NI VeriStand 2010 Custom Device Developer's Guide (Beta)

This is a beta version of the guide. Please post questions, comments and feedback on the NI Developer Zone.

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Conventions

This document uses the following formatting and typographical conventions.

<>	Angle brackets that contain numbers separated by an ellipsis represent a range of values associated with a bit or signal name—for example, AO <0..3>.
»	The » symbol leads you through nested menu items and dialog box options to a final action. The sequence File » Page Setup » Options directs you to pull down the File menu, select the Page Setup item, and select Options from the last dialog box.
	This icon denotes a tip, which alerts you to advisory information.
	This icon denotes a note, which alerts you to important information.
	This icon denotes a caution, which advises you of precautions to take to avoid injury, data loss, or a system crash.
bold	Bold text denotes items that you must select or click in the software, such as menu items and dialog box options. Bold text also denotes parameter names, controls and indicators on the front panel, dialog boxes, sections of dialog boxes, menu names, and palette names.
green	Underlined text in this color denotes a link to a help topic, help file, or Web address.
purple	Underlined text in this color denotes a visited link to a help topic, help file, or Web address.
italic	Italic text denotes variables, emphasis, cross-references, or an introduction to a key concept. Italic text also denotes text that is a placeholder for a word or value that you must supply.
`monospace`	Text in this font denotes text or characters that you should enter from the keyboard, sections of code, programming examples, and syntax examples. This font is also used for the proper names of disk drives, paths, directories, programs, subprograms, subroutines, device names, operations, variables, filenames, and extensions.

Introduction

NI VeriStand is a ready-to-use, open software environment for configuring real-time testing applications, including hardware-in-the-loop (HIL) test systems. With NI VeriStand, you can configure real-time input/output (IO), stimulus profiles, data logging, alarming, and other tasks; implement control algorithms or system simulations by importing models from a variety of software environments; and build test system interfaces quickly with a run-time editable user interface complete with ready-to-use tools. See NI Developer Zone Tutorial: What is NI VeriStand for more information.

When necessary, you can customize and extend NI VeriStand's open environment with LabVIEW, ensuring it always meets application requirements. The purpose of this document is to provide the background, design decisions, and technical information required to understand and develop custom devices in NI VeriStand 2010.

> Understanding the NI VeriStand Engine is prerequisite to this document. See NI VeriStand Help » Components of a Project » Understanding the VeriStand Engine for more information.

What is a Custom Device?

While NI VeriStand provides most of the functionality required by a real-time testing application, NI has designed the environment to be customized and extended when necessary to ensure it always meets application requirements. Custom devices are one of several ways to customize and extend NI VeriStand. To learn about other ways you can customize NI VeriStand, see NI Developer Zone Tutorial: Using LabVIEW and Other Software Environments with NI VeriStand.

Custom devices give the developer complete freedom in regards to execution. Any LabVIEW code, or any code you can call from LabVIEW, can be made into a custom device.

Custom devices give the developer complete freedom to customize the operator interface to within System Explorer. Custom devices may present whatever configuration experience desired by the developers. From simple controls on a VI front panel, to a company branded pop-up window, to a silent routine that scrapes the configuration from an ActiveX database – the developer defines the configuration experience.

Custom devices typically consist of two VI libraries (*configuration* and *engine*) that define the behavior of the device, and an XML file that tells NI VeriStand how to load, display, use and deploy the device. Custom devices come from developers including National Instruments, 3rd parties, and in-house developers. The developer builds the configuration and engine libraries and the XML file from Source Distributions in LabVIEW.

The LabVIEW Project for most custom devices starts with a template project. A VI called the *Custom Device Template Tool* scripts the template project based on a few inputs from the developer. The developer then adds-to and changes the template project to fulfill the requirements of the custom device. The Custom Device Template Tool installs on top of NI LabVIEW with the Full and PC versions of NI VeriStand.

> 💡 The LabVIEW Project is needed to build the custom device, but only the configuration and engine libraries and the XML file are required to use the custom device in NI VeriStand.

After obtaining (or building himself) the custom device's libraries, the operator places them in the NI VeriStand `<Common Data>\Custom Devices` directory. This directory varies with the host operating system.

Table of Directories and Aliases

`<Common Data>`	Alias: `To Common Doc Dir`
Generic Windows OS	`<Public Documents>\National Instruments\NI VeriStand 2010`
Default Windows XP	`C:\Documents and Settings\All Users\Shared Documents\National Instruments\NI VeriStand 2010`
Default Windows Vista & 7	`C:\Users\Public\Documents\National Instruments\NI VeriStand 2010`

`<Application Data>`	Alias: `To Application Data Dir`
Generic Windows OS	`<Application Data>\National Instruments\NI VeriStand 2010`
Default Windows XP	`C:\Documents and Settings\All Users\Application Data\National Instruments\NI VeriStand 2010`
Default Windows Vista & 7	`C:\ProgramData\National Instruments\NI VeriStand 2010`

`<Base>`	Alias: `To Base`
Generic Windows OS	`<Program Files>\National Instruments\NI VeriStand 2010`
Default Windows XP, Vista & 7	`C:\Program Files\National Instruments\VeriStand 2010`

`<Custom Device Engine Destination>`	
PharLap / ETX	`C:\ni-rt\veristand\custom devices\<custom device name>\`

NI VeriStand parses `<Common Data>\Custom Devices` for custom device XML files when it first launches. You must restart NI VeriStand to recognize newly added or modified custom device XML files. The custom device may then be added to the system definition by right-clicking **Custom Devices** from System Definition » Targets » Controller in the configuration tree.

It's not necessary for the operator to have any knowledge of LabVIEW or custom device development to use the custom device. It's not necessary to have the LabVIEW Project to use

a custom device. It's courteous common practice to provide the LabVIEW Project along with the custom device. Providing the project allows operators and other developers to modify the custom device to suit their specific requirements.
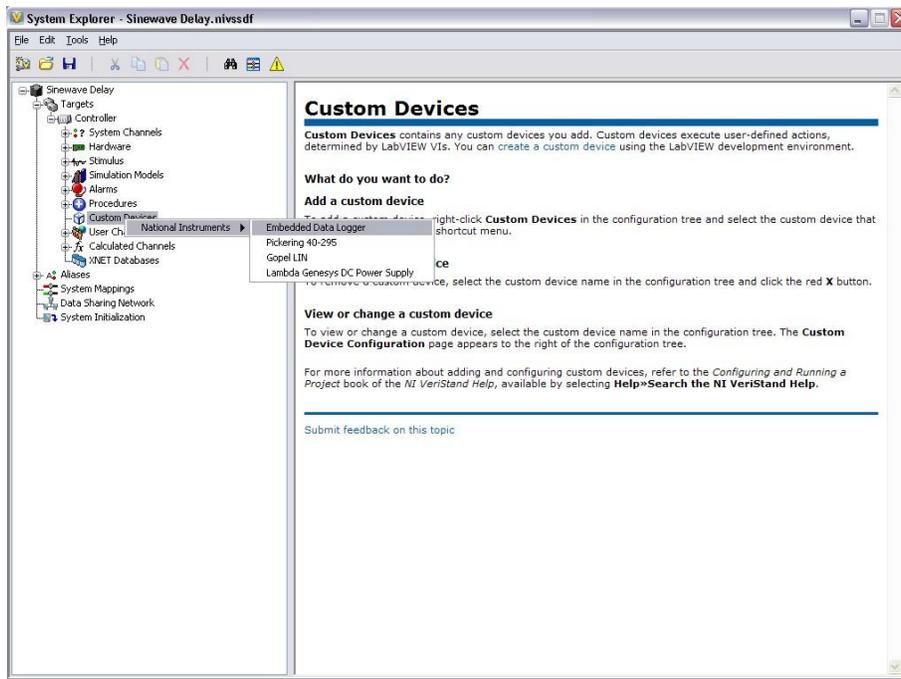
Figure: Adding a Custom Device to a System Definition

Most custom devices consist of the two VI libraries and XML file mentioned above. Logically, custom devices consist of three parts.

1. Custom Device Framework
2. Custom Code
3. Custom Device XML File

Custom Device Framework

The custom device framework consists of type definitions, specifically-named controls and indicators, template VIs and a LabVIEW API. Together these items for the rules, or framework, that allows any conforming VI to interact with NI VeriStand. There are five prebuilt types of custom devices. Almost any requirement can be accomplished by adding or modifying code in one of the five prebuilt devices.

The five prebuilt devices start with the Custom Device Template Tool. The template tool is located in `<vi.lib>\ NI Veristand\Custom Device Tools\Custom Device Template Tool\Custom Device Template Tool.vi`.

The developer specifies the type of custom device before running the template tool. The tool generates the LabVIEW Project for the new custom device. The exact resources in the project depend on the type of custom device selected.

The project is pre-populated with VIs, LabVIEW Libraries, an XML File, and two build specifications. These resources provide the framework upon which almost all custom devices are built.

NI VeriStand evolved from NI Dynamic Test Software (NI-DTS). NI-DTS evolved from Intellectual Property (IP) called EASE obtained from a 3rd party. EASE made basic provisions for add-on LabVIEW code. In a sense this was the first custom device framework. Several "custom devices" were built for the original framework, and NI has mutated them from EASE through NI-DTS and into NI-VeriStand. If you come across a custom device that doesn't fit into the framework provided by the Custom Device Template Tool, you may have stumbled upon one of the original custom devices.

For each of the five types of custom devices, you'll see two VI libraries in the LabVIEW source project: `Custom Device API.lvlib` and *Custom Device Name* `Custom Device.lvlib`.

The Custom Device API library contains most of the type definitions, template VIs and LabVIEW API needed to interact with NI VeriStand's data and timing resources. They give a VI the ability to behave as a native task in the NI VeriStand Engine. Some of these VIs also appear on the LabVIEW palette in NI VeriStand » Custom Device API.

The *<custom device name>* library contains the custom device's configuration and RT Engine VIs. These correspond to the configuration and engine VI libraries (or LLBs) mentioned earlier. Notice the front panel and block diagram of these VIs have been populated with objects from the Custom Device API library.
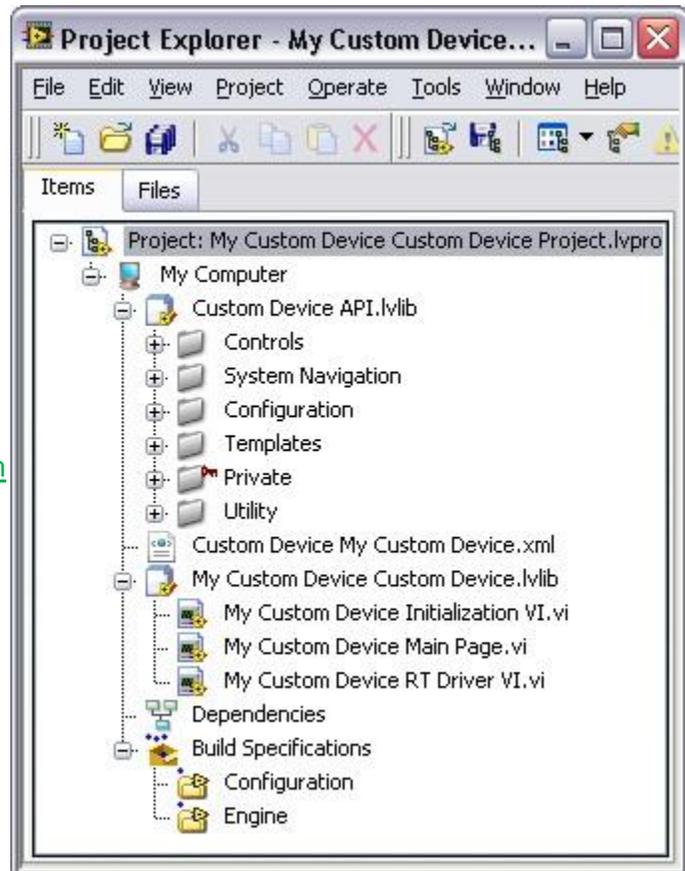

Figure: A New Custom Device Project

Configuration

The custom device's configuration defines the operator's experience adding and configuring the custom device. It is the device's operator interface (OI) or user interface (UI). The Custom Device Template Tool provides two VIs for configuration: Initialization and Main. Additional VIs may be added as needed.

> When a custom device VI's front panel is presented to the operator in the System Explorer window, that VI is called a *page*. Pages are a subset of the VIs that make up a custom device.

Initialization VI

The Custom Device Template Tool names the initialization VI `<Custom Device Name>` `Initialization VI.vi`. It runs in the background when the custom device is first added to the system definition. The initialization page does not run again unless the operator removes and re-adds the custom device.

> ⚠ While you may rename certain objects in the custom device's LabVIEW Project, it's important to understand the ramifications of doing so. For example, the Initialization VI is referenced by name in the custom device XML file. This file is generated when you first run the Custom Device Template Tool. If you rename the Initialization VI after running the tool, you'll need to manually change the path to the Initialization VI in the custom device XML file.

The Initialization Page runs each time a new instance of the same custom device is added to the system definition. NI VeriStand retains state information for each instance of a custom device in the System Definition (.nivssdf) file. State is defined by the value of each control, indicator, and *property* (properties are covered later) of the page. This file is human-readable XML, so you can open the file with a text editor and take a look. There's also a .NET API for modifying the System Definition programmatically.

Main Page

The Custom Device Template Tool names the main page `<Custom Device Name>` `Main Page.vi`. After the custom device has been added to the system definition, the main page runs whenever the operator clicks on the on the custom device's top-level item in System Explorer's configuration tree.

The top-level custom device item is selected in the configuration tree.

Main Page VI runs in the configuration pane.

Figure: Highlighting the Top-Level Item Runs the Main Page

Engine

The Custom Device Template Tool names the engine `<Custom Device Name> RT Driver.vi.` It defines the behavior of the custom device on the execution host. The RT Driver VI runs on the execution host regardless of the target's operating system.

> NI VeriStand 2009 did not support the NI VeriStand Engine on VxWorks operating systems. Starting with NI VeriStand 2010, if you want to support VxWorks targets such as Compact RIO, you must compile the engine library for VxWorks. PharLap and Windows engines do not require additional compilation.

The engine runs after the custom device has been added to the system definition, configured by the operator, and deployed to the execution host. The developer usually adds initialization, steady-state, and shutdown code to the engine template. There aren't any hard boundaries on what code you can put into the engine, only on what code you *should* put in the engine.

NI VeriStand deploys the engine when the operator clicks **Run Project** from the NI VeriStand Getting Started Window, selects **Operate » Run** or **Operate » Deploy** from the Project Explorer, or when the system definition is deployed using the NI VeriStand Execution API.

