Static Structural Test Reference Architecture

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Aerospace and Defense Static and Fatigue Structural Test Systems

The Challenge

Aircraft, space-launch vehicles, satellites, and missiles undergo extensive continuous fatigue testing to prove that they will survive the stresses of flight before deployment. Because structural test and mechanical engineering teams want to be confident that they will pass the monthslong or yearslong tests, preliminary structural testing must gather enough information about possible failure points to improve the design before beginning fatigue test. Test requirements include:

- Minimizing the risk of structure, equipment, and measurement failures during fatigue test
- Gathering enough information about the structure from preliminary static testing before beginning fatigue test
- Optimizing the structural design to withstand stress by connecting the test data to the design and subsequent test runs

Static Structural Test Reference Architecture

The Static Structural Test Reference Architecture is a formula for building static structural measurement systems with NI hardware and software in a design pattern that has been tested and validated. The reference architecture includes the following documents:

Reference Architecture Documentation

- **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.

- **Commissioning a System from the Static Structural Test Reference Architecture**—This document contains information that is necessary to set up and operate the components included in the reference architecture, including hardware installation and software configuration procedures.

- **Using the Static Data Viewer**—This document is a user's guide for a new piece of application software built for structural engineers and analysts who use the data obtained during the static or fatigue structural test.

- **Creating a FlexLogger Project from an Excel Spreadsheet**—This document outlines the process for defining a FlexLogger project in an Excel spreadsheet, setting up the worksheets in the spreadsheet, and importing a new FlexLogger project from a spreadsheet.

- **Benchmarking a System Built from the Static Structural Test Reference Architecture**—This document includes the expected performance specifications of a static structural test system built using the previous documents based on actual system testing.

The reference architecture calls for instrumentation nodes that are composed of cDAQ-9189 CompactDAQ Chassis, NI-9235 or NI-9236 C Series Strain/Bridge Input Modules, NI-9213 C Series Temperature Input Modules, and NI-9215 C Series Voltage Input Modules for up to 2,000 measurement channels. The instrumentation nodes are connected via a redundant network that is managed by cRIO-9805 Expansion Module for CompactRIO network switches and powered by PS-25 Industrial Power Supplies.
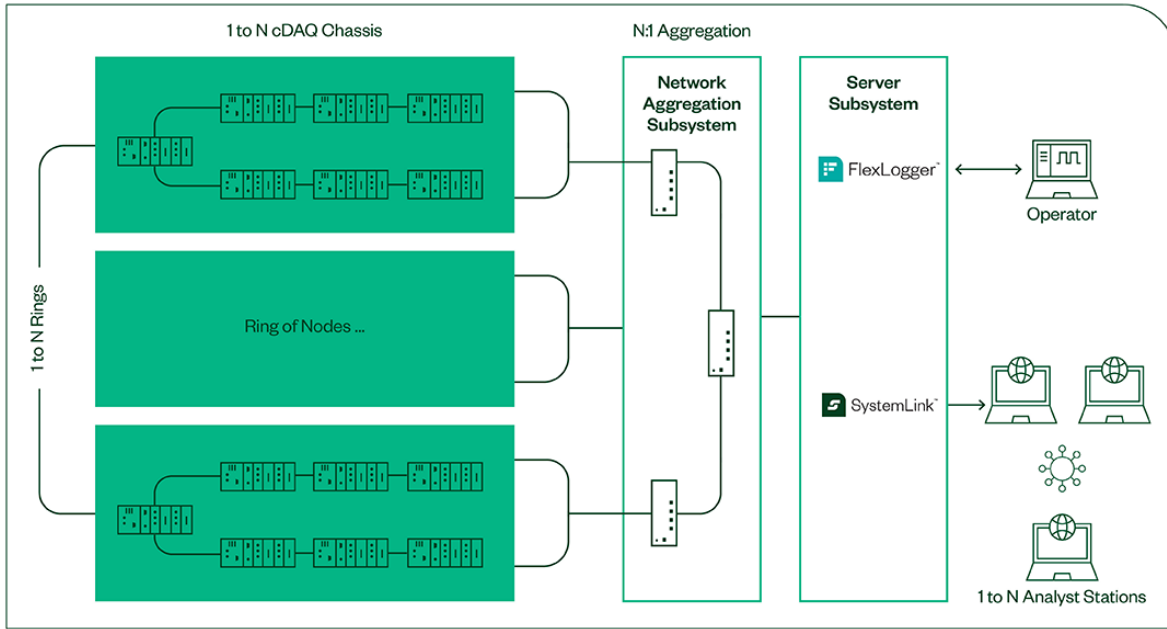
Figure 1. The Static Structural Test Reference Architecture describes building static test systems composed of NI instruments and additional third-party hardware components grouped into a pattern of nodes, rings, and subsystems. See the Static Structural Test Reference Architecture System Design Guide for more information.

