Pro Tips for Validating Designs With CompactDAQ

Adam Dewhirst

Chief Engineer, NI

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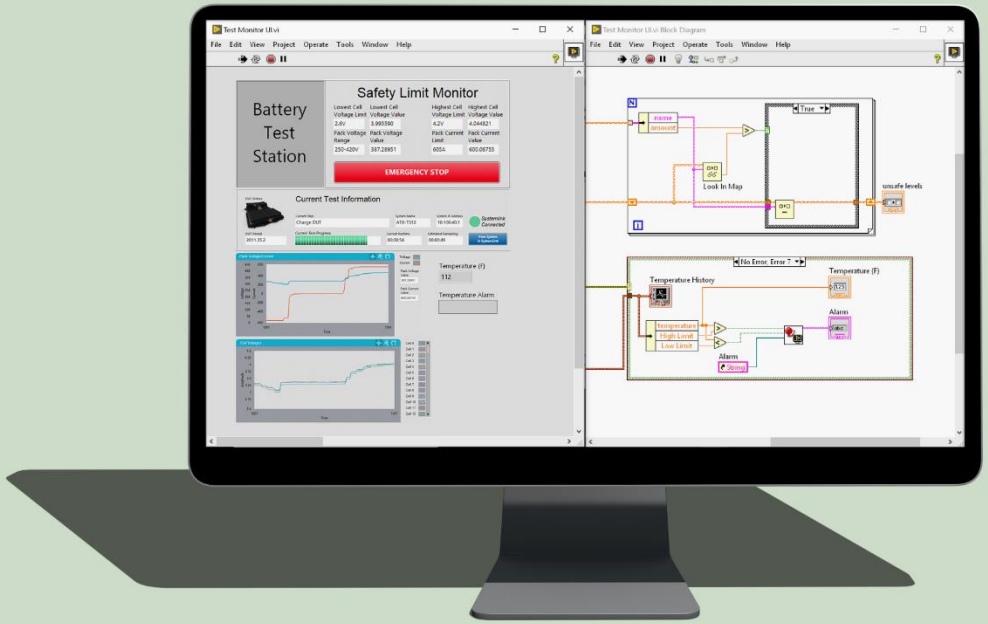


Featured Product

NI CompactDAQ

For electrical and sensor-based measurements

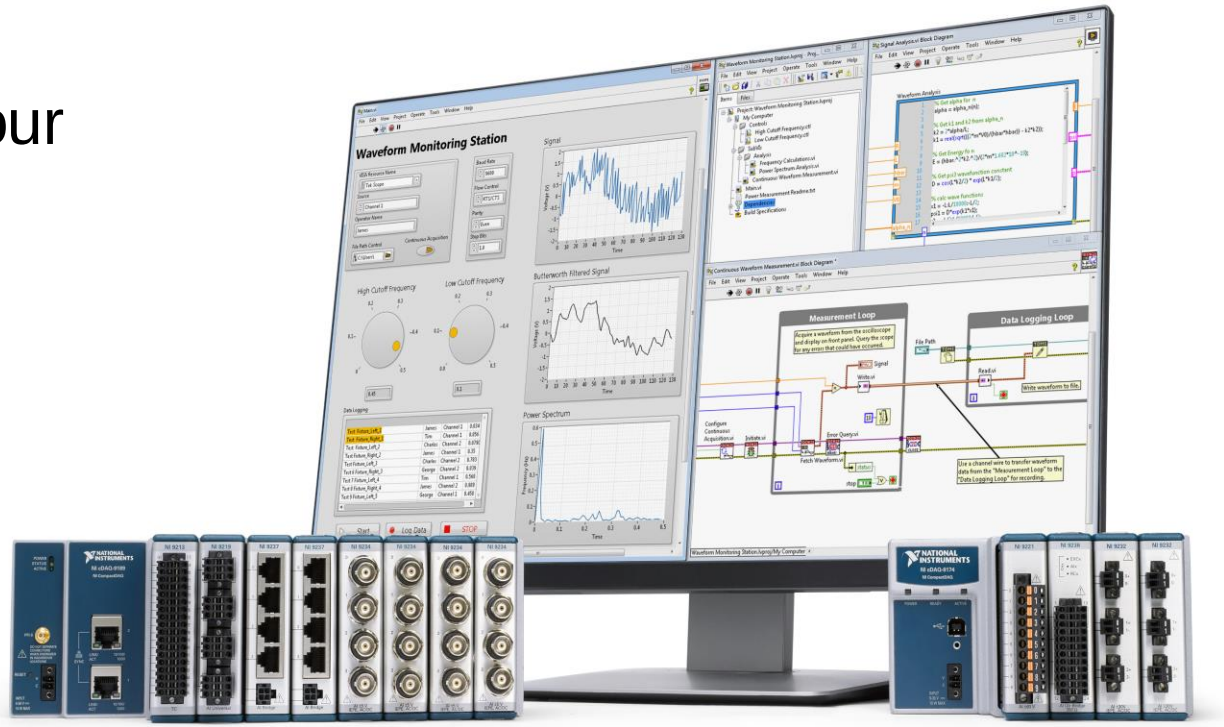
- Mix and match measurement modules
- Synchronize measurements in chassis that hold up to 8 modules
- Trusted NI brand quality for confidence in the data and fewer test re-runs
- Daisy-chain ethernet chassis to go beyond 8 modules for a validation system

- Software options so you can work your way
  - Flexlogger™
  - LabVIEW
  - C#, .NET, Python, MATLAB®

EMERSON | NI

Overview

- Learn from a Pro: Infinitum
- Choose the Best DAQ System for Your Application
- Application Tips



Infinitum

cDAQ in Action

David McDaniel

Senior Manager – Test & Integration

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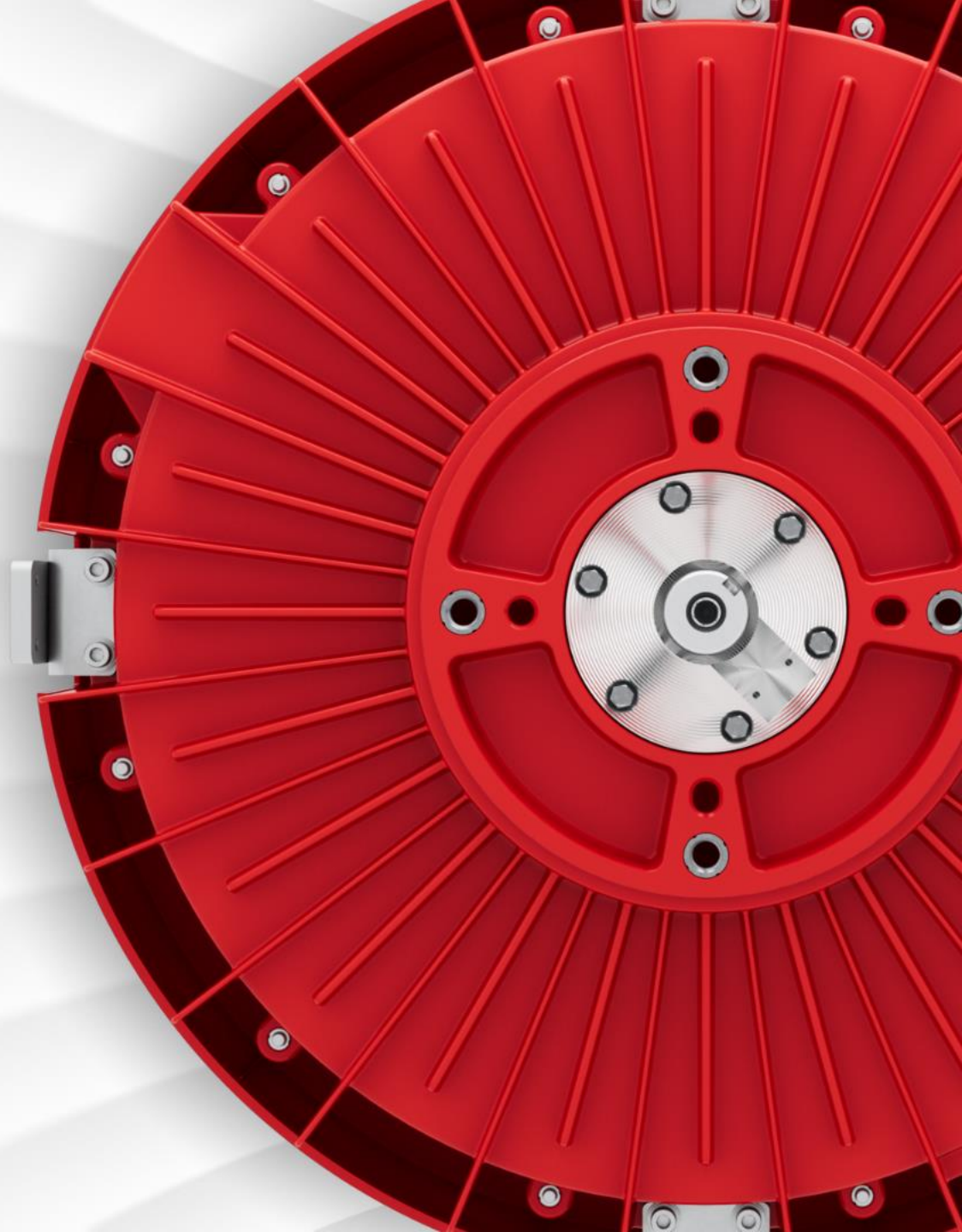
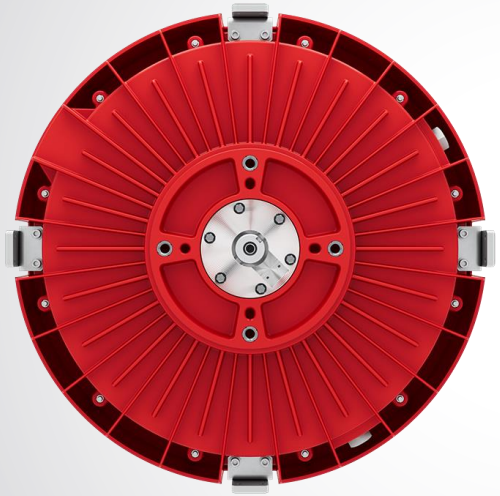


Infinitum: to infinity; endless; without limit

Our vision is to go beyond expectations by creating a more efficient motor with less resources that is better for people and the planet.



A next generation motor

66% Less Copper

50% Smaller/Lighter

10% Less Energy

No Iron Core | Circular Design

Headquartered in Round Rock, TX

Patents
108

Employees
200+

Established in 2016
Founder & CEO, Ben Schuler

Sustainable modular design for serviceability and remanufacturing

Over $345m raised to design, develop and scale production of a revolutionary integrated motor and inverter.

APPLIED Ventures

chevron technology ventures

CATERPILLAR

Rockwell Automation

Infinitum EC Motor

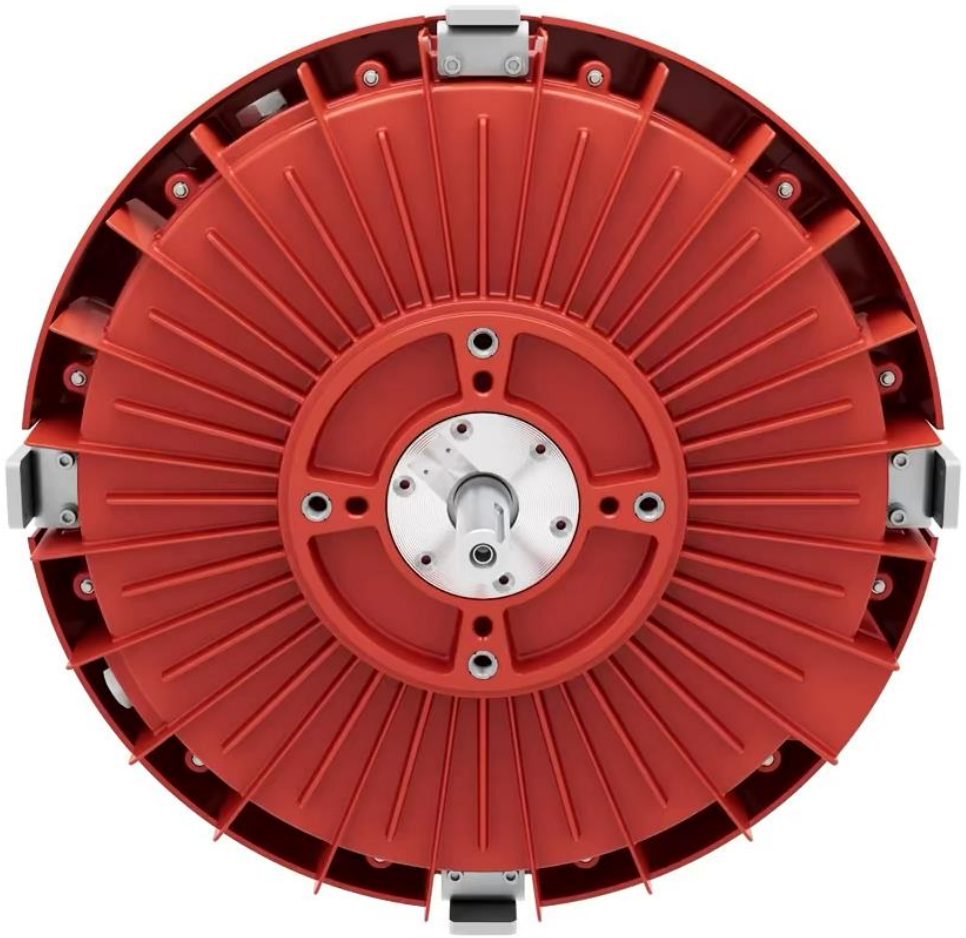
Power, Intelligence & Controls All in One

- No iron
- 66% less copper
- Lightweight PCB stator lasts 10x longer
- Up to 10% More efficient (at partial load)
- Embedded connectivity
- Recyclable, repairable and sustainable

AC Induction Motor and External VFD

- Heavy iron core
- Copper winding failures are common
- High noise level
- Low efficiency
- Easily damaged by overheating
- Additional VFD pairing required
- Not recyclable

