Designing Systems Using the Static Structural Test Reference Architecture

This document provides guidance for designing structural test systems that use NI hardware and the Static Structural Test Reference Architecture design pattern. Refer to this document to create a system schematic for your specific testing requirements.

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Static Structural Test Reference Architecture Overview

The Static Structural Test Reference Architecture provides a pattern for designing systems that monitor and log responses from a variety of structures. The reference architecture is designed for short and long-term tests configured with up to 2,000 channels.

The Static Structural Test Reference Architecture is a customizable modular design that uses the NI Network-based C Series platform. Network-based products enable the deployment of instrumentation over a large area which reduces the amount of sensor cabling that would otherwise be needed.

Figure 1. Structural Flex Test

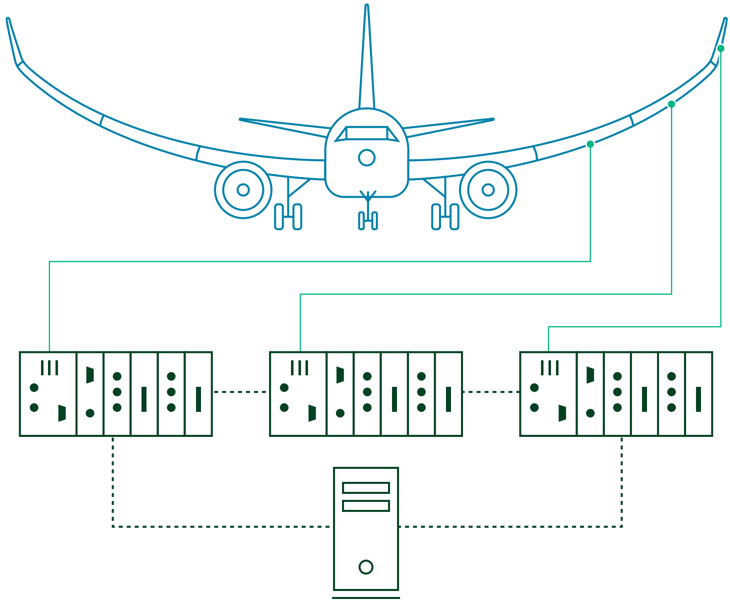
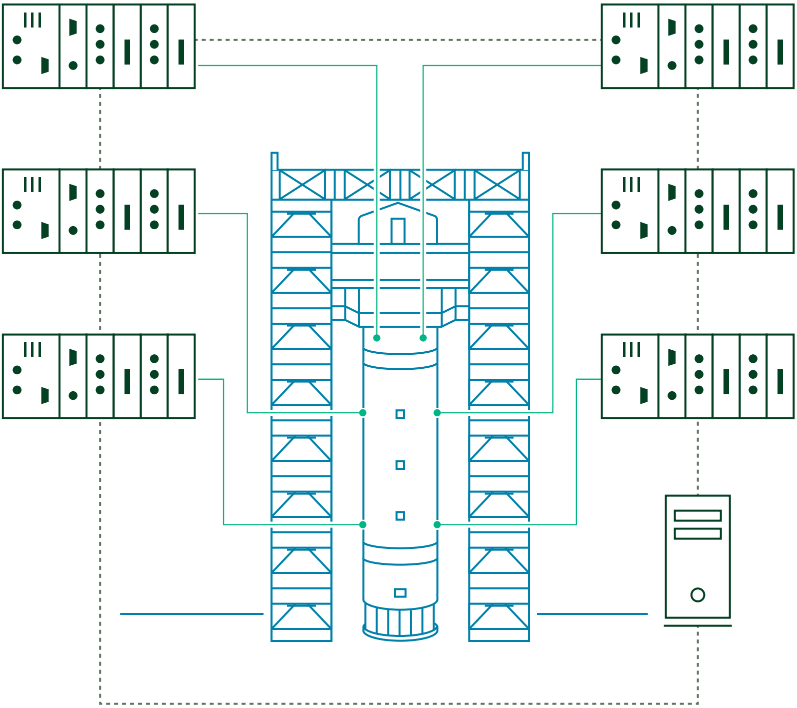


