

# **NEMO: Hardware Accessories**

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# 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

#### **Chapter 1 Introduction**

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

# Equipment Interlocks

The National Institute of Standards and Technology (NIST), Center for Nanoscale Science and Technology (CNST) NanoFab has utilized the multi-channel relay module to interlock equipment throughout the NanoFab laboratory spaces. This portable system, designed for easy implementation, allows scientists to interlock numerous instruments using the MODBUS communication protocol.

The system uses the X-432 web-enabled, programmable Ethernet I/O module with 16 independent relays. While the X-432 module offers additional functionalities like 18 digital inputs, 4 analog inputs, and support for up to 16 temperature and/or humidity sensors via a 1-wire bus, these features are not employed in the below implementation.

The X-432 interlock module is housed in a self-contained enclosure that holds all the necessary components and connections for the 16 relays. It has external connections for power, Ethernet, and 16 interlock signals. The enclosure also features sixteen 2-way switches with LEDs on the door. These switches display the status of each relay and control whether the system is interlocked by NEMO or is in the interlock-bypass mode.

Once the MODBUS-based interlock module and NEMO are configured, each relay channel connects to a specialized interlock control box using a simple two-wire cable.

This box can be customized with specific input and output ports, making it compatible with a wide range of equipment control systems. While this example focuses on a solution for USB-controlled instruments, the box can also be configured for connections like standard power outlets, HDMI/DVI/VGA monitors, and more.

The following sections provide diagrammatic details of the interlock system construction and setup procedures, that allow you to fully construct and implement a 16-channel, relay-based, interlock system 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 jeffhawks@verizon.net 2.1 The X-432 interlock wiring diagram





-Ó

MCB 1P

7B21 0V

G1 Power Supply

SK1

Power



# 2.2 Images of the interlock module

					2	12-	-D	10.	5-	- 1
1		2	3	4	5	E	3	7		8
4		-	-		ig				1	
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				1						
Ð			ALC: NO.							
-		10		1						
S	)	10	11	12	1:	3 1	4	15		16
					light	-		10		
7										
									11.	
					•••	• • •	•	•	1:	
					••••					
			Inte	erlock	215-B	103-1				
	Relay	Equipme	Inte	erlock	215-B Relay	103-1 Equipme	ent			
	Relay	Equipme	Inte	erlock	215-B Relay 9	103-1 Equipme Oxford H	ent ligh Ten	np ICP-CVI		
	Relay 1 2	Equipme AFM Zeiss Ger	Internet in the second se	erlock	215-B Relay 9 10	103-1 Equipme Oxford F PlasmaT	ent High Ten herm P	np ICP-CVI ECVD		
	Relay 1 2 3	Equipme AFM Zeiss Ger Zeiss Ger	International Second	erlock	215-B Relay 9 10 11	103-1 Equipme Oxford H PlasmaT Oxford P	ent ligh Ten herm P	np ICP-CVE ECVD ab PECVD		
	Relay 1 2 3 4	Equipme AFM Zeiss Ger Zeiss Ger Sensofar	International States St	erlock EEM EEM filometer	215-B Relay 9 10 11 12	103-1 Equipme Oxford H PlasmaT Oxford P AllWin D	ent High Ten herm P HasmaLi	np ICP-CVI ECVD ab PECVD eam Ashee		
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	Relay 1 2 3 4 5 6 7	Equipme AFM Zeiss Ger Zeiss Ger Denton S Denton S E-Beam L	Int nt nini 500 FES nini 500 FES Optical Prot putter Left putter Right ithography	erlock EEM iEM iilometer	215-B Relay 9 10 11 12 13 14 15	103-1 Plasmat Oxford H Plasmat Oxford P AllWin D SUSS Wa SPTS Dee Unaxis D	ent High Tenn PilasmaLu Jownstrut For Bonn gep Etchdreep	np ICP-CVD ECVD ab PECVD eam Ashee der er her		

#### 2.2.1 Front view

Figure 2.2: Front view of the interlock module showing the 2-way switches.

#### 2.2.2 Bottom view



Figure 2.3: Bottom view of the interlock module showing the relay interlock outputs and the power cable connection.

#### 2.2.3 Side view



Figure 2.4: Side view of the interlock module showing the ethernet connection.

#### Interior of door view 2.2.4



Figure 2.5: Interior door view of the interlock module showing 2-way switch connections.

# 2.2.5 Interior of door view



Figure 2.6: Interior view of the interlock module showing the X-432 system connections.

# 2.3 Custom interlock controls

The following subsections explore our custom interlock control boxes. We have designed a variety of control boxes to interlock various aspects of instrumentations. This includes USB, which you'll see below, and coming soon: contact closure, HDMI, power, and more We'll keep this section updated as we develop new interlocking mechanisms. These custom interlock boxes have integrated tapped holes for wall mounting (see Figure 2.10), however, these boxes can be mounted on top of instruments or portable computer carts (see Figure 2.13).