FlexLogger software and SystemLink software from NI are used to configure, operate, and monitor the test instruments as well as collect and host test data. The Static Test Viewer is a web application for test data analysts that works with SystemLink. Analysts can view the data at any terminal with access to the network hosting the test data, monitor ongoing tests, create alarm triggers, build graphs, analyze past data, and more.
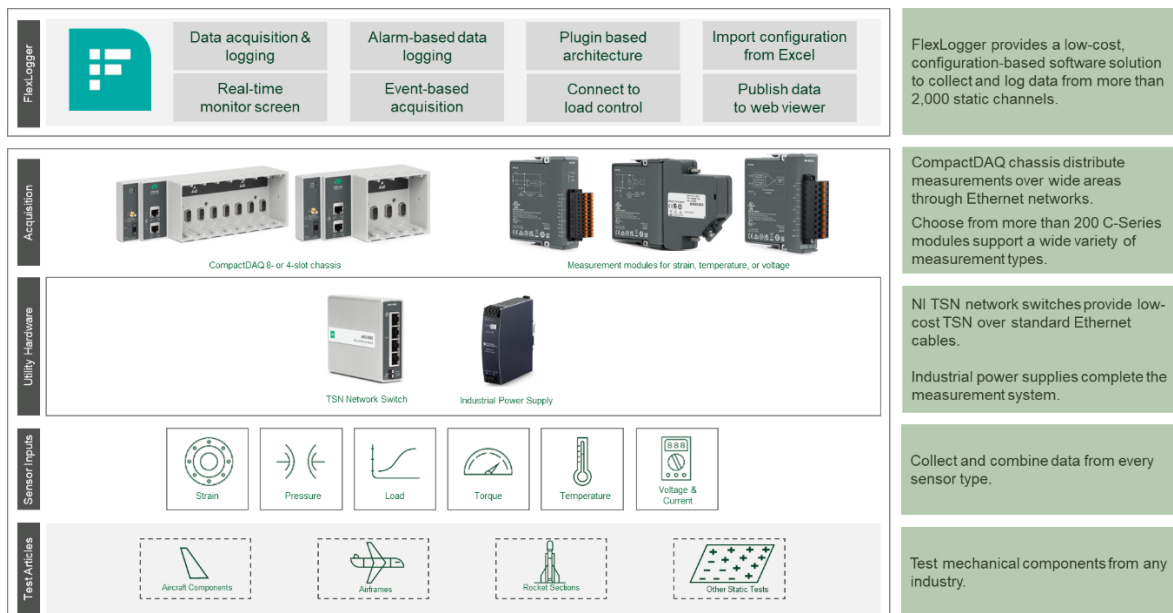

Figure 2. NI software and hardware tools are interoperable and are support by, and support, a wide range of industry standard tools. The Static Structural Test Reference Architecture is a guide for designing a test system that has been validated and tested with performance metrics. If your specifc requirements call for other tools, there is a good chance the components of the reference architecture can suppport you.

Static Test Bundles

The reference architecture describes how to select, order, configure, and deploy standard NI components into a solution for solutions ranging from 20-2,000 channels. System engineers can design specific systems and order these parts individually.

