NATIONAL RENEWABLE ENERGY LABORATORY

Modular Oceanographic Instrumentation System (MOIS) User Guide

E. Nelson
National Renewable Energy Laboratory

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List of Acronyms

MOIS	Modular Ocean Instrumentation System
NREL	National Renewable Energy Laboratory
cRIO	NI Compact RIO Controller
LabVIEW	Laboratory Virtual Instrument Engineering Workbench
LabVIEW RTE	Run time engine, allows LabVIEW compiled code to run without LabVIEW installed
HMI	Human Machine Interface program
CFG	Channel / sample rate configuration program
TDMS	NI Technical Data Management Storage file format
GPS	Global Positioning System
SSH	Secure Shell, an encrypted network protocol for initiating text-based shell sessions on remote machines in a secure way
SCP	SSH secure copy between two machines. The command name is scp on a Linux system

Table of Contents

Overview

This document describes the procedures necessary to setup, configure and operate the Modular Ocean Instrumentation System (MOIS).

System Overview

MOIS is a complete data acquisition system developed to support laboratory and field testing of Marine Hydrokinetic (MHK) technologies. It is a deterministic real-time measurement system, data logger, and device controller which provide extensive and reconfigurable measurement capabilities. The hardware is housed in a waterproof enclosure and uses water tight connections so it can be deployed in harsh ocean environments. The software was developed in the LabVIEW programming language and runs on a LabVIEW real-time target. MOIS consists of the following components:

- MOIS enclosure: a water tight subsea enclosure with underwater connectors
- MOIS hardware: a National Instruments Compact RIO (cRIO) with supporting power supplies, a digital channel splitter, a cellular/wireless modem and a remote administration board.
- MOIS software: precompiled cRIO kernel, configuration file generator (CFG) and user interface (UI)
- Cables and instrumentation as needed for the test
- GPS antenna, WiFi antenna, and cell modem antenna, along with antenna cables for each. The GPS is required for accurate timestamps. However, the system will run without GPS available.
- Human Machine Interface (HMI) computer with LabVIEW development software (13 or higher) or the LabVIEW run-time engine (RTE, version 6.1 or higher) installed.

MOIS Capabilities and Functions

The MOIS software acquires analog measurements as continuous waveform data and serial data as ASCII data from attached instruments. MOIS can be configured to sample analog sensors such as: strain gages, temperature sensors, accelerometers, anemometers, microphones, and hydrophones. MOIS can also be configured to record streaming digital data from instruments, as well as, configure and control instruments such as: ADCPs (Acoustic Doppler Current Profiler), CTDs (Conductivity Temperature Depth), GPSs (Global Positioning System), and most oceanographic instruments. For some instruments custom instrument driver software is required. In this case, the MOIS Software Developer Guide explains how to get started with the LabVIEW source code. The key software features are:

- Supports data communication protocols (RS-232/422/485, Ethernet). Supports additional protocols, like CAN, by swapping in a c-series module and modifying MOIS software
- Supports sampling rates up to 1kHz on analog voltage modules
- Sample rates and data scaling can be set using the CFG utility program

- Analog measurement data and messages from RS-232 serial instruments data are time stamped via on-board GPS based timing
- Logs analog and digital data to a single data file. Messages from RS-232 serial instruments are logged to a separate tab for each instrument in the TDMS data file.
- Data files are an hour in length and are archived once a day in a single daily zip file.
- The UI can be used to display live measurement data, monitor MOIS performance and health, and download data files from MOIS to the HMI computer
- Error logging and Event Handling
- MOIS can be programmed to actively control an instrument, e.g. commanding it for a specific task such as outputting stored data or changing parameters on the instrument itself. This requires customization of the LabVIEW software to incorporate a specific instrument driver
- MOIS can also be programmed to trigger if an event occurs on one of the analog channels, e.g. a high signal level on an analog channel should trigger a new data file. This requires customization of the LabVIEW software to add a custom trigger

The MOIS hardware is a complete self-contained data acquisition system that is based on the NI cRIO model 9068. The hardware is housed in a water tight marine grade aluminum enclosure rated to 100m water depth where all external electrical connections are made using subsea rated bulkhead connectors. This include coaxial connectors allow external antenna mounting for optimal reception. The power system can supply 12 and 24 VDC to instruments while isolating from the core data logger functions. The power system also allows independent control of power to instruments and provides redundant power to the real-time controller (cRIO). Key features of the hardware are:

- High internal data storage (250GB) via USB memory stick
- Cellular telemetry (4G) ,WiFi (802.11), and wired Ethernet to remotely configure, monitor and download data
- Power system allowing power control instruments
- Commercially available underwater connectors
- Direct heat transmission between electronics, housing and the external environment
- Modular components for easy repair (and reconfiguration when required)
- Can be deployed above or below water at depths of up to 70m

Setup and Operation

MOIS comes fully assembled with a generic compiled MOIS executable file installed on the cRIO-9068. This executable is for the system as configured in the system documentation. For basic data logging no reprogramming is required and a LabVIEW license is not required. There are many instances where it will be necessary for the software to be customized to meet specific test requirements. If this is the case, the MOIS Software Developer's Guide provides a walkthrough of the MOIS software architecture.

The following is included:

1. The MOIS enclosure (including all hardware)

2. Antennae and cables for the GPS, WiFi, cellular communications

3. 24 VDC supply for bench testing. Supply includes a power cable with the required two pin subsea connector. The supply plugs into a standard 110VAC outlet

4. A USB drive with the software and manuals

5. Ethernet cable for bench testing

MOIS Powering and Connecting

After setting up the UI, MOIS needs to be started. MOIS requires input power from a DC power source. A supply for bench top testing and checkout is included. The input DC power source voltage can range from 10-28 VDC and must supply at least 50W to run the equipment in the enclosure. Attached instruments will require the input power to be increased up to 200W depending on the instrument power load. The internal MOIS 24VDC power source has a 100W output capability which is sufficient to run any test system NREL has deployed so far with MOIS.

Please read Appendix B on use of subsea electrical connectors. It is very important that the connectors are lubed prior to use, even in bench testing. Failure to properly lube the subsea connectors can damage the rubber sea. Never use a petroleum based lube as it will damage the neoprene rubber and compromise the integrity of the connectors.

The MOIS executable file is already installed and MOIS will automatically start when powered up. When powering up MOIS for the first time, be sure that no external cables are connected but the power supply. The following steps are used to power up MOIS:

- Plug the 24 VDC power cable into the power supply and plug the power supply into a 110 VAC outlet – DO NOT CONNECT the power cable to the MOIS enclosure at this time.

- Using a voltmeter, measure the polarity on the 24VDC input power and make sure the voltage is about 24 VDC and that Pin 1 is +24VDC and Pin 2 is the return (-). If the voltage exceeds 30 VDC or the polarity is incorrect, do not use the power supply and locate a suitable replacement. The pins on both the MOIS enclosure and power cord are labeled. The pin numbers are hard to read and a small flashlight or other light source may be needed in order to read the pin numbers.

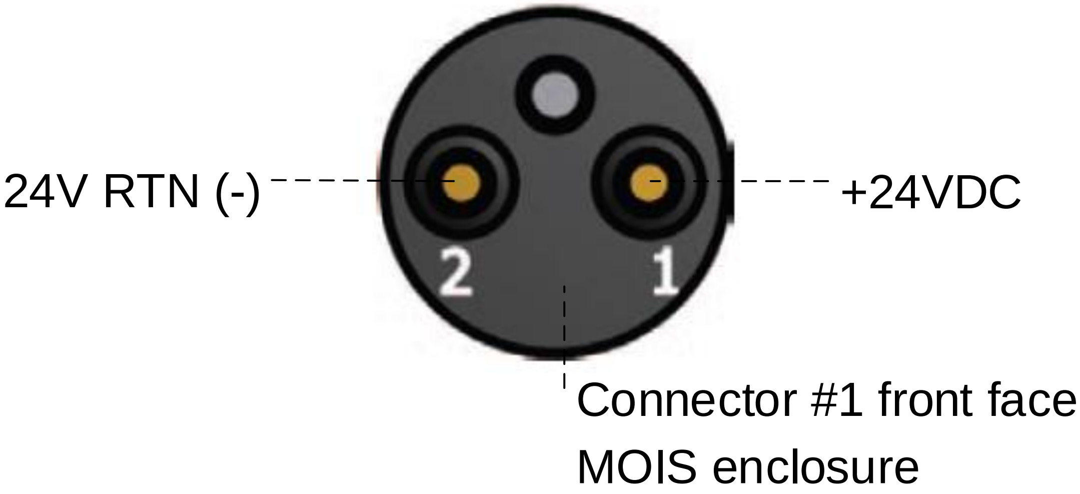


Figure 1 MOIS Power Input Connector

- Prior to plugging the power cable into MOIS, please read Appendix A on use of subsea electrical connectors if you have not already done so

- Unplug the power supply from the 110 VAC outlet, then carefully insert the power cable into Connector #1 (marked on MOIS enclosure and shown in Figure 1). Now, plug the power supply back into the 110 VAC outlet

See Appendix A Figure 3 “Lid and Connectors” for the location of the power connector on the enclosure lid. There is only 2 pin connector on the enclosure and is on the side with 8 right angular circular connectors.

- After a few minutes, the cRIO and other boards should be operational and data will start collecting and recording data. This auto start feature automatically recovers MOIS from unintended power cycles without direct user intervention.

Setup and Configuration on PC (HMI computer)

The user will need to provide a computer which acts as the HMI computer. The computer is used for configuration, monitoring, and downloading of data from MOIS. It is recommended the HMI computer have WiFi (802.11) capability to connect with MOIS; however, a hardwired connection is possible with the supplied custom Ethernet cable. The following steps need to be completed to configure the HMI computer:

1. Install either LabVIEW (purchased from NI) or LabVIEW RTE (freely available from www.ni.com). LabVIEW RTE is needed to run the compiled user interface and the

configuration file generator. To modify and recompile main program on the cRIO, installation of LabVIEW is required on the HMI computer.

2. From the supplied USB drive, copy the following folders into a working directory on the HMI computer:

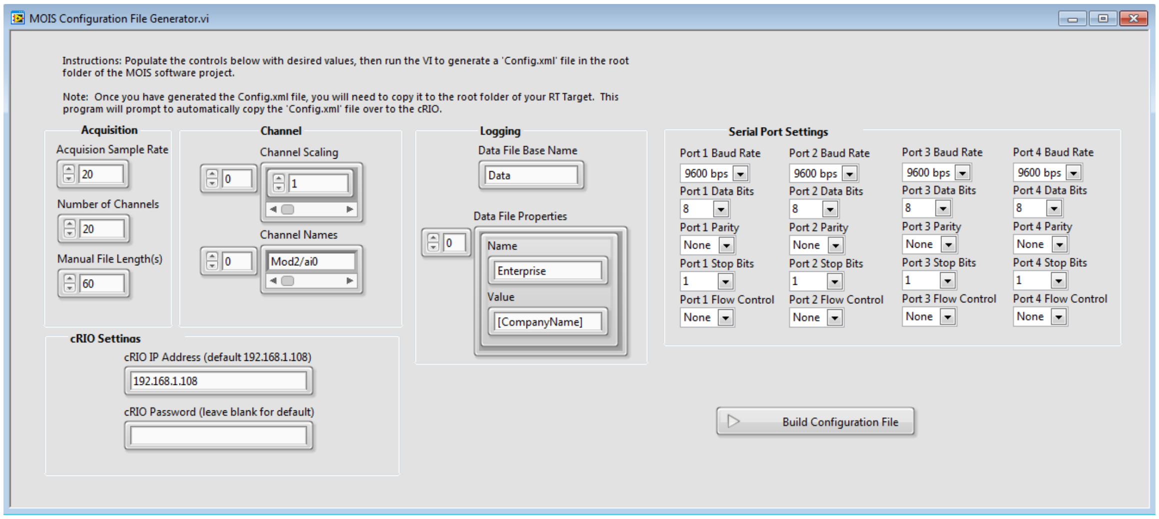
   a. MOIS User Interface

   b. MOIS Config File Gen

   The folders contain the MOIS User Interface.exe and MOIS Configuration File Gen.exe programs. The other files in the folders are required by these executable files. It is helpful to create a shortcut to each of these .exe files and move to a convenient location on the HMI computer.

Configuring MOIS

MOIS comes pre-configured to run with the supplied hardware. However, some basic configuration changes may be needed to meet the needs of an experiment or to interface instruments. The MOIS Configuration File Generator can be used to change analog channel sample rate, file recording time, individual analog channels scale factors, channel name (in record), file names, and serial port settings, as shown in Figure 2. Values for these parameters can be set in the MOIS Configuration File Generator then a new configuration file is created. When prompted, this new configuration file is uploaded to the cRIO. When the cRIO is restarted, it loads the new settings from the configuration file. For more advanced configuration settings, please see the Software Development Guide.



Instructions: Populate the controls below with desired values, then run the VI to generate a 'Config.xml' file in the root folder of the MOIS software project.

Note: Once you have generated the Config.xml file, you will need to copy it to the root folder of your RT Target. This program will prompt to automatically copy the 'Config.xml' file over to the cRIO.

Acquisition

Acquision Sample Rate: 20

Number of Channels: 20

Manual File Length(s): 60

Channel

Channel Scaling: 0 | 1

Channel Names: 0 | Mod2/ai0

Logging

Data File Base Name: Data

Data File Properties: 0 | Name: Enterprise | Value: [CompanyName]

cRIO Settings

cRIO IP Address (default 192.168.1.108): 192.168.1.108

cRIO Password (leave blank for default):

Serial Port Settings

Port 1 Baud Rate	Port 2 Baud Rate	Port 3 Baud Rate	Port 4 Baud Rate
9600 bps	9600 bps	9600 bps	9600 bps
Port 1 Data Bits	Port 2 Data Bits	Port 3 Data Bits	Port 4 Data Bits
8	8	8	8
Port 1 Parity	Port 2 Parity	Port 3 Parity	Port 4 Parity
None	None	None	None
Port 1 Stop Bits	Port 2 Stop Bits	Port 3 Stop Bits	Port 4 Stop Bits
1	1	1	1
Port 1 Flow Control	Port 2 Flow Control	Port 3 Flow Control	Port 4 Flow Control
None	None	None	None

Figure 2. MOIS Configuration File Generator interface

Acquisition Configuration

- **Acquisition Sample Rate:** in the *Acquisition Sample Rate* box, use the inner set of up/down buttons or directly enter the value, in Hz of the desired sample rate for all analog channels. Different sample rates cannot be set for different channels. For very high sample rates, check the CPU usage in System Monitoring tab in the UI to make sure utilization is less than 50%. The processor utilization is normally less than 30% unless another operation like file archiving is occurring.

- **Number of Channels:** it is possible to change the number of analog channels– the number of channels must match the number of analog channels available on the cRIO and is also programmed into the FPGA code. Changing the number of channels should not be done unless the hardware is changed and the FPGA code is updated and recompiled, otherwise, MOIS will log an error at startup and shutdown.

- **Manual File Length:** a new data file is started at the change of every hour. The first data file after powering up the system will be partial in length. Each subsequent file will have one hour of data for each channel. The file length can be changed from editing the LabVIEW source code in the "Check Trigger" case inside the Acquisition and Logging code. See the MOIS Software Developer's Guide for information about getting started with the source code.

Channel Configuration

- **Changing Channel Scaling:** the scale factor is multiplied with the channel data prior to storage. The channel can be selected using the up/down buttons or by directly entering the channel number in the box to the left of the scale factor. The channels are in fields 0-19 on the channel scaling array. The scaling applied to each channel can be changed using the out up/down buttons or by directly entering the scale factor. For example, if the output from a channel is volts and the sensor measurement is 0.1 V/tonnes, using a scale factor of 10 would change the output from volts to tonnes. The individual channel types and connection to MOIS are available on the Gen3 System Architecture drawing in Appendix A

- **Changing Names:** individual channel names can be changed from their default value to a more meaningful string. These names show up in the data file to allow easier identification of channels. Similar to the channel scaling, the channel can be selected using the out up/down buttons or by directly entering the channel number in the box to the left of the channel name box. It can also be selected using the slider bar below the channel name box.

- **Data File Base Name:** MOIS automatically creates file names using the date with a name appended to it. The file name format is;

  <Day of year>_<Hour>_<Minute>_<Year>_<Name>.tdms

  The Name be changed in the configuration file and is Data by default. The name after the date can be changed by entering the new name in the dialog field when creating the Configuration.xml file using MOIS ConfigFileGen.exe.

- Data File Properties: These are used to tag the data file with meta-data that can be used as identifiers for the data files. These properties are listed on the first tab of a data file along with channel information and the size of the data for each channel. For instance, the data files can list the test engineer, name of the test, test location, etc. There are eight fields that can be filled out. All fields are optional.

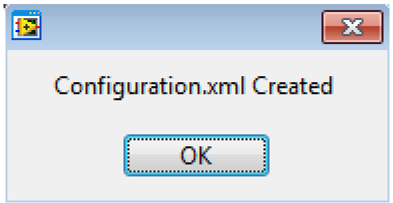
- Serial Port Settings: each of the serial port communication settings can be changed in the dialog box on the right hand side. The serial port information is listed vertically for each port, starting at port 1 on the left side of the dialog box to port 4 on the right side. The value for each of the parameters can be changed using the drop down menu that is accessed by clicking the menu (the upside down triangle) to the right of each value. A list of values is provided for each setting.

cRIO Settings

- To connect and automatically upload the configuration file to the cRIO, the IP address and password must be specified. The address should be 192.168.1.xxx, where xxx is a number and specific to your DAS. Verify that the controller address is the same as the label on the MOIS enclosure or in the NetworkAddresses.txt file on the USB stick.

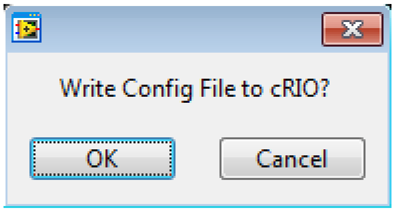
- Generate and Upload the Configuration File

- The MOIS Configuration File Generator automatically generates the configuration file and provides you with the option to upload the file to the cRIO. Once all of the custom configurations have been specified, click on the *Build Configuration File* button which is located on the lower right of the window. When clicked, the dialog box shown in Figure 3 should appear. When OK is clicked, another dialog box shown in Figure 4 should appear which provides the option to upload the configuration file to the cRIO. Click OK to upload the file and Cancel to abort the upload. The Configuration.xml is still created, even if Cancel is chosen.