# 2.3.1 Dual-USB interlocks

The dual-USB interlock system allows for controlled access of up to two USB devices. This system is perfect for interlocking a keyboard and mouse. It's also ideal for touchscreen monitors, where you can secure the connection using just one of the two available USB ports. This section features images and schematics of the custom dual-USB interlock control box for your reference.



Figure 2.7: Custom dual-USB interlock control box wiring diagram schematic.



Figure 2.8: Front view of the dual-USB custom interlock control box showing the interlock status LED.



Figure 2.9: Top view of the dual-USB custom interlock control box showing the input control connection.

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Each side of the custom interlock control box has 2 USB ports. For instance, both USB ports could be used to interlock a keyboard and a mouse. Alternatively, a single (one of the two USB ports) could be utilized to interlock a single USB device, such as a touch-screen monitor. The below side-view image of the unit highlights the USB connectors and wall-mounting holes. Both sides of unit have 2 USB ports and 2 wall-mounting holes.



Figure 2.10: Side view of the dual-USB custom interlock control box showing the 2 USB connections with (top image) and without (bottom image) covers, and 2 wall-mounting holes.

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Figure 2.11: Inside view of the dual-USB custom interlock control box showing the input control connection.

**Chapter 2 Equipment Interlocks** 



Figure 2.12: Example of a cleanroom wall-mounted dual-USB custom interlock control box in the disabled and the enabled state, as shown in the top and bottom images, respectively. The green LED lights up when the interlock is in the enabled state, as shown in the bottom image.



Figure 2.13: Examples of a dual-USB custom interlock control box mounted on top of an instrument and on top of a computer cart, as shown in the top and bottom images, respectively.

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# 2.4 Bill of materials

#### 2.4.1 Interlock 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: 32

Description: NAN Receptacle 3 pole female 24 AWG.

#### 2. Automation Direct www.automationdirect.com

Part Number: DN-24J2Y Quantity: 1 Description: DINnector terminal block jumper, push-in type, 24-pole, orange, 25 A, 600 V rated (UL).

3. Automation Direct www.automationdirect.com

Part Number: DN-QD12-A Quantity: 1 Description: DINnector screwless double-level feedthrough terminal block.

#### 4. 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.

#### 5. Automation Direct www.automationdirect.com

Part Number: ZP-MC03A-2-SBHM Quantity: 1 Description: ZIPport bulkhead housing, single lever, connector housing size 3 A.

- 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.
- Automation Direct www.automationdirect.com
   Part Number: BMX-13-W
   Quantity: 1
   Description: Bimed cable gland, PG11 thread type.

#### 8. Automation Direct www.automationdirect.com

Part Number: FAZ-D2-1-SP Quantity: 1 Description: REaton miniature supplementary protector, 2 A, 277 VAC/48 VDC, 1-pole, D curve.

#### 9. Automation Direct www.automationdirect.com

Part Number: PSL-12-030 Quantity: 1 Description: RHINO PSL series switching power supply, 12 VDC output, 2.1 A, 25 W, 120/240 VAC.

#### 10. Automation Direct www.automationdirect.com

Part Number: KN-TL14S Quantity: 1 Description: Konnect-It screw triple-level sensor terminal block.

#### 11. Automation Direct www.automationdirect.com

Part Number: ZP-MC03A-2-STE11M Quantity: 1 Description: Hood housing, 2-peg, top entry, connector housing size 3 A.

#### 12. Automation Direct www.automationdirect.com

Part Number: DN-SUPP-2-1 Quantity: 1 Description: DINnector mini supplementary protector, with reset, 2 A, 250 VAC/75 VDC, blade connection, 1-pole, UL 1077 recognized.

# 13. Automation Direct www.automationdirect.com

Part Number: KN-10JTL12 Quantity: 1 Description: terminal block jumper, screw-down type, 10-pole, 24 A, 440 V.

#### 14. Automation Direct www.automationdirect.com

Part Number: DN-FE4L12-5 Quantity: 1 Description: DINnector screw circuit protection terminal block, accepts wire size 24-12 AWG, gray, 12 VAC/VDC LED indicator(s).

#### 15. Automation Direct www.automationdirect.com

Part Number: DN-R35S1-2 Quantity: 1 Description: DIN rail, slotted, 35 mm, 7.5 mm height.

#### 16. Amazon www.amazon.com

Quantity: 32 Description: BATIGE 2 Ports Dual USB 3.0 Male to USB 3.0 Female AUX Flush Mount.