NI also offers pre-configured bundles in a variety of options to simplify the design and purchase of these systems. Ordering these bundles offers a number of benefits:

- Reduce the time to find the right parts and assemble a quote
- Single line item on purchase orders
- Systems are assembled by NI's expert technicians, reducing deployment time
- Systems are pre-tested as a system by NI's manufacturing team
- Bundle systems are discounted saving project costs

The following bundle part numbers are available:

	12-Ohm Strain	350-Ohm Strain	Temperature
64 Channels • 1 chassis • 8 modules • 1 power supply	868106-01B	868106-02B	
128 Channels • 1 chassis • 8 modules • 1 power supply			868106-03B
192 Channels • 3 chassis • 24 modules • TSN Switch • 4 power supply	868106-04B	868106-05B	
384 Channels • 3 chassis • 24 modules • TSN Switch • 4 power supply			868106-06B
448 Channels • 7 chassis • 56 modules • TSN Switch • 8 power supply	868106-07B	868106-08B	
896 Channels • 7 chassis • 56 modules • TSN Switch 8 power supply			868106-09B

CompactDAQ

CompactDAQ systems collect and deliver the data validation you need to meet test requirements at any distance and in any environment, including static and fatigue structural test facilities and other harsh environments. These portable, customizable solutions—made of data acquisition modules that can synchronize measurements across a network—help you get exactly the measurement capability you need while digitizing data closer to sensors, minimizing noise, and simplifying cabling in the field.

CompactDAQ chassis and modules are designed to meet the rigorous requirements of structural test facilities and withstand operating temperatures from -40 °C to 70 °C and up to 50 g of shock.

With the modularity of CompactDAQ, you can create static test systems of up to 2,000 channels with exactly the number of quarter-bridge strain gage, thermocouple, and voltage input channels you need.

The cDAQ-9189 chassis complies with IEEE 802.1 Time Sensitive Networking (TSN) synchronization standards that enable the tight alignment of measurements taken from distributed instruments.

CompactDAQ offers best-in-class strain measurement performance at the best price point along with accurate thermocouple and voltage measurements, resulting in a highly reliable and repeatable measurement system.

C Series Strain/Bridge Input Module

NI-9235

10 kS/s/channel, 120 Ω Quarter-Bridge Strain Gage, 8-Channel, C Series Strain/Bridge Input Module

The NI-9235 measures dynamic strain on all channels simultaneously, allowing for synchronized, high-speed measurements. This capability is important for applications, such as impact tests, that require comparison across many channels at a particular instant in time.

The NI-9235 includes built-in voltage excitation for quarter-bridge sensors. It also has 60 VDC isolation and 1,000 Vrms transient isolation, providing high-common-mode noise rejection and increased safety.

SPECIFICATIONS	
Strain gage compatibility	120 Ω quarter-bridge
Resolution	24-bit
Accuracy	Input noise: 0.38 μV/V RMS @ 1 kS/s; 0.85 μV/V RMS @ 1 kS/s
	SFDR (1 kHz, -60 dBFS): 110 dB
	THD (1 kHz, -20 dBFS): -90 dB
Sample rate	10 kS/s/channel
Channels	8 simultaneously sampled
Operating range	-40 °C to 70 °C, 5 g vibration, 50 g shock
MTBF	566,796 hours at 25 °C; Bellcore Issue 2, Method 1, Case 3, Limited Part Stress Method

NI-9236

10 kS/s/channel, 350 Ω Quarter-Bridge Strain Gage, 8-Channel, C Series Strain/Bridge Input Module

The NI-9236 measures dynamic strain on all channels simultaneously, allowing for synchronized, high-speed measurements. This capability is important for applications, such as impact tests, that require comparison across many channels at a particular instant in time.

The NI-9236 includes built-in voltage excitation for quarter-bridge sensors. It also has 60 VDC isolation and 1,000 V rms transient isolation, providing high-common-mode noise rejection and increased safety.

