

New Horizons Demo EMS Logger

Design Notes

New Horizons, a division of Global Health Labs

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1 Overview

1.1 Motivation

Following the publication of the WHO IMD-PQS Equipment Monitoring System (EMS) specifications, New Horizons developed an EMS level 1 logger as a demonstration product and an opportunity to learn.

As a level 1 EMS device, the unit conforms to EMS data logger specification WHO/PQS/E006/DL01, but not to the "equipment monitoring device" (EMD) specification (WHO/PQS/E006/EM01). The logger collects cold chain equipment (CCE) data, stores it in non-volatile memory, and makes it available over a USB Type-C port. It does not have a display or audio-visual alarming functions.

1.2 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.
 - AC power presence can be logged based on the appliance power input.
 - Compressor runtime can be logged based on a digital input.
 - Optional connection to smart compressor controllers like the Secop 101N3110 weak grid/solar controller to obtain more detailed power and compressor operation data.
- 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.

1.3 Hardware

- ST Microelectronics STM32L476 microcontroller
- Winbond W25N01GWZEIG 1 Gbit NAND SPI flash memory
- AMS AS6212 I2C temperature sensors
- USB Type-C receptacle and protection circuitry
- 6-24 VDC power input
- DC/DC converter with current limiting for M2M power output
- LIN interface to optional Secop controller

A block diagram is below in Figure 1. Schematics are included in this package in the Docs folder.