Motor and Drive in a Single Compact Design



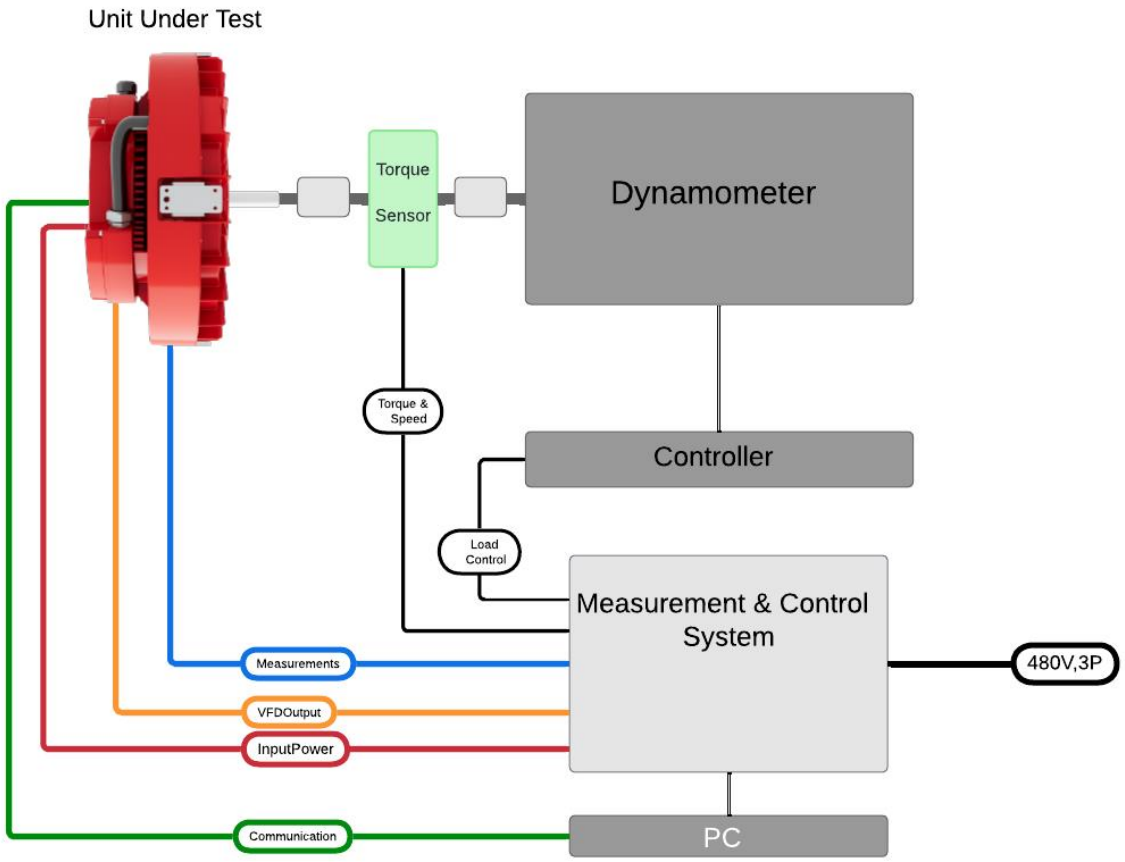
Infinitum Test Requirements

Software Requirements:

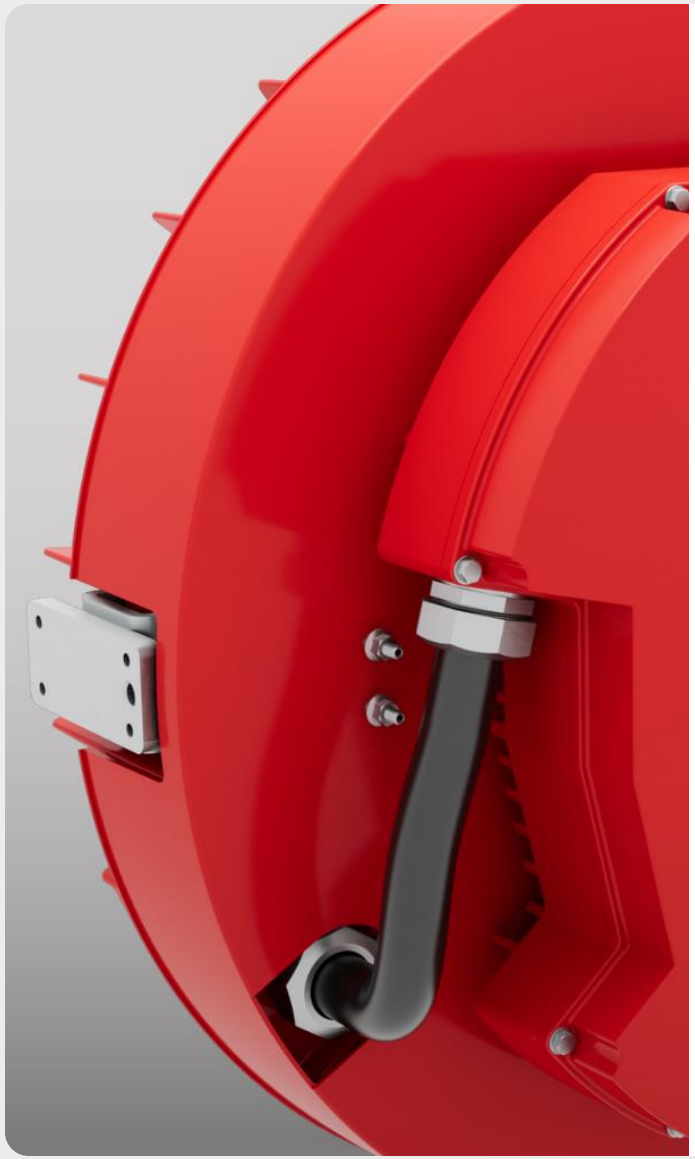
Measurement Capability:

- Voltage (600V)
- Current (50A)
- Temperature (Thermocouple, RTD)
- Accelerometer
- Microphone
- Digital I/O
- Analog I/O

System Test Diagram



Test System Considerations



Key drivers in selecting a test platform for next generation motors.

- ✓ Accuracy
- ✓ Flexibility
- ✓ Scalability
- ✓ Capability
- ✓ Supportability
- ✓ Cost

NI CompactDAQ Platform

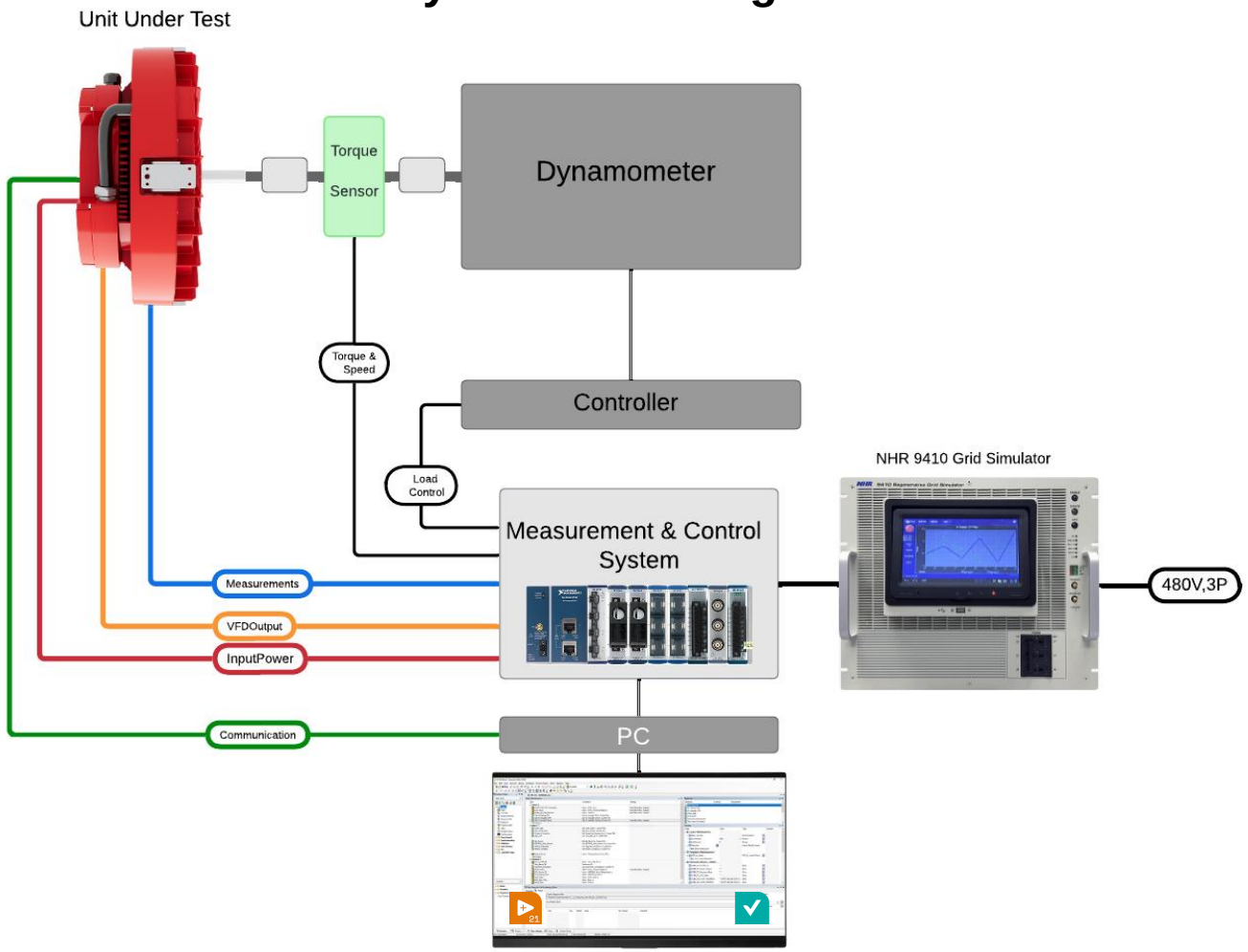
Infinitum Test System

Software Requirements:

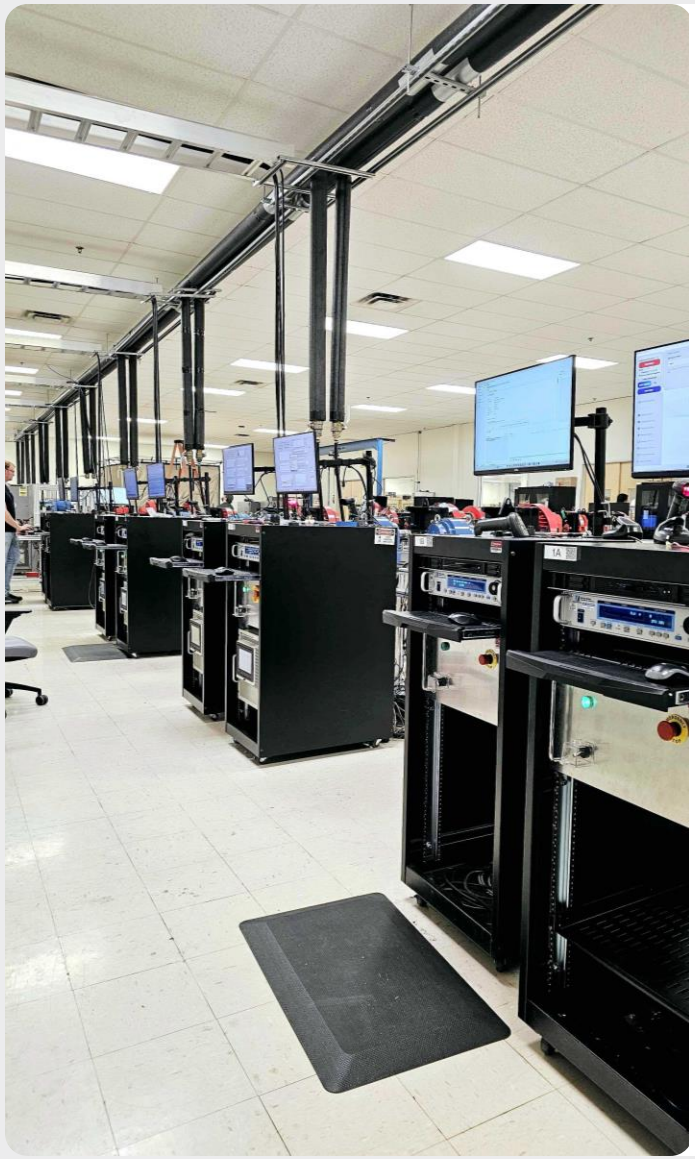
Measurement Capability:

- Voltage (600V) (NI 9244)
- Current (50A) (NI 9247)
- Temperature (NI 9210, 9212, 9216, 9219)
- Accelerometer (NI 9230, 9234)
- Microphone (NI 9230, 9234)
- Digital I/O (NI 94xx Series)
- Analog I/O (NI 9223, 9229, 9269)
- NI 9189 Ethernet Chassis

