NEMO: Hardware Accessories

VERSION: 1.0.0

GitHub: https://github.com/usnistgov/NEMO

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NIST
National Institute of Standards and Technology

Contents

CHAPTER 1

Introduction

The National Institute of Standards and Technology (NIST), Center for Nanoscale Science and Technology (CNST) NanoFab provides researchers with rapid access to state-of-the-art, commercial nanoscale measurement and fabrication tools and methods, along with associated technical expertise, at economical hourly rates. It is well equipped to process and characterize a wide range of nanoscale materials, structures, and devices.

In November 2013, the Center for Nanoscale Science and Technology (CNST) replaced its original lab management software with an in-house designed and developed web application called NEMO. NEMO was developed to improve the efficiency and effectiveness of laboratory operations by providing a centralized platform for managing equipment reservations and usage, controling access to areas and tools, and streamlines logistics and communication. NEMO is also highly customizable, which allows end users to tailor it to the specific needs of their laboratory.

NEMO has been used successfully by CNST researchers ever since its introduction in 2013. In 2017, CNST began to offer NEMO to other organizations, and it has since been successfully implemented in academic, government, and industrial settings.

Chapter 1 Introduction

In 2022, CNST expanded NEMO's capabilities to interface with hardware via the Modbus communication protocol. This allows NEMO to communicate with a wide range of sensors and control systems, which greatly enhances its functionality.

The first edition of the NEMO hardware accessories was released in May 2023. The scope of the manual is to provide detailed information on building and interfacing sensor and control systems with NEMO. The manual includes a number of illustrations and step-by-step diagrams to help guide the end-user through the process of building systems and interfacing them with NEMO. We cover the following topics:

- Building sensor and control systems

    - Wiring diagrams

    - Bill of materials

- Interfacing sensor and control systems with NEMO using the Modbus communication protocol

The first example in the manual includes multi-sensor temperature and relative humidity monitoring within a laboratory environment.

In addition to the information provided in this manual, the CNST NanoFab plans to release a new equipment interlock hardware infrastructure and digital/analog input modules for monitoring equipment states. These new features will further expand NEMO's capabilities and make it an even more powerful tool for managing laboratory operations.

1.1   Terms Of Use

The instrumentation and software, described in this manuscript, were developed at the National Institute of Standards and Technology (NIST) by employees of the Federal Government in the course of their official duties. Pursuant to title 17 Section 105 of the United States Code this software is not subject to copyright protection and is in the public domain. NEMO is an experimental system. NIST assumes no responsibility whatsoever

for its use by other parties, and makes no guarantees, expressed or implied, about its quality, reliability, or any other characteristic. We would appreciate acknowledgment if the software is used. This software can be redistributed and/or modified freely provided that any derivative works bear some notice that they are derived from it, and any modified versions bear some notice that they have been modified.

1.2 Disclaimer

This manual identifies certain commercial equipment, instruments, and materials to specify the experimental procedure. Such identification does not imply recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that the equipment, instruments, and materials identified are necessarily the best available for the purpose.

CHAPTER 2

Temperature and Humidity Sensing

The National Institute of Standards and Technology (NIST), Center for Nanoscale Science and Technology (CNST) NanoFab has utilized the built-in NEMO sensor module to measure temperature and humidity throughout the NanoFab laboratory spaces. Temperature and relative humidity interface was designed to provide an easy implementation for remote monitoring of temperature and relative humidity via the MODBUS communication protocol.

The system uses the X-410 web-enabled programmable controller (without power-over-ethernet) to monitor temperature and relative humidity. The controller can also monitor 4 digital inputs, control 4 relays, and up to 16 1-Wire sensors. The digital input and relay control features are not used in the below implementation.

The X-410 controller is connected to the internet via an Ethernet cable. The temperature and relative humidity probes X-DTHS-P are connected to the controller via a 1-wire bus. In our implementation, the controller is coupled to 8 X-DTHS-P temperature and relative humidity probes.

The interface module is a self-contained unit that houses all of the necessary components for multi-point temperature and humidity monitoring. It is housed in a

Chapter 2 Temperature and Humidity Sensing

NEMA-rated enclosure, which provides protection from the elements. The enclosure has external connections for power, Ethernet, and eight sensor connections. A LED on the door indicates the status of the power for the enclosure.

Once the interface module and NEMO are configured, you can use it to monitor the temperature and humidity of up to eight temperature and humidity sensor pairs. NEMO is configured to poll the controller at a set interval to extract the temperature and relative humidity data values. The NEMO software will display the data in real time and allow you to export the data for further analysis. NEMO can also send alerts if the temperature or relative humidity exceeds a set threshold.

The following sections provide diagrammatic details of the interface construction and setup procedures, that allow you to fully construct and implement multi-point temperature and humidity monitoring with NEMO. If you do not want to construct the interface module yourself, you can purchase a fully built module from Jeff Hawks, from Hawks Technical Services LLC. The fully built module includes all of the necessary components and is ready to use. The following is contact information for Hawks Technical Services LLC:

Jeff Hawks
Hawks Technical Services LLC.
2715 Swamp Creek Rd.
Green Lane, PA. 18054
C 215-872-0944

