

New Horizons Demo EMS Logger

Technician Manual

New Horizons, a division of Global Health Labs

2025-06-03

This document is licensed under the Creative Commons CC-BY 4.0 License
(<https://creativecommons.org/licenses/by/4.0/>).

Table of Contents

1 Introduction	2
1.1 Features.....	2
2 Safety Precautions	2
3 Overview of Logger.....	3
3.1 Connection Diagram	3
3.2 Inputs and Outputs	3
3.3 More details	4
4 Logger operation	4
4.1 Autonomous operation.....	4
4.2 Handling the logger and M2M interface.....	4
4.3 Accessing stored data	4
5 Installation.....	9
5.1 Main enclosure	9
5.2 Temperature sensors	9
5.3 LIN compressor connection or auxiliary power	10
5.4 Door sensors	10
5.5 Provisioning	11
5.6 Verifying installation	11
6 Maintenance	11
6.1 Preventative maintenance	11
6.2 Servicing and corrective maintenance.....	12
7 Diagnostics and Troubleshooting	15
8 Spare Parts	17
9 End-of-Life Disposal and Recycling.....	18
10 User Training	18
11 Abbreviations	18

1 Introduction

The World Health Organization's Performance Quality, and Safety group (WHO PQS) has published a set of specifications collectively known as the Equipment Monitoring System (EMS). These specifications define functionality for the next generation of cold chain equipment (CCE) monitoring solutions. The set contains three related specifications and their associated verification protocols:

- **WHO/PQS/E006/DL01** consists of basic data logging functionality: obtaining data from sensors and storing it in non-volatile memory. These data must be made available over a USB-C port, but no visual display is required. Future CCE must have at least this level of monitoring.
- **WHO/PQS/E006/EM01** defines "equipment monitoring devices" (EMDs) that present monitored data to the user of the CCE and optionally transmit it to remote data systems for use by others. The EMS specifications enable EMDs either to be separate from data logger devices or to have both functions integrated into a single device.
- **WHO/PQS/E006/DS01** is the data standard that defines the required data to be gathered from CCE. It also discusses the format of both required and optional data and definitions of when alarms should be sounded.

The Demonstration EMS Logger is a sample implementation of the DL01 specification. That is, it collects temperature, door opening, and power system data from the CCE and stores it for at least one year. It is intended to serve as a test of the specification and its verification protocol. During the design and evaluation process, New Horizons has been looking for areas where the specification can be clarified. The device can also serve as a reference design for others implementing the DL01 specification.

1.1 Features

- Data sources
 - Internal ambient temperature sensor.
 - One or two temperature sensor harnesses for vaccine and freezer compartments.
 - One or two door sensor harnesses with magnetic sensors.
 - Connection to smart compressors to obtain power and compressor operation data (LIN port, also a source of power when the CCE is powered).
- Storage
 - Non-volatile memory to store several years of data.
 - Emulates USB mass storage controller to provide data over USB-C connection.
- Power
 - Operates for up to 5 years from a non-rechargeable standard CR123A battery.
 - Also powered by USB and CCE power, when available.
 - Can provide 5 V, 1.1 A power to the "machine-to-machine" (M2M) interface.

2 Safety Precautions

This device is powered by a non-rechargeable lithium battery. For safe operation, ensure that it is installed in the correct orientation when replacing. To avoid the risk of fire, do not short the battery terminals or puncture the battery case. Do not dispose of the battery in a fire.

When retrofitting to a refrigerator and supplying DC power to the LIN power input, use only a safety isolated power supply to generate that power. This step will prevent the risk of electric shock to people connecting equipment to the M2M port.

3 Overview of Logger

The Demonstration EMS Logger consists of a small box containing a circuit board and a non-rechargeable battery, and attached sensors and cables. It is intended to be installed inside the fridge and not accessible to the end customer except via an extension of the USB-C port.



Figure 1: Image of Demo EMS Logger installed in an example fridge.