#### 17. Amazon www.amazon.com

Quantity: 1 Description: Zulkit Junction Box ABS Plastic Dustproof Waterproof IP65 Universal Electrical Boxes Project Enclosure with Fixed Ear Black ( $6.22 \times 3.54 \times 2.36$ ) inch.

#### 18. Amazon www.amazon.com

Quantity: 1

Description: Bergen Industries Inc PS913163 3-Wire Appliance and Power Tool Cord, 9 ft, 16 AWG, 13 A/125 VAC, 1625 W, Black.

#### 19. Amazon www.amazon.com

Quantity: 16 Description: HiLetgo 2pcs DC 12V 2 Channel Relay Module with Isolated Optocoupler.

#### 20. Amazon www.amazon.com

Quantity: 1

Description: QILIPSU Hinged Cover Stainless Steel Latch (370  $\times$  270  $\times$  150) mm (14.6  $\times$  10.6  $\times$  5.9) inches Junction Box with Mounting Plate.

#### 21. Amazon www.amazon.com

Quantity: 2

Description: Nilight 8 Gang Rocker Switch Panel 5Pin On Off Toggle Switch Aluminum Holder 12V 24V.

#### 22. Amazon www.amazon.com

Quantity: 3 Description: JAIZAIWJ 6 pcs 12 V Led Indicator Light 6 mm 1/4".

#### 23. Amazon www.amazon.com

Quantity: 1 Description: ANMBEST 2PCS Panel Mounting RJ45 Waterproof Connector M25 Cat5/5e/6 Ethernet LAN Cable Coupler with Shield.

# 2.4.2 Connecting the interlock relay modules to a custom interlock control box

To connect each of the 16 interlock channels to custom interlock control boxes, we utilized 2 conductors from a 3 conductor 22 AWG cable, and screw terminal connectors. The components for connecting the interlock control box to the interlock module are listed directly below.

# Mencom Corporation www.mencom.com Part Number: NAN-T-3MP-FW-ST Quantity: 32 Description: NAN, Field Wireable, 3 Pole, Male Straight, Screw Terminals.

#### 2. Digikey www.digikey.com

Part Number: 1173LSL001-ND Quantity: 1000 ft. Description: 3 conductor multi-conductor cable slate 22 AWG.

# Digikey www.digikey.com Part Number: 380-1422-ND Quantity: 32 Description: USB 2.0 Cable A Male to A Male 6.00' (1.83m) Shielded.

# 2.5 NEMO setup and configuration of the control by web X-432 16 channel relay module for equipment interlocks



Figure 2.14: The control by web X-432 16 channel relay module.

# 2.5.1 X-432 Configuration

X-432   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 1.0

Figure 2.15: The X-432 quick start guide.

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.

X432		Programmable Web-Enabled I/O Controller
✗ General Settings ▼	✗ GENERAL SETTIN	IGS
Remote Devices		<b>I</b> ATION
Control/Logic V	Part Number:	X-432-I
Logging	Firmware Revision: Serial Number:	3.0 00:0c:c8:06:70:ea
🥙 Monitor & Control 🛛 🗸	C Latitude:	41.6796
	Longitude:	-111.8737
	Temperature Units:	Fahrenheit Celsius Kelvin
		Submit Cancel

Figure 2.16: X-432 general information under the general settings tab.

Click on the **General Settings** then **Ethernet** will show you the following screen.

🗲 General Settings 🔹 🗸	✗ GENERAL SETTINGS								
General Information									
Ethernet	NETWORK SETTINGS The following reduced settings will require reduct to take affect								
Advanced Network									
Email	Use DHCP:	Yes No							
Passwords	IP Address:	###.###.###.###							
Date/Time	Subnet Mask:	###.###.###.###							
Backup/Restore	Gateway:		٦						
Remote Devices	Preferred DNS Server:	###.###.###	1						
🛱 I/O Setup 🗸 🗸	Alternate DNS Server:	###.###.###							
📰 Control/Logic 🛛 🗸	HTTP Port Enabled	Ves No							
Logging									
🎯 Monitor & Control 🛛 🗸	HTTP Port:	System Defaults							
	HTTPS Port:	443	-						
		Upload/View SSL Certificate Upload/View SSL Key							
		Supports 1024-bit and 2048-bit encryption.							
		Submit Cancel							

Figure 2.17: The X-432 network settings.

Within the **General Settings** click on the **Advanced Network**, then under the MODBUS section click on the YES button to enable the MODBUS protocol. The default value for the Port can be changed, however, the Endianness default value of Little must not be changed.

<b><u>432</u></b>		
✔ General Settings ◆ General Information Ethernet	GENERAL SETTINGS	NGS
Advanced Network Email Passwords	CORS Origin: MTU:	1476 (Requires reboot to take affect.)
Date/Time Backup/Restore Remote Devices	• MODBUS Enable:	Yes No
I/O Setup       I/O Setup       Control/Logic	Port: Endianness: Modbus Address Table:	Big Little

Figure 2.18: Enabling the X-432 MODBUS.