Figure 2. Static Structural Test



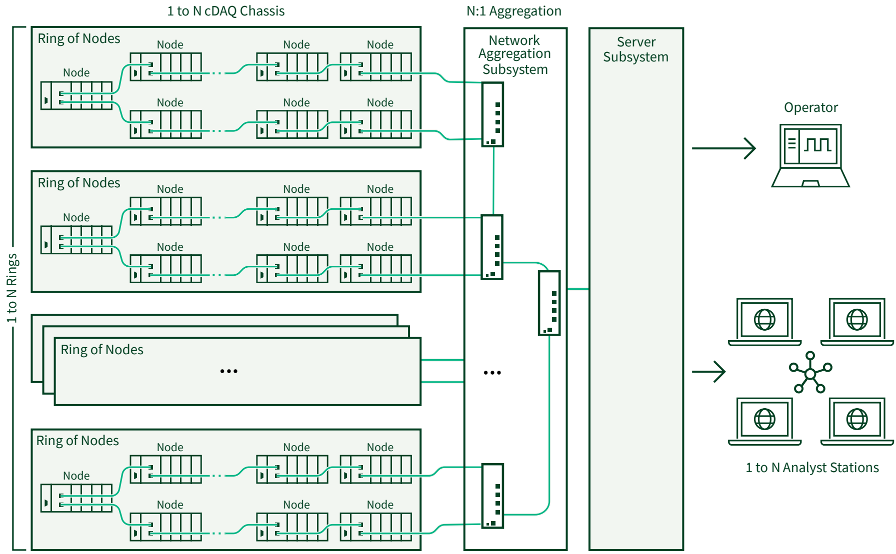
After August 2021, refer to the *Static Structural Test Reference Architecture Datasheet* for more information about the specific hardware and software components used in the validated test system and performance benchmarks for various tests.

Note Your test requirements may not be easily satisfied by strict adherence to the design pattern described in this document. Deviations from the design pattern and the use of additional instrumentation is expected; however, consider the deviation when performing a trade analysis of your design.

Hardware Overview

The Static Structural Test Reference Architecture is fundamentally a design pattern that you can use to instantiate a family of high-channel-count test systems, ranging from dozens to thousands of channels.

Figure 3. Static Structural Test Reference Architecture Hardware Overview



The Static Structural Test Reference Architecture comprises a combination of NI instrumentation and additional third-party hardware components grouped into a pattern of *nodes*, *rings*, and *subsystems*, further defined in the following sections. Refer to *Designing Your System* on page 7 for more information about choosing the hardware components for your test system needs.

Node

A *node* is a single cDAQ-9189 TSN-enabled Ethernet CompactDAQ chassis configured with up to eight C series modules. The chassis serves as the foundation for all instrumentation in the test system and the modular design enables you to tailor the distribution and makeup of the channels in the system.

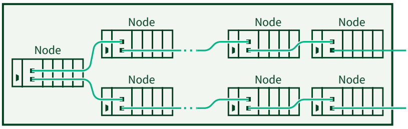
The reference architecture is intended for test systems composed of mostly quarter bridge strain gauges; however, the design also supports thermocouple and voltage channel types. The reference architecture supports the following C Series modules:

- NI-9235 C Series Strain/Bridge Input Module
- NI-9236 C Series Strain/Bridge Input Module
- NI-9213 C Series Temperature Input Module
- NI-9215 C Series Voltage Input Module

Ring

A *ring* is a network of nodes arranged in a *ring topology*, as shown in the following figure. A ring topology introduces redundancy into the system design so that any single node or cable failure cannot cripple adjacent instrumentation.

Figure 4. Ring Topology



Note You can scale the design pattern for your test needs by expanding the number of nodes in each ring and number of rings in each test system.