3.1 Connection Diagram

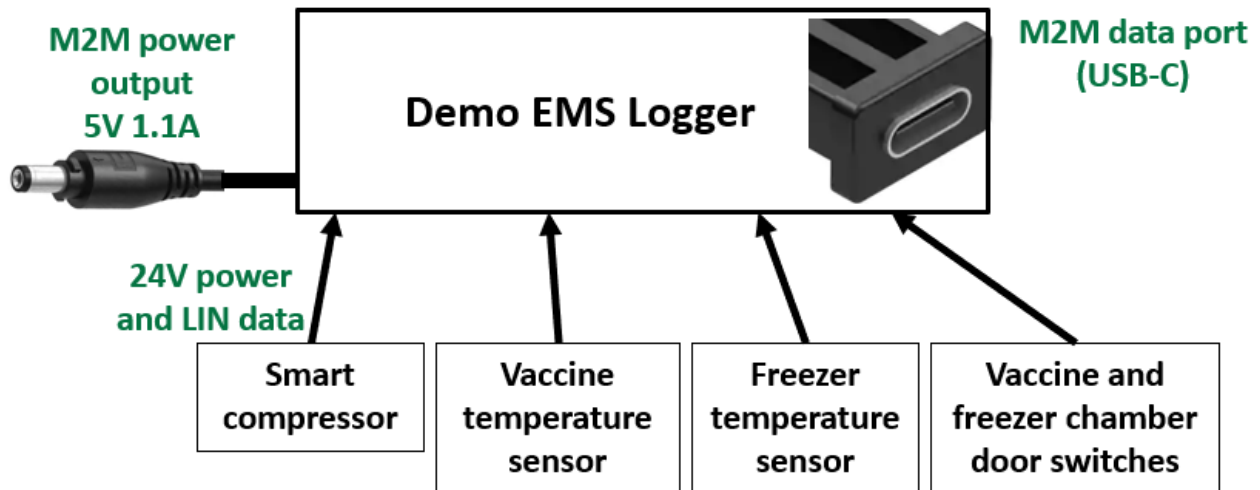


Figure 2: Demo EMS Logger connection diagram

3.2 Inputs and Outputs

Temperature sensors: The temperature sensors are digital types with accuracy of $\pm 0.2^{\circ}\text{C}$ over the range -10°C to $+65^{\circ}\text{C}$ and calibrated traceable to NIST standards. There is one ambient temperature sensor on the circuit board, and connectors to add remote sensors for the vaccine compartment and freezer compartment. These remote sensors are encapsulated to protect them from humidity in their respective chambers.

Door sensors: The door sensors are switches that are open circuit (not conducting) when the door is in the closed position. The sensors supplied with the Demo EMS Logger are reed switches attached to the cabinet and activated by a nearby magnet placed on the door.

LIN and auxiliary power input: Some future smart compressors will have a LIN communications bus that can be used to obtain data or send control parameters. The LIN connector provides a way for the Demo EMS Logger to query such compressors for power and compressor run data. It also is a power input to reduce power consumed from the Demo EMS Logger's battery and provide power for the M2M power output.

M2M data (USB-C): The M2M data port provides a way for Equipment Monitoring Devices (EMDs) or local users with a phone or computer to obtain data from the logger. When plugged into a USB host, the logger presents a USB mass-storage drive. The data files on this drive are described in Section 4.3 . Power supplied by the host reduces battery power consumption and extends battery life.

M2M power: The M2M power port provides a 5 V power output at up to 1.1 A to power external EMDs.

Button: The button is presently not used.

3.3 More details

For more details about internal operation, refer to the architecture description document.

4 Logger operation

4.1 Autonomous operation

Normally, the logger operates without the need for user intervention. It collects data every 15 minutes and stores it in non-volatile memory. If an EMD is connected to the M2M Interface, the EMD will periodically obtain data over the USB-C portion of that interface.

4.2 Handling the logger and M2M interface

The logger is ordinarily installed inside CCE and is not intended to be handled by users. When servicing, it is recommended to use anti-static procedures (e.g., grounded wrist strap and work surface) to prevent damage to the circuit board components.

The M2M power port provides 5 VDC to power an external EMD. It is a low-voltage and current-limited output and so does not present an electric shock or fire hazard. It is protected against short circuits, however it is best to avoid shorting the two contacts together.

The M2M data port is a regular USB-C port. Avoid getting dust or liquids into the port.

4.3 Accessing stored data

The logger will store several years of data, which can be transferred to a compatible data device.

Accessing data with a personal computer

These instructions were written with Microsoft Windows in mind, but the process with MacOS is similar.

- Using a computer, plug in to the logger with a USB-C cable. Within a few seconds, a file explorer window should pop up, much like a USB flash drive. It will resemble the window of Figure 3, although the initial number in the filenames (serial number) will be different and the "P205DT18H11M25S" part of the filenames (timestamp) will be different as well. The timestamp is a representation of how many days, hours, minutes, and seconds it has been since the logger battery was inserted.
- Copy the files to a folder on the PC.

- Safely disconnect the drive from the operating system (Windows: Safely Eject system tray icon; Mac: drag to trash) and unplug the USB connector. This allows the logger to continue writing data to its files.