# 2.5.2 Retrieving the Modbus relay coil address

The Modbus coil address for each relay is needed when adding relays to NEMO. From the Control by Web X-432 browser window:

- 1. Under the General Settings, click on the **Advanced Network**.
- 2. Click on the View Modbus Address Table button.

<ul> <li>✔ General Settings</li> <li>♦</li> <li>General Information</li> <li>Ethernet</li> </ul>	GENERAL SETTINGS	IGS
Advanced Network Email	1 OCRS Origin:	
Passwords Date/Time		1476 (Requires reboot to take affect.)
Backup/Restore  Remote Devices	Enable:	Yes No
↓     I/O Setup       ↓     ↓       ↓     ↓       ↓     ↓       ↓     ↓       ↓     ↓	Endianness:	Big Little
	Modbus Address Table:	View Modbus Address Table 2

Figure 2.19: The X-432 Advanced Network settings and accessing the Modbus address table.

			Register A	ddr		Coil Addr	Input Addr
IO Name	10	Pulse Timer	Counter/Freq	On Timer	Total On Timer	10	10
Relay 1	36	548				18	_
Relay 2	38	550				19	
Relay 3	40	552				20	
Relay 4	42	554				21	
Relay 5	44	556				22	
Relay 6	46	558				23	
Relay 7	48	560				24	
Relay 8	50	562				25	
Relay 9	52	564				26	
Relay 10	54	566				27	
Relay 11	56	568				28	
Relay 12	58	570				29	
Relay 13	60	572				30	
Relay 14	62	574				31	
Relay 15	64	576				32	
Relay 16	66	578				33	

Figure 2.20: The Modbus address table for the X-432 module.

Table in figure 2.20 shows the Modbus address table. Each relay has a corresponding Coil Address IO. As highlighted in figure 2.20, Relay 1 has a Coil Address IO value of 18. Relays 2, 3 and 4, for instance, have Coil Address IO values of 19, 20, and 21, respectively. During the NEMO setup, we will be using the Coil Address IO values to setup the corresponding relays.

# 2.5.3 Configuring interlock cards and interlocks in NEMO

#### 2.5.3.1 Interlock card setup

In NEMO, Click Administration  $\rightarrow$  Detailed Administration  $\rightarrow$  Interlock cards and you will see the following page. Click the ADD INTERLOCK CARD button.

NEMO WELCOME, ROBERT. VIEW SITE / LOG OUT					
Home > Nemo > Interlock cards			2		
Doors	+ Add	•			
Email logs			Select Interlock card to change		
Interlock card categories	🕂 Add		Q Search	ı	
Interlock cards	+ Add	1			
Interlocks	+ Add		Action: Go 0 of 6 selected		

Figure 2.21: NEMO interlock card setup.

After clicking the	ADD INTERLOCK	CARD button.	the following	menu will appear.
		•••••••••••••••••••••••••••••••••••••••		

Contact information categories	+ Add <sup>^</sup>	Add interlock card	
Customizations	+ Add		
Doors	+ Add	Name:	215-B103-1 <b>1</b>
Email logs		Server	2
Interlock card categories	+ Add	Gerver.	
Interlock cards	+ Add	Port:	502 3
Interlocks	+ Add	Number	
Landing page choices	+ Add	Number.	
Membership histories	+ Add	Even port:	
News	+ Add		
Notifications	+ Add	Odd port:	
Onboarding phases	+ Add	Category:	ModbusTcp 🗸 🖌 4
Physical access levels	+ Add		
Physical access logs		Username:	
Project disciplines	+ Add	Password:	
Projects	+ Add		
Reservation questions	+ Add	✓ Enabled	
Reservations	+ Add		6
Resource categories	+ Add		Save and add another Save and continue editing SAVE
Resources	+ Add		

Figure 2.22: NEMO interlock card configuration setup.

- 1. Select a name for your X-432 module. We chose the naming convention of room where the interlock resides.
- 2. Enter the IP address of the X-432 module.
- 3. Enter the Port number of the module.
- 4. Choose Modbus Tcp as the protocol.
- 5. Check Enabled checkbox.
- 6. Click the **SAVE** button. At this point the enabled interlock card information will appear on the main **Interlock Cards** menu.

Figure 2.23 shows the added interlock card **215-B103-1** as Modbus TCP enabled on port 502.