Each of the five prebuilt custom devices has a different engine VI. Each engine VI executes at a different time with respect to other NI VeriStand components. The timing requirements of a custom device, and thus the type of device selected, are functions of when the device needs to execute with respect to other NI VeriStand Engine components. We'll cover this in detail later on.

Not all requirements can be satisfied by one of the five types of prebuilt custom devices. Some custom devices require multiple engine libraries (to support different real-time operating systems for example). NI VeriStand – Set Custom Device Driver VI allows you to programmatically change the driver library for a custom device. Some custom devices use the prebuilt template as a launching pad for multiple parallel processes or complex frameworks. See the section Beyond the Template Frameworks for more information. Again, custom devices give the developer complete freedom with regard to OI/UI and execution.

Custom Code

The custom code performs any functionality desired by the custom device developer. While the initialization and engine frameworks provide access to NI VeriStand data and timing resources, it's up to the developer to implement the code to meet specification.

For example, the custom code might perform a single A/D conversion on a 3rd party digitizer. The framework provides the means for sending the digitized value to the rest of the NI VeriStand system so it can be mapped to channels, used in a stimulus profile, etc. Again, there aren't any hard boundaries on the code you *can* put into the driver.

Custom Device XML

Each custom device has an XML file that contains information used by NI VeriStand to load, configure, display, deploy and run the device. The basic information includes VI and dependency paths, page names, action and menu items, and Meta data for the various pages that make up the custom device. The Custom Device Template Tool generates an XML file for

you and include it in the template LabVIEW Project. Any properly-formatted XML file will be parsed by NI VeriStand. After the XML file is created by the Custom Device Template Tool, all edits to it are manual, i.e. it is not automatically updated to reflect changes made by the developer.

> ⚠️ The custom device XML does not automatically synchronize with changes to the LabVIEW project, nor does it automatically deploy. Be sure to modify the XML in the LabVIEW Project directory when making changes. Building the Initialization specification overwrites the XML in the `<Common Data>\Custom Devices` folder.

The XML file provides the ability to customize the appearance and behavior of the custom device in System Explorer. For example, you can change the default glyph or add a right-click menu to a custom device by adding tags to the custom device XML file.

> ⚠️ Since NI VeriStand parses `<Common Data>` for custom devices when it launches, a corrupt custom device XML file can affect the overall NI VeriStand system. You should exercise care and make a backup of the custom device XML before modifying it.
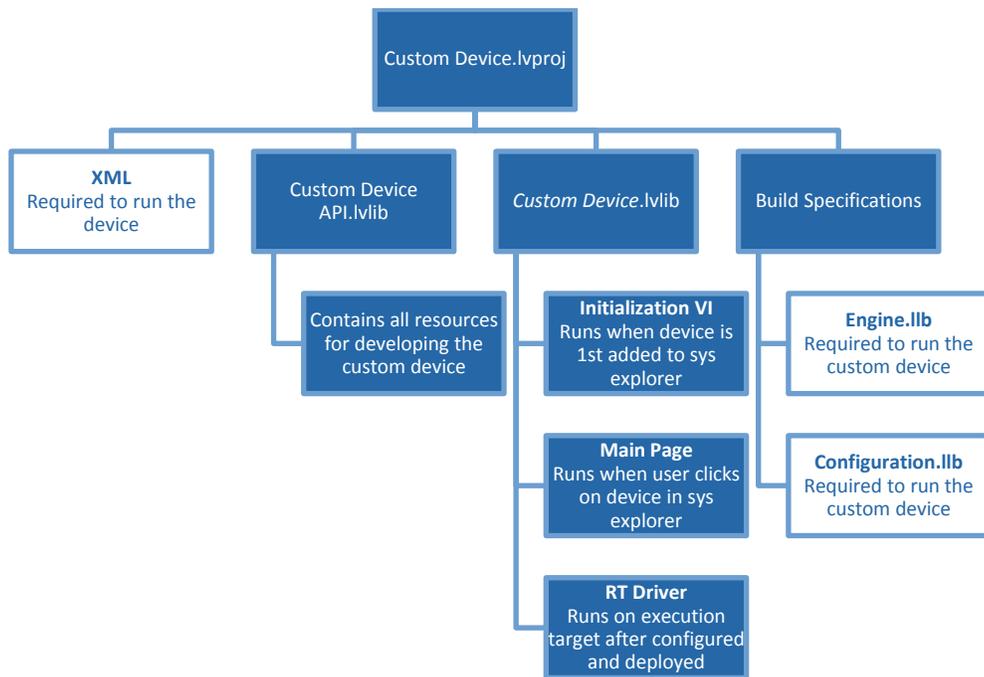
Figure: Diagram of the LabVIEW Project Created by the Custom Device Template Tool

When do you Need a Custom Device?
The built-in components of an NI VeriStand Project are listed in NI VeriStand Help » Navigating the NI VeriStand Environment » System Explorer Window. If the built-in components do not fulfill a specification, it can most likely be fulfilled by one of the customization methods shown in NI Developer Zone Tutorial: Using LabVIEW and Other Software Environments with NI VeriStand.

Four custom devices are included with NI VeriStand 2010. These devices are listed in NI VeriStand Help » NI VeriStand Reference » Custom Devices Included with NI VeriStand.

1. Embedded Data Logger
2. Gopel LIN
3. Lambda Genesys DC Power Supply
4. Pickering 40-295

In addition to these four devices, a variety of custom devices have already been implemented by National Instruments and are available for download. You should consult NI Developer Zone Tutorial: NI VeriStand Add-ons to determine if a custom device has already been developed to fulfill your specification.

Several hardware vendors have implemented custom devices for their hardware. You should check with the manufacturer that a custom device doesn't exist before you build one.

In general, there are three specifications that are best-suited for a custom device.

1. 3rd Party Hardware
2. Unsupported Measurement or Generation Mode
3. Feature

3rd Party Hardware

A list of hardware natively supported by NI VeriStand is found in NI VeriStand Help » NI VeriStand Reference » Supported National Instruments Hardware. If the application requires other hardware, it can probably be implemented in a custom device.

Unsupported Measurement or Generation Mode

Check NI VeriStand Help » Configuring and Running a Project » Configuring a System Definition File » Adding and Configuring Hardware Devices to determine if the required measurement or generation mode of your hardware is supported. If not, it can probably be implemented in a custom device. For example, single-point hardware-timed analog acquisition on NI-DAQ devices is supported out-of-the-box. Continuous analog acquisition can be implemented as a custom device.

Feature

All of the common functionality necessary for most real-time testing applications such as host interface communication, data logging, stimulus generation, etc, is provided by NI VeriStand – ready to configure and use. You should first try to meet specifications with the built-in functionality because it is engineered, tested, and supported by National Instruments.

If a built-in feature does not exist, it can be implemented by extending NI VeriStand. See NI Developer Zone Tutorial: Using LabVIEW and Other Software Environments with NI VeriStand for a complete list of ways to customize and extend NI VeriStand. Certain features are best implemented as custom devices. To determine when a custom device is the most appropriate mechanism to meet a specification, you should be familiar with all the customization methods available. A general rule-of-thumb is that custom devices implement features that require or use NI VeriStand channel data on the execution host.

For example, there is a TDMS File Viewer tool built into the NI VeriStand Workspace. If you need to log NI VeriStand channels to TDMS without first sending it back to the Workspace (as with high-speed streaming), a custom device called the Embedded Data Logger fulfills this requirement. This custom device ships with NI VeriStand 2010. On the other hand, if you need to display previous test results on the workspace while a new test is running, a custom workspace object may be more appropriate than a custom device. See NI Developer Zone Tutorial: Creating Custom Workspace Objects for NI VeriStand for more information.

Custom Device Risk Analysis

The open nature of NI VeriStand is a strong advantage over other real-time/HIL testing solutions. It's easy to take advantage of this extensibility by using custom devices written by other developers. Writing your own custom device incurs a set of manageable risks. This section provides a list of risks that should be considered before custom device development begins.

LabVIEW Application Development

Custom devices are written in LabVIEW. The framework generated by the Custom Device Template Tool is single-loop or action-engine VI. This architecture may be suitable for simple custom devices.

Non-trivial devices will require more advanced architecture. A requisite for custom device development is thorough knowledge of LabVIEW programming and application architectures. This knowledge represents NI Certified LabVIEW Developer (CLD) level expertise, and is typically obtained through NI's Training and Certification program by completing the LabVIEW Core 1, Core 2, and Core 3 courses.

It should be mentioned that NI VeriStand custom devices are typically not large LabVIEW applications. Custom devices are designed to be modular, self-contained plug-ins that add a specific functionality to NI VeriStand. While custom devices are typically developed by a single programmer, large application development best-practices may still apply. See LabVIEW 2010 Help: Best Practices for Large Application Development for more information.

LabVIEW Real-Time Application Development
Custom devices are typically designed to execute on real-time systems. This allows the operator to perform deterministic HIL and RT test procedures. Programming for a real-time system requires knowledge of real-time operating systems (RTOS) and specialized LabVIEW development techniques. This knowledge is typically obtained through NI's Training and Certification program by completing the Real-Time Application Development course, and it is refined by working on several LabVIEW Real-Time applications.

NI VeriStand Background
Familiarity with the NI VeriStand Engine is crucial to successful custom device development. The correct type of custom device cannot be selected in the Custom Device Template Tool without understanding the implications of each. This knowledge is typically obtained by reading the NI VeriStand 2010 Help, with an emphasis on Understanding the VeriStand Engine.

Experience with NI VeriStand from an operator's perspective is highly desired. This experience enables you to build operator-friendly interfaces that conform to the standard look and feel of other NI VeriStand components. Familiarity with NI VeriStand allows the developer to build-up a complex system definition, which allows thorough and realistic testing and benchmarking.

Hardware Driver Development
Custom device must call a hardware or instrument driver to support 3rd-party hardware. All National Instruments hardware comes with a LabVIEW Application Program Interface (API) that can be used in the custom device. However, just because a LabVIEW API exists does not guarantee the custom device can be easily implemented. Consider the following points when evaluating the feasibility of a custom device for 3rd-party hardware.

- Does an Instrument Driver exist? See NI Developer Zone » Instrument Driver Network to search for instrument drivers.
- Is a hardware driver available?
- Is the driver well documented?
- If necessary, is the driver compatible with LabVIEW Real-Time? See KnowledgeBase 3BMI76L1: How Can I Verify that My DLL is Executable in LabVIEW Real-Time for instructions on checking compatibility.

NI VeriStand uses *channels* to pass data between different parts of the system, including to and from custom devices. All NI VeriStand channels are LabVIEW double data type (DBL). See LabVIEW 2010 Help » Fundamentals » Building the Block Diagram » How-To » Floating Point Numbers for more information on LabVIEW data types.

☐ Can the hardware requirement be met by passing LabVIEW DBLs to and from the custom device during steady state operation?

If the hardware driver returns a vector, structure, or any non-DBL data, it cannot be passed directly from the custom device to the rest of the NI VeriStand system. The developer is responsible for coercing the data (or using an alternative communication mechanism) to pass data from the custom device to the rest of the system. For more information on the available communication mechanisms, see LabVIEW 2010 Real-Time Module Help » Real-Time Module Concepts » Sharing Data in Deterministic Applications » Exploring Remote Communication Methods.

NI VeriStand also exposes its TCP pope via dynamic event registration. This pipe may suite your remote communication requirements. See the Custom Device Engine Events section for more information.

Testing

A custom device is one part of an NI VeriStand system. The complete state of the operator's system is seldom known by the custom device developer. System state includes the following information.

☐ What are the specifications of the execution host and host computer?
☐ What components are in the system definition?
     o How computationally intense are the simulation models?
☐ What loop rates are required?
☐ What is the health and resource utilization of the system?

Ideally, the custom device is implemented to be minimally burdensome, extremely efficient, and easy to use. Depending on its complexity, it may become necessary to test, debug, and optimize the code on systems representative of the operator's system. Consider the following example.

A custom device developer needs to benchmark a 3rd-party hardware custom device. He adds the custom device to the Sine Wave example that ships with NI VeriStand 2010. He deploys the system definition to a quad-core NI-8110 RT controller. Adding the custom device to the system in increased the target's CPU load by 10% per-core and RAM utilization increased 120KB. If the operator is deploying the same custom device to a single-core 8101 RT controller, with an average CPU load of 60% because of a computationally intense model, it's unlikely the operator will achieve the same loop rate after adding the custom device. This system may be incapable of running the custom device at all.

Time to test, debug and optimize the code must be factored into the development timeline. If you're developing for a specific operator, then it's best to test on a system representative of their system. If you're developing for unknown systems, then it may be appropriate to include the specifications of the system used to obtain benchmarking and timing information with the custom device documentation.

Planning the Custom Device

The most critical phase of custom device development is planning. Several idiosyncrasies of NI VeriStand require more thorough planning than does a small stand-alone LabVIEW application. There are five main things that must be planned.

1. Channels

2. Properties
3. Hierarchy
4. Pages
5. Device Type

After you have a clear idea of the channels, properties, hierarchy, pages, and type of custom device, you're ready to start implementation. In the following discussion, we'll refer to a hypothetical 3rd party analog to digital (A/D) converter, the AES-201. A hypothetical device was chosen to simplify this discussion. If you prefer to follow along with an actual device, please refer to NI DeveloperZone Tutorial: Building Custom Devices for NI VeriStand 2010.
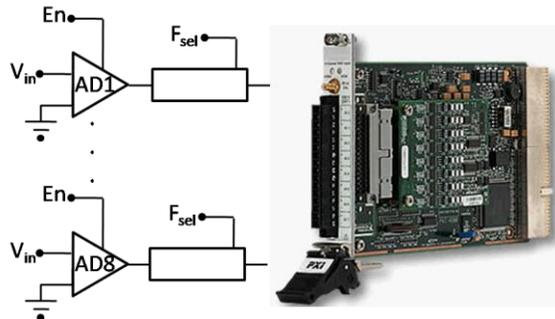

Figure: A Hypothetical Digitizer called the AES-201

The AES-201 has (8) 32-bit analog input channels (AI). The device can digitize on ±1V or ±500mV. The card has a single software trigger line. Each channel has a software enable that is ON by default, and a 6Hz low pass filter that is OFF by default. A call to the hardware API makes a single A/D conversion on the specified channel and returns raw data. The range of the device cannot be changed after the device has been initialized.

Channels
Channels are the built-in mechanism used to exchange data between the custom device and the rest of the NI VeriStand system. All channels are 64-bit floating point numbers; there is no built-in mechanism for other channel data types. There are three common use cases for planning a custom device channel.