Configuration.xml Created

Figure 3. Pop up window that confirms that the configuration file has been successfully written



Write Config File to cRIO?

Figure 4. Pup up window asking if the configuration file should be written to the cRIO.

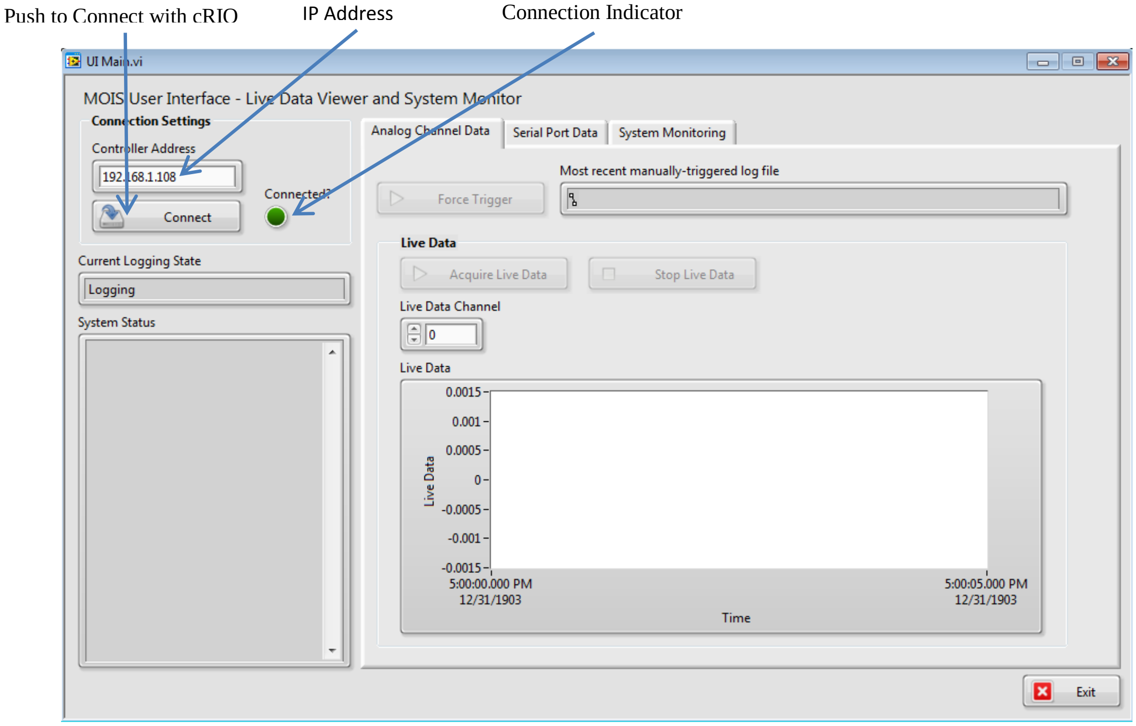
Connecting to MOIS and Monitoring Status – MOIS UI

As previously mentioned, when MOIS is powered up, it automatically boots and starts to collect data. The purpose of the UI is to monitor the system and individual data channels from the HMI. Anytime a network connection is available from the MOIS system to a UI host machine, the MOIS UI may be used. This is convenient for verification of channel data and operational state of MOIS during remote deployments. The UI simply "listens" to the various data streams being recorded by MOIS and is not used for control.

Connecting

On the HMI, go to the UI and click the "connect" button which is located in the upper left of the window in the Connection Settings box under the controller address, Figure 5. When the UI successfully connects to MOIS, the connection indicator to the right will light up and turn bright green. If the UI fails to connect, an error message should appear in the System Status box directly below the connection settings. Check that the correct IP address has been entered and that the host PC has an Ethernet connection to the cRIO in MOIS. If there is still no connection try to ping the IP address of the cRIO to confirm the cRIO is running.

1. Execute MOIS UI.exe and set the controller IP address, Figure 5. The controller IP address is located in the upper left of the window in the Connection Settings box and should be 192.168.1.xxx, where xxx is a number and specific to your DAS. 192.168.1.108 is the address of the cRIO used in development of the system. Verify that the controller address is the same as the label on the MOIS enclosure or in the NetworkAddresses.txt file on the USB stick.



Controller Address: 192.168.1.108

Current Logging State: Logging

Live Data Channel: 0

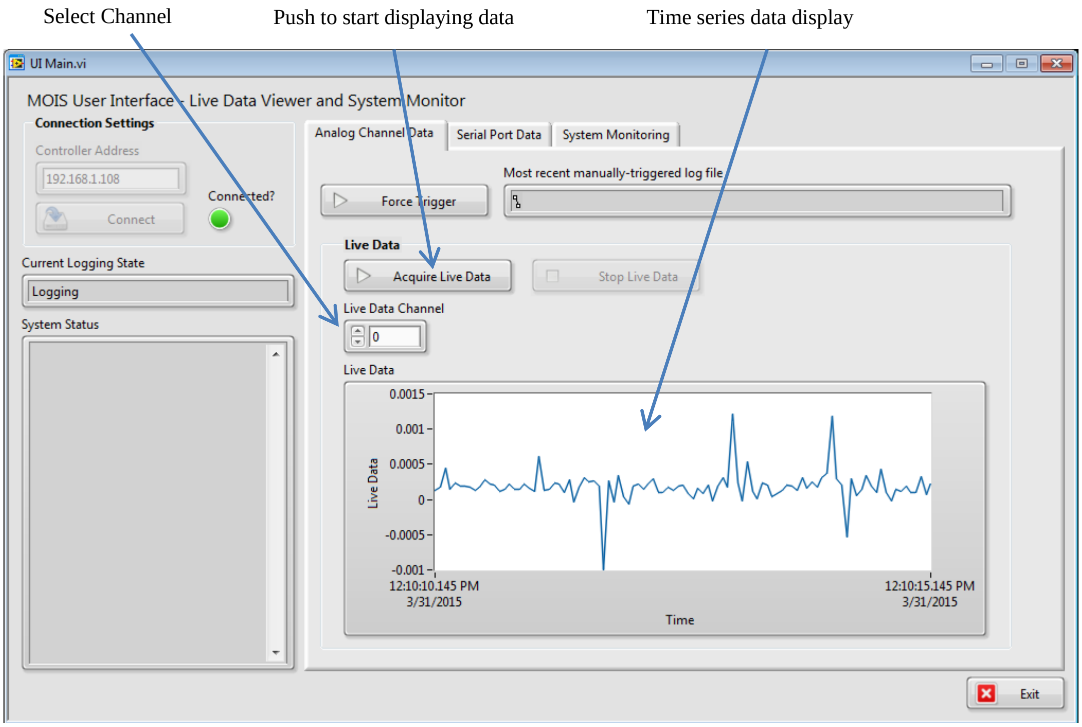
Figure 5. MOIS User Interface where the UI is not connected to the cRIO hardware. When connected the connection indicator light turns lights up to bright green.

Channel and Status Monitoring

To the right of the connection settings, there are three tabs that allow users to conveniently monitor the analog channels via the *Analog Channel Data* tab, the digital streaming data channels via the *Serial Port Data* tab, and the cRIO health and status via the *System Monitoring* tab. Note: these functions only ‘listen’ to and display data being acquired by MOIS, it does not control or change the operation of MOIS.

Analog Data

Real time measurements from each analog channel can be viewed one at a time by clicking the *Analog Channel Data* tab. Specific channels can be selected by either using the up/down buttons on the left of the *Live Data Channel* indicator or directly entering the channel number in the indicator. To view data, push the *View Live Data* button directly above the *Live Data Channel* indicator. Time series of the data are shown in the panel below the *View Live Data* button. Data are decimated for viewing clarity and to minimize communication overhead. Click the *Stop Live Data* button to stop displaying real time data. This does not stop MOIS, it just stops the UI from updating the window. It is not necessary to do this before exiting the UI as the process with automatically terminate. The Force Tigger button is used to manually start a new data file. This new feature is useful when performing system checkout or when short duration files useful like while performing calibrations. The Force Trigger starts a new data file and it is ended automatically at the next hour roll over. To manually end a force triggered file click the Force Trigger button once more.



Select Channel

Push to start displaying data

Time series data display

UI Main.vi

MOIS User Interface - Live Data Viewer and System Monitor

Connection Settings

Controller Address: 192.168.1.108

Connected? ●

Current Logging State: Logging

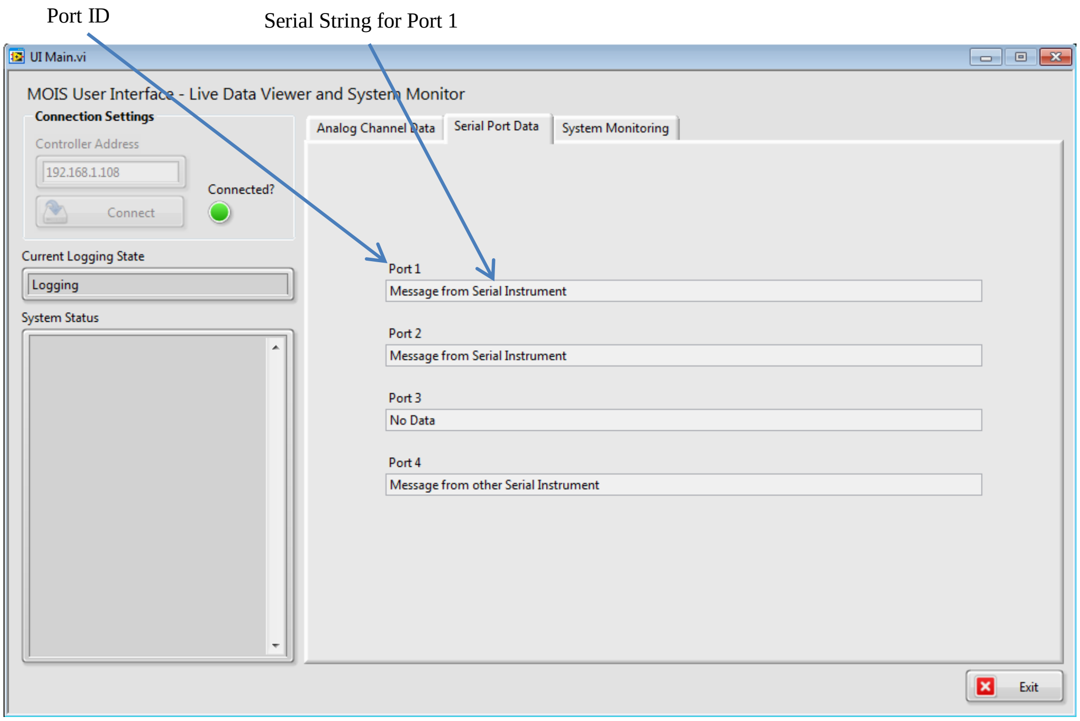
System Status

Live Data Channel: 0

Figure 6. MOIS User Interface showing the Analog Channel Data tab with data being displayed from Channel 0.

Serial Port Data (from instruments)

Real time text strings that are being acquired from the four streaming digital channel (coming from the instruments) can be simultaneously viewed by clicking the *Serial Port Data* tab, Figure 7. A single string is automatically shown for each instrument every second – all intermediate strings are not displayed. If MOIS is not receiving data from a port, 'No Data' is shown. If a set of random characters is shown, the serial port settings could be wrong; the serial port settings can be changed using the MOIS Configuration File Generator.



Port ID

Serial String for Port 1

UI Main.vi

MOIS User Interface - Live Data Viewer and System Monitor

Connection Settings

Controller Address: 192.168.1.108

Connected? ●

Current Logging State: Logging

System Status

Port 1: Message from Serial Instrument

Port 2: Message from Serial Instrument

Port 3: No Data

Port 4: Message from other Serial Instrument

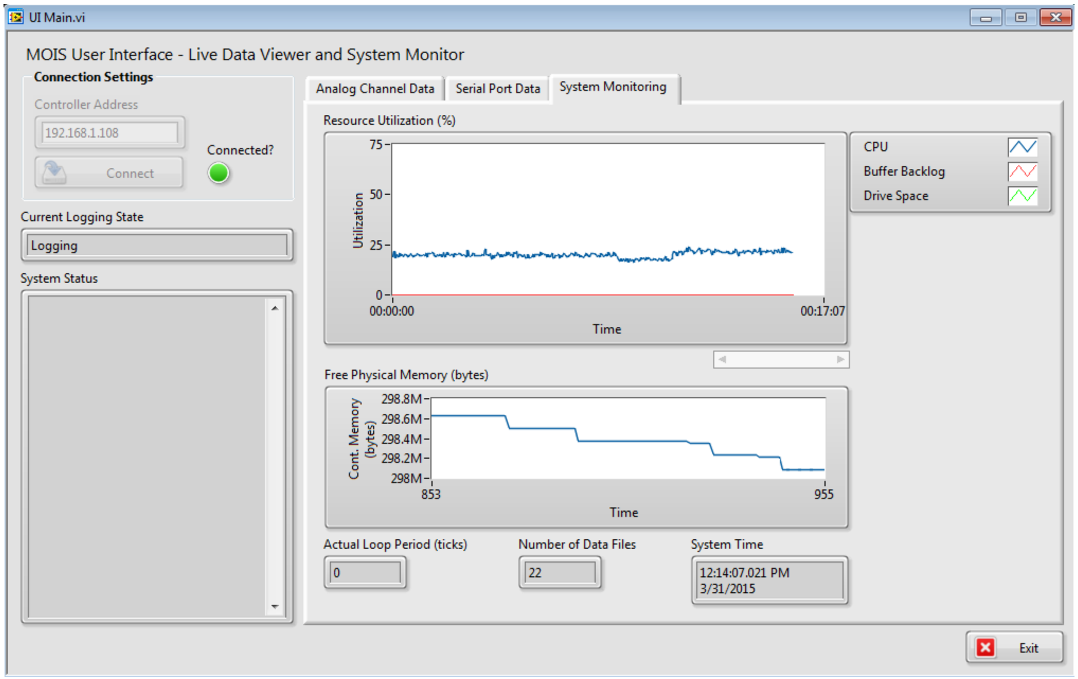
Figure 7. MOIS User Interface showing the Serial Port Data tab with data

System Monitoring

The *System Monitoring* tab is set up to display important health information for the cRIO to help users assess MOIS and quickly determine if it is operating correctly, Figure 8. Information is displayed including the CPU usage, the buffering backlog and the free disk space in the upper plot. The free physical memory is plotted separately in the bottom plot. Also shown are the loop period, number of data files stored on the hard drive, and the current system time.

> *CPU resource utilization* limits are monitored on the System Monitoring tab. The average CPU % utilization should be in the range of 25% most of the time. CPU utilization spikes occur when opening and closing a data file or data file archiving operations. If CPU % utilization is above 50% on average or spikes to 100% then special attention should be paid to the data files to look for loss of data records. National Instruments recommends that the processor utilization be kept at 80% or less in their Compact RIO Developer Guide http://www.ni.com/pdf/products/us/fullcriodevguide.pdf.

Free physical memory in bytes is also listed on the System Monitoring tab. This represents the memory available to the cRIO system. The data files are written to this memory space in order to be able to stream the data to disk efficiently. The archiving software on the cRIO moves the data files once days to the archive directory on the USB stick. This is critical for operation of the MOIS software to have available memory. If the archiving software fails to move data files to the USB stick the system will run out of memory and stop logging data. Use this graph to monitor the available memory.



UI Main.vi

MOIS User Interface - Live Data Viewer and System Monitor

Connection Settings

Controller Address: 192.168.1.108

Connected? ●

Current Logging State: Logging

System Status

Actual Loop Period (ticks): 0

Number of Data Files: 22

System Time: 12:14:07.021 PM 3/31/2015

Figure 8 MOIS User Interface showing the System Monitoring tab

Downloading Data

Manual file downloading can be accomplished with SSH via a shell terminal session. Use SSH's file utility secure copy or SCP. A common terminal application for use with SSH is called PSCP. After PSCP is downloaded and the pscp.exe is placed in the system path of the host computer, the file download is done by typing at the Command Prompt (DOS window) along with the proper path and other required syntax. The PSCP program may be downloaded for free at http://www.chiark.greenend.org.uk/~sgtatham/putty/download.html

Automated file downloading can be performed by using the MOIS FTP.exe program included on the USB stick. Copy the MOIS FTP folder from the USB stick to a working directory on your HMI computer. This program will download the data file for the previous hour data file when left running. To immediately download files that are not already copied to the HMI computer click the start download button. The program will only download files that the HMI computer does not already have a copy of.

Data File Format

The data files are written in the National Instruments Technical Data Management Storage (TDMS) file format. A thorough introduction to the TDMS file format can be read at http://www.ni.com/white-paper/3727/en/. The file format works well for MOIS because all data types can be stream to the data file without having to convert them to numbers or strings before storing. In addition TDMS functions are efficient in LabVIEW and require little additional CPU processor to stream data to disk. The effect is that changing the sample rate from a few samples a second to hundreds of samples a second has little effect on CPU % utilization while writing to data files.

The easiest way to get started viewing TDMS files is to use the "TDM Excel Add-In for Microsoft Excel" converter utility. The utility with instructions is located at http://www.ni.com/example/27944/en/. Once loaded to open a data file right click on the TDMS data file and choose open with Excel Importer.