System Test Diagram



Leveraging cDAQ Architecture



Standardized Hardware

Shared Test Code

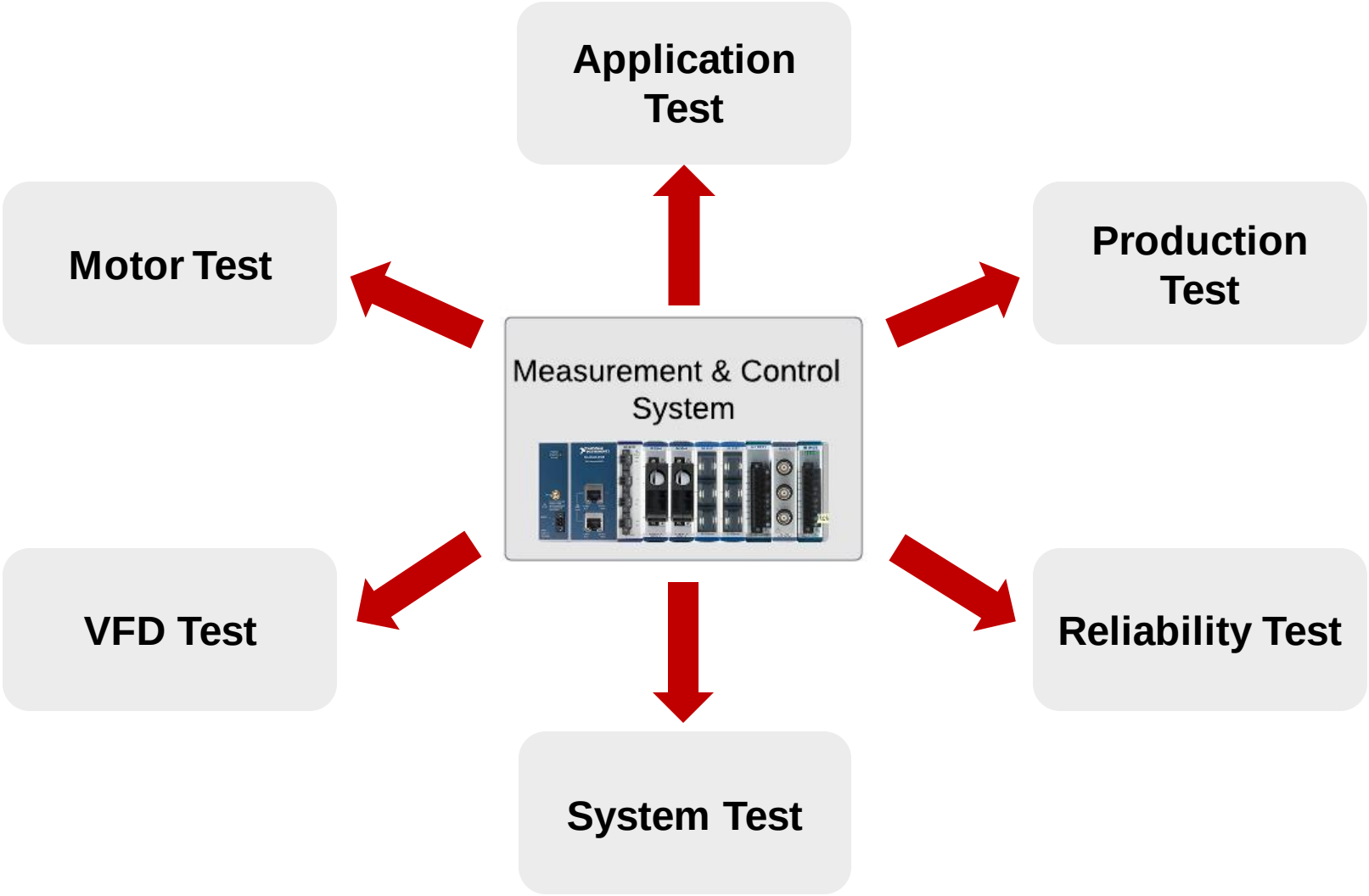
Minimize Development Time

Maximize Investment

Reduce Lead-times

Faster Time-to-Market

Leveraged Hardware Platform



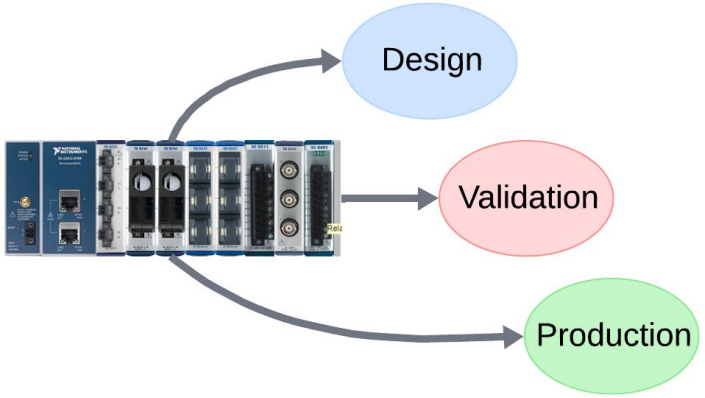
Standardize Across Test Cells

In the Laboratory

On the Test Bench

In the Factory

One Platform for Long-Term Success



One unified platform helped Infinitum bridge the gaps between design, validation and production.

Infinitum

Questions?

David McDaniel

Senior Manager – Test & Integration

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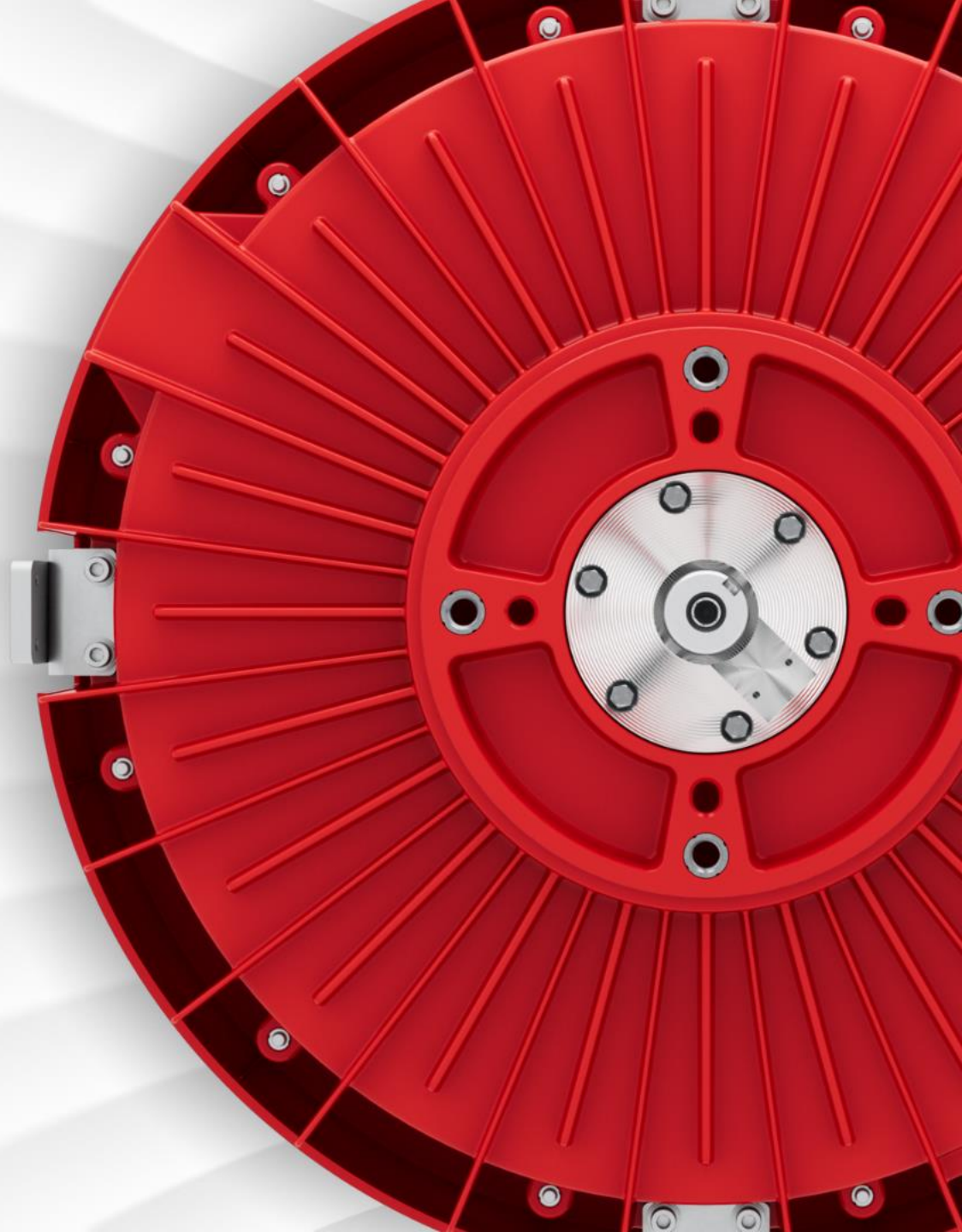


Choosing the Best Modules for Your Application

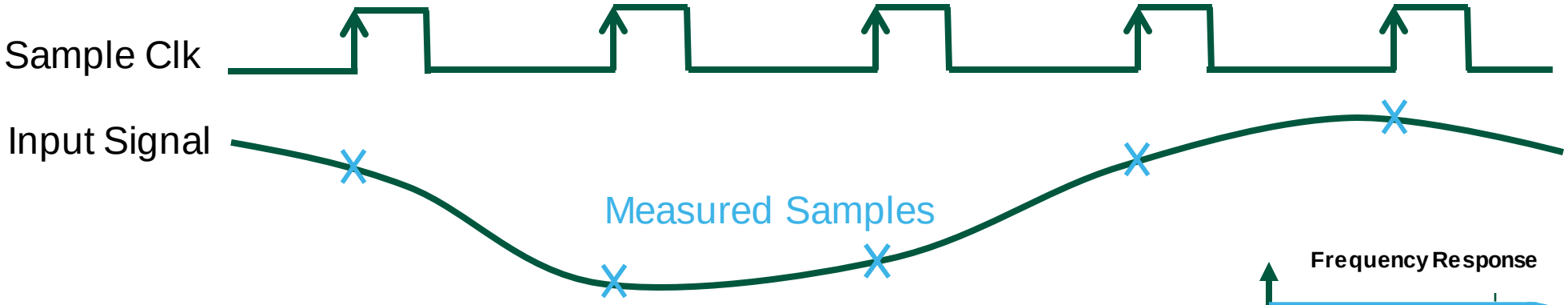
EMERSON

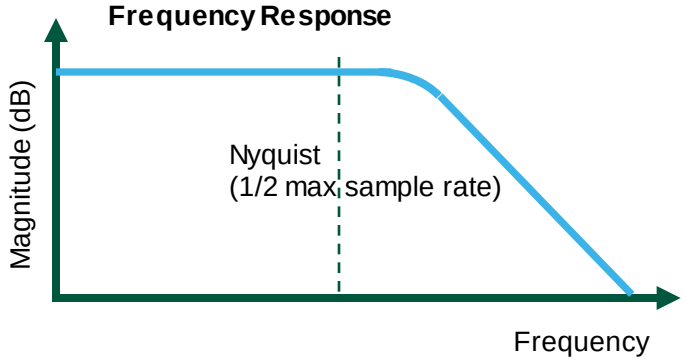
Define Your Needs, Choose your Modules

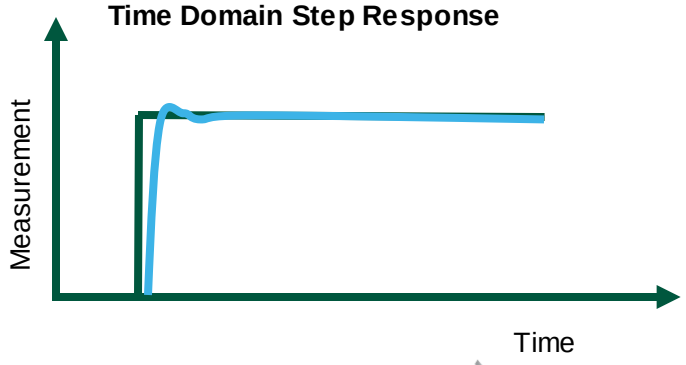
NI offers more that 70 C Series IO modules

- Modules differ based on measurement type (Voltage Input, Thermocouple Input, etc.)
- And internal architecture

SAR ADC Architecture







- **SAR (Successive Approximation Register) ADCs**
  - Takes an immediate measurement on each Sample Clock
  - Fast sample rates (up to 1 MS/s on C Series)
  - Wide Bandwidth, with Bandwidth > Sample rate
  - Support arbitrary timing
  - Fixed noise, independent of sample rate
  - Good for control applications

Example SAR ADC Modules

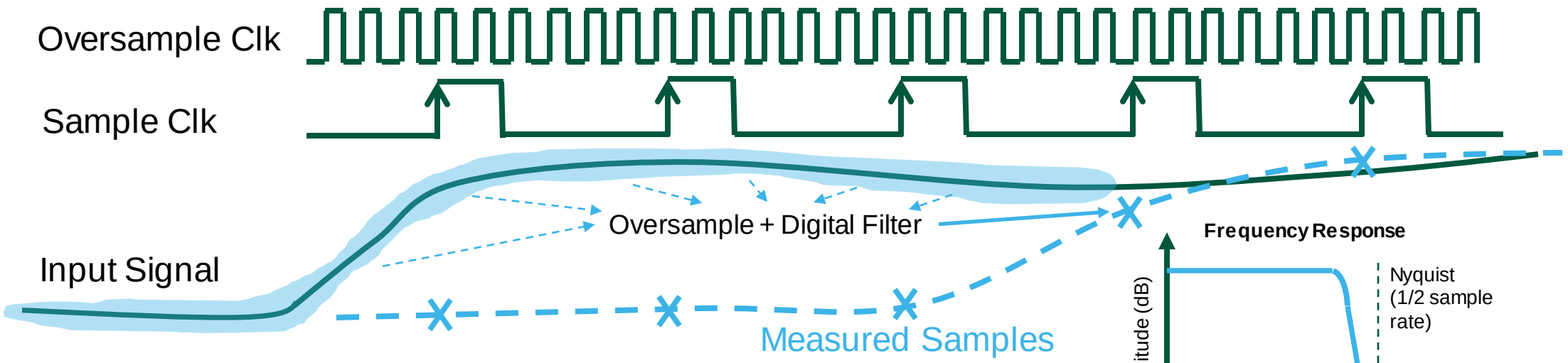
NI-9205

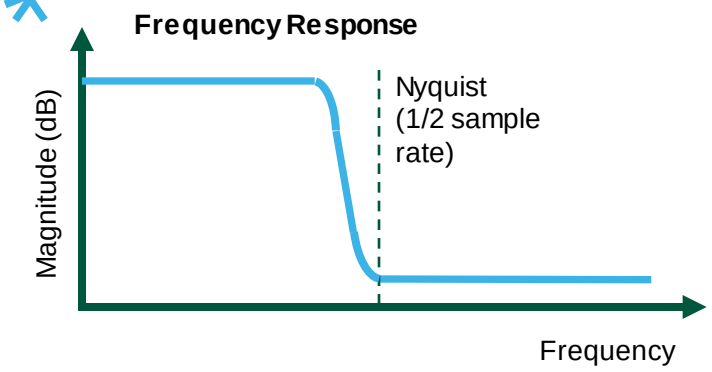
±10 V, 250 kS/s, 16-Bit, 32-Channel C Series Voltage Input Module