1. Data generated by the custom device after it's deployed that *may be* required by other parts of the NI VeriStand system.
2. Data originating elsewhere in the NI VeriStand system that *may be* consumed by the custom device after it's deployed.
3. Dynamic properties that may change after the device is deployed can be implemented in channels.

> 💡 Notice the emphasis on "*may*". Custom devices should be designed with a generic use-case in mind. Just because your customer doesn't use all channels and settings of the hardware doesn't mean you shouldn't expose everything to the operator.

Given these use cases, the AES-201 custom device should have one channel each for `ADDataFromCh<1..8>`. The digitized data is going to change while the device is running. The operator may need that data to be available to the rest of the NI VeriStand system. For example, operators often map data from hardware to simulation model inputs.

The operator may need the ability to map the AES-201 software trigger to another channel in the system explorer (a calculated channel for instance). So the developer should create a channel for `SWTrig`. The operator may need the ability to disable a channel or toggle the input filter or the AES-201 while the device is running. The developer should plan an additional 16 channels: one each for `FilterEnCh<1..8>` and `ADEnCh<1..8>`.

> NI VeriStand channels are always LabVIEW DBLs. It may be easier to flatten data to DBL than it is to implement a background communication loop that passes native data types to the rest of the system. While the AES-201's LabVIEW API calls for Boolean data to enable the channel or filter, you can still use a DBL channel with the assumption that `0 = False` and `!0 = True`.

Channels are created with NI VeriStand Custom Device API » Configuration » Add Custom Device Channel. The type of channel is either Input or Output. Channel type is with respect *to the custom device*. If the custom device passes data *to* the rest of the NI VeriStand system, it requires an *output* channel. If the custom device gets data *from* the rest of the system, it requires an *input* channel. For example, the AES-201 may have 8 output channels (`ADDataFromCh<1..8>`) and 17 input channels (`ADEnCh<1..8>, FilterEnCh<1..8>` and `SWTrig`).

Once the custom device is loaded into NI VeriStand, the operator can map each input channel to a *single data source*. Similarly, the operator can map each output channel to an *arbitrary number of sinks*. For example, you can map `ADDataFromCh1` to several simulation model inputs, but `SWTrig` may be mapped to a user channel or model output, but not both.

NI VeriStand – Add Custom Device Channel VI
**Owning Palette:** Configuration

Adds a channel to the device or device subsection specified by **Parent Ref in**. If the **Channel Name** you specify already exists, the VI overwrites the existing channel settings without affecting any custom properties.
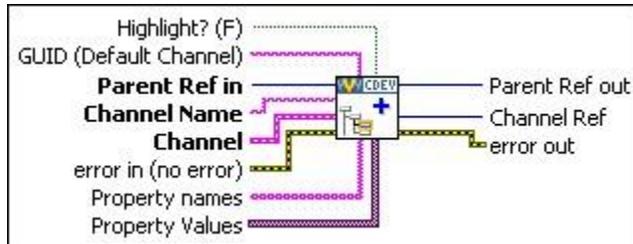
Highlight? makes the item active in System Explorer.
GUID (Default Channel) the GUID of a custom channel defined in the custom device XML file.
Parent Ref in is the NI VeriStand reference to the parent section for the new channel.
Channel Name is the name of the new channel. The name is applied to the channel when the VI runs. If the operator changes the name of the channel in the System Explorer, the changed name persists.
Channel defines the type, units, and default value of the channel. It also toggles Faultable and Scalable properties on the channel.
error in describes error conditions that occur before this node runs. This input provides standard error in functionality.
Property names is an string array of arbitrary property names associated with the channel.
Property Values is a variant array that cooresponds one-to-one with the property names.
Parent Ref out is a duplicate of the Parent Ref in.
Channel Ref provides the NI VeriStand reference to the new channel within the custom device.
error out contains error information. This output provides standard error out functionality.

The Add Custom Device Channel VI may be called from any VI that runs on the host computer. There are several other VIs in the NI VeriStand Custom Device LabVIEW palette that operate on custom device channels. The behavior of the VI is what you'd expect given the name of the VI.

- ☐ Configuration » Get Custom Device Channel Data VI
- ☐ Configuration » Rename Custom Device Item VI
- ☐ Configuration » Remove Custom Device Item VI
- ☐ Channel Properties » Set Custom Device Channel Default Value VI
- ☐ Channel Properties » Set Custom Device Channel Faultability VI
- ☐ Channel Properties » Set Custom Device Channel Scalability VI
- ☐ Channel Properties » Set Custom Device Channel Type VI
- ☐ Channel Properties » Set Custom Device Channel Units VI
- ☐ Driver Functions » Get Custom Device Channel List VI

In addition to these channel-specific VIs, any VI from the Item Properties palette may be used with a custom device channel.

Properties
Properties are used within the custom device to communicate state information. Property names are case-sensitive strings. Unlike channels, property values may be any standard LabVIEW data type. Properties are the recommended way to transfer configuration and state

information from the configuration to the engine on a *one-time basis*. The transfer occurs when the system definition is deployed to the execution host.

After the system definition is deployed, the engine may still read and write properties on the execution host, but it may not exchange properties with the host computer using the property VIs.

The range setting on the AES-201 is best implemented as a custom device property because the range cannot be changed after the card has been initialized. The configuration routine on the host computer can set the Range property of the card based on operator input. When the operator deploys the system definition, the engine can then read the Range property. The engine can then make the appropriate call to the hardware API to set the range.

After the AES-201 has been started, the range cannot be changed. If the operator wants to change the range setting, he must launch System Explorer, reconfigure the custom device, and redeploy the system definition. The engine may still read or write the Range property, but the change is *not* reflected in System Explorer.

You may decide to implement the filter setting as a property. The operator would enable or disable the filter in System Explorer by toggling a check-box on each channel's page. On one hand, the device would require 8 fewer channels. On the other hand, the operator could no longer toggle the input filter while the custom device was running. To illustrate several aspects of custom device development, we will implement the filter setting as a property.

In this small example, we have eluded to a design decision often faced by custom device developers. As the number of use-cases and flexibility of a custom device increases, so does the complexity of planning and implementing the device. The tradeoff is a more robust device that requires less customization by the operator.

NI VeriStand – Set Item Property VI
Owning Palette: Item Properties VIs

Sets a **Property Name** and **Value** for an item. If the **Property Name** you specify already exists, NI VeriStand overwrites the property.
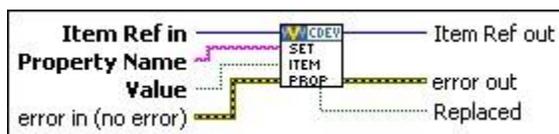
Item Ref In is the NI VeriStand reference to the item destined for the property.
Property Name is an arbitrary case-sensitive name for the property.
Value corresponds to the value of the property. This is a polymorphic VI and the data type of the value input cooresponds with the instance.
error in describes error conditions that occur before this node runs. This input provides standard error in functionality.
Item Ref out is a duplicate of the Item Ref in.
error out contains error information. This output provides standard error out functionality.
Replaced indicates if the property was overwriten by the new value.

The Set Item Property VI may be called from any VI in the custom device. Properties can be applied to any channel or section. In addition to the Set Item Property VI, properties can be set

when a channel or section is created by using the **Property Names** and **Property Values** terminals.

A property must be read from the item to which it was set. For example, if you set the `Filter_Enabled` property on the `ADDataFromCh1` channel, you cannot read the value of the `Filter_Enabled` property directly from the parent section or any reference other than `ADDataFromCh1`. Properties do not inherit.

NI VeriStand – Get Item Property VI
Owning Palette: Item Properties VIs

Returns the Value of a specific item **Property Name**. If the **Property Name** does not exist for the specified item, **Value** returns **Default Value**.
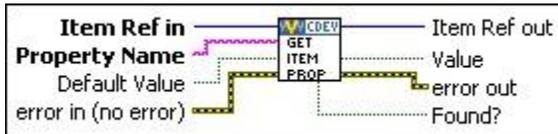
|	
Item Ref in is the NI VeriStand reference to query for the property.
Property Name is an arbitrary case-sensitive name for the property.
Default Value is returned by the **Value** terminal if the property is not found.
error in describes error conditions that occur before this node runs. This input provides standard error in functionality.
Item Ref out is a duplicate of Item Ref in.
value is the value of the property. This is a polymorphic VI and the data type of the **Default Value** and **Value** terminals coorespond with the instance.
error out contains error information. This output provides standard error out functionality.
Found indicates if **Property Name** was found on **Item Ref in** (true) or if the default value was returned (false).

It's good programming practice to always use the **Found** terminal of the Get Item Property VI to check that the intended property name was found on the item.

NI VeriStand – Remove Item Property VI
Owning Palette: Item Properties VIs

Removes the **Property Name** from an item.
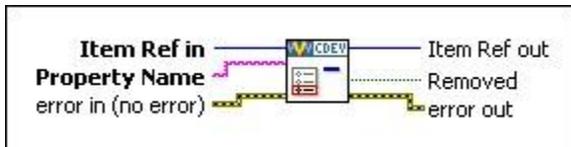
Item Ref in is the NI VeriStand reference to the item.
Property Name is an arbitrary case-sensitive name for the property.
error in describes error conditions that occur before this node runs. This input provides standard error in functionality.
Item Ref out is a duplicate of **Item Ref in**.
Removed indicates if the property was found and removed successfully.
error out contains error information. This output provides standard error out functionality.

The Get Item Property and Remove Item Property VIs may be called from any VI in the custom device. There are several other VIs in the NI VeriStand Custom Device LabVIEW palette that operate on custom device properties. The behavior of the VI is what you'd expect from the name of the VI.

- ☐ Item Properties » Get Item Description
- ☐ Item Properties » Get Item GUID
- ☐ Item Properties » Get Property Names List
- ☐ Item Properties » Set Item Description
- ☐ Item Properties » Set Item GUID
- ☐ Device Properties » Get Custom Device Decimation
- ☐ Device Properties » Get Custom Device Driver
- ☐ Device Properties » Get Custom Device Version
- ☐ Device Properties » Set Custom Device Decimation
- ☐ Device Properties » Set Custom Device Driver
- ☐ Device Properties » Set Custom Device Version
- ☐ Device Properties » Specify Custom Device Execution Mode

Custom Device Decimation

You can set decimation for any type of custom device. However, decimation is handled differently for inline and asynchronous devices. We'll discuss the difference between these devices later in the document.

An inline custom device is not called if its decimation indicates not to. For example, when you decimate an inline custom device by 4, the PCL calls the custom device at every fourth iteration. It does *not* mean the custom device has four times as long to execute. The inline custom device must execute in short enough time for the entire PCL to complete its iteration *including the time to execute the inline custom device*. Asynchronous devices have their channel FIFOs read on the N'th iteration of the PCL, where N is the decimation rate of the asynchronous device.

This information will make more sense after you understand the difference between inline and asynchronous custom devices.

Hierarchy

NI VeriStand's System Explorer allows each custom device to present a hierarchal user configuration interface. A hierarchal structure is not required, but it's a convenient way for the developer to organize and present the device logically to the operator.

The Pickering 40-295 device that ships with NI VeriStand has a simple hierarchy. This custom device hierarchy begins with the **Pickering 40-295** custom device. This is the *top-level* item in this custom device's hierarchy.

Within the next echelon are sections for **Desired Values** and **Actual Values**. Within each section are the individual channels. If you're familiar with this 3rd party hardware, the hierarchy is an intuitive configuration interface for the Pickering 40-295 resistive module.

There are an arbitrary number of possible hierarchies for most custom devices.

Top-level item in the Pickering custom device.
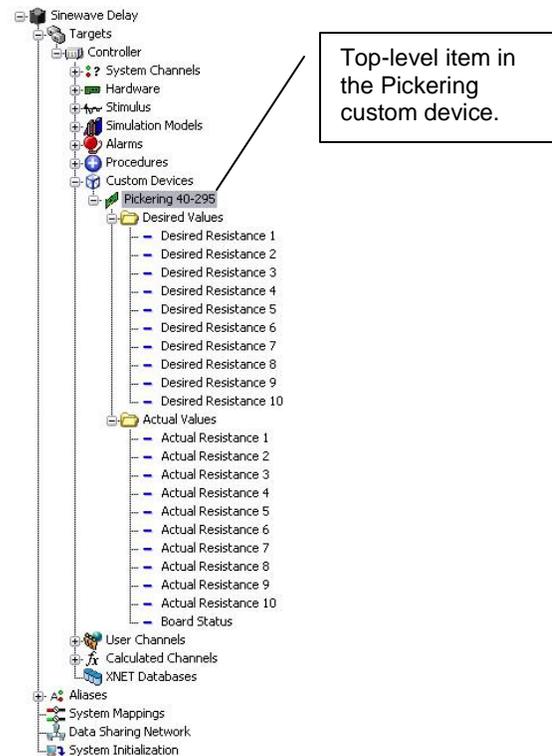
Figure: Hierarchy of the Pickering 40-295 Custom Device

Within the hierarchy, there are two types of objects: *sections* and *channels*. We've already discussed custom device channels. *Sections* provide a logical way to group items in the hierarchy. The default section glyph (icon) is a folder, as shown in the Pickering 40-295 custom device. The developer can change the glyph by modifying the custom device XML. A collection of glyphs that install with NI VeriStand 2010 is found in `<Application Data>\System Explorer\Glyphs`.

All items in a custom device's configuration tree are either channels or sections, regardless of their glyph. You cannot create additional levels of custom device hierarchy from channels. You cannot map sections to other items in NI VeriStand. You cannot exchange data through sections during run-time as you can with channels.

Sections are created with NI VeriStand Custom Device API » Custom Device API VIs » Configuration VIs » NI VeriStand - Add Custom Device Section.

NI VeriStand – Add Custom Device Section VI
Owning Palette: Configuration

Adds a section with the name **Section Name** to the device specified by **Parent Ref in**. If the **Section Name** you specify already exists for that device, this VI updates only the **GUID** of that section without affecting any properties or any child items.
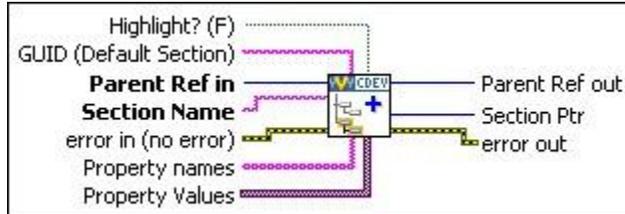
TF	**Highlight?** makes the item active in System Explorer.
abc	**GUID (Default Section)** specifies the GUID of a custom page in the custom device XML file.
U64	**Parent Ref in** is the NI VeriStand reference to the parent for the new section.
abc	**Section Name** is the name of the new section. The name is applied to the channel when the VI runs. If the operator changes the name of the section in the System Explorer, the changed name persists.
error	**error in** describes error conditions that occur before this node runs. This input provides standard error in functionality.
abc	**Property names** is an string array of arbitrary property names assigned to the section.
[◇]	**Property Values** is a variant array that cooresponds one-to-one with the property names.
U64	**Parent Ref out** is a duplicate of the Parent Ref in.
U64	**Section Ptr** provides the NI VeriStand reference to the new section.
error	**error out** contains error information. This output provides standard error out functionality.