2.1 The wiring diagram
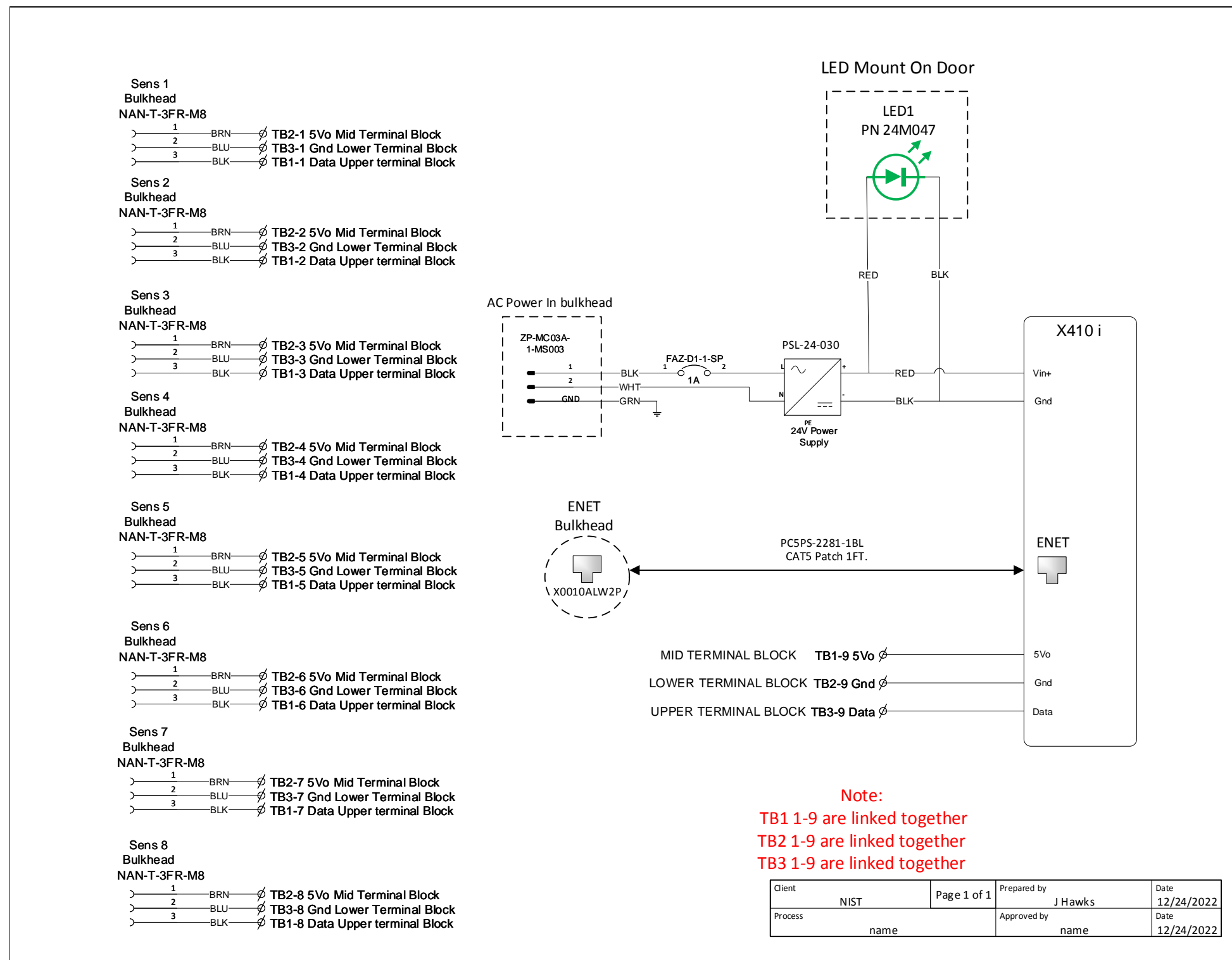
Figure 2.1: *Interface box wiring diagram.*

2.2 Images of the interface box

2.2.1 Front view
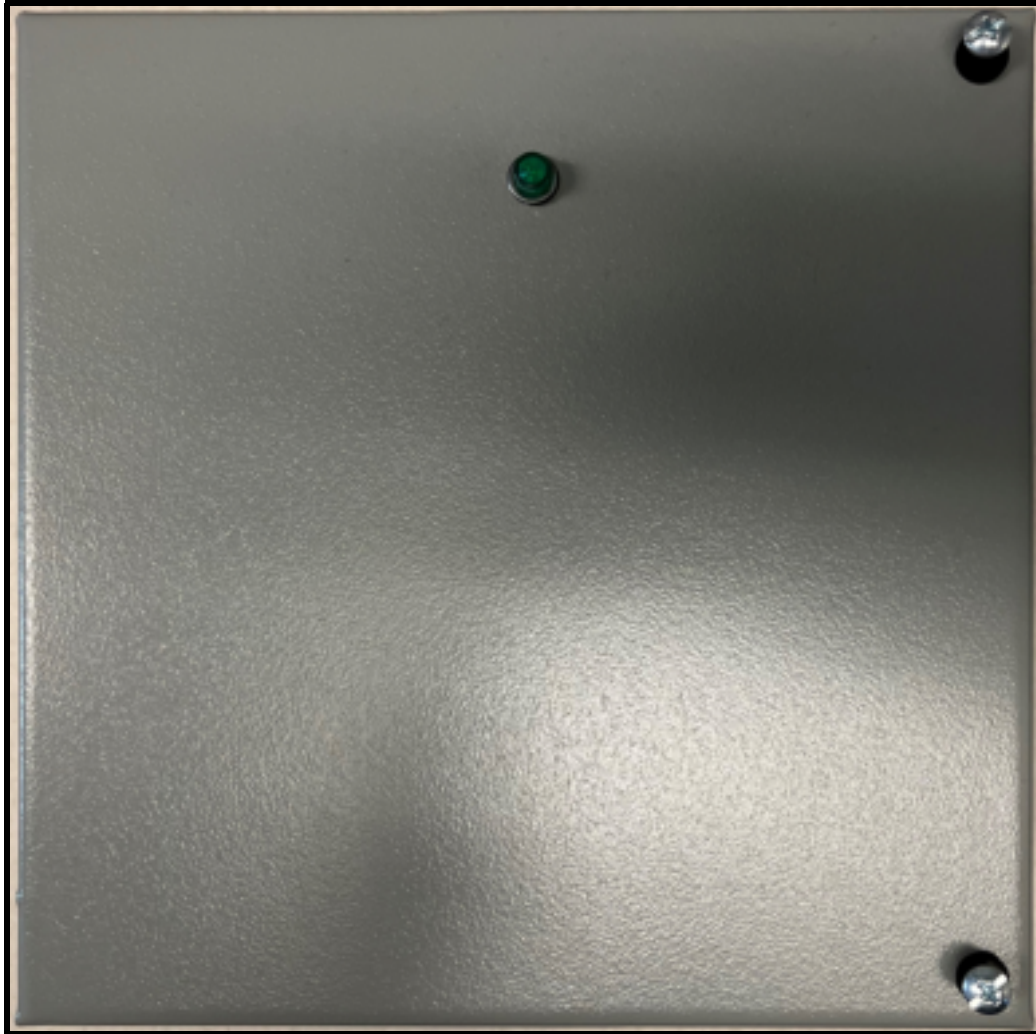
Figure 2.2: *Front view of the interface box.*

2.2.2   Bottom view

Figure 2.3: *Bottom view of the interface box.*

2.2.3   Interior of door view

Figure 2.4: *Interior door view of the interface box.*
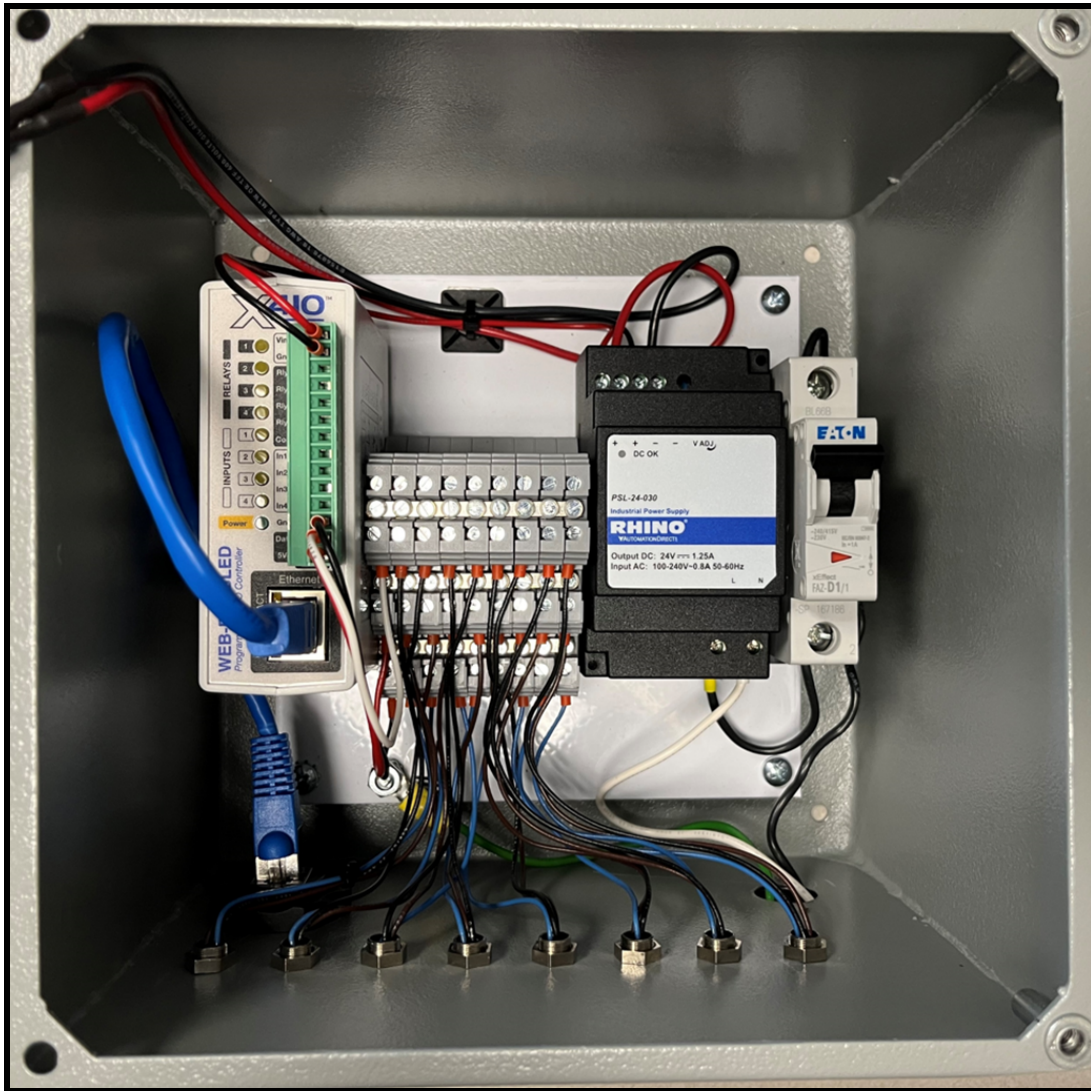
Figure 2.5: *Interior view of the interface box.*

2.3   Bill of materials

2.3.1   Interface Module

Below are details of the specific parts that were used to build the interface module.

1. **Mencom Corporation** www.mencom.com
   Part Number: NAN-T-3FR-M8
   Quantity: 8
   Description: NAN, Receptacle, 3 Pole, Female Straight, 1 ft, 24 AWG, M8.

2. **Mencom Corporation** www.mencom.com
   Part Number: NAN-T-3MP-FW-ST
   Quantity: 8
   Description: NAN, Field Wireable, 3 Pole, Male Straight, Screw Terminals.

3. **Automation Direct** www.automationdirect.com
   Part Number: ZP-MC03A-1-MS003
   Quantity: 1
   Description: ZIPport male insert, connector housing size 3 A, 3-pole, screw terminals, accepts wire size 20 AWG to 14 AWG, 10 A, 600 VAC/VDC, poles numbered 1 to 3. For use with ZIPport multi-wire housings.