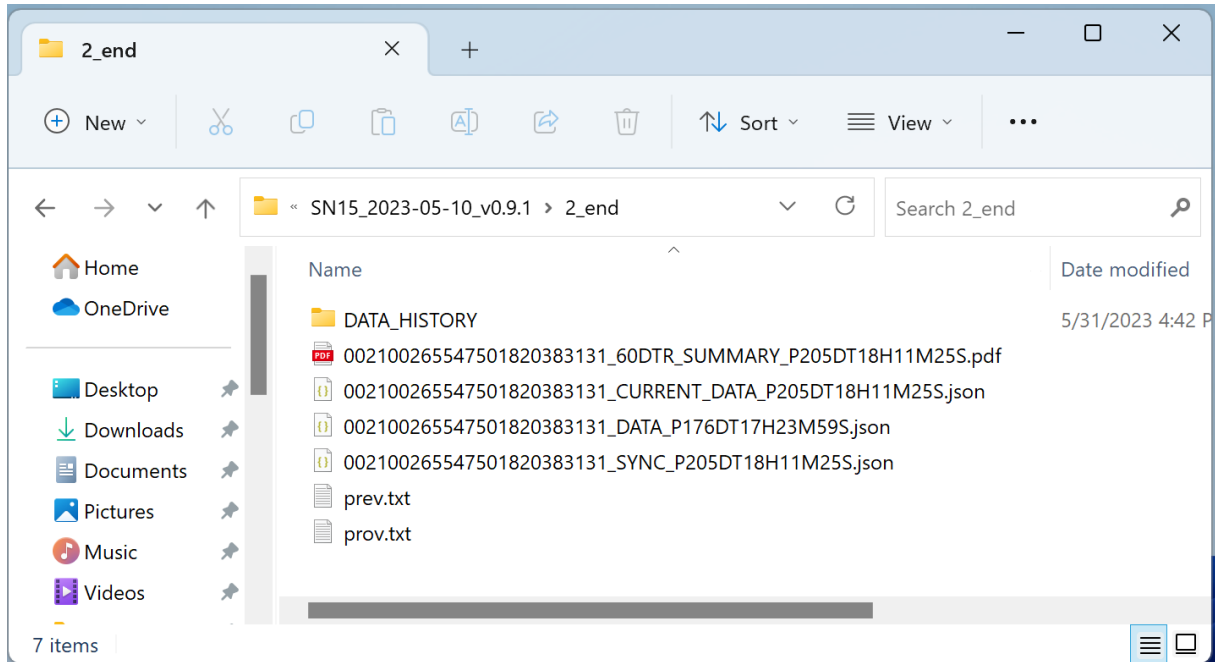


Figure 3: Example folder structure on the logger USB drive

The files available on the logger are:

- **60-Day User-Readable Summary:** A report showing device summary information for the previous 60 days, in **.pdf** format.
- **60-Day Current Data:** A file containing 15-minute resolution vaccine storage compartment temperature, ambient temperatures, door openings, and power data, in **.json** format.
- **Historical data:** in a DATA file in the same **.json** format as CURRENT_DATA, and similar older files in the DATA_HISTORY folder.
- **Synchronization data:** the SYNC file, also in **.json** format, which contains the most recent data record and information that helps external EMDs synchronize time.
- **Data History Folder:** Folder containing raw data for all monitored parameters for the previous two years, in **.json** format.

Understanding the user-readable summary

The first portion of the user-readable summary looks like:

60 DAY PERFORMANCE REPORT

Appliance PQS Code: E003/XXX
Appliance Serial number: V60C-4432-80A7
Report Creation Time: P205DT18H11M25S
Upper alarm limit: Above +8.0 °C for 10h
Lower alarm limit: Below -0.5 °C for 1h

Day	Average storage temp. (°C)	Status	Low Temperature			High Temperature			Door openings	Door open time (hh:mm)	AC Power availability (hh:mm)	Compressor runtime (hh:mm)	Average ambient temp	Faults
			Min. temp. (°C)	Total time < -0.5°C (hh:mm)	Total low alarm time (hh:mm)	Max. temp. (°C)	Total time > 8.0 C (hh:mm)	Total high alarm time (hh:mm)						
Today	3.6	OK	3	0:00	0:00	5.8	0:00	0:00	0	0:00	8:48	3:13	24.6	
2	5.1	OK	4.2	0:00	0:00	6.1	0:00	0:00	0	0:00	4:36	0:53	35.4	
3	4.7	OK	3.5	0:00	0:00	5.9	0:00	0:00	0	0:00	9:09	3:29	33.6	3886
4	4.4	OK	3.4	0:00	0:00	5.5	0:00	0:00	0	0:00	1:15	0:03	35.6	
5	4.5	OK	3.6	0:00	0:00	5.5	0:00	0:00	0	0:00	20:03	16:45	35.6	
6	4.5	OK	3.4	0:00	0:00	5.5	0:00	0:00	0	0:00	1:42	0:07	35.6	
7	4.8	ALARM	3.6	0:00	0:00	14.5	10:05	0:05	1	0:06	6:05	1:32	24.5	

Figure 4: Example 60-day PDF summary report found on the logger's USB drive

The top of the report contains information about the appliance and when the report was created, in relative time. Note that this time is the same as in the filename above. It also shows the criteria used to calculate if there is a condition that warrants an alarm.

The table contains rows for each of the last 60 days of operation. The columns are summaries of temperatures, alarm conditions, door openings, power availability, and compressor runtime. The "Faults" column contains codes to identify logger errors, such as a missing temperature sensor.

Understanding the data files

The data files (CURRENT_DATA, DATA, and SYNC) are Javascript Object Notation (JSON) formatted files. These are plain text and can be opened in Windows Notepad or another text editor. An example SYNC file for a Demo Logger installed in a hypothetical fridge-freezer combination ILR is shown below.

The file consists of three sections: model and serial number values (for the fridge, logger, and potentially compressor), a synchronization record, and a data record. Each line in the section has a data key name and then a value for that key.

```
{
  "AMOD": "Vax 60/780",
  "AMFR": "Didgeridoo Equipment Corp.",
  "ASER": "V60C-4432-80A7",
  "ADOP": "2017-06-06",
  "APQS": "E003/XXX",
  "CNAM": "NL6.1MF",
  "CSER": "uninit",
  "CSOF": "uninit",
  "LDOP": "2022-07-31",
  "LMFR": "Global Health Labs",
  "LMOD": "Demo EMS Logger",
  "LPQS": "E006/XXX",
  "LSER": "002000255547501820383131",
  "LSV": "v0.9.2",
  "records": [
    {
      "RELT": "P205DT18H11M25S",
      "RTCW": "P0DT0H0M0S",
      "TVC": 3.5,
      "IDRV": 0,
      "TFRZ": -12.6,
      "IDRF": 0
    },
    {
      "RELT": "P205DT18H11M25S",

