sample media

### Installing filter cartridges and size-selective inlets for PM sampling

Before installing an inlet and filter cartridge in a filter socket, confirm that the filter socket O-ring is in place and in good condition (see **Figure 3**). If the O-ring is damaged or missing, replace it before collecting a filter sample. The filter socket O-ring has a 35-mm inner diameter and a 1-mm-diameter round cross section.



**Figure 6.** A diagram illustrating how the size-selective inlet and filter cartridge should be installed in the HHB filter socket. The  $2 \text{ L min}^{-1} \text{ PM}_{2.5}$  inlet is shown here as an example. Use either the filter inlet flow check adapter (left) or the filter inlet tool (right) to screw down and tighten the size-selective inlet.

A GEN2 inlet and filter cartridge should be installed in the filter socket as shown in **Figure 6**. The easiest way to do this is to start by placing the inlet into the filter inlet tool [**Figure 4(h)**] or flow check adapter [**Figure 4(g)**]. Next, set the filter cartridge in the inlet so that the 8-mm-diameter hole in the top of the cartridge is facing the inlet. Then, use the tool to align the inlet and filter cartridge with the filter socket. Finally, screw the inlet into the socket and tighten it all the way.

## Installing sorbent tubes or cartridges for VOC sampling

- 1 Remove the sorbent media cover (see **Figure 1**) by using the T8 security Torx® driver to unscrew the two M3 screws.
- 2 Pull the sorbent inlet block and the sorbent pump tubing bulkhead (see **Figure 2**) up out of the sorbent media pocket so that you have more room to work with the inlet block and sorbent pump tubing.

**IMPORTANT!** Do not disconnect the 1/8" OD, 1/16" ID sorbent pump tubing from the HHB. If the left end of the sorbent pump tube is pulled out of the HHB enclosure, the HHB will need to be returned to AST so that the tube can be reconnected to the pump.

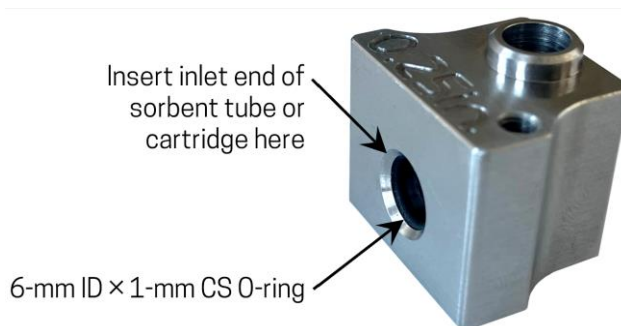
- 3 Insert the inlet end of the sorbent tube/cartridge into the hole on the left side of the sorbent inlet block (see **Figure 2** and **Figure 7**).

**IMPORTANT!** Make sure there is an O-ring installed in this hole and that the O-ring is in good condition so that the inlet of the sorbent tube or cartridge will seal to the inlet block.

- 4 On the outlet end of the sorbent tube or cartridge, connect whatever tubing and fittings are needed to adapt the outlet to the 1/8" OD, 1/16" ID sorbent pump tube. See **Figure 2** for examples of how ¼" (6.35 mm) OD x 3.5" (89 mm) long thermal desorption tubes and Waters™ Sep-Pak® Luer-Tip cartridges can be installed in the HHB.
- 5 Slide the completed assembly (consisting of the inlet block, the tube or cartridge, the sorbent pump tubing, and the tubing bulkhead) down into the grooved sorbent media pocket as shown in **Figure 2**.
- 6 Reinstall the sorbent media cover using the T8 security Torx® driver and two M3 screws.



**CAUTION:** Never run a HHB filter sample channel without a filter cartridge and filter in place. Never run a HHB sorbent sample channel without sorbent media in place. If these channels are run without sample media in place, dust and other particulate matter can damage the pumping elements.



**Figure 7.** Sorbent inlet block for ¼-inch- (6.35-mm-) diameter media.

## Installing a microSD™ card

HHB data are logged to a microSD™ card that is installed behind the sorbent media cover (see **Figure 1** and **Figure 2**). Remove the sorbent media cover by using the T8 security Torx® driver to unscrew the two M3 screws. Insert a microSD™ card into the microSD™ card slot with the pins on the microSD™ card facing the “SD” label that is molded into the HHB enclosure. Press down on the microSD™ card until it bottoms out.

## Power on/off sequence

### Plugging the Home Health Box into a wall outlet

To connect the HHB to line power, insert the USB Type-C® end of the 5V DC power adapter into the USB Type-C® port on the front of the HHB (see **Figure 1**). Then, plug the other end of the power adapter into a wall outlet.

**IMPORTANT!** The HHB comes with a 5 V USB Type-C® wall adapter that is rated for 15 W. Using a different wall adapter with a lower power rating could prevent the HHB from operating correctly. Always use the HHB with the power adapter that was supplied by AST.

The HHB contains a Li-ion battery to prevent sample loss during a short-term interruption of line power. The HHB will run for several hours on a fully-charged battery, but we do not recommend relying on battery for long-duration HHB operation. Plug the HHB into a wall outlet during sampling.

### Turning the Home Health Box on and off

To turn the HHB on, press the power button firmly until you feel a click. Continue holding the button down until the button light turns on (about five seconds). Release the button. The pushbutton requires an uninterrupted hold down of at least five seconds. If the pushbutton is released before the light turns on, the HHB does not power on; repeat the process.

To turn the HHB off, press the power button firmly until you feel a click. Continue holding the button down until the button light turns off (about five seconds). Release the button. If the HHB has been successfully powered down, the button light will remain off. If the HHB fails to shut down, try again with a fresh five-second button hold.

## Interpreting the main indicator light

The main indicator light is the light behind the HHB power button. See **Table 1** for descriptions of what the colors and the solid vs. flashing status of this light indicate about HHB operation.

**Table 1.** Interpreting the color and solid/flashing status of the main indicator light behind the power button.

Light color	Solid or flashing?	Home Health Box status
<b>Red</b>	Solid	Starting up.
<b>Blue</b>	*Flashing*	<p>Waiting; this could mean:</p> <ul style="list-style-type: none"> <li>a) The HHB is programmed to start a sample on this power up, but the microSD™ card is not installed; reinstall the microSD™ card and power cycle the HHB to start the sample.</li> <li>b) The HHB is programmed to start a sample at a specific UTC date and time, but that date and time has not yet been reached.</li> <li>c) The HHB is not programmed to start a sample on this power up; it is waiting to connect to the Configurator software to be programmed</li> </ul>
<b>Green</b>	*Flashing*	The HHB is waiting for the time to reach HH:MM:00 before starting the sample.
<b>Green</b>	Solid	Sampling, all volumetric flow rates within 4% of targets, HHB is plugged in and receiving power.
<b>Orange</b>	Solid	Sampling, all volumetric flow rates within 4% of targets, HHB is not plugged in or not receiving power from the outlet; restore line power to the HHB to ensure continued operation.
<b>Orange</b>	*Flashing*	Sampling, all volumetric flow rates within 4% of targets, HHB is not plugged in or not receiving power from the outlet, battery is very low; restore line power to the HHB immediately to prevent shutdown.

# 2 Programming Sample Settings

## Using the “HHBv2 Configurator” desktop software

These instructions were written for HHBv2 Configurator V1.3R1, which was released May 29, 2025 and was designed to work with firmware version “HHBv2\_Firmware\_250529.bin”.

### Installing the desktop software

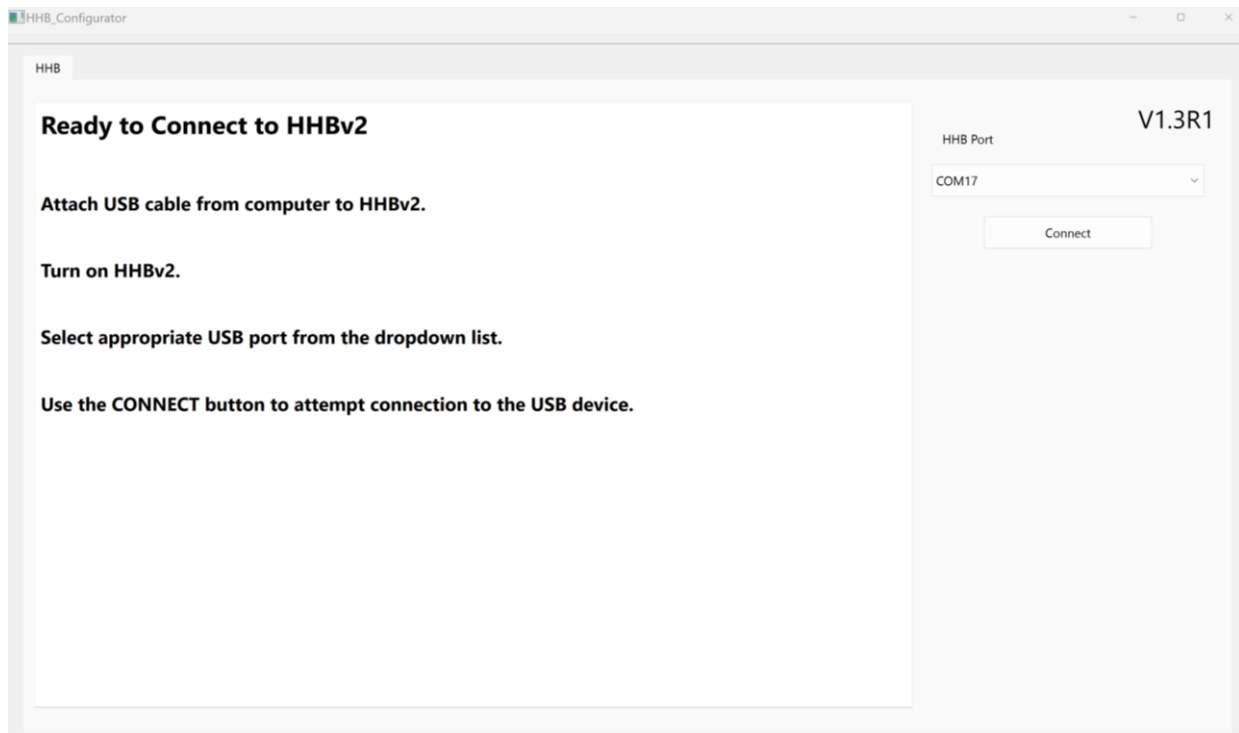
On a 64-Bit Windows PC

Download the “HHBv2 Configurator VX.XRX-executable.zip” folder (preferably to a folder on your hard drive, i.e., not a cloud-based location). Then, extract the files by right-clicking on the .zip folder and selecting “Extract All...” When the “Extract Compressed (Zipped) Folders” pop-up menu appears, confirm the folder to which the files will be extracted and then click the “Extract” button.

### Running the desktop software

On a 64-Bit Windows PC


Open the “HHBv2 Configurator VX.XRX-executable” folder to which the software files were extracted. Double click the “HHB\_Configurator.exe” executable file to open the software application. When the application opens, you should see the window shown in **Figure 8**.

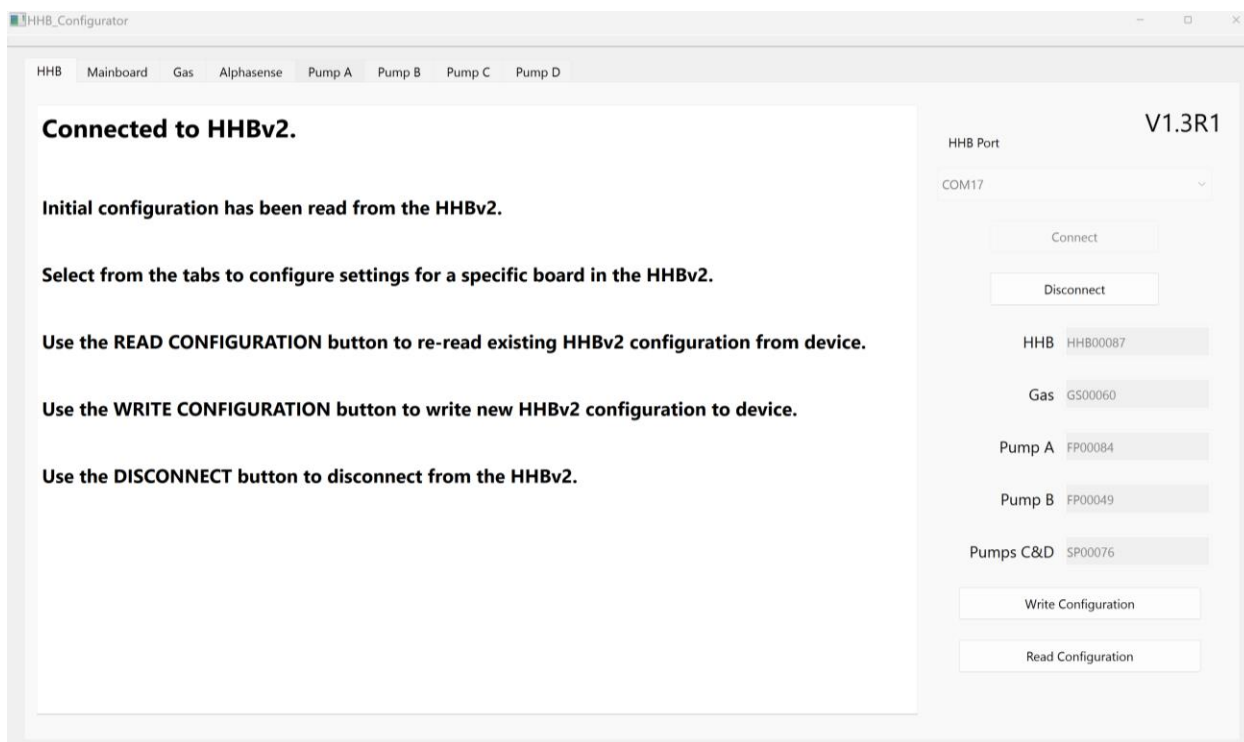


**Figure 8.** The window displayed when the HHBv2 Configurator software is opened. Follow these instructions to connect to a Home Health Box.

## Connecting to the Home Health Box

Follow the instructions displayed in the HHBv2 Configurator graphical user interface (GUI) to connect to a HHB (**Figure 8**):

- 1 Connect the Home Health Box to a Thunderbolt™ port on your computer using the USB Type-C® to USB Type-C® cable. A Thunderbolt™ port is a USB Type-C® receptacle marked with this symbol: 
- 2 Turn the Home Health Box on. Press the power button down until you feel a click and then continue to hold the button down until the button LED light turns on (approximately five seconds). When the HHB turns on, the button LED should blink blue.
- 3 Identify the COM port associated with the Home Health Box.  
**On a Windows PC:** Open the Device Manager, expand the list of “Ports (COM & LPT)”, and note the COM port number associated with the HHB. The HHB will be called “USB Serial Device.”
- 4 Select the appropriate COM port in the “HHB Port” drop-down menu in the upper-right corner of the GUI.
- 5 Hit the “Connect” button below the “HHB Port” drop-down menu.



**Figure 9.** The display shown when the HHBv2 Configurator software has connected to the Home Health Box.

Once the software has connected to the HHB, the display window will appear as shown in **Figure 9**. The main window will say “Connected to HHBv2” at the top, followed by “Initial configuration has been read from the HHBv2.” Below this text, instructions for programming the HHB sample settings will be listed. On the right side of the window, the “HHB Port” drop-down menu and “Connect” button will be grayed out. A “Disconnect” button will appear below the “Connect” button. Below the

“Disconnect” button, the serial numbers of the circuit boards installed in the HHB will be shown. Below the serial numbers, buttons labeled “Write Configuration” and “Read Configuration” will appear.

## Overview of the graphical user interface

There are eight tabs in the HHBv2 Configurator GUI—HHB, Mainboard, Gas, Alphasense, Pump A, Pump B, Pump C, and Pump D—where you can enter different settings and select variables that you want written to the log file (see **Figure 9**). Each tab includes settings related to the following:

- **Mainboard:** The HHB as a whole and the time-resolved PM sensor.
- **Gas:** Time-resolved gas sensors that are *not* Alphasense B-series electrochemical sensors.
- **Alphasense:** Alphasense B-series electrochemical sensors.
- **Pump A** and **Pump B:** Particulate matter samples.
- **Pump C** and **Pump D:** Gas samples.

When the Configurator software connects to an HHB, all fields in the Mainboard, Gas, Alphasense, Pump A, Pump B, Pump C, and Pump D tabs will populate with the most recent sample settings.

The next five sections contain the following information for each tab: (a) an image of the tab, (b) descriptions of the settings that can be adjusted in that tab, and (c) descriptions of the log variables that can be selected in that tab.

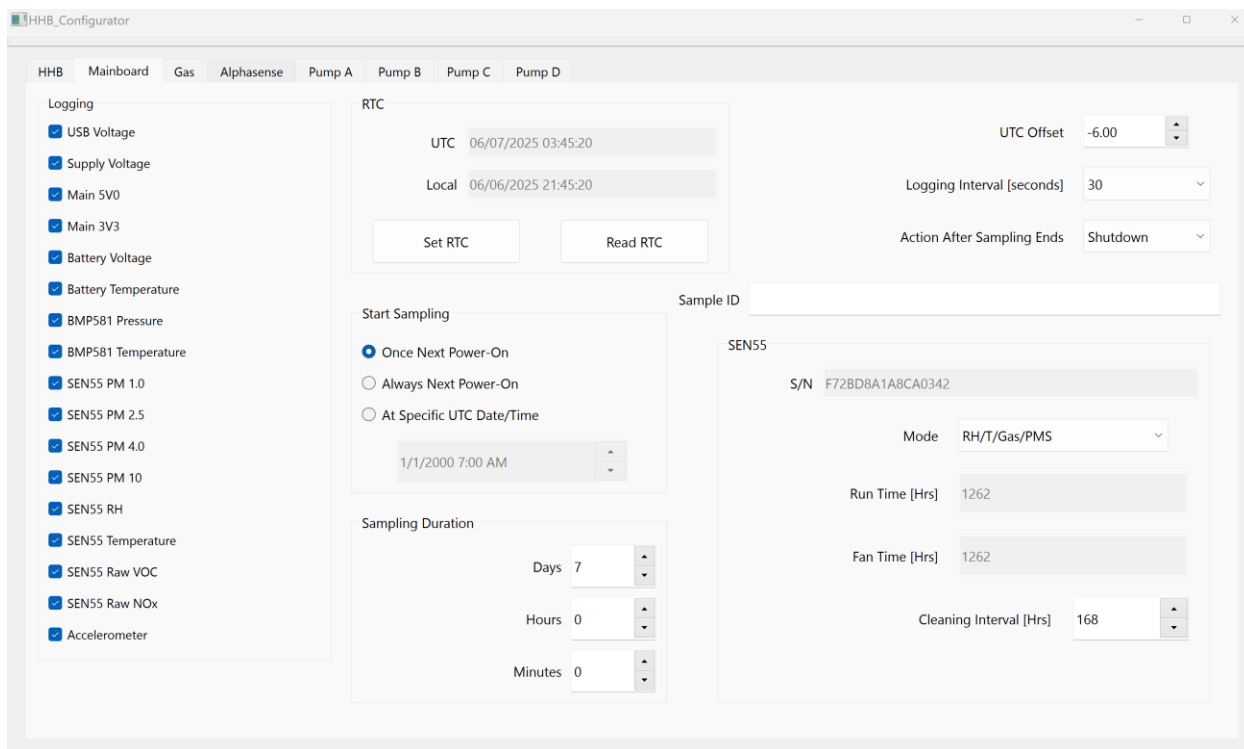
## Mainboard

The Mainboard tab is shown in **Figure 10**. There are four settings displayed in the top-right corner:

- **UTC Offset:** All HHB data are logged in Coordinated Universal Time (UTC). This box can be used to specify the offset, in hours, between UTC and the local time zone in the location where the HHB sample will be collected. The value specified here will be written to the header in the HHB log file and might be useful for displaying HHB log data with local timestamps. Changing this value does *not* affect the timestamp associated with the HHB log data; HHB data will be logged in UTC regardless of the value entered here.
- **Logging Interval [seconds]:** The interval, in seconds, at which HHB data will be logged. Options include 5, 15, 30, and 60 s.
- **Action After Sampling Ends:** What should the HHB do once the sample is complete? If “Shutdown” is selected, the HHB will turn off completely. If “Idle” is selected, the HHB will remain on, but air will no longer be sampled through the filters or sorbent media and data will no longer be written to the log file.
- **Sample ID:** Allows the user to enter a name that can be used to identify the sample. This name will be written in the HHB log file header.

## Logging

On the left side of the Mainboard tab, a list of variables is displayed. If the box next to the variable is checked, that variable will be logged. Conversely, if the box next to the variable is unchecked, that variable will *not* be logged. See **Table 2** for a description of each variable.



**Figure 10.** The mainboard sample settings in the HHBv2 Configurator software.

## RTC

The “RTC” box is used to set the timestamp on the real-time clock (RTC) inside the Home Health Box. When the software initially connects to the HHB, it will read the Coordinated Universal Time (UTC) from the HHB and display that time on the line labeled “UTC.” The line labeled “Local” will display the local time in the time zone to which the PC clock is set.

Clicking the “Set RTC” button will send the timestamp from the computer to the RTC in the HHB. Using the “Set RTC” button to update the time on the HHB regularly can help minimize clock drift and maintain accurate timestamps in the log file.

**IMPORTANT!** To ensure that the RTC gets set to the correct UTC time, make sure your computer has the correct timestamp and is set to the correct local time zone.