SPECIFICATIONS	
Strain gage compatibility	350 Ω quarter-bridge
Resolution	24-bit
Accuracy	Input noise: 0.25 μV/V RMS @ 1 kS/s; 0.5 μV/V RMS @ 1 kS/s
	SFDR (1 kHz, -60 dBFS): 115 dB
	THD (1 kHz, -20 dBFS): -95 dB
Sample rate	10 kS/s/channel
Channels	8 simultaneously sampled
Operating range	-40 °C to 70 °C, 5 g vibration, 50 g shock
MTBF	566,796 hours at 25 °C; Bellcore Issue 2, Method 1, Case 3, Limited Part Stress Method

C Series Temperature Input Module

NI-9214

16-Channel, 68 S/s Aggregate, ±78 mV C Series Temperature Input Module

The NI-9214 is a high-density thermocouple input module that is designed for higher channel-count systems. With this module, you can add thermocouples to mixed-signal test systems without taking up too many slots. The NI-9214 includes anti-aliasing filters, open-thermocouple detection, and cold-junction compensation for high-accuracy thermocouple measurements. It features NIST-traceable calibration and a channel-to-earth ground double isolation barrier for safety, noise immunity, and high-common-mode voltage range.

SPECIFICATIONS	
Thermocouple compatibility	J, K, T, E, N, B, R, S thermocouple types
Resolution	24-bit
Sensitivity	Up to 0.01 °C measurement sensitivity
Sample rate	68 S/s aggregate
Channels	16 multiplexed
Operating range	-40 °C to 70 °C, 5 g vibration, 50 g shock
MTBF	1,457,513 hours at 25 °C; Bellcore Issue 2, Method 1, Case 3, Limited Part Stress Method

C Series Voltage Input Module

NI-9215

±10 V, 100 kS/s/ch, 16-Bit, Simultaneous Input, 4-Channel C Series Voltage Input Module

The NI-9215 performs differential analog input. The module contains NIST-traceable calibration, a channel-to-earth ground double isolation barrier for safety and noise immunity, and high-common-mode voltage range. It is also offered in two connectivity variants: 10-position screw terminal or BNC.

SPECIFICATIONS	
Input range	±10 V
Resolution	16-bit
Accuracy	Input noise: 1.2 LSB_{rms} or 7 LSB (peak-to-peak)
Sample rate	100 kS/s/channel
Channels	4 simultaneously sampled
Operating range	-40 °C to 70 °C, 5 g vibration, 50 g shock
MTBF	1,167,174 hours at 25 °C; Bellcore Issue 6, Method 1, Case 3, Limited Part Stress Method

FlexLogger Application Software

FlexLogger is a measurement configuration and test operation tool that test engineers and technicians use to label channels, implement rules or channel math, adjust instrument settings, perform calibration, and run tests. It works seemlessly with C Series Strain/Bridge Input Modules and C Series Temperature Input Modules, making it fast and easy to select sensors and properly document measurement channels in software when installing and commissioning static and fatigue test systems.