```

```

"RTCW": "P0DT0H0M0S",
"TV": 3.5,
"DORV": 0,
"DRVC": 0,
"FRZ": -12.6,
"DORF": 0,
"TAMB": 23.7,
"BLOG": 1826,
"CMPR": 11,
"CMPS": null,
"DCCD": null,
"DCSV": null,
"SVA": 900,
"LERR": null
}
]
}

```

Looking at the green highlighted lines in the synchronization record, note the vaccine chamber and freezer chamber temperatures (TV and FRZ). They should correspond to the expected values in the CCE. Also looking at the instantaneous door values, IDRV and IDRF, these represent the number of seconds the doors were open at the time USB was plugged in. Most of the time, they will be zero.

- TV: Vaccine chamber temperature, expect 2-8°C.
- FRZ: Freezer chamber temperature, expect < 0°C.
- IDRV: Instantaneous vaccine door opening time in seconds, expect 0 if the door is closed when USB was plugged in, or the number of seconds it has been open if it is open when USB was plugged in.
- IDRF: Instantaneous freezer door opening time in seconds, analogous to IDRV but for a freezer compartment door.

The periodic data record contains further information about the operation and performance of the fridge over the most recent 15 minutes. The DATA and CURRENT_DATA files contain many records like this, one for each 15-minute period. The data fields are:

- RELT: Relative Time, the duration since the logger started operation. It uses ISO 8601 durations format, which contains days, hours, minutes, and seconds. This value should also be in the filename.
- RTCW: Real-Time Clock Wake, used to indicate if the logger has lost all power, including battery. If it is zero (P0DT0H0M0S), the logger is still operating on its initial battery. Non-zero values indicate the RELT value at the time power was lost (battery depleted or was removed).
- TV: Vaccine chamber temperature, expect 2-8°C.
- DORV: Number of seconds vaccine chamber door was open in the last 15 minutes (maximum: 900).
- DRCV: Count of the number of times the vaccine chamber door was opened in the last 15 minutes. Note: this data object was added to the DL01.2 and DS01.2 revisions of the specification set, along with a corresponding "DRCF" for freezer chamber door opening counts. DRCF is not included in this file.
- FRZ: Freezer chamber temperature, expect < 0°C.
- DORF: Number of seconds freezer chamber door was open in the last 15 minutes (maximum: 900).
- TAMB: Ambient temperature in °C.
- BLOG: Logger's expected battery life remaining in days.
- CMPR: Number of minutes that the compressor ran in the last 15 minutes.
- CMPS: Peak compressor speed in revolutions per minute during the last 15 minutes. This value is optional and is unlikely to be provided for AC-input appliances that use AC-compressors. That is why the example value is null. Some SDDs will provide this information.

- DCCD: DC current drawn from the solar panel for solar appliances. This example is an AC-powered ILR, hence the null value. The field might also be omitted for a logger installed in an ILR.
- DCSV: DC supply voltage, or the solar panel voltage for solar appliances. Optional for ILRs, required for SDDs.
- SVA: Number of seconds that the AC supply was available in the last 15 minutes (maximum: 900).
- LERR: Logger error codes, or null if there are no errors in logger operation.

Accessing data using an Android Device with Varo App

First, download the Varo App onto any Android device with USB OTG (On-The-Go) or USB-C connectivity. Next, follow these steps to collect data and reports from the Indigo Vaccine Carrier using Varo.

1. Open Varo – Follow the instructions in the application. No account is needed.
2. Connect your phone/tablet to a logger – Use a USB cable to connect between the logger and a phone with USB-C. If the phone has a USB mini or micro connector, you will need a USB OTG adapter.
3. Create Report – When prompted, click “Create Report” for Varo to automatically download data stored on the lid.
4. Record details – Enter location, device information, and photos of the refrigerator. If you have made a report in the same place, Varo will automatically match the current report with the previous record.
5. Send report – Varo generates a standardized report. Enter the recipient’s email address, and Varo hands off the report to your phone’s email app, ready to send.
6. Once data transfer is complete, unplug the USB cable.

Find more information on Varo at: <https://varo-app.org/>.

Connecting an External Equipment Monitoring Device (E-EMD)

External Equipment Monitoring Devices (E-EMDs) obtain data from the logger, display it, and optionally send it to remote data systems. At the time of this writing, no E-EMDs exist on the market. The photo in Figure 5 below illustrates the necessary connections using a stand-in device. The procedure is as follows:

1. Connect the M2M power output plug from the logger to the power input jack on the E-EMD.
2. Using a male-male USB-C cable, connect the M2M data cable between the two devices.
3. Attach the E-EMD to the appliance using the mounting materials provided by its manufacturer.