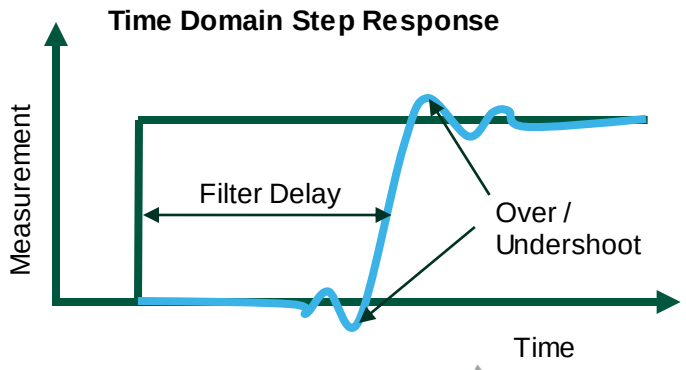
NI-9215

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

Delta-Sigma ADC with Brickwall Filter







- **Delta-Sigma ADCs**
  - Moderate sample rates (up to 102.4 kS/s on C Series)
  - Limited sample rates based on dividing down Oversample Clock (aka SampleClk Timebase)
  - Noise <u>may</u> improve with lower rates
  - Brickwall filter: bandwidth ≈ ½ sample rate
  - Full alias protection
  - Very high latency, bad for control applications

Example Delta-Sigma w/ Brickwall Filter Modules

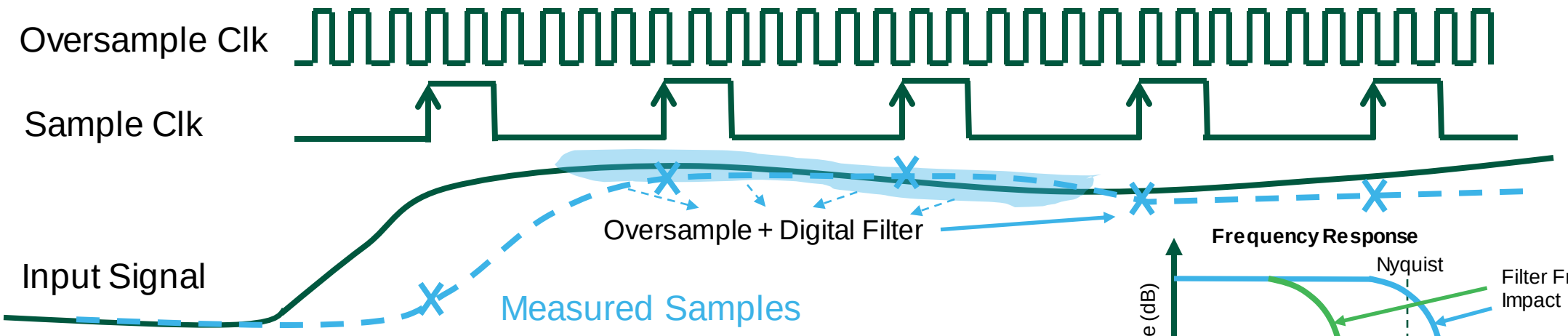
NI-9234

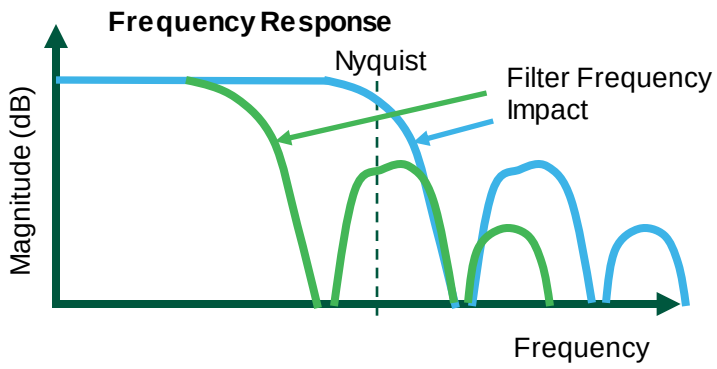
4-Channel, 51.2 kS/s/channel, ±5 V, C Series Sound and Vibration Input Module

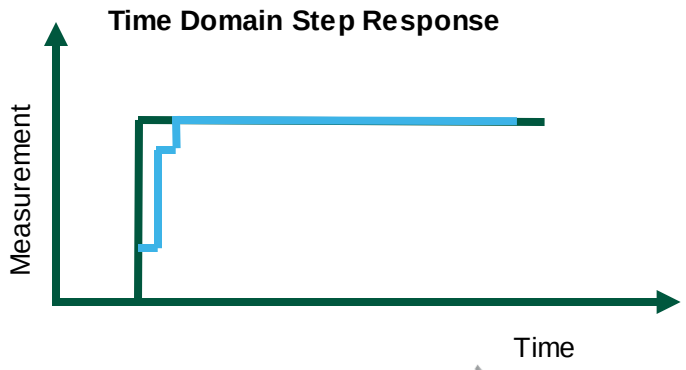
NI-9239

±10 V, 50 kS/s/ch, 24-Bit, Simultaneous Input, 4-Channel C Series Voltage Input Module

Delta-Sigma ADC with Comb Filter







- **Delta-Sigma ADCs**
  - Moderate sample rates (up to 50 kS/s on C Series)
  - Limited sample rates based on dividing down Oversample Clock (aka SampleClk Timebase)
  - Sinc / Comb / Notch shaped filters
    - Rejection and notch adjustable with Filter Frequency and sample rate
    - Partial alias protection
  - Moderate latency, OK for control applications

Example Delta-Sigma w/ Comb Filter Modules

NI-9202

±10 V, 10 kS/s, 24-Bit, 16-Channel C Series Voltage Input Module

NI-9252

±10 V, 50 kS/s/ch, 24-Bit, 8-Channel C Series Voltage Input Module

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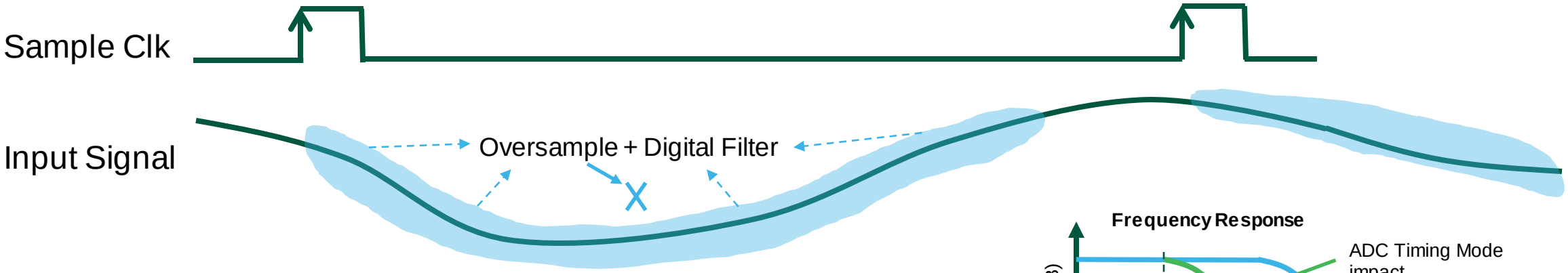
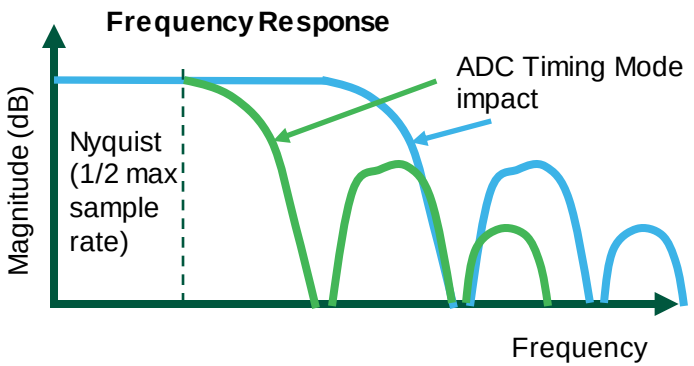
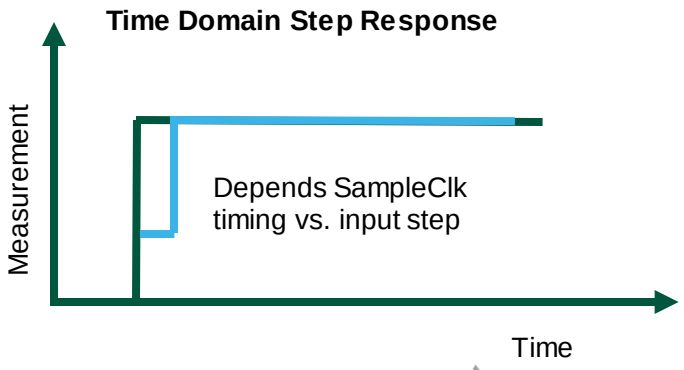
Low Speed Delta-Sigma ADC Architecture



- **Low Speed Delta-Sigma ADCs**
  - Operate in one-shot mode: Each SampleClk resets digital filter
  - Slow to moderate sample rates (1 S/s … 1000 S/s)
  - Sinc / Comb / Notch shaped filters
    - Adjustable with ADC Timing Mode
      - Use for lower noise at slower rates and/or filter notches at 50/60 Hz
  - Moderate latency, OK for slow control applications





Example Low Speed Delta-Sigma Modules

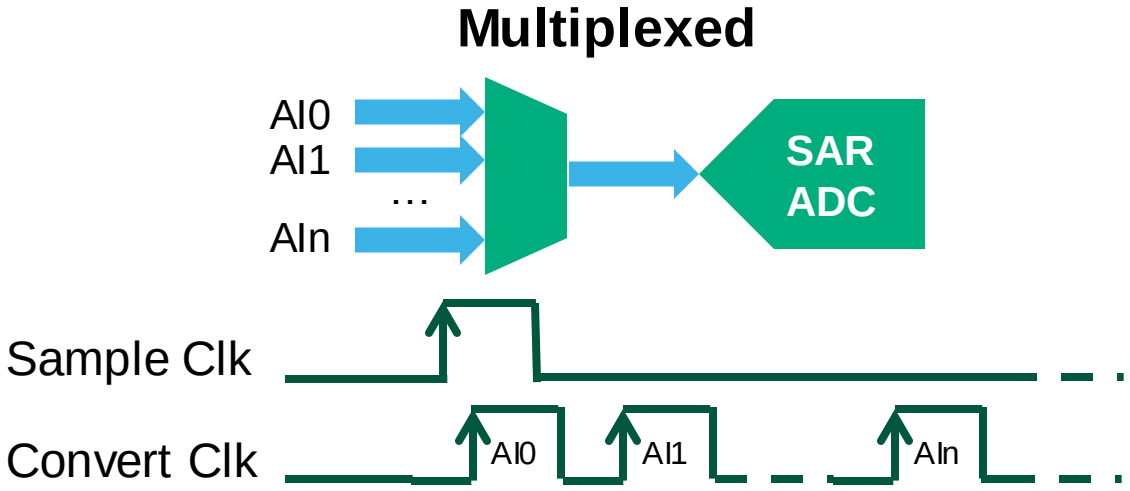
NI-9213

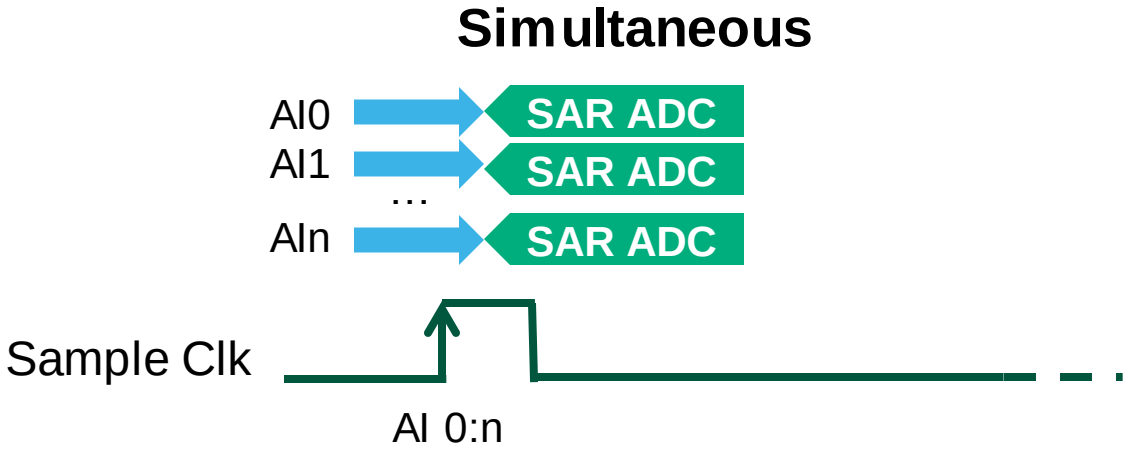
16-Channel, 75 S/s Aggregate, ±78 mV C Series Temperature Input Module

NI-9208

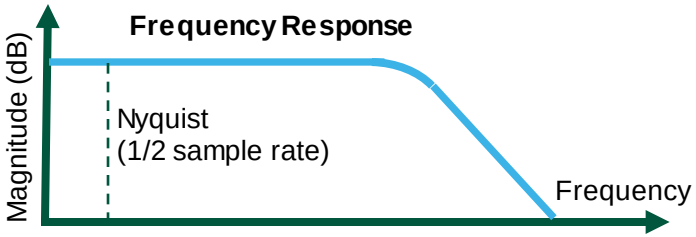
500 S/s, ±20 mA, 16-Channel C Series Current Input Module