Clicking the “Read RTC” button will read the UTC time from the HHB and display it on the line labeled “UTC.” Additionally, the line labeled “Local” will update with local time in the time zone to which the PC clock is set. You can also confirm that the RTC is set to the correct UTC time and that the clock is advancing by clicking the “Read RTC” button and confirming that the correct times are displayed next to “UTC” and “Local.”

## Start Sampling

When should the HHB start the *overall* sample? In other words, when should the HHB start logging data from the time-resolved sensors?

- **Once Next Power-On:** The next time the HHB is powered on, it will start the sample. If the HHB turns off before the specified sample duration is complete and is turned back on later, it will resume sampling until the duration is reached and append data to the original log file.

Example: The HHB is programmed to sample for 7 days (168 h). When the HHB is turned on the next time, it will sample for 7 days and then stop. When the HHB is turned on again after the 7-day sample has completed, it will not start sampling; instead, the HHB will wait to connect to the Configurator to receive new sample settings.

Example of behavior in non-ideal scenario: The HHB is programmed to sample for 168 h. When the HHB is turned on the next time, it samples for 120 h before it is turned off. Later, the HHB is turned back on. Because the specified sample duration was not reached, the HHB will start sampling again automatically. The HHB will sample for another 48 h to reach the specified duration and will append the new data to the log file recorded during the initial 120 h of sampling. After the HHB has sampled for 168 h total, it will shut down. When the HHB is turned on again after it has sampled for a total of 168 h, it will wait to connect to the Configurator to receive new sample settings.

To prevent the HHB from resuming a sample the did not run to completion, remove the microSD™ card before turning the HHB back on; then, connect the HHB to the Configurator to program a new sample.

- **Always Next Power-On:** Each time the HHB is powered on, it will start a sample automatically using the settings specified here.

Example: The HHB is programmed to sample for 168 h. The HHB is turned on, samples for 168 h, and then shuts down. Later, when the HHB is turned back on, it starts a new sample automatically using the same settings. A new log file is written for each sample.

Example (non-ideal scenario): The HHB is programmed to sample for 168 h. When the HHB is turned on the next time, it samples for 120 h before it is turned off. Later, the HHB is turned back on. Because the specified sample duration was not reached, the HHB will sample for another 48 h to reach the specified duration and will append the new data to the log file recorded during the initial 120 h of sampling. After the HHB has sampled for 168 h total, it will shut down. When the HHB is turned on again after it has sampled for a total of 168 h, it will start a new 168-h sample automatically using the same settings. A new log file will be written for the new 168-h sample.

To exit this start mode and program new sample settings, remove the microSD™ card and connect the HHB to the Configurator.

- **At Specific UTC Date/Time:** The HHB will start sampling at the specified UTC time, assuming that the HHB is on at that time. If the HHB is powered off at the specified time, the HHB will start sampling immediately the next time it is powered on. Format the specified UTC time as mm/dd/YYYY HH:MM AM/PM.

Example: The HHB is programmed to start sampling at 06/15/2025 07:00:00 UTC. The HHB is turned on at 06/14/2025 23:30:00 UTC. The HHB will sit idle until 06/15/2025 07:00:00 UTC, when the HHB will begin sampling for the specified duration.

Example (non-ideal scenario): The HHB is programmed to start sampling at 06/15/2025 07:00:00 UTC. The HHB is turned on at 06/15/2025 12:00:00 UTC. The HHB will begin sampling immediately and will sample for the specified duration. The HHB will stop once the specified sample duration has elapsed since the actual sample start time.

## Sampling Duration

Specify the duration for which the HHB should sample, in days, hours, and minutes. The maximum number of hours that can be specified is 23 and the maximum number of minutes that can be specified is 59. To specify a duration longer than 23 hours and 59 minutes, increase the number of days.

Note that this is the *overall* sample duration. In other words, this is the duration for which all time-resolved sensors will run and log data. Any particulate matter and gas samples must also start and run within this duration—although each individual PM and gas sample can start after the beginning of the overall sample and stop before the end of the overall sample.

If the HHB turns off before the specified sample duration is complete and is then turned back on later, it will resume the sample until the specified duration has been reached. The resumed sample will append data to the original log file. To prevent the HHB from resuming a sample the did not run to completion, remove the microSD™ card before turning the HHB back on; then, connect the HHB to the Configurator to program a new sample.

## SEN55

These are settings related to the Sensirion SEN55 time-resolved PM sensor installed in the HHB:

- **S/N:** This line displays the serial number of the SEN55 sensor installed in the HHB.
- **Mode:** Use the drop-down menu to select the SEN55 operating mode.
  - Idle: The SEN55 sensor will go into a low-power mode. The fan will remain off. No measurements will be made, and no data will be logged from the sensor.
  - RH/T/Gas: The fan in the SEN55 will remain off. The sensor will measure RH and temperature as well as qualitative, relative levels of total volatile organic compounds (tVOCs) and nitrogen oxides (NO<sub>x</sub>) (see **Table 2**).
  - RH/T/Gas/PMS: The fan in the SEN55 will run. The sensor will measure RH, temperature, particulate matter (PM) concentrations, as well as qualitative, relative levels of tVOCs and NO<sub>x</sub>.
- **Run Time [Hrs]:** The number of hours for which this sensor has run.
- **Fan Time [Hrs]:** The number of hours for which the fan in this sensor has run.
- **Cleaning Interval [Hrs]:** The interval, in hours, at which the SEN55 fan-cleaning procedure should run. During cleaning, the fan will accelerate to its maximum speed for 10 s to try to clear accumulated dust. Measurements are not collected during this 10-s period. Sensirion recommends running the cleaning procedure once every 168 h. The cleaning procedure will run every time the SEN55 sensor is powered on. If the sensor is still running after the cleaning interval has elapsed, the cleaning procedure will run again.

**Table 2.** Variables that can be selected or deselected for logging in the HHBv2 Configurator Mainboard tab.

Variable	Units	Description
USB Voltage	(V)	Voltage on the USB Type-C® connector; will = 0 if USB power was not connected; otherwise, this value could range from 3.5 to 9.5 V; useful for troubleshooting.
Supply Voltage	(V)	Main supply voltage, converted from either the USB Type-C® or battery voltage, for powering the HHB and generating all necessary voltage rails; should be 4.25 to 4.75 V; useful for troubleshooting.
Main 5V0	(V)	Voltage on the 5.0 V rail on the main circuit board; should be 4.75 to 5.25 V; useful for troubleshooting.
Main 3V3	(V)	Voltage on the 3.3 V rail on the main circuit board; should be 3.15 to 3.47 V; useful for troubleshooting.
Battery Voltage	(V)	Battery voltage (i.e., state of charge): Maximum = 4.25; below 3.2 is "low battery"; below 3.0 the HHB will shut down if not plugged in.
Battery Temperature	(°C)	Battery temperature; useful for troubleshooting in the event of a high- or low-temperature shutdown event.
BMP581 Pressure	(PaA)	Absolute pressure measured by the Bosch BMP581 sensor that is mounted to the main circuit board and vented to the inside of the sorbent media compartment. This pressure is expected to be closest to the "true" atmospheric pressure.
BMP581 Temperature	(°C)	Temperature measured by the Bosch BMP581 sensor that is mounted to the main circuit board and vented to the inside of the sorbent media compartment.
SEN55 PM 1.0	( $\mu\text{g m}^{-3}$ )	PM <sub>1</sub> concentration reported by the Sensirion SEN55. We expect this value to be correlated with the true PM <sub>1</sub> concentration, but do not recommend interpreting this value as an exact concentration.
SEN55 PM 2.5	( $\mu\text{g m}^{-3}$ )	PM <sub>2.5</sub> concentration reported by the Sensirion SEN55. We expect this value to be correlated with the true PM <sub>2.5</sub> concentration, but do not recommend interpreting this value as an exact concentration; scaling these sensor-reported values to a filter-derived PM <sub>2.5</sub> concentration might improve accuracy. For additional information, see: <a href="https://doi.org/10.1016/j.jaerosci.2020.105654">https://doi.org/10.1016/j.jaerosci.2020.105654</a>
SEN55 PM 4.0	( $\mu\text{g m}^{-3}$ )	PM <sub>4</sub> concentration reported by the Sensirion SEN55. Published data suggest that other low-cost optical PM sensors, similar to the SEN55, do not detect 4.0- $\mu\text{m}$ particles efficiently; therefore, this value might not be correlated with the true PM <sub>4</sub> concentration and we do not recommend using it. For additional information, see: <a href="https://doi.org/10.5194/amt-13-2413-2020">https://doi.org/10.5194/amt-13-2413-2020</a>
SEN55 PM 10	( $\mu\text{g m}^{-3}$ )	PM <sub>10</sub> concentration reported by the Sensirion SEN55. Published data suggest that other low-cost optical PM sensors, similar to the SEN55, do not detect 10- $\mu\text{m}$ particles efficiently; therefore, this value might not be correlated with the true PM <sub>10</sub> concentration and we do not recommend using it. For additional information, see:

<https://doi.org/10.1021/acs.estlett.3c00030>  
<https://doi.org/10.5194/amt-13-2413-2020>

SEN55 RH	(%)	Relative humidity measured by the SEN55. This value is expected to be closest to the true atmospheric RH because there is continuous airflow through the SEN55 in RH/T/Gas/PMS mode.
SEN55 Temperature	(°C)	Temperature measured by the SEN55. This value is expected to be closest to the true atmospheric temperature because there is continuous airflow through the SEN55 in RH/T/Gas/PMS mode.
SEN55 Raw VOC	(integer)	Raw VOC output signal from the Sensirion SEN55. This value is from a Sensirion SGP41 sensor installed in the SEN55. This value should decrease as the VOC concentration increases; see the <a href="#">SGP41</a> datasheet from Sensirion for additional details. AST has not verified independently that this value is correlated with or accurately reflects the total VOC concentration.
SEN55 Raw NO <sub>x</sub>	(integer)	Raw NO <sub>x</sub> output signal from the Sensirion SEN55. This value is from a Sensirion SGP41 sensor installed in the SEN55. This value should increase as the NO <sub>x</sub> concentration increases; see the <a href="#">SGP41</a> datasheet from Sensirion for additional details. AST has not verified independently that this value is correlated with or accurately reflects the NO <sub>x</sub> concentration.
Accelerometer	(integer)	Checking this box logs three columns of data from the accelerometer inside the HHB: linear acceleration in the x-direction, linear acceleration in the y-direction, and linear acceleration in the z-direction, all relative to the accelerometer position on the HHB. These values can be used to estimate the orientation of the HHB.

## Gas sensors

On the Gas tab shown in **Figure 11**, settings can be programmed for time-resolved gas sensors that are *not* Alphasense B-series electrochemical sensors. If a given sensor is not installed, all settings within the box corresponding to that sensor, and the associated log variables, will be grayed out.

### Logging

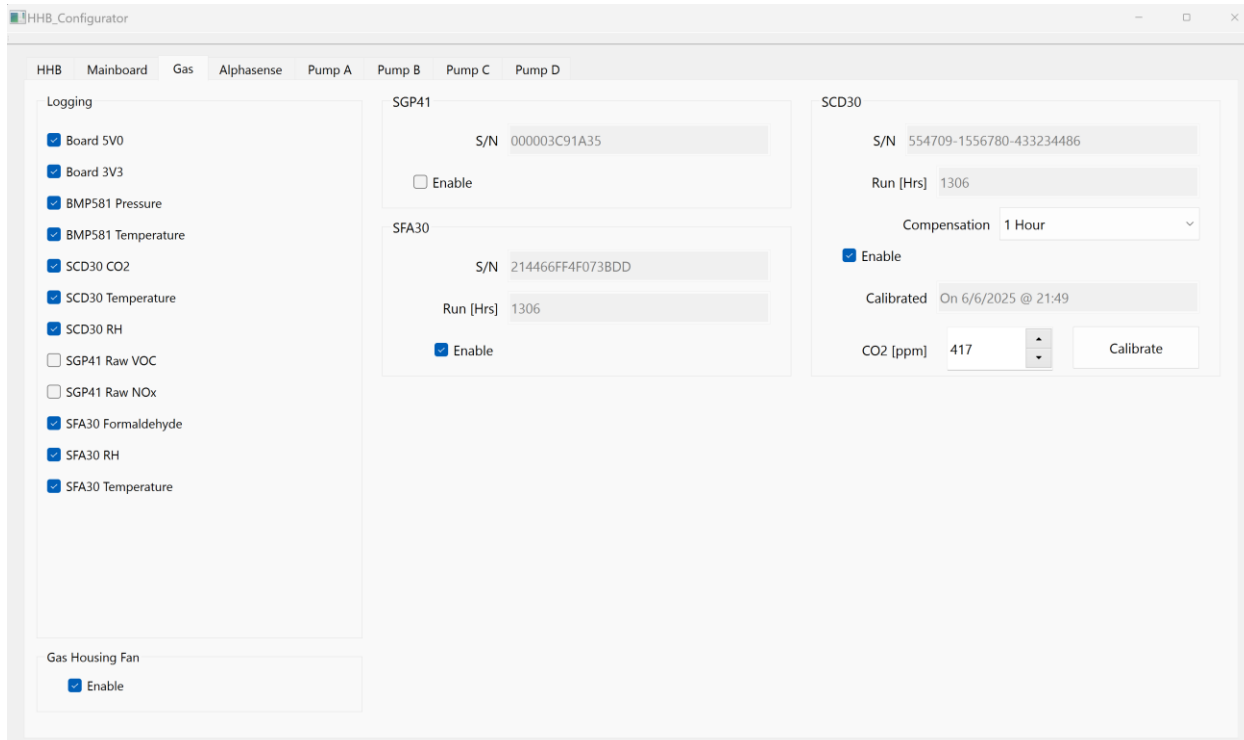
On the left side of the Gas tab, a list of variables is displayed. If the check box next to the variable is selected, that variable will be logged. Conversely, if the check box next to the variable is deselected, that variable will *not* be logged. See **Table 3** for a description of each variable.

### Gas Housing Fan

There is a fan installed on the outlet of the gas sensor housing that pulls air through the inlet of the gas sensor housing and past the CO<sub>2</sub> and electrochemical sensors (see **Figure 1**).

When the “Enable” box is checked, the gas housing fan will turn on when the “Write Configuration” button on the “HHB” tab is pressed and will also turn on during any subsequent samples. **We recommend enabling the gas housing fan during sampling to minimize the response time associated with measurements from the CO<sub>2</sub> and electrochemical gas sensors inside the HHB.**

If the “Enable” box is unchecked, the gas housing fan will turn off when the “Write Configuration” button on the “HHB” tab is pressed and will remain off during any subsequent samples. For most sampling applications, we *do not* recommend turning the gas housing fan off. You might want to turn the gas housing fan off in a special application; for example, if you want to log HHB data while flowing calibration gas into the inlet of the gas sensor housing and you want the flow rate through the housing to be controlled by the flow rate of your calibration gas (as opposed to the fan).



**Figure 11.** The gas sensor settings that can be programmed using the HHBv2 Configurator software.

## SGP41

If the HHB has a Sensirion SGP41 sensor installed on the gas sensor PCB (i.e., in addition to the SGP41 sensor in the SEN55 sensor), the serial number of this sensor will be displayed next to the “S/N” label. If the “Enable” box is checked, the sensor will operate normally and raw VOC and NO<sub>x</sub> values from the sensor will be written to the log file (unless those variables are manually unchecked in the “Logging” box on the left side of the Gas tab). If the “Enable” box is unchecked, the sensor will go into a low-power mode and no data from the sensor will be written to the log file.

## SCD30

These are settings related to the Sensirion SCD30 NDIR CO<sub>2</sub> sensor installed in the HHB:

- **S/N:** This line displays the serial number of the SCD30 sensor installed in the HHB.
- **Run [Hrs]:** The number of hours for which this sensor has run.
- **Compensation:** CO<sub>2</sub> readings from the SCD30 sensor should be corrected for temperature, humidity, and pressure. In the HHB, CO<sub>2</sub> readings are compensated using the temperature and RH values read by the SCD30 sensor as well as the pressure measured by a Bosch BMP581 sensor in the gas sensor housing (the SCD30 sensor is also inside the gas sensor housing).

housing). Use this drop-down menu to select the frequency at which the temperature, RH, and pressure values used for compensation are updated.

- None: Readings will not be corrected for temperature or air density.
  - 1 Minute: The values used for compensation will be updated every minute.
  - 1 Hour: The values used for compensation will be updated every hour. This is the default selection.
  - 1 Day: The values used for compensation will be updated every 24 hours.
- **Enable:** If this box is checked, the sensor will operate normally and CO<sub>2</sub>, temperature, as well as RH readings from the sensor will be written to the log file (unless those variables are manually unchecked in the “Logging” box on the left side of the Gas tab). If this box is unchecked, the sensor will be put into a low-power mode and no data from the sensor will be written to the log file.
  - **Calibrated:** This line displays the local date and time (mm/dd/yyyy @ HH:MM) when the sensor was last calibrated to a known CO<sub>2</sub> concentration. If the sensor has never been manually calibrated, this line will say “None” instead of displaying a date and time.
  - **CO<sub>2</sub> [ppm] and Calibrate button:** The SCD30 sensor can be calibrated by placing the HHB in an environment where the CO<sub>2</sub> concentration is known, entering the known concentration in the box labeled “CO<sub>2</sub> [ppm],” and clicking the “Calibrate” button. The sensor must run for at least 2 minutes before it can be calibrated. Write a configuration with the SCD30 enabled to the HHB and then let the HHB run with the SCD30 enabled for at least 2 minutes (the HHB can remain connected to the configurator during this time; a formal sample need not be started). Then, enter the known CO<sub>2</sub> concentration and press the “Calibrate” button to recalibrate the sensor instantaneously.

**Note:** If the sensor is being recalibrated using outdoor air, the CO<sub>2</sub> concentration in outdoor air is approximately 420 ppm.

### SFA30 [obsolete]

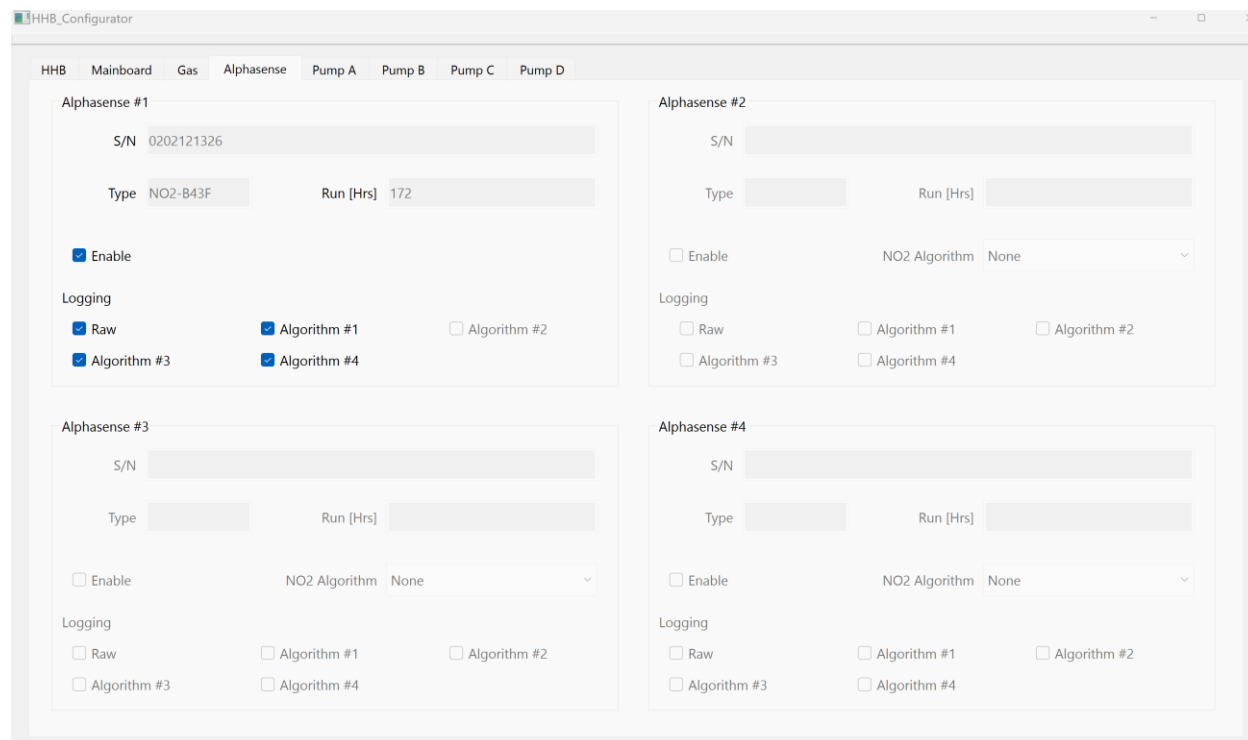
This box corresponded to the Sensirion SFA30 electrochemical formaldehyde sensor that could have been installed in the HHB before Sensirion discontinued the SFA30. If this sensor was installed, the serial number of the sensor was displayed next to the “S/N” label and the total number of hours for which the sensor had been powered on was displayed next to the “Run [Hrs]” label. If the “Enable” box was checked, the sensor operated normally and the formaldehyde concentration, RH, and temperature measured by the sensor were written to the log file (unless those variables were manually unchecked in the “Logging” box on the left side of the Gas tab). If the “Enable” box was unchecked, the sensor was put into a low-power mode and no data from the sensor was written to the log file.