4. **Automation Direct** www.automationdirect.com
   Part Number: ZP-MC03A-2-SBHM
   Quantity: 1
   Description: ZIPport bulkhead housing, single lever, connector housing size 3 A. For use with ZIPport size 3 A, 2-peg connector housings.

5. **Automation Direct** www.automationdirect.com
   Part Number: ZP-MC03A-1-FS003
   Quantity: 1
   Description: ZIPport female insert, connector housing size 3 A, 3-pole, screw

terminals, accepts wire size 20 AWG to 14 AWG, 10 A, 600 VAC/VDC, poles numbered 1 to 3. For use with ZIPport multi-wire housings.

6. **Automation Direct** www.automationdirect.com
   Part Number: ZP-MC03A-2-STE11M
   Quantity: 1
   Description: ZIPport hood housing, 2-peg, top entry, connector housing size 3 A, (1) Pg 11 threaded hole, heavy-duty die cast aluminum. For use with ZIPport size 3 A single lever connector housings.

7. **Automation Direct** www.automationdirect.com
   Part Number: BMX-13-W
   Quantity: 1
   Description: Bimed cable gland, PG11 thread type, polyamide, light gray, accepts 5 to 10mm diameter cable, IP68. Package of 5. Mounting hardware included.

8. **Automation Direct** www.automationdirect.com
   Part Number: FAZ-D1-1-SP
   Quantity: 1
   Description: Eaton miniature supplementary protector, 1 A, 277 VAC / 48 VDC, 1-pole, D curve, thermal magnetic, 5 kA at 277 VAC interrupting rating, 35 mm DIN rail mount.

9. **Automation Direct** www.automationdirect.com
   Part Number: PSL-24-030
   Quantity: 1
   Description: RHINO PSL series switching power supply, 24 VDC to 28 VDC output, 1.25 A, 30 W, 120/240 VAC or 125 VDC to 375 VDC nominal input, 1-phase, enclosed, plastic housing, 35mm DIN rail mount, screw terminals, NEC Class 2.

10. **Automation Direct** www.automationdirect.com
    Part Number: KN-TL14S

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Quantity: 1

Description: Konnect-It screw triple-level sensor terminal block, accepts wire size 24 AWG to 12 AWG, gray, 24 A, 300 V rated (UL), 35 mm DIN rail mount, 100 kA SCCR. Package of 20. For use with jumpers KN-2JTL12, KN-3JTL12, KN-4JTL12 and KN-10JTL12.

11. **Automation Direct** www.automationdirect.com
    Part Number: KN-ECTLS
    Quantity: 1
    Description: Konnect-It terminal block end cover, gray. Package of 10. For use with KN-TL14S series terminal blocks.

12. **Automation Direct** www.automationdirect.com
    Part Number: KN-10JTL12
    Quantity: 1
    Description: Konnect-It terminal block jumper, screw-down type, 10-pole, 24 A, 440 V. Package of 5. For use with multiple terminal blocks.

13. **Automation Direct** www.automationdirect.com
    Part Number: WA080806GIE
    Quantity: 1
    Description: Wiegmann enclosure, NEMA 12/13, 8 in $\times$ 8 in $\times$ 6 in (H $\times$ W $\times$ D), wall mount, carbon steel, ANSI 61 gray, powder coat finish, hinged screw cover.

14. **Automation Direct** www.automationdirect.com
    Part Number: N1P0808
    Quantity: 1
    Description: Wiegmann subpanel, carbon steel, white, powder coat finish. For use with 8 $\times$ 8 (H $\times$ W) N1C08080x, RHC08080x and WA08080xGIE enclosures.

15. **Automation Direct** www.automationdirect.com
    Part Number: DN-R35S1-2

Quantity: 1
Description: DIN rail, slotted, 35 mm, 7.5 mm height (8-inch length required).

16. **Tripp Lite** www.mouser.com; www.alliedelec.com; www.digikey.com; www.cdw.com
Part Number: N206-BC01-IND
Quantity: 1
Description: Cat6 RJ45 Shielded Industrial Panel Mount Bulkhead Coupler, Female to Female feed through, with Dust Cap.

17. **Primus Cable** www.primuscable.com
Part Number: PC5PS-2281-1BL
Quantity: 1
Description: CAT5E Shielded Patch cord 12 inch.

18. **Grainger** www.grainger.com
Part Number: 24M047
Quantity: 1
Description: Round Indicator Light: Green, Male 0.110 Connector, LED, 24 VDC, 8 mm mounting diameter.

2.3.2   Connecting Temperature and Humidity Probes

To connect 6 temperature and humidity probes, we utilized a 3 conductor 22 AWG cable, screw terminals, and Y-style splitters. The Y-style splitters were used to minimize losses by daisy chaining multiple sensors from various laboratories. Sensors can be attached to the 1-Wire Bus with a maximum recommended total cable lenght of 182 m (600 feet) from the module without any loss of measurement accuracy. The components for connecting sensors to the interface box are listed directly below.

1. **Mencom Corporation** www.mencom.com
Part Number: NAN-T-3MP-FW-ST
Quantity: 7

Description: NAN, Field Wireable, 3 Pole, Male Straight, Screw Terminals.

2. **Mencom Corporation** www.mencom.com
   Part Number: NAN-T-3MP-FW-ST
   Quantity: 8
   Description: NAN, Field Wireable, 3 Pole, Female Straight, Screw Terminals.

3. **Newark** www.newark.com
   Part Number: 46AC2348
   Quantity: 7
   Description: TE Connectivy: 3P M8 T distributor, Y-style, 3 position M8 plug.

4. **Digikey** www.digikey.com
   Part Number: 1173LSL001-ND
   Quantity: 1000 ft.
   Description: 3 conductor multi-conductor cable slate 22 AWG.
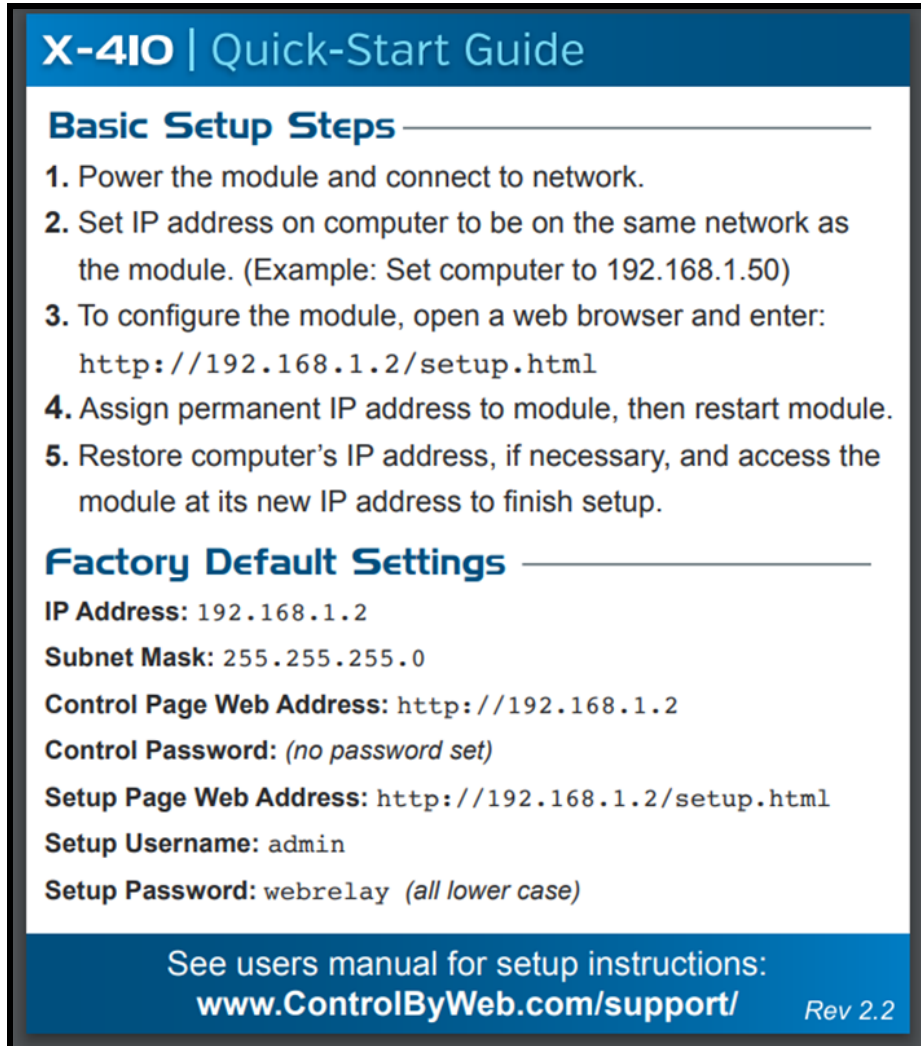
2.4   The control by web X-410 module for temperature and relative humidity monitoring

Figure 2.6: *The control by web X-410 module.*

2.4.1   X-410 Configuration

X-4IO | Quick-Start Guide

Basic Setup Steps

1. Power the module and connect to network.
2. Set IP address on computer to be on the same network as the module. (Example: Set computer to 192.168.1.50)
3. To configure the module, open a web browser and enter:
   `http://192.168.1.2/setup.html`
4. Assign permanent IP address to module, then restart module.
5. Restore computer's IP address, if necessary, and access the module at its new IP address to finish setup.