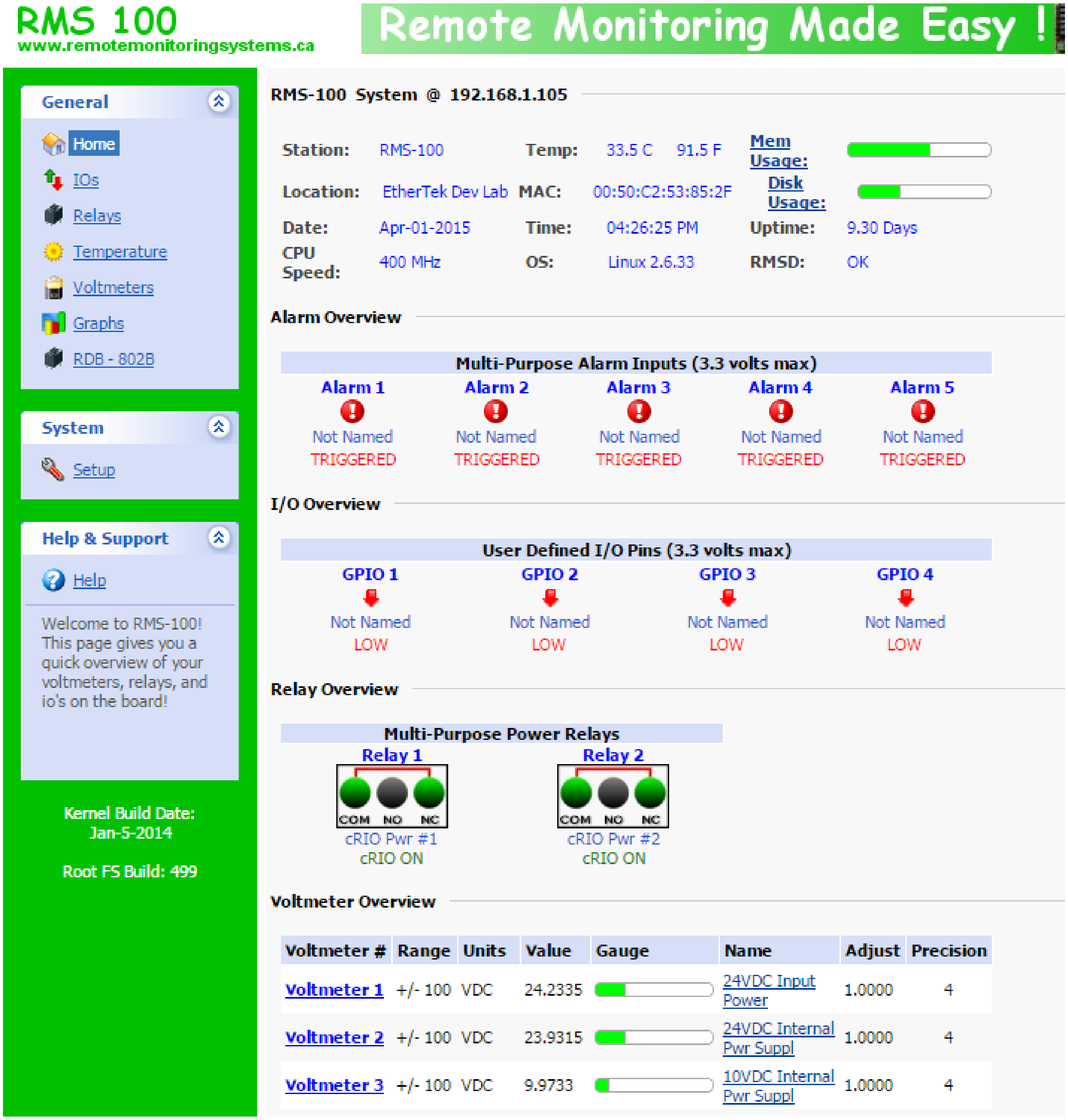
Additional Remote Administration Tools

Installed within the MOIS enclosure is a RMS-100 is a remote monitoring, data acquisition, and control circuit board. This stand-alone device is designed for use on remote equipment as a way to monitor the remote equipment and determine the state of the remote equipment. The RMS-100 has power consumption at only 1.2W and requires 10-60V input voltage. MOIS powers the RMS-100 from a 12V supply. RMS-100 uses an embedded microprocessor and the LINUX operating system for versatility, stability, and security. With MOIS the RMS-100 allows a situational awareness about the state of MOIS keeping it operational and reliable. This secondary system may be very useful in determining the state of MOIS should issues arise when deployed at a remote test location.

Additional resources for the RMS-100 including a detailed overview and setup information can be found at http://www.remotemonitoringsystems.ca/rms100/rms-100-setup.php

The RMS-100 on MOIS can be found by opening a web browser on a PC that has connected to MOIS via wired LAN, WiFi, or cell modem. On the WiFi or LAN type the IP address (192.168.1.105) into the address bar of your web browser. For connecting via cell modem type the cell modem WAN address and then redirect the port to 8888. For example, using NREL's Verizon account the user would type 166.140.246.217:8888 into the web browser address bar to connect to the RMS-100. The default username is "root" with a password of "pass". These can be changed for the duration of the test by following the directions in the RMS-100 setup manual from the manufacturer. The browser window can be resized as needed and the RMS-100 display shifts the icons around the window when resized.

Once logged in the home page is displayed. The homepage contains an overview of the state of the MOIS including: Voltage of input power supply and voltage of the 24 and 10V internal power supplies.



General

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- Graphs
- RDB - 802B

System

- Setup

Help & Support

- Help

Welcome to RMS-100! This page gives you a quick overview of your voltmeters, relays, and io's on the board!

Kernel Build Date: Jan-5-2014

Root FS Build: 499

RMS-100 System @ 192.168.1.105

Station:	RMS-100	Temp:	33.5 C 91.5 F	Mem Usage:	
Location:	EtherTek Dev Lab	MAC:	00:50:C2:53:85:2F	Disk Usage:	
Date:	Apr-01-2015	Time:	04:26:25 PM	Uptime:	9.30 Days
CPU Speed:	400 MHz	OS:	Linux 2.6.33	RMSD:	OK

Alarm Overview

Multi-Purpose Alarm Inputs (3.3 volts max)

Alarm 1	Alarm 2	Alarm 3	Alarm 4	Alarm 5
Not Named	Not Named	Not Named	Not Named	Not Named
TRIGGERED	TRIGGERED	TRIGGERED	TRIGGERED	TRIGGERED

I/O Overview

User Defined I/O Pins (3.3 volts max)

GPIO 1	GPIO 2	GPIO 3	GPIO 4
Not Named	Not Named	Not Named	Not Named
LOW	LOW	LOW	LOW

Relay Overview

Multi-Purpose Power Relays

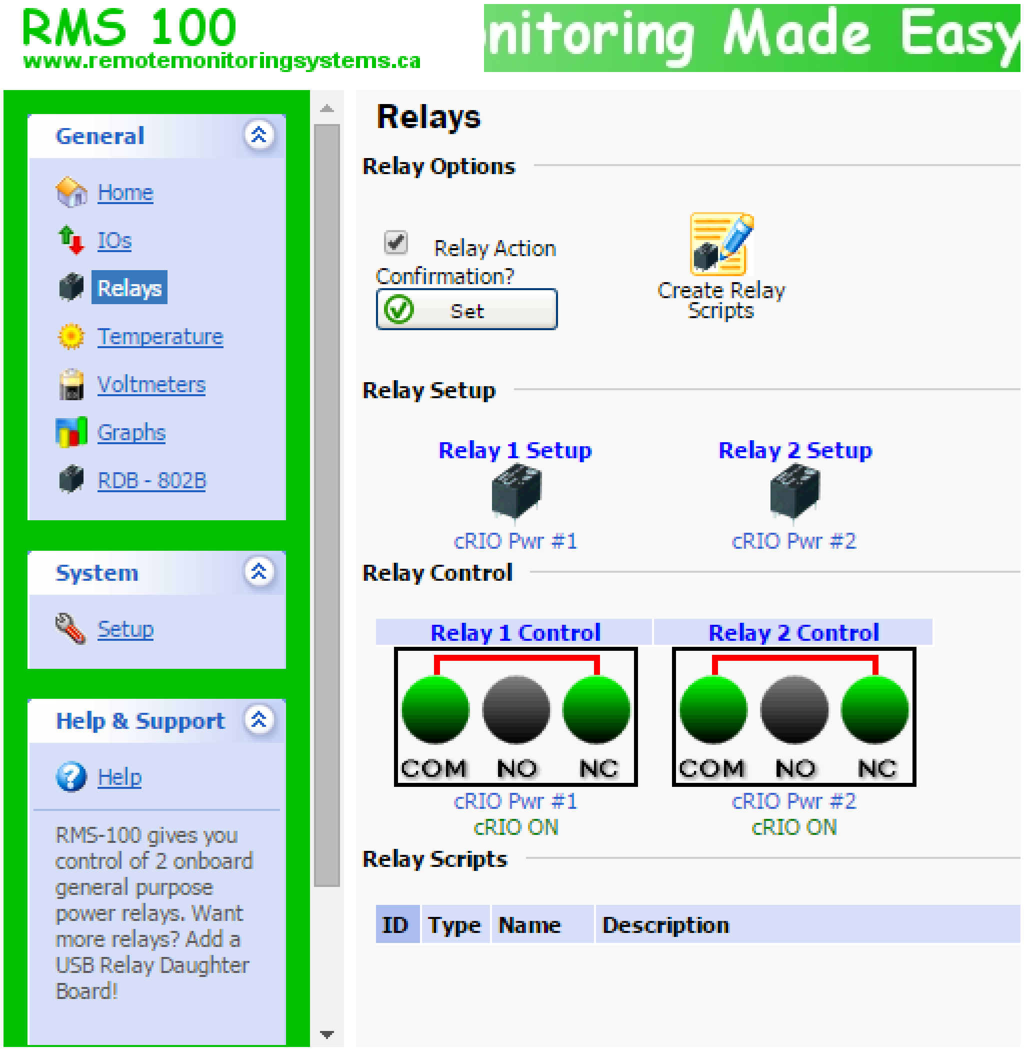
Relay 1	Relay 2
COM NO NC	COM NO NC
cRIO Pwr #1	cRIO Pwr #2
cRIO ON	cRIO ON

Voltmeter Overview

Voltmeter #	Range	Units	Value	Gauge	Name	Adjust	Precision
Voltmeter 1	+/- 100	VDC	24.2335		24VDC Input Power	1.0000	4
Voltmeter 2	+/- 100	VDC	23.9315		24VDC Internal Pwr Suppl	1.0000	4
Voltmeter 3	+/- 100	VDC	9.9733		10VDC Internal Pwr Suppl	1.0000	4

Figure 9 RMS 100 Homepage

The RMS-100 onboard relays are connected to the cRIO power inputs. The cRIO accepts power from two different power supplies for redundancy and reliability. cRIO power 1 has 24VDC and power 2 has 12V connected. *Note: the 12V is not monitored by the RMS-100.* These are fed to the cRIO via Relays 1 and 2 on the RMS-100. To power down or reboot the cRIO via the RMS-100 both relays 1 and 2 must be set to power OFF. To activate the relay click on the NO button on the Relays screen. You will be prompted to confirm the relay action. After the relay has moved the cRIO OFF text will appear below the Relay control button. Do this for both relay 1 and 2 to disconnect both the primary and secondary power supplies from the cRIO. The relays are wired in a normally closed manner and supply power to the cRIO by default. If the RMS-100 becomes inoperable or is disconnected from power any equipment connected to the RMS-100 or the USB relay expansion board will remain energized. The relays are all wired in the through the normally closed and common terminals. The 10VDC supply monitored on Voltmeter 3 is an MOIS internal supply that is used for excitation of strain gages and as a supply to the RS-232 serial module.



RMS-100 gives you control of 2 onboard general purpose power relays. Want more relays? Add a USB Relay Daughter Board!

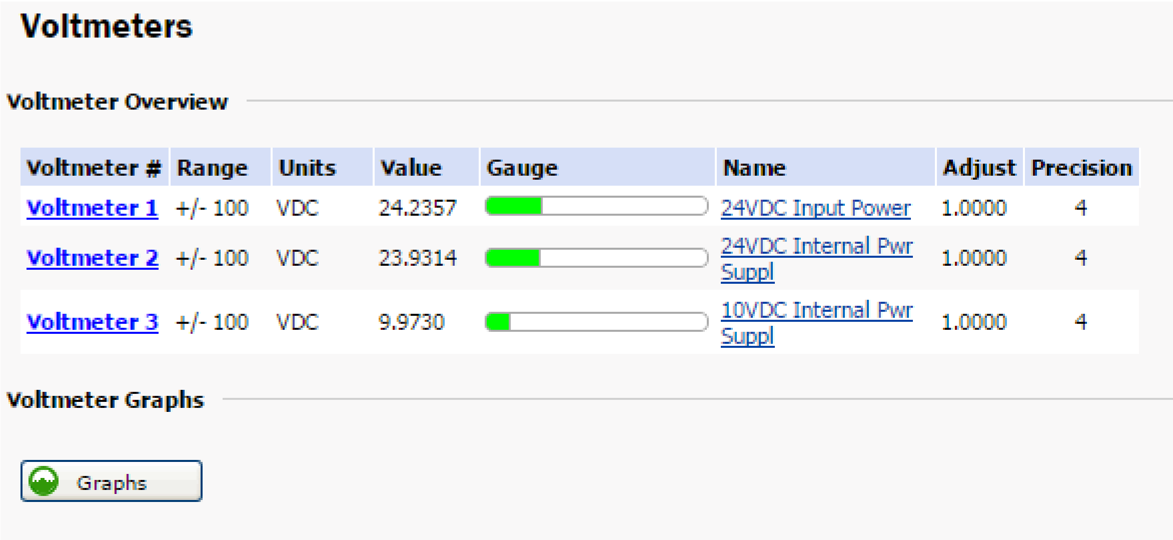
☑ Relay Action Confirmation?

Relay 1	Relay 2
cRIO Pwr #1	cRIO Pwr #2
cRIO ON	cRIO ON

ID	Type	Name	Description

Figure 10 Relay Page

Additionally, instruments powered through MOIS subsea connectors 9-12 can be controlled via an RMS-100 relay expansion board RDB-802E. Click the RDB-802E link on the left side of the homepage to access these relays. Relay control is performed the same way as with the cRIO relays. Again, the relays are wired in a normally closed manner so power is supplied to the MOIS connectors by default. If the RMS-100 or the RDB-802E were to stop working the ports will remain powered.



Voltmeters

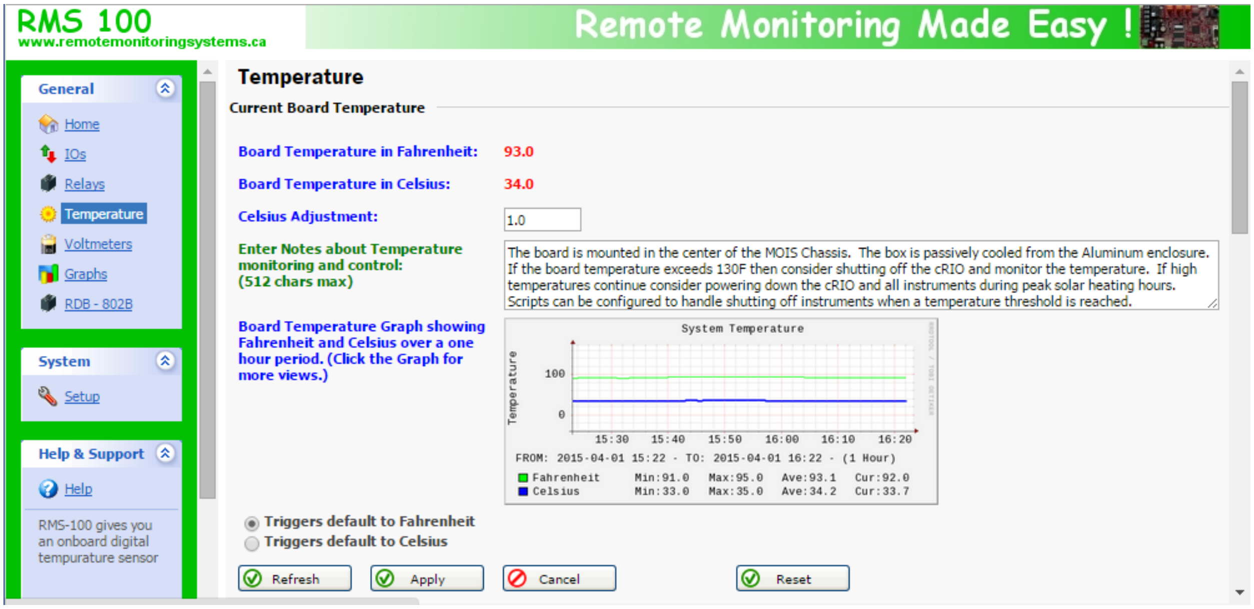
Voltmeter Overview

Voltmeter #	Range	Units	Value	Gauge	Name	Adjust	Precision
Voltmeter 1	+/- 100	VDC	24.2357		24VDC Input Power	1.0000	4
Voltmeter 2	+/- 100	VDC	23.9314		24VDC Internal Pwr Suppl	1.0000	4
Voltmeter 3	+/- 100	VDC	9.9730		10VDC Internal Pwr Suppl	1.0000	4

Voltmeter Graphs

Figure 11 RMS 100 Voltmeters

Temperature of MOIS is logged by the RMS-100. This is the board temperature of the RMS-100 and as such it reads higher than the actual ambient temperature inside the enclosure. We have used this temperature measurement as a relative value that can be used to determine the temperature changes inside the enclosure. Optionally, a temperature offset can be set on the RMS-100 to scale the reading the ambient temperature inside the enclosure. Note: the internal temperature of the cRIO is logged by MOIS automatically and is viewable in the MOIS tab within any data file.



RMS 100
www.remotemonitoringsystems.ca
Remote Monitoring Made Easy !
General
Home
IOs
Relays
Temperature
Voltmeters
Graphs
RDB - 802B
System
Setup
Help & Support
Help
RMS-100 gives you an onboard digital tempurature sensor

Temperature

Current Board Temperature

Board Temperature in Fahrenheit: 93.0

Board Temperature in Celsius: 34.0

Celsius Adjustment: 1.0

Enter Notes about Temperature monitoring and control: (512 chars max)

The board is mounted in the center of the MOIS Chassis. The box is passively cooled from the Aluminum enclosure. If the board temperature exceeds 130F then consider shutting off the cRIO and monitor the temperature. If high temperatures continue consider powering down the cRIO and all instruments during peak solar heating hours. Scripts can be configured to handle shutting off instruments when a temperature threshold is reached.