The Add Custom Device Section VI may be called from any VI that runs on the host computer. You build-up the custom device hierarchy by using the **Parent Reference** terminal and the **Section Pointer** terminal. **Parent Reference** is the level of the hierarchy that will contain the new section. **Section Pointer** is the reference to the new section, *one level deeper in the custom device hierarchy* than the Parent Reference. Now we'll examine several hierarchies for the AES-201 and discuss the advantages and disadvantages of each.
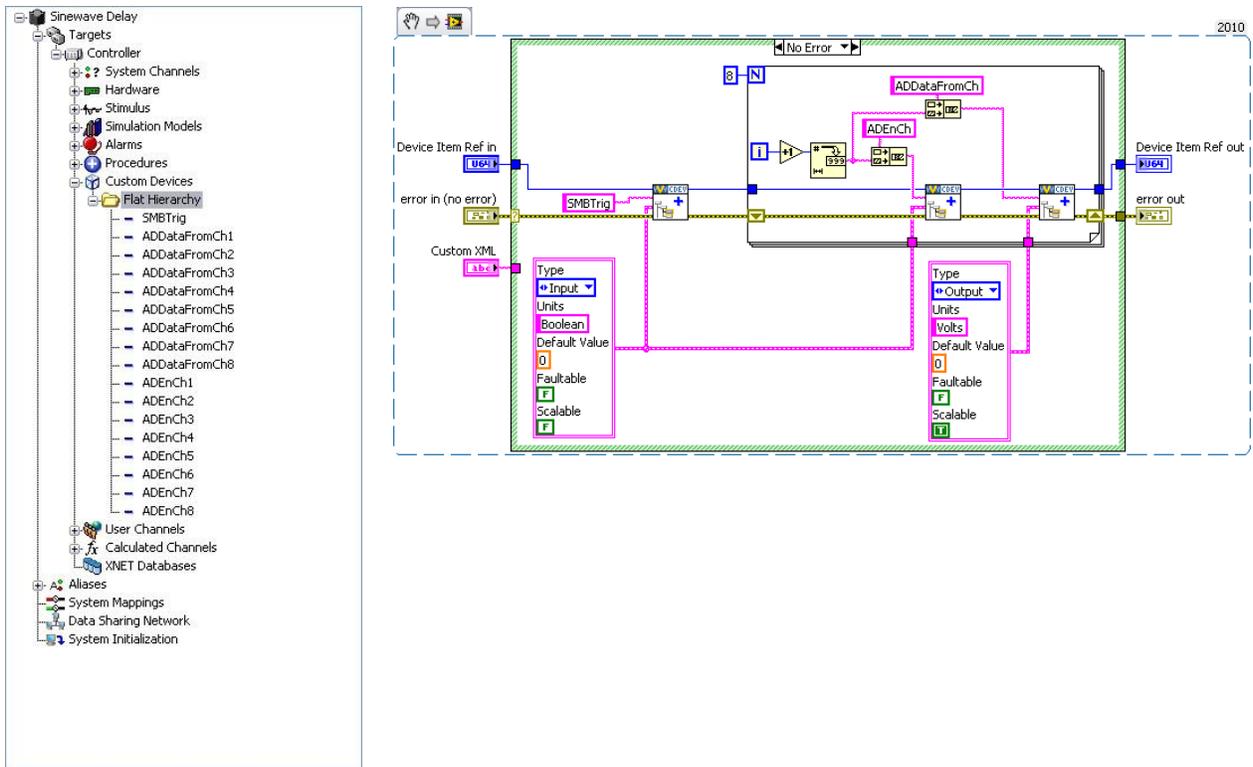
Figure: Flat Custom Device Hierarchy and Corresponding Initialization VI

The figure above is an example of a *flat* or *single-level* hierarchy for the AES-201. All of the channels are under the main section in the configuration tree. While it's easy to determine how many channels are available, the type of channel is unknown and the function of the channel is implied by the channel name. A flat hierarchy is suited for devices with a small number of channels that all perform the same function. A flat hierarchy is less suited for large channel count devices, or when channels perform different functions. For example, a custom device for a multifunction data acquisition board would be difficult to present in a flat hierarchy.

Notice that the same **Device Item Ref in** is used to create the SWTrig, ADEnCh<1..8>, and ADDataFromCh<1..8> channels. As a result, all of these channels appear at the same echelon of the hierarchy. In the code above, you should be able to identify the input and output channels. SWTrig and ADEnCh<1..8> are input channels because the custom device sinks data from them. ADDataFromCh<1..8> are output channels because they source data to the rest of NI VeriStand. We'll be showing clusters as icons in much of the following material.

From an operator's perspective, custom device inputs and outputs may seem backwards. *Hardware inputs* correspond to *custom device outputs*. The operator is not required to interact with the custom device source code, only System Explorer. If the developer did a good job, channel direction should make sense to the operator.
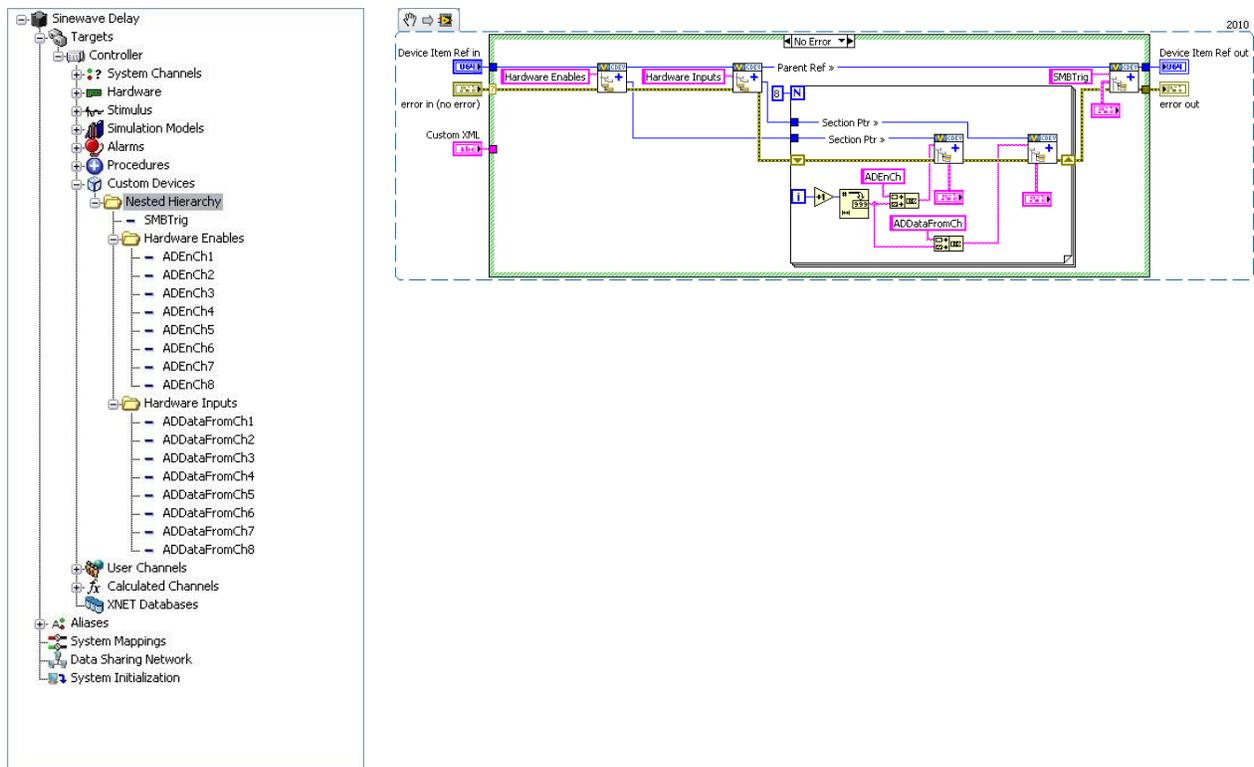
Figure: Nested Custom Device Hierarchy and Corresponding Initialization VI

The figure above is an example of a nested hierarchy for the AES-201. The channels have been organized into `Hardware Enables` and `Hardware Inputs` sections. This device is well-organized and fairy intuitive. Note how the **Section Ptr** outputs are used to create channels beneath the corresponding section in the Initialization VI. Also note how the parent reference is used to create the trigger channel at the same level as the two sections in the custom device hierarchy.

You can create an arbitrarily complex hierarchy. You should plan the custom device hierarchy to use the minimum number of sections that make the hierarchy well-organized, intuitive, and user friendly.

Pages

Pages are VIs that System Explorer displays in the configuration pane. The configuration pane is a Subpanel. Subpanels are LabVIEW front panel containers that allow a VI to display the front panel of another VI. See LabVIEW 2010 Help » Fundamentals » Building the Front Panel » Concepts » Front Panel Controls and Indicators » Subpanel Controls for more information.

An item's page gets displayed in the Subpanel when the operator clicks on the item in system Explorer's configuration tree. Pages run on the host computer; they define the appearance and configuration experience of the custom device. The Custom Device Template Tool creates two configuration VIs by default: Initialization and Main. The Initialization VI is a simple VI (it doesn't get populated into the Subpanel), the Main VI is a page.

When you click on the top-most custom device item in the configuration tree, *<Custom Device Name>* `Main Page.vi` goes into System Explorer's configuration pane's Subpanel and its block diagram executes.

The Main Page

Clicking the top-level item in the configuration tree…

…runs the main page and puts it in the configuration pane's Subpanel.
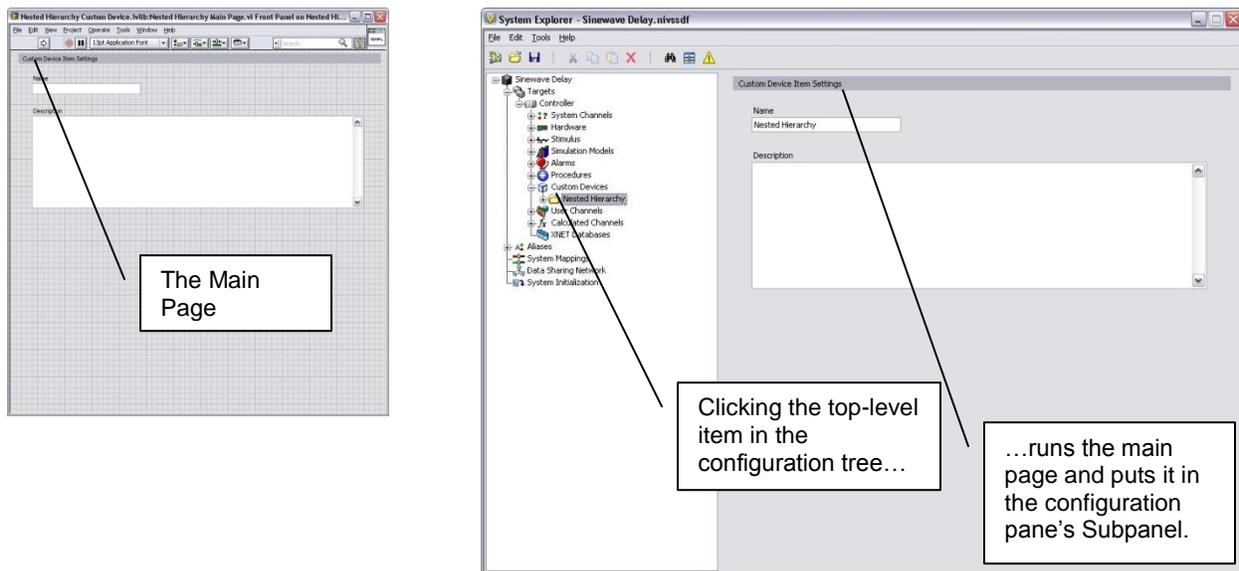
Figure: Main VI Populated into System Explorer when the Operator Clicks the Top-level Custom Device Item in the Configuration Tree

If the developer did not assign a custom page to a new *section* or *channel*, the default section or channel page is shown when the operator clicks on the item in the configuration tree.


A section is highlighted.
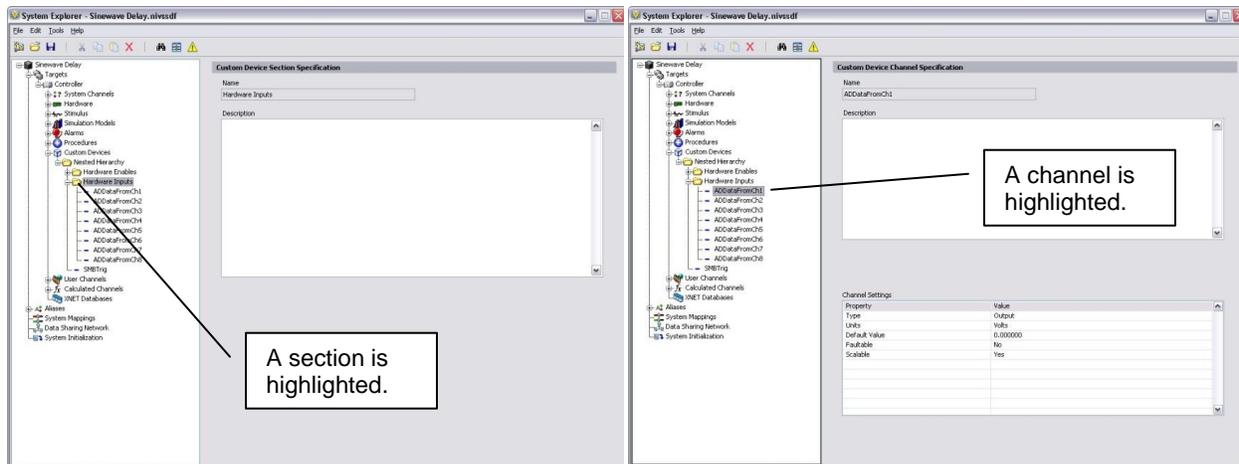
Figure: The Default Section Page

A channel is highlighted.