NEMO								WELCOME,	ROBERT. VIEW S	SITE / LOG OUT
Home > Nemo > Interlock car										
categories		*								
Customizations	+ Add	Se	lect interlock	card to	change				ADD INTERL	OCK CARD +
Doors	+ Add	0			Se	earch				
Email logs		~				dion				
Interlock card categories	+ Add	Ac	tion:		✓ Go 0 d	of 6 select	ed			
Interlock cards	+ Add		NAME	ENABLED	SERVER 1 A	PORT	NUMBER 2 4	CATEGORY	EVEN PORT	ODD PORT
Interlocks	+ Add		215-B103-1	•	###.###.###.###	502		ModbusTcp	-	-

Figure 2.23: NEMO interlock cards status display.

#### 2.5.3.2 Adding and Configuring Interlocks

In NEMO, Click Administration  $\rightarrow$  Detailed Administration  $\rightarrow$  Interlocks and you will see the following page. Click the ADD INTERLOCK button.

			NEMO welcome, <b>robert</b> . <u>view site</u> / <u>log out</u>	
Home > Nemo > Interlocks				
Interlock cards	+ Add	•	Select interlock to change	ADD INTERLOCK +
Interlocks	+ Add		Sciect interioek to change	
Landing page choices	+ Add		Q Search	FILTER
				By enabled

Figure 2.24: Adding interlocks through the NEMO interlocks menu.

After clicking the	ADD INTERLOCK	button, the fo	ollowing menu	will appear.
			••	

Home > Nemo > Interlocks > /	Add interlock		
categories			
Customizations	+ Add	Add interlock	
Doors	+ Add		Delay 01
Email logs		Name:	Relay 01
Interlock card categories	+ Add	Card:	215-B103-1: ###.###.#### 🔹 🧨 🕂 <b>2</b>
Interlock cards	+ Add		
Interlocks	+ Add	Coil address:	18 3
Landing page choices	+ Add	Multiplier/Unit id/Bank:	
Membership histories	+ Add		
News	+ Add	State:	Unknown
Notifications	+ Add	Most recent reply:	None
Onboarding phases	+ Add		
Physical access levels	+ Add	Most recent reply time:	
Physical access logs			4
Project disciplines	+ Add		Save and add enother Save and continue adition
Projects	+ Add		Save and add another Save and continue editing

Figure 2.25: NEMO interlock configuration.

- 1. Select a name for your interlock. We chose to name our interlocks with their corresponding relay number, in this case **Relay 01**.
- 2. From the pull-down menu, choose one of the available interlock cards.
- 3. Enter the Coil Address for the corresponding relay. As shown in figure 2.20, relay 1 corresponds to a Coil Address IO value of 18.
- 4. Click the **SAVE** button. At this point the information for the configured interlock will appear on the main **Interlocks** menu.

Figure 2.26 shows the configured 16 relay interlocks.

ID	NAME	CARD ENABLED	CARD	CHANNEL/RELAY/COIL
321	Relay 01	•	215-B103-1: ###.###.####	18
322	Relay 02	•	215-B103-1: ###.###.####	19
323	Relay 03	•	215-B103-1: ###.###.####.####	20
324	Relay 04	•	215-B103-1: ###.###.####.####	21
325	Relay 05	•	215-B103-1: ###.###.####	22
326	Relay 06	•	215-B103-1: ###.###.########	23
327	Relay 07	•	215-B103-1: ###.###.####	24
328	Relay 08	•	215-B103-1: ###.###.####	25
329	Relay 09	•	215-B103-1: ###.###.####.####	26
330	Relay 10	•	215-B103-1: ###.###.####	27
331	Relay 11	•	215-B103-1: ###.###.#############################	28
332	Relay 12	•	215-B103-1: ###.###.####	29
333	Relay 13	•	215-B103-1: ###.###.####.####	30
334	Relay 14	•	215-B103-1: ###.###.####.####	31
335	Relay 15	•	215-B103-1: ###.###.####	32
336	Relay 16	0	215-B103-1: ###.###.###	33

Figure 2.26: Fully configured 16-channel relays on the X-432 module.

# 2.5.4 Interlocking Equipment NEMO

In NEMO, Click Administration  $\rightarrow$  Detailed Administration  $\rightarrow$  Tools and you will see the equipment list. Click on any of the displayed tools, then scroll to the interlock section, click on the pull-down menu, choose the appropriate card and relay number, and click the SAVE button at the bottom of the page.