Factory Default Settings

IP Address: `192.168.1.2`

Subnet Mask: `255.255.255.0`

Control Page Web Address: `http://192.168.1.2`

Control Password: *(no password set)*

Setup Page Web Address: `http://192.168.1.2/setup.html`

Setup Username: `admin`

Setup Password: `webrelay` *(all lower case)*

See users manual for setup instructions:
www.ControlByWeb.com/support/ *Rev 2.2*

Figure 2.7: *The X-410 quick start guide.*

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Once the system is connected to your network (consult with IT for assistance), enter the IP address followed by /**Setup.html**. Login with the admin username and password when prompted. You should see the following screen.
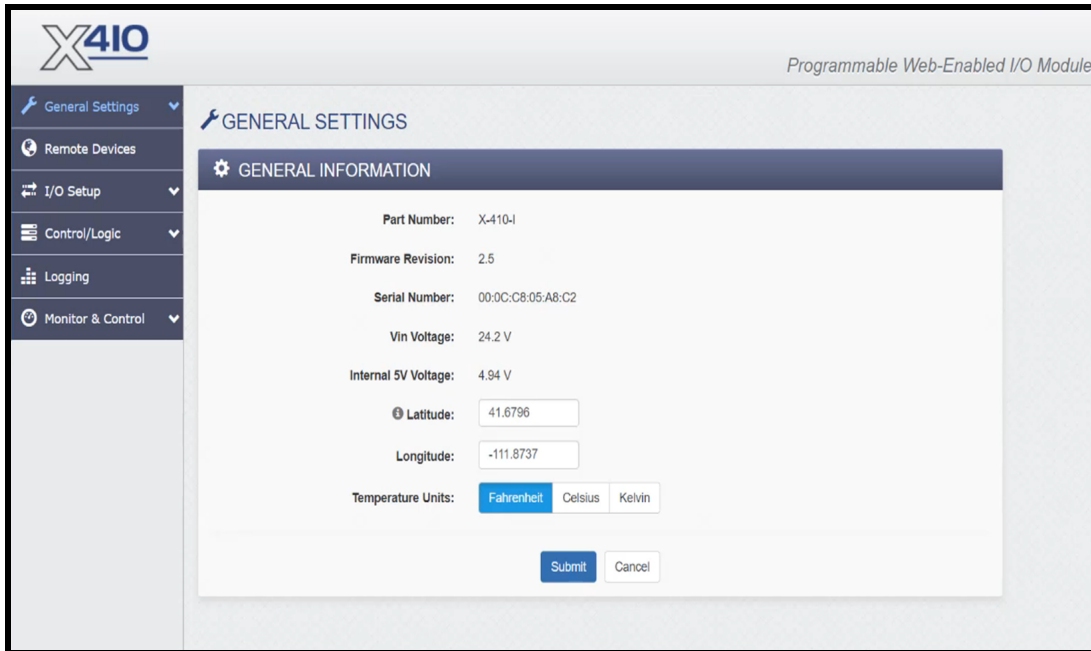
Figure 2.8: *General information under the general settings tab.*

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Clicking on **General Settings** then **Network** will show you the following screen.
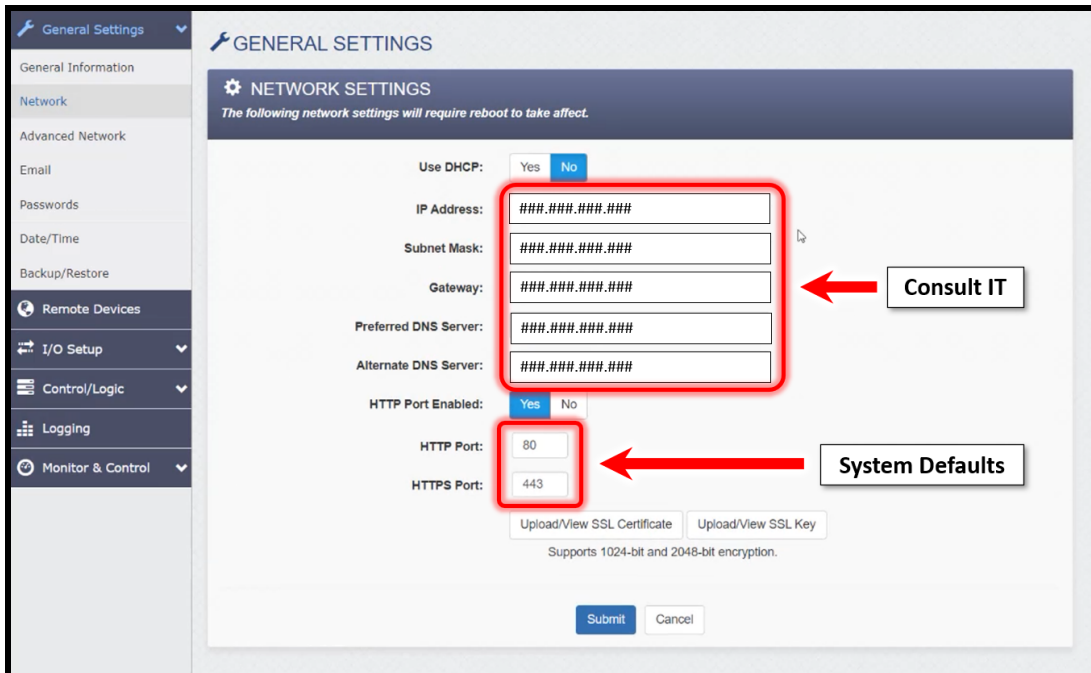
Figure 2.9: *The X-410 network settings.*

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Click on **I/O Setup** then click on the **1-Wire Sensors** option.
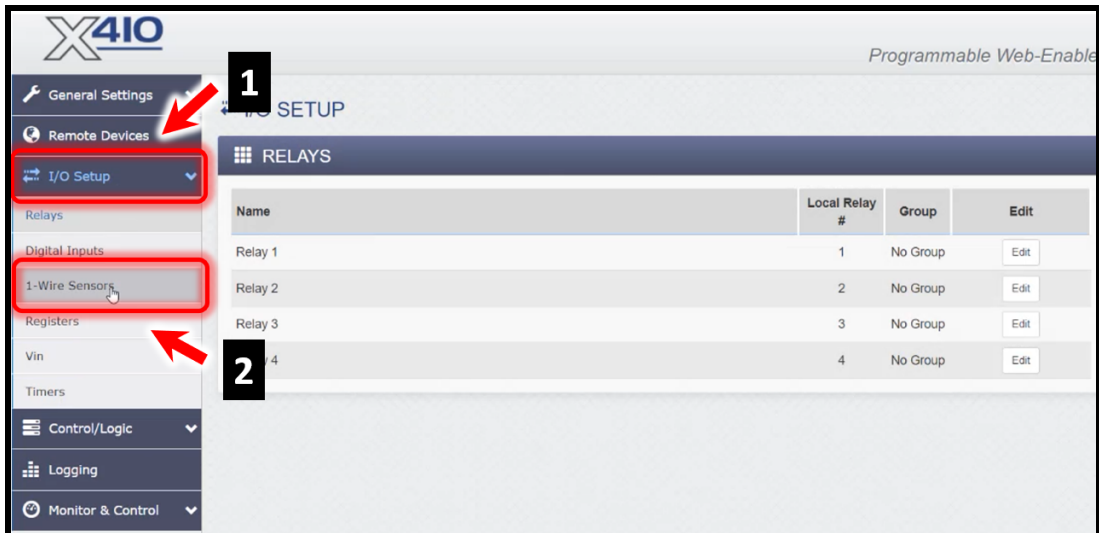
Figure 2.10: *The X-410 I/O setup for the 1-wire sensors.*