Figure: The Default Channel Page

The default pages allow the operator to set a description for the section or page. NI VeriStand retains this data in the System Definition (nivssdf) file. You cannot individually modify the block diagram or font panel of the default pages. The Custom Device Template Tool allows the developer to specify *extra pages*. Extra pages can be used to override the default page for an item. When the developer creates an extra page and associates it with a section or channel, he overrides the default page for that item. You can individually modify the front panel and block diagram of extra pages. The block diagram executes when the operator clicks on the item in the configuration tree.

Before we discuss adding extra pages in detail, we must cover a two rules for modifying custom device pages.

- ☐ You must not change the size of any page's front panel. The page's front panel is loaded into a Subpanel in the configuration pane. If you change the size of the front panel, it may not fit correctly into the Subpanel and may be unusable.
- ☐ You must not change the names or connector pane associations of any terminal generated by the page template or Custom Device Template Tool. NI VeriStand uses these objects to interface with the page. If they are changed, the custom device will not work and will likely prevent the operator from deploying the system definition.

Extra Pages

Extra pages provide a way to customize the appearance and/or behavior of any item in the custom device's hierarchy. Extra pages override the default pages. You should plan an extra page for each item in the custom device you wish to customize *differently*. For example, if you want to customize the page for each `ADDataFromCh` channel, but you'll customize all `ADDataFromCh` channels the same (say by adding an extra button for the filter), you only need one extra page. NI VeriStand stores state data for each individual item in the custom device hierarchy in the nivssdf file.

The AES-201 may call for five extra pages. One page for each section, one page each for the `ADDataFromCh<1..8>` and `ADEnCh<1..8>` channels, and one page for the `SWTrig` channel. Even if you don't wind up using the extra pages, it's better to have extra pages that you don't need than to need extra pages that you don't have.

NI VeriStand requires four things in order to override a default page with an extra page in the custom device.

1. Page
2. Globally Unique IDentifier (GUID)
3. XML Declaration
4. Build Specification

Page

A properly formed page VI must exist. If you plan properly, you'll be able to specify all the extra pages when you run the Custom Device Template Tool. An extra page is created for each element in the **Extra Page Names (No Extension)** control.

The tool generates the page, GUID, XML Declaration, and includes the page in the build specification. You'll find the extra page template in `Custom Device API.lvlib\Templates\Subpanel Page VI\Page Template.vit`.
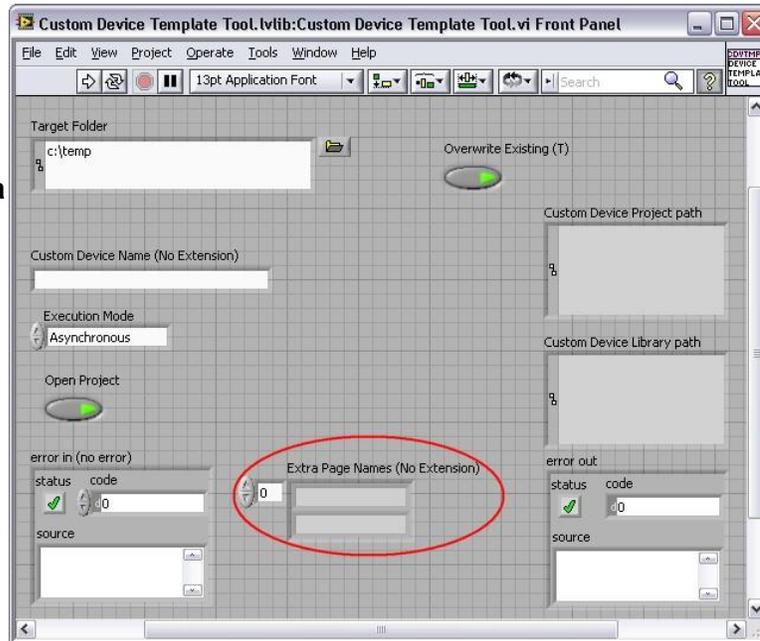

Figure: Extra Page Names Array

> If you do not use the Custom Device Template Tool to create extra pages, you must manually add and configure them.

Manually adding extra pages to a custom device after running the Custom Device Template Tool is cumbersome. Avoid this issue by creating a few extra pages beyond what you think will be necessary. Unused extra pages are not executed, but they do consume marginal space on disk.

GUID

When you associate an extra page with a channel or section, you override the default page for that item. This is done by specifying a GUID when the item is created, or by setting the item's GUID using NI VeriStand Custom Device API » Configuration » Item Properties » Set Item GUID.
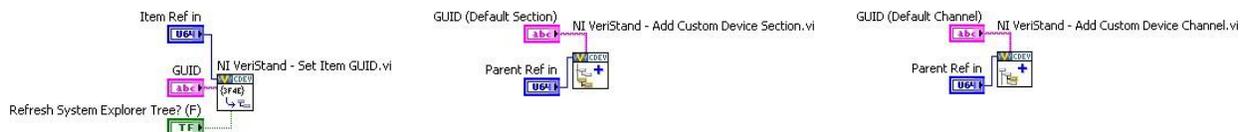

Figure: NI VeriStand API to Set an Item's GUID

The Custom Device Template Tool generates a GUID for each extra page in the **Extra Page Names (No Extension)** control.

There is a GUID Generator VI in `<vi.lib>\NI Veristand\Custom Device Tools\Custom Device Template Tool\Custom Device Template Tool.lvlib:GUID Generator.vi`. Before you can run this VI by itself, you must change the `Custom Device Template Tool.lvlib\subVIs` access scope to public, and set the

VI's Execution Priority to Normal. There is a stand-alone GUID generator VI attached to KnowledgeBase 571B7IYP: Adding a Page to an NI VeriStand Custom Device's Configuration Library after Running the Custom Device Template Tool. There are also a variety of free GUID generators on-line.

XML Declaration

The custom device API associates a *channel* or *section* with a *GUID*. The custom device XML associates the *GUID* with the *page VI*. The page and its GUID must be declared in the custom device XML `<PAGES>` section within a `<PAGE>` schema. If the developer planned for the extra pages before running the Custom Device Template Tool, the tool makes the appropriate entries in the custom device XML file for each extra page.

```
<Page>
  <Name>
    <eng>Extra Page 1</eng>
    <loc>Extra Page 1</loc>
  </Name>
  <GUID>36481013-A447-6517-7D1C-FBB21CAE1E9F</GUID>
  <Glyph>
    <Type>To Application Data Dir</Type>
    <Path>System Explorer\Glyphs\default fpga category.png</Path>
  </Glyph>
  <Item2Launch>
    <Type>To Common Doc Dir</Type>
    <Path>Custom Devices\Extra Page Demo\Demo Configuration.llb\Extra Page 1.vi</Path>
  </Item2Launch>
</Page>
```
Custom Device XML Showing the Page Name, GUID, and VI

Build Specification

Extra pages are dynamically called VIs. Since they are not a part of the custom device's VI hierarchy, they must be explicitly included in the custom device's Build Specification. If the developer planned for the required extra pages before running the Custom Device Template Tool, the tool configures the build specifications to include the extra pages into the initialization library.

If a page must be added to the custom device after the tool has been run, the developer must edit the configuration Build Specification to include the extra page and all its dynamically called dependencies (if any).

Type

While deployed to the execution host, all custom devices run inside the NI VeriStand Engine. The engine is the non-visible mechanism that controls the timing of the entire system as well as communication between the execution host and host computer. See NI VeriStand Help » Components of a Project » Understanding the VeriStand Engine for more information.

The Custom Device Template Tool generates a new LabVIEW Project containing one of five pre-built device frameworks. The framework is determined by the **Execution Mode** control.
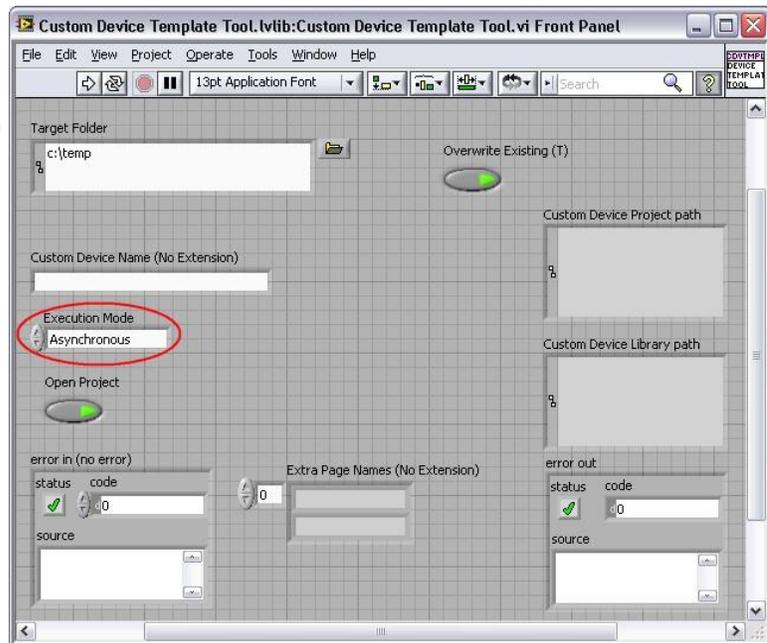
Figure: Execution Mode Control

The Execution Mode determines when the device will run *with respect to the other operations performed by the NI VeriStand Engine*. There are five pre-built device frameworks. Three of the frameworks are for custom devices; the other two are for custom timing and synchronization devices.

Custom timing and synchronization devices are the same as regular custom devices, but they can be configured as the *hardware synchronization master* to drive RTSI0. For more information about the Real Time System Integration (RTSI) bus see KnowledgeBase 2R5FK53J: What is RTSI and How is it Configured? Custom timing and synchronization devices are not covered in detail in this document. For more information about custom timing and synchronization devices, see NI VeriStand Help » Configuring and Running a Project » Configuring a System Definition File » Adding and Configuring Timing and Sync Devices. Multi-chassis synchronization may also be accomplished using built-in features. See NI DeveloperZone Tutorial: Creating a Distributed System With NI VeriStand 2010 for more information.

Two of the regular custom devices run *in-line* with the Primary Control Loop (PCL), the other runs in *parallel* with the PCL. A custom device is not limited to using just one type of framework. Some developers have built both in-line and parallel engines for a single custom device and allow the operator to select which mode to deploy.

Generally it's OK to alter the code within the framework depending on your needs. However you must maintain the connector pane, controls, and indicators provided by the Custom Device Template Tool or VI template. NI VeriStand uses these objects to interface with the custom device. If they are changed, the custom device will not work and will likely cause errors.

Asynchronous

The asynchronous custom device framework provides a simple, single-loop architecture. There are sections for initialization and cleanup before and after the loop. The asynchronous template provides a Timed Loop which may be exchanged for a While at the developer's discretion.

The loop runs in parallel loop to the PCL. If proper real-time development practices are adhered to, it is unlikely to block the PCL or slow it down. Essentially this means that the rest of the NI VeriStand system will continue to execute as expected even if the asynchronous custom device is latent or stalls.

The loop can be synchronized to the PCL's timing source, making it pseudo-synchronous. This applies to asynchronous devices that use a Timed Loop, While Loops cannot be used   for this purpose. The benefit of an asynchronous custom device synchronized to the PCL is that it will not cause the PCL to be late just because the custom device finishes late. Use NI VeriStand – Set Loop Type to specify the asynchronous Timed Loop uses the device clock. NI VeriStand tics the device clock for all Timed Loops that have **Use Device Clock** set to `true`.

The asynchronous device can also run at a different rate than the PCL. The rate may be defined using any execution timing method available in LabVIEW, and may iterate faster than the PCL. The rate can also be a decimation of the PCL rate specified by Custom Device API » Configuration » Item Property » Device Properties » Set Custom Device Decimation VI.

The asynchronous template provides two RT FIFOs (Device Inputs FIFO and Device Outputs FIFO) to exchange channel data with the rest of NI VeriStand. Since the asynchronous device runs in parallel to the PCL and passes channel data via RT FIFOs, there is a minimum of one cycle delay from when data leaves the PCL and when it enters the custom device and vice versa. These FIFOs correspond exactly to those shown in NI VeriStand 2010 Help » Components of a Project » Understanding the VeriStand Engine.
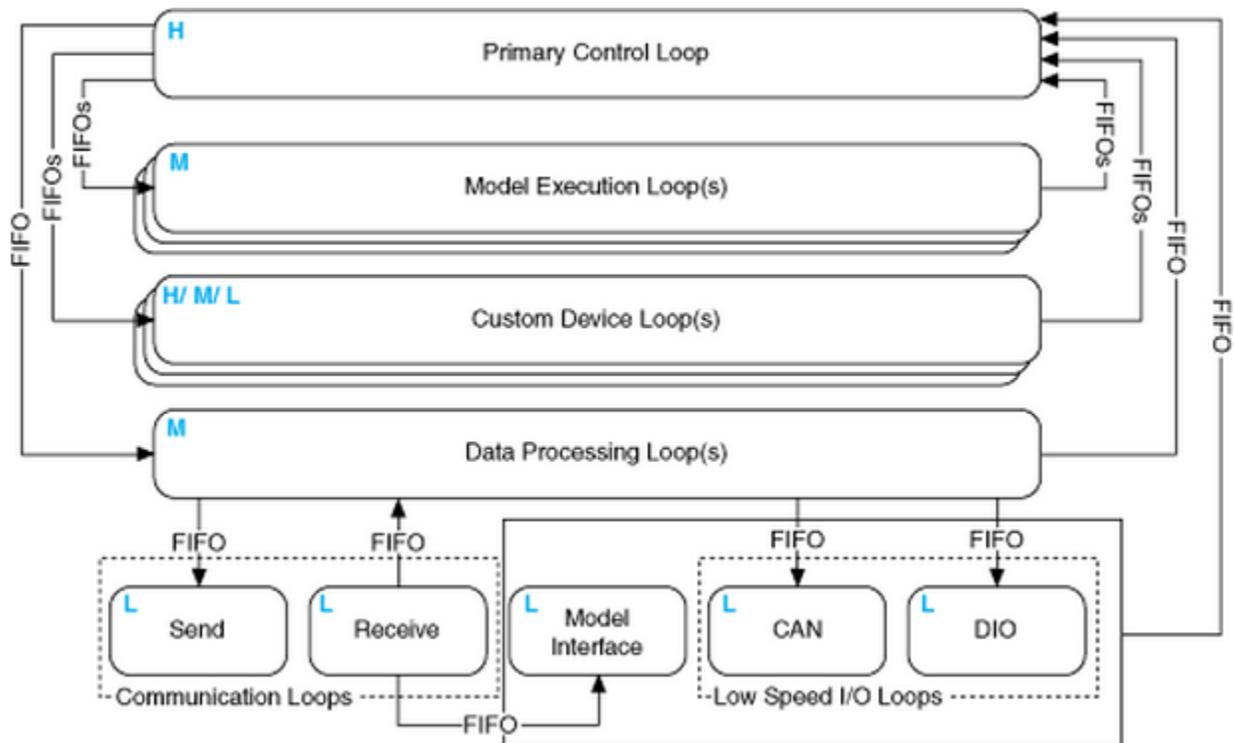

Figure: The NI VeriStand Engine

The asynchronous device is not guaranteed to execute at the same time with respect to the other components of the system. For example, the first iteration may execute before the PCL processes alarms; the second and third iterations after, the fourth before et cetera.