,		J
Interlock:	215-B103-1: 129.6.134.209, Relay 01, Coil address 18	~
	215-B103-1: 129.6.134.209, Relay 01, Coil address 18	
Allow Delayed Logoff	215-B103-1: 129.6.134.209, Relay 02, Coil address 19	
Upon logging off users may enter a	215-B103-1: 129.6.134.209, Relay 03, Coil address 20	0
	215-B103-1: 129.6.134.209, Relay 04, Coil address 21	-
Ask To Leave Area When D	215-B103-1: 129.6.134.209, Relay 05, Coil address 22	
Check this have to calk the year if the	215-B103-1: 129.6.134.209, Relay 06, Coil address 23	
Check this box to ask the user if the	215-B103-1: 129.6.134.209, Relay 07, Coil address 24	
	215-B103-1: 129.6.134.209, Relay 08, Coil address 25	
	215-B103-1: 129.6.134.209, Relay 09, Coil address 26	
Dependencies	215-B103-1: 129.6.134.209, Relay 10, Coil address 27	
Dependencies	215-B103-1: 129.6.134.209, Relay 11, Coil address 28	
	215-B103-1: 129.6.134.209, Relay 12, Coil address 29	-
Required Resources:	215-B103-1: 129.6.134.209, Relay 13, Coil address 30	
	215-B103-1: 129.6.134.209, Relay 14, Coil address 31	-
	215-B103-1: 129.6.134.209, Relay 15, Coil address 32	
	215-B103-1: 129.6.134.209, Relay 16, Coil address 33	_

Figure 2.27: Interlocking equipment through NEMO.

# CHAPTER 3

### 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 powerover-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 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 jeffhawks@verizon.net

# 3.1 The wiring diagram



Figure 3.1: Interface box wiring diagram.



# **3.2** Images of the interface box

# 3.2.1 Front view



Figure 3.2: Front view of the interface box.

# 3.2.2 Bottom view



Figure 3.3: Bottom view of the interface box.

# 3.2.3 Interior of door view



Figure 3.4: Interior door view of the interface box.



Chapter 3 Temperature and Humidity Sensing

Figure 3.5: Interior view of the interface box.

# 3.3 Bill of materials

#### 3.3.1 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

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

- 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.

# 3.3.2 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

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

- Mencom Corporation www.mencom.com
   Part Number: NAN-T-3MP-FW-ST
   Quantity: 8
   Description: NAN, Field Wireable, 3 Pole, Female Straight, Screw Terminals.
- Newark www.newark.com
   Part Number: 46AC2348
   Quantity: 7
   Description: TE Connectivy: 3P M8 T distributor, Y-style, 3 position M8 plug.
- Digikey www.digikey.com
   Part Number: 1173LSL001-ND
   Quantity: 1000 ft.
   Description: 3 conductor multi-conductor cable slate 22 AWG.

# 3.4 NEMO setup and configuration of the control by web X-410 module for temperature and relative humidity monitoring



Figure 3.6: The control by web X-410 module.

# 3.4.1 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:

Figure 3.7: The X-410 quick start guide.

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.

<u> </u>		Programmable Web-Enabled I/O Module
🗲 General Settings 🛛 👻	✗ GENERAL SETTINGS	
Remote Devices	GENERAL INFORMATION	
👬 I/O Setup 🗸 🗸	Part Number:	X.410J
📑 Control/Logic 🗸 🗸	Firmware Revision:	2.5
	Serial Number:	00:0C:C8:05:A8:C2
	Vin Voltage:	24.2 V
	Internal 5V Voltage:	4.94 ∨
	Latitude:	41.6796
	Longitude:	-111.8737
	Temperature Units:	Fahrenheit Celsius Kelvin
		Submit Cancel

Figure 3.8: General information under the general settings tab.

🗲 General Settings 🛛 👻	✓ GENERAL SETTINGS	
General Information		
Network	NETWORK SETTINGS The following network settings will require report to take affect	
Advanced Network	The foreign greaters of any of the require report to the arton	
Email	Use DHCP: Yes No	
Passwords	IP Address: ###.###.###	
Date/Time	Subnet Mask: ###.###.###	l⊋
Backup/Restore	Gateway: ###.###.###	Consult IT
Remote Devices	Preferred DNS Server: ####.####.####	
🖬 I/O Setup 🗸 🗸	Alternate DNS Server:	
📰 Control/Logic 🛛 🗸	HTTP Bort Enabled:	
Logging		
🕜 Monitor & Control 🛛 🗸	HTTP Port: 80	System Defaults
	HTTPS Port: 443	
	Upload/View SSL Certifica	Upload/View SSL Key
	Supports 1024-bit an	d 2048-bit encryption.
	Submit	ancel

Clicking on **General Settings** then **Network** will show you the following screen.

Figure 3.9: The X-410 network settings.

Click on I/O Setup then click on the 1-Wire Sensors option.

<u>×410</u>		F	Programmable V	Veb-Enable
🗲 General Settings	↓ ₩ ₩ SETUP			
Remote Devices	III RELAYS			
🛱 I/O Setup 🗸 🗸		L cool Bolov		
Relays	Name	Local Relay #	Group	Edit
Digital Inputs	Relay 1	1	No Group	Edit
1-Wire Sensors	Relay 2	2	No Group	Edit
Registers	Relay 3	3	No Group	Edit
Vin	2 14	4	No Group	Edit
Timers				
📑 Control/Logic 🛛 🗸				
Logging				
Monitor & Control 🗸 🗸				



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.