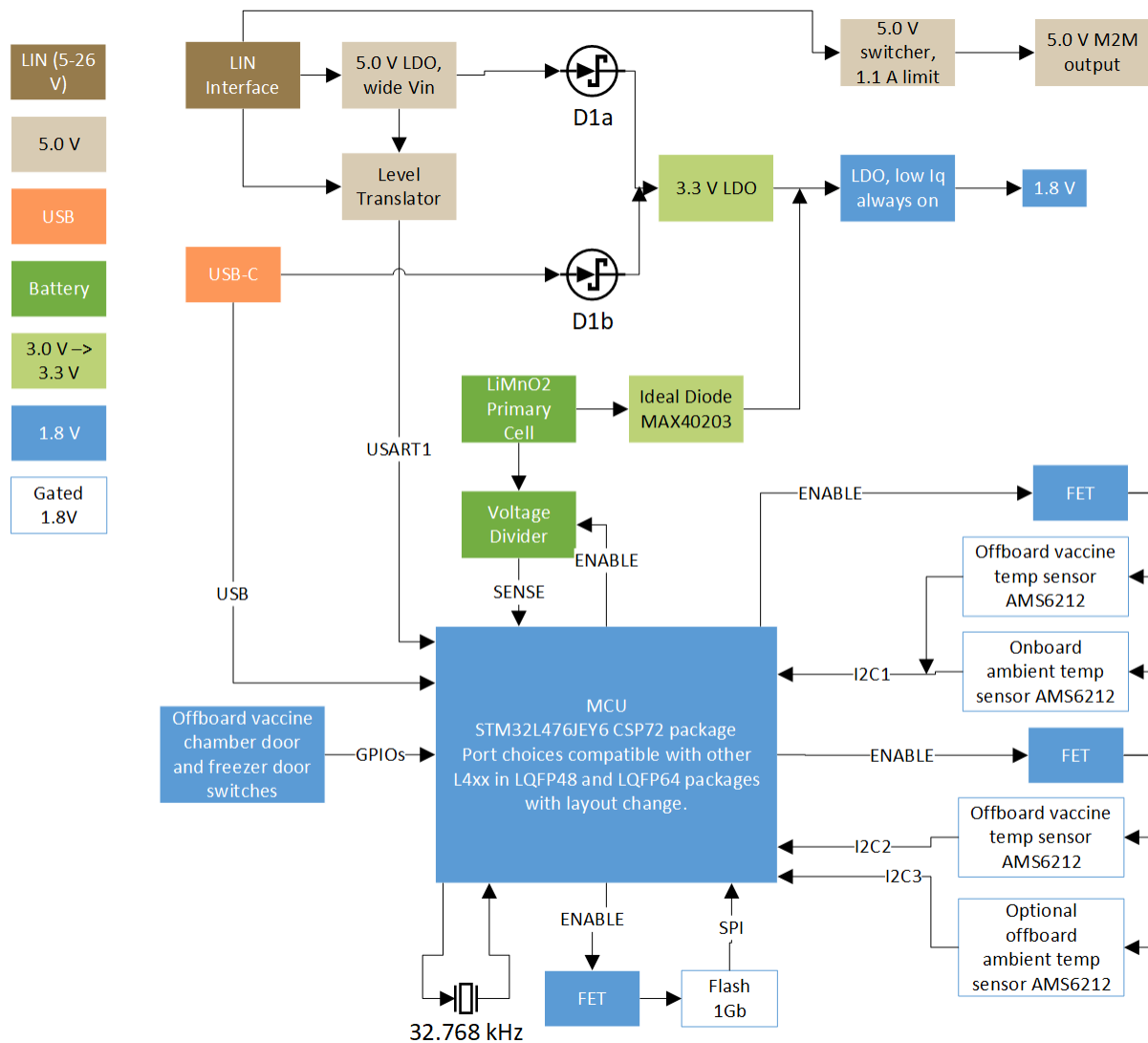


Figure 1: A block diagram emphasizing the power flow but also showing major components

1.4 References

Version 3 of the WHO IMD-PQS specification WHO/PQS/E006/DL01 is available at <https://extranet.who.int/prequal/key-resources/documents/pqs-performance-specification-e006dl012-data-logger-and-machine-machine-0>, as of this document's date. In future, the latest version should be available at <https://extranet.who.int/prequal/immunization-devices/performance-specifications>.

The package containing this file is available at docs.2to8.cc.

2 Design Notes

2.1 Notes on the existing design

Power:

Power path design decisions are documented in notes on the Power schematic page. In general, power-consuming components are switched off when not needed to minimize average consumption. Many of these loads are supplied through zero-ohm resistors and unplaced headers that would enable detailed power measurements by removing the resistor and placing an ammeter across the header's contacts.

The LIN input port may be used with a Secop 101N3110 weak-grid and PV controller. That controller will provide 24 VDC that can power the logger and also provide power to the M2M power output. In this case, the firmware is able to obtain a number of power and performance data from the controller and its connected compressor. If the appliance does not have a LIN data connection, the power supply contacts of the connector may be used as an external source of power. There are notes on the LIN schematic page describing different protection component options.

Microcontroller:

Port choices were informed by the ports available on alternate packages and microcontrollers from the same family. Pin allocation information is in the spreadsheet called `MCU_pins_R1.0.xlsx`.

The PCB has a feature that allows firmware to determine which hardware revision it is running on. Resistors R41 and R43 form a resistive divider that can be read by the analog-to-digital converter. Each hardware revision is given a unique ratio to identify it. The divider is powered by a microcontroller output pin so that it does not consume power for more than the time required to read the value. In this design, although hardware revisions 2.0 added the M2M power output and has a different resistive divider, there is no difference between revisions from the firmware's point of view.

Sensors:

Temperature sensors are AMS AS6212 sensors, but other low-voltage, low-power sensors like Texas Instruments TI TMP117 could be used. A footprint for a TMP117 is included. If using an external AMS sensor for vaccine chamber temperature it will be important to configure it for a different I2C address, since it is on the same I2C bus as the onboard ambient sensor.

It is possible to use identical addresses for the external vaccine and freezer temperature sensors, since they are on separate I2C busses. There is also an uninserted connector for a third offboard sensor using a third I1C bus. It is labeled as an external ambient temperature sensor, but could be used for anything (with appropriate firmware additions).