The following screen shows you the sensors that are currently configured and allows for you to add additional sensors. Make sure the sensor you wish to configure is securely attached then click the **Add 1-Wire Sensor** button.
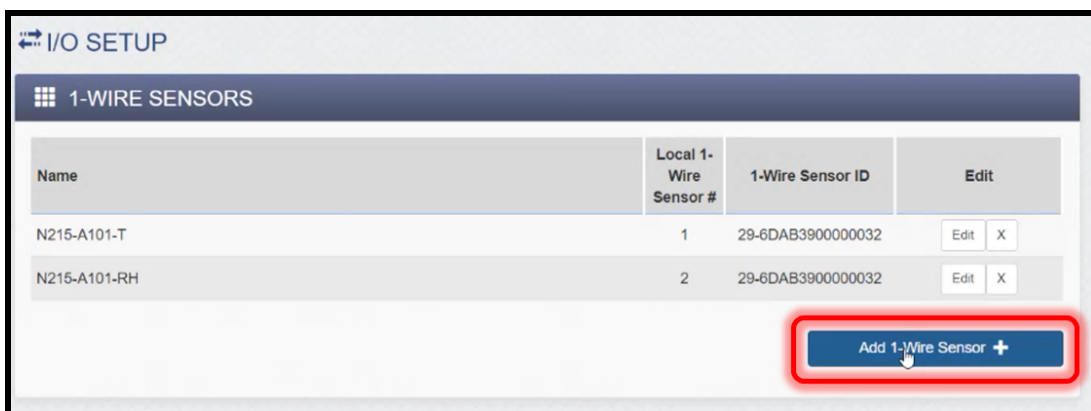
Figure 2.11: *Adding the temperature and humidity 1-wire sensors.*

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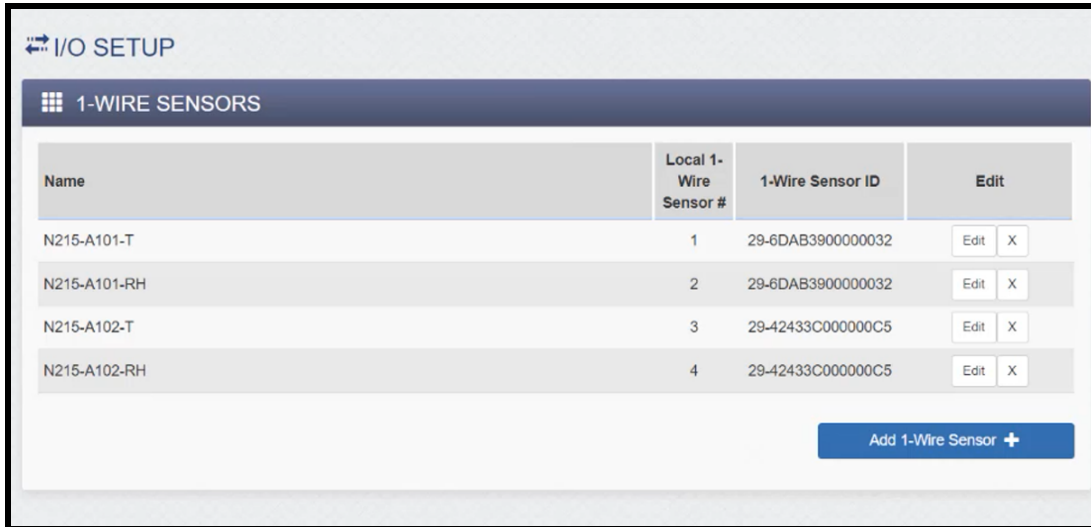
1. Select the sensor you wish to add from the Sensor ID pulldown menu.

2. Enter the appropriate Local 1-Wire Number.

3. Enter the number of decimal places you wish to record.

4. Click the **Add 1-Wire Sensor** button.

Figure 2.12: *Adding the temperature and humidity 1-wire sensors configuration.*

After the addition of the sensor, you will return to the I/O Setup for 1-Wire Sensors page.

Figure 2.13: *The X-410 I/O setup for the 1-wire sensors showing all the added sensors.*

Please leave the Control by Web browser window open. You will need it later in the setup process.

2.4.2   Retrieving the sensor Modbus address

The Modbus address for each sensor is needed when adding sensors to NEMO. From the Control by Web X-410 browser window:

1. Under the General Settings, click on the **Advanced Network**.
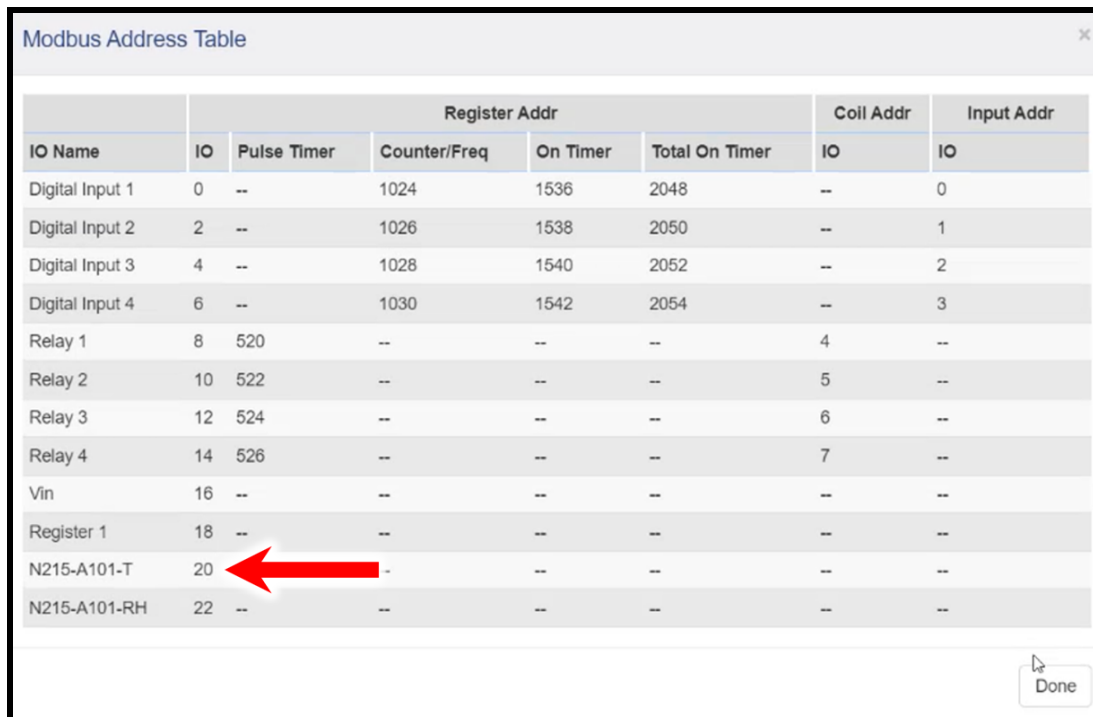
2. Click on the **View Modbus Adress Table** button.
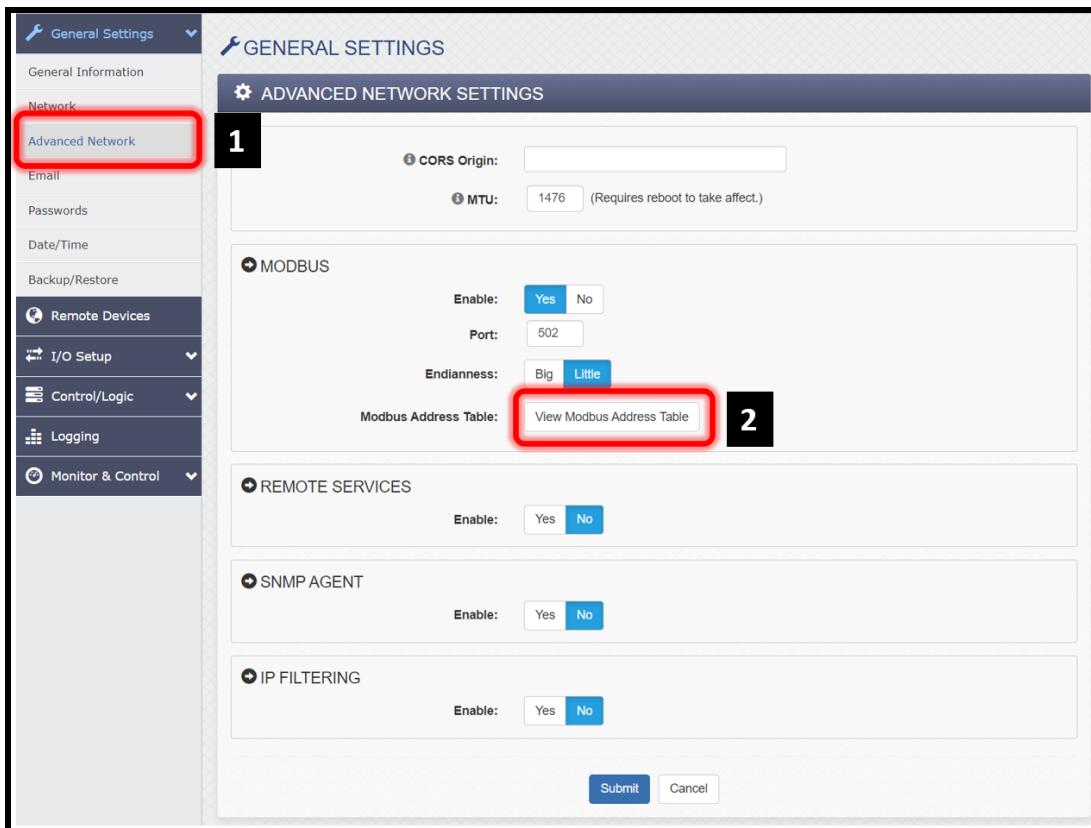
Figure 2.14: *The X-410 Advanced Network settings and accessing the Modbus address table.*