Board Temperature Graph showing Fahrenheit and Celsius over a one hour period. (Click the Graph for more views.)

```
FROM: 2015-04-01 15:22 - TO: 2015-04-01 16:22 - (1 Hour)
🟩 Fahrenheit    Min:91.0   Max:95.0   Ave:93.1   Cur:92.0
🟦 Celsius       Min:33.0   Max:35.0   Ave:34.2   Cur:33.7
```

● Triggers default to Fahrenheit
○ Triggers default to Celsius

Figure 12 RMS-100 Temperature

Troubleshooting

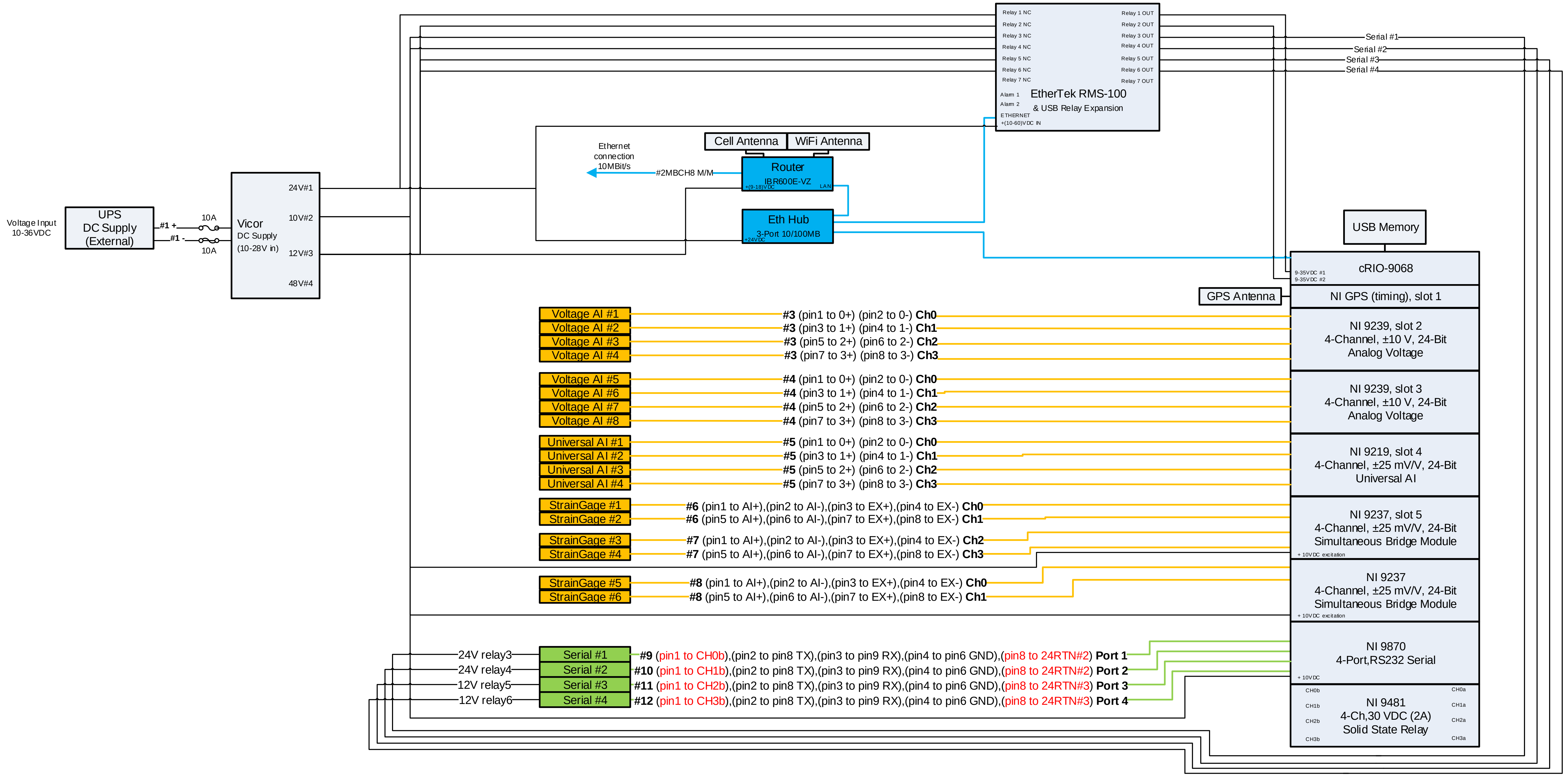
UI connection errors are the most common error the MOIS UI.exe will record. These occur when trying to connect from the host PC to the MOIS cRIO controller. This error occurs after the connect button has been pressed and a timeout occurs instead of connecting.

UI Error -314004 - Create Network Stream Writer Endpoint in UI - Initiate Connection.vi->UI Main.vi. This occurs when "LabVIEW cannot create the endpoint within the timeout period. Ensure that you specify the URL (192.168.1.108) of a remote endpoint with the reader url terminal of the Create Network Stream Writer Endpoint function or the writer url terminal of the Create Network Stream Reader Endpoint function."

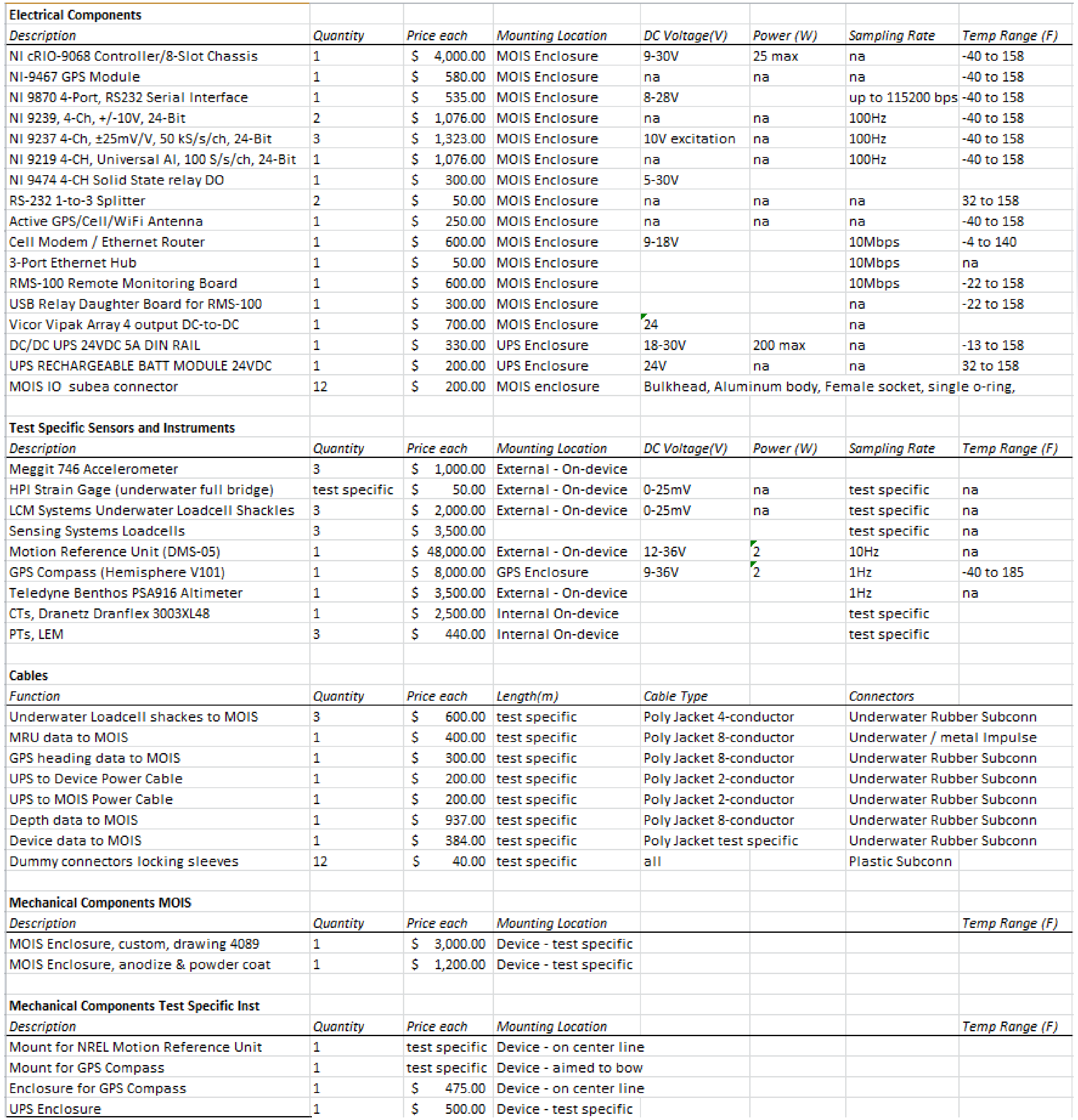
1. Verify that the Config.xml is copied to the root / directory on the cRIO.
2. Verify the MOIS software is running on the cRIO. Open a SSH session to the cRIO and watch for data file size increase on in the /data directory. Alternately files can be viewed in a web browser with the controller address as the hyperlink (192.168.1.108). If no data file is being written to the MOIS software on the RT system has stopped operation. Check log files in /log.

Appendix A: MOIS Drawings

The system level drawings and parts with costs are listed in the following drawings. The drawings give details of the MOIS enclosure equipment and explain how it is wired inside the enclosure. The cable pin outs for the final three drawings are examples of cables for specific sensors and instruments for the Azura wave energy converter test in Hawaii. The images below are included from the MOIS Gen3 Drawings.vsd Visio document included on the USB stick.


Relay 1 NC
Relay 2 NC
Relay 3 NC
Relay 4 NC
Relay 5 NC
Relay 6 NC
Relay 7 NC
Relay 1 OUT
Relay 2 OUT
Relay 3 OUT
Relay 4 OUT
Relay 5 OUT
Relay 6 OUT
Relay 7 OUT
Alarm 1
Alarm 2
ETHERNET
+(10-60)VDC IN
EtherTek RMS-100
& USB Relay Expansion
Serial #1
Serial #2
Serial #3
Serial #4
Ethernet
connection
10MBit/s
#2MBCH8 M/M
Cell Antenna
WiFi Antenna
Router
IBR600E-VZ
+(9-18)VDC
LAN
Eth Hub
3-Port 10/100MB
+24VDC
Voltage Input
10-36VDC
UPS
DC Supply
(External)
#1 +
#1 -
10A
10A
Vicor
DC Supply
(10-28V in)
24V#1
10V#2
12V#3
48V#4
USB Memory
cRIO-9068
9-35VDC #1
9-35VDC #2
GPS Antenna
NI GPS (timing), slot 1
NI 9239, slot 2
4-Channel, ±10 V, 24-Bit
Analog Voltage
NI 9239, slot 3
4-Channel, ±10 V, 24-Bit
Analog Voltage
NI 9219, slot 4
4-Channel, ±25 mV/V, 24-Bit
Universal AI
NI 9237, slot 5
4-Channel, ±25 mV/V, 24-Bit
Simultaneous Bridge Module
+ 10VDC excitation
NI 9237
4-Channel, ±25 mV/V, 24-Bit
Simultaneous Bridge Module
+ 10VDC excitation
NI 9870
4-Port,RS232 Serial
+ 10VDC
CH0b
CH1b
CH2b
CH3b
CH0a
CH1a
CH2a
CH3a
NI 9481
4-Ch,30 VDC (2A)
Solid State Relay
Voltage AI #1
Voltage AI #2
Voltage AI #3
Voltage AI #4
#3 (pin1 to 0+) (pin2 to 0-) Ch0
#3 (pin3 to 1+) (pin4 to 1-) Ch1
#3 (pin5 to 2+) (pin6 to 2-) Ch2
#3 (pin7 to 3+) (pin8 to 3-) Ch3
Voltage AI #5
Voltage AI #6
Voltage AI #7
Voltage AI #8
#4 (pin1 to 0+) (pin2 to 0-) Ch0
#4 (pin3 to 1+) (pin4 to 1-) Ch1
#4 (pin5 to 2+) (pin6 to 2-) Ch2
#4 (pin7 to 3+) (pin8 to 3-) Ch3
Universal AI #1
Universal AI #2
Universal AI #3
Universal AI #4
#5 (pin1 to 0+) (pin2 to 0-) Ch0
#5 (pin3 to 1+) (pin4 to 1-) Ch1
#5 (pin5 to 2+) (pin6 to 2-) Ch2
#5 (pin7 to 3+) (pin8 to 3-) Ch3
StrainGage #1
StrainGage #2
#6 (pin1 to AI+),(pin2 to AI-),(pin3 to EX+),(pin4 to EX-) Ch0
#6 (pin5 to AI+),(pin6 to AI-),(pin7 to EX+),(pin8 to EX-) Ch1
StrainGage #3
StrainGage #4
#7 (pin1 to AI+),(pin2 to AI-),(pin3 to EX+),(pin4 to EX-) Ch2
#7 (pin5 to AI+),(pin6 to AI-),(pin7 to EX+),(pin8 to EX-) Ch3
StrainGage #5
StrainGage #6
#8 (pin1 to AI+),(pin2 to AI-),(pin3 to EX+),(pin4 to EX-) Ch0
#8 (pin5 to AI+),(pin6 to AI-),(pin7 to EX+),(pin8 to EX-) Ch1
24V relay3
24V relay4
12V relay5
12V relay6
Serial #1
Serial #2
Serial #3
Serial #4
#9 (pin1 to CH0b),(pin2 to pin8 TX),(pin3 to pin9 RX),(pin4 to pin6 GND),(pin8 to 24RTN#2) Port 1
#10 (pin1 to CH1b),(pin2 to pin8 TX),(pin3 to pin9 RX),(pin4 to pin6 GND),(pin8 to 24RTN#2) Port 2
#11 (pin1 to CH2b),(pin2 to pin8 TX),(pin3 to pin9 RX),(pin4 to pin6 GND),(pin8 to 24RTN#3) Port 3
#12 (pin1 to CH3b),(pin2 to pin8 TX),(pin3 to pin9 RX),(pin4 to pin6 GND),(pin8 to 24RTN#3) Port 4

Appendix A Figure 1 MOIS Gen3 System Level Architecture



Electrical Components

Description	*Quantity*	*Price each*	*Mounting Location*	*DC Voltage(V)*	*Power (W)*	*Sampling Rate*	*Temp Range (F)*
NI cRIO-9068 Controller/8-Slot Chassis	1	$ 4,000.00	MOIS Enclosure	9-30V	25 max	na	-40 to 158
NI-9467 GPS Module	1	$ 580.00	MOIS Enclosure	na	na	na	-40 to 158
NI 9870 4-Port, RS232 Serial Interface	1	$ 535.00	MOIS Enclosure	8-28V		up to 115200 bps	-40 to 158
NI 9239, 4-Ch, +/-10V, 24-Bit	2	$ 1,076.00	MOIS Enclosure	na	na	100Hz	-40 to 158
NI 9237 4-Ch, ±25mV/V, 50 kS/s/ch, 24-Bit	3	$ 1,323.00	MOIS Enclosure	10V excitation	na	100Hz	-40 to 158
NI 9219 4-CH, Universal AI, 100 S/s/ch, 24-Bit	1	$ 1,076.00	MOIS Enclosure	na	na	100Hz	-40 to 158
NI 9474 4-CH Solid State relay DO	1	$ 300.00	MOIS Enclosure	5-30V			
RS-232 1-to-3 Splitter	2	$ 50.00	MOIS Enclosure	na	na	na	32 to 158
Active GPS/Cell/WiFi Antenna	1	$ 250.00	MOIS Enclosure	na	na	na	-40 to 158
Cell Modem / Ethernet Router	1	$ 600.00	MOIS Enclosure	9-18V		10Mbps	-4 to 140
3-Port Ethernet Hub	1	$ 50.00	MOIS Enclosure			10Mbps	na
RMS-100 Remote Monitoring Board	1	$ 600.00	MOIS Enclosure			10Mbps	-22 to 158
USB Relay Daughter Board for RMS-100	1	$ 300.00	MOIS Enclosure			na	-22 to 158
Vicor Vipak Array 4 output DC-to-DC	1	$ 700.00	MOIS Enclosure	24		na	
DC/DC UPS 24VDC 5A DIN RAIL	1	$ 330.00	UPS Enclosure	18-30V	200 max	na	-13 to 158
UPS RECHARGEABLE BATT MODULE 24VDC	1	$ 200.00	UPS Enclosure	24V	na	na	32 to 158
MOIS IO subea connector	12	$ 200.00	MOIS enclosure	Bulkhead, Aluminum body, Female socket, single o-ring,			

Test Specific Sensors and Instruments

Description	*Quantity*	*Price each*	*Mounting Location*	*DC Voltage(V)*	*Power (W)*	*Sampling Rate*	*Temp Range (F)*
Meggit 746 Accelerometer	3	$ 1,000.00	External - On-device				
HPI Strain Gage (underwater full bridge)	test specific	$ 50.00	External - On-device	0-25mV	na	test specific	na
LCM Systems Underwater Loadcell Shackles	3	$ 2,000.00	External - On-device	0-25mV	na	test specific	na
Sensing Systems Loadcells	3	$ 3,500.00				test specific	na
Motion Reference Unit (DMS-05)	1	$ 48,000.00	External - On-device	12-36V	2	10Hz	na
GPS Compass (Hemisphere V101)	1	$ 8,000.00	GPS Enclosure	9-36V	2	1Hz	-40 to 185
Teledyne Benthos PSA916 Altimeter	1	$ 3,500.00	External - On-device			1Hz	na
CTs, Dranetz Dranflex 3003XL48	1	$ 2,500.00	Internal On-device			test specific	
PTs, LEM	3	$ 440.00	Internal On-device			test specific	