**Table 3.** Variables that can be selected or deselected for logging in the Gas tab of the HHBv2 Configurator

Variable	Units	Description
Board 5V0	(V)	The voltage on the 5.0 V rail on the gas sensor circuit board; should be 4.75 to 5.25 V; useful for troubleshooting.
Board 3V3	(V)	The voltage on the 3.3 V rail on the gas sensor circuit board; should be 3.15 to 3.47 V; useful for troubleshooting.
BMP581 Pressure	(PaA)	Absolute pressure measured by the Bosch BMP581 sensor inside gas sensor housing.
BMP581 Temperature	(°C)	Temperature measured by Bosch BMP581 sensor in gas sensor housing. This sensor is mounted to the gas sensor circuit board.
SCD30 CO2	(ppm)	CO <sub>2</sub> concentration measured by the Sensirion SCD30 NDIR sensor. This value accounts for the most recent calibration. If the compensation setting is “1 Minute,” “1 Hour,” or “1 Day,” this value has also been corrected for atmospheric pressure and temperature.
SCD30 Temperature	(°C)	Temperature measured by the Sensirion SCD30 sensor (inside the gas sensor housing). This temperature is recommended for interpreting data from any Alphasense B-series electrochemical sensors installed in the HHB.
SCD30 RH	(%)	Relative humidity measured by the Sensirion SCD30 sensor (inside the gas sensor housing). This RH value is recommended for interpreting data from any Alphasense B-series electrochemical sensors installed in the HHB.
SGP41 Raw VOC	(integer)	Raw VOC output signal from the Sensirion SGP41 sensor on the gas sensor circuit board. This value should decrease as the VOC concentration increases; see the <a href="#">SGP41</a> datasheet from Sensirion for additional details. AST has not verified independently that this value is correlated with or accurately reflects the total VOC concentration.
SGP41 Raw NO <sub>x</sub>	(integer)	Raw NO <sub>x</sub> output signal from the Sensirion SGP41 sensor on the gas sensor circuit board. This value should increase as the NO <sub>x</sub> concentration increases; see the <a href="#">SGP41</a> datasheet from Sensirion for additional detail. AST has not verified independently that this value is correlated with or accurately reflects the NO <sub>x</sub> concentration.
SFA30 Formaldehyde	(ppb)	Formaldehyde concentration reported by the <a href="#">Sensirion SFA30</a> sensor [ <b>obsolete</b> ].
SFA30 RH	(%)	Relative humidity measured by the Sensirion SFA30 sensor inside the gas sensor housing [ <b>obsolete</b> ].
SFA30 Temperature	(°C)	Temperature measured by the Sensirion SFA30 sensor inside the gas sensor housing [ <b>obsolete</b> ].

## Alphasense electrochemical gas sensors

Settings related to any Alphasense B-series electrochemical gas sensors installed in the HHB are controlled on the Alphasense tab (**Figure 12**). Up to four such sensors can be installed in the HHB. The boxes labeled Alphasense #1–#4 correspond to positions where these sensors can be installed. The box associated with a position will be grayed out if there is no sensor installed there.



**Figure 12.** Settings for the Alphasense B-series electrochemical gas sensors that can be programmed using the HHBv2 Configurator software.

If a sensor is installed in a given position, the serial number of the sensor will be displayed next to the “S/N” label, the model of the sensor (e.g., NO2-B43F, CO-B4) will be displayed next to “Type,” and the total number of hours for which that sensor has been powered on will be displayed next to “Run [Hrs].” If the “Enable” box is checked, the sensor will be powered on. If the “Enable” box is unchecked, the sensor will *not* be powered on and no data from the sensor will be written to the log file.

Below the “Enable” box for each sensor, the following variables are listed under “Logging:” Raw, Algorithm #1, Algorithm #2, Algorithm #3, and Algorithm #4. If the check box next to one of these variables is selected, that variable will be logged; if the check box next to a variable is deselected, that variable will *not* be logged. See **Table 4** for a description of each variable.

If there is an NO2-B43F sensor installed in one position *and* an OX-B431 sensor installed in another position, a drop-down menu labeled “NO2 Algorithm” will appear to the right of the “Enable” box for the OX-B431 sensor. The OX-B431 sensor responds to both O<sub>3</sub> and NO<sub>2</sub>; so, to estimate an O<sub>3</sub> concentration in ppb, the working electrode (WE) and auxiliary electrode (AE) voltages output by the OX-B431 sensor must be corrected to account for the NO<sub>2</sub> concentration. Use the “NO2 Algorithm” drop-down menu to choose an algorithm to be used to estimate the NO<sub>2</sub> concentration (from the NO2-B43F sensor WE and AE voltages) that will be used for this correction. Up to five options may

appear in this drop-down menu: None, Algorithm #1, Algorithm #2, Algorithm #3, and Algorithm #4. If the NO<sub>2</sub>-B43F sensor's auxiliary electrode output in zero air (AE<sub>0</sub>) is equal to zero, the "Algorithm 2" option will *not* be available. Alphasense recommends using Algorithm #1 to estimate NO<sub>2</sub> concentrations from NO<sub>2</sub>-B43F sensor WE and AE voltages.

**Table 4.** Variables that can be selected or deselected for logging in the Alphasense tab of the Configurator.

Variable	Units	Description
Raw	(V)	Checking this box logs the working and auxiliary electrode voltages from the Alphasense B-series electrochemical sensor.
Algorithm #1	(ppb)	Checking this box logs the gas concentration calculated from the working electrode (WE) and auxiliary electrode (AE) voltages using Algorithm 1 from Alphasense Application Note (AAN) 803-05.
Algorithm #2	(ppb)	Checking this box logs the gas concentration calculated from the WE and AE voltages using Algorithm 2 from AAN 803-05. <b>If the sensor auxiliary electrode output in zero air (AE<sub>0</sub>) is equal to zero, Algorithm 2 cannot be used and this checkbox will be grayed out.</b>
Algorithm #3	(ppb)	Checking this box logs the gas concentration calculated from the WE and AE voltages using Algorithm 3 from AAN 803-05.
Algorithm #4	(ppb)	Checking this box logs the gas concentration calculated from the WE and AE voltages using Algorithm 4 from AAN 803-05.

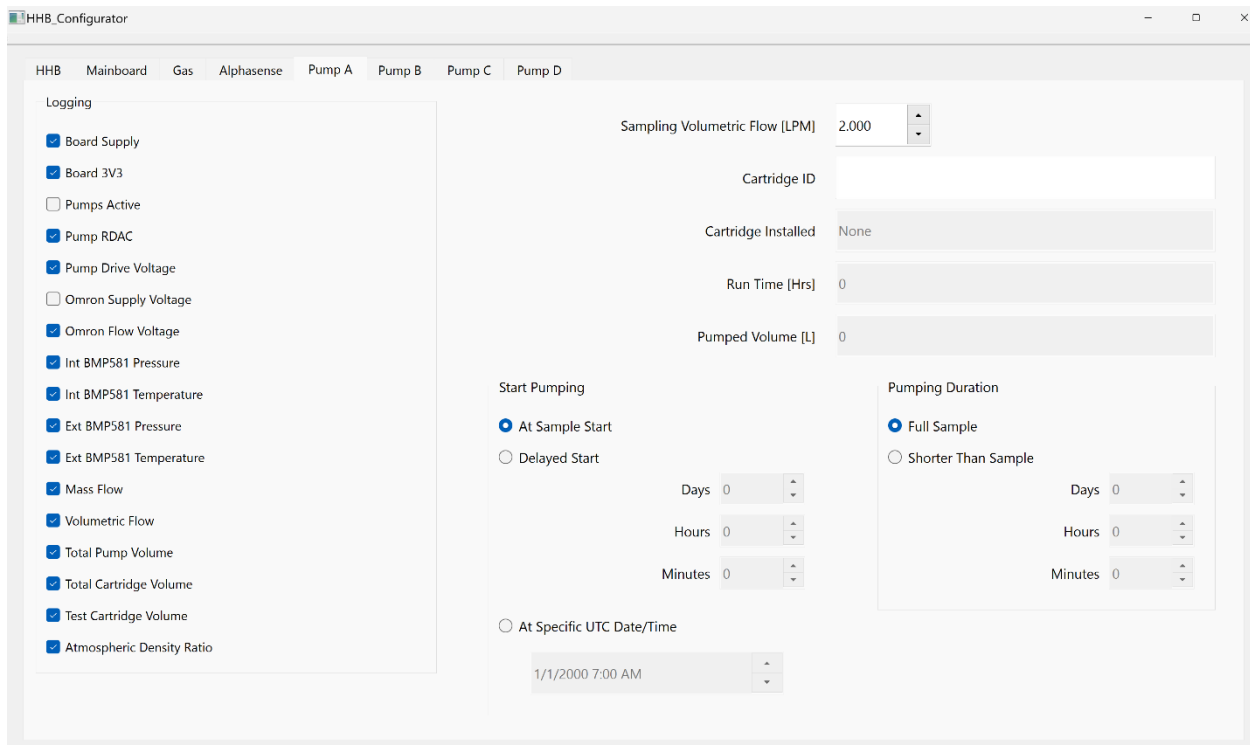
## Filter samples

The Pump A and Pump B tabs are identical. Use the Pump A tab (**Figure 13**) to set up the Channel A filter sample, which corresponds to the filter cartridge/inlet socket on the left side of the HHB. Use the Pump B to set up the Channel B filter sample, which corresponds to the filter cartridge/inlet socket on the right side of the HHB.

On the left side of the Pump A and Pump B tabs, a list of variables is displayed. If the check box next to the variable is selected, that variable will be logged. Conversely, if the check box next to the variable is deselected, that variable will *not* be logged. See **Table 5** for a description of each variable.

There are two settings and three informational lines displayed on the top right side of each tab:

- **Sampling Volumetric Flow [LPM]:** Enter the volumetric flow rate at which you want the filter sample to be collected. This flow rate should correspond to the flow rate for which the size-selective inlet was designed (either 1 L min<sup>-1</sup> or 2 L min<sup>-1</sup>; this value will be etched on the front of the inlet). **If you want the pump to remain off during the sample, enter zero.**
- **Cartridge ID:** Enter the identifier for the filter cartridge that will be used to collect the sample. Updating this value will reset the following variables in the log file to zero: FilterCartridgeStartingVolume, FilterCartridgeStartingRuntime, and TotalCartridgeVol.
- **Cartridge Installed:** Date and time that the cartridge ID for this channel was last updated.
- **Run Time [Hrs]:** Displays the duration for which air has been sampled through the filter cartridge since the cartridge identifier for this channel was last updated.
- **Pumped Volume [L]:** Displays the cumulative volume of air that has been sampled through the cartridge since the cartridge identifier for this channel was last updated.



**Figure 13.** The filter sample settings that can be programmed using the HHBv2 Configurator.

## Start Pumping

When should the HHB start this filter sample?

- **At Sample Start:** Start this filter sample when the overall HHB sample starts (i.e., at the time specified in the “Start Sampling” box on the Mainboard tab).
- **Delayed Start:** Start this filter sample the specified number of days, hours, and minutes after the overall HHB sample starts. The maximum number of hours that can be specified is 23 and the maximum number of minutes that can be specified is 59. To specify a duration longer than 23 hours and 59 minutes, increase the number of days.
- **At Specific UTC Date/Time:** This sample will start at the specified UTC time, assuming that the overall HHB sample is running at that time. Format the specified UTC time as mm/dd/YYYY HH:MM AM/PM. If the overall HHB sample is set to start “Once Next Power-On” or “Always Next Power-On,” this option will not be available.

## Pumping Duration

For how long should this filter sample be collected?

- **Full Sample:** The sample will be collected until the overall HHB sample ends.
- **Shorter Than Sample:** Specify the duration for which this sample should be collected in days, hours, and minutes. The maximum number of hours that can be specified is 23 and the maximum number of minutes that can be specified is 59. To specify a duration longer than 23 hours and 59 minutes, increase the number of days.

Each pump should be programmed to start at the same time or after the overall HHB sample and

should be programmed to end before or at the same time as the overall HHB sample. See **Table 7** for an explanation of how the Configurator and HHB will behave if the Start Pumping or Pumping Duration parameters are specified in a manner that conflicts with the Start Sampling and Sampling Duration parameters on the Mainboard tab.

**Table 5.** Variables that can be selected or deselected for logging in the HHBv2 Configurator Pump A and B tabs.

Variable	Units	Description
Board Supply	(V)	Supply voltage, converted from either the USB Type-C® or battery voltage, for powering the HHB; used for generating the 3.3V supply and pump drive voltages on the filter pump circuit board; should be 4.25 to 4.75 V; useful for troubleshooting.
Board 3V3	(V)	Voltage on the 3.3 V rail on the filter pump circuit board; should be 3.15 to 3.47 V; useful for troubleshooting.
Pumps Active	(integer)	ID numbers of the pumping elements that are active; useful for troubleshooting.
Pump RDAC	(integer)	Pump power level; useful for troubleshooting.
Pump Drive Voltage	(V)	Voltage input to drive the pumps; useful for troubleshooting.
Omron Supply Voltage	(V)	Voltage supplied to power the mass flow sensor; useful for troubleshooting.
Omron Flow Voltage	(V)	Voltage output by the mass flow sensor; this is the raw reading of the air mass flow rate.
Int BMP581 Pressure	(PaA)	Absolute pressure measured by the Bosch BMP581 sensor installed inside the pump manifold.
Int BMP581 Temperature	(°C)	Temperature measured by the Bosch BMP581 sensor installed inside the pump manifold.
Ext BMP581 Pressure	(PaA)	Absolute pressure measured by the Bosch BMP581 sensor installed outside the pump manifold.
Ext BMP581 Temperature	(°C)	Temperature measured by the Bosch BMP581 sensor installed outside the pump manifold.
Mass Flow	(g min <sup>-1</sup> )	Mass flow rate of air through the sample filter.
Volumetric Flow	(L min <sup>-1</sup> )	Volumetric air flow rate through the sample filter.
Total Pump Volume	(L)	Cumulative volume of air sampled through this channel since the pump was installed.
Total Cartridge Volume	(L)	Cumulative volume of air sampled through the filter during all samples since the filter was installed.
Test Cartridge Volume	(L)	Cumulative volume of air sampled through the filter during this sample.
Atmospheric Density Ratio	(g L <sup>-1</sup> )	Air density calculated from measured temperature/pressure/RH values and used to relate mass flow to volumetric flow for the filter sample.

## Gas samples

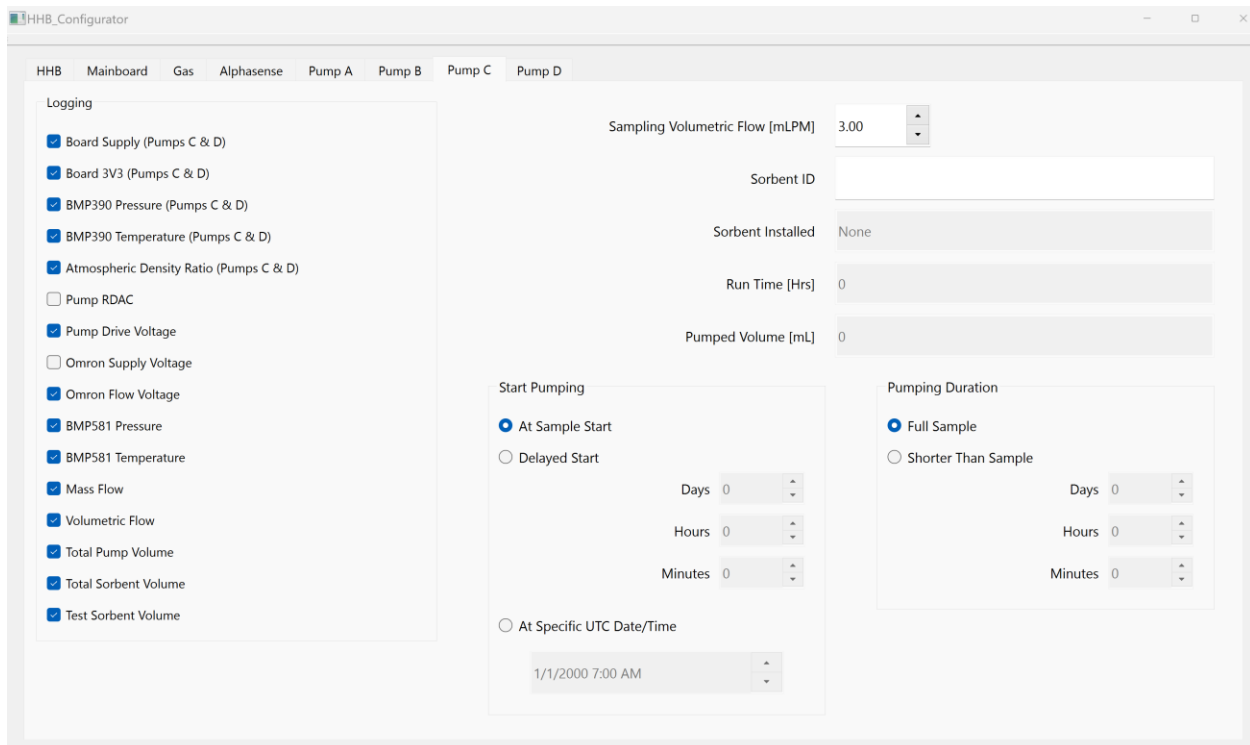
The Pump C and Pump D tabs are identical. Use the Pump C tab (**Figure 14**) to set up the Channel C gas sample (on the top of the sorbent media pocket) and the Pump D tab to set up the Channel D

gas sample (on the bottom of the sorbent media pocket).

On the left side of the Pump C and Pump D tabs, a list of variables is displayed. If the check box next to the variable is selected, that variable will be logged. Conversely, if the check box next to the variable is deselected, that variable will *not* be logged. See **Table 6** for a description of each variable. If the label next to a variable includes “(Pumps C & D)” at the end, that variable is common to both Channel C and Channel D. Selecting or deselecting one of these variables on *either* the Pump C or Pump D tab will automatically select or deselect that variable on the other tab.

There are two settings and three informational lines displayed on the top right side of each tab:

- **Sampling Volumetric Flow [mLPM]:** Enter the volumetric flow rate, in  $\text{mL min}^{-1}$ , at which you want the sample to be collected. **If you want the pump to remain off during the sample, enter zero.**
- **Sorbent ID:** Enter the identifier for the sorbent tube or cartridge that will be used to collect the sample. Updating this value will reset the following variables in the log file to zero: SorbentCartridgeStartingVolume, SorbentCartridgeStartingRuntime, and TotalSorbentVol.
- **Sorbent Installed:** Displays the date and time when the sorbent ID was last updated.
- **Run Time [Hrs]:** Displays the duration for which air has been sampled through the sorbent since the sorbent identifier for this channel was last updated.
- **Pumped Volume [mL]:** Displays the cumulative volume of air that has been sampled through the sorbent since the sorbent identifier for this channel was last updated.



**Figure 14.** The gas sample settings that can be programmed using the HHBv2 Configurator.

## Start Pumping

When should the HHB start this gas sample?

- **At Sample Start:** Start this sample when the overall HHB sample starts (i.e., at the time specified in the “Start Sampling” box on the Mainboard tab.
- **Delayed Start:** Start this sample the specified number of days, hours, and minutes after the overall HHB sample starts. The maximum number of hours that can be specified is 23 and the maximum number of minutes that can be specified is 59. To specify a duration longer than 23 hours and 59 minutes, increase the number of days.
- **At Specific UTC Date/Time:** This sample will start at the specified UTC time, assuming that the overall HHB sample is running at that time. Format the specified UTC time as mm/dd/YYYY HH:MM AM/PM. If the overall HHB sample is set to start “Once Next Power-On” or “Always Next Power-On,” this option will not be available.

## Pumping Duration

For how long should this sample be collected?

- **Full Sample:** The sample will be collected until the overall HHB sample ends.
- **Shorter Than Sample:** Specify the duration for which this sample should be collected in days, hours, and minutes. The maximum number of hours that can be specified is 23 and the maximum number of minutes that can be specified is 59. To specify a duration longer than 23 hours and 59 minutes, increase the number of days.

Each pump should be programmed to start at the same time or after the overall HHB sample and should be programmed to end before or at the same time as the overall HHB sample. See **Table 7** for an explanation of how the Configurator and HHB will behave if the Start Pumping or Pumping Duration parameters are specified in a manner that conflicts with the Start Sampling and Sampling Duration parameters on the Mainboard tab.

**Table 6.** Variables that can be selected or deselected for logging in the HHBv2 Configurator Pump C and D tabs.

Variable	Units	Description
Board Supply (Pumps C & D)	(V)	Supply voltage, converted from either the USB Type-C® or battery voltage, for powering the HHB; used for generating the 3.3V supply and pump drive voltages on the circuit board; should be 4.25 to 4.75 V; useful for troubleshooting.
Board 3V3 (Pumps C & D)	(V)	Voltage on the 3.3 V rail on the circuit board; should be 3.15 to 3.47 V; useful for troubleshooting.
BMP390 Pressure (Pumps C & D)	(PaA)	Absolute pressure measured by the Bosch BMP390 sensor installed on the circuit board and outside of the pump manifolds.
BMP390 Temperature (Pumps C & D)	(°C)	Temperature measured by the Bosch BMP390 sensor installed on the circuit board and outside of the pump manifolds.
Atmospheric Density Ratio (Pumps C & D)	(g L <sup>-1</sup> )	Air density calculated from measured temperature/pressure/RH values and used to relate mass flow to volumetric flow for the gas sample(s).