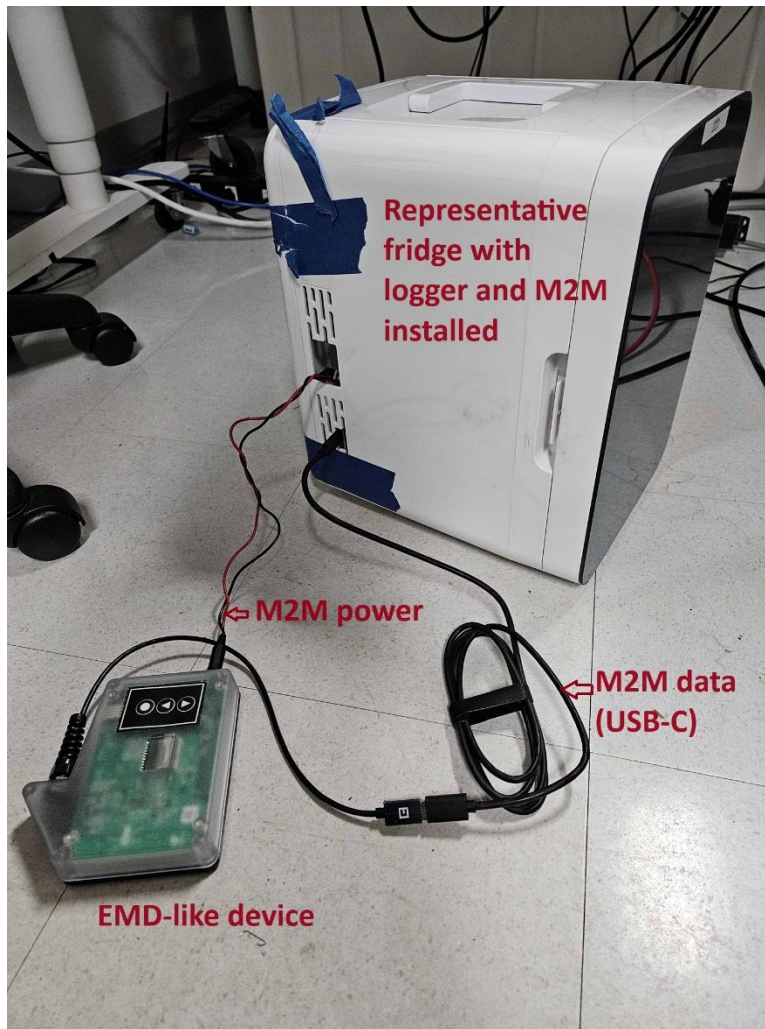


Figure 5: EMD-like device connected to M2M power and data ports on a sample mini-fridge

5 Installation

The details of initial installation depend upon the appliance design, and installation should be done by the appliance manufacturer. To retrofit an *existing* appliance with a Demo EMS Logger or replace a sensor, follow these considerations:

5.1 Main enclosure

Place the logger where its USB-C port and power output can be accessed, and where it will experience ambient temperatures. You may want to attach it to the fridge with double-sided tape. You may also want to add USB-C and power extension cables if the enclosure is out of reach of users, and provide strain relief so the cables are not accidentally unplugged from the logger.

5.2 Temperature sensors

The two temperature sensors are interchangeable. Route one through the door seal (or other suitable retrofitting technique) into the vaccine compartment, attaching it to a shelf or something inside so that it will stay in place.

Route the other temperature sensor into the freezer compartment (if there is one) in the same way. Then plug the vaccine compartment sensor into the VAX port and the freezer temperature sensor into the FRZ port.

5.3 LIN compressor connection or auxiliary power

If the appliance has a compatible smart compressor, connect the supplied LIN harness between it and the logger. The compressor will also provide a source of DC power when the appliance has power available.

If appliance does not have a smart compressor it may have a source of DC power in the range 6 V to 24 V available, such as from a solar energy harvesting control or an AC/DC power supply. In that case, connect the positive (+) and negative (-) terminals of the LIN harness to that power source. Leave the LIN data wire disconnected.

5.4 Door sensors

The door sensors work with a magnet attached to the door and a sensor switch attached to the body of the fridge. When the door is closed, the sensor switch will be an open circuit between the two wires. When the magnet moves away, that switch will be a short circuit. Attach the sensors and magnets to the fridge and door of the vaccine compartment using the adhesive on them. Make sure to verify with a multimeter that the sensor wires are open circuit when the vaccine compartment door is closed. Repeat for the freezer door.

Below is a picture of door sensor and magnet attached to an ILR at the bottom of the door. Note how the magnet is near the sensor when the door is closed:



Figure 6: Example retrofit door sensor installation showing magnet on door and sensor attached to refrigerator body

When the sensors are installed, plug the connector into the DOOR port on the logger.

When the logger is not being used for testing, it is better to disconnect the door sensor harness from the logger. The logger draws more current when the switches are closed (the “door open” state), so battery life will be reduced should the doors be open for long periods of time.

5.5 Provisioning

A newly installed logger will need to be provisioned, as described in Section 6.2 .

5.6 Verifying installation

After installation, wait at least 15 minutes, as that is the sampling interval.