Cables

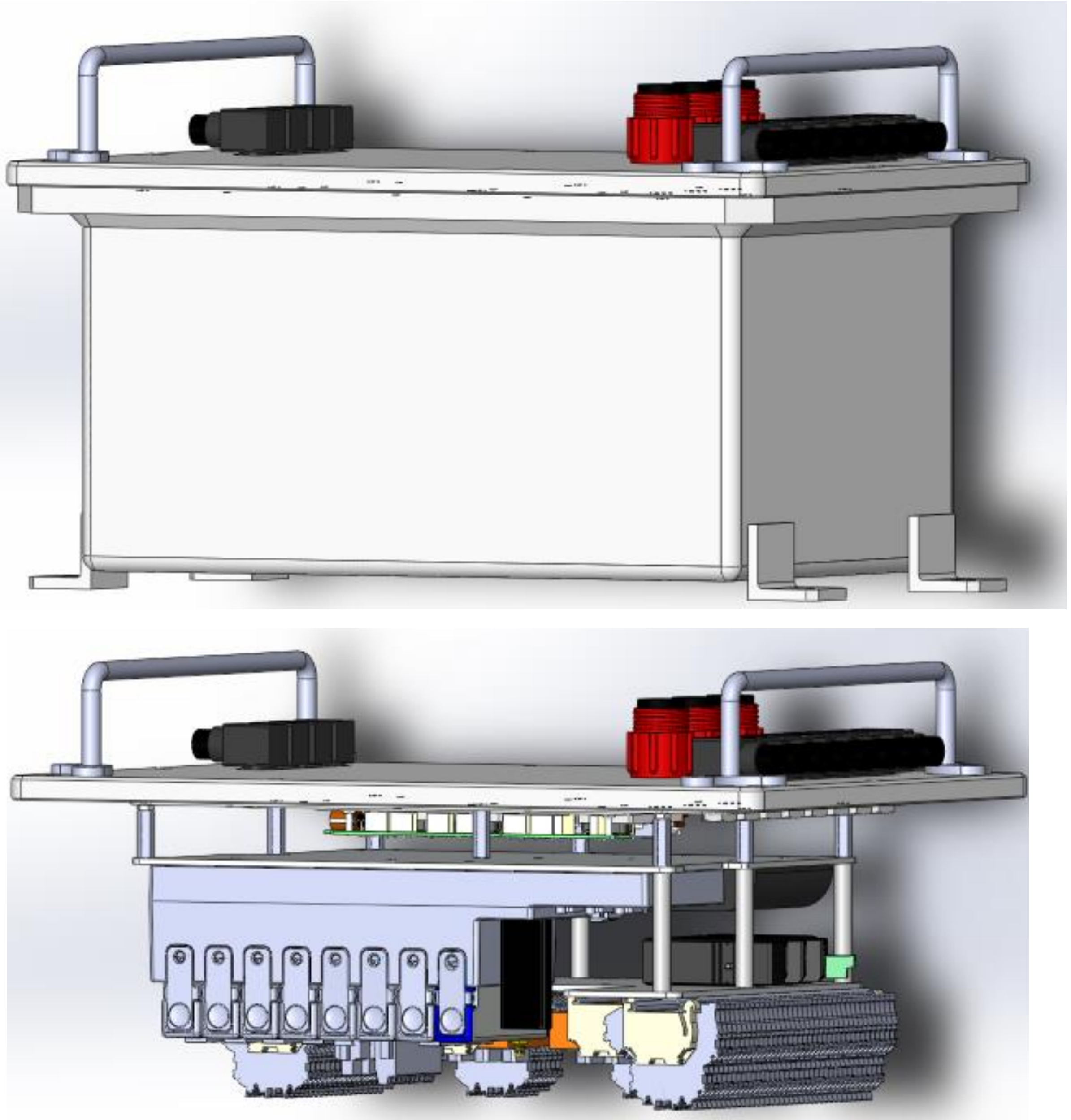
Function	*Quantity*	*Price each*	*Length(m)*	*Cable Type*	*Connectors*
Underwater Loadcell shackes to MOIS	3	$ 600.00	test specific	Poly Jacket 4-conductor	Underwater Rubber Subconn
MRU data to MOIS	1	$ 400.00	test specific	Poly Jacket 8-conductor	Underwater / metal Impulse
GPS heading data to MOIS	1	$ 300.00	test specific	Poly Jacket 8-conductor	Underwater Rubber Subconn
UPS to Device Power Cable	1	$ 200.00	test specific	Poly Jacket 2-conductor	Underwater Rubber Subconn
UPS to MOIS Power Cable	1	$ 200.00	test specific	Poly Jacket 2-conductor	Underwater Rubber Subconn
Depth data to MOIS	1	$ 937.00	test specific	Poly Jacket 8-conductor	Underwater Rubber Subconn
Device data to MOIS	1	$ 384.00	test specific	Poly Jacket test specific	Underwater Rubber Subconn
Dummy connectors locking sleeves	12	$ 40.00	test specific	all	Plastic Subconn

Mechanical Components MOIS

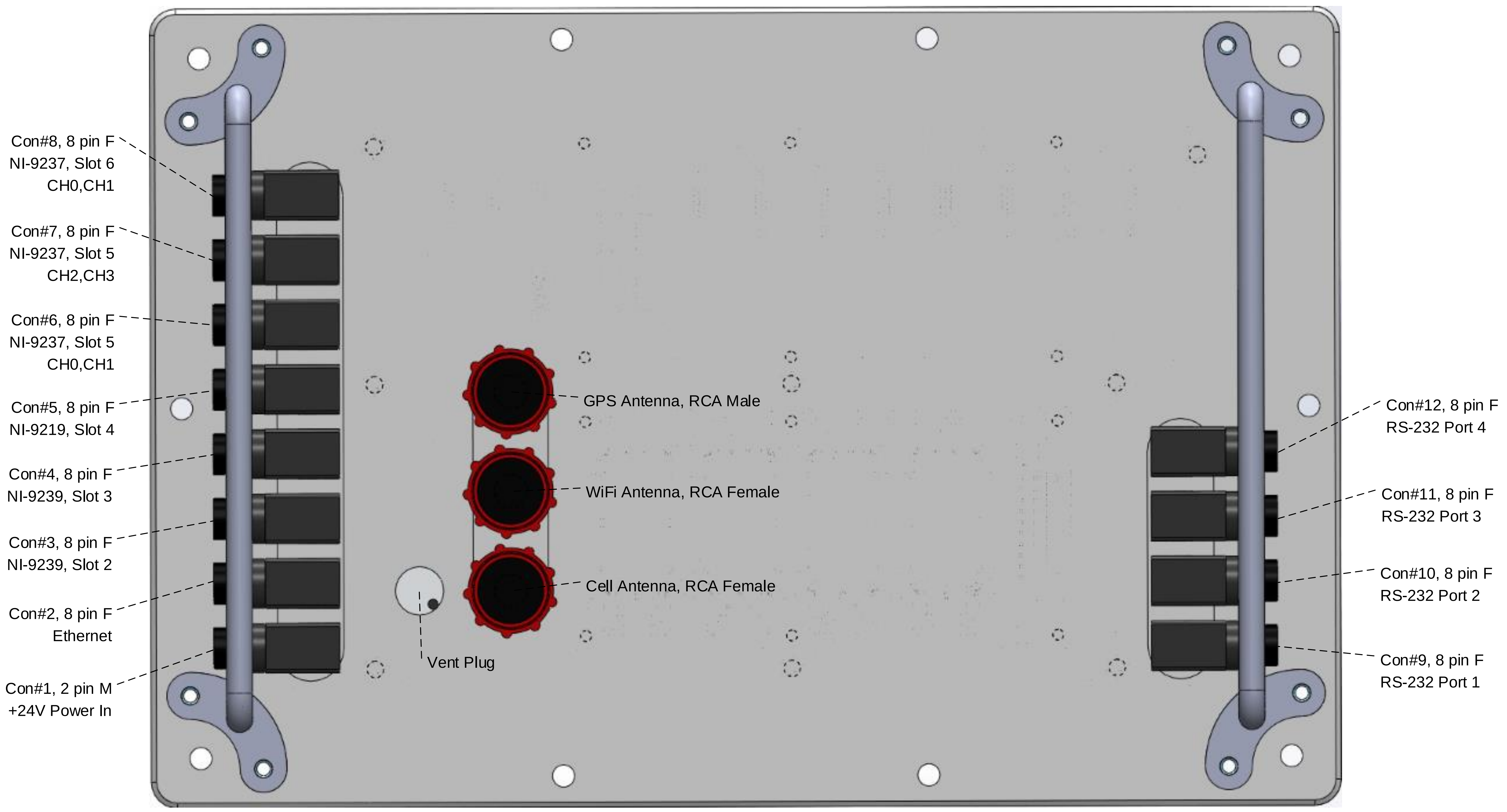
Description	*Quantity*	*Price each*	*Mounting Location*	*Temp Range (F)*
MOIS Enclosure, custom, drawing 4089	1	$ 3,000.00	Device - test specific	
MOIS Enclosure, anodize & powder coat	1	$ 1,200.00	Device - test specific	

Mechanical Components Test Specific Inst

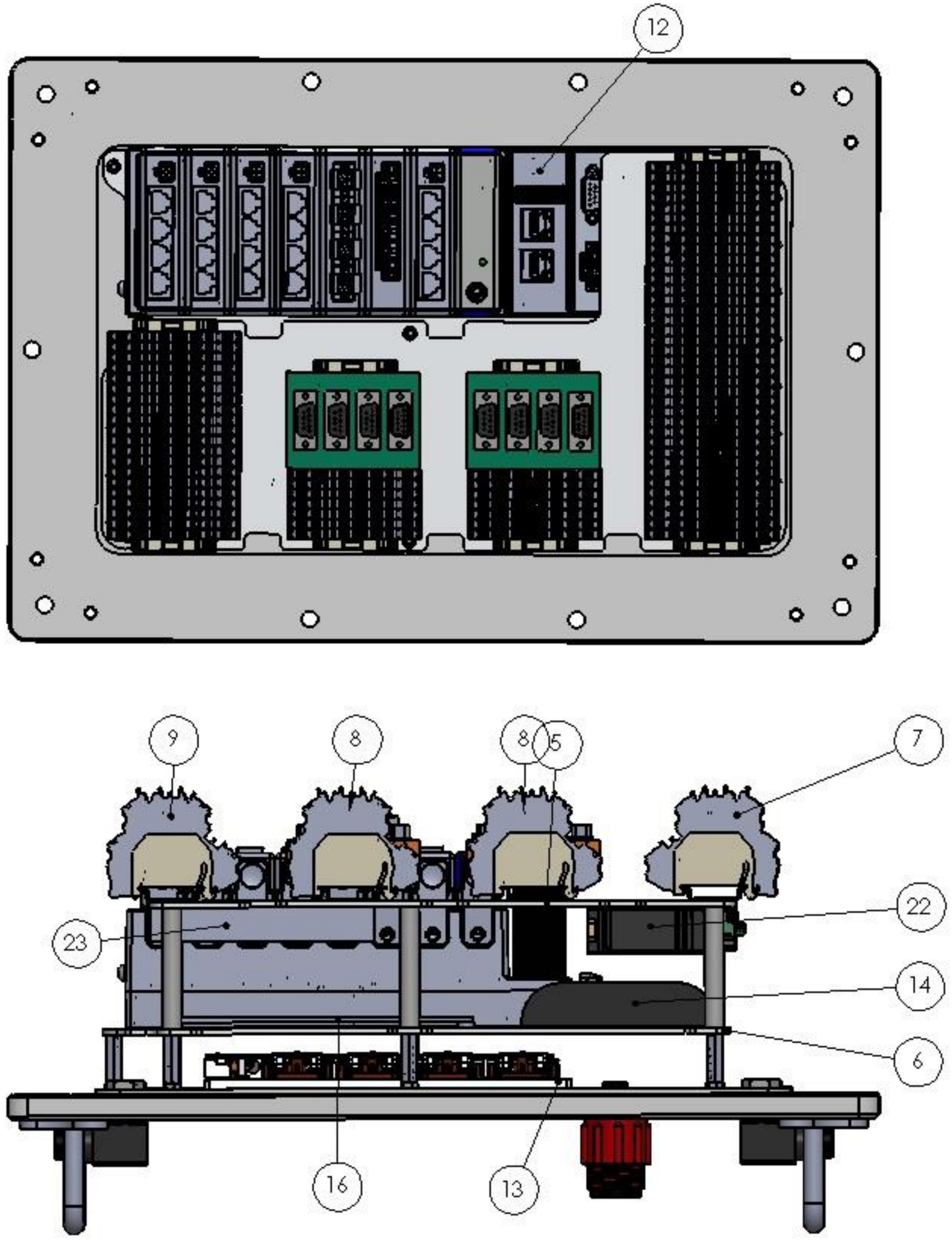
Description	*Quantity*	*Price each*	*Mounting Location*	*Temp Range (F)*
Mount for NREL Motion Reference Unit	1	test specific	Device - on center line	
Mount for GPS Compass	1	test specific	Device - aimed to bow	
Enclosure for GPS Compass	1	$ 475.00	Device - on center line	
UPS Enclosure	1	$ 500.00	Device - test specific	



Appendix A Figure 2 Components and Costs



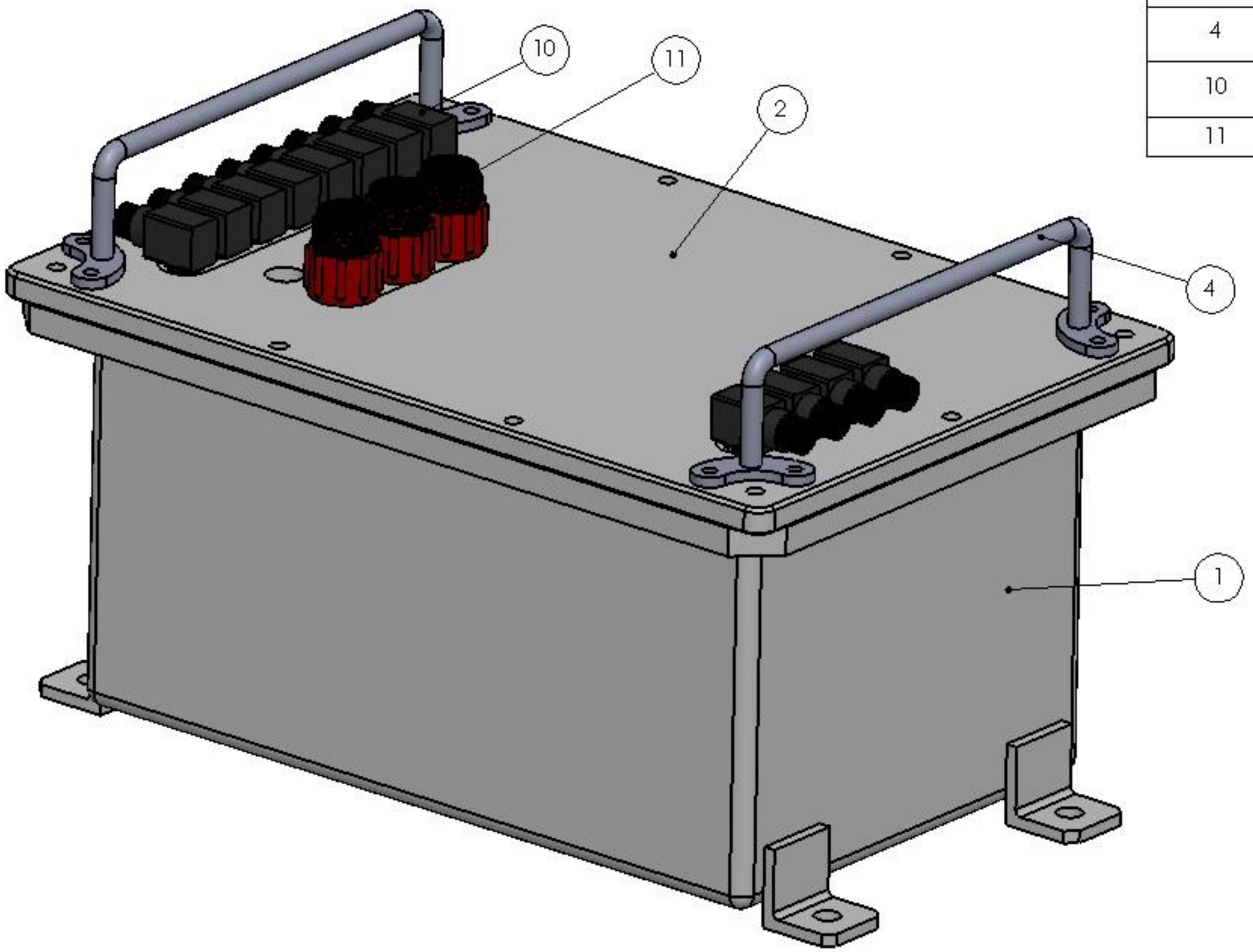
Appendix A Figure 3 Lid and Connectors



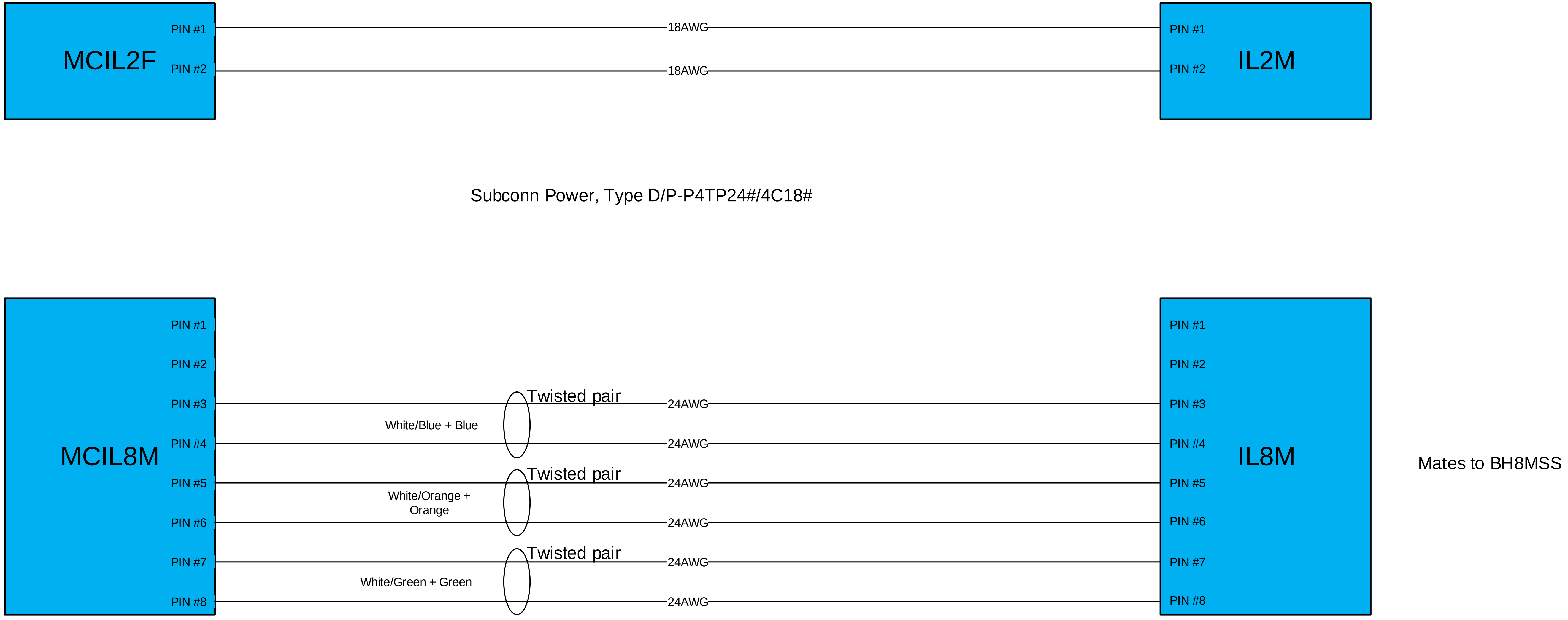
Appendix A Figure 4 Internal Components

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
2	PLATE_LID	Lid for MOIS Gen3 System Enclosure	1
5	Mounting plate TOP Gen3 Narrow	Mounting for Terminal Blocks and Wiring from Subsea Connectors. Terminal Blocks Allow for Deployment Specific Wiring.	1
6	Mounting plate BASE Gen3 Narrow	Mounts for Compact RIO, Cell Modem, Ethernet Hub, and Remote Administraion Boards.	1
7	Right Side Terminal Blocks	Terminal Blocks for Analog Inputs ie Analog Voltage, Strain Gage, etc	1
8	Mid Terminal Blocks	Terminal Blocks for DC power and RS-232 Serial 1 to 3 Splitter	2
9	Left Side Terminal Blocks	Terminal Blocks for RS-232 Serial Instruments	1
10	MCBH Right Angle Connector	8 pin subsea electrical connector, right angle	12
11	RCA Bulkhead	Subsea coaxial connector 50 ohm	3
12	cRIO_9068	Compact RIO 9068, 8 Slot Data Acquision System	1
13	VipakArray-4OUT	DC Power Supply Module, 1 DC Input to 4 DC Isolated Outputs	2
14	COR Modem	Cell Modem / WiFi / Ethernet Router	1
15	USB Stick	256GB USB Flash Drive	1
16	RMS-100 Outline	RMS-100 Remote System Administration Board	1
22	W4S1_03B	3-Port Ethernet Hub	1
23	RMS Relay Board	5 Relay Expansion Board for RMS-100 Remote Admin System	1