The input controls are specially named controls that the system will use to provide the device loop with data. The controls are not required for the device loop to run. For instance, if the device doesn't produce any output data, then you don't need the Device Outputs FIFO control. If you do need these controls, they must have these exact names to be functional.

The optional status notifier element is used to notify the RT engine of the last state of the custom device, and to indicate the device has completed execution. If this control is not used, a default No Error value is returned to the system when the device finishes execution. This error state is not checked until the system shuts down. Use an output channel to send more immediate status values to the system.

The asynchronous framework includes VIs from the NI VeriStand Asynchronous Device Properties VIs palette.
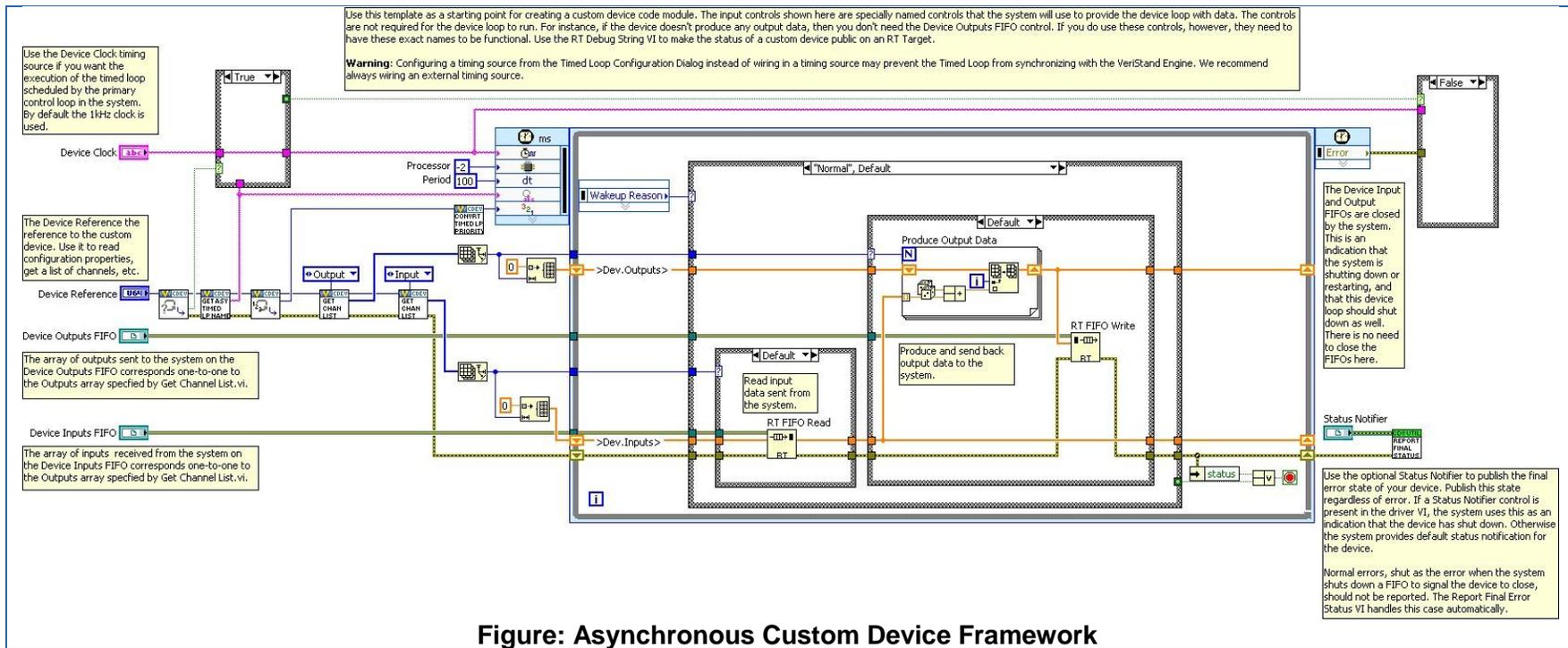
Figure: Asynchronous Custom Device Framework

Get Loop Type - Returns the type of loop that an asynchronous custom device uses. The type can be either While Loop or Timed Loop. If it's a Timed Loop, this VI also returns whether the loop uses the device clock.

Get Asynchronous Driver VI Timed Loop Name - Returns the name of the Timed Loop that a custom device uses. The VeriStand Engine synchronizes the start of this Timed Loop with the other system Timed Loops. Use the name to ensure synchronization occurs successfully.

Get Timed Loop Priority - Returns the priority (Low, Medium, or High) of an asynchronous custom device Timed Loop. To convert this enumerated value to a numeric value that the Timed Loop input terminal accepts, use the Convert Timed Loop Priority Property to Number VI.

Convert Timed Loop Priority to Number - Converts a priority value (Low, Medium, High) for a custom device Timed Loop into a numeric value that the Timed Loop Input Node accepts. To set the priority, use the Set Timed Loop Priority VI.

> ⚠ Whenever a timing source is specified for a Timed Loop, the **dt** terminal is in tics of the timing source. The asynchronous template has a default period of 100. The default timing source is a 1KHz clock, so the default configuration iterates at 10Hz. If you set **Use Device Clock** = `true` in the Set Loop Type VI, the Timed Loop will iterate every once every 100 iterations of the PCL.

See LabVIEW 2010 Help » VI and Function Reference » Programming VIs and Functions » Structures » Timed Loop for more information about the Timed Loop and its terminals.

Inline Hardware Interface
The inline hardware interface template is similar to state machine architecture. Some developers will recognize it as an *action-engine*. See NI Discussion Forums » LabVIEW » Community Nugget 4/08/2007 Action Engines for a discussion on action engines. The PCL specifies the case to execute. An uninitialized Feedback Node is used for iterative data transfer. There are five cases defined by the **Operation** enumerated control.

1. Initialize
2. Start
3. Read Data from Hardware
4. Write Data to Hardware
5. Close

This custom device runs in-line with the PCL, which calls each case at a specific time with respect to the other components in the NI VeriStand engine. The PCL will not proceed until the custom device case has completed.

Initialize
The *Initialize* case executes before the PCL starts. In this case, you can read the device configuration information from properties using the reference to the device. Initialize data and buffers used internally in the device. The framework compiles the list of Data References for the custom device Inputs and Outputs in advance using Custom Device API » Driver Functions » Get Custom Device Channel List and `Custom Device API.lvlib` » `Templates` » `RT Driver VIs` » `Inline` » `Inline Driver Utilities` » `Channel Data References` » `Get Channel Data Reference.vi`.
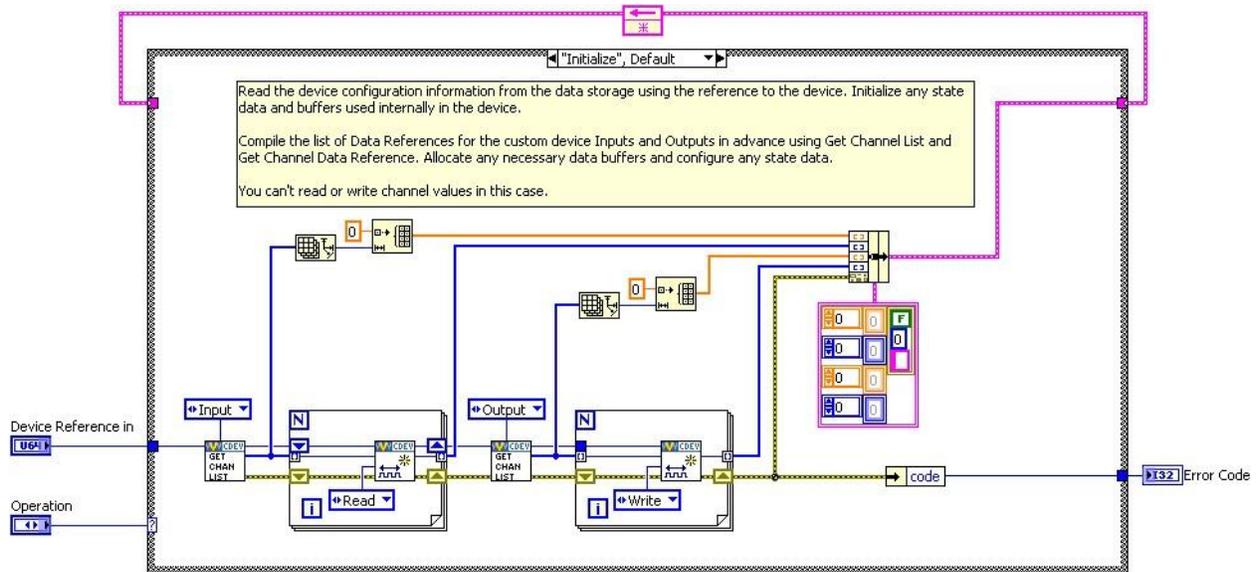
Figure: Initialize State of the Inline Hardware Interface Framework

Since the PCL hasn't started yet, you can't read or write channel values in the Initialize case.

Start
The Start case executes after Initialization and before the PCL starts running. There's no difference between what code you can place in the Initialize and Start states. Since the PCL hasn't started yet, you can't read or write channel values in the Start case.

Read Data from HW
The Read Data from HW case executes at the beginning of the PCL, before other components (such as Stimulus, Faults, Alarms, Procedures, et cetera) execute. For a detailed timing diagram, see the Outline of PCL Iteration section. After processing system mappings, the data obtained in this case is available to the other components of the system for the remainder of the PCL iteration.
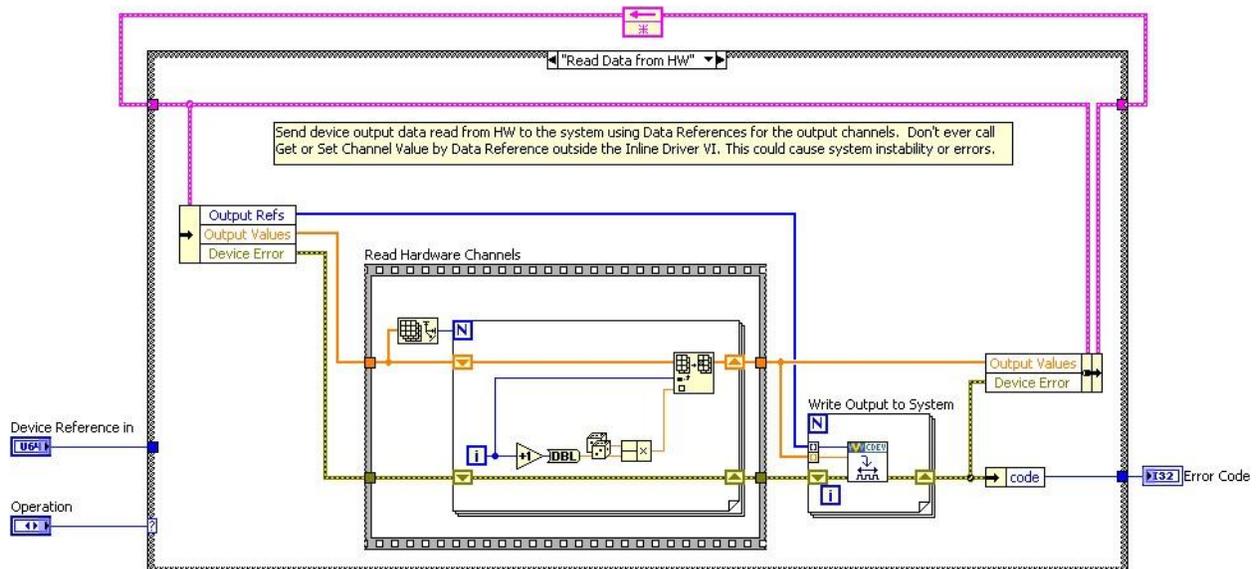
Figure: Read Data from HW State of the Inline Hardware Interface Framework

The template contains a Flat Sequence frame named *Read Hardware Channels*. You can replace the code inside the frame with the API calls necessary to obtain data from a hardware API.

> ⚠️ Do not call **Get** or **Set Channel Value by Data Reference** outside the inline driver VI. Doing so could cause system instability or errors.

Write Data to HW

The Write Data to HW case executes at the end of the PCL, after the other components (such as Stimulus, Faults, Alarms, Procedures, et cetera) have executed.
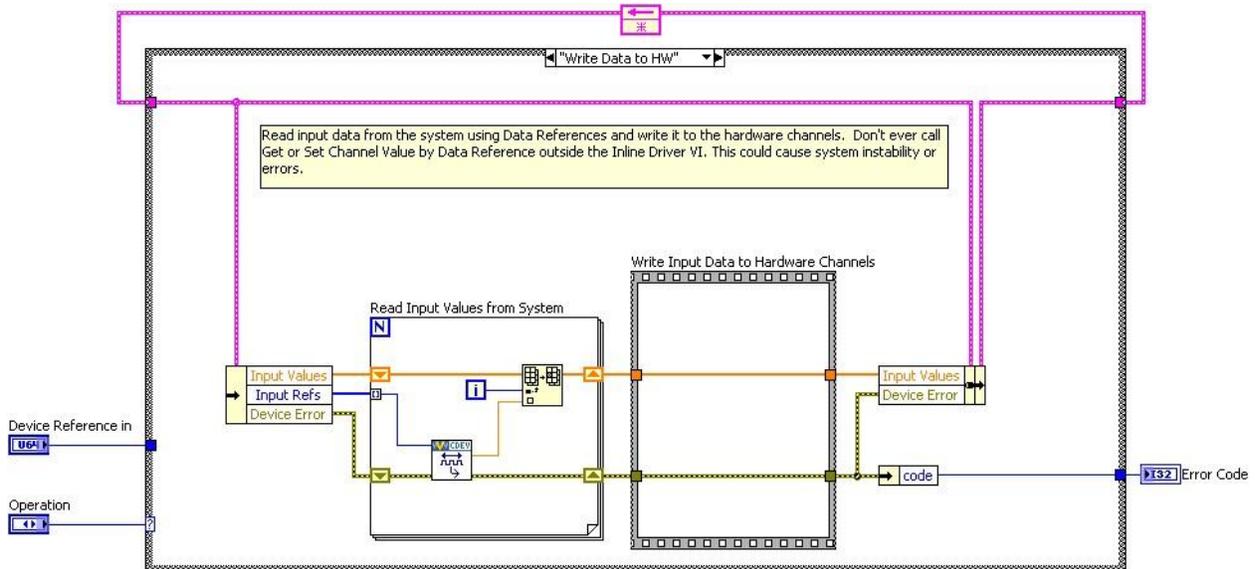
Figure: Write Data to HW State of the Inline Hardware Interface Framework

The case contains a Flat Sequence frame named *Write Input Data to Hardware Channels*. You can replace the code inside the frame with the API calls necessary to send data to a hardware device.