Modbus Address Table   ×

| IO Name | IO | Pulse Timer | Register Addr | | | Coil Addr | Input Addr |
			Counter/Freq	On Timer	Total On Timer	IO	IO
Digital Input 1	0	--	1024	1536	2048	--	0
Digital Input 2	2	--	1026	1538	2050	--	1
Digital Input 3	4	--	1028	1540	2052	--	2
Digital Input 4	6	--	1030	1542	2054	--	3
Relay 1	8	520	--	--	--	4	--
Relay 2	10	522	--	--	--	5	--
Relay 3	12	524	--	--	--	6	--
Relay 4	14	526	--	--	--	7	--
Vin	16	--	--	--	--	--	--
Register 1	18	--	--	--	--	--	--
N215-A101-T	20	--	--	--	--	--	--
N215-A101-RH	22	--	--	--	--	--	--

Done

Figure 2.15: *The Modbus address table.*

Table in figure 2.15 shows the Modbus address table. The temperature and relative humidity sensors have an IO address of 20 and 22, respectively. During the NEMO setup, we will be using the IO address 20 to set up the temperature sensor named N215-A101-T. Also, since the IO address values are in increments of 2, this is the value that will be used in the NEMO sensor setup.

2.4.3   Configuring and adding sensors in NEMO

2.4.3.1   Sensor card setup

In NEMO, Click **Administration** $\rightarrow$ **Detailed Administration** $\rightarrow$ **Sensors** $\rightarrow$ **Sensor cards** and you will see the following page. Click the ADD SENSOR CARD button.
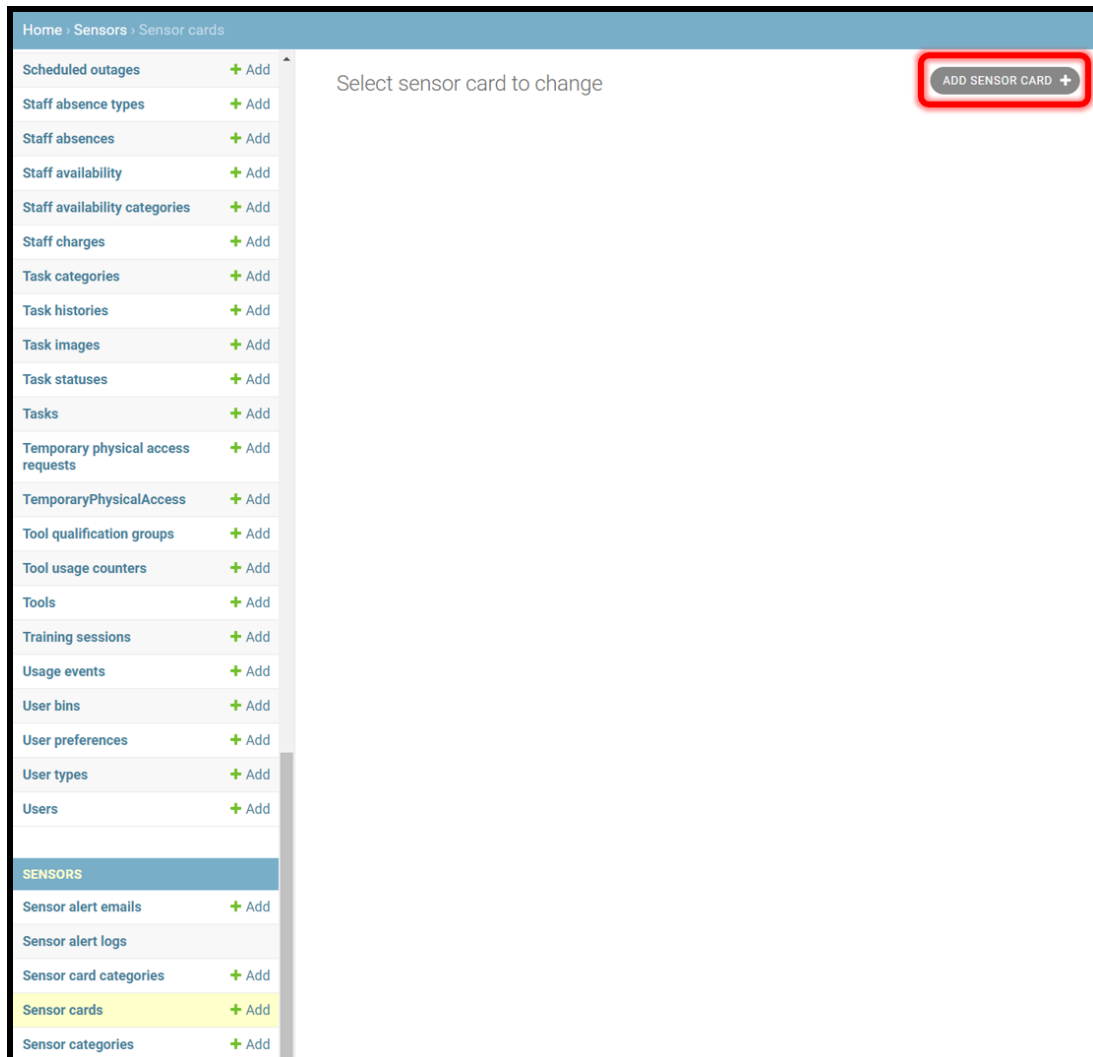
Figure 2.16: *NEMO sensor card setup.*

After clicking the Add Sensor Card button, the following menu will appear.

Figure 2.17: *NEMO sensor card configuration setup.*

1. Select a name for your X-410 module.

2. Enter the IP address of the X-410 module.

3. Enter the Port number of the module.

4. Choose Modbus Tcp as the protocol, and ensure that the Enabled checkbox is checked.

5. Click the **SAVE** button. At this point the enabled sensor card information will appear on the main **Sensor Card** menu.

2.4.3.2 Sensor category setup

In NEMO, Click **Administration** → **Detailed Administration** → **Sensors** → **Sensor categories** and you will see the following page. Click the ADD SENSOR CATEGORY button.
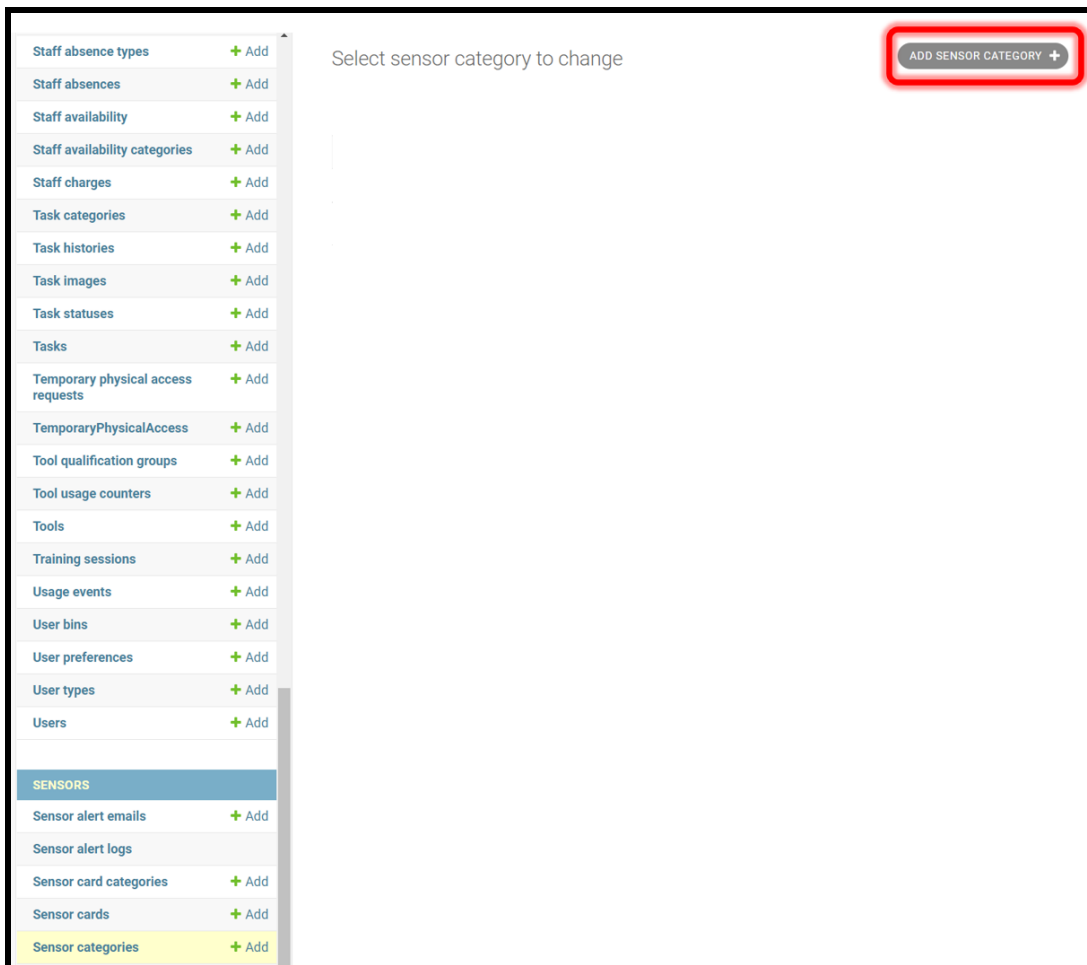