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Box	Subsea Enclosure Box for MOIS Gen3 System	1
2	PLATE_LID	Lid for MOIS Gen3 System Enclosure	1
4	HANDLE_BAR	Handles for Moving Box and Protection of Subsea Connectors.	2
10	MCBH Right Angle Connector	8 pin subsea electrical connector, right angle	12
11	RCA Bulkhead	Subsea coaxial connector 50 ohm	3



Appendix A Figure 5 External Components

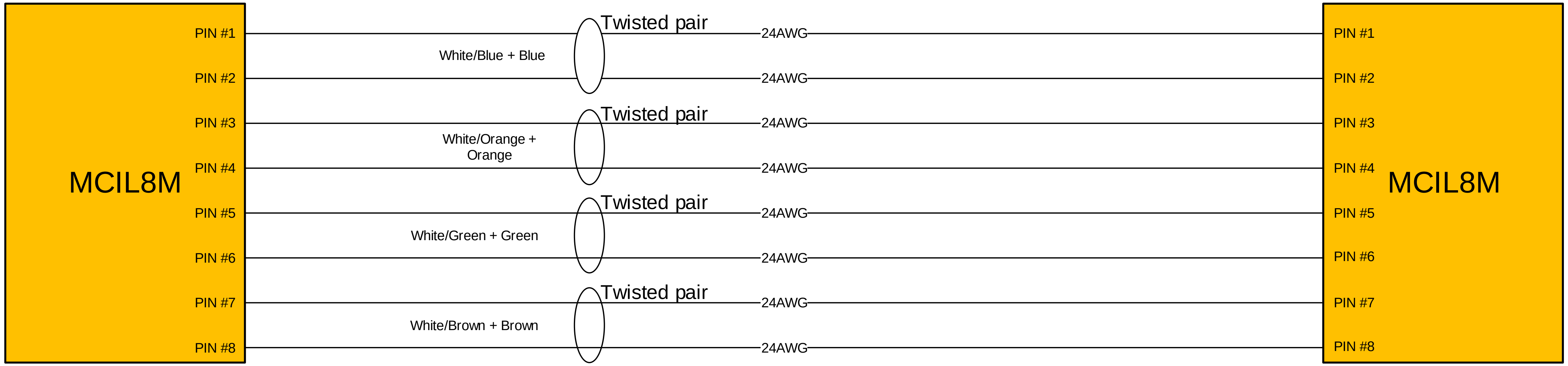


Subconn Power, Type D/P-P4TP24#/4C18#

Mates to BH8MSS

Ethernet Cable, Type D/P-P4TP24#/4C18#

Appendix A Figure 6 Power and Ethernet Cable Pinouts

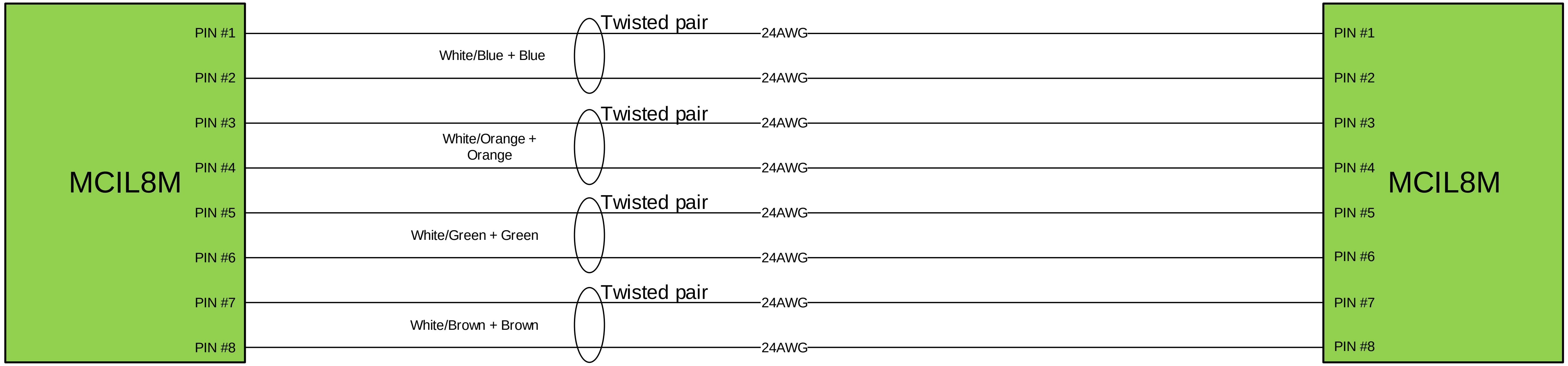


Mates to BH8MSS

Subconn Power / Ethernet Cable, Type D/P-P4TP24#/4C18# OR equivalent without the power conductors

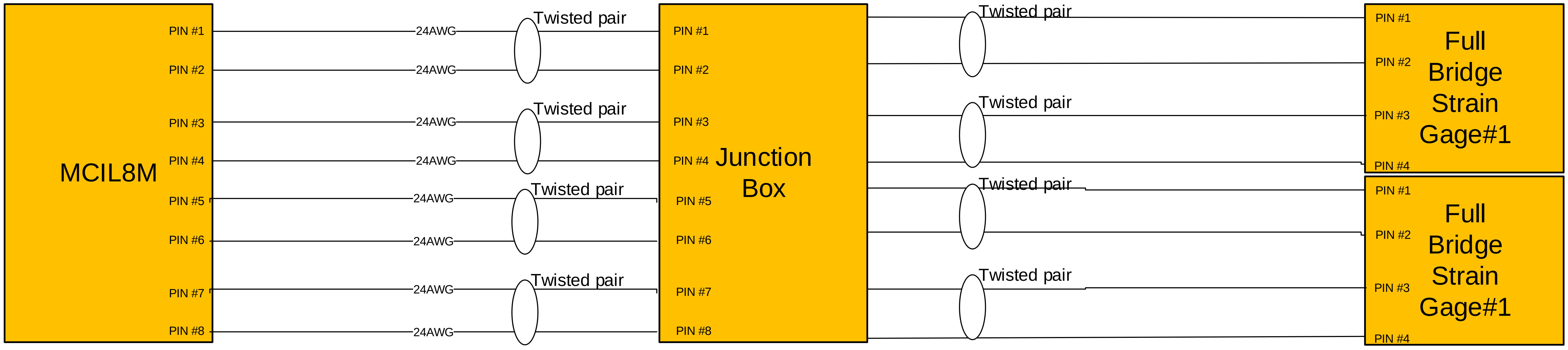
Cable length built as needed. For full 4- channel count a junction box is necessary or direct wiring from device under test

Appendix A Figure 7 Analog Signals Cable



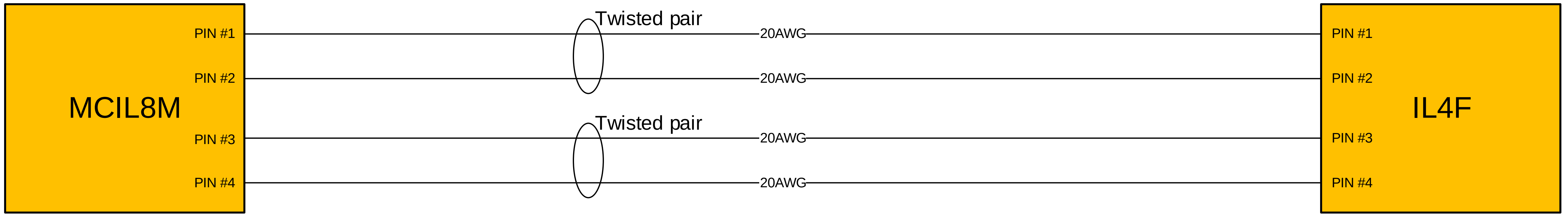
Subconn Power / Ethernet Cable, Type D/P-P4TP24#/4C18# OR equivalent without the power conductors

Appendix A Figure 8 Serial Instrument Cable



Polyurethane outer jacket, PVC or Teflon wire insolation

Appendix A Figure 9 Two Full-bridge Strain Gages in MOIS Connector

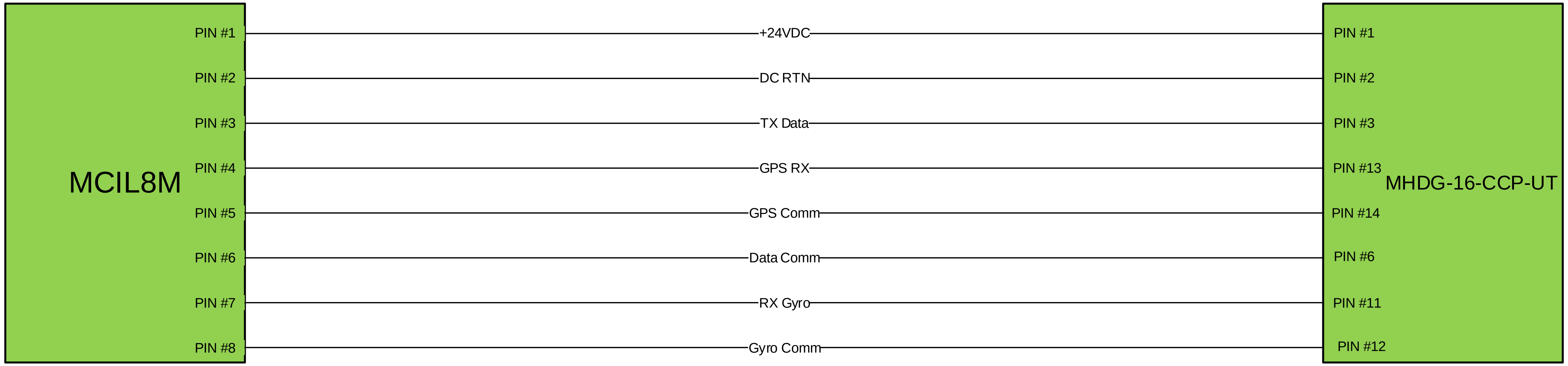


PINS #5-#8 not connected

2 cables at 70'
2 cables at 85'

Polyurethane outer jacket, PVC or Teflon wire insolation

Appendix A Figure 10 Load Cell Cable from Azura Deployment

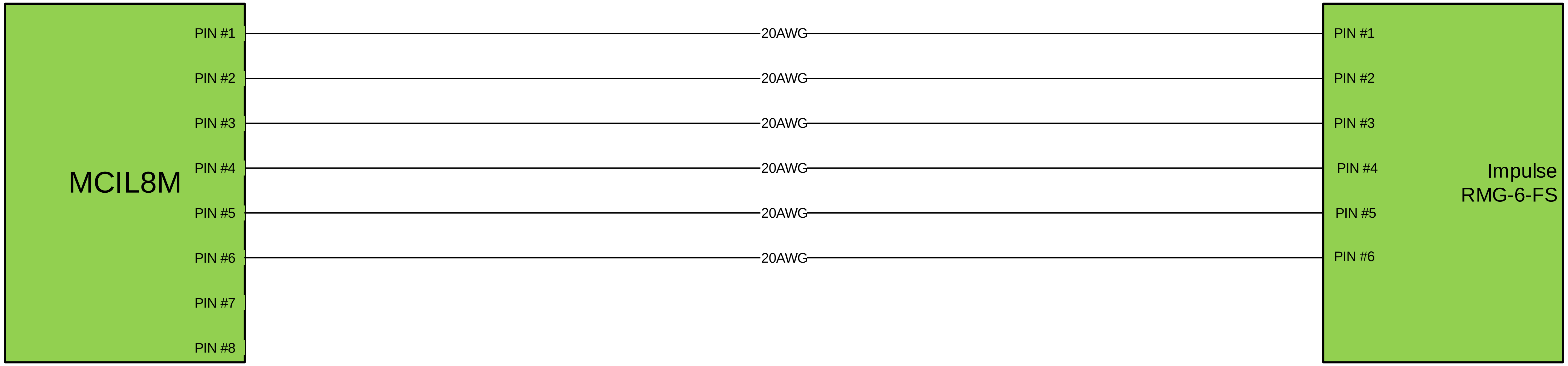


Supplied Teledyne TSS DMS-05 cable. Jacket is polyurethane /w a cable diameter of 0.5". Cable will be sent cut at 20ft in length and already has the MHDG-16-CCP-UT installed on one end.

All unassigned pins not connected

Cable length 16(ft)

Appendix A Figure 11 TSS-DMS05 Cable from Azura Deployment



All unassigned pins not connected

Polyurethane jacket.

Cable length 80(ft)

Appendix A Figure 12 PSA 916 Cable from Azura Deployment

Appendix B: Care For and Plugging In Underwater Connectors

All sensors and instruments are connected to MOIS via the 8 pin subsea electrical connectors. Please review the instructions for connecting and disconnecting the Subconn rubber molded subsea connectors available at:

http://macartney.com/sites/default/files/SubConn_handling_instructions_web_4.pdf.

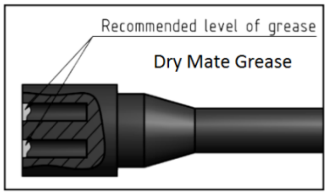
In general, the underwater cables are likely to be either polyurethane or neoprene jacketed, in some cases of extreme conditions, steel armored cables may be used. **Connecting underwater cables to connectors can be difficult and are a leading cause of field failures.** For highest reliability connectors and cables should be molded together by a factory specializing in subsea cables. It is possible to build cables using "field installable" connectors as well. To construct "field installable" cables please carefully follow manufacturer instructions.

General Handling

- Always apply grease before mating
- Disconnect by pulling straight, not at an angle
- Do not pull on the cable and avoid sharp bends at cable entry
- When using a bulkhead connector, ensure that there are no angular loads
- Do not over-tighten the bulkhead nuts
- SubConn connectors should not be exposed to extended periods of heat or direct sunlight. If a connector becomes very dry, it should be soaked in fresh water before use again. Surface installations will generally cause UV damage to the connector. Connectors used for more than two years in direct sunlight should be inspected and replaced if the neoprene rubber is damaged.

Greasing and mating above water (dry mate)

- Connectors must be greased with Molykote 44 Medium before every mating
- A layer of grease corresponding to minimum 1/10 of socket depth should be applied to the female connector
- The inner edge of all sockets should be completely covered, and a thin transparent layer of grease left visible on the face of the connector
- After greasing, fully mate the male and female connector in order to secure optimal distribution of grease on pins and in sockets
- To confirm that grease has been sufficiently applied, de-mate and check for grease on every male pin. Then re-mate the connector

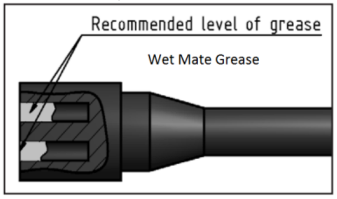


Appendix B Figure 1

Greasing and mating under water (wet mate)

- Connectors must be greased with Molykote 44 Medium before every mating
- A layer of grease corresponding to approximately 1/3 of socket depth should be applied to the female connector

- All sockets should be completely sealed, and transparent layer of grease left visible on the face of the connector
- After greasing, fully mate the male and female connector and remove any excess grease from the connector joint



Appendix B Figure 2

Appendix C: Hardware

Figures 13-16 show the MOIS equipment enclosure and placement of equipment within the enclosure.