Pump RDAC	(integer)	Pump power level; useful for troubleshooting.
Pump Drive Voltage	(V)	Voltage input to drive the pump; useful for troubleshooting.
Omron Supply Voltage	(V)	Voltage supplied to power the mass flow sensor; useful for troubleshooting.
Omron Flow Voltage	(V)	Voltage output by the mass flow sensor; this is the raw reading of the air mass flow rate.
BMP581 Pressure	(PaA)	Absolute pressure measured by the Bosch BMP581 sensor installed inside the pump manifold.
BMP581 Temperature	(°C)	Temperature measured by the Bosch BMP581 sensor installed inside the pump manifold.
Mass Flow	(g min <sup>-1</sup> )	Mass flow rate of air through the sorbent.
Volumetric Flow	(L min <sup>-1</sup> )	Volumetric air flow rate through the sorbent.
Total Pump Volume	(L)	Cumulative volume of air sampled through this channel since the pump was installed.
Total Sorbent Volume	(L)	Cumulative volume of air sampled through the sorbent during all samples since the sorbent cartridge was installed.
Test Sorbent Volume	(L)	Cumulative volume of air sampled through the sorbent during this sample.

## Write configuration

Once you have entered your desired settings on each tab of the Configurator, return to the HHB tab and click the “Write Configuration” button in the lower-right corner (see **Figure 9**). Your new settings will be sent to the HHB. You can now click the “Disconnect” button to disconnect the HHB from the Configurator. Then, physically disconnect the HHB from the computer. The HHB will need to be power-cycled (i.e., turned off and then turned back on) to start a new sample.

**Table 7.** Expected HHB behavior if the Start Sampling parameter on the Mainboard tab; the Sampling Duration on the Mainboard tab; the Start Pumping parameter on the Pump A, B, C, or D tab; and the Pumping Duration parameter on the Pump A, B, C, or D tab are specified in a manner that is unusual or conflicting.

Start Sampling specification on Mainboard tab	Start Pumping specification on Pump tab	Pumping Duration specification on Pump tab	Conflict	Example	Configurator behavior	HHB behavior
Once Next Power-On or Always Next Power-On	At Sample Start	Shorter Than Sample	The pumping duration is longer than the sampling duration	Sampling Duration = 1 day Pumping Duration = 2 days	The Configurator will accept these settings and no warnings will be displayed.	The HHB will run for the sampling duration that was programmed on the Mainboard tab and then shut down. The pump will run for the full sample.
Once Next Power-On or Always Next Power-On	Delayed Start	Full Sample	None	Sampling Duration = 2 days Delayed Start = 1 day Pumping Duration = Full Sample	The Configurator will accept these settings and no warnings will be displayed.	The HHB will run for 2 days (48 h). The pumped sample will start 1 day (24 h) after the overall HHB sample starts and will run until the overall HHB sample is complete (i.e., the pumped sample will run for 24 h).
Once Next Power-On or Always Next Power-On	Delayed Start	Shorter Than Sample	The delay is shorter than the sampling duration, but the delay plus the pumping duration exceeds the sampling duration	Sampling Duration = 1 day, 12 hours Delayed Start = 1 day Pumping Duration = 1 day	The Configurator will accept these settings and no warnings will be displayed.	The HHB will run for the sampling duration programmed on the Mainboard tab (36 h) and then shut down. The pump will start after the specified delay (24 h) and run for the rest of the overall sample (12 h).

**Table 7.** Continued...

Start Sampling...	Start Pumping...	Pumping Duration...	Conflict	Example	Configurator...	HHB behavior
Once Next Power-On or Always Next Power-On	Delayed Start	Shorter Than Sample or Full Sample	The delay before the pump start is longer than the sampling duration	Sampling Duration = 1 day Delayed Start = 2 days Pumping Duration = Full Sample	A warning will be displayed when Write Configuration is clicked: "You are specifying that the starting delay for Pump [A, B, C, or D] is longer than the total sample duration. Are you sure you wish to proceed?"	The HHB will run for the sampling duration (1 day), but the pumped sample will never start.
At Specific UTC Date/Time	At Specific UTC Date/Time	Shorter Than Sample	The overall HHB sample start time is later than the start pumping time plus the pumping duration.	Sampling Duration = 2 days Start Sampling = 04/19/2025 12:00 PM UTC Start Pumping = 04/17/2025 08:00 AM UTC Pumping Duration = 1 day	A warning will be displayed when Write Configuration is clicked: "You are specifying that Pump [A, B, C, or D] starts at a specific UTC data/time that is earlier than the sample starting UTC date/time. Are you sure you wish to proceed?"	The HHB will start at the "start sampling" time and run for the sampling duration (2 days). The pumped sample will start when the HHB starts and run for the programmed pumping duration (1 day).
At Specific UTC Date/Time	At Specific UTC Date/Time	Shorter Than Sample or Full Sample	The pump is scheduled to start <i>after</i> the overall HHB sample ends.	Sampling Duration = 1 day Start Sampling = 04/16/2025 08:00 AM UTC Start Pumping = 04/17/2025 12:00 PM UTC	A warning will be displayed when Write Configuration is clicked: "You are specifying that Pump [A, B, C, or D] starts at a specific UTC data/time that is later than when the sample will stop. Are you sure you wish to proceed?"	The HHB will start at the "start sampling" time and run for the sampling duration (1 day) but the pumped sample will never start.

# 3 Data Download and Analysis

## Removing the microSD™ card

Remove the sorbent media cover by unscrewing the two M3 screws using the T8 security Torx® driver that came with the HHB. Grab the end of the microSD™ card with a pair of tweezers and pull it straight out of the microSD™ card slot.

## Downloading data from the microSD™ card

### On a Windows PC

Insert the microSD™ card into your computer using: (a) a microSD™ port on your computer, (b) a full-size SD card adapter and an SD card port on your computer, or (c) a microSD™-to-USB adapter. Then, navigate to “This PC” and open the drive associated with the microSD™ card. On the microSD™ card, you will see a .csv log file for each sample. The filename will be formatted as “HHBXXXXX\_LOG\_YYYY-mm-ddTHH\_MMUTC.csv” where “XXXXX” is the serial number of the Home Health Box and “YYYY” is the year, “mm” is the month, “dd” is the day, “HH” is the hour, and “MM” is the minute of the UTC date/time when the sample started. Copy the log file from the microSD™ card to the location where you want to store it for analysis.

**NOTE:** In accordance with data management best practices, we advise against renaming log files.

## R Package

AST offers a package for reading log file data into R.

The `astr` package can be installed from our GitHub: <https://github.com/accsensors/astr>

Refer to the README and the function documentation, especially for the `read_ast_header` and `read_ast_log` functions, for information on how to use the package.

## Understanding the log file

For a detailed description of each line in the log file header and each column in the sample log, see **Table 8**, **Table 9**, and **Table 10**.

**Table 8.** Description of sample log header data variables, organized by section.

	Parameter	Format/Units	Description
Device Information	HHBserial	(-)	Serial number of the Home Health Box (HHB)
	SEN55_Serial	(-)	Serial number of Sensirion SEN55 sensor installed in HHB
	HHBslot1	(-)	Serial number of PCB installed in slot 1 of HHB (sorbent pump channels C/D)
	HHBslot2	(-)	Serial number of the PCB installed in slot 2 of the HHB (filter pumping channel A)
	HHBslot3	(-)	Serial number of PCB installed in slot 3 of HHB
	HHBslot4	(-)	Serial number of PCB installed in slot 4 of HHB (filter pumping channel B)
	HHBslot5	(-)	Serial number of PCB installed in slot 5 of HHB
	HHBslot6	(-)	Serial number of the PCB installed in slot 6 of the HHB (gas sensor expansion PCB)
	G.Alphasense1_ID	(-)	Serial number of Alphasense B-series electrochemical sensor in gas sensor housing position 1
	G.Alphasense1_Type	(-)	Model number of Alphasense B-series electrochemical sensor in gas sensor housing position 1
	G.Alphasense1_ISB_Gain	(mV nA <sup>-1</sup> )	The gain on the individual sensor board (ISB) to which the Alphasense B-series electrochemical sensor in gas sensor housing position 1 is mounted; should be equal to -0.726 for NO <sub>2</sub> -B43F sensors, 0.8 for NO-B4 sensors, 0.8 for CO-B4 sensors, and -0.746 for OX-B431 sensors.
	G.Alphasense1_WEt	(mV)	The total working electrode (WE) zero offset for the Alphasense B-series electrochemical sensor installed in gas sensor housing position 1; WE <sub>t</sub> in Alphasense Application Note (AAN) 803-05; "WE Zero" on the calibration datasheet from Alphasense.
	G.Alphasense1_AEt	(mV)	The total auxiliary electrode (AE) zero offset for the Alphasense B-series electrochemical sensor installed in gas sensor housing position 1; AE <sub>t</sub> in AAN 803-05; "Aux Zero" on the calibration datasheet from Alphasense.
	G.Alphasense1_Sensitivity	(nA ppm <sup>-1</sup> )	The WE sensitivity for the Alphasense B-series electrochemical sensor installed in gas sensor housing position 1; "WE Sensor" on the calibration datasheet from Alphasense.
	G.Alphasense1_WEe	(mV)	The WE electronic offset on the individual sensor board (ISB) from Alphasense that is installed in gas sensor housing position 1; WE <sub>e</sub> in AAN 803-05; "ELECTRONIC ZERO (WE)" on the calibration datasheet from Alphasense.
	G. Alphasense1_AEe	(mV)	The AE electronic offset on the ISB from Alphasense that is installed in gas sensor housing position 1; AE <sub>e</sub> in AAN 803-05; "ELECTRONIC ZERO (AUX)" on the calibration datasheet from Alphasense.
	G.Alphasense1_NO2Sensitivity	(nA ppm <sup>-1</sup> )	The WE sensitivity to NO <sub>2</sub> for the Alphasense B-series electrochemical sensor installed in gas sensor housing position 1; "NO <sub>2</sub> Sensitivity" on the calibration datasheet from Alphasense. Only applicable if there is an OX-B431 sensor installed in position 1.
G.Alphasense1_NO2CorrectionSensor	(-)	If there is an OX-B431 sensor installed in gas sensor housing position 1 and the WE output from this OX-B431 sensor must be corrected for response to NO <sub>2</sub> before an O <sub>3</sub>	

		concentration can be estimated, this parameter indicates the gas sensor housing position (2, 3, or 4) of the NO <sub>2</sub> -B43F sensor that is being used for the correction.
G. Alphasense1_NO2CorrectionAlgorithm	(-)	If there is an OX-B431 sensor installed in gas sensor housing position 1 and the WE output from this OX-B431 sensor must be corrected for response to NO <sub>2</sub> before an O <sub>3</sub> concentration can be estimated, this parameter indicates the algorithm being used to estimate the NO <sub>2</sub> concentration used in the correction: 0 (none), 1, 2, 3, or 4.
G.Alphasense2_ID	(-)	Serial number of Alphasense B-series electrochemical sensor in gas sensor housing position 2
G.Alphasense2_Type	(-)	Model number of Alphasense B-series electrochemical sensor in gas sensor housing position 2
G.Alphasense2_ISB_Gain	(mV nA <sup>-1</sup> )	The gain on the ISB to which the Alphasense B-series electrochemical sensor in gas sensor housing position 2 is mounted; should be equal to -0.726 for NO <sub>2</sub> -B43F sensors, 0.8 for NO-B4 sensors, 0.8 for CO-B4 sensors, and -0.746 for OX-B431 sensors.
G.Alphasense2_WEt	(mV)	The total working electrode (WE) zero offset for the Alphasense B-series electrochemical sensor installed in gas sensor housing position 2; WE <sub>t</sub> in Alphasense Application Note (AAN) 803-05; "WE Zero" on the calibration datasheet from Alphasense.
G.Alphasense2_AEt	(mV)	The total auxiliary electrode (AE) zero offset for the Alphasense B-series electrochemical sensor installed in gas sensor housing position 2; AE <sub>t</sub> in AAN 803-05; "Aux Zero" on the calibration datasheet from Alphasense.
G.Alphasense2_Sensitivity	(nA ppm <sup>-1</sup> )	The WE sensitivity for the Alphasense B-series electrochemical sensor installed in gas sensor housing position 2; "WE Sensor" on the calibration datasheet from Alphasense.
G.Alphasense2_WEe	(mV)	The WE electronic offset on the individual sensor board (ISB) from Alphasense that is installed in gas sensor housing position 2; WE <sub>e</sub> in AAN 803-05; "ELECTRONIC ZERO (WE)" on the calibration datasheet from Alphasense.
G. Alphasense2_AEe	(mV)	The AE electronic offset on the ISB from Alphasense that is installed in gas sensor housing position 2; AE <sub>e</sub> in AAN 803-05; "ELECTRONIC ZERO (AUX)" on the calibration datasheet from Alphasense.
G.Alphasense2_NO2Sensitivity	(nA ppm <sup>-1</sup> )	The WE sensitivity to NO <sub>2</sub> for the Alphasense B-series electrochemical sensor installed in gas sensor housing position 2; "NO <sub>2</sub> Sensitivity" on the calibration datasheet from Alphasense. Only applicable if there is an OX-B431 sensor installed in position 2.
G.Alphasense2_NO2CorrectionSensor	(-)	If there is an OX-B431 sensor installed in gas sensor housing position 2 and the WE output from this OX-B431 sensor must be corrected for response to NO <sub>2</sub> before an O <sub>3</sub> concentration can be estimated, this parameter indicates the gas sensor housing position (1, 3, or 4) of the NO <sub>2</sub> -B43F sensor that is being used for the correction.
G. Alphasense2_NO2CorrectionAlgorithm	(-)	If there is an OX-B431 sensor installed in gas sensor housing position 2 and the WE output from this OX-B431 sensor must be corrected for response to NO <sub>2</sub> before an O <sub>3</sub>

		concentration can be estimated, this parameter indicates the algorithm being used to estimate the NO <sub>2</sub> concentration used in the correction: 0 (none), 1, 2, 3, or 4.
G.Alphasense3_ID	(-)	Serial number of Alphasense B-series electrochemical sensor in gas sensor housing position 3
G.Alphasense3_Type	(-)	Model number of Alphasense B-series electrochemical sensor in gas sensor housing position 3
G.Alphasense3_ISB_Gain	(mV nA <sup>-1</sup> )	The gain on the ISB to which the Alphasense B-series electrochemical sensor in gas sensor housing position 3 is mounted; should be equal to -0.726 for NO <sub>2</sub> -B43F sensors, 0.8 for NO-B4 sensors, 0.8 for CO-B4 sensors, and -0.746 for OX-B431 sensors.
G.Alphasense3_WEt	(mV)	The total working electrode (WE) zero offset for the Alphasense B-series electrochemical sensor installed in gas sensor housing position 3; WE <sub>t</sub> in Alphasense Application Note (AAN) 803-05; "WE Zero" on the calibration datasheet from Alphasense.
G.Alphasense3_AEt	(mV)	The total auxiliary electrode (AE) zero offset for the Alphasense B-series electrochemical sensor installed in gas sensor housing position 3; AE <sub>t</sub> in AAN 803-05; "Aux Zero" on the calibration datasheet from Alphasense.
G.Alphasense3_Sensitivity	(nA ppm <sup>-1</sup> )	The WE sensitivity for the Alphasense B-series electrochemical sensor installed in gas sensor housing position 3; "WE Sensor" on the calibration datasheet from Alphasense.
G.Alphasense3_WEe	(mV)	The WE electronic offset on the individual sensor board (ISB) from Alphasense that is installed in gas sensor housing position 3; WE <sub>e</sub> in AAN 803-05; "ELECTRONIC ZERO (WE)" on the calibration datasheet from Alphasense.
G. Alphasense3_AEe	(mV)	The AE electronic offset on the ISB from Alphasense that is installed in gas sensor housing position 3; AE <sub>e</sub> in AAN 803-05; "ELECTRONIC ZERO (AUX)" on the calibration datasheet from Alphasense.
G.Alphasense3_NO2Sensitivity	(nA ppm <sup>-1</sup> )	The WE sensitivity to NO <sub>2</sub> for the Alphasense B-series electrochemical sensor installed in gas sensor housing position 3; "NO <sub>2</sub> Sensitivity" on the calibration datasheet from Alphasense. Only applicable if there is an OX-B431 sensor installed in position 3.
G.Alphasense3_NO2CorrectionSensor	(-)	If there is an OX-B431 sensor installed in gas sensor housing position 3 and the WE output from this OX-B431 sensor must be corrected for response to NO <sub>2</sub> before an O <sub>3</sub> concentration can be estimated, this parameter indicates the gas sensor housing position (1, 2, or 4) of the NO <sub>2</sub> -B43F sensor that is being used for the correction.
G. Alphasense3_NO2CorrectionAlgorithm	(-)	If there is an OX-B431 sensor installed in gas sensor housing position 3 and the WE output from this OX-B431 sensor must be corrected for response to NO <sub>2</sub> before an O <sub>3</sub> concentration can be estimated, this parameter indicates the algorithm being used to estimate the NO <sub>2</sub> concentration used in the correction: 0 (none), 1, 2, 3, or 4.
G.Alphasense4_ID	(-)	Serial number of Alphasense B-series electrochemical sensor in gas sensor housing position 4
G.Alphasense4_Type	(-)	Model number of Alphasense B-series electrochemical

		sensor in gas sensor housing position 4
G.Alphasense4_ISB_Gain	(mV nA <sup>-1</sup> )	The gain on the ISB to which the Alphasense B-series electrochemical sensor in gas sensor housing position 4 is mounted; should be equal to -0.726 for NO <sub>2</sub> -B43F sensors, 0.8 for NO-B4 sensors, 0.8 for CO-B4 sensors, and -0.746 for OX-B431 sensors.
G.Alphasense4_WEt	(mV)	The total working electrode (WE) zero offset for the Alphasense B-series electrochemical sensor installed in gas sensor housing position 4; WE <sub>t</sub> in Alphasense Application Note (AAN) 803-05; "WE Zero" on the calibration datasheet from Alphasense.
G.Alphasense4_AEt	(mV)	The total auxiliary electrode (AE) zero offset for the Alphasense B-series electrochemical sensor installed in gas sensor housing position 4; AE <sub>t</sub> in AAN 803-05; "Aux Zero" on the calibration datasheet from Alphasense.
G.Alphasense4_Sensitivity	(nA ppm <sup>-1</sup> )	The WE sensitivity for the Alphasense B-series electrochemical sensor installed in gas sensor housing position 4; "WE Sensor" on the calibration datasheet from Alphasense.
G.Alphasense4_WEe	(mV)	The WE electronic offset on the individual sensor board (ISB) from Alphasense that is installed in gas sensor housing position 4; WE <sub>e</sub> in AAN 803-05; "ELECTRONIC ZERO (WE)" on the calibration datasheet from Alphasense.
G. Alphasense4_AEe	(mV)	The AE electronic offset on the ISB from Alphasense that is installed in gas sensor housing position 4; AE <sub>e</sub> in AAN 803-05; "ELECTRONIC ZERO (AUX)" on the calibration datasheet from Alphasense.
G.Alphasense4_NO2Sensitivity	(nA ppm <sup>-1</sup> )	The WE sensitivity to NO <sub>2</sub> for the Alphasense B-series electrochemical sensor installed in gas sensor housing position 4; "NO <sub>2</sub> Sensitivity" on the calibration datasheet from Alphasense. Only applicable if there is an OX-B431 sensor installed in position 4.
G.Alphasense4_NO2CorrectionSensor	(-)	If there is an OX-B431 sensor installed in gas sensor housing position 4 and the WE output from this OX-B431 sensor must be corrected for response to NO <sub>2</sub> before an O <sub>3</sub> concentration can be estimated, this parameter indicates the gas sensor housing position (1, 2, or 3) of the NO <sub>2</sub> -B43F sensor that is being used for the correction.
G. Alphasense4_NO2CorrectionAlgorithm	(-)	If there is an OX-B431 sensor installed in gas sensor housing position 4 and the WE output from this OX-B431 sensor must be corrected for response to NO <sub>2</sub> before an O <sub>3</sub> concentration can be estimated, this parameter indicates the algorithm being used to estimate the NO <sub>2</sub> concentration used in the correction: 0 (none), 1, 2, 3, or 4.
G.SCD30_Serial	(-)	Serial number of the Sensirion SCD30 NDIR CO <sub>2</sub> sensor installed in the HHB
G.SFA30_Serial	(-)	Serial number of the Sensirion SFA30 electrochemical formaldehyde sensor installed in the HHB <b>[obsolete]</b>
Firmware	(-)	Current version of firmware running on HHB