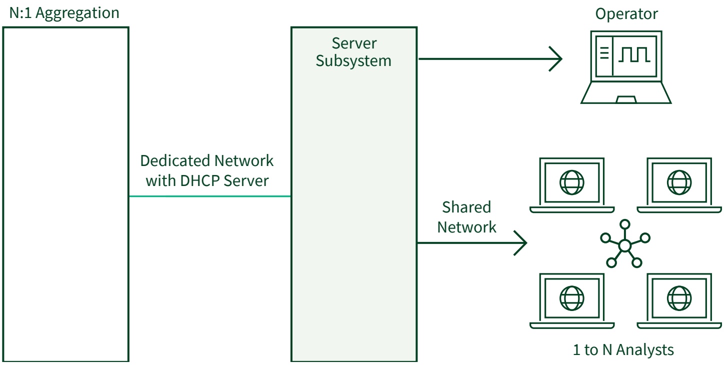
Network Aggregation Subsystem

The *network aggregation subsystem* aggregates all ring communication down to a single port using the cRIO-9805 Ethernet Switch Expansion Modules for CompactRIO. The network aggregation subsystem can include as many Ethernet switches that are required to aggregate the ring count in your system. The Ethernet switches are arranged in a prescribed pattern depending on the amount of rings in your system design, as described in *Aggregate Rings* on page 8.

Server Subsystem

The *server subsystem* is a host PC that receives all the aggregated Ethernet communication across a dedicated network, then sends the test data across a shared network to *operators* and *analysts* interested in monitoring the tests.

Figure 5. Detail View of Server Subsystem



Note All node IP Addresses must be assigned and managed by a DHCP server.

The server subsystem is responsible for test configuration and control and data logging. Refer to *Software Overview* on page 6 for more information about the software components in the server subsystem.

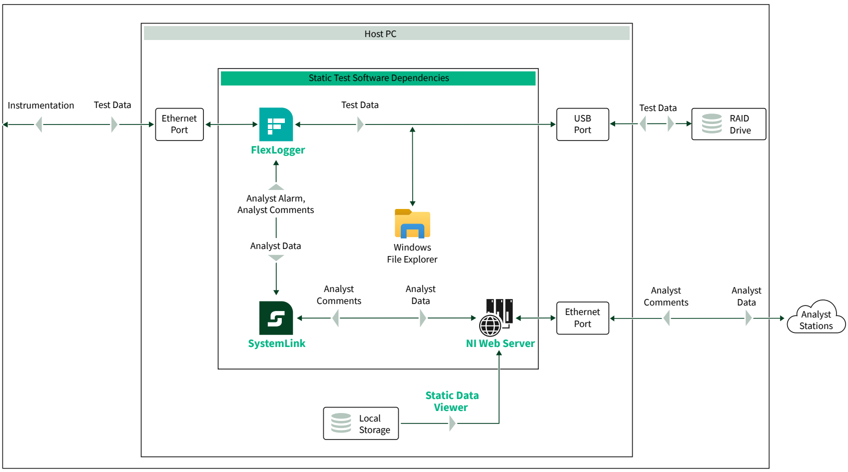
- **Operator**—Responsible for running and configuring the test on the host PC. The operator primarily interacts with FlexLogger to configure all instrumentation and test parameters and control the test system.
- **Analyst**—Responsible for monitoring active test data and verifying the completeness and success of the test. The analyst primarily interacts with the Static Data Viewer web application on their *analyst station* to view relevant channels, configure local alarms, and add comments to the log file.

Software Overview

The server subsystem hosts the Static Test Software, which is responsible for acquiring, logging, and sending test data to analysts and operators monitoring the test.

The following figure depicts the software architecture of the server subsystem when used with a RAID drive.

Figure 6. Static Test Software Architecture



The Static Structural Test Reference Architecture uses the following major software components.