1. Using a computer, plug in to the logger with a USB-C cable, accessing the data as described in Section 4.3 .
2. Copy the files to a folder on the computer, perhaps called “door closed”.
3. Unplug the USB-C.
4. Open the vaccine compartment door and wait about 3 minutes. Keep the vaccine door open and also open the freezer door (if there is one) and wait about 2 more minutes.
5. Plug in USB-C and copy the files from the logger to a different folder on the computer, perhaps called “door open”.
6. Unplug the USB-C and close the door(s).
7. Open the SYNC file from the “door closed” folder.
8. Looking at the highlighted lines in the synchronization record that are highlighted in Section 4.3 , note the vaccine chamber and freezer chamber temperatures (TVC and TFRZ). They should correspond to the expected values in the CCE. Also looking at the instantaneous door values, IDRV and IDRF, they should be zero, indicating that the door was closed when USB was plugged in.
 - a. TVC: Vaccine chamber temperature, expect 2-8°C.
 - b. TFRZ: Freezer chamber temperature, expect < 0°C.
 - c. IDRV: Instantaneous vaccine door opening time in seconds, expect 0.
 - d. IDRF: Instantaneous freezer door opening time in seconds, expect 0.
9. Now open the SYNC file from the “door open” folder and verify the following:
 - a. TVC: expect 2-8°C, probably warmer than last time since the door had been open.
 - b. TFRZ: expect < 0°C, also probably warmer than before.
 - c. IDRV: vaccine door opening, expect > 300 (5 minutes = 300 seconds).
 - d. IDRF: freezer door opening, expect > 120 (2 minutes).

If the temperatures are good and the door opening times are zero when closed and the proper number of seconds when open, the retrofit installation is complete.

6 Maintenance

6.1 Preventative maintenance

Monthly:

- Check that the temperature sensors in the fridge are unobstructed by the contents.
- Check appliance temperatures and logger battery life remaining. Download sync file and summary report using USB-C procedure described in Section 4.3 .
 - Use the summary report to verify that the appliance temperatures have been appropriate and there have been no alarm conditions.
 - Also check the summary report for any logger faults, which could be a sign of problems.
 - Check the sync file’s logger battery life remaining field (BLOG). If the number of days remaining is less than 180 (6 months), replace the battery.

Yearly:

- Check that door sensors operate as intended. To do this:
 - Open the door(s) for a few minutes and time how long they have been open.

- Close the door(s) and wait for at least 15 minutes for the logger to save its latest data record.
- Download the summary report using USB-C method.
- Check that the “today” row of the summary report contains at least one door opening and at least the duration that you had it open.

6.2 Servicing and corrective maintenance

Changing the battery

- Make sure you have a replacement battery of type CR123A. Do not use any other battery type.
- Unplug the appliance from mains or turn off the breaker of a solar appliance to eliminate the chance of inadvertent electric shock. Open the appliance to access the logger, if necessary.
- Remove the 4 screws holding the enclosure top to the bottom.
- Remove old battery.
- Replace it with the new battery, making sure to insert it in the proper orientation.
- Replace enclosure top, close appliance and plug it back in or reset the breaker.

Firmware updates

The system formats its non-volatile memory as a FAT file system, and when USB is plugged in, it appears as a mass storage device like a USB thumb drive. The file system appears to the host as read/write, but the firmware will ignore all data blocks written to the device except for ones with a special format. This format, known as UF2, enables technicians to update firmware or change configurable parameters (known as “provisioning”). The process is the same.

To update the firmware, make sure you have a firmware UF2 file.

1. Plug in USB to your computer.
2. When a file explorer window shows up displaying the contents of the logger, copy the firmware file to the logger.
3. Windows will show that copying has started, and then you will get a warning that the operation cannot be completed. This is a byproduct of the way UF2 is implemented and is not an error. Do not hit cancel right away.
4. After the file has been copied, the logger will disconnect logically from the computer as it updates its firmware, and the file explorer window will disappear. Now you can click cancel.
5. After the update, the logger will reconnect, and you will get another file explorer window.
6. You can open the SYNC JSON file to check that the update worked. The present firmware version is contained in the “LSV” data object, and you can verify that it is the same number as in the update filename.

Occasionally the copy operation appears to do nothing. In this case, unplug USB and replug it before trying again.

Provisioning (changing options)

The Demo EMS Logger has one operational mode that can be configured. It is also possible to change the administrative data corresponding to the appliance model and serial number information as well as the logger manufacture date. Making these changes is called “provisioning”, and ordinarily would only be done at the time of manufacture when the logger is installed into a fridge or when replacing a logger as part of repair.

Provisioning information is stored in a file “prov.txt” in the logger’s root directory. An example file is below; it consists of three columns: a number, an EMS data object key, and a value (the blue text is comments, and is not in the file):

1	ACAT E003	(PQS equipment category)
2	AMOD Vax 60/780	(Appliance model name)
3	AMFR Digeridoo Equipment Corp.	(Appliance manufacturer)
4	ASER V60C-4432-80A7	(Appliance serial number)
5	ADOP 2017-06-06	(Appliance date of production)
6	APQS E003/XXX	(Appliance PQS-assigned number)
7	CNAM NL6.1MF	(Compressor name)
8	CSER uninit	(Compressor serial number)
9	CSOF uninit	(Compressor software version)
10	LDOP 2022-07-31	(Logger date of production)
11	LMFR Global Health Labs	(Logger manufacturer)
12	LMOD Demo EMS Logger	(Logger model name)
13	LPQS E006/XXX	(Logger PQS-assigned number)
14	LSER 002000255547501820383131	(Logger serial number)
15	LSV v0.9.2	(Logger software version)
16	zftyp 3	(fridge type)

Logger serial number and software version are automatically generated from the MCU's unique ID and values in the firmware file, respectively. Compressor information can either be configured or read from a smart compressor. The other values can be changed via provisioning.