Sample Identification	LogFileName	(-)	Log filename as saved on the microSD card (automatically defined)
	SampleName	(-)	Sample name entered by the user
	D.SorbentCID	(-)	Identifier for sorbent media installed in Channel D (as entered by the user)
	C.SorbentCID	(-)	Identifier for sorbent media installed in Channel C (as entered by the user)
	A.FilterCID	(-)	Identifier for filter cartridge installed in Channel A (as entered by the user)
B.FilterCID	(-)	Identifier for filter cartridge installed in Channel B (as entered by the user)	
Mass flow sensor calibration	D.SorbentCalDate	(YYYY-MM-DDTHH:MM:SS) (UTC date time format)	Sorbent Channel D: The timestamp when the mass flow sensor was calibrated (coordinated universal time)
	D.SorbentCalVoutMin	(V)	Sorbent Channel D: Mass flow sensor output voltage measured at minimum flow during calibration
	D.SorbentCalVoutMax	(V)	Sorbent Channel D: Mass flow sensor output voltage measured at maximum flow during calibration
	D.SorbentCalMFMin	(mg min <sup>-1</sup> )	Sorbent Channel D: Minimum flow rate measured during calibration when the flow was unblocked
	D.SorbentCalMFMax	(mg min <sup>-1</sup> )	Sorbent Channel D: Maximum mass flow rate measured during calibration
	D.SorbentMF4	(-)	Sorbent Channel D: Coefficient of 4th-degree term in polynomial describing mass flow calibration curve
	D.SorbentMF3	(-)	Sorbent Channel D: Coefficient of 3rd-degree term in polynomial describing mass flow calibration curve
	D.SorbentMF2	(-)	Sorbent Channel D: Coefficient of 2nd-degree term in polynomial describing mass flow calibration curve
	D.SorbentMF1	(-)	Sorbent Channel D: Coefficient of 1st-degree term in polynomial describing mass flow calibration curve
	D.SorbentMF0	(-)	Sorbent Channel D: Coefficient of 0th-degree term in polynomial describing mass flow calibration curve
	C.SorbentCalDate	(YYYY-MM-DDTHH:MM:SS)	Sorbent Channel C: The timestamp when the mass flow sensor was calibrated (coordinated universal time)
	C.SorbentCalVoutMin	(V)	Sorbent Channel C: Mass flow sensor output voltage measured at minimum flow during calibration
	C.SorbentCalVoutMax	(V)	Sorbent Channel C: Mass flow sensor output voltage measured at maximum flow during calibration
	C.SorbentCalMFMin	(mg min <sup>-1</sup> )	Sorbent Channel C: Minimum flow rate measured during calibration when the flow was unblocked
	C.SorbentCalMFMax	(mg min <sup>-1</sup> )	Sorbent Channel C: Maximum mass flow rate measured during calibration
	C.SorbentMF4	(-)	Sorbent Channel C: Coefficient of 4th-degree term in polynomial describing mass flow calibration curve
	C.SorbentMF3	(-)	Sorbent Channel C: Coefficient of 3rd-degree term in polynomial describing mass flow calibration curve
	C.SorbentMF2	(-)	Sorbent Channel C: Coefficient of 2nd-degree term in polynomial describing mass flow calibration curve
	C.SorbentMF1	(-)	Sorbent Channel C: Coefficient of 1st-degree term in polynomial describing mass flow calibration curve
	C.SorbentMF0	(-)	Sorbent Channel C: Coefficient of 0th-degree term in polynomial describing mass flow calibration curve

	A.FilterCalDate	(YYYY-MM-DDTHH:MM:SS)	Filter Channel A: The timestamp when the mass flow sensor was last calibrated (coordinated universal time)	
	A.FilterCalVoutMin	(V)	Filter Channel A: Mass flow sensor output voltage measured at minimum flow during calibration	
	A.FilterCalVoutMax	(V)	Filter Channel A: Mass flow sensor output voltage measured at maximum flow during calibration	
	A.FilterCalMFMin	(g min <sup>-1</sup> )	Filter Channel A: Minimum flow rate measured during calibration when the flow was unblocked	
	A.FilterCalMFMax	(g min <sup>-1</sup> )	Filter Channel A: Maximum mass flow rate measured during calibration	
	A.FilterMF4	(-)	Filter Channel A: Coefficient of 4th-degree term in polynomial describing mass flow calibration curve	
	A.FilterMF3	(-)	Filter Channel A: Coefficient of 3rd-degree term in polynomial describing mass flow calibration curve	
	A.FilterMF2	(-)	Filter Channel A: Coefficient of 2nd-degree term in polynomial describing mass flow calibration curve	
	A.FilterMF1	(-)	Filter Channel A: Coefficient of 1st-degree term in polynomial describing mass flow calibration curve	
	A.FilterMF0	(-)	Filter Channel A: Coefficient of 0th-degree term in polynomial describing mass flow calibration curve	
	B.FilterCalDate	(YYYY-MM-DDTHH:MM:SS)	Filter Channel B: The timestamp when the mass flow sensor was last calibrated (coordinated universal time)	
	B.FilterCalVoutMin	(V)	Filter Channel B: Mass flow sensor output voltage measured at minimum flow during calibration	
	B.FilterCalVoutMax	(V)	Filter Channel B: Mass flow sensor output voltage measured at maximum flow during calibration	
	B.FilterCalMFMin	(g min <sup>-1</sup> )	Filter Channel B: Minimum flow rate measured during calibration when the flow was unblocked	
	B.FilterCalMFMax	(g min <sup>-1</sup> )	Filter Channel B: Maximum mass flow rate measured during calibration	
	B.FilterMF4	(coefficient)	Filter Channel B: Coefficient of 4th-degree term in polynomial describing mass flow calibration curve	
	B.FilterMF3	(coefficient)	Filter Channel B: Coefficient of 3rd-degree term in polynomial describing mass flow calibration curve	
	B.FilterMF2	(coefficient)	Filter Channel B: Coefficient of 2nd-degree term in polynomial describing mass flow calibration curve	
	B.FilterMF1	(coefficient)	Filter Channel B: Coefficient of 1st-degree term in polynomial describing mass flow calibration curve	
	B.FilterMF0	(coefficient)	Filter Channel B: Coefficient of 0th-degree term in polynomial describing mass flow calibration curve	
	Setup Summary	UTCOffset	(Hr)	UTC offset for local time zone
		StartOnNextPowerOn	(integer)	Was the HHB programmed to start on next power-on? (0 = no, 1 = yes, 4 = always start on next power-on)
		ProgrammedStartTime	(YYYY-MM-DDTHH:MM:SS)	Time when the overall HHB sample was programmed to start (coordinated universal time); will be blank if the HHB was programmed to start on next power-on.
		ProgrammedRuntime	(Hr)	Programmed sample run time.
SEN55_Runtime		(Hr)	Cumulative hours that the currently-installed Sensirion SEN55 sensor has operated.	
SEN55_FanRuntime		(Hr)	Cumulative hours that the fan in the currently-installed	

		SEN55 sensor has operated.
D.SorbentPumpStartingVolume	(L)	Sorbent Channel D: Cumulative volume of air that the pump had sampled at the start of the sample
D.SorbentPumpStartingRuntime	(Hr)	Sorbent Channel D: Cumulative hours that the pump had operated at the start of the sample
D.SorbentCartridgeStartingVolume	(L)	Sorbent Channel D: Cumulative volume of air that had been sampled through the currently-installed sorbent media at the start of the sample (resets to zero when the value of "D.SorbentCID" is reset)
D.SorbentCartridgeStartingRuntime	(Hr)	Sorbent Channel D: Cumulative hours for which air had been sampled through the currently-installed sorbent media at the start of the sample (resets to zero when the value of "D.SorbentCID" is reset)
D.SorbentVolumetricFlowRate	(L min <sup>-1</sup> )	Sorbent Channel D: Programmed volumetric sample flow rate
D.SorbentDutyCycle	(%)	Sorbent Channel D: Duty cycle; only 100% (continuous operation) is supported at this time.
D.SorbentProgrammedStartDelay	(Hr)	Sorbent Channel D: Programmed delay between the start of the overall sample and the start time for this sample pump; will be blank if the pump was programmed to start at a specific UTC date/time.
D.SorbentProgrammedStartTime	(YYYY-MM-DDTHH:MM:SS)	Sorbent Channel D: Programmed start time for this sample pump (coordinated universal time); will be empty if the pump was programmed to start with the overall sample or after some delay following the start of the overall sample.
D.SorbentProgrammedRuntime	(Hr)	Sorbent Channel D: Programmed pump runtime
C.SorbentPumpStartingVolume	(L)	Sorbent Channel C: Cumulative volume of air that the pump had sampled at the start of the sample
C.SorbentPumpStartingRuntime	(Hr)	Sorbent Channel C: Cumulative hours that the pump had operated at the start of the sample
C.SorbentCartridgeStartingVolume	(L)	Sorbent Channel C: Cumulative volume of air that had been sampled through the currently-installed sorbent media at the start of the sample (resets to zero when the value of "C.SorbentCID" is reset)
C.SorbentCartridgeStartingRuntime	(Hr)	Sorbent Channel C: Cumulative hours for which air had been sampled through the currently-installed sorbent media at the start of the sample (resets to zero when the value of "C.SorbentCID" is reset)
C.SorbentVolumetricFlowRate	(L min <sup>-1</sup> )	Sorbent Channel C: Programmed volumetric sample flow rate
C.SorbentDutyCycle	(%)	Sorbent Channel C: Duty cycle; only 100% (continuous operation) is supported at this time.
C.SorbentProgrammedStartDelay	(Hr)	Sorbent Channel C: Programmed delay between the start of the overall sample and the start time for this sample pump; will be blank if the pump was programmed to start at a specific UTC date/time.
C.SorbentProgrammedStartTime	(YYYY-MM-DDTHH:MM:SS)	Sorbent Channel C: Programmed start time for this sample pump (coordinated universal time); will be empty if the pump was programmed to start with the overall sample or after some delay following the start of the overall sample.
C.SorbentProgrammedRuntime	(Hr)	Sorbent Channel C: Programmed pump runtime
A.FilterPumpStartingVolume	(L)	Filter Channel A: Cumulative volume of air that the pump had sampled at the start of the sample
A.FilterPumpStartingRuntime	(Hr)	Filter Channel A: Cumulative hours that the pump had

		operated at the start of the sample
A.FilterCartridgeStartingVolume	(L)	Filter Channel A: Cumulative volume of air that had been sampled through the currently-installed sorbent media at the start of the sample (resets to zero when the value of "A.FilterCID" is reset)
A.FilterCartridgeStartingRuntime	(Hr)	Filter Channel A: Cumulative hours for which air had been sampled through the currently-installed sorbent media at the start of the sample (resets to zero when the value of "A.FilterCID" is reset)
A.FilterVolumetricFlowRate	(L min <sup>-1</sup> )	Filter Channel A: Programmed volumetric sample flow rate
A.FilterDutyCycle	(%)	Filter Channel A: Duty cycle; only 100% (continuous operation) is supported at this time.
A.FilterProgrammedStartDelay	(Hr)	Filter Channel A: Programmed delay between the start of the overall sample and the start time for this sample pump; will be blank if the pump was programmed to start at a specific UTC date/time.
A.FilterProgrammedStartTime	(YYYY-MM-DDTHH:MM:SS)	Filter Channel A: Programmed start time for this sample pump (coordinated universal time); will be empty if the pump was programmed to start with the overall sample or after some delay following the start of the overall sample.
A.FilterProgrammedRuntime	(Hr)	Filter Channel A: Programmed pump runtime
B.FilterPumpStartingVolume	(L)	Filter Channel B: Cumulative volume of air that the pump had sampled at the start of the sample
B.FilterPumpStartingRuntime	(Hr)	Filter Channel B: Cumulative hours that the pump had operated at the start of the sample
B.FilterCartridgeStartingVolume	(L)	Filter Channel B: Cumulative volume of air that had been sampled through the currently-installed sorbent media at the start of the sample (this value resets to zero when the value of "B.FilterCID" is reset)
B.FilterCartridgeStartingRuntime	(Hr)	Filter Channel B: Cumulative hours for which air had been sampled through the currently-installed sorbent media at the start of the sample (resets to zero when the value of "B.FilterCID" is reset)
B.FilterVolumetricFlowRate	(L min <sup>-1</sup> )	Filter Channel B: Programmed volumetric sample flow rate
B.FilterDutyCycle	(%)	Filter Channel B: Duty cycle; only 100% (continuous operation) is supported at this time.
B.FilterProgrammedStartDelay	(Hr)	Filter Channel B: Programmed delay between the start of the overall sample and the start time for this sample pump; will be blank if the pump was programmed to start at a specific UTC date/time.
B.FilterProgrammedStartTime	(YYYY-MM-DDTHH:MM:SS)	Filter Channel B: Programmed start time for this sample pump (coordinated universal time); will be empty if the pump was programmed to start with the overall sample or after some delay following the start of the overall sample.
B.FilterProgrammedRuntime	(Hr)	Filter Channel B: Programmed pump runtime
G.Alphasense1_Runtime	(Hr)	Cumulative hours that the Aphasense B-series sensor in gas sensor housing position 1 had operated at the start of the sample
G.Alphasense2_Runtime	(Hr)	Cumulative hours that the Aphasense B-series sensor in gas sensor housing position 2 had operated at the start of the sample
G.Alphasense3_Runtime	(Hr)	Cumulative hours that the Aphasense B-series sensor in gas

			sensor housing position 3 had operated at the start of the sample
	G.Alphasense4_Runtime	(Hr)	Cumulative hours that the Aphasense B-series sensor in gas sensor housing position 4 had operated at the start of the sample
	G.FanRuntime	(Hr)	Cumulative hours that the fan in the gas sensor housing had operated at the start of the sample
	G.SCD30_Runtime	(Hr)	Cumulative hours that the Sensirion SCD30 CO <sub>2</sub> sensor currently installed in the gas sensor housing had operated at the start of the sample
	G.SFA30_Runtime	(Hr)	Cumulative hours that the Sensirion SFA30 formaldehyde sensor in the gas sensor housing had operated at the start of the sample <b>[obsolete]</b>
Sample Summary	StartDateTimeUTC	(YYYY-MM-DDTHH:MM:SS) (UTC date time format)	Timestamp when overall Home Health Box sample started (coordinated universal time)
	EndDateTimeUTC	(YYYY-MM-DDTHH:MM:SS)	Timestamp when overall Home Health Box sample ended (coordinated universal time)
	HHBSampledRuntime	(Hr)	Overall Home Health Box sample log duration
	D.SorbentStartDateTimeUTC	(YYYY-MM-DDTHH:MM:SS)	Sorbent Channel D: Timestamp when sample started (coordinated universal time); will be blank if the sample never started.
	D.SorbentEndDateTimeUTC	(YYYY-MM-DDTHH:MM:SS)	Sorbent Channel D: Timestamp when sample ended (coordinated universal time); will be blank if the sample never started.
	D.SorbentShutdownMode	(integer)	Sorbent Channel D: 0 = uncontrolled; 1 = test finished; 2 = high power
	D.SorbentSampledRunTime	(Hr)	Sorbent Channel D: Sample duration
	D.SorbentSampledVolume	(L)	Sorbent Channel D: Volume of air sampled through the sorbent during this sample
	D.SorbentAverageVolumetricFlowRate	(L min <sup>-1</sup> )	Sorbent Channel D: Average flow rate of air through the sorbent during this sample
	C.SorbentStartDateTimeUTC	(YYYY-MM-DDTHH:MM:SS)	Sorbent Channel C: Timestamp when sample started (coordinated universal time); will be blank if the sample never started.
	C.SorbentEndDateTimeUTC	(YYYY-MM-DDTHH:MM:SS)	Sorbent Channel C: Timestamp when sample ended (coordinated universal time); will be blank if the sample never started.
	C.SorbentShutdownMode	(integer)	Sorbent Channel C: 0 = uncontrolled; 1 = test finished; 2 = high power
	C.SorbentSampledRunTime	(Hr)	Sorbent Channel C: Sample duration
	C.SorbentSampledVolume	(L)	Sorbent Channel C: Volume of air sampled through the sorbent during this sample
	C.SorbentAverageVolumetricFlowRate	(L min <sup>-1</sup> )	Sorbent Channel C: Average flow rate of air through the sorbent during this sample
	A.FilterStartDateTimeUTC	(YYYY-MM-DDTHH:MM:SS)	Filter Channel A: Timestamp when sample started (coordinated universal time); will be blank if the sample never started.
	A.FilterEndDateTimeUTC	(YYYY-MM-DDTHH:MM:SS)	Filter Channel A: Timestamp when sample ended (coordinated universal time); will be blank if the sample never started.

A.FilterShutdownMode	(integer)	Filter Channel A: 0 = uncontrolled; 1 = test finished; 2 = high power
A.FilterSampledRunTime	(Hr)	Filter Channel A: Sample duration
A.FilterSampledVolume	(L)	Filter Channel A: Volume of air sampled through the filter during this sample
A.FilterAverageVolumetricFlowRate	(L min <sup>-1</sup> )	Filter Channel A: Average flow rate of air through the filter during this sample
B.FilterStartDateTimeUTC	(YYYY-MM-DDTHH:MM:SS)	Filter Channel B: Timestamp when sample started (coordinated universal time); will be blank if the sample never started.
B.FilterEndDateTimeUTC	(YYYY-MM-DDTHH:MM:SS)	Filter Channel B: Timestamp when sample ended (coordinated universal time); will be blank if the sample never started.
B.FilterShutdownMode	(integer)	Filter Channel B: 0 = uncontrolled; 1 = test finished; 2 = high power
B.FilterSampledRunTime	(Hr)	Filter Channel B: Sample duration
B.FilterSampledVolume	(L)	Filter Channel B: Volume of air sampled through the filter during this sample
B.FilterAverageVolumetricFlowRate	(L min <sup>-1</sup> )	Filter Channel B: Average flow rate of air through the filter during this sample

**Table 9.** Sample log data categories.

Sample Log Category	Description
<b>DateTime</b>	Timestamps
<b>MainPCB</b>	Data associated with components mounted/connected to the main circuit board (accelerometer, battery, and Bosch BMP581 temperature/pressure sensor)
<b>PMSensor</b>	Data from the Sensirion SEN55 particulate matter sensor
<b>SorbentPumps</b>	Data associated with the Channel D and Channel C sorbent samples
<b>FilterPumpA</b>	Data associated with the Channel A filter sample
<b>FilterPumpB</b>	Data associated with the Channel B filter sample
<b>GasSensors</b>	Data from the gas sensors (Sensirion SCD30 NDIR CO <sub>2</sub> sensor and any Alphasense B-series electrochemical sensors)

**Table 10.** Description of sample log data variables, organized by category.

	Variable	Format/ Units	Description
Date/Time	SampleTime	(HH:MM:SS)	Elapsed time since the sample started
	DateTimeUTC	(YYYY-MM-DDTHH:MM:SS) (UTC date time format)	Primary timestamp in Coordinated Universal Time. This timestamp is the start of the 5-, 15-, 30-, or 60-s averaging period (depending on the logging interval that was selected).
Main PCB	AccelX	(integer)	Linear acceleration in the X-direction, relative to the accelerometer position on the HHB; used to estimate the orientation of the HHB; see <b>Table 11</b> .
	AccelY	(integer)	Linear acceleration in the Y-direction, relative to the accelerometer position on the HHB; used to estimate the orientation of the HHB; see <b>Table 11</b> .
	AccelZ	(integer)	Linear acceleration in the Z-direction, relative to the accelerometer position on the HHB; used to estimate the orientation of the HHB; see <b>Table 11</b> .
	Vbus	(V)	Voltage on the USB Type-C® connector; will = 0 if USB power was not connected; otherwise, this value could range from 3.5 to 9.5 V.
	M.Vsupply	(V)	Main circuit board: Main supply voltage, converted from either the USB-C or battery voltage, for powering the HHB and generating all necessary voltage rails; should be 4.25 to 4.75 V.
	M.5V0	(V)	Main PCB: Voltage measured on 5.0 V rail; should be 4.75 to 5.25 V.
	M.3V3	(V)	Main PCB: Voltage measured on 3.3 V rail; should be 3.15 to 3.47 V.
	Vbattery	(V)	Battery voltage: Maximum = 4.25 V; below 3.2 V is "low battery"; below 3.0 V the HHB will shut down if not plugged in.
	Battery_Temp	(°C)	Battery temperature
	M.BMP581_Press	(Pa)	Absolute pressure measured by the Bosch BMP581 sensor that is mounted to the main circuit board and vented to the inside of the sorbent media compartment. This pressure is expected to be closest to the "true" atmospheric pressure.
M.BMP581_Temp	(°C)	Temperature measured by the Bosch BMP581 sensor that is mounted to the main circuit board and vented to the inside of the sorbent media compartment	
PM Sensor	SEN55_PM1.0	( $\mu\text{g m}^{-3}$ )	PM <sub>1</sub> concentration reported by the Sensirion SEN55. We expect this value to be correlated with the true PM <sub>1</sub> concentration, but do not recommend interpreting this value as an exact concentration; scaling these sensor-reported values to a filter-derived PM <sub>1</sub> concentration might improve accuracy, but no PM <sub>1</sub> inlet is available for the HHB filter sample channels.
	SEN55_PM2.5	( $\mu\text{g m}^{-3}$ )	PM <sub>2.5</sub> concentration reported by the Sensirion SEN55. We expect this value to be correlated with the true PM <sub>2.5</sub> concentration, but do not recommend interpreting this value as an exact concentration; scaling these sensor-reported values to a filter-derived PM <sub>2.5</sub> concentration might improve accuracy. For additional information, see: <a href="https://doi.org/10.1016/j.jaerosci.2020.105654">https://doi.org/10.1016/j.jaerosci.2020.105654</a>
	SEN55_PM4.0	( $\mu\text{g m}^{-3}$ )	PM <sub>4</sub> concentration reported by the Sensirion SEN55. Published data suggest that other low-cost optical PM sensors, similar to the SEN55, do not detect 4.0- $\mu\text{m}$ particles efficiently; therefore, this value might not be correlated with the true PM <sub>4</sub> concentration and we do not recommend using it. For additional information: <a href="https://doi.org/10.5194/amt-13-2413-2020">https://doi.org/10.5194/amt-13-2413-2020</a>
	SEN55_PM10	( $\mu\text{g m}^{-3}$ )	PM <sub>10</sub> concentration reported by the Sensirion SEN55. Published data suggest that other low-cost optical PM sensors, similar to the SEN55, do not detect 10- $\mu\text{m}$ particles efficiently; therefore, this value might not be correlated with the true PM <sub>10</sub> concentration and we do not recommend