Multiplexed SAR ADC Inputs Impact



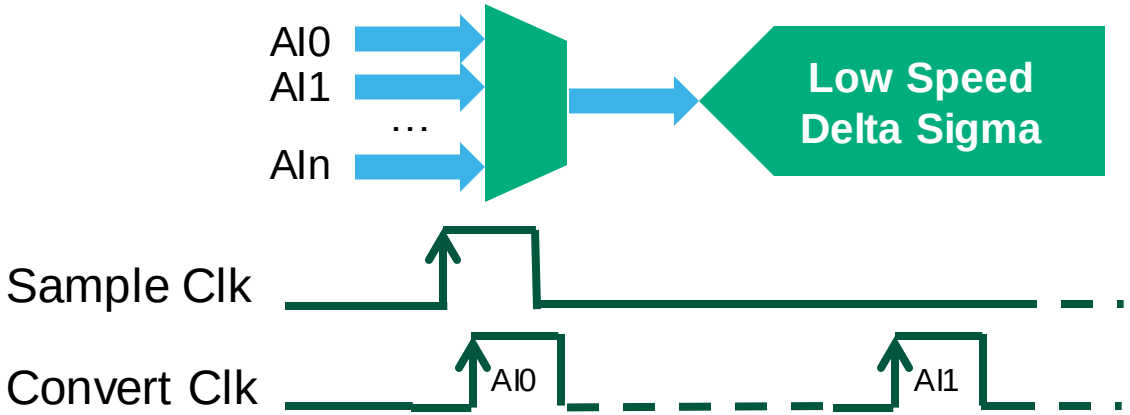


- Compared to Simultaneously Sampled Inputs:
  - Not phase aligned
  - Higher noise, crosstalk, and aliasing
- Input bandwidth >> Sample Rate

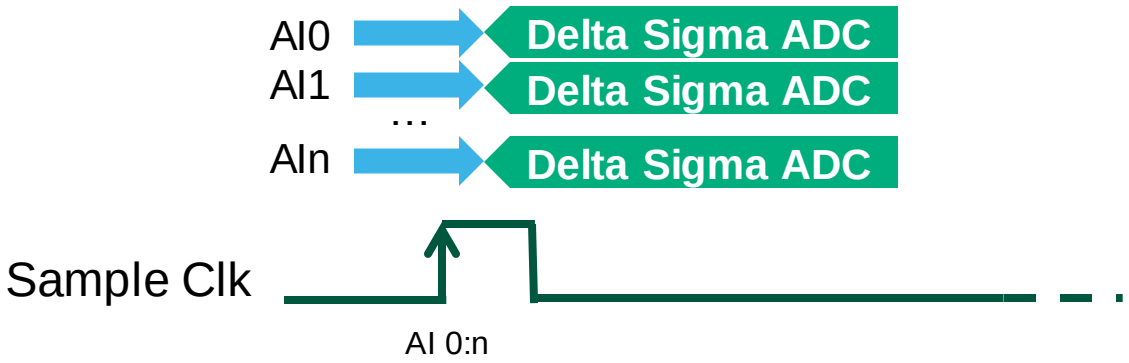


Multiplexed Delta-Sigma ADC Inputs Impact

Multiplexed



Simultaneous

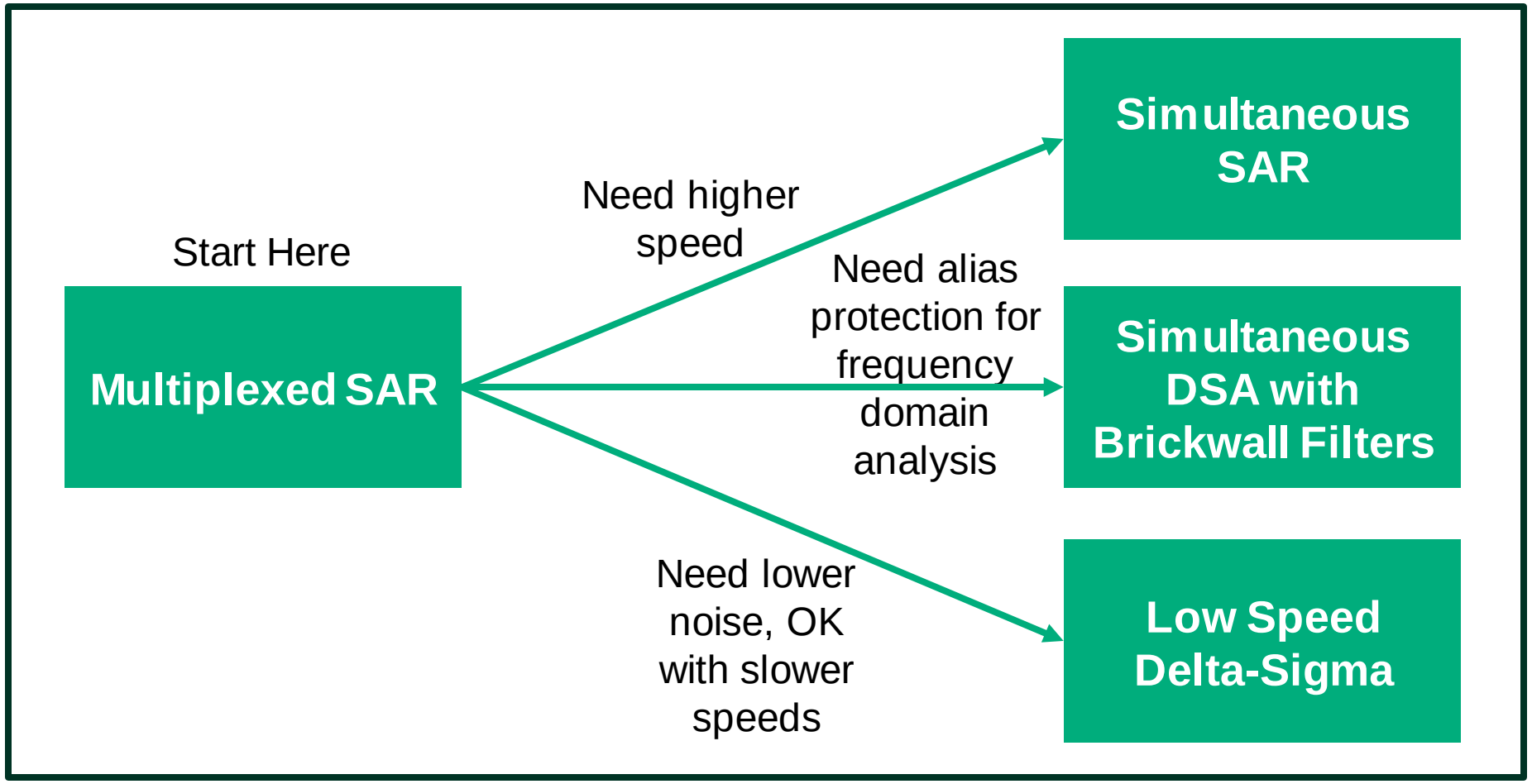


- Compared to Simultaneously Sampled Inputs:
  - Even slower
  - Not phase aligned
- Multiplexing not compatible high High-Speed Delta-Sigmas

- Simultaneous Sampling can be done for either Low or High-Speed Delta-Sigma ADCs

Pro Tip

Choose module architecture to match your application needs



Choosing the Best Modules

- Basic Measurement Architecture (ADC types) for AI modules
  - Successive Approximation Register (SAR)
  - Delta Sigma (ΔΣ)
  - Simultaneous vs. Multiplexed
- **Basic Measurement architectures for AO modules**

Pro Tip

Choose DAC architecture for AO modules to match your application needs

C Series AO Voltage Module Comparison					
Product Name	Number of channels	Output Range	Update Rate	Linearity	Isolation
Simultaneously Updated String DAC					
NI 9263	4	±10V	100 kS/s	12 LSB	Bank
NI 9264	16	±10V	25 kS/s	12 LSB	Bank
Simultaneously Updated R2R DAC					
NI 9262	6	±10V	1 MS/s	2 LSB	Bank
NI 9269	4	±10V	100 kS/s	2 LSB	Chan-Chan
Simultaneously Updated Delta-Sigma DAC					
NI 9260	2	3 Vrms	51.2 kS/s	-110 dB	None

String DACs – best for control loops

- Excellent differential linearity
- Very low glitch energy
- Worse integral non-linearity and accuracy

R-2R DACs – best for DAQ/Waveform

- Very good integral non-linearity and accuracy
- High glitch energy at code transitions

Delta-Sigma DACs – best for audio waveform generation

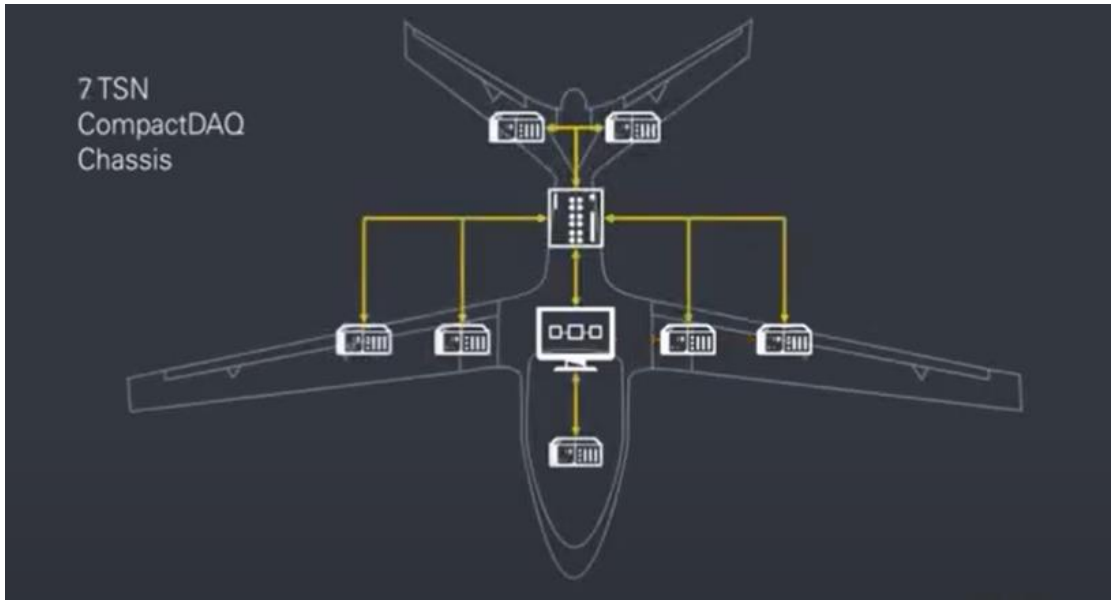
- Excellent dynamic range and SFDR
- Moderate update rates (up to 51.2 kS/s in C Series)
- Long latencies and limited sample rates

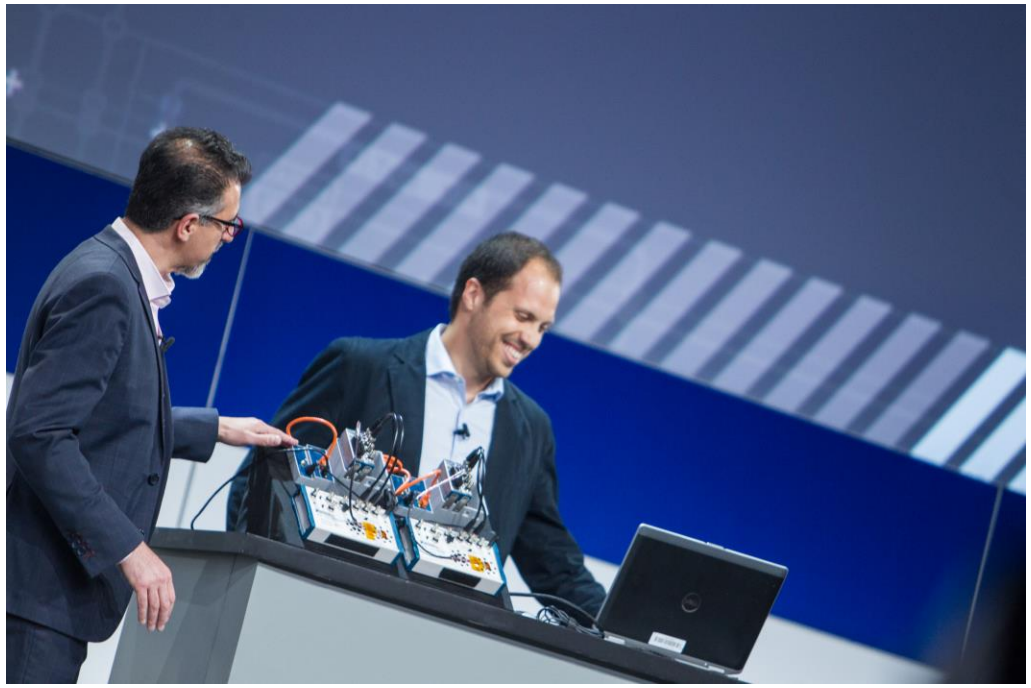
Application Tips

Application Tips

- **Timing and Synchronization**
- Counters
- Software

Synchronization is Key for Complex Systems

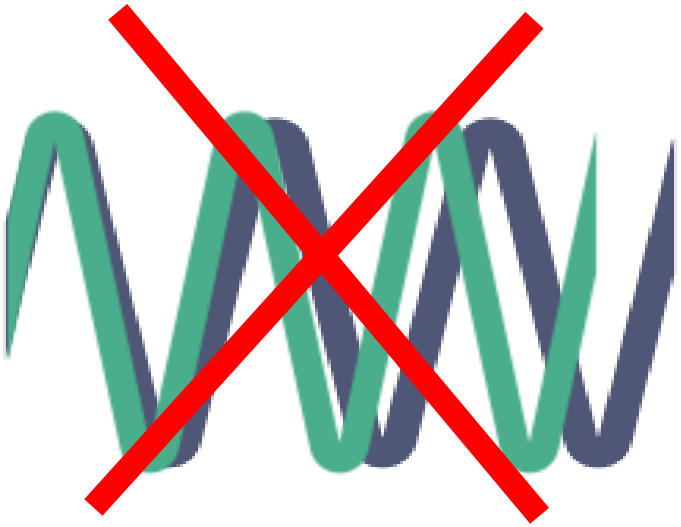




Joby aircraft data acquisition system, NI Week 2018

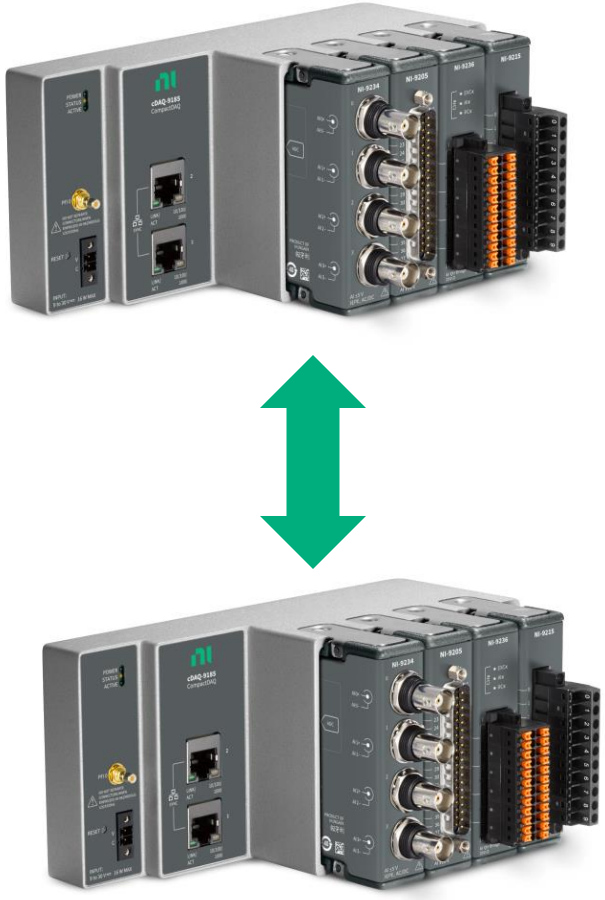
Synchronization Criteria

&



Drift = difference in sampling frequencies

Multi-device Synchronization



Signal Based vs. Time-based

Signal-Based

- Synchronization via **signals** routed between devices. Synchronize using a combination of sharing:
  - Sample Clock Timebase, Sample Clock, and/or Start Trigger
- **Pro**:
  - Works for any chassis
  - Can achieve very low skews with ideal star topologies
- **Cons**:
  - Requires additional hardware and cabling
  - Harder to program