The data object **zftyp** configures the logger for the fridge type. It consists of a sum of integers representing different features that are present or not. In computer science terms, it uses 5 bits to represent 5 features.

Bit number	Reset (0) meaning	Set (1) meaning	Add to sum if bit is set
0	No vaccine compartment	Vaccine compartment present	1
1	No freezer compartment	Freezer compartment present	2
2	Smart compressor connected (Secop BD Nano with SDD controller 101N3110)	No smart compressor connected	4
3	The presence of LIN power is used to initiate communication with a smart compressor.	The presence of LIN power indicates that external AC power is available.	8
4	Freezer door sensor input has its usual meaning.	The freezer door sensor input is repurposed to indicate compressor running.	16

Some common configurations are:

zftyp value	Components of the sum	Configuration
1	1	Fridge with a vaccine compartment but no freezer compartment. The firmware ignores freezer compartment temperature and door sensors. The fridge contains

		a smart compressor that may have AC and/or PV input power, and the firmware communicates with the compressor to obtain power and compressor information.
3	1 + 2	Combination fridge/freezer with a smart compressor and possible AC and/or PV input power. The firmware uses both vaccine and freezer compartment temperature and door sensors, and communicates with the compressor to obtain power and compressor information.
29	16 + 8 + 4 + 1	Fridge with a vaccine compartment but no freezer compartment. Uses an AC-powered compressor or other cooling device. An AC/DC converter provides power to the LIN input, also indicating when AC is available. The freezer door input is connected to a relay or optocoupler that closes when the cooling device is active.

Because the filesystem prevents write operations, one cannot change provisioning by editing the prov.txt file. Instead, a provisioning UF2 file is used to tell the logger to change provisioning values. This file is created by first creating a text file with the fields to be changed, and then processing it with a Python program. The details won't be covered in this document. Should you need to provision a Demo EMS Logger, contact New Horizons.

To provision, copy the provisioning file to the logger's filesystem as described above for firmware updates. To verify, unplug and replug USB. You can open the prov.txt file or the SYNC file to see if the changes were successful.

Changing temperature and door sensors

Sensors are changed in much the same way as they are installed. See Sections 5.2 and 5.4 for details on temperature and door sensors, respectively.

Changing the M2M power output cable

The M2M power output cable is a captive cable on the appliance held in place with strain-relief clamps and connected to the logger in one of two ways. Change it with this procedure.

For revision 1 logger + M2M circuit board assemblies:

- Remove the existing cable by loosening the strain-relief cable clamps.
- Unsolder the cable wires at the current limiter circuit board. Keep track of which terminal is positive and negative.
- Solder the replacement cable onto the terminals, taking care that the red (positive) wire is on the same terminal as before.
- Feed the cable through the strain-relief clamps, and through the appliance wall.
- Retighten the clamps to hold the cable in place.

For future revision 2 logger circuit boards:

- Remove the existing cable by loosening the strain-relief cable clamps.
- Unplug the connector at the circuit board and remove the cable from the clamps.
- Feed the replacement cable through the strain-relief clamps, and through the appliance wall.
- Plug the replacement connector into the logger circuit board.
- Retighten the clamps to hold the cable in place.

7 Diagnostics and Troubleshooting

Below are some potential problems, steps to troubleshoot them, and corrective actions.

Problem	Troubleshooting steps and corrective actions
When plugging USB into a computer, no file window appears.	Open the enclosure and press the reset button.
When plugging USB into a mobile phone with Varo, there is no connection.	To be written.
The PDF summary file contains no vaccine temperature reading.	Try to reseat the connector where the sensor plugs into the logger, wait a few minutes, and check the SYNC file for a TVC reading. Temporarily replace the sensor with a spare sensor. Wait a few minutes and check the SYNC file for a TVC reading.
The PDF summary file contains no ambient temperature reading.	The ambient sensor and vaccine compartment sensor share a communication bus. Try unplugging the vaccine sensor. Wait at least 15 minutes and check the SYNC file to see if it has TAMB with a reasonable temperature reading. If there is an ambient reading when the vaccine compartment sensor is removed, the vaccine temperature sensor may be damaged, and its reading may be faulty. If the ambient temperature reading does not return, you will need to replace the logger.
The PDF summary file shows that the door has been closed all day (in the “Today” row), but it actually has been opened recently.	Check that the sensor connector is seated properly in the logger. A disconnected sensor will read as a closed door. Unplug the door sensor from the logger and use a multimeter to check that the sensor conducts when the door is open and is open circuit when the door is shut. Also double-check the timing and the firmware version. - For firmware v0.9.4 and before, the “Today” row covers the 24 hours ending when USB was plugged in. - For firmware v0.9.5 and later, all days in the PDF file are 24 hours long except for “Today”, which is the length of time from PxxxDT00H00M00S to USB plug in. For example, if the RELT value in the SYNC file or