			using it. For additional information, see: <a href="https://doi.org/10.1021/acs.estlett.3c00030">https://doi.org/10.1021/acs.estlett.3c00030</a> <a href="https://doi.org/10.5194/amt-13-2413-2020">https://doi.org/10.5194/amt-13-2413-2020</a>
	SEN55_RH	(%)	Relative humidity measured by the Sensirion SEN55. This value is expected to be closest to the true atmospheric RH because there is continuous active airflow through the SEN55.
	SEN55_Temp	(°C)	Temperature measured by the Sensirion SEN55. This value is expected to be closest to the true atmospheric temperature because there is continuous active airflow through the SEN55.
	SEN55_RawVOC	(integer)	Raw VOC output signal from the Sensirion SEN55. This value is from a Sensirion SGP41 sensor installed in the SEN55. This value should decrease as the VOC concentration increases; see the datasheet for the <a href="#">SGP41</a> sensor for additional details. Access Sensor Technologies has not verified independently that this value is correlated with or accurately reflects the total VOC concentration.
	SEN55_RawNOx	(integer)	Raw NO <sub>x</sub> output signal from the Sensirion SEN55. This value is from a Sensirion SGP41 sensor installed in the SEN55. This value should increase as the NO <sub>x</sub> concentration increases; see the datasheet for the Sensirion <a href="#">SGP41</a> for additional details. Access Sensor Technologies has not verified independently that this value is correlated with or accurately reflects the NO <sub>x</sub> concentration.
SorbentPumps	1.Vsupply	(V)	Supply voltage, converted from either the USB-C or battery voltage, for powering the HHB; used for generating 3.3V supply and pump drive voltages on the sorbent pump circuit board; should be 4.25 to 4.75 V.
	1.3V3	(V)	Voltage measured on the 3.3 V rail on the sorbent pump circuit board; should be 3.15 to 3.47 V.
	1.BMP390_Press	(PaA)	Absolute pressure measured by the Bosch BMP390 sensor intalled on the sorbent pump circuit board and outside the pump manifold(s)
	1.BMP390_Temp	(°C)	Temperature measured by the Bosch BMP390 sensor intalled on the sorbent pump circuit board and outside the pump manifold(s)
	D.RDAC	(integer)	Sorbent Channel D: Pump power level
	D.Vboost	(V)	Sorbent Channel D: Voltage input to drive the pump
	D.Vomron	(V)	Sorbent Channel D: Voltage supplied to power the mass flow sensor
	D.Vflow	(V)	Sorbent Channel D: Voltage output by the mass flow sensor; this is the raw reading of the air mass flow rate.
	D.BMP581_Press	(PaA)	Sorbent Channel D: Absolute pressure measured by the Bosch BMP581 sensor intalled inside the pump manifold
	D.BMP581_Temp	(°C)	Sorbent Channel D: Temperature measured by the Bosch BMP581 sensor installed inside the pump manifold
	D.MassFlow	(g min <sup>-1</sup> )	Sorbent Channel D: Mass flow rate of air through the sorbent.
	D.VolFlow	(L min <sup>-1</sup> )	Sorbent Channel D: Volumetric air flow rate through the sorbent
	D.TotalPumpVol	(L)	Sorbent Channel D: Cumulative volume of air sampled through this channel since the pump was installed.
	D.TotalSorbentVol	(L)	Sorbent Channel D: Cumulative volume of air sampled through the sorbent during all samples since the sorbent cartridge was installed.
	D.SampledSorbentVol	(L)	Sorbent Channel D: Cumulative volume of air sampled through the sorbent during this sample.
C.RDAC	(integer)	Sorbent Channel C: Pump power level	
C.Vboost	(V)	Sorbent Channel C: Voltage input to drive the pump	
C.Vomron	(V)	Sorbent Channel C: Voltage supplied to power the mass flow sensor	
C.Vflow	(V)	Sorbent Channel C: Voltage output by the mass flow sensor; this is the raw reading of the air mass flow rate.	


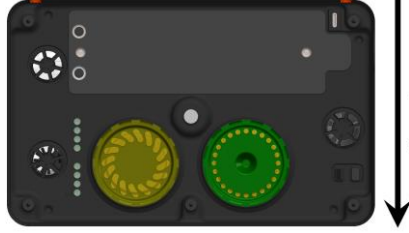


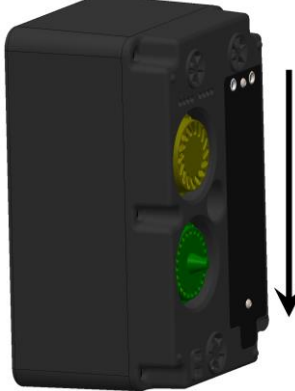
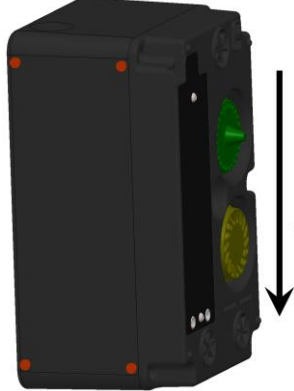
	C.BMP581_Press	(PaA)	Sorbent Channel C: Absolute pressure measured by the Bosch BMP581 sensor intalled inside the pump manifold
	C.BMP581_Temp	(°C)	Sorbent Channel C: Temperature measured by the Bosch BMP581 sensor installed inside the pump manifold
	C.MassFlow	(g min <sup>-1</sup> )	Sorbent Channel C: Mass flow rate of air through the sorbent.
	C.VolFlow	(L min <sup>-1</sup> )	Sorbent Channel C: Volumetric air flow rate through the sorbent
	C.TotalPumpVol	(L)	Sorbent Channel C: Cumulative volume of air sampled through this channel since the pump was installed.
	C.TotalSorbentVol	(L)	Sorbent Channel C: Cumulative volume of air sampled through the sorbent during all samples since the sorbent cartridge was installed.
	C.SampledSorbentVol	(L)	Sorbent Channel C: Cumulative volume of air sampled through the sorbent during this sample.
	1.AtmoDensity	(g L <sup>-1</sup> )	Air density calculated from measured temperature/pressure/RH values and used to relate "MassFlow" to "VolFlow" for the sorbent sample(s).
FilterPumpA	A.Vsupply	(V)	Filter Channel A: Supply voltage, converted from either the USB-C or battery voltage, for powering the HHB; used for generating the 3.3V supply and pump drive voltages on the filter pump circuit board; should be 4.25 to 4.75 V.
	A.3V3	(V)	Filter Channel A: Voltage measured on 3.3 V rail on pump circuit board; should be 3.15 to 3.47 V.
	A.Pumps	(integer)	Filter Channel A: ID numbers of the pumping elements that are active (should be = 123)
	A.RDAC	(integer)	Filter Channel A: Pump power level
	A.Vboost	(V)	Filter Channel A: Voltage input to drive pumps
	A.Vomron	(V)	Filter Channel A: Voltage supplied to power the mass flow sensor
	A.Vflow	(V)	Filter Channel A: Voltage output by the mass flow sensor; this is the raw reading of the air mass flow rate.
	A.BMP581Int_Press	(PaA)	Filter Channel A: Absolute pressure measured by the Bosch BMP581 sensor intalled inside the pump manifold
	A.BMP581Int_Temp	(°C)	Filter Channel A: Temperature measured by the Bosch BMP581 sensor installed inside the pump manifold
	A.BMP581Ext_Press	(PaA)	Filter Channel A: Absolute pressure measured by the Bosch BMP581 sensor intalled outside the pump manifold
	A.BMP581Ext_Temp	(°C)	Filter Channel A: Temperature measured by the Bosch BMP581 sensor installed outside the pump manifold
	A.MassFlow	(g min <sup>-1</sup> )	Filter Channel A: Mass flow rate of air through the sample filter
	A.VolFlow	(L min <sup>-1</sup> )	Filter Channel A: Volumetric air flow rate through the sample filter
	A.TotalPumpVol	(L)	Filter Channel A: Cumulative volume of air sampled through this channel since the pump was installed
	A.TotalCartridgeVol	(L)	Filter Channel A: Cumulative volume of air sampled through the filter during all samples since the filter was installed
	A.SampledCartridgeVol	(L)	Filter Channel A: Cumulative volume of air sampled through the filter during this sample
	A.AtmoDensity	(g L <sup>-1</sup> )	Filter Channel A: Air density calculated from measured temperature/pressure/RH values and used to relate "MassFlow" to "VolFlow" for this sample.
	FilterPumpB	B.Vsupply	(V)
B.3V3		(V)	Filter Channel B: Voltage measured on 3.3 V rail on pump circuit board; should be 3.15 to 3.47 V.

B.Pumps	(integer)	Filter Channel B: ID numbers of the pumping elements that are active (should be = 123)
B.RDAC	(integer)	Filter Channel B: Pump power level
B.Vboost	(V)	Filter Channel B: Voltage input to drive pumps
B.Vomron	(V)	Filter Channel B: Voltage supplied to power the mass flow sensor
B.Vflow	(V)	Filter Channel B: Voltage output by the mass flow sensor; this is the raw reading of the air mass flow rate.
B.BMP581Int_Press	(PaA)	Filter Channel B: Absolute pressure measured by the Bosch BMP581 sensor intalled inside the pump manifold
B.BMP581Int_Temp	(°C)	Filter Channel B: Temperature measured by the Bosch BMP581 sensor installed inside the pump manifold
B.BMP581Ext_Press	(PaA)	Filter Channel B: Absolute pressure measured by the Bosch BMP581 sensor intalled outside the pump manifold
B.BMP581Ext_Temp	(°C)	Filter Channel B: Temperature measured by the Bosch BMP581 sensor installed outside the pump manifold
B.MassFlow	(g min <sup>-1</sup> )	Filter Channel B: Mass flow rate of air through the sample filter
B.VolFlow	(L min <sup>-1</sup> )	Filter Channel B: Volumetric air flow rate through the sample filter
B.TotalPumpVol	(L)	Filter Channel B: Cumulative volume of air sampled through this channel since the pump was installed
B.TotalCartridgeVol	(L)	Filter Channel B: Cumulative volume of air sampled through the filter during all samples since the filter was installed
B.SampledCartridgeVol	(L)	Filter Channel B: Cumulative volume of air sampled through the filter during this sample
B.AtmoDensity	(g L <sup>-1</sup> )	Filter Channel B: Air density calculated from measured temperature/pressure/RH values and used to relate "MassFlow" to "VolFlow" for this sample.
B.Vsupply	(V)	Filter Channel B: Supply voltage, converted from either the USB-C or battery voltage, for powering the HHB; used for generating the 3.3V supply and pump drive voltages on the filter pump circuit board; should be 4.25 to 4.75 V.
B.3V3	(V)	Filter Channel B: Voltage measured on 3.3 V rail on pump circuit board; should be 3.15 to 3.47 V.
B.Pumps	(integer)	Filter Channel B: ID numbers of the pumping elements that are active (should be = 123)
B.RDAC	(integer)	Filter Channel B: Pump power level
B.Vboost	(V)	Filter Channel B: Voltage input to drive pumps
B.Vomron	(V)	Filter Channel B: Voltage supplied to power the mass flow sensor
B.Vflow	(V)	Filter Channel B: Voltage output by the mass flow sensor; this is the raw reading of the air mass flow rate.
B.BMP581Int_Press	(PaA)	Filter Channel B: Absolute pressure measured by the Bosch BMP581 sensor intalled inside the pump manifold
B.BMP581Int_Temp	(°C)	Filter Channel B: Temperature measured by the Bosch BMP581 sensor installed inside the pump manifold
B.BMP581Ext_Press	(PaA)	Filter Channel B: Absolute pressure measured by the Bosch BMP581 sensor intalled outside the pump manifold
B.BMP581Ext_Temp	(°C)	Filter Channel B: Temperature measured by the Bosch BMP581 sensor installed outside the pump manifold
B.MassFlow	(g min <sup>-1</sup> )	Filter Channel B: Mass flow rate of air through the sample filter
B.VolFlow	(L min <sup>-1</sup> )	Filter Channel B: Volumetric air flow rate through the sample filter
B.TotalPumpVol	(L)	Filter Channel B: Cumulative volume of air sampled through this channel since the pump was installed

	B.TotalCartridgeVol	(L)	Filter Channel B: Cumulative volume of air sampled through the filter during all samples since the filter was installed
	B.SampledCartridgeVol	(L)	Filter Channel B: Cumulative volume of air sampled through the filter during this sample
GasSensors	G.5V0	(V)	Voltage measured on 5.0 V rail on gas sensor circuit board; should be 4.75 to 5.25 V.
	G.3V3	(V)	Voltage measured on 3.3 V rail on gas sensor circuit board; should be 3.15 to 3.47 V.
	G.BMP581_Press	(PaA)	Absolute pressure measured by Bosch BMP581 sensor inside gas sensor housing
	G.BMP581_Temp	(°C)	Temperature measured by Bosch BMP581 sensor inside gas sensor housing
	G.SCD30_CO2	(ppm)	CO <sub>2</sub> concentration measured by Sensirion SCD30 sensor. This value accounts for the most recent calibration and has been corrected for atmospheric pressure and temperature.
	G.SCD30_Temp	(°C)	Temperature measured by the Sensirion SCD30 sensor (inside the gas sensor housing). This temperature is recommended for interpreting data from the Alphasense B-series electrochemical sensors installed in the gas sensor housing.
	G.SCD30_RH	(%)	Relative humidity measured by the Sensirion SCD30 sensor (inside the gas sensor housing). This RH value is recommended for interpreting data from the Alphasense B-series electrochemical sensors installed in the gas sensor housing.
	G.SGP41_RawVOC	(integer)	Raw VOC output signal from the Sensirion SGP41 sensor on the gas sensor circuit board. This value should decrease as the VOC concentration increases; see the datasheet for the Sensirion SGP41 for additional details. Access Sensor Technologies has not independently verified that this value is correlated with or accurately reflects the total VOC concentration.
	G.SGP41_RawNOx	(integer)	Raw NO <sub>x</sub> output signal from the Sensirion SGP41 sensor on the gas sensor circuit board. This value should increase as the NO <sub>x</sub> concentration increases; see the datasheet for the Sensirion SGP41 for additional details. Access Sensor Technologies has not independently verified that this value is correlated with or accurately reflects the NO <sub>x</sub> concentration.
	G.SFA30_Formaldehyde	(ppb)	Formaldehyde concentration measured by Sensirion SFA30 sensor <b>[obsolete]</b> .
	G.SFA30_RH	(%)	Relative humidity measured by the Sensirion SFA30 sensor inside the gas sensor housing <b>[obsolete]</b> .
	G.SFA30_Temp	(°C)	Temperature measured by the Sensirion SFA30 sensor inside the gas sensor housing <b>[obsolete]</b> .
	G.WE1	(V)	Alphasense B-series sensor in gas sensor housing position 1: Working electrode (WE) voltage
	G.AUX1	(V)	Alphasense B-series sensor in gas sensor housing position 1: Auxiliary electrode (AE) voltage
	G. Alphasense1_Algorithm1	(ppb)	Alphasense B-series sensor in gas sensor housing position 1: Gas concentration calculated using Algorithm 1 in Alphasense Application Note (AAN) 803-05.
	G. Alphasense1_Algorithm2	(ppb)	Alphasense B-series sensor in gas sensor housing position 1: Gas concentration calculated using Algorithm 2 in AAN 803-05.
	G. Alphasense1_Algorithm3	(ppb)	Alphasense B-series sensor in gas sensor housing position 1: Gas concentration calculated using Algorithm 3 in AAN 803-05.
	G. Alphasense1_Algorithm4	(ppb)	Alphasense B-series sensor in gas sensor housing position 1: Gas concentration calculated using Algorithm 4 in AAN 803-05.
G.WE2	(V)	Alphasense B-series sensor in gas sensor housing position 2: WE voltage	

G.AUX2	(V)	Alphasense B-series sensor in gas sensor housing position 2: AE voltage
G. Alphasense2_Algorithm1	(ppb)	Alphasense B-series sensor in gas sensor housing position 2: Gas concentration calculated using Algorithm 1 in AAN 803-05.
G. Alphasense2_Algorithm2	(ppb)	Alphasense B-series sensor in gas sensor housing position 2: Gas concentration calculated using Algorithm 2 in AAN 803-05.
G. Alphasense2_Algorithm3	(ppb)	Alphasense B-series sensor in gas sensor housing position 2: Gas concentration calculated using Algorithm 3 in AAN 803-05.
G. Alphasense2_Algorithm4	(ppb)	Alphasense B-series sensor in gas sensor housing position 2: Gas concentration calculated using Algorithm 4 in AAN 803-05.
G.WE3	(V)	Alphasense B-series sensor in gas sensor housing position 3: WE voltage
G.AUX3	(V)	Alphasense B-series sensor in gas sensor housing position 3: AE voltage
G. Alphasense3_Algorithm1	(ppb)	Alphasense B-series sensor in gas sensor housing position 3: Gas concentration calculated using Algorithm 1 in AAN 803-05.
G. Alphasense3_Algorithm2	(ppb)	Alphasense B-series sensor in gas sensor housing position 3: Gas concentration calculated using Algorithm 2 in AAN 803-05.
G. Alphasense3_Algorithm3	(ppb)	Alphasense B-series sensor in gas sensor housing position 3: Gas concentration calculated using Algorithm 3 in AAN 803-05.
G. Alphasense3_Algorithm4	(ppb)	Alphasense B-series sensor in gas sensor housing position 3: Gas concentration calculated using Algorithm 4 in AAN 803-05.
G.WE4	(V)	Alphasense B-series sensor in gas sensor housing position 4: WE voltage
G.AUX4	(V)	Alphasense B-series sensor in gas sensor housing position 4: AE voltage
G. Alphasense4_Algorithm1	(ppb)	Alphasense B-series sensor in gas sensor housing position 4: Gas concentration calculated using Algorithm 1 in AAN 803-05.
G. Alphasense4_Algorithm2	(ppb)	Alphasense B-series sensor in gas sensor housing position 4: Gas concentration calculated using Algorithm 2 in AAN 803-05.
G. Alphasense4_Algorithm3	(ppb)	Alphasense B-series sensor in gas sensor housing position 4: Gas concentration calculated using Algorithm 3 in AAN 803-05.
G. Alphasense4_Algorithm4	(ppb)	Alphasense B-series sensor in gas sensor housing position 4: Gas concentration calculated using Algorithm 4 in AAN 803-05.

**Table 11.** How to use the AccelX, AccelY, and AccelZ values in the sample log to determine the orientation of the HHB.

If...	The HHB is oriented as shown...	If...	The HHB is oriented as shown...
<p>AccelX <math>\cong</math> 0                      AccelY <math>\cong</math> 2000                      AccelZ <math>\cong</math> 0</p>	 <p>This is the desired orientation</p>	<p>AccelX <math>\cong</math> 0                      AccelY <math>\cong</math> -2000                      AccelZ <math>\cong</math> 0</p>	
<p>AccelX <math>\cong</math> 0                      AccelY <math>\cong</math> 0                      AccelZ <math>\cong</math> -2000</p>	 <p>This orientation is not ideal if the HHB is set on a flat surface because the exhaust vents on the back of the enclosure will be covered.</p>	<p>AccelX <math>\cong</math> 0                      AccelY <math>\cong</math> 0                      AccelZ <math>\cong</math> 2000</p>	 <p>This orientation is not acceptable if the HHB is set on a flat surface because the sample inlets will be against the surface instead of facing the room or ambient air.</p>
<p>AccelX <math>\cong</math> -2000                      AccelY <math>\cong</math> 0                      AccelZ <math>\cong</math> 0</p>		<p>AccelX <math>\cong</math> 2000                      AccelY <math>\cong</math> 0                      AccelZ <math>\cong</math> 0</p>	

## Interpreting electrochemical sensor data

Gas concentrations can be estimated from the working electrode (WE) and auxiliary electrode (AE) voltages logged from Alphasense B-series electrochemical sensors using: (a) calibration constants that are measured by Alphasense when the sensors are manufactured in combination with (b) four different algorithms as outlined in Alphasense Application Note 803-05. In HHB sample log files, gas concentrations estimated using these four algorithms have variable names formatted as “G. AlphasenseX\_AlgorithmY” where “X” is the position in the gas sensor housing where the Alphasense sensor is installed (1–4) and “Y” is the algorithm used to estimate the gas concentration (1–4).

Which algorithm (1, 2, 3, or 4) should you use to interpret the data from each gas sensor? The answer is not always straightforward and, rather than using any of the four Alphasense algorithms, you might wish to perform your own calibration and develop your own models for estimating gas concentrations from the sensor WE and AE voltages. Alphasense recommends using Algorithm 1 for NO<sub>2</sub>-B43F sensors, Algorithm 2 or 3 for NO-B4 sensors, Algorithm 1 for CO-B4 sensors, and Algorithm 1 for OX-B431 sensors. It is not always possible to use Algorithm 2 because, for some sensors, a calibration constant that appears in the denominator of Algorithm 2 is equal to zero. In a prior study in which we collocated HHBs with a regulatory-grade NO<sub>2</sub> monitor inside an occupied home with a gas stove, we found that NO<sub>2</sub> concentrations estimated using Algorithm 4 were most accurate, but that all four algorithms performed similarly well (DOI: [10.1016/j.buildenv.2021.108398](https://doi.org/10.1016/j.buildenv.2021.108398)).