The MOIS data acquisition system is based on the National Instruments Compact RIO platform and model cRIO-9068 is used. The hardware is shown is figures 12 and 13 where the location of each component is shown in the drawings. The components are listed below with a brief description of their functionality. Detailed instructions about the configuration of the operation of the RMS-100 r remote administration board and COR modem are described in their respective user manuals which are included on the USB stick.

cRIO-9068

The cRIO-9068 is the core of the MOIS data acquisition system. The Compact RIO model is the cRIO 9068 8-slot controller with integrated chassis. The NI cRIO-9068 combines a dual-core processor, a reconfigurable FPGA, and eight slots for C Series I/O modules within one chassis. Featuring a 667 MHz dual-core ARM Cortex-A9 processor running the NI Linux Real-Time OS and an Artix-7 FPGA, this system is well-suited for advanced embedded control and monitoring applications. The cRIO-9068 has a -40 °C to 70 °C operating temperature range along with dual 9 VDC to 30 VDC power supply inputs for use in applications that demand a rugged and temperature-tolerant controller. The device features 512 MB of DDR3 memory for embedded operation, 1 GB of nonvolatile memory for data logging, and a wide range of connectivity options including two Gigabit Ethernet, one USB Hi-Speed, and three serial ports. The cRIO-9068 is loaded with the following c-series IO modules:

> **Slot 1:** NI-9467, GPS time stamping and Synchronization Module, Pulse per second (PPS) accuracy of ±100 ns, >99 percent typical, SMA female antenna connector type, +5 VDC (up to 30 mA) for active GPS antenna, Returns stationary global position after self-survey. This module is used to timestamp the measurement data
>
> Slot 2: NI-9239, Simultaneous Analog Input, 50 kS/s, 4 Ch Module. 4 differential channels, ±10 V measurement range, 24-bit resolution, Anti-alias filter, 250 Vrms ch-ch,
>
> Slot 3: NI-9239, Simultaneous Analog Input, 50 kS/s, 4 Ch Module. 4 differential channels, ±10 V measurement range, 24-bit resolution, Anti-alias filter, 250 Vrms ch-ch,
>
> Slot 4: NI -9219, Universal Analog Input, 24-Bit, 100 S/s/ch, 4 Ch Module, Support for thermocouple, RTD, resistance, bridge, voltage, and current measurements, Built-in quarter-, half-, and full-bridge support; built-in voltage and current excitation, 250 Vrms, CAT II, channel-to-channel isolation
>
> Slot 5: NI-9237, ±25 mV/V, Bridge Analog Input, 50 kS/s/ch, 4 Ch Module, ±25 mV/V input range, 24-bit resolution, Programmable half- and full-bridge completion with up to 10 V internal excitation, 60 VDC, Category I bank isolation

Slot 6: NI-9237, ±25 mV/V, Bridge Analog Input, 50 kS/s/ch, 4 Ch Module, ±25 mV/V input range, 24-bit resolution, Programmable half- and full-bridge completion with up to 10 V internal excitation, 60 VDC, Category I bank isolation

Slot 7: NI-9870, 4-Port, RS232 (TIA/EIA-232) serial ports, Baud rates from 14 b/s to 921.6 kb/s

Data bits: 5, 6, 7, 8; Stop bits: 1, 1.5, 2; Flow control: XON/OFF, RTS/CTS, None, Individual 64 B UART FIFO buffers per port, 8 to 28 VDC externally powered

Slot 8: NI-9485, 8 solid-state relay (SSR) outputs, 60 VDC, 30 Vrms switching voltage, Switching current of 1.2 A/channel for up to 4 channels; 750 mA/channel for all channels, Compatibility with NI CompactDAQ counters, 250 Vrms CAT II continuous channel-to-earth ground, and 60 VDC channel-to-channel isolation

COR IBR600LP-AT AT&T 4G LTE / HSPA+

Ethernet connectivity to MOIS is done through The CradlePoint COR Series modem. It is a, highly-featured compact router designed for critical enterprise applications that require, 24x7, connectivity. Connections are made from shore to MOIS via cell modem, 802.11 WiFi, or directly connected fiber optic cable. The installed modem is an AT&T modem. Verizon modems are available and can be installed in place of the AT&T model. The COR modem seamlessly uses these different connection types into one network. The modem has a compact size, metal case, mounting bracket, and external mobile broadband and WiFi antennas, COR is ideal for use in high-availability applications and is well suited for MOIS telemetry. The modem is configured to automatically failover to cell service if the fiber optic or WiFi connections are unavailable. WiFi connections are only for service from a boat in close proximity to the COR modem.

The COR can be configured to provide secure and reliable VPN functionality, allowing users to create, manage, and terminate up to 5 concurrent IPSec VPN sessions. It allows for secure access to company networks for enterprise applications and provides a secure way to transmit sensitive data to and from a remote site.

RMS-100 Remote Administration Board

The RMS-100 is used to monitor various properties within the MOIS enclosure. The monitored items include supply voltages, enclosure temperature, and control relays to isolate instruments or reboot the cRIO 9068 controller. The RMS-100 has 3 onboard isolated voltmeters giving it the ability to measure DC voltage from -100 to +100 volts with 24 bit accuracy. RMS-100 also has 2 power relays giving it the unique ability to turn on/off devices remotely using an Internet connection. RMS-100 has two USB 2.0 ports that support several USB devices concurrently using a USB hub. The USB Relay Expansion card is used to add an additional 5 items under relay control. The RMS-100 can alert you via email or SMS messages when the supply voltage is low or the internal temperature is too warm. RMS-100 has ping monitor software that allows you to monitor network devices and alert you to failure and possibly power cycle the device. Monitor all this information remotely over an Internet connection using an ordinary web browser. The RMS-100 also logs voltage levels and internal temperature and is useful in looking for diurnal or temperature effects. RMS-100 gives you direct control of power to external instruments which can be rebooted or turned off as part of the remote administration of a MOIS installation.

USB Relay Board

The USB Relay Board has five power relays to control your equipment via a USB cable to the RMS-100. The USB Relay board is powered via the USB cable from the RMS-100. The USB Relay Board is a passive control device only, and requires a PC, SBC, or RMS unit to communicate. Each relay is capable of switching up to 250VAC, 10 Amps or 100VDC, 5 Amps. The relays are mechanical relays and, as such, are not intended to be switched other than through manual control via the RMS-100 web interface. For programmatic control of devices use the NI 9485 SSR module from the cRIO-9068.

Vipac Array

DC voltage to power the MOIS hardware is provided from a Vicor Vipac Array DC-to-DC converter with four outputs. The Vipac Array takes 10-28 VDC in and provides isolated power outputs. The Vipac Array for MOIS is configured with three 24VDC and one 10VDC outputs. This allows a dedicated 24VDC output for the cRIO-9068 and other internal electrical gear and then 24VDC instrument busses A and B. The 10VDC output is used to provide excitation voltage for strain gages and supply power for the NI 9870 RS232 communication module. If one of the supply outputs are short-circuited then that power supply is automatically shut down while the other outputs unaffected. The Vipac Array also serves to smooth noise on the input power line so that if MOIS is used without the DC UPS the supply power will be conditioned for the cRIO-9068.

W4S1-03B

The Omron W4S1-03B 3-port Ethernet hub provides the MOIS internal LAN connections between components. The hub is a rugged industrial Ethernet hub that uses 24VDC power and supports up to 100Mbps data rates.

Appendix D: MOIS Software Developer's Guide

MOIS Overview

The Modular Ocean Instrumentation System (MOIS) software was developed in the LabVIEW programming language. The software runs on a LabVIEW real-time target. The National Instruments produced real-time target MOIS uses is called a CompactRIO (Compact Real-Time Input/Output) or is abbreviated as cRIO. The MOIS software acquires analog measurements as continuous waveform data and serial data as ASCII text data from attached instruments. The software logs both types of data to disk on the real-time controller in a single data file. The data files are an hour in length and the hourly files are archived once a day in a single daily zip file. The MOIS software was created with the LabVIEW FPGA Module, LabVIEW RT Module, and LabVIEW Professional development products.

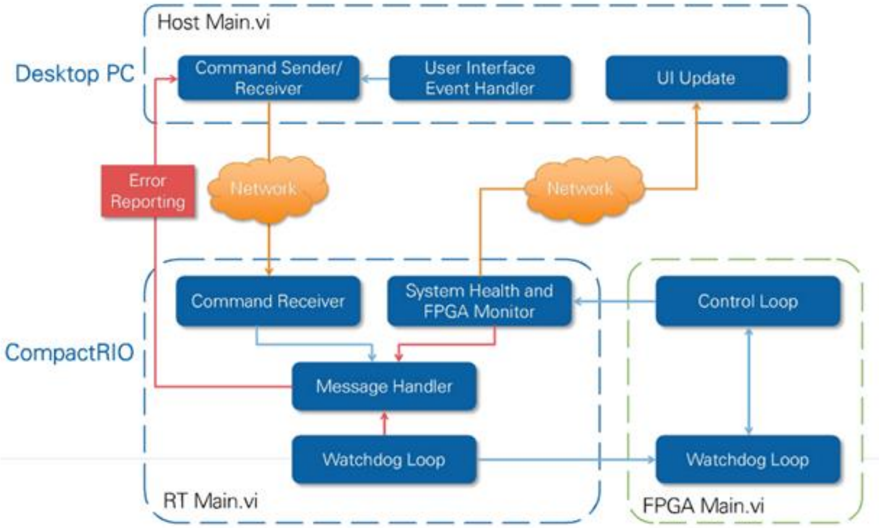
A generic compiled MOIS executable file is installed on the CompactRIO (cRIO-9068) as shipped. For basic data logging no reprogramming is required. There are many instances where it will be desirable for the software to be customized for specific test requirements. For information on the basic operation of MOIS refer to the MOIS User's Manual.

This developer's guide is intended to point the user in the correct direction for enhancing the software to meet specific needs of an individual test. The MOIS software is developed on using an advanced LabVIEW architecture that can be most readily developed further by an experienced LabVIEW developer. New to LabVIEW developers will need more time with the code, and LabVIEW in general, in order to come up to speed with MOIS software development. This guide will attempt to explain the overall architecture where developers can then go to sections of code that may be expanded upon to modify or add functionality. This document is not intended to be a "how to" for programming in LabVIEW.

Developer Walkthrough

The MOIS software architecture is adapted from the LabVIEW Waveform Acquisition and Logging on CompactRIO Sample Project that is included with LabVIEW since 2012. This sample project using a queued message handler (QMH) architecture serves as a basis of understanding the MOIS software operation. While the sample project uses a single c-series module microphone module, the MOIS software acquires measurements from five analog input c-series modules and one RS-232 serial c-series module. The software/hardware system diagram is shown below. The software runs on three different computer hardware components: desktop PC, real-time controller, and a FPGA. The Compact RIO contains both the real-time controller and the FPGA. The desktop PC is needed to build a new configuration file and can be used to view data and system status of the cRIO. The analog channel acquisition rate is set in the Configuration.xml file that is generated from the Configuration File Generator.vi. This is the configuration file that appears in the root directory of the cRIO-9068 controller. The desktop PC is not needed for normal operations where MOIS is recording measurements and serial instrument data.

The diagram in Figure 1 below details the data flow of the in an abstracted manner. The diagram is not specific to the MOIS software but rather CompactRIO systems in general. The three basic pieces are the FPGA, Real-Time (RT) operating system, and an optional user interface (UI) that runs on a PC.



Appendix D Figure 1 Data Flow in cRIO and Host PC

Basic Features

cRIO runs in headless operation with optional user interface on a PC:

- The user interface VI interacts with the CompactRIO device and displays data. This VI can connect and disconnect from the device at any time without affecting the acquisition and logging loop.

Continuous or triggered (from UI) data logging:

The real-time VI logs acquired data to disk as TDMS files continuously or, optionally, when a trigger condition is met. The data is then written to a data file.

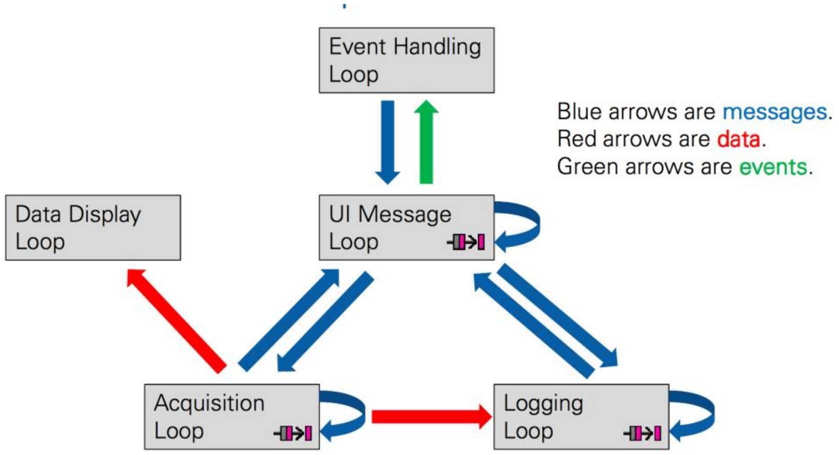
- A new file is created every hour.
- MOIS manages the amount of disk space being used and stops the application if disk space is critically low.

Error handling:

- The application reports and logs all errors from the CompactRIO device, shutting down on any critical error.

Overall Architecture

The MOIS LabVIEW software project is based on the Simple State Machine and Queued Message Handler architectures. To learn more about these architectures from within the LabVIEW development environment, refer to the Simple State Machine and Queued Message Handler templates and their documentation, available from the Create Project dialog box, for information about how these templates work or search on ni.com. The diagram below shows the basic architecture of a queued message handler. The architecture allows for a user interface with some control of a real time controller from a desktop PC while being very efficient in terms of processor resources on the real time controller. The architecture lends itself to adding functionality as the software is improved over time. For instance, error handling and logging can be expanded for new error conditions. Additionally, items can be added to the user interface when required.



Appendix D Figure 2 Data, Message, and Events Queued Message Handler Architecture

The MOIS software project is a complete application with based on the QMH architecture. The software has three message handlers (MHL): the primary MHL, an acquisition MHL, and a logging MHL.

Required Development Software and Hardware

In order to modify and recompile the MOIS software it is necessary to have the LabVIEW development environment installed on a development PC. The following LabVIEW licenses and modules are necessary to program the cRIO-9068 controller. It is possible to download all of the required LabVIEW software for a 30-day evaluation when the expense of software licenses is prohibitive.

Required hardware needed to run the MOIS software:

- NI Compact RIO using ARM processor and RT Linux
- NI C Series modules (in slots as listed below):

3. NI-9467 GPS Module
4. NI-9239 +/-10V Analog Input Module
5. NI-9239 +/-10V Analog Input Module

6. NI-9219 Universal Analog Input Module
7. NI-9237 Full / Half Bridge Strain Gage Module
8. NI-9237 Full / Half Bridge Strain Gage Module
9. NI-9870 RS-232 Serial Module
10. NI-9485 Solid State Relay Module

Software Development System (installed on development PC):

- All versions below are 2014 or higher
- LabVIEW Full or Professional Development System
- LabVIEW FPGA Module
- LabVIEW Real-Time Module
- NI-RIO device driver software
- NI CompactRIO Device in FPGA Interface Mode

CompactRIO installed components:

These are installed through National Instruments Measurement and Automation Explorer (MAX) program. If the software modules listed above are installed on the development PC the following software will be available to load on the cRIO using MAX.

- LabVIEW Real-Time
- Network Streams
- Network Variable Engine
- NI System Configuration
- NI-RIO
- NI-Watchdog

Overview

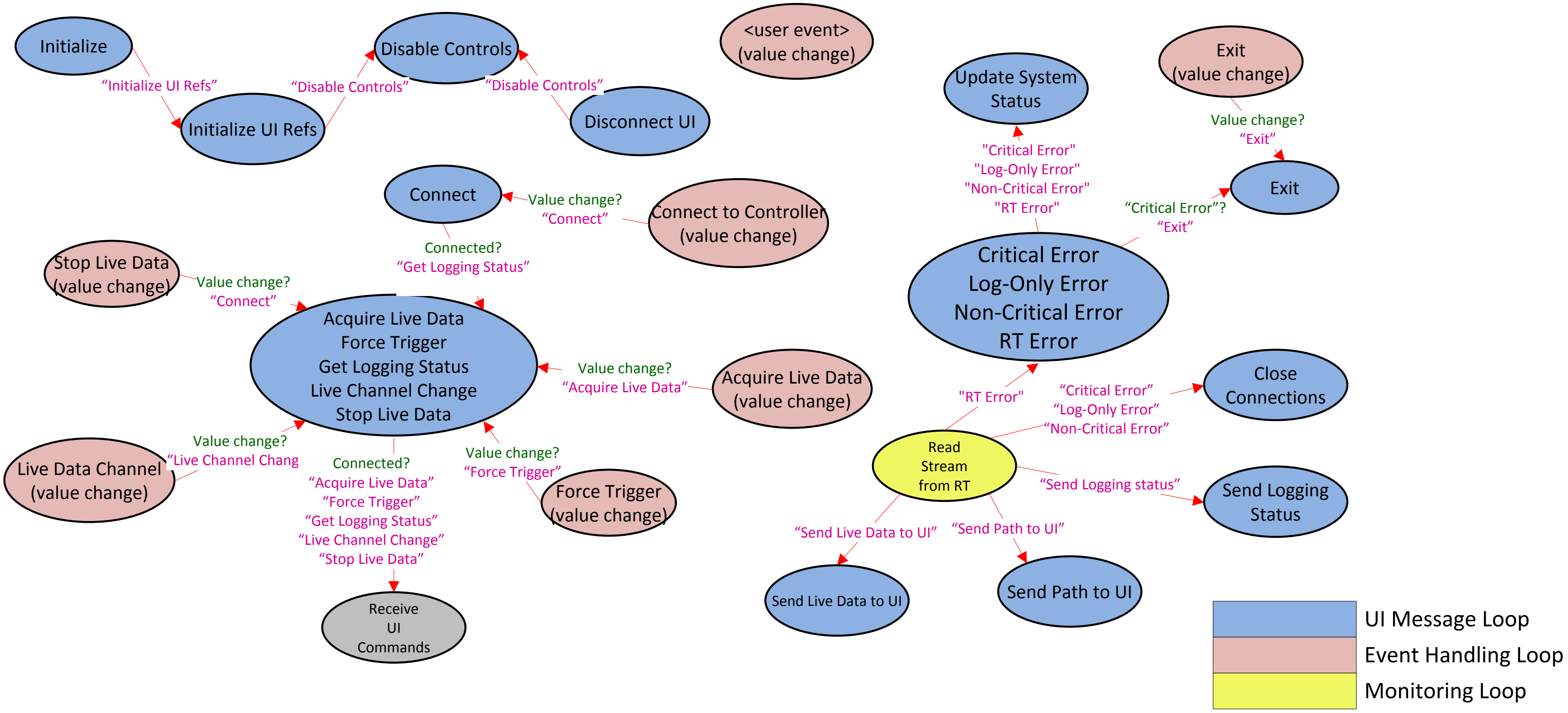
MOIS User Interface (UI)

The UI runs on a host PC. The purpose of the user interface UI is only to monitor the system and individual data channels from the RT system. For deployments in the field the UI is normally used for pre deployment verification of channel data and operational state of MOIS. The MOIS UI may be used any time a network connection is available from the MOIS system to a UI host machine. The requested data passed between the RT system and UI are communicated via LabVIEW network streams. LabVIEW network streams are an Ethernet based communication method designed and optimized for lossless, high throughput data communication.

Overall the MOIS software project consists of nine parallel loops across three execution targets. The diagram in Figure 1 shows how information is passed between the FPGA, RT, and PC environments. The following loops run in parallel on the desktop computer:

- Handling events from the user interface (UI Main.vi - Event Handling Loop)—Produces messages to the UI Message Loop based on front panel events.
- Handling messages from the user interface and the real-time controller (UI Main.vi - UI Message Loop)—Receives and responds to messages from the Event Handling Loop and, using network streams, the RT Message Handling Loop.
- Displaying messages and data from the CompactRIO device (UI Main.vi - Monitoring Loop)—Displays the latest values of information acquired from RT Loop - System Health and FPGA Monitoring.vi

The diagram shows message flow and state machine states for the software that runs in the UI. The drawing shows the states that occur during the operation of the software and arrows represent the message queue. The message strings and Boolean operators that imitate the state changes are shown on the arrows. Don’t be overly concerned about the complexity of the message passing and flow at this point. The diagram is useful in learning how data is passed and for debugging purposes. The complete diagram is attached at the end of the document.