The door opening sensors can be any contact closure device. Assuming the door is closed most of the time, it is better for total battery life to configure them so that the switch conducts when the door is open.

2.2 Thoughts for future designs

We expect that PCB layout revisions would be necessary for industrialization purposes, and that an organization taking it to market would want to make changes to best fit customer applications, form factor, any packaging or enclosure interfaces. This design was created during the height of the COVID-19 pandemic-induced supply challenges in early 2022, and that affected many component choices. We purchased components that were available and finalized the design after obtaining enough components for our anticipated needs. In some cases, these choices were not what we would have used in an ideal world, and we have noted them below.

Microcontroller factors:

- We used a BGA/chip-scale microcontroller package that requires laser-drilling the PCB to make vias small enough to get the signals out. A simpler package could be used for future designs, which should lower PCB fabrication costs.
- Possibly the LQFP64 package would be sufficient.
- The present firmware occupies 236 kB of flash for the main application and another 49 kB for the bootloader that allows drag-and-drop USB firmware updates. If that bootloader is not needed, it would be feasible to use a version with 256 kB of flash rather than 512 kB. That does not leave much room for flexibility but could reduce cost ~\$0.50-\$1.

Component removal and optimization:

- The three tactile buttons could be removed for a production version – these were used for reset, firmware boot/programming options, and an optional user-button that has not been implemented in firmware.
- The NAND flash is 1 Gib capacity, which gives ~21 years of data storage, that could be reduced to a 512 or 128 Mib version and still satisfy EMS storage requirements. That could save ~\$0.70 in BOM cost.
- In a vaccine refrigerator application, it is possible that one would want to remove the on-board USB-C connector. An appliance manufacturer might install a panel mount

IP-rated connector on the side of the appliance, with a wiring harness connected to the logger.

- Rather than using individual connectors for the different I/Os, the connectors could be integrated into one or two connectors for simpler assembly/integration by an appliance manufacturer.
- There is a test point to the ground plane that wouldn't be needed for production.

Other design considerations:

- The LIN transceiver is End of Life, so that will need to be updated. The transceiver IC recommended by Secop is the NXP TJA1028T, and it also includes a linear regulator that can be used to power the logger from the LIN power input (removing U6).
- The LIN power is regulated to 5 V by U6. When we added the M2M power output for Rev. 2.0, we just added a separate switching power regulator to create 5 V and did not modify the rest of the layout. This means that there are redundant 5 V supplies. An implementer would want to evaluate the risk but could potentially eliminate U6 (or use the TJA1028T as mentioned in the above paragraph).
- We have found two aspects of the USB implementation that should be considered to improve robustness with a wide variety of USB hosts:
 - The data signals D+ and D- each have a ferrite bead to provide EMI filtering. However, the impedance of these beads is high enough that the signal slew rates are slower than permitted by the USB Full Speed specification (130-660 V/μsec), and are further impacted by cable loading. We have found many USB hosts are tolerant of this non-compliance, but some Android phones are not tolerant. We recommend changing to a common-mode choke such as Murata DLW21SN900SQ2 or Würth 7442335900 (or probably many other options). Another option would be a combination filter + ESD protection device like STMicroelectronics' ECMF02. The 0Ω resistors could also be removed from the design.
 - U18 is used to provide several functions for USB-C: protection against Vbus > 5 V, protection of the CCx lines, and clamping the CCx to signal that the device is an upstream-facing port with "dead battery" charging implemented. As we understand it, this implementation with voltage clamps on the CCx lines is compliant with the USB specification as an alternative to using 5.1 kΩ pull-down resistors. However, we have found that certain Android phone models appear to be confused by the higher voltage level that is developed by these clamps, and will not connect. We recommend using 5.1 kΩ pull-down resistors instead, which we have found to work with those phones.

Revision History

Date	Person	Changes
2024-08-15	Rod Hinman	Initial version
2025-06-03	Rod Hinman	Update to share via docs.2to8.cc.