**Application note:** Alphasense B-series electrochemical sensors are designed for long-term operation and require a few hours to “warm up” each time they are turned on. If the HHB has been off for a while and the electrochemical sensor data recorded at the beginning of a sample appear unusual (more specifically, if the pollutant concentrations calculated from the working and auxiliary electrode voltages appear unusually high), we recommend ignoring the first few (i.e., 1-4) hours of electrochemical sensor data. If you wish to measure a short-duration pollution event using the electrochemical sensors in the HHB, we recommend starting the HHB sample several hours before the event is expected to take place to give the sensors time to warm up.

## Interpreting particulate matter sensor data

The PM<sub>2.5</sub> concentration reported by a low-cost optical PM sensor, like the Sensirion SEN55 used in the Home Health Box, is typically correlated with the “true” PM<sub>2.5</sub> concentration, but is often an under- or overestimate of the true PM<sub>2.5</sub> concentration due to differences between the size distribution, refractive index, and shape of the real-world PM being measured versus the size distribution, refractive index, and shape of the PM used to calibrate the sensor. To improve the accuracy of the time-resolved PM<sub>2.5</sub> estimates, we recommend scaling the PM<sub>2.5</sub> concentrations reported by the SEN55 sensor inside the HHB during each sample (“SEN55\_PM2.5” in the sample log) by the ratio of the sample-averaged PM<sub>2.5</sub> concentration derived from gravimetric analysis of a concurrent filter sample to the sample-averaged PM<sub>2.5</sub> concentration reported by the sensor. Using this approach, the “corrected” PM<sub>2.5</sub> concentration is calculated as:

$$PM_{2.5,corrected} = PM_{2.5,SEN55} \left( \overline{PM_{2.5,filter}} / \overline{PM_{2.5,SEN55}} \right) \quad (1)$$

where  $PM_{2.5,corrected}$  is the corrected 30-s average  $PM_{2.5}$  concentration,  $PM_{2.5,SEN55}$  is the 30-s average  $PM_{2.5}$  concentration reported by the SEN55 sensor (“SEN55\_PM2.5” in the sample log),  $PM_{2.5,filter}$  is the sample-averaged  $PM_{2.5}$  concentration derived from gravimetric analysis of the filter sample, and  $\overline{PM_{2.5,SEN55}}$  is the time-averaged  $PM_{2.5}$  concentration reported by the SEN55 over the duration of the filter sample (all in  $\mu\text{g m}^{-3}$ ).

Several peer-reviewed studies have shown that low-cost optical PM sensors, similar to the SEN55 sensor installed in the HHB, do a poor job detecting  $PM_4$  and  $PM_{10}$ . It is unlikely that the  $PM_{4.0}$  and  $PM_{10}$  concentrations reported by the SEN55 (“SEN55\_PM4.0” and “SEN55\_PM10”, respectively, in the sample log) are correlated with the true  $PM_4$  and  $PM_{10}$  concentrations, respectively, and we do not recommend using these data.

For additional information, we recommend the following references:

- Tryner et al., 2020, DOI: [10.1016/j.jaerosci.2020.105654](https://doi.org/10.1016/j.jaerosci.2020.105654)
- Tryner et al., 2021, DOI: [10.1016/j.buildenv.2021.108398](https://doi.org/10.1016/j.buildenv.2021.108398)
- Kuula et al., 2020, DOI: [10.5194/amt-13-2413-2020](https://doi.org/10.5194/amt-13-2413-2020)
- Molina Rueda et al., 2023, DOI: [10.1021/acs.estlett.3c00030](https://doi.org/10.1021/acs.estlett.3c00030)
- Ouimette et al., 2023, DOI: [10.1080/02786826.2023.2285935](https://doi.org/10.1080/02786826.2023.2285935)

# 4 Device Maintenance and Sample Quality Assurance

## Verifying sample flow rates

### How often should I check sample flow rates against an external meter?

For the highest level of sample quality assurance, you can use an external flow meter to verify filter and sorbent sample volumetric air flow rates on a regular basis. Many air sampling protocols require that the flow rate of each sample be checked at the start of the sample and again at the end of the sample. We recognize that checking the volumetric flow rate of each sample at the start and end of the sample can be time-consuming and logistically-challenging—and therefore might not be possible or desirable in every sampling campaign. For that reason, each sampling channel on the HHB is equipped with a mass flow sensor that monitors the air flow rate through the pump continuously so that the device firmware can use the measured mass flow rate—along with continuously-measured air temperature, pressure, and RH data—to actively adjust the pump power so that the target volumetric flow rate through the inlet and sample filter/tube/cartridge is maintained within 4% of the target value over the full duration of the sample. This system should ensure that each sample flow rate is always equal to the setpoint value; still, it is good practice to use an external flow meter to confirm regularly that the volumetric air flow rate through each HHB sampling channel matches the setpoint. If something in the flow control system malfunctions, all samples collected since the flow rate was last confirmed to match the target value might need to be rejected.

We recommend that users establish a sample quality assurance protocol that includes a schedule for sample flow rate verification before completing a large-scale sampling campaign. The frequency at which sample flow rate verification is scheduled should be determined based on consideration of: (a) availability of a suitable external flow meter, (b) field campaign logistics, (c) personnel availability, (d) the requirements of any predefined sampling protocols that are being used, and (e) the user's own quality assurance goals.

### Recommended flow meters

We recommend using Alicat Whisper™ **MW-** or **MWB-Series** Low Pressure Drop Mass Flow Meters with all AST samplers (HHB and UPAS). Specific part numbers that we recommend are as follows:

Model number	Specifications
MWB-5SLPM-D MW-5SLPM-D	For checking particulate matter sample flow rates up to 5 L min <sup>-1</sup> ; MWB = portable battery-powered version; MW = line-powered version
MWB-50SCCM-D MW-50SCCM-D	For checking gas sample flow rates up to 50 mL min <sup>-1</sup> ; MWB = portable battery-powered version; MW = line-powered version

Other meters that can be used include the Bronkhorst® [LOW- \$\Delta\$ P-FLOW F-101D](#), [mini-BUCK™ Calibrators](#), and the BGI triCal® or [tetraCal®](#).

Do not use an Alicat M-series meter or a piston-type flow meter (e.g., DryCal®) with the Home Health Box. HHB sample flow rates can only be measured using flow measurement devices that are non-pulsative and have a relatively low pressure drop. Therefore, no moving-piston type meters may be used with the HHB. Flow measurement devices that impose relatively high pressure drops or use moving pistons will result in large measurement errors or will make flow measurement impossible.

## Verifying filter sample flow rates

Install the filter cartridge and size-selective inlet in the filter sample channel of interest. Then, program and start a sample with the target sample volumetric flow rate. Connect the filter calibration and flow adapter to your flow meter using a piece of flexible tubing. Then, seal the adapter over the size-selective inlet as shown in **Figure 15**. The flow rate might initially appear low while the active flow control system takes a minute or two to adjust to the pressure drop imposed by the meter. After waiting a couple of minutes for the flow rate to stabilize, confirm that the meter reads the target volumetric flow rate.



**Figure 15.** A photograph illustrating how to seal the filter calibration and flow adapter over a size-selective inlet and connect the adapter to a meter to check the volumetric flow rate of the filter sample.

## Verifying sorbent sample flow rates

Install the sorbent media in the sorbent sample channel of interest. Then, program and start a sample with the target sample volumetric flow rate. Connect the larger-diameter end of the sorbent inlet block calibration adapter to your flow meter using a piece of flexible tubing. Then, insert the smaller-diameter end of the calibration adapter into the sorbent inlet block, as shown in **Figure 16**, so that the O-ring on the outside of the adapter seals to the inlet hole in the block. The sample flow rate might initially appear low while the active flow control system takes a minute or two to adjust to the pressure drop imposed by the meter. After waiting a couple of minutes for the flow to stabilize, confirm that the meter reads the target volumetric flow rate.



**Figure 16.** A photograph illustrating how to insert the sorbent inlet block calibration adapter into the sorbent inlet block and connect the adapter to a meter to check the volumetric flow rate of a sorbent sample.

## Cleaning

### How often should I clean...?

#### Size-selective PM inlets

We recommend cleaning size-selective inlets regularly to prevent PM that has accumulated in the inlet from contaminating future samples. The frequency at which an inlet must be cleaned depends on the PM concentration in the environment where the inlet is being used. It's a good idea to clean each inlet after each sample, especially if the inlet was used in a very dirty environment. We also recognize that cleaning each inlet after each sample might not be feasible in every sampling campaign and might not be necessary in cleaner sampling environments.

We recommend users establish a sample quality assurance protocol that includes a schedule for inlet cleaning, and evaluate the effectiveness of said protocol, before completing a large-scale sampling campaign. The frequency at which cleaning is scheduled should be determined based on: (a) the anticipated time-averaged PM concentration in the environment to be sampled, (b) the duration of each sample, (c) field campaign logistics, (d) personnel availability, (e) the requirements of any predefined sampling protocols being used, and (f) the user's own quality assurance goals.

#### Filter cartridges

We recommend cleaning each filter cartridge after each sample to prevent cross-contamination between samples.

## Sorbent inlet blocks

The frequency at which the sorbent inlet blocks must be cleaned depends on (a) the gas-phase pollutants that are anticipated to be present in the environment to be sampled, (b) the gas-phase pollutants for which samples will be analyzed, and (c) the sensitivity of the sorbent sample analysis method(s) to carryover contamination from previous samples. It might be necessary to clean each sorbent inlet block after each sample. We also recognize that cleaning each sorbent inlet block after each sample might not be feasible in every sampling campaign.

We recommend that users establish a sample quality assurance protocol that includes a schedule for sorbent inlet block cleaning, and evaluate the effectiveness of said protocol, before completing a large-scale field sampling campaign. The frequency at which inlet block cleaning is scheduled should be determined based on consideration of the factors mentioned in the preceding paragraph as well as: (a) field campaign logistics, (b) personnel availability, (c) the requirements of any predefined sampling protocols being used, and (d) the user's quality assurance goals.

## How do I clean...?

### Size-selective inlets and filter cartridges

To disassemble, clean, and reassemble the size-selective inlets and filter cartridges, follow the instructions in our Size-Selective Inlet User Guide, which is available on our [website](#).

### The filter sockets

We recommend wiping the filter sockets out regularly with a damp lint-free wipe to remove any accumulated dirt, dust, or debris. You can wet the wipe with water, isopropyl alcohol, or ethanol. Do not apply any other solvents to the HHB enclosure.

### Sorbent inlet blocks

The sorbent inlet blocks can be removed completely from the HHB for cleaning. The sorbent inlet blocks can be removed by screwing the sorbent block lifting tool (or another M3 × 0.5 mm screw) into the M3 × 0.5 mm threaded hole on the front of the block (**Figure 2**) and then using the tool to lift the block straight out of the sorbent media pocket. Once removed from the HHB, the sorbent inlet blocks can be (a) washed with a mild detergent and then rinsed in water, (b) sonicated in a solvent, (c) rinsed with one or more solvents, and/or (d) heated to drive off volatile compounds. The sorbent inlet blocks are machined from stainless steel and equipped with Viton™ O-rings. Consider the compatibility of these materials with any solvent with which you plan to wash the blocks or any temperature to which you plan to heat the blocks. Remove and replace the O-rings if necessary. The O-rings in our ¼" sorbent inlet blocks are 6-mm ID × 1 mm CS. Allow the sorbent inlet blocks to dry completely and cool to room temperature (if applicable) before reinstalling them in the HHB.

### The outside of the Home Health Box

If the outside of the HHB enclosure becomes dirty, you can wipe it down with a damp lint-free cloth. You can wet the cloth with water, isopropyl alcohol, or ethanol. Do not apply any other solvents to the HHB enclosure. The HHB is not waterproof. **Do not spray liquids directly onto the HHB, place the HHB under a running liquid stream, or submerge the HHB in liquid.**

## Calibrating the CO<sub>2</sub> sensor

We recommend calibrating the CO<sub>2</sub> sensor after every seven (7) days of sampling. To calibrate the CO<sub>2</sub> sensor, follow the instructions for the [SCD30](#) on pages 25–26.

## Recommended maintenance intervals

We recommend returning the HHB to AST annually for service. The frequencies at which key maintenance activities should be completed are listed below. If you suspect any component of your HHB is malfunctioning, share a sample log file with one of our engineers to see if the problem can be diagnosed remotely; if needed, the HHB can be returned AST for further evaluation and replacement of degraded components.

Maintenance activity	Recommended frequency
Recalibration of filter pumps	Annually
Recalibration of sorbent pumps	Annually
Replacement of Alphasense B-series electrochemical sensors	Every two years


# 5 Updating the Device Firmware

The following software is required to update the HHB firmware:

- A terminal emulation application, such as PuTTY or TeraTerm.
- [STM32CubeProgrammer](#)

**The HHB firmware cannot be updated while a sample is running.** Before updating the firmware, (a) make sure that the sample has successfully finished running (if the last “Start Sampling” setting was “Once Next Power On” or “At Specific UTC Date/Time”) or (b) power the HHB on with the microSD™ card removed to prevent a sample from starting or resuming.

Once the required software applications have been installed on your computer and any active HHB sample has been completed or interrupted, you can update the HHB firmware using these steps:

- 1 Connect the Home Health Box to a Thunderbolt™ port on your computer using the USB Type-C® to USB Type-C® cable. A Thunderbolt™ port is a USB Type-C® receptacle marked with this symbol: 
- 2 Turn the Home Health Box on. Press the power button down until you feel a click and then continue to hold the button down until the button LED light turns on (approximately five seconds). When the HHB turns on, the button LED should blink blue.
- 3 Identify the COM port associated with the Home Health Box.

On a Windows PC: Open the Device Manager, expand the list of “Ports (COM & LPT)”, and note the COM port number associated with the HHB. The HHB will be called “USB Serial Device.”

- 4 In your terminal emulation application, open a new serial connection to the HHB using the following settings:

Speed: 115200  
Data: 8 bit  
Parity: none  
Stop bits: 1 bit  
Flow control: none

Once the connection is open, you should see the menu shown in **Figure 17**. If this menu is not visible, try hitting the ‘Enter/Return’ key on your keyboard.

- 5 Type ‘@’ (without the quotes) into the terminal emulation application to prepare the HHB to receive the new firmware. The button LED will stop flashing and turn solid blue.
- 6 Exit out of the terminal emulation application.

**IMPORTANT!** Close the terminal emulation application completely (i.e., do not just minimize the application). If you do not exit the terminal emulation application, you will not be able to connect to the Home Health Box in the STM32CubeProgrammer.

```

Board: Main
  ID: MB00085
  RTC: 22:59:22 1/9/2024   UTC TZ: -7.00
  UBUS: 4.748 U           UUSB Present: Yes
  USUPPLY: 4.242 U       PB: Not pressed
  5U0: 5.035 U           EXPA_I2C_FAULT: OK
  3U3: 3.407 U           EXPB_I2C_FAULT: OK
  BATTERY U: 4.167 U     BAT INSTALL: 11/7/23 21:58
  T: 18.650 C           BAT SHUTDOWN: 3.000 U
  SAMPLE: FINISHED      BAT WARM: 3.200 U
LOG INTUL: 30 SEC
DURATION: 168.000 HR
RUN TIME: 168.000 HR
STOP: SHUTDOWN
LOG VARS: HHBv2
SUMMARY: SAMPLING
LOG NAME: MB00085_LOG_2023-11-29T02_49UTC.csv
SMPL ID:
ACCEL: X= 68 Y= 2007 Z= 65
uSD: Mounted as "", 7.552GB of 7.572GB Free
XTSD: Mounted as "", 491MB of 491MB Free

SEN55  MODE: RH/T/GAS/PMS
PM1.0: 1.200
PM2.5: 1.400
PM4.0: 1.500
PM10: 1.600
RH: 34.29 %
T: 18.73 C
rawUOC: 29467
rawNOx: 13611
STATUS: 0x00000000
INSTALL: 11/7/23 20:55
RUN TIME: 355.358 HR
FAN TIME: 355.358 HR
BMP581  P: 83234.0 PaA
T: 19.74 C

Board Selection:
M> Main
1> Slot #1 [Sorbent Pumping]
2> Slot #2 [Filter Pumping]
3> Slot #3 [Empty]
4> Slot #4 [Filter Pumping]
5> Slot #5 [Empty]
6> Slot #6 [Gas Sensor]

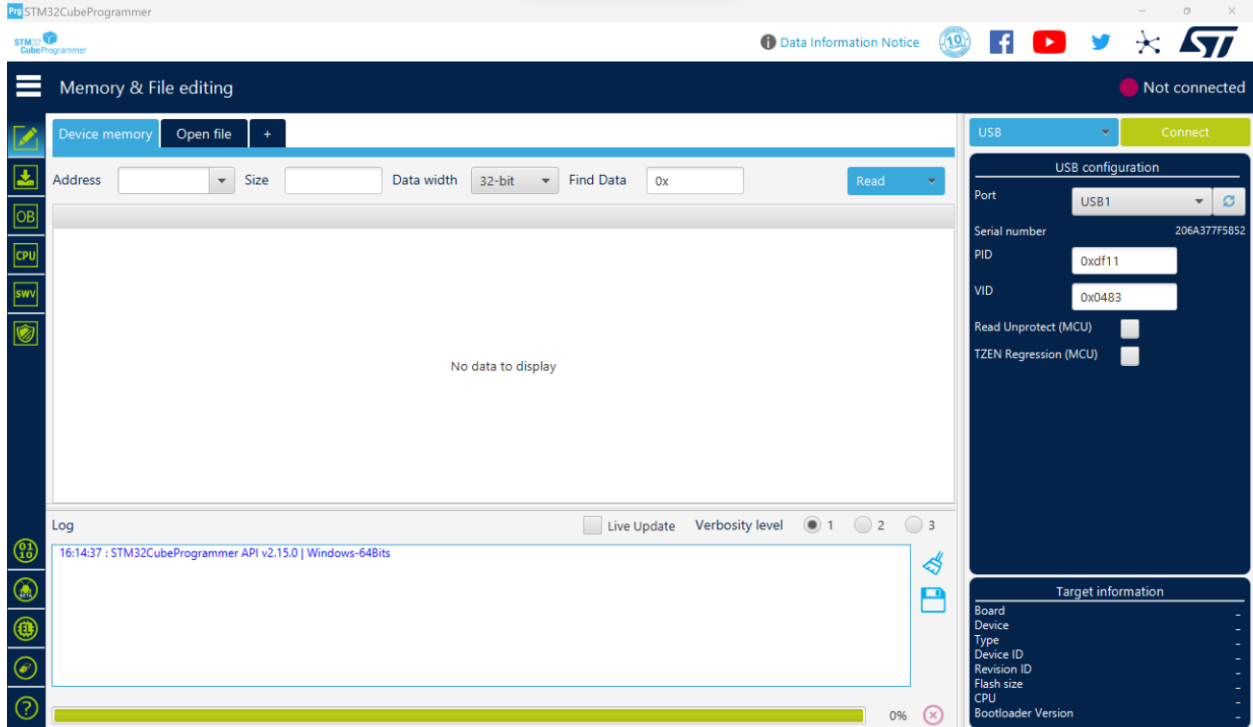
Action:
?) Transfer FRAM contents to external SD card
@) Prepare for new firmware upload
D) Defaults menu
H) Hardware menu
L) Logging menu
P) SEN55 menu
S) Sampling configuration menu
T) Time menu
-->

```

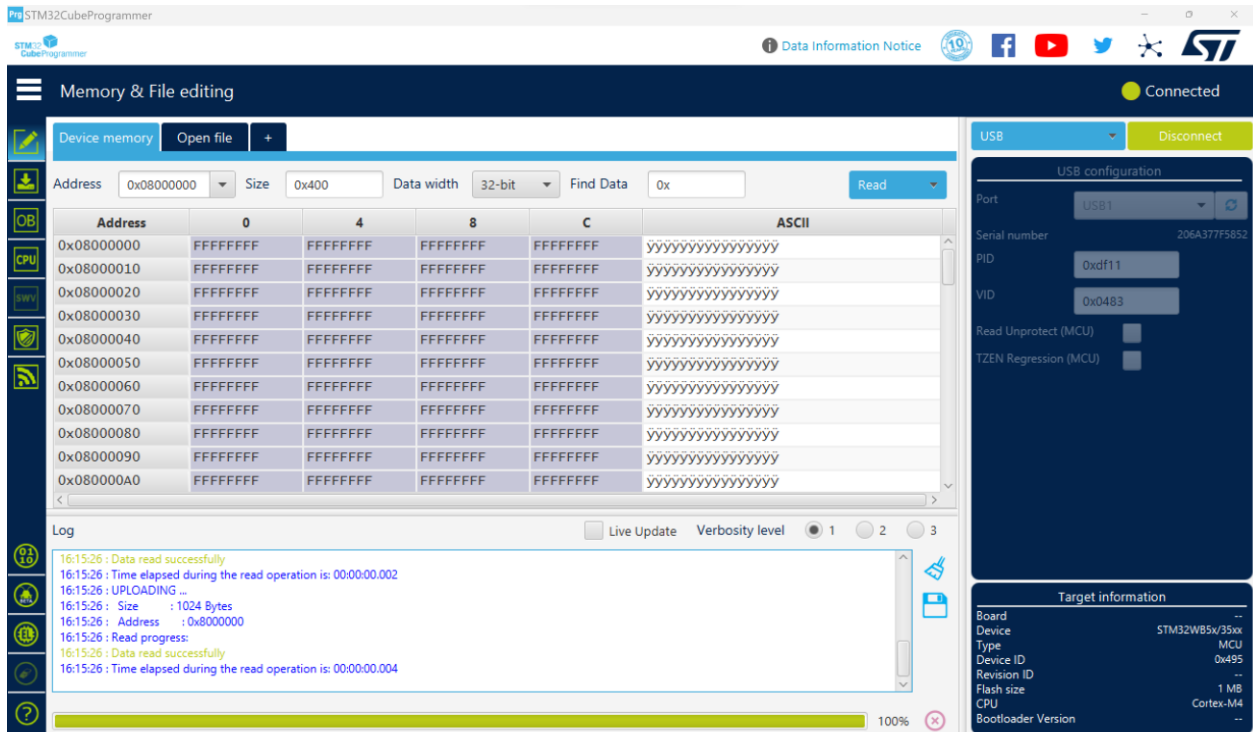
Figure 17. The menu displayed when serial communication to the Home Health Box is opened.