Time-based

- Synchronization via events scheduled **with respect to the time** on a device.
- **Pros**:
  - 100ns … 1us accuracy synchronization with no extra hardware or cabling required
  - Simplified programming
- **Cons**:
  - Only supported by ethernet chassis (TSN capable)
  - Less accurate than optimized signal-based synchronization

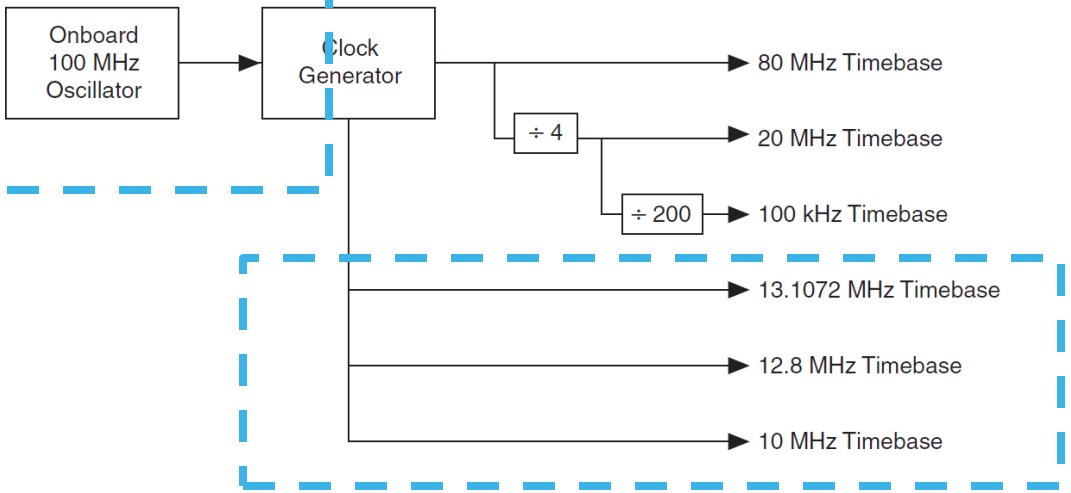
Chassis Clock Generation & AI Timing Engines

Chassis Clock Generation

Network Time

Adjusts

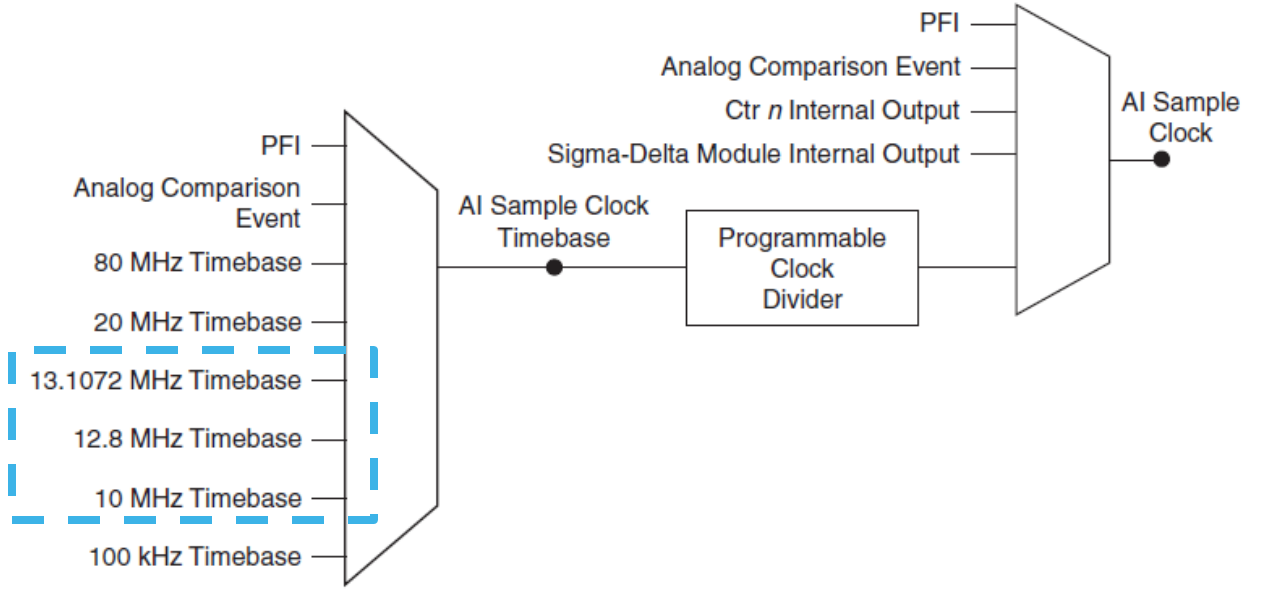
Figure 7-1. Clock Routing Circuitry



Only on TSN Chassis

AI Timing Engines (x3)

Figure 3-1. AI Sample Clock Timing Options



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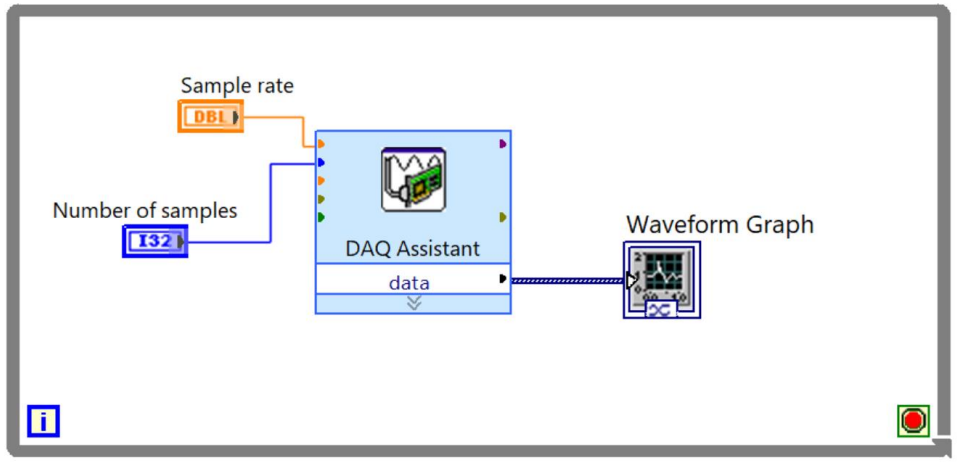
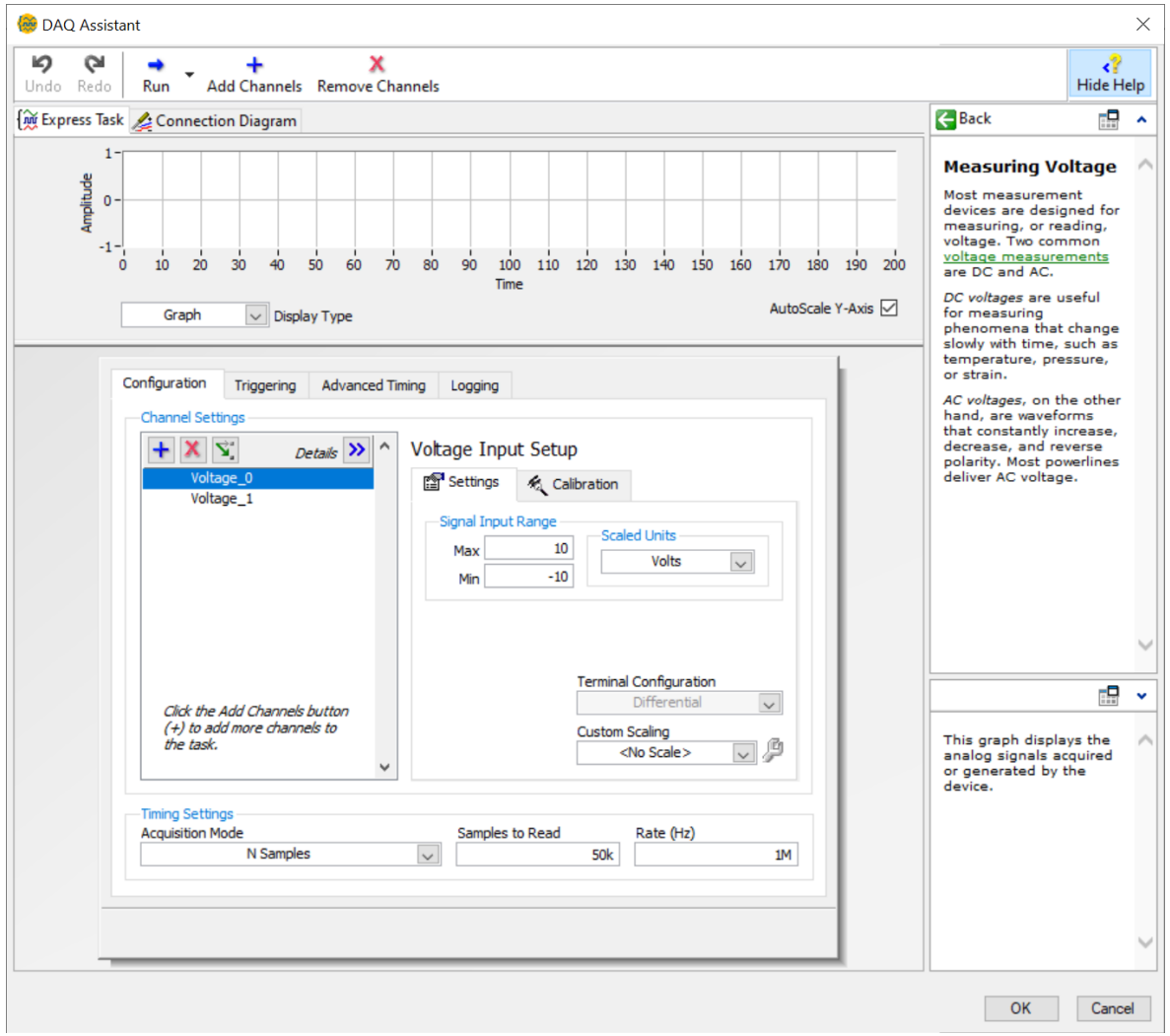
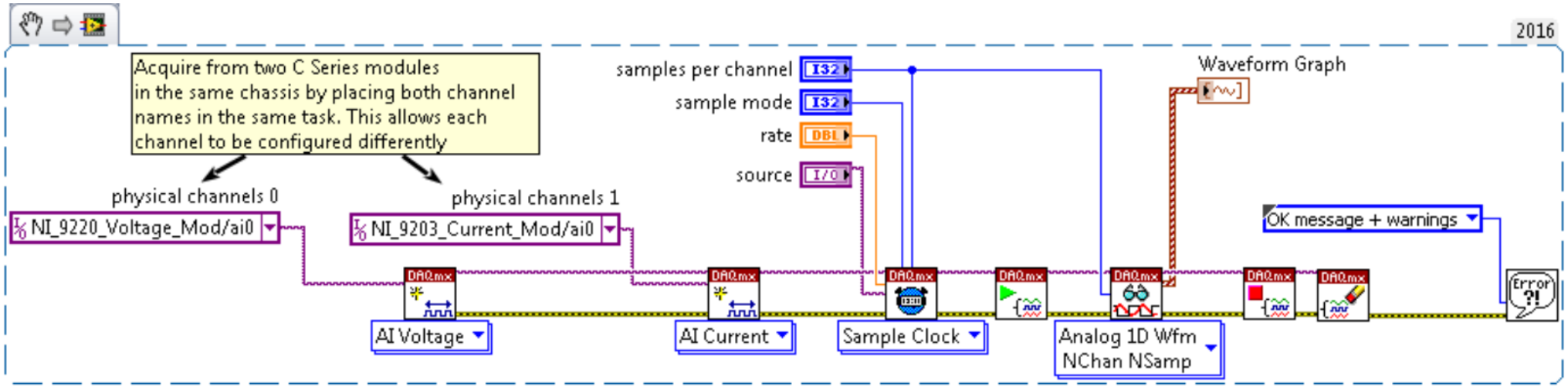
Multi-Device Synchronization