Figure 2.18: *NEMO sensor category setup.*

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After clicking the Add Sensor Category button, the following menu will appear.

Figure 2.19: *Adding sensor categories to NEMO.*

1. Select a name the sensor area. In our case we select Building 215 as the prefix identifier. Multiple sensor categories can be grouped into parent-child relationship. See NEMO feature manual for more information on this topic.

2. Click the **SAVE** button. At this point the sensor category information will appear on the main **Sensor Categories** menu, as shown in the below figure 2.20.

Figure 2.20: *Sensor categories menu showing the added category.*

2.4.3.3 Adding sensors

In NEMO, Click **Administration** → **Detailed Administration** → **Sensors** → **Sensors** and you will see the following page. Click the ADD SENSOR button.
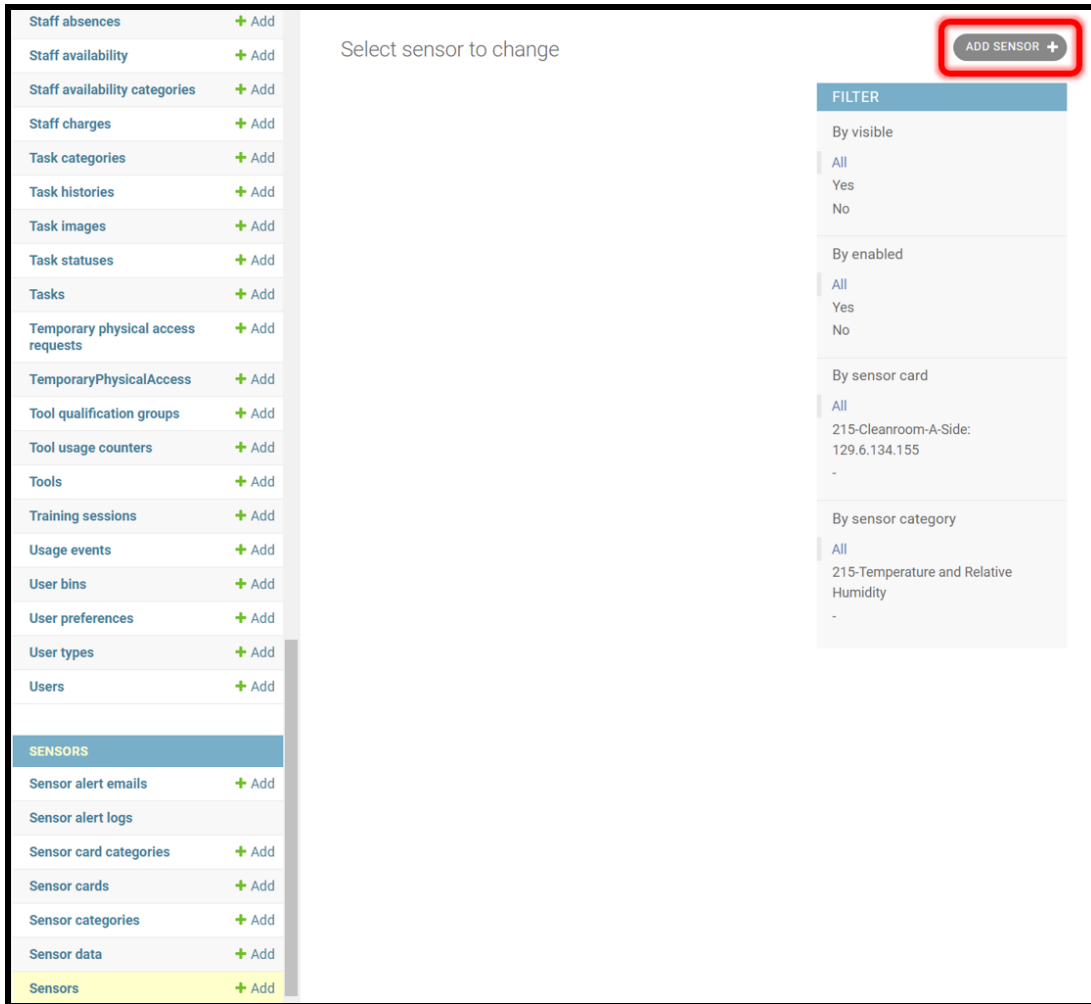

Figure 2.21: *NEMO sensor configuration setup.*

Figure 2.22: *The top portion of the NEMO sensor configuration setup information menu.*

1. Type the name of the sensor. In our case 215-A101-T represents; building 215; Room A101; and temperature sensor.

2. From the dropdown menu choose the sensor card.

3. From the drop down menu choose the sensor category.

4. Type in the data label for the graph and data table.

5. Type in the data suffix for the sensor data vales. Here we are using Fahrenheit temperature scale, hence the data suffix is set to F.

The sensor can be linked to either a sensor card or an already existing interlock card, provided it's a Modbus interlock card. The interlock card can be used for both interlocks and sensors.

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The bottom portion of the sensor setup information menu is shown below

Figure 2.23: *The bottom portion of the NEMO sensor configuration setup information menu.*

1. Type in the read address for the sensor. See figure 2.15 for IO address details.

2. Type in the number of values for the sensor. For the X-410, the number of values are 2, as seen in figure 2.15.

3. Type in the formula for the value formatting. In this case the number is a float with 2 decimal places.

4. Type in the read frequency in minutes. Value of 0 will disable the sensor data reading.

5. Click the **SAVE** button to save the sensor configuration.

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The main sensor screen will show the added sensor. To test the added sensor:

1. Ensure that the checkbox left of the sensor name is checked

2. From the Action pulldown menu choose the "Read selected sensors" option, and click the **Go** button. Then move the scroll bar to see the values.
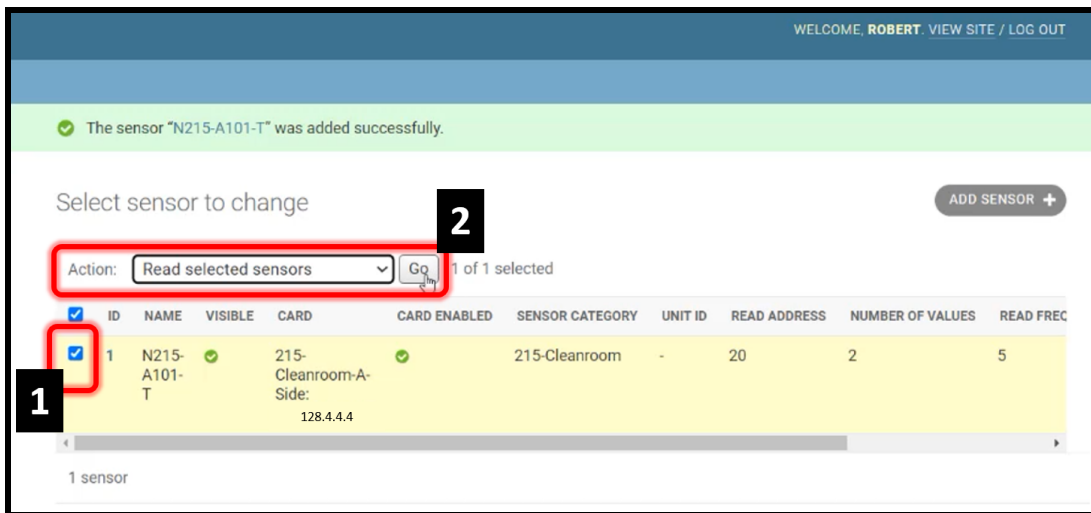

Figure 2.24: *Testing the sensor by reading values within NEMO.*

2.4.3.4   Setting up sensor alert emails

In NEMO, Click **Administration** → **Detailed Administration** → **Sensors** → **Sensor alert emails**, then click on the ADD SENSOR ALERT EMAIL button, as shown in figure 2.25.