- **FlexLogger**—Configures the test and instrumentation, logs data, visualizes channels, and sets events. FlexLogger allows you to import sensor configurations and provides an environment to manage and analyze test data during the test process.
- **Static Data Viewer**—Provides multiple test analysts a concurrent, personalized view into subsets of the test. Analysts can view test system health and live data of selected channels whenever an acquisition is active. The Static Data Viewer is a web-based application that enables numerous analysts to annotate log files and configure and set alarms on specific

channels. The Static Data Viewer is accessible by any remote system with a web browser and access to the application.

- **NI Web Server**—Delivers the Static Data Viewer web application to remote analyst stations and responds to HTTP requests from the Static Data Viewer.
- **File Explorer**—Manages the log files created by FlexLogger. Use File Explorer to browse, move, and archive the test data.
- **SystemLink**—Provides communication between FlexLogger and the Static Data Viewer.

Designing Your System

Complete the following steps to implement the Static Structural Test Reference Architecture design pattern for your specific test needs.

1. *Map your sensor list to NI instruments*.
2. *Group modules into nodes*.
3. *Group nodes into rings*.
4. *Aggregate rings to a single port*.
5. *(Optional) Adjust ring sizes*.
6. *Select power supplies*.
7. *Select network cables*.
8. *Select power wiring*.
9. *Select sensor wiring*.
10. *Select the host PC*.
11. *Select storage hardware*.
12. *Select devices for analyst stations*.

Map Your Sensor List to NI Instruments

Map your sensor list to the supported C series modules in the following table.

Table 1. Supported C Series Modules

Channel Type	Model	Description
Quarter Bridge Strain	NI-9235	8-Channel, 10 kS/s/channel, 120 Ω Quarter-Bridge Strain Gage, C Series Strain/Bridge Input Module
	NI-9236	8-Channel, 10 kS/s/channel, 350 Ω Quarter-Bridge Strain Gage, C Series Strain/Bridge Input Module
Thermocouple	NI-9213	16-Channel, 75 S/s Aggregate, ±78 mV C Series Temperature Input Module
Voltage	NI-9215	4-Channel, ±10 V, 100 kS/s/ch, 16-Bit, Simultaneous Input, C Series Voltage Input Module

Group Modules Into Nodes

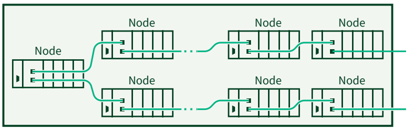
Group your C Series modules into nodes.

1. Arrange C Series modules into groups of up to eight and position them around the structure by optimizing total module count with the benefits of module proximity to the structure.
2. Assign each group of C Series modules to one cDAQ-9189 TSN-enabled Ethernet CompactDAQ chassis to complete a single node.

Group Nodes Into Rings

Arrange your nodes into rings, as shown in the following figure.

Figure 7. Ring Topology



Note The allowable distance between each node is equal to the maximum length of a CAT-5 cable (100 m).

The maximum number of nodes per ring is dependent on the amount of cRIO-9805 Ethernet switches needed to aggregate the system. The maximum ring sizes are also based on the total number of nodes in the system. Design your rings within the limits in the following table.

Total Nodes	Maximum Nodes per Ring
1-15	15
16-18	9
18-42	7

Note The maximum amount of nodes per ring reduces as total nodes in the system increase to account for the allowable amount of network hops in the TSN network. Refer to *Figure 10.* on page 10 for more information.

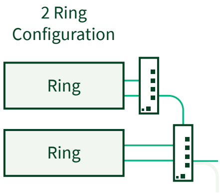
Aggregate Rings

Aggregate the list of rings to a single port.

The cRIO-9805 Ethernet switch can aggregate communication on up to three out of its four Ethernet ports. When arranging the cRIO-9805 devices, the two ports coming off of a ring must be connected to the same switch.