Close

The Close case executes after the PCL has finished executing. It's good practice to close references and release resources in this state. Since the PCL has terminated, you cannot read or write channel values in this case.

Inline Model Interface

The Inline Model Interface custom device template is state machine/action engine architecture. An uninitialized Feedback Node is used for iterative data transfer. There are four cases defined by the Operation enumerated control.

1. Initialize – Same as Inline HW Interface
2. Start – Same as Inline HW Interface

3. Execute Model
4. Close – Same as Inline HW Interface

This custom device is run in-line with the PCL, which calls each case at a specific time with respect to the other components in the system. The PCL will not proceed until the custom device case has returned.

Execute Model

The execute model case is called in the middle of the PCL. This is the one state of this device that executes during the PCL. This state reads input data, performs a calculation, and then writes output data to NI VeriStand. Using the Inline Model Interface mode enables you to process data acquired from hardware inputs and send the processed values to hardware outputs with no latency.
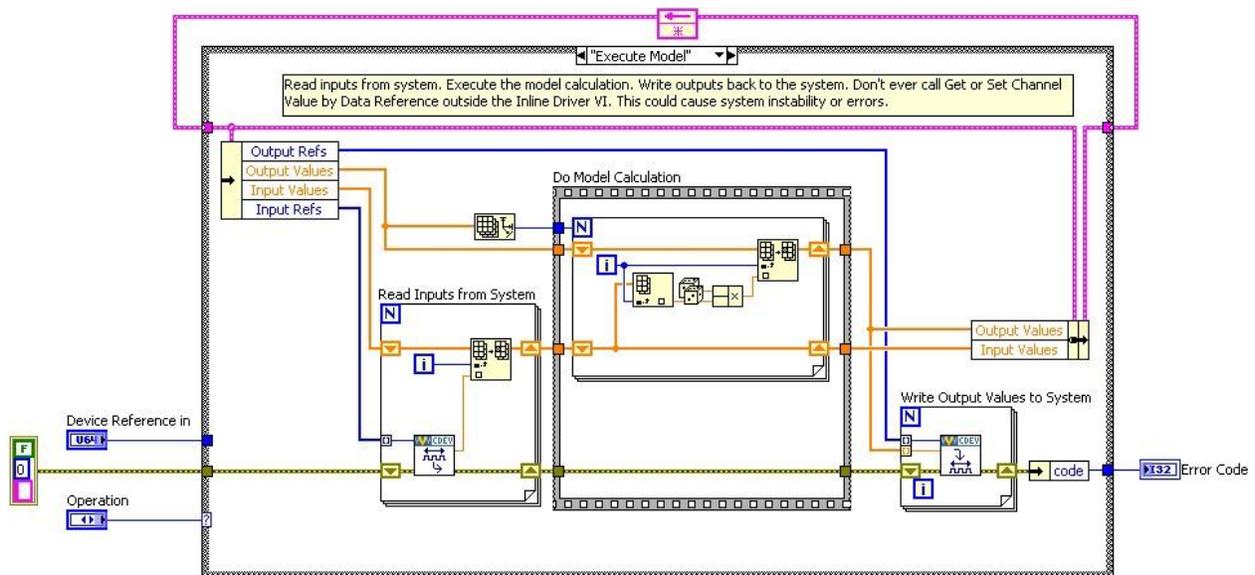
Figure: Execute Model State of the Inline Model Interface Framework

> ⚠ Do not call **Get** or **Set Channel Value by Data Reference** outside the inline driver VI. Doing so could cause system instability or errors.

Table of Custom Device Frameworks

Device Type	Basic Architecture	Framework Data Interface	Timing	Pros	Caveats	Use Cases
Asynchronous	Single Loop	Input and Output FIFO	Synchronized w/ PCL Decimation of PCL rate (FIFOs are read ever N'th iteration of PCL) Any user defined rate	Unlikely to adversely affect timing of other components in the system May run faster, slower, or decimation of PCL	1-cycle latency to get data to/from the device due to RT FIFOs	Shared resources, background processes, non-deterministic hardware/ protocols, system health monitoring, logging, offline analysis
Inline Hardware Interface	State machine Two steady-state cases	Channel references	In-line with the PCL Decimation of the PCL (device executes every N'th iteration of PCL, does not have N-times as long to finish)	Presents data to engine before other components execute Receive data from engine after other components have executed	Can adversely affect the timing of the PCL	Most hardware, deterministic operations, two-phase operations such as stimulus-response
Inline Model Interface	State machine One steady-state case	Channel references	In-line with the PCL Decimation of the PCL (device executes every N'th iteration of PCL, does not have N-times as long to finish)	Send data to engine with low latency	Can adversely affect the timing of the PCL	Low-latency calculations such as PID, interpolation, etc.

Outline of PCL Iteration

The order of operations in the Primary Control Loop varies with respect to the execution mode of the controller. You can adjust this setting in System Explorer » Targets » Controller » Other Settings » Execution Mode.

The Data Processing Loop (DPL) is responsible for executing Procedures, alarms, and calculated channels. For more information about hardware timing in NI VeriStand see KnowledgeBase 58BFIFAF: Hardware I/O Latency Times in NI VeriStand.

(N-1) means "from the previous iteration".

Parallel Mode

1. Get hardware inputs from Controller » Hardware » Chassis
   - DAQ Digital Lines and Counters are read after *Read From HW* case of Inline Hardware custom devices
2. Read asynchronous custom device FIFOs (N-1)
3. Run *Read Data From HW* case of Inline Hardware custom devices
   - Scaling is applied after all hardware inputs have been acquired
4. Read models from Controller » Simulation Models
5. Read from DPL (N-1)
6. Process system mappings[1]
7. Run the *Execute Model* case of Inline Model custom devices
   - All hardware inputs have been acquired and all channels have been scaled *before* this case runs
8. Process system mappings[1]
9. Execute generators
10. Process system mappings[1]
11. Write to DPL
12. Write to Controller » Simulation Models
13. Write hardware outputs to Controller » Hardware » Chassis
14. Run the *Write to Hardware* case of Inline Hardware custom devices
15. Write to Asynchronous device FIFOs

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[1] You can't read data from a previous step until a "process system mappings" step has executed, even if that step acquired the data you want. For example, you write an inline HW custom device, and inside the read data from HW state of this custom device, you want to read the channel data from a DAQ card in the configuration. The DAQ executes at step 1, your code executes at step 3. However, if you read the channel for the DAQ in your code in step 3, you would get the data from the previous iteration (N-1) because "process system mappings" hasn't executed yet. This is the case for NIVS 2010, it will likely change in the future.

Low-Latency Mode
Low latency mode executes models in-line.

1. Get hardware inputs from Controller » Hardware » Chassis
   - DAQ Digital Lines and Counters are read after *Read From HW* case of Inline Hardware custom devices
2. Read asynchronous custom device FIFOs (N-1)
3. Run the *Read Data From HW* case of Inline Hardware custom devices
   - Scaling is applied after all hardware inputs have been acquired
4. Read from DPL (N-1)
5. Process system mappings[1]
6. Run the *Execute Model* case of Inline Model custom devices
   - All hardware inputs have been acquired and all channels have been scaled *before* this case runs
7. Process system mappings[1]
8. Execute generators
9. Process mappings[1]
10. Write to Controller » Simulation Models
11. Wait for models to finish
12. Read from Controller » Simulation Models
13. Process system mappings[1]
14. Write to DPL
15. Write hardware outputs to Controller » Hardware » Chassis
16. Run the *Write to Hardware* case of Inline Hardware custom devices
17. Write to Asynchronous device FIFOs

Based on the timing requirements of the custom device, plan the type of device before executing the Custom Device Template Tool. The AES-201 API sinks and sources data during steady-state operation; the custom device needs input and output channels. The operator needs deterministic hardware data. The AES-201 should be implemented with the *Inline Hardware* type of custom device.

Implement the Custom Device
You should thoroughly plan before you implement the custom device. We'll now implement the custom device for the AES-201. Recall this is a hypothetical 3rd party device. By inventing our own device and API, we're able to focus on the custom device process and avoid the programming tedium. If you'd like to walk through building an actual custom device, you can follow NI DeveloperZone Tutorial: Building Custom Devices for NI VeriStand 2010.

AES-201 Analog Input Specifications	
Range: ±1V or ±500mV Cannot be changed while digitizing Return: 32-bit raw Trigger: 1 software SW Enable: Default on Filter: 6Hz LPF default off	 **Figure: AES-201**
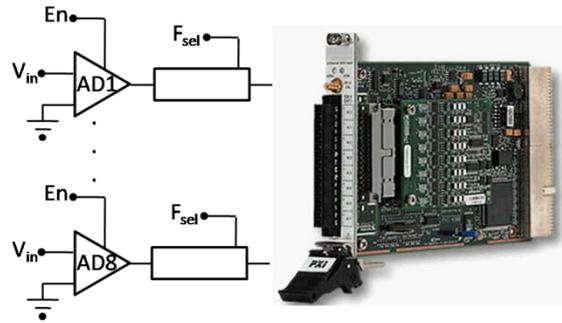
Do we need a custom device?

Our customer requires 32-bits of resolution for their RT test system. This is the only PXI digitizer that fulfills this requirement. After checking with NI.com and the manufacturer, we found no custom device exists for the AES-201, so we determine that a new custom device is necessary.

What are the risks?

The AES-201 ships with a hardware driver that's compatible with LabVIEW Real-Time and a LabVIEW API. We have a real-time desktop target that's identical to our customer's platform. At our request, the customer has provided their model dll, so we can test and benchmark on a system very similar to our customer's system.

Implementation

Based on the AES-201, we create the following specifications.

- Eight output channels `ADDataFromCh<1..8>`
- Nine input channels `ADEnCh<1..8>`, `SWTrig`
- Nine properties: `FilterEn<1..8>` and `Range`
- We will use a nested two-level hierarchy
- We plan to override the default channel page for `ADDataFromCh<1..8>` but we'll use the default page for everything else. We'll create a few extra pages just to be safe.
- To avoid FIFO latency, we'll use the Hardware Inline custom device.

Build the Template Project

Open `<vi.lib>\NI Veristand\Custom Device Tools\Custom Device Template Tool\Custom Device Template Tool.vi`. Configure the front panel to generate a LabVIEW Project for the AES-201 custom device and then run the VI.