I/O SETUP			
I-WIRE SENSORS			
Name	Local 1- Wire Sensor #	1-Wire Sensor ID	Edit
N215-A101-T	1	29-6DAB390000032	Edit X
N215-A101-RH	2	29-6DAB3900000032	Edit X
		Add 1-1	/ire Sensor +

Figure 3.11: Adding the temperature and humidity 1-wire sensors.

- 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 3.12: 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.

1-WIRE SENSORS			
Name	Local 1- Wire Sensor #	1-Wire Sensor ID	Edit
N215-A101-T	1	29-6DAB390000032	Edit X
N215-A101-RH	2	29-6DAB3900000032	Edit X
N215-A102-T	3	29-42433C000000C5	Edit X
N215-A102-RH	4	29-42433C000000C5	Edit X

Figure 3.13: 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.

#### 3.4.2 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 Address Table button.

🗲 General Settings 🔹 🗸	GENERAL SETTINGS	$\otimes$
General Information	ADVANCED NETWORK SETTINGS	Ĩ
Advanced Network	CORS Origin:	
Passwords	MTU: 1476 (Requires reboot to take affect.)	
Date/Time Backup/Restore	• MODBUS	
Remote Devices	Enable: Yes No Port: 502	
📫 I/O Setup 🗸 🗸	Endianness: Big Little	
📰 Control/Logic 🛛 🗸	Modbus Address Table: View Modbus Address Table 2	
Logging		
🤭 Monitor & Control 🛛 🗸	REMOTE SERVICES     Enable: Yes No	
	Enable: Yes No	
	IP FILTERING	
	Submit Cancel	

Figure 3.14: The X-410 Advanced Network settings and accessing the Modbus address table.

Modbus Address Table							×
			Coil Addr	Input Addr			
IO Name	10	Pulse Timer	Counter/Freq	On Timer	Total On Timer	10	10
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	<b>—</b>	-		-	-	-
N215-A101-RH	22	-	-		_	-	-
							Done

Figure 3.15: The Modbus address table.

Table in figure 3.15 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.

## 3.4.3 Configuring and adding sensors in NEMO

#### 3.4.3.1 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.

Home > Sensors > Sensor car	ds
Scheduled outages	+ Add
Staff absence types	+ Add
Staff absences	+ Add
Staff availability	+ Add
Staff availability categories	+ Add
Staff charges	+ Add
Task categories	+ Add
Task histories	+ Add
Task images	+ Add
Task statuses	+ Add
Tasks	+ Add
Temporary physical access requests	+ Add
TemporaryPhysicalAccess	+ Add
Tool qualification groups	+ Add
Tool usage counters	+ Add
Tools	+ Add
Training sessions	+ Add
Usage events	+ Add
User bins	+ Add
User preferences	+ Add
User types	+ Add
Users	+ Add
SENSORS	
Sensor alert emails	+ Add
Sensor alert logs	
Sensor card categories	+ Add
Sensor cards	+ Add
Sensor categories	+ Add

Figure 3.16: NEMO sensor card setup.

Add sensor card	
Name:	215-Cleanroom-A-Side
Server:	XXX.XXX.XXX.XXX 2
Port:	502 3
Category:	ModbusTcp V + 4
Username:	
Password:	
✓ Enabled	
	5
	Save and add another Save and continue editing SAVE

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

Figure 3.17: 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.

#### 3.4.3.2 Sensor category setup

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

Staff absence types	+ Add
Staff absences	+ Add
Staff availability	+ Add
Staff availability categories	+ Add
Staff charges	+ Add
Task categories	+ Add
Task histories	+ Add
Task images	+ Add
Task statuses	+ Add
Tasks	+ Add
Temporary physical access requests	+ Add
TemporaryPhysicalAccess	+ Add
Tool qualification groups	+ Add
Tool usage counters	+ Add
Tools	+ Add
Training sessions	+ Add
Usage events	+ Add
User bins	+ Add
User preferences	+ Add
User types	+ Add
Users	+ Add
SENSORS	
Sensor alert emails	+ Add
Sensor alert logs	
Sensor card categories	+ Add
Sensor cards	+ Add
Sensor categories	+ Add



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

Change sensor category					
215-Temperature and R	elative Humidity		HISTORY		
Name:	215-Temperature and Relative Humidity	1			
	The name for this sensor category				
Parent:	v / + x				
			2		
Delete	Save and add another	Save and continue editing	SAVE		

Figure 3.19: 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 3.20.

	NAME		PARENT	CHILDREN			
	215-Temperature and Relative Humidity						
1 se	1 sensor category						

Figure 3.20: Sensor categories menu showing the added category.