- DAQ Assistant





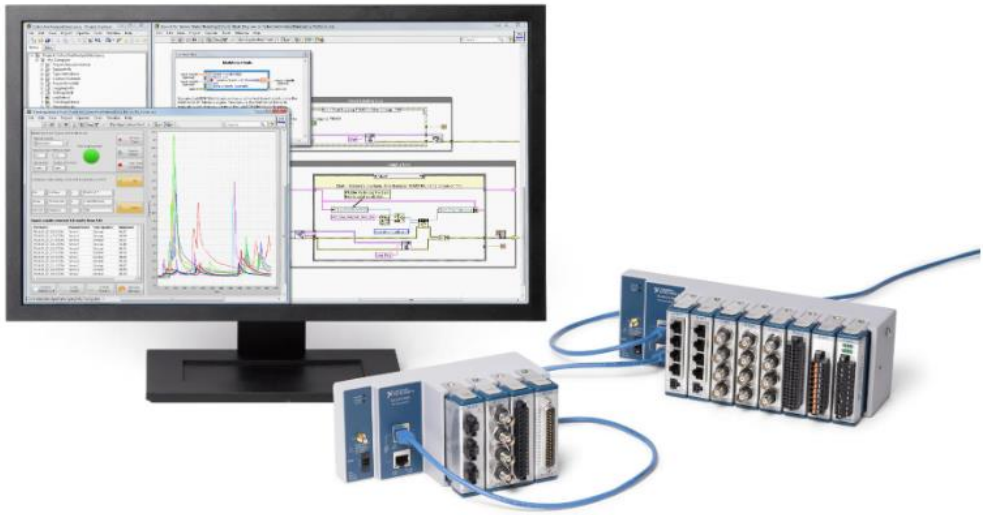
Multi-Device Synchronization



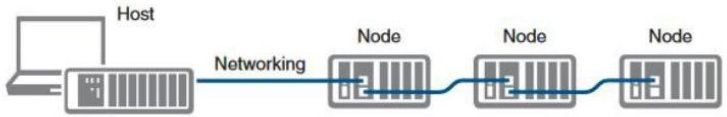
- Channels are synced because in same task
- Only same I/O type in 1 task
- Can mix different types of AI modules (SAR, Delta Sigma)
- Single same sample rate

Multi-Chassis Synchronization

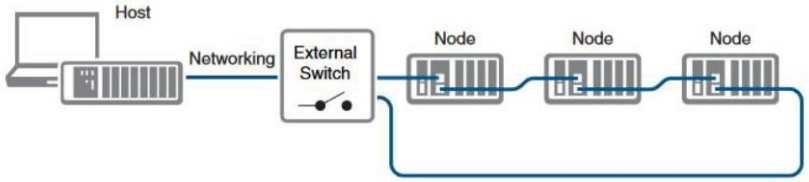
- Use multi-device DAQmx task + ENET Chassis
- **Time-based synchronization** via Time Sensitive networking (TSN) in the Ethernet standard IEEE 802.1AS
  - Uses packet-based communication
  - Requires the two end devices to have IEEE 802.1AS standard switches (cDAQ-9185/9189 are compliant)



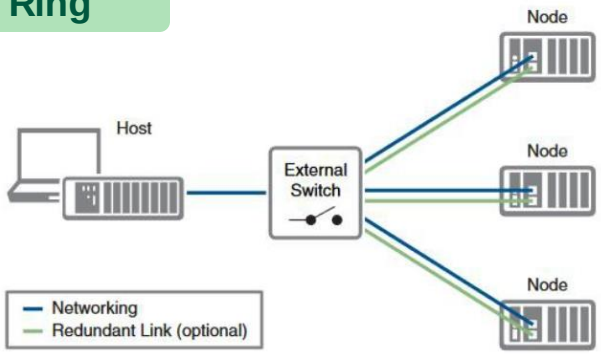
Select a topology



Line

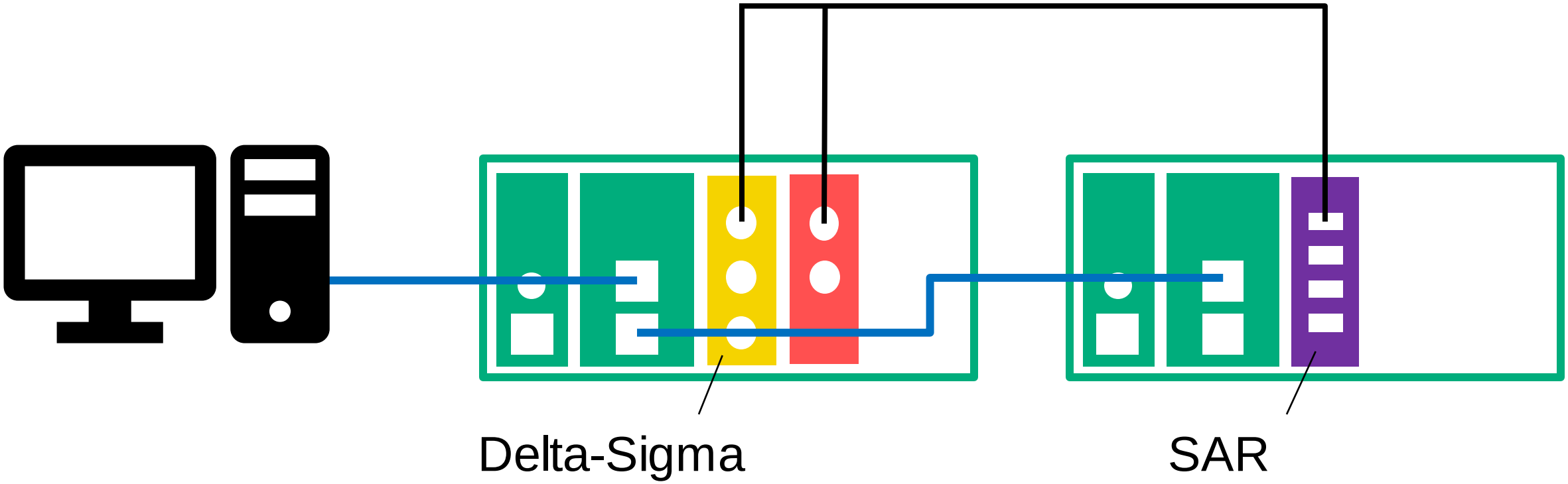


Ring



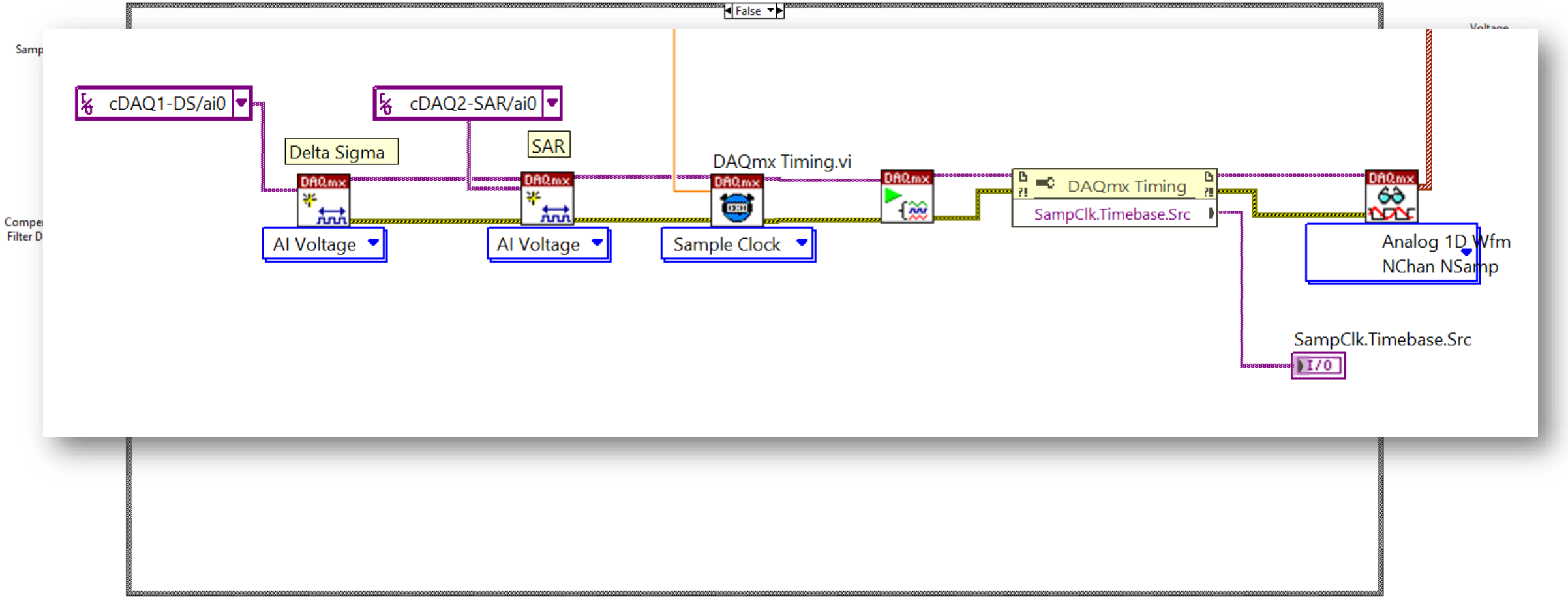
Star

Multi-Chassis Demo



Multi-Chassis Synchronization

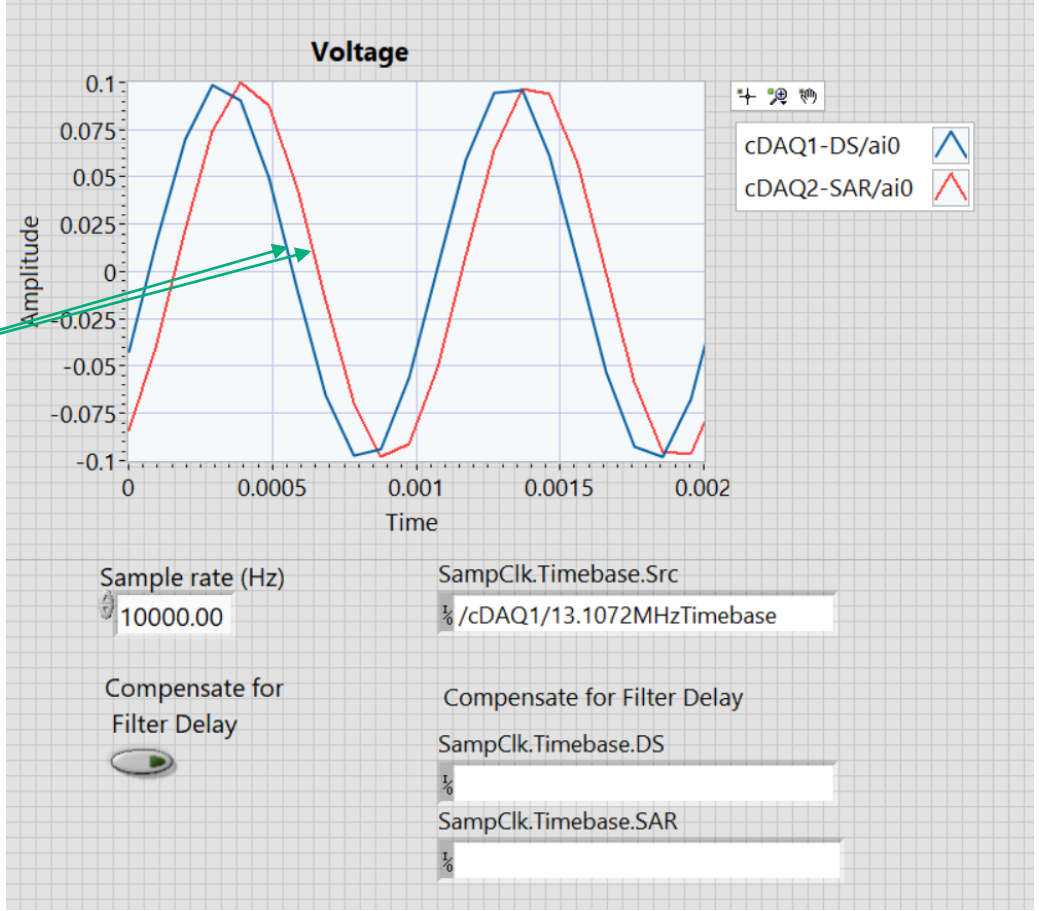
- No compensation for the filter delay from the Delta-sigma module



Multi-Chassis Synchronization

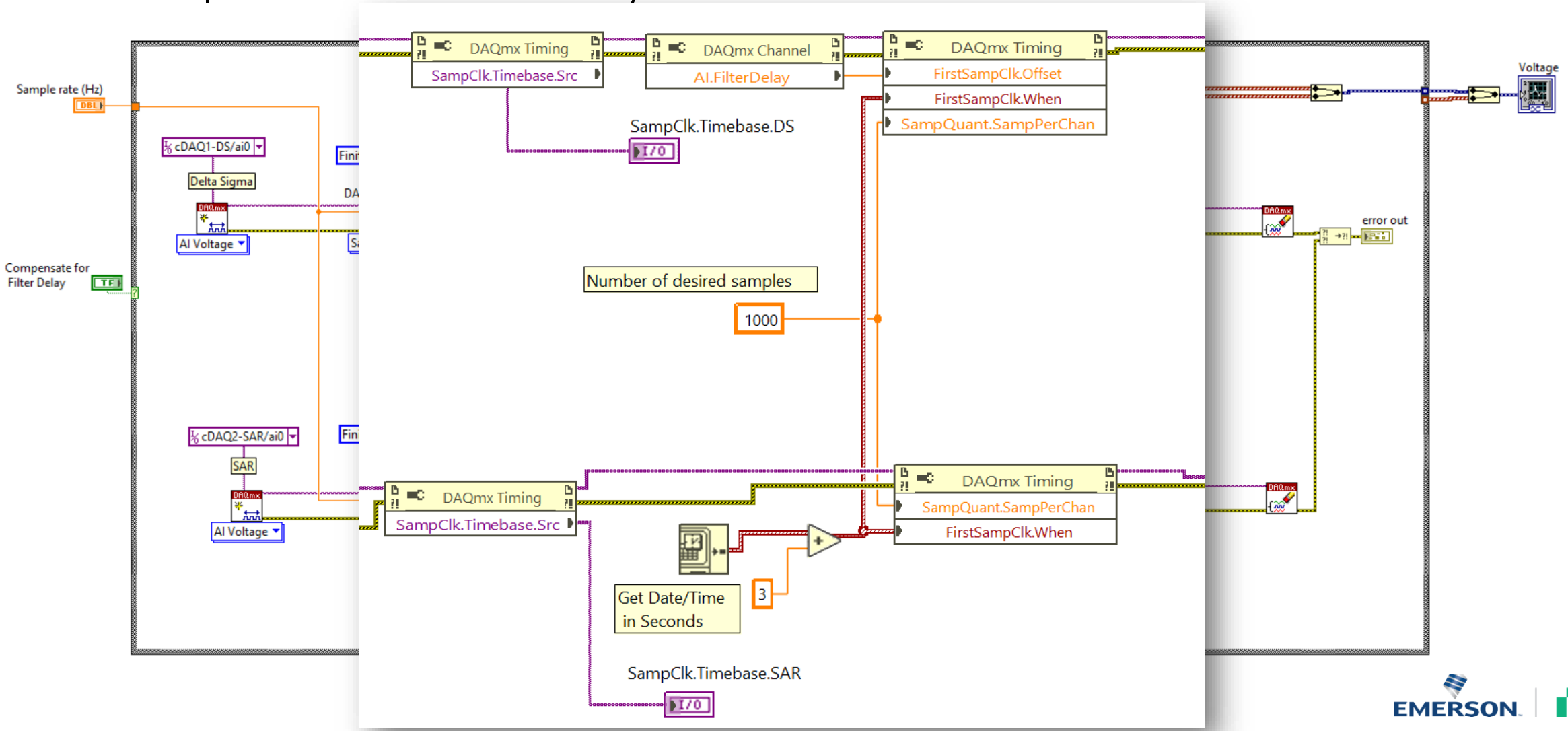
- No compensation for the filter delay from the Delta-sigma module