FlexLogger makes building flexible, scalable data-logging systems with NI DAQ hardware simple—no programming required. You can use sensor-specific configuration workflows to quickly set up, validate, and log a mix of synchronized measurements from strain gages, other bridge sensors, thermocouples, and analog signals. The software automatically saves metadata documenting your test configuration, so you can quickly trace test results and make comparisons across multiple tests. FlexLogger works with SystemLink software to log test data to multiple local or network locations based on your system needs and settings.
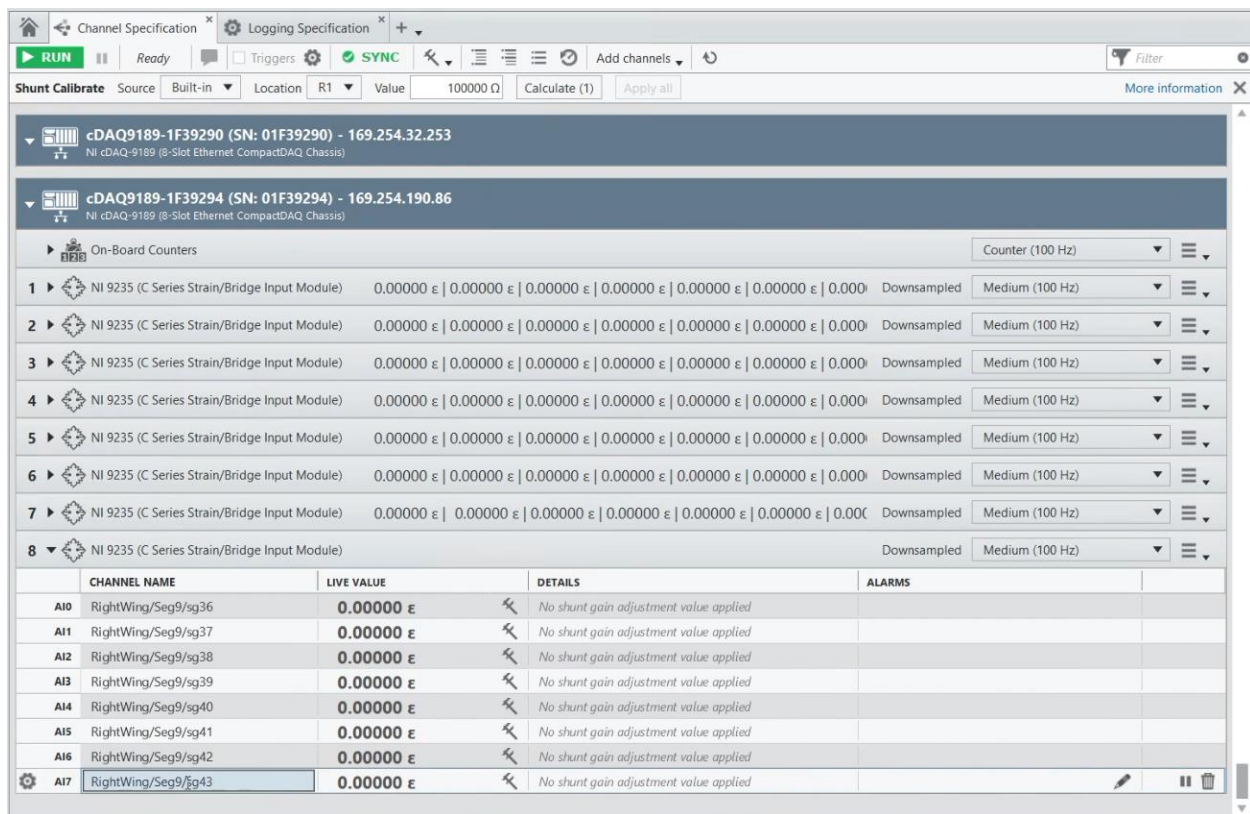

Figure 3. FlexLogger software gives you immediate access to up to 2,000 measurement channels of the C Series modules in your static structural test system. You can easily label, add channel math, run shunt calibration over many channels at once, and more with this ready-out-of-the-box software tool.

SystemLink Application Software

SystemLink software helps enterprises analyze test and measurement data to remove operational inefficiencies, uncover actionable insights, and improve overall performance across their test workflows. This network-based test system and test data management tool can operate on a dedicated or enterprise network.
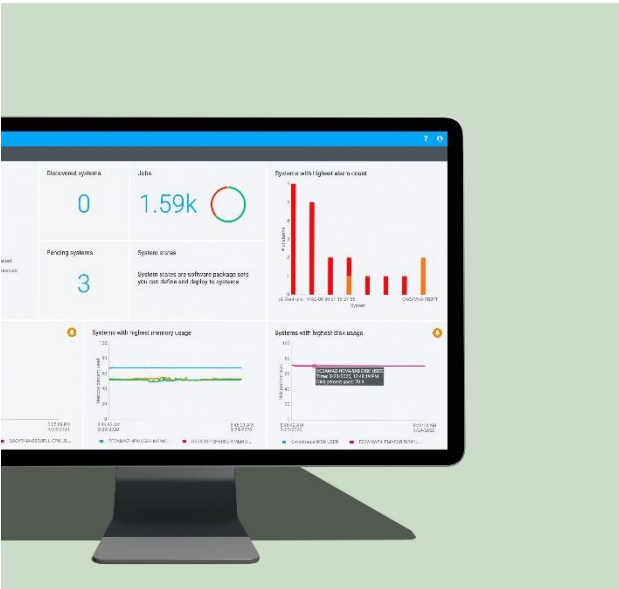
Test engineering teams and technicians use SystemLink to:

- Centrally manage and support all test assets
- Minimize standup and maintenance time
- Ensure system configuration compliance
- Efficiently manage, search, share, and analyze measurement data

Structural analysts, design teams, and mechanical engineering teams use SystemLink to:

- Access centralized data via the Static Data Viewer dashboard
- Improve overall test execution, tracking, and test result management
- Automate reports with proactive notifications
- Analyze all test data, current and past

Static Data Viewer Web Application

The Static Test Data Viewer is a thin-client application that is loaded from the SystemLink server and configured within a web browser. Any number of structural and mechanical analysts or design engineers can access test data from current or previous test runs with any computer that has access to the SystemLink server. Those engineers and analysts can then use the Static Data Veiwer to organize, configure, collate, and publish measurement data, reports, and alerts.

SEE THE STATIC STRUCTURAL TEST
REFERENCE ARCHITECTURE IN ACTION

PVI Systems—Advanced Structural Test Expertise

PVI Systems, a US-based NI Partner with extensive experience in static and dynamic structural test systems, offers expertise in designing and delivering systems with NI hardware and PVI Systems Chameleon software.

Chameleon's unique architecture provides incredible power and flexibility with an easy-to-use interface. Other data-logging solutions can be overly complex and inflexible, but Chameleon features the same intuitive interface, whether you're configuring low-channel-count (10 to 100) systems, high-channel-count (1,000+) systems, or anything in between.

Chameleon offers compatibility with a wide variety of NI controllers and data acquisition modules so you can configure a system to meet your specific application requirements. You can get your system up and running in minutes and acquiring static and dynamic signals at multiple sample rates from a variety of sensor types.

CHAMELEON Specifications

System Configuration		
Scalability to 1,000+ channels	Multiple control head and chassis configurations with distributed controllers or MXI interface	NI PXI and PXI Express, NI CompactDAQ, and NI FieldDAQ™ hardware platforms
Measurements		
Measurement recipe management	Strain and bridge sensor calibration (offset and gain adjustment)	Voltage, IEPE, strain, bridge-based, thermocouples, RTDs, current, resistance signal types
AC or DC coupling	Strain features designed specifically for structural testing, including null offset and shunt calibration	Analog-to-digital and digital-to-analog conversion up to 24 bits with 118 dB dynamic range
Timing		
Multiple-chassis time synchronization	Synchronization with interchannel skew as low as 5 ns	Sampling rates from less than 1 S/s up to 2 MS/s
	Mixed sample rates across modules with variable data-logging rates that update on the fly	External timing source GPS, IEEE 1588, IRIG-B

PVI Systems, the makers of Chameleon, also offers the ability to customize and modify this software to meet your needs. The company has worked with numerous test groups to add sensor types, data export formats, and custom display options to ensure Chameleon works for you.

PVI Systems also provides installation and commissioning services including complete system design, sensor selection and installation, system installation and verification, software customization, and training.

From software architecture to system-level hardware design, PVI Systems focuses on developing the most effective solutions, resulting in critical benefits for its customers. The company implements the highest standards in every project through "Engineered Excellence"—a process that starts from a fundamental understanding of the problem to determine the best and most innovative path to the solution and continues through project completion and delivery. PVI Systems believes constant communication and interaction between its engineers and customers are crucial to the success of each project and key to building valuable and trustworthy relationships.

To learn how you can decrease program risk and shorten test timelines, contact PVI Systems at (860) 739-8044 or info@pvisys.com. You also can connect with your NI account manager at (888) 280-7645 or info@ni.com.

Ensuring Successful Static and Fatigue Structural Test Systems

NI offers a variety of service options for static and fatigue structural test systems including hardware services and calibration, on-site system calibration, installation verification to ensure the NI content is properly installed and configured in your system, and in-person or online training for FlexLogger software.

Contact your account manager or call or email us to learn more about how NI can help you reduce the design, deployment, and commissioning times in your next structural test system at (888) 280-7645 or info@ni.com.

NI Services and Support

Repair and Calibration

Installation Reviews and Verification

FlexLogger Software Training

Gobal Support

Image Courtesy of Rocket Factory Augsburg (RFA)

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