#### 3.4.3.3 Adding sensors

In NEMO, Click Administration  $\rightarrow$  Detailed Administration  $\rightarrow$  Sensors  $\rightarrow$  Sensors and you will see the following page. Click the ADD SENSOR button.

Staff absences	+ Add
Staff availability	+ Add
Staff availability categories	+ Add
Staff charges	+ Add
Task categories	+ Add
Task histories	+ Add
Task images	+ Add
Task statuses	+ Add
Tasks	+ Add
Temporary physical access requests	+ Add
TemporaryPhysicalAccess	+ Add
Tool qualification groups	+ Add
Tool usage counters	+ Add
Tools	+ Add
Training sessions	+ Add
Usage events	+ Add
User bins	+ Add
User preferences	+ Add
User types	+ Add
Users	+ Add
SENSORS	
Sensor alert emails	+ Add
Sensor alert logs	
Sensor card categories	+ Add
Sensor cards	+ Add
Sensor categories	+ Add
Sensor data	+ Add
Sensors	+ Add





Name:	215-A101-T
✓ Visible Specifies whether this sens	sor is visible in the sensor dashboard
Sensor card:	215-Cleanroom-A-Side: 128.4.4.4 V
Interlock card:	~ ~ <b>~</b> +
Sensor category:	215-Temperature and Relative Humidity 🗸 🥜 🕂 3
Data label:	215-A101 Temperature Label for graph and table data
Data prefix:	Prefix for sensor data values
Data suffix:	F 5

Figure 3.22: 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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Unit id:	
Read address:	20 1
Number of values:	2 2
Formula:	round(decode_32bit_float(registers),2)
	Enter a formula to compute for this sensor values. The list of registers read is available as variable <b>registers</b> . Specific functions can be used based on the
	sensor type. See documentation for details.
Read frequency:	5 Enter the read frequency in minutes. Every 2 hours = 120, etc. Max value is 1440 min (24hrs). Use 0 to disable sensor data read.
·	5
Delete	Save and add another Save and continue editing SAVE

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

Figure 3.23: The bottom portion of the NEMO sensor configuration setup information menu.

- 1. Type in the read address for the sensor. See figure 3.15 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 3.15.
- 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.

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.

						WELCO	IME, ROBERT. VIEW SIT	E / LOG OUT
📀 The sensor "N	215-A101-T	was added succ	essfully.					
Select senso Action: Read	ADD SENSOR +					SENSOR +		
	VISIBLE	CARD	CARD ENABLED	SENSOR CATEGORY	UNIT ID	READ ADDRESS	NUMBER OF VALUES	READ FREC
1 N215- A101- T	0	215- Cleanroom-A- Side: 128.4.4.4	0	215-Cleanroom	-	20	2	5
<li>1 sensor</li>								*

Figure 3.24: Testing the sensor by reading values within NEMO.

#### 3.4.3.4 Setting up sensor alert emails

In NEMO, Click Administration  $\rightarrow$  Detailed Administration  $\rightarrow$  Sensors  $\rightarrow$  Sensor alert emails, then click on the ADD SENSOR ALERT EMAIL button, as shown in figure 3.25.

Add sensor alert	t email
Enabled	
Sensor:	215-A101-T V 1
Trigger no data Check this box to trigger th	sis alert when no data is available
Trigger condition:	value < 67 and value > 71       2         The trigger condition for this alert. The sensor value is available as a variable named value. e.g. value == 42 or value > 42.
Additional emails:	Additional email address to contact when this alert is triggered. A comma-separated list can be used.
Triggered on:	- 4
	Save and add another Save and continue editing SAVE

Figure 3.25: 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.

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### 3.4.4 NEMO sensor display

In NEMO, Click **Administration**  $\rightarrow$  **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 3.26. 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 3.27. To view a graphical plot of temperature values, click on the right temperature sensor icon "215-A101-T".

NEMO	Calendar	Tool control	Status dashboard	Requests	Safety	Administration -	Welcome, Robe	ert 🗘
Sense	or Dashl	ooard						
			215-	Temperature a Humidit	and Relative y			

Figure 3.26: NEMO sensor dashboard.



Figure 3.27: NEMO sensor dashboard.

The default graph displays the temperature data over the last 24 hours, as shown in the below figure 3.28. Hovering over a data value will display a the date, time, sensor name and sensor value results, as seen in the below figure 3.28 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 3.28: 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.

# CHAPTER 4

# NEMO Hardware Accessories Release Notes

# 4.1 v2.0.0

04/25/2024: Chapter describing the build, installation and configuration with NEMO of the 16 channel, relay-based interlock module and custom equipment dual-USB interlock connections.

# 4.2 v1.0.0

05/19/2023: 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.