Appendix D Figure 3 States and Messages for UI Software

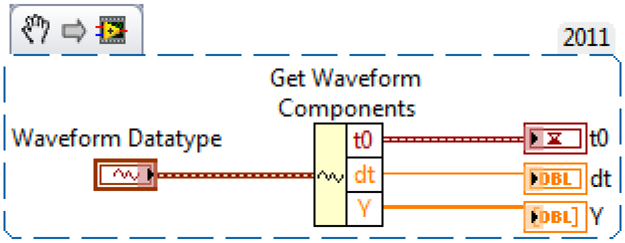
MOIS Real-Time (RT)

The RT code runs on the CompactRIO. The RT code reads measurement and timestamp data from the FPGA and writes it to the data file. The RT code monitors the communication between the FPGA and RT system and logs errors to the log file for supported errors. The RT system periodically receives updates of current time of day from the FPGA system time and updates the RT system clock. The RT system also includes a watchdog function that checks to ensure that the system is RT system is operating at via an inactivity watchdog. The inactivity watchdog uses a continuously incrementing counter. When this counter reaches some terminal count, it executes the expiration action which causes the RT software to log an error to log.txt.

The following loops run in parallel on the real-time controller:

- Handling commands from the user interface (RT Loop - UI Commands.vi)—Reads commands that are sent from UI Main.vi on the development computer and produces the appropriate messages.
- Handling messages from all loops on the real-time controller (RT Main.vi - Message Handling Loop)—Consumes messages from all loops that run on the real-time controller.
- Ensuring the RT controller remains responsive (RT Loop - Watchdog.vi)—Pets the watchdog, ensuring the RT controller remains responsive.
- Monitoring diagnostic information from the real-time controller and data from the FPGA (RT Loop - System Health and FPGA Monitoring.vi)—Monitors CPU and memory usage of the real-time controller and data from the FPGA VI. This information is written to network-published shared variables and appears on the System Monitoring tab of UI Main.vi.
- Acquiring and logging data from the FPGA (RT Loop - Acquisition and Logging.vi)—Runs FPGA Main.vi, reads data from the DMA FIFO, and logs this data to disk. The analog data is written to the DMA FIFO with each acquisition. When it is determined that a second of data loaded into the FIFO the RT system reads this block of data. The data block contains all channel measurements and has time stamp data added to the FIFO. The time stamp is read and then used as a t0 and the data is converted to a LabVIEW waveform. The delta t for the waveform is determined from the sampling rate. The data is then logged to disk. A new data file is started every hour. This is done by adding an hourly "trigger" to the check trigger state.

The waveform data type is a cluster comprised of the following:



Appendix D Figure 4

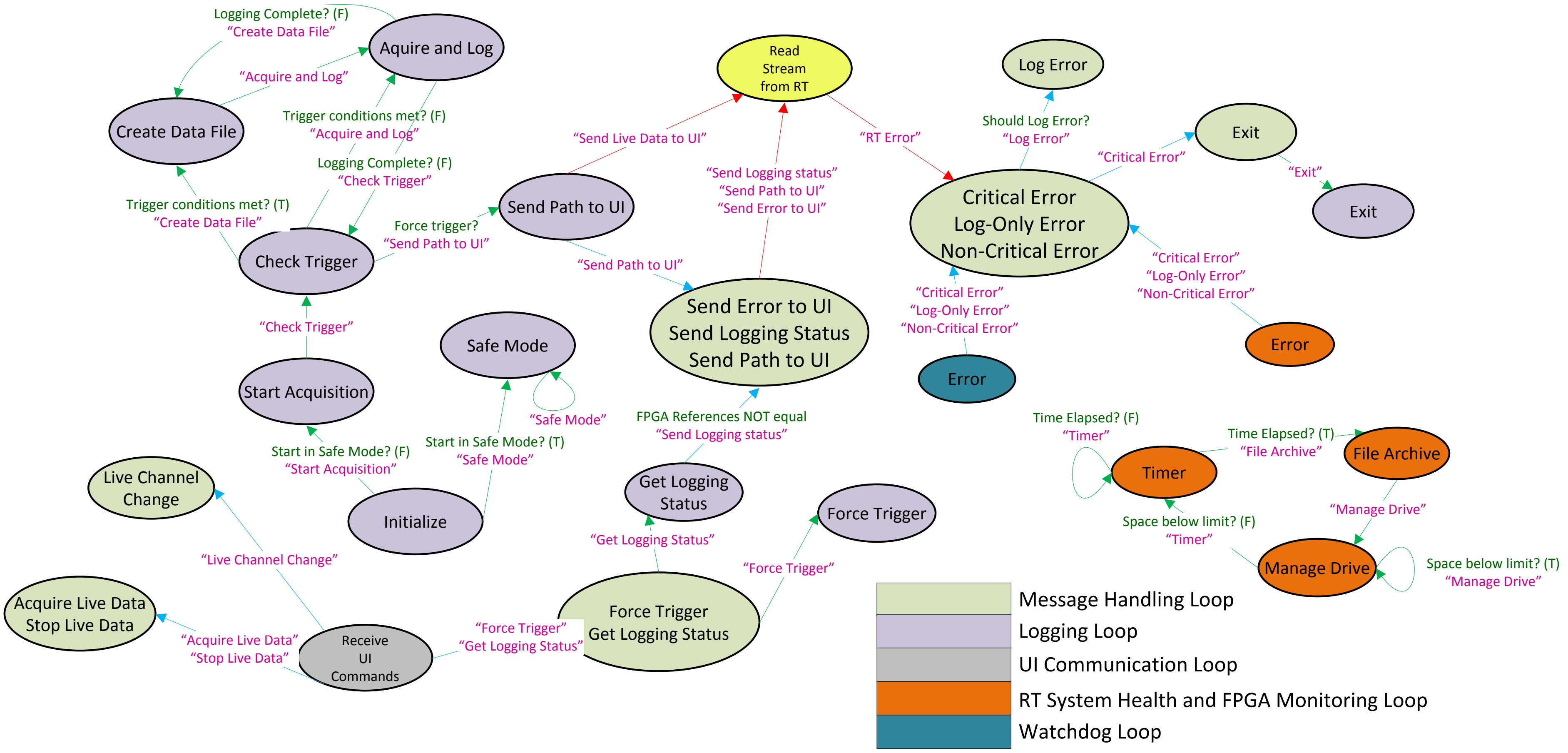
`t0` A Time Stamp representing the time at which the signal measurement starts

`dt` A double numeric that describes the difference in time in milliseconds between each sample in the signal

`Y` A 1D array of doubles that contains the values of the samples of that signal.

Timestamps for each value can be calculated by using t0, dt, and the index for the value. Other arbitrary information can be added to the waveform cluster as variants. This can be useful to attach additional information about the signal to show what manipulation may have already been performed on it.

- Serial — (RT Loop – Acquisition and Logging v2.vi) serial port acquisition and the update of the real time clock system time run parallel to rest of the software. They are not integrated into the QMH architecture at the time of writing this guide. The serial acquisition software uses FPGA FIFOs to pass the serial data and time stamp information from the FPGA to the RT system. The serial data is then written to the data file by using the reference to the current data file.
- Update System Time — (TimeSyncNI_GPS_RT_9068.vi) update system time software is used to update the RT clock to the FPGA GPS disciplined clock. The RT clock is used for the time and date in the naming of the data files. The actual data timestamps are passed up from the FPGA with the data.



Appendix D Figure 5 RT States and Messages

MOIS Field Programmable Gate Array (FPGA)

The FPGA code is run on the FPGA built into the CompactRIO system. The FPGA code looks much like any other LabVIEW code but is compiled by a separate compiler that generates a FPGA bitfile. The FPGA acts as the interface between the I/O modules and the RT system. All of the analog and serial module measurements are read into the FPGA and then passed up to the RT system via FIFO buffers or I/O nodes. The FPGA also reads the pulse per second (PPS) timestamp from the GPS module in slot 1 and runs the FPGA timekeeper to generate a FPGA based system clock that is used for data time stamping.

The following loop runs on the FPGA:

- Acquiring data (FPGA Main.vi - Acquisition Loop)—Acquires data from the C Series module inputs and writes this data to a DMA FIFO. The analog data is written to the DMA FIFO with each acquisition. When the RT codes determine that a second worth of data from all channels is loaded into the FIFO the RT system reads this block of data.
- Serial — The serial acquisition software uses a separate while loop for each serial port on the NI-9870 RS-232 module. The data flow from the FPGA to the RT is handled via FPGA interrupt requests (IRQ).
- FPGA Timekeeper—The FPGA code does not contain a state machine but has several components that run in parallel on the FPGA. Refer to the block diagram of FPGA9068.vi to see the code. The block diagram has comments explaining the various code sections of the timekeeper software.

1. Place the FPGA Timekeeper (Timekeeper.vi) in the top level outside of all structures
2. Update the FPGA Timekeeper time indicators with the current value of the FPGA Timekeeper nanosecond clock
3. In a flat sequence structure do this and the next steps in separate frames. Wait for a GPS PPS to occur. Timeout is in terms of 40 MHz clock ticks. A value of 41M (1.025 seconds) ensures enough time is given to receive a PPS before a timeout occurs.
4. Timestamp the arrival of the GPS PPS using the FPGA Timekeeper using Get Time.vi.
5. Wait for GPS timing data to arrive. Timeout is in terms of 40 MHz clock ticks. A value of 15M (375 milliseconds) ensures enough time is given to receive GPS timing data before a timeout occurs.
6. If GPS Status is Normal and a timeout did not occur while waiting for a GPS PPS and associated GPS Timing data, synchronize the FPGA Timekeeper.
7. Synchronize the FPGA Timekeeper to GPS by giving the Timekeeper two timestamps that correlate to the GPS PPS:
   A. GPS time of PPS
   B. Timekeeper timestamp of PPS
8. Update the GPS and FPGA Timekeeper status indicators using Get Status.vi.

Running MOIS from LabVIEW Development Environment

You can configure, run, and monitor MOIS entirely from executable files, but it's necessary to run from source code in the LabVIEW developer environment to make any changes other than channel scaling and serial port configuration changes. To get started with MOIS in the LabVIEW development environment:

1. Adapt the MOIS software project to your hardware. The MOIS project is already configured to work with the cRIO-9068 controller and specific modules installed. The MOIS User's Manual identifies the installed I/O modules and measurement channels.
2.
3. In the Project Explorer window, open My Computer»Utility - Configuration File Generator.vi.
   - Enter the configuration values that are appropriate for your application. Be sure to look at all the values in the TDMS Properties array for data file properties.
   - Sample rate
   - Analog channel scaling
   - Serial port configuration
4. Run the VI. LabVIEW generates a configuration file, Config.xml in the same directory as the .lvproj file.
5. Transfer this XML file to the root folder of the real-time controller. We use ssh and the client called puTTY that is available to download free online. The pscp.exe file is needed to perform a secure copy from the pc to the cRIO.

Run RT CompactRIO Target»RT Main.vi. This VI begins acquiring data and logging it using the configuration settings in Config.xml.

Open and run My Computer» MOIS UI Main.vi.

Enter the IP address of the MOIS CompactRIO device in the Controller Address text box and click Connect.

After you are connected, display live data in the waveform chart by clicking Acquire Live Data. Change the Live Data Channel control to see live data from different channels.

Click Exit to exit the application.

Adapting the MOIS Software Project to other NI Hardware

The FPGA VI in the MOIS LabVIEW project is compiled for specific FPGA and I/O hardware. If you would like to use a different FPGA or different C Series I/O modules, you must adapt the MOIS project to your hardware. The following steps refer to NI CompactRIO devices, but you also can adapt this software project to a NI Single-Board RIO device.

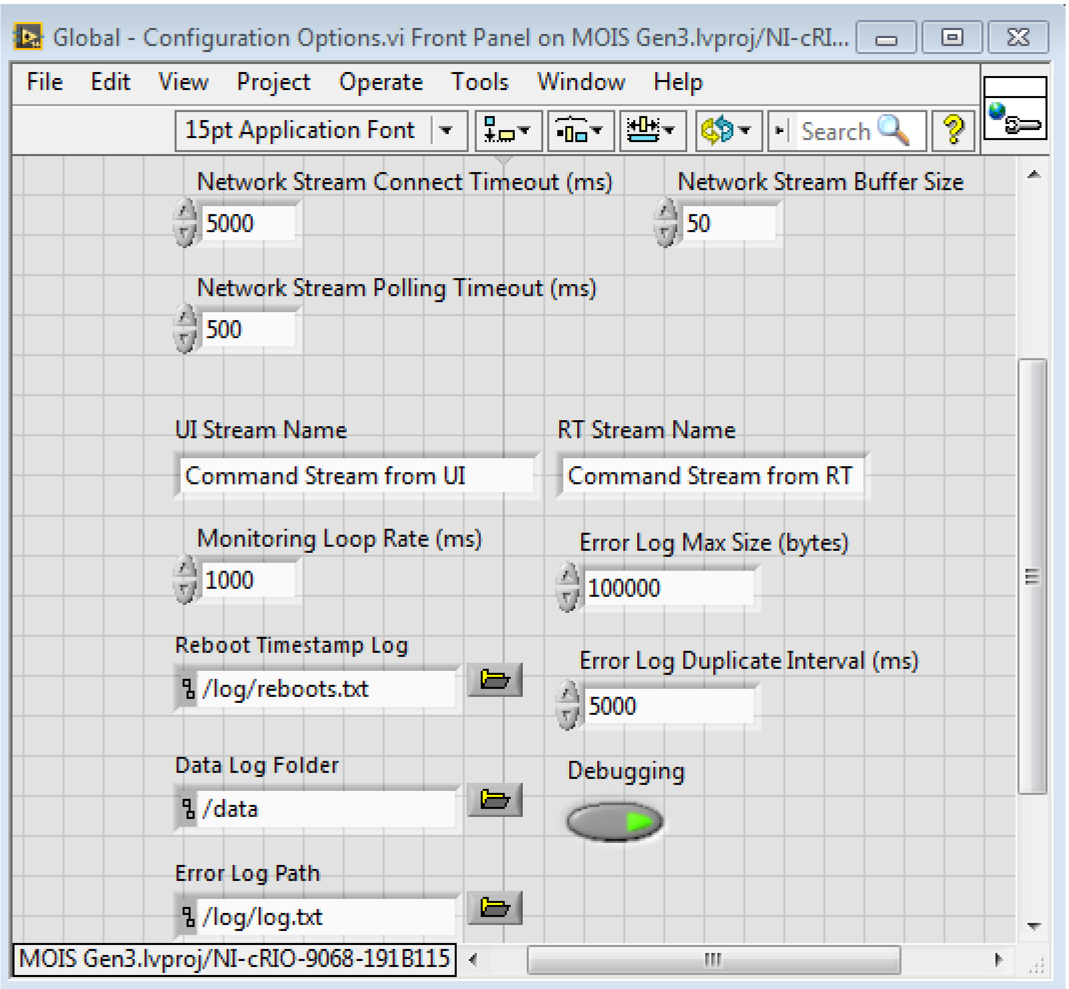
1. Ensure all devices are configured and connected to the same network as the development computer.
2. In the Project Explorer window, add or discover your RT CompactRIO target to the top-level project item.
3. Add or discover your CompactRIO chassis to the RT Compact RIO target you added in the previous step. Ensure the chassis is set to LabVIEW FPGA Interface mode.
4. Add or discover your FPGA target to the CompactRIO chassis you added in the previous step. When prompted to deploy settings, click Deploy Later.
5. Add or discover your C Series input module to the FPGA target you added in the previous step.
6. Drag the following project items from the default RT CompactRIO target to the one you added in step 2:
    - Error Handlers folder
    - Globals folder
    - Support VIs folder
    - RT Loops folder
    - Type Definitions folder
    - Shared Variables.lvlib
    - RT Main.vi
7. Drag the following project items from the default FPGA target to the one you added in step 4:
    - Support VIs folder
    - Type Definitions folder
    - FPGA Main.vi
8. Delete the default RT CompactRIO Target project item that no longer has any VIs associated with it.
9. Re-establish the link between RT Main.vi and the bitfile:
    - Open Start Acquisition and Logging.vi, located in the Support VIs folder on the RT CompactRIO Target.
    - Drag FPGA Main.vi from the Project Explorer window to the Open FPGA VI Reference VI function.
    - Open FPGA Main.vi and ensure the FPGA I/O Node uses the input channels you want. For example, you may want the FPGA I/O Node to read from Mod2/AI5 instead of Mod1/AI2. The actual channels you read from depend on your application.
    - By default, the FPGA I/O Node in this VI reads from Mod1/AI0–3.

10. You now can compile the FPGA VI and run it as part of your application.

Configuring MOIS Project Settings

In the Project Explorer window, open My Computer»Globals»Global - Configuration Options.vi and configure the MOIS project settings. For the default MOIS configuration no changes are needed for this global variable. It contains the paths to the data and log folders. Note that when opening the global from the folder in the My Computer folder tree the Windows the controls will automatically show paths in Windows format instead of the Linux path format. This is confusing but LabVIEW will automatically adjust the paths for the environment where the file is in the virtual folders in the project. If you open up the Globals virtual folder from the cRIO target folders the paths are correct for the Linux cRIO.

Change paths and file names as desired for the cRIO. The software does not create directories so you will need to create the folder on the cRIO if you wish to use a new folder.


Global - Configuration Options.vi Front Panel on MOIS Gen3.lvproj/NI-cRI...
File
Edit
View
Project
Operate
Tools
Window
Help
15pt Application Font
Search
MOIS Gen3.lvproj/NI-cRIO-9068-191B115

Network Stream Connect Timeout (ms) 5000

Network Stream Buffer Size 50

Network Stream Polling Timeout (ms) 500

UI Stream Name Command Stream from UI

RT Stream Name Command Stream from RT

Monitoring Loop Rate (ms) 1000

Error Log Max Size (bytes) 100000

Reboot Timestamp Log /log/reboots.txt

Error Log Duplicate Interval (ms) 5000

Data Log Folder /data

Debugging

Error Log Path /log/log.txt

Appendix D Figure 6 Global - Configuration Options.vi opened from cRIO target folders