Figure 2.25: *Adding sensor alert emails.*

1. Ensure that the Enabled option is checked, then choose the sensor from the dropdown menu.

2. The sensors can be triggered when data read fails by checking the "Trigger no data" option. Set the trigger condition of the value variable using equals (==) and boolean (and, or) conditions.

3. Type in the comma separated email address that will receive the alerts

4. Click the **SAVE** button to save the sensor alert email configuration.

2.4.4   NEMO sensor display

In NEMO, Click **Administration** → **Sensor data**. The sensor dashboard will appear with the sensor categories. In our case, we created the "215-Temperature and Relative Humidity" sensor category, as seen in the below figure 2.26. Click on the "215-Temperature and Relative Humidity" sensor category icon. The dashboard with the active sensors will display realtime values as shown in the below figure 2.27. To view a graphical plot of temperature values, click on the right temperature sensor icon "215-A101-T".
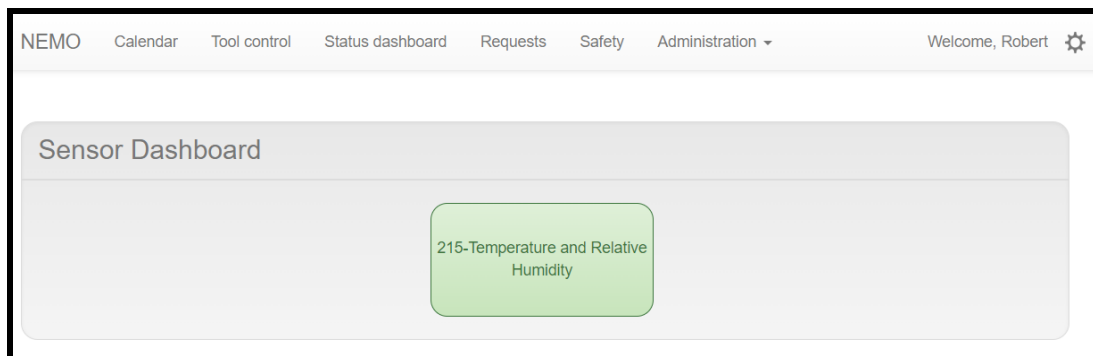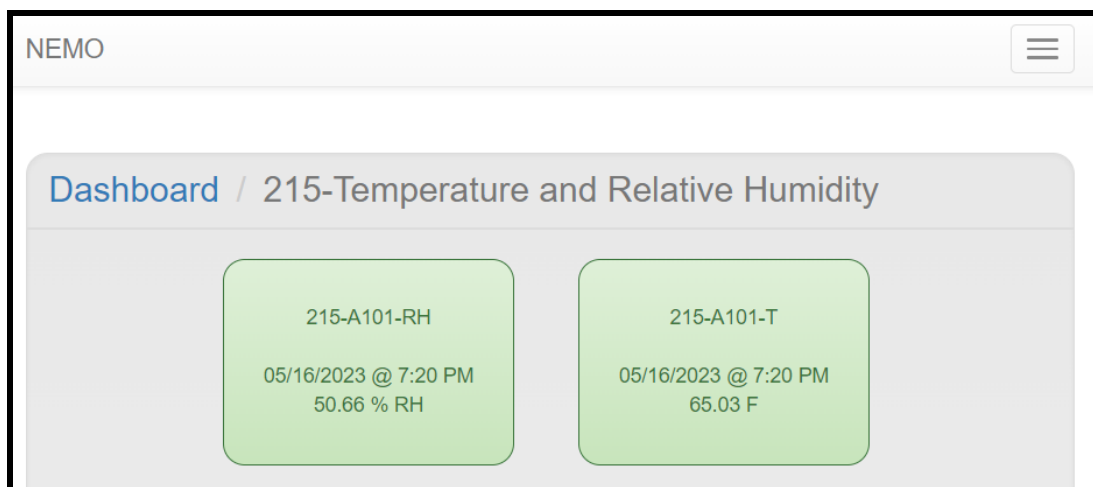

Figure 2.26: *NEMO sensor dashboard.*

Figure 2.27: *NEMO sensor dashboard.*

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The default graph displays the temperature data over the last 24 hours, as shown in the below figure 2.28. Hovering over a data value will display a the date, time, sensor name and sensor value results, as seen in the below figure 2.28 for May 16, 2023, 4:00:02 pm, sensor 215-A-A101, 64.85 F. Click on the Date Range to either choose a range of dates or to choose one of the programmed values (Last 72 hrs, Last 7 days, Last 30 days, Last month, Last Year, etc).
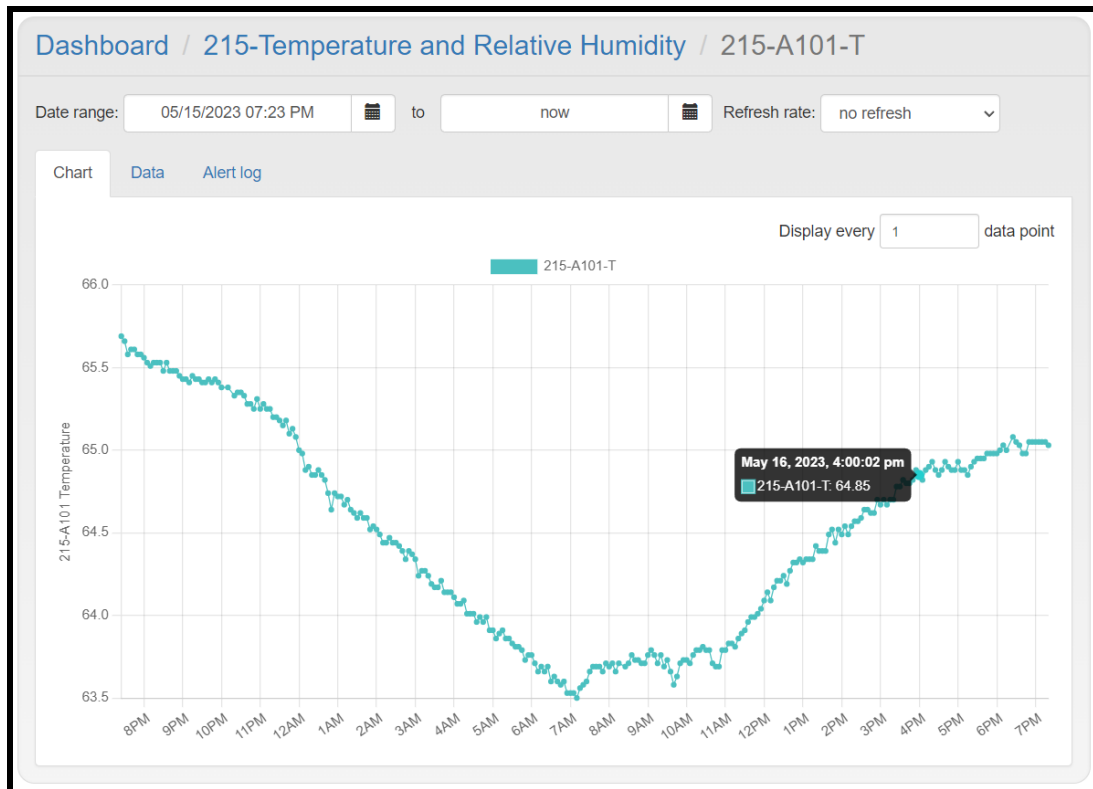

Figure 2.28: *Plot of temperature over the last 24 hours.*

To export comma separated valued data, click on the Data then click the export button. To clear alert alarms, click on the Alert log tab, then clear the alert.

NEMO Hardware Accessories Release Notes

3.1 v1.0.0

The first release of the NEMO Hardware Accessories manual highlights the build, installation, and configuration of the temperature and humidity monitoring system with the NEMO lab management system.