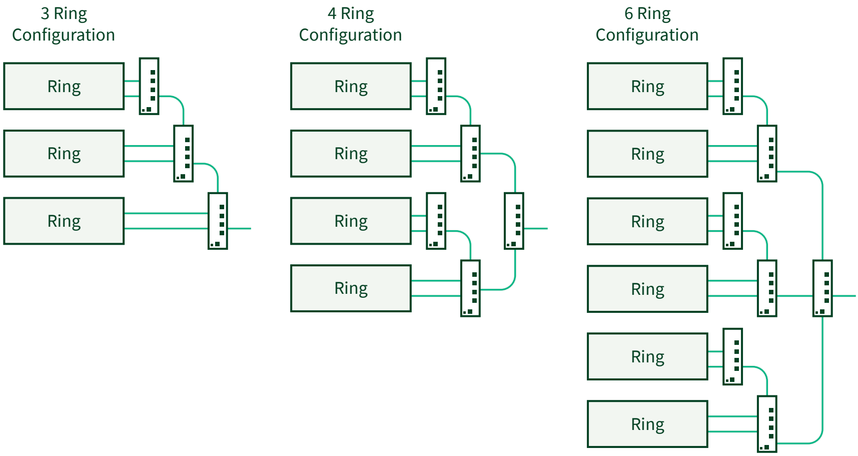
Divide your ring list into pairs and aggregate each pair together according to the pattern in the following figure.

Figure 8. Ring Pair Aggregation



An additional cRIO-9805 can aggregate up to three ring pairs, as shown in the following figure. Use this recursive pattern to group rings until all ring communication aggregates to a single network port.

Figure 9. Aggregation for Additional Ring Configurations

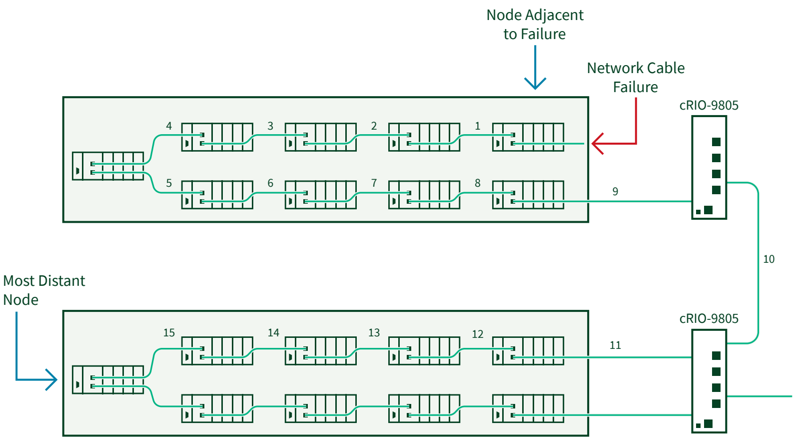


(Optional) Adjust Ring Sizes

You can adjust the ring sizes in your design so long as no two nodes are more than 15 hops apart.

The TSN network can tolerate a maximum number of 15 hops between any two nodes in the network. When a cable or node fails within a ring, the remaining nodes in the ring reconfigure into two daisy chains. In a worst case scenario, a ring of *N* nodes could reconfigure into a daisy chain of *N* nodes.

Figure 10. Network Hops Between Nodes After Network Cable Failure



Select Power Supplies

Select the power supplies for your nodes and the network aggregation subsystem. Each CompactDAQ chassis and Ethernet switch in your system needs its own DC power connection.

Instead of using the dedicated power supply that ships with these components, you can consolidate AC power conversion into larger power supplies that distribute their DC outputs to multiple components in the system.

Component Power Requirements

The CompactDAQ chassis and Ethernet switch have the following power requirements per component:

- cDAQ-9189 Chassis—16 W, 9 V to 30 V
- cRIO-9805 Ethernet switch—5 W, 9 V to 30 V

Note The power requirement for the cDAQ-9189 includes maximum 1 W power load per slot across rated temperature. Quarter bridge strain gauge modules can draw close to 1 W depending on the use case. Refer to documentation for each component to create more sophisticated power budgets.

Power Supply Options

Refer to the following table to determine the best power supply option for your specific system design.