	the timestamp that is part of PDF & SYNC filenames is P158TD6H35M10S, the “Today” row covers the past 6 hours, 35 minutes, and 10 seconds.
The PDF summary file shows that the door has been open all day, but I can see that the door is closed.	Unplug the door sensor from the logger and use a multimeter to check that the sensor conducts when the door is open and is open circuit when the door is shut. Also operate the logger with the door sensor harness disconnected. Wait a few minutes and check the SYNC file. It should show that the door is closed (IDRV = 0), because a missing sensor registers as door closed. If it still shows an open door, you may need to replace the logger.
The PDF summary file shows incorrect AC power availability (either more or less than expected).	If the logger is configured with a smart compressor: The firmware calculates AC power availability by querying data from the smart compressor. Check that the LIN connector is seated well and connected to the smart compressor. If the logger is configured without a smart compressor: The firmware recognizes AC power available when there is power on the LIN connector’s positive terminal. Typically, the LIN connector is connected to an AC/DC power supply. Check that there is power at the LIN connector when the fridge has AC power.
The PDF summary file shows incorrect compressor runtime (either more or less than expected).	If the logger is configured with a smart compressor: The firmware calculates compressor runtime by querying data from the smart compressor. Check that the LIN connector is seated well and connected to the smart compressor. If the logger is configured without a smart compressor: The firmware may use the freezer door sensor input to sense contact closure. Closed (conducting) contacts signal that the compressor is running. Open contacts signal that it is stopped. Check that the door sensor connector is seated well.

	Use a multimeter to check that the “freezer door” sensor harness is a closed circuit when the compressor is running and is open when the compressor is off.
Faults or errors shown in the PDF summary file’s faults column. These are also shown in the various JSON data files’ “LERR” field.	Troubleshooting steps and corrective actions
TVC, TFRZ, TAMB: the corresponding sensor cannot be read or is producing an unlikely value.	Follow the steps above for the relevant sensor temperature missing from the PDF summary file.
DORV, DORF: the corresponding door sensor is indicating door openings too fast to be real.	Follow the steps above for diagnosing door sensors.
FS: logger file system error.	Replace the logger.
CC: smart compressor communication error.	Check for loose connections at both ends of the LIN/smart compressor wiring harness. Reseat connections if necessary. Force a compressor run using a method appropriate for the refrigerator, wait 15 minutes, and then check the latest data record in the SYNC file to make sure that the CMPR field is non-zero. Replace the harness if needed.
C0, C1, C2, etc.: error codes returned from a smart compressor.	Refer to the compressor’s documentation to determine the meaning of the number after the “C”, and find troubleshooting steps for the issue.

8 Spare Parts

The following spare parts are available:

Part number	Name	Description
To be assigned.	Temperature sensor	Temperature sensor with cable and connector. Suitable for either vaccine or freezer compartments.
To be assigned.	Door sensor	A door sensor and its associated magnet to mount on the door.
To be assigned.	Door sensor harness, vaccine	Wiring harness and connector to connect a door sensor to the logger.
To be assigned.	Door sensor harness, freezer	Wiring harness and connector to connect a door sensor to the logger.
To be assigned.	Door sensor harness, combination	Wiring harness and connector to connect two door sensors to the logger.

To be assigned.	LIN power/data harness	Wiring harness to connect a smart compressor to the logger, or to supply external 6-24 VDC power to the logger.
To be assigned.	M2M power output harness	Wiring harness to provide output power to the M2M port.

9 End-of-Life Disposal and Recycling

Follow local regulations for disposal and recycling of lead-free electronic waste.

10 User Training

No user training is provided. New Horizons can provide consultation to technicians on the use of this reference design on an individualized basis.

11 Abbreviations

CCE: Cold Chain Equipment.

EMD: Equipment Monitoring Device. The display, alarm, and optional remote data transmission component of the Equipment Monitoring System.

EMS: Equipment Monitoring System. A set of specifications published by WHO PQS.

ILR: Ice-Lined Refrigerator, that is, a vaccine refrigerator that stores energy in ice for periods when there is no power available. The acronym is generally used as shorthand for an *AC-powered* ice-lined refrigerator.

JSON: Javascript Object Notation. JSON provides a way to describe data in a text file that is both human and computer readable.

LIN: Local Interconnect Network. A serial network protocol often used for communication between components in vehicles.

M2M: machine to machine. The interface within the EMS specification set consisting of a USB-C data port and a barrel connector to supply power to external EMDs.

MCU: microcontroller unit, the integrated circuit “chip” that is the brains of the Demo EMS Logger.

PQS: Performance, Quality, and Safety group at WHO.

SDD: Solar Direct Drive, or a solar powered appliance that does not rely on a battery to store electricity to provide cooling at night.

USB: Universal serial bus, a computer connection standard.

USB-C: Symmetrical plugs and jacks that conform to the USB standard.

WHO: World Health Organization

Revisions

Date	Person	Notes
2023-08-08	Rod Hinman	Initial version: applies to Revision 1.0 hardware and v0.9.2 or later firmware
2024-02-05	Rod Hinman	Updated for v0.9.4 and later firmware and updated PQS specification versions DL01.2 and DS01.2. Also added text in anticipation of Rev. 2 circuit boards, and added diagnostics.
2024-09-18	Rod Hinman	Update to apply to Rev. 2 PCBs, including file name.
2025-06-03	Rod Hinman	Update to Rev. 2.1 PCBs, and edits for open sourcing.

End of document.