- 7 Power off the Home Health Box. Press the power button until you feel a click and then continue to hold the button down until the button LED turns off.
- 8 Power on the Home Health Box. Press the power button until you feel a click and then continue to hold the button down for at least five seconds. **The button LED will not light up when the HHB turns back on.**
- 9 Open the STM32CubeProgrammer software application.  
Once open, the Graphical User Interface (GUI) should appear as shown in **Figure 18**.
- 10 Click on the blue drop-down menu in the upper-right corner of the GUI and select 'USB.'
- 11 Click the drop-down menu next to the "Port" label and select the appropriate USB port.
- 12 Click the green "Connect" button to connect to the Home Health Box.

If the STM32CubeProgrammer software has connected to the HHB, the green button in the upper-right corner will say "Disconnect" instead of "Connect," the "Device memory" tab will be populated with text, and the text in the console at the bottom of the GUI will say "Data read successfully" (see **Figure 19**).

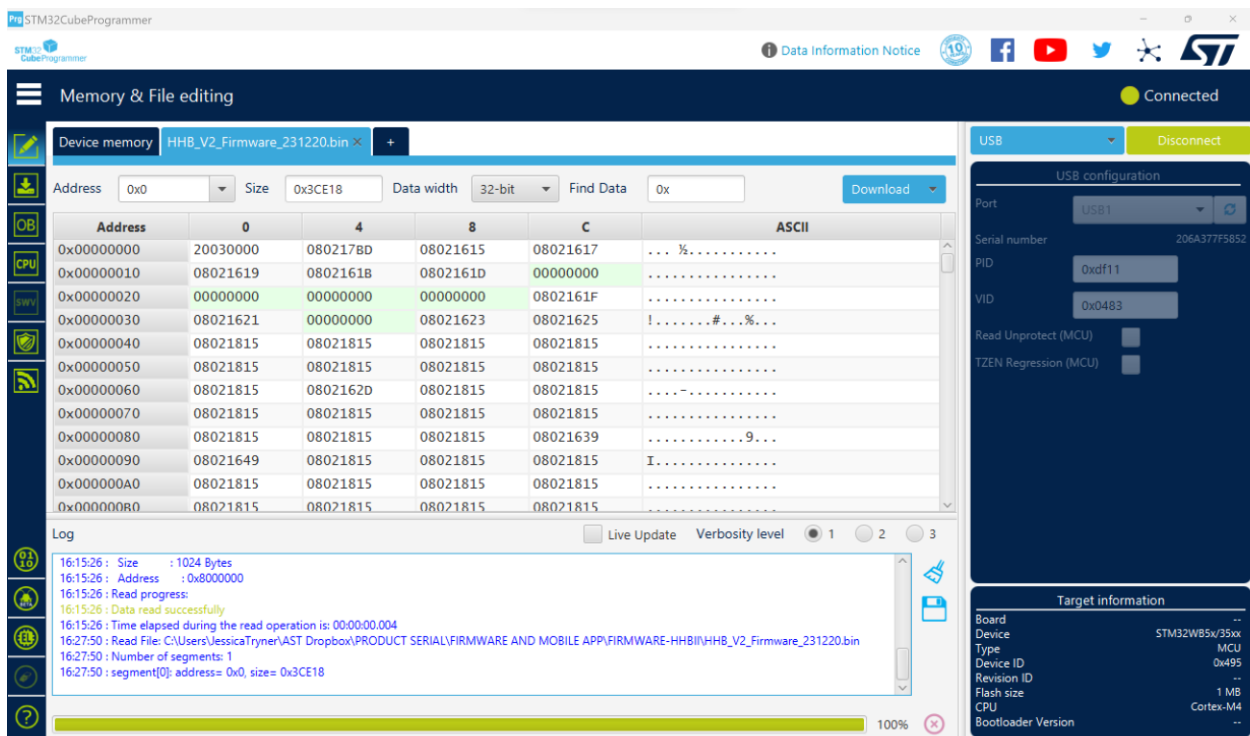


**Figure 18.** The GUI displayed when the STM32CubeProgrammer software application opens. Click on the blue drop-down menu in the upper-right corner and select “USB”. Next, click on the “Port” drop-down menu and select the appropriate USB port. Finally, click the green “Connect” button to connect to the HHB.

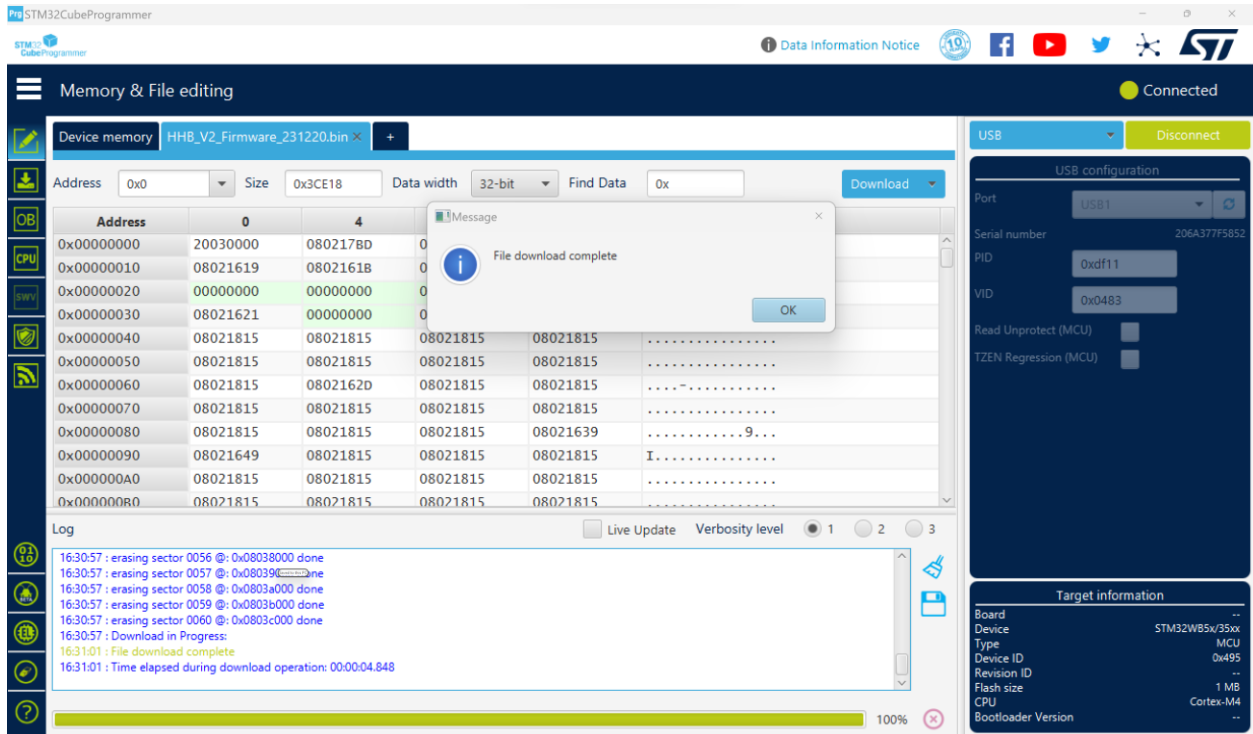


**Figure 19.** The GUI display once the STM32CubeProgrammer software has connected to the HHB. The green button in the upper-right corner says “Disconnect” instead of “Connect,” there is text populated in the “Device memory” tab, and the text in the console at the bottom of the GUI says “Data read successfully.”

- 13 Click on the “Open file” tab in the STM32CubeProgrammer GUI.
- 14 When the “Open file” pop-up menu appears, navigate to the location of the firmware .bin file that you wish to install on the Home Health Box. Click on the .bin file and hit the “Open” button on the pop-up menu.  
The most recent firmware version is: `HHBv2_Firmware_250529.bin`
- 15 Click the blue “Download” button in the STM32CubeProgrammer GUI (see **Figure 20**).  
When the new firmware file has been successfully downloaded to the HHB, the text in the console at the bottom of the GUI will say “File download complete,” the progress bar at the bottom of the GUI will be filled in green with 100% displayed on the right-hand side, and a pop-up menu will appear with the text “File download complete” (see **Figure 21**).
- 16 Click the “OK” button on the pop-up menu that says “File download complete.”
- 17 Click the green “Disconnect” button in the upper-right corner of the STM32CubeProgrammer GUI to disconnect from the Home Health Box.
- 18 Close the STM32CubeProgrammer software application.
- 19 Power off the Home Health Box. Press the power button until you feel a click and then continue to hold the button down for at least five seconds before releasing it.
- 20 The firmware update process should now be complete. When you turn the Home Health Box back on (by pressing the power button down until you feel a click and then holding the button down for approximately five seconds), the button LED should light up again.



**Figure 20.** The STM32CubeProgrammer GUI display once the firmware .bin file has been opened. Click the blue “Download” button to install the new firmware on the HHB.



**Figure 21.** The GUI display once the new firmware file has been downloaded to the HHB successfully. The text in the console at the bottom of the GUI says “File download complete,” the progress bar at the bottom of the GUI is filled in green with 100% displayed on the right-hand side, and a pop-up menu has appeared with the text “File download complete.”

# 6 Frequently Asked Questions

## What filters can I use to collect PM samples with the HHB?

The type of filter used to collect PM samples is typically determined by the analysis or analyses that will be performed on the sample. For samples that will undergo gravimetric, optical black carbon, and/or X-ray fluorescence (XRF) analyses, we typically use Measurement Technology Laboratories (MTL) PTFE membrane filters (Item # PT37P-PF03); however, there are other sample analysis techniques that will require other filter materials (e.g., quartz, polyvinyl chloride, mixed cellulose ester). See **Table 12** for additional information on (a) the filter materials commonly used with different sample analysis techniques and (b) how example filters of each material affect the power consumption of the ultrasonic pumping elements in AST samplers.

## What sorbent media can I use to sample VOCs with the HHB?

The Home Health Box sorbent media pocket will accommodate  $\frac{1}{4}$ " OD  $\times$  3.5" long (6.35-mm OD  $\times$  89-mm long) stainless steel thermal desorption tubes, Waters™ Sep-Pak® cartridges, as well as most common (e.g., 6- to 10-mm diameter) glass sorbent tubes. The standard sorbent inlet blocks that come with the HHB are designed to accommodate sorbent media with a  $\frac{1}{4}$ " (6.35 mm) OD inlet. The larger-diameter end of a Waters™ Sep-Pak® cartridge with Luer-Tip connections will fit securely into the  $\frac{1}{4}$ " sorbent inlet block. To use sorbent tubes or cartridges with OD  $>$   $\frac{1}{4}$ " (6.35 mm), contact AST regarding the availability of larger-diameter sorbent inlet blocks.

**Table 12.** 37-mm-diameter filters that have been tested by Access Sensor Technologies for use with our ultrasonic sample pumps.

Gravimetric analysis	Dissolvable (for chemical analysis)	Scannable via XRF, etc.	Microscopy analysis	Biological sampling	Thermal-optical elemental and organic carbon (EC/OC) analysis	Relative flow resistance (lower means lower power consumption)	Manufacturer	Product family	Product ID	Filter media material type	Filter media pore size (µm)	Support ring material
+	-	+	+	+	-	1.0	Tisch Scientific	PTFE	SF17382	PTFE (Teflon™) membrane	5.0	None
+	-	+	+	+	-	1.2	GE Lifesciences Whatman	TE 38	10411108	PTFE (Teflon™) membrane	5.0	None
+	-	+	+	+	-	1.3	Pall Laboratory	Teflo	R2PJ037	PTFE (Teflon™) membrane	2.0	PMP ring
+	-	+	+	+	-	1.7	Measurement Technology Laboratories (MTL)*	PTFE	PT37P-PF03	PTFE (Teflon™) membrane	2.0	FEP ring
+	±	+	+	+	-	4.2	SKC	PVC	225-5-37	PVC membrane	5.0	None
±	-	±	-	-	+	5.0	Pall Laboratory	Tissuquartz	2500QAT-UP	Quartz fiber (unbonded)	-	None
+	-	+	-	-	-	5.1	Pall Laboratory	EMFAB	Tx40HI20WW-37 mm	Borosilicate microfiber w/ woven glass, PTFE bonded	-	None
+	-	+	+	+	-	6.6	Pall Laboratory	Zefluor	P5PJ037	PTFE (Teflon™) membrane	2.0	PTFE ring
±	+	+	+	+	-	10.0	SKC	MCE	225-1938	Mixed cellulose ester (MCE) membrane	5.0	None
±	+	+	+	+	-	16.2	SKC	MCE	225-1939	MCE membrane	0.8	None
±	+	+	+	+	-	16.2	SKC	MCE	225-334	MCE membrane	0.8	None
±	+	+	+	+	-	17.7	EMD Millipore	MF	AAWP03700	MCE membrane	0.8	None
±	+	+	+	+	-	19.0	GE Lifesciences Whatman	ME27	10400909	MCE membrane	0.8	None
+	Typical use		±	Optional use		-	Not typically used					

\* Access Sensor Technologies recommends these filters for HHB samples intended for gravimetric, optical black carbon, and XRF analyses

## How long will the HHB run on the internal battery?

The Home Health Box is designed to be plugged into a wall outlet during sampling. The battery inside the HHB is designed to serve as a backup power source to prevent sample failure during a short-term interruption in line power. The battery in the HHB is not sized for long-term sampling (i.e., for samples lasting more than  $\approx 8$  hours).

The duration for which the HHB can run on a fully-charged battery alone will depend on the sample configuration, the filter media used to collect PM samples, the sorbent media used to collect gas samples, which time-resolved pollutant sensors are enabled, and the local air density. As an example, the HHB will run for 8 hours on a fully-charged battery when collecting two PM samples onto MTL PT37P-PF03 PTFE membrane filters at  $2 \text{ L min}^{-1}$  and two gas samples onto Markes Carbopack X SafeLok™ thermal desorption tubes at  $30 \text{ mL min}^{-1}$  with the PM sensor,  $\text{CO}_2$  sensor, and one Alphasense B-series electrochemical sensor running in a location with air density =  $1.0 \text{ g L}^{-1}$ . Using filters with a higher flow resistance, sorbent media with a higher flow resistance, operating additional Alphasense B-series electrochemical sensors, and sampling in a location with higher air density (e.g.,  $1.2 \text{ g L}^{-1}$ ) would all decrease this battery life. Using filters with a lower flow resistance, using sorbent media with a lower flow resistance, collecting PM and gas samples at lower flow rates (e.g.,  $1 \text{ L min}^{-1}$  and  $3 \text{ mL min}^{-1}$ , respectively), operating fewer time-resolved sensors, and sampling in a location with lower air density would all increase this battery life.

We recommend testing the duration for which the HHB can run on a fully-charged battery alone, with no line power input, under your planned sampling conditions before initiating a large-scale sampling campaign.

# 7 Returns, Warranty, and Repairs

## Limited product warranty

Access Sensor Technologies (known hereafter as ‘AST’) provides a one-year limited warranty on the Home Health Box (known hereafter as ‘this product’). This limited warranty extends only to the original purchaser, for a period of one-year after product is received.

Please note that any warranty services or questions must be accompanied by the order number from the transaction through which the warranted product was purchased. The original transaction will include a list of serial number(s) of the products included in the sale, which are covered by this warranty. The order number serves as your warranty number and must be retained. AST will not offer warranty coverage to products with serial numbers not included in the original sale.

AST warrants this product and its parts against defects in materials, workmanship or function for a period of one year from the original ship date. During this period, AST will repair or replace defective parts with new or reconditioned parts at AST’s option, without charge for this repair to you.

Shipping fees incurred from returns for under-warranty service will be split between the customer and AST as follows. The customer will pay all shipping, import and duty fees to ship defective product back to AST, who will then service or replace the products. AST will then pay all shipping, import and duty fees to return the repaired or replaced product to the customer at the original, previously agreed upon customer location.

All original parts (parts installed by AST at the original system build) removed by AST or its authorized service center during the process of any warranty service become the property of AST. Any after-market additions or modifications will not be warranted.

AST makes no other warranty, either express or implied, including but not limited to implied warranties of merchantability, fitness for a particular purpose, or conformity to any representation or description, with respect to this product other than as set forth below. AST makes no warranty or representation, either express or implied, with respect to any other manufacturer’s product or documentation, its quality, performance, merchantability, fitness for a particular purpose, or conformity to any representation or description.

Except as provided below, AST is not liable for any loss, cost, expense, inconvenience, or damage that may result from use or inability to use the product. Under no circumstances shall AST be liable for any loss, cost, expense, inconvenience or damage exceeding the purchase price of the product.

The warranty and remedies set forth below are exclusive and in lieu of all others, oral or written, expressed or implied. No reseller, agent or employee is authorized to make any modification, extension or addition to this warranty.

## Warranty conditions

The above Limited Warranty is subject to the following conditions:

- This warranty extends only to product distributed and/or sold by AST.
- This warranty covers only normal use of the product. AST shall not be liable under this warranty if any damage or defect results from (i) misuse, abuse, neglect, improper shipping or installation; (ii) disasters such as fire, flood, lightning or improper electric current; or (iii) service or alteration by anyone other than an authorized AST representative; (iv) damages incurred through irresponsible use, including those resulting from non-recommended practices.
- No warranty extension will be granted for any replacement part(s) furnished to the purchaser in fulfillment of this warranty.
- This warranty does not cover any third-party software or virus-related problems.
- AST makes no warranty either expressed or implied regarding third-party (non-AST) firmware.

## Return of non-defective products

A non-defective product may be returned to AST within thirty (30) days of the invoice date for a refund of the original purchase price with the following amendments/fees:

AST will refund neither the original shipping cost nor the shipping and handling fees incurred from the product's return. No refund will be granted for product that has been opened, used, or tampered with in any way which jeopardizes AST's ability to remarket or resell the product. AST maintains full discretion in decisions regarding a product's fitness for return.

## Procedures for obtaining warranty service

To return a defective product, please contact our Customer Service Department for a Return Merchandise Authorization (RMA) number and follow the Return of Products Instructions below.

If the product must be repaired, an RMA number will be issued for shipment to our repair department. Please follow the instructions given by AST technical support staff to ship your product. AST will not accept any shipments without an RMA number.

Pack the product in its original box or a well-protected box, as outlined in the Return Shipping Instructions. AST will not be responsible for shipping damage/loss of any product outside the 1-year AST-paid service period. Ship the product with a copy of your bill of sale or other proof of purchase, your name, address, phone number, description of the problem(s), and the RMA number you have obtained to Access Sensor Technologies.

Upon receiving the product, AST will repair or replace your product (at AST's discretion) and will ship it back to you within two weeks (dependent on parts availability) via common carrier of AST's choice for normal delivery.

AST will pay for shipping back to the customer only within one-year of the original product ship date. The customer assumes full liability for losses or damages resulting from shipping as well as all responsibility to pursue remuneration for such issues with their selected carrier.

## **After one-year warranty – post warranty repair**

Post warranty repair is possible if both customer and AST can agree to terms before initiating such repair. In the case of such agreement, the procedure is the same as outlined above for RMA and shipping. However, the customer is responsible for shipping charges both ways, current labor (at a rate to-be-determined before repair initiation) and the current price of part(s) used in repair.

## **Warranty exclusions**

AST does not offer technical support for any aftermarket firmware/software including installed OS or other programs. AST does not offer service or coverage of any external connective software such as mobile device or personal computer applications, etc. Technical support should be pursued through technical support channels offered by the makers of such software. AST accepts no liability for problems caused by after-market software or hardware modifications or additions. AST is not responsible for giving any technical support concerning the installation or integration of any software or component the customer did not pay AST to install. AST is not responsible for loss of data or time, even with hardware failure. Customers are responsible for backing up any data for their own protection. AST is not responsible for any loss of work (“down time”) caused by a product requiring service. This warranty is null and void if the defect or malfunction was due to damage resulting from operation not within manufacturer specifications including but not limited to accidental dropping, collisions with other objects, water immersion or submersion, overheating (over 130F), application of unapproved solvents/liquids/solids, use of a non-approved battery charger, or any other treatment not associated with typical use. The warranty will be null and void if there are indications of misuse and/or abuse. AST has the option of voiding the warranty if anyone other than an AST technician attempts to open or service the product without AST’s express permission being granted. AST will not warrant any problems arising from an act of God (lighting, flooding, tornado, etc.), electrical spikes or surges, or problems arising out of hardware, software, or additional devices added to complement any system/component bought at AST, including battery chargers, charging and data transfer cords, etc. Under no circumstances will AST be responsible for any refund or remuneration exceeding the original purchase price of the product less any shipping fees. AST will not be held responsible for typographical errors on sales receipts, repair tickets, or on our website. AST makes every effort to make sure all information on our website and in literature pertaining to the product is correct.



**ACCESS SENSOR  
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Sampling made simple.®

Revision 2.4  
March 2026  
<https://www.accsensors.com>