Samples are offset



Multi-Chassis Synchronization

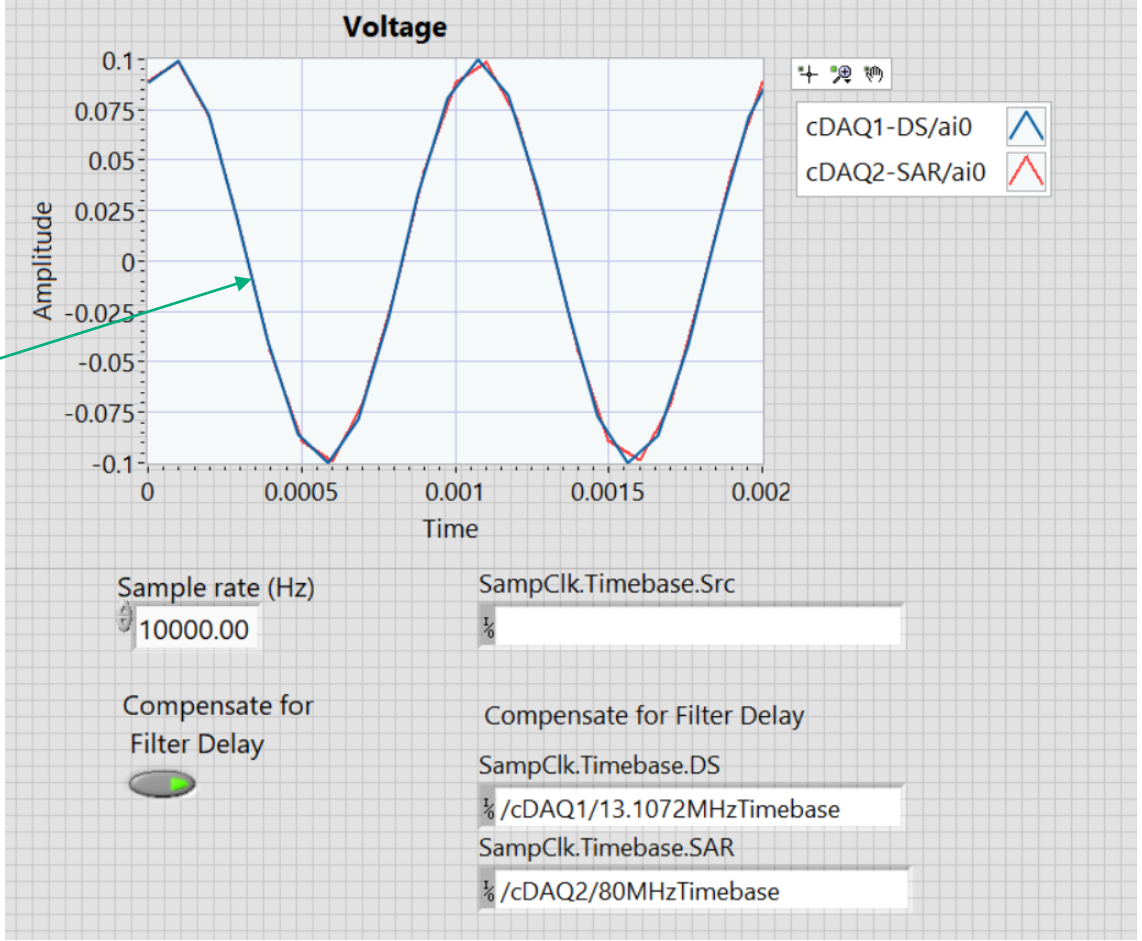
- With compensation for the filter delay



Multi-Chassis Synchronization

- With compensation for the filter delay

Samples are aligned



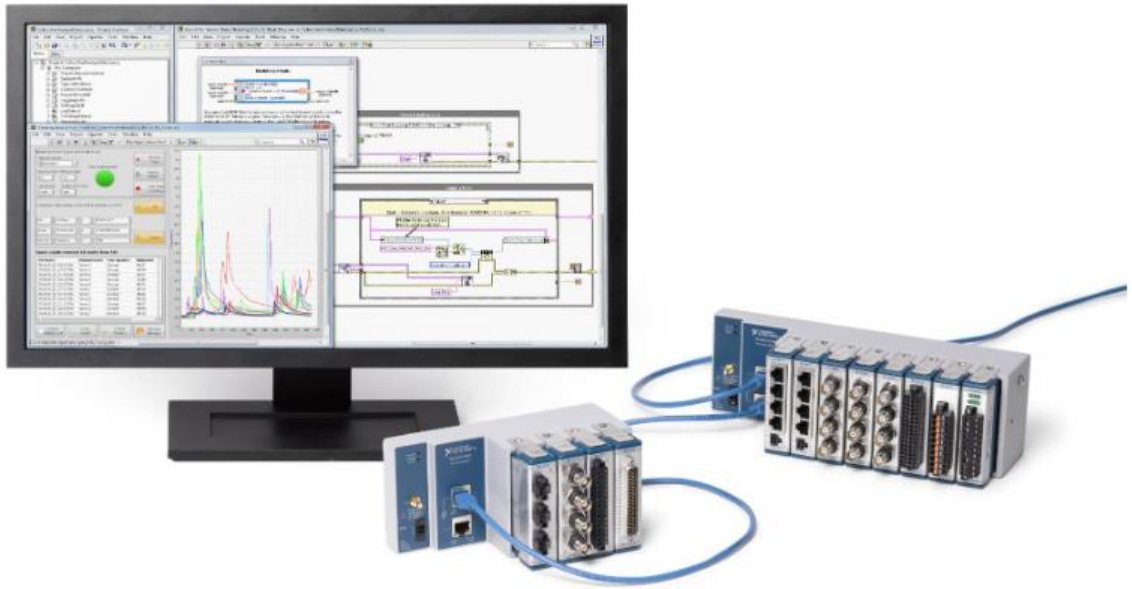
Signal-based Synchronization

- Can do multi-device sync through channel expansion
- Multi-chassis, Multi-rate sync VI is more complicated than time-based

NI-9469
(1 per chassis)

Pro Tip

Use time-based synchronization especially when doing multi-rate



Application Tips

- Timing and Syncrhonization
- **Counters**
- Software

Counters

Four 32-bit counters available for Counter Input/Output operations

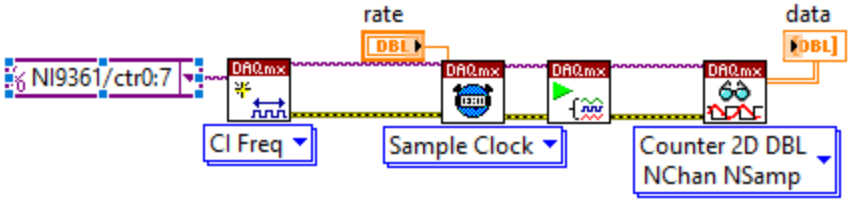
Need parallel (≤ 8 lines) DI/O modules to route the signals

Use for:

- monitoring incremental encoders
- event counting
- period measurement
- pulse generation
- pulse-train generation
- two-edge separation measurement, and more.

Pro Tip

Use dedicated counter Input modules (NI 9361 and NI 9326) instead of backplane counters



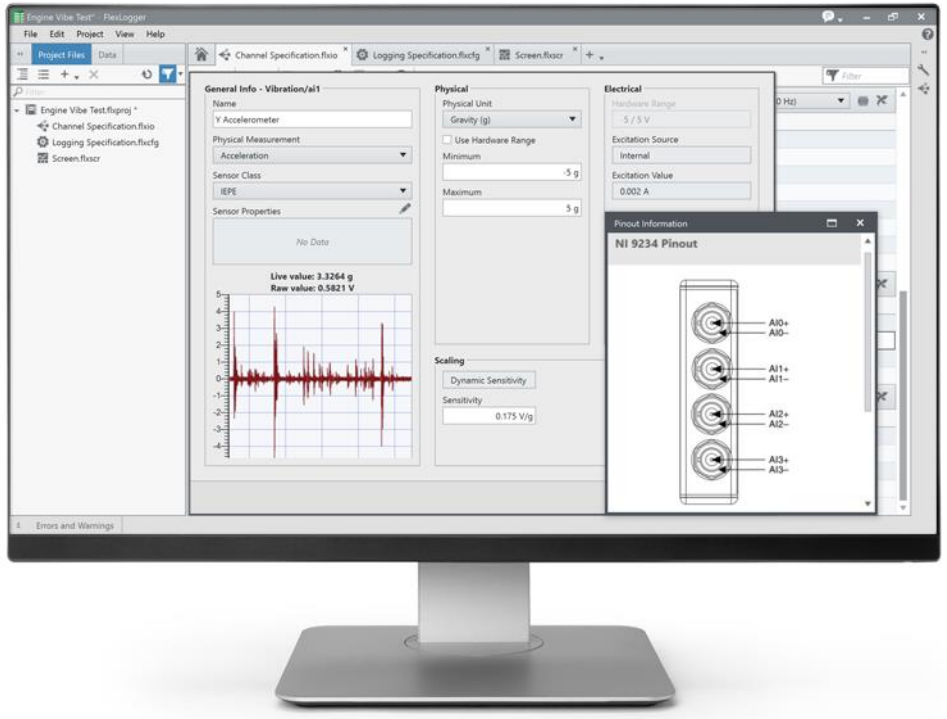
- More counters
- Easier to program and synchronize with AI/O tasks
- Better measurement accuracy
- Front-end optimized for sensors

Application Tips

- Timing and Syncrhonization
- Counters
- **Software**

Pro Tip

Use Flexlogger™ to quickly setup manual data logging tests without programming



- Interactively configure and monitor test
- Save measurement data to file
- Perform basic arithmetic on channels
- Configure alarms and events
- And more

Flexlogger Lite

	FlexLogger Lite	FlexLogger
User Value	Manual/Simple Validation	Automated/Enhanced Validation
Measure with nearly any NI DAQ device	✓	✓
Create monitoring dashboards	✓	✓
Log to standard formats (TDMS, CSV)	✓	✓
Visually inspect logged data (TDMS Viewer)	✓	✓
Develop and run custom measurement and control plugins		✓
Include additional measurements and visualizations (live calculations, CAN/LIN, etc.)		✓
Automate measurement sequences with Python, LabVIEW*, or TestStand*		✓
Automate response with alarms, events, and logging triggers		✓
Scale to multiple chassis		✓
Remotely monitor tests and manage data (SystemLink)		✓
Operator mode		✓
Technical support from NI		✓
Price (per node per year)	$0	$793

Download at ni.com

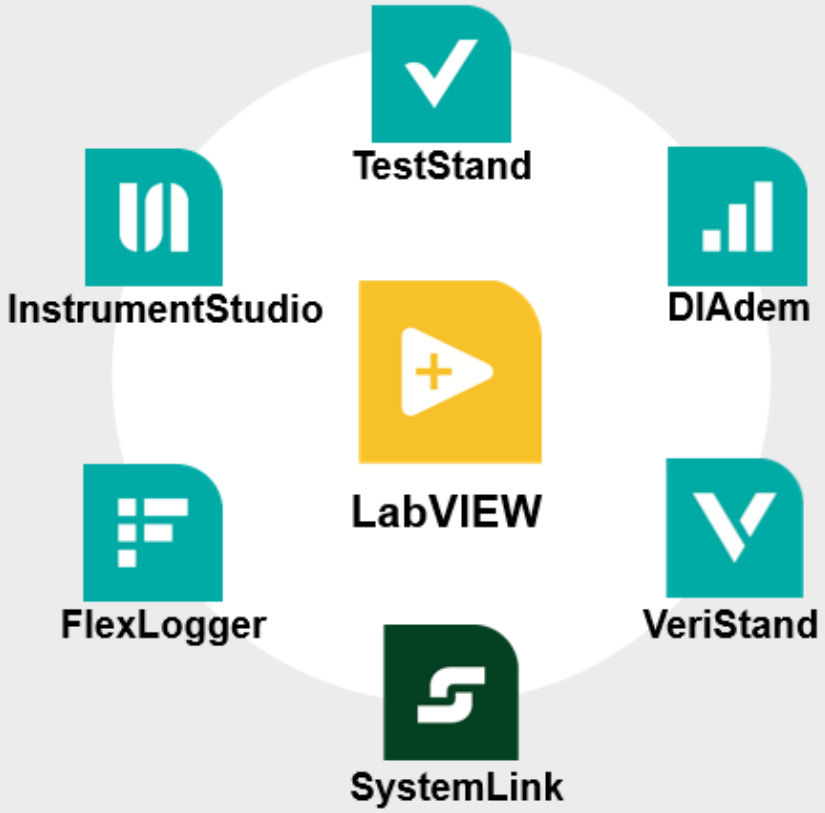
EMERSON | ni

Up Next!

- That’s the Suite Life! A Session on the LabVIEW+ Suite

  3:15PM-4:15PM

  MR 19A



Q&A

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