Table 2. Supported Power Supplies

Model	Description
PS-14	24 VDC, 3.3 A, 80 W DIN-Mountable Industrial Power Supply
PS-15	24 VDC to 28 VDC, 5 A, 120 W, DIN-Mountable Industrial Power Supply
PS-16	24 VDC to 28 VDC, 10 A, 240 W, DIN-Mountable Industrial Power Supply

Note For example, a single PS-15 can comfortably power six fully loaded CompactDAQ chassis and one Ethernet switch, and the PS-16 can comfortably power 13 fully loaded CompactDAQ chassis and three Ethernet switches.

Related Information

cDAQ-9189 Specifications

cRIO-9805 Specifications

NI-9235 Specifications

NI-9236 Specifications

NI-9213 Specifications

NI-9215 Specifications

Select Network Cables

Select the network cables needed for daisy chaining nodes and connecting rings to the Ethernet switches in the network aggregation subsystem.

NI offers the following CAT-5E Ethernet cables in various lengths.

Table 3. NI Ethernet Cables

Model	NI Part Number	Length
8-Pin Male Ethernet to 8-Pin Male Ethernet, CAT-5E Ethernet Cable	151733-0R3	0.3 M
	151733-01	1 M
	151733-02	2 M
	151733-05	5 M
	151733-10	10 M

Select Power Wiring

Select the power wiring for the cDAQ-9189 chassis and Ethernet switches.

NI does not offer off-the-shelf cable assemblies for the CompactDAQ chassis or Ethernet switch. NI recommends using ferrules for stranded wires, and using the following wire gauge as defined in the specifications document for each model.

Table 4. Power Wire Gauges

Model	Wire Gauge
cDAQ-9189	24 AWG to 14 AWG
cRIO-9805	24 AWG to 16 AWG

Select Sensor Wires

Select the sensor wiring for the C Series modules.

NI does not offer off-the-shelf cable assemblies for sensors, and recommends the following wire gauges as defined in the specifications document for each model.

Table 5. C Series Module Wire Gauges

Model	Wire Gauge
NI-9213	28 AWG to 18 AWG copper conductor wire
NI-9215	Screw-terminal: 16 AWG to 14 AWG copper conductor wire
	Spring-terminal: 30 AWG to 12 AWG copper conductor wire
NI-9235	28 AWG to 18 AWG copper conductor wire
NI-9236	

Select the Host PC

Select a host PC for the server subsystem that meets the following minimum requirements:

- 64 GB RAM
- Intel Xeon E-2286G CPU 4.0 GHz, 6-Core
- 2 Gigabit Ethernet adapters (one dedicated for instrumentation network)
- Windows 10 64-bit
- 30 GB minimum of free disk space
- DHCP server support or an external DHCP-enabled router

Select Storage Hardware

Select the storage hardware to store data logs from your tests.

Consider data throughput and test duration to choose storage hardware that is appropriately sized for your system needs.

FlexLogger encodes all data into 8 byte data points, so 2,000 channels acquired at 100 S/s produces 1.6 MB/s of data.

Refer to the following table for an example of how to determine the storage size needed for your system requirements.

Table 6. Example of Data Throughput for 2,000 Channels Acquired at 100 S/s

Data Throughput	Redundant Logging
1.6 MB/s	3.2 MB/s
6 GB/hr	12 GB/hr
140 GB/day	280 GB/day
1 TB/week	2 TB/week

Select Devices for Analyst Stations

Select the devices to use for analyst stations.

Consider the following recommendations to ensure the devices are compatible with the Static Data Viewer.

- Multiple monitors—The Static Data Viewer can pop-out into multiple browser tabs for a single test; users can configure channels and alarms in one tab while displaying waveforms in another.
- Browser—Google Chrome
- Screen resolution—1440 x 900 pixels

Next Steps

After you design your system, refer to the *Static Structural Test Reference Architecture Getting Started* document for guidance on setting up your system components, instructions for configuring the Static Data Viewer, and verifying your system setup.

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