The Custom Device Template Tool
puts the new LabVIEW Project in a
sub folder inside the target folder
(A). The name of the custom
device (B) is also the name of the
sub folder. That is, you don't have
to specify a sub folder for your
device because the tool makes one
for you. Select the type of custom
device from the **Execution Mode**
control (C). We'll only need one
extra page, but we'll create several
just in case requirements change
(D).
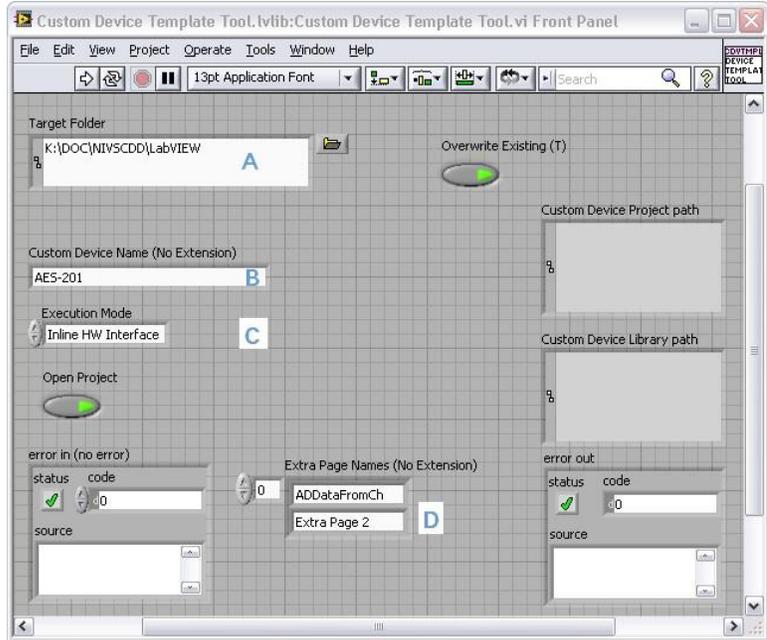
Build the Configuration
Now we'll modify the LabVIEW
Project VIs generated by the
Custom Device Template Tool.
We'll start with AES-201
Initialization.vi. In the
initialization VI, we'll build-up the
default channel list. You've already
seen Add Custom Device Channel
VI.
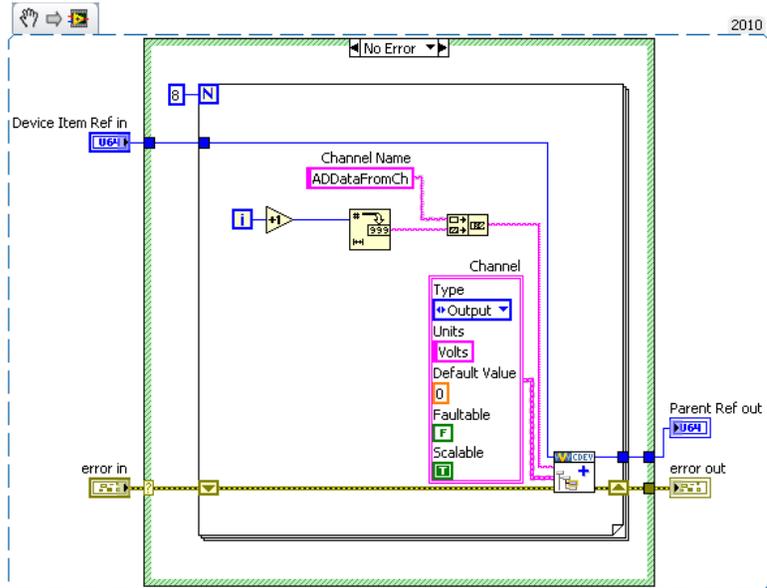
Add a Boolean property to each channel using Set Item Property. The property will indicate the state of the filter on the channel.
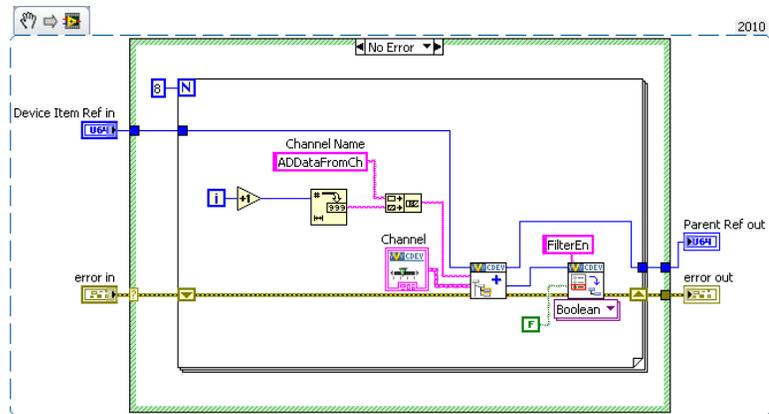
It's good practice to use Global Variables or enum type definitions for any constants that will be reused throughout the custom device. Replace the string constant with a global variable that has *the same default value as the constant*. Add the global variable to the custom device lvlib in the LabVIEW Project.
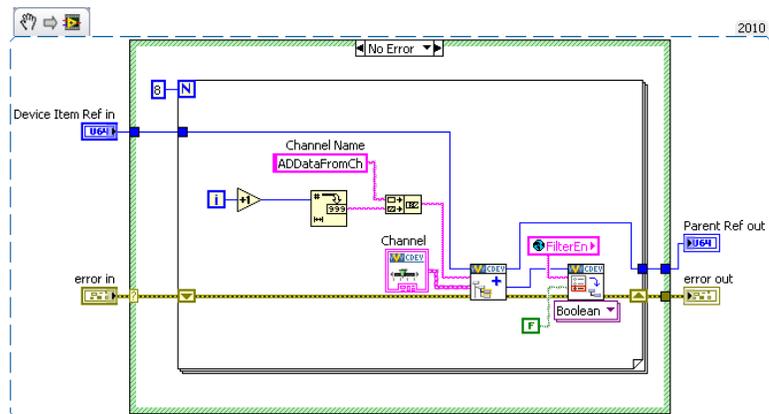
We want to override the default channel page so we can add a control to the page that allows the operator to set the filter. We created an extra page called `ADDataFromCh.vi` for this purpose. Look in the custom device XML and find the GUID associated with the extra page. While you're at it, change the glyph for the custom channel page to `default fpga channel`.

```
<Page>
  <Name>
    <eng>ADDataFromCh</eng>
    <loc>ADDataFromCh</loc>
  </Name>
  <GUID>8AB4F65B-85C9-6BD6-B869-680C60278524</GUID>
  <Glyph>
    <Type>To Application Data Dir</Type>
    <Path>System Explorer\Glyphs\default fpga
channel.png</Path>
  </Glyph>
  <Item2Launch>
    <Type>To Common Doc Dir</Type>
    <Path>Custom Devices\AES-201
Configuration.llb\ADDataFromCh.vi</Path>
  </Item2Launch>
  </Page>
<Page>
```

Operators are used to having channels associated with that glyph. Likewise, change the glyph of the main page to `daq device`.

Add the GUID to the global variable. Wire the global into the GUID terminal of Add Custom Device Channel. *This associates the channel with the VI.*

Now when the operator clicks on `ADDataFromCh<1..8>` in the configuration tree, `ADDataFromCh.vi` runs as a sub panel in System Explorer *instead of the default channel page*.
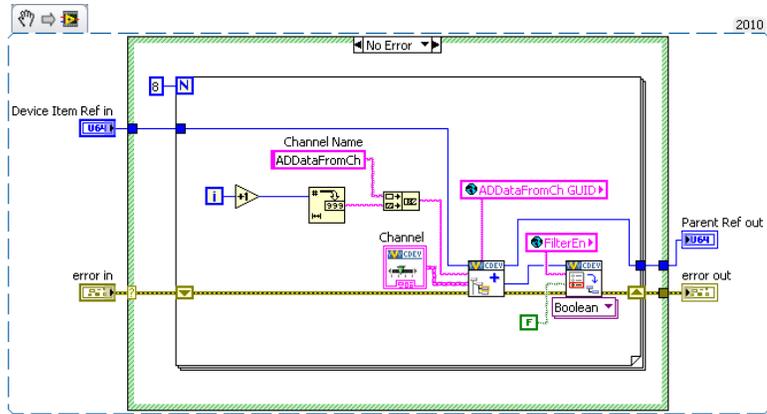
From here-on, we'll set properties when we create the item rather than using the Set Item Property VI to set them on the item reference.

Now that we've linked the channels to the extra page, we'll make edits to the extra page, `ADDataFromCh.vi`. In the Initialization frame, we'll add code to display the channel information.
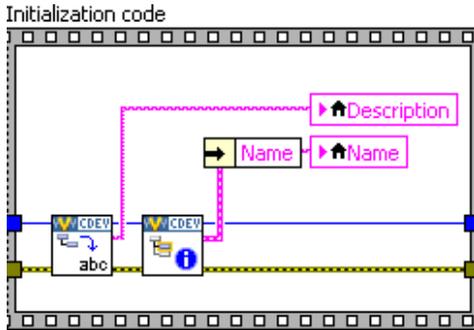
Operators are used to seeing channel data when they click on a channel, so we want to preserve that experience. If the device is a channel, we'll send the channel data to an indicator on the front panel.

It's good practice to use the Boolean outputs from functions in the API to make sure that you're operating on a valid reference.
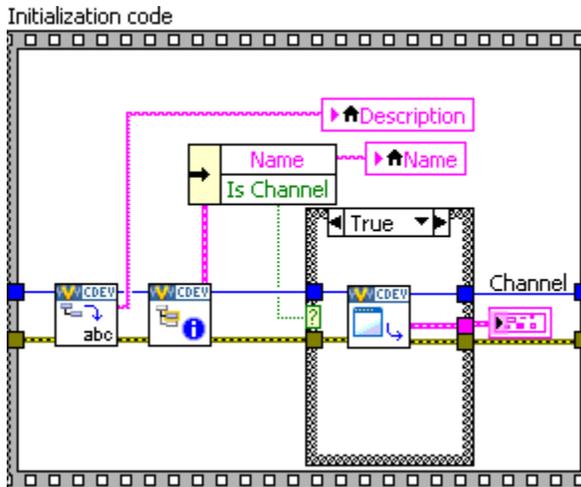
In this case, we'll only retrieve the channel data if we have a valid channel reference. Another option is to specify the default property value. The default property value is returned if the property is not found. Using the default property value does not set the property.

Notice how the initialization frame reads the name and description from the device reference.

Do the same thing for the `FilterEn` property so the operator can see the state of the channel's filter setting. NI VeriStand is responsible for passing the correct channel reference to our custom device, and storing state data for all the controls and indicators. The developer is responsible for acting on the reference *and* displaying the state.
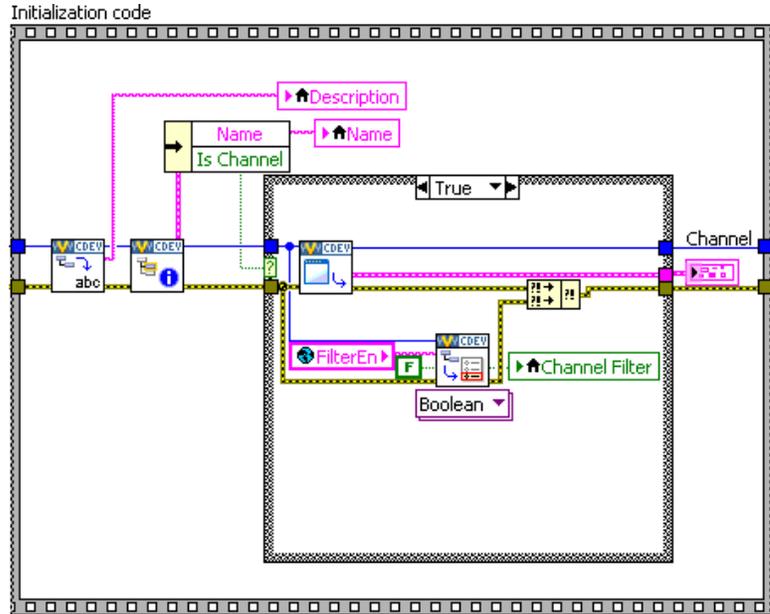
Add a Boolean control to the front panel called **Channel Filter.** Create a case in the Event Structure for the control's value change. If the `FilterEn` property is found, set the property according to the value of the control. If the `FilterEn` property is not found, show a dialog box with debugging information.
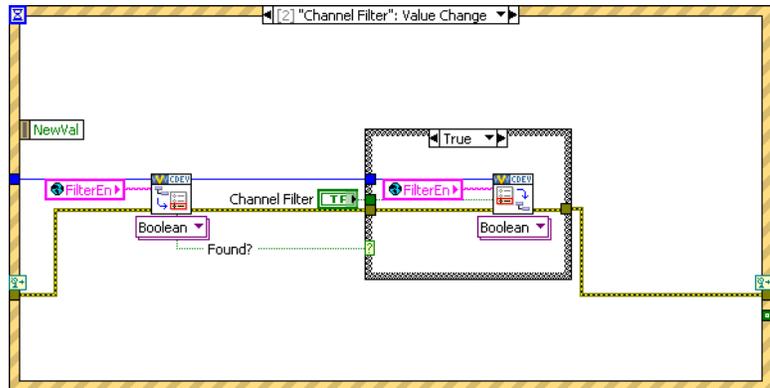
> ⚠ If the operator does not change this control, the property is never created. There are several ways around this. You could initialize the property in the Initialization VI, or you can assume a default value when you read the property.

Remember, this VI runs on the host computer, so we can launch a pop-up dialog box to assist with debugging.
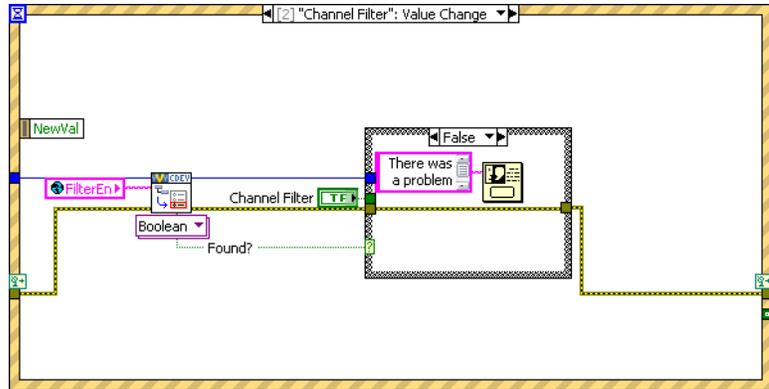
Now we'll build a subVI that creates channels so we can reuse it for the enable channels.

Add the *default channel GUID* to the global variable. You can get it from the front panel of Add Custom Device Channel.

Here it is for your reference:
03D3BB99-1485-13A6-561D1F898F032919.
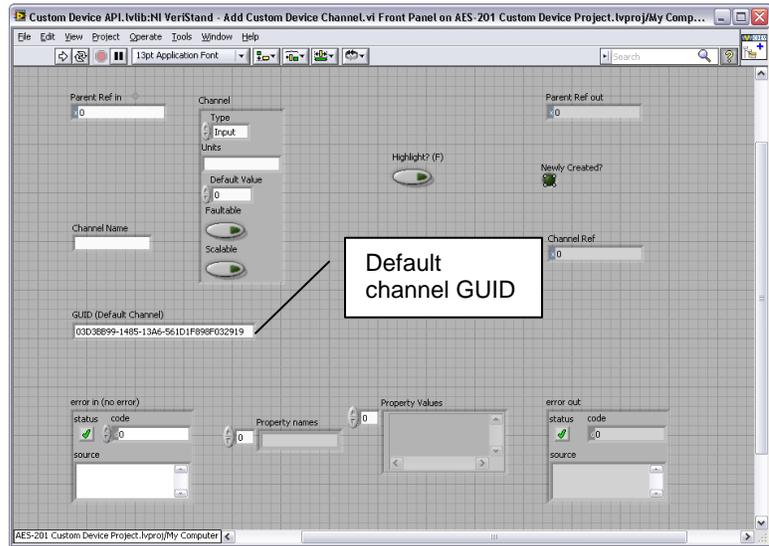
If the **Override Default Channel?** terminal of our subVI is true, the VI takes a GUID from the caller. If not, the VI uses the default channel GUID.

Notice how properties are set from the Add Custom Device Channel VI directly. You can use this subVI in many custom device projects.
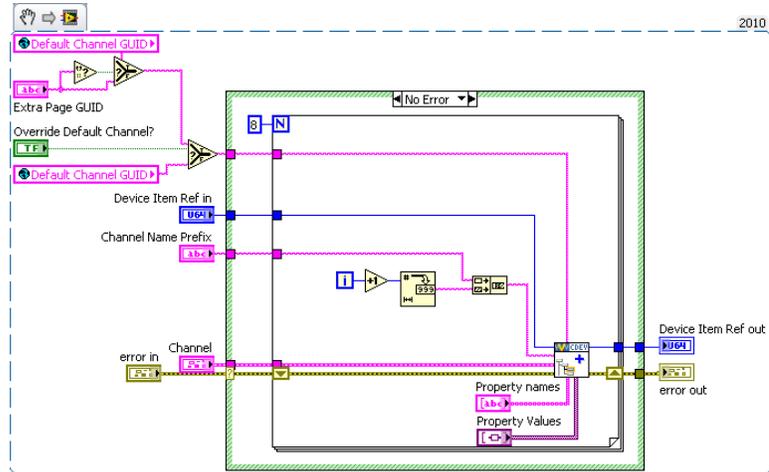
Custom devices execute as reentrant on the execution host. This enables the operator to run multiple independent instances of the same custom device. Consider the case if the operator has several AES-201 cards. Be sure to enable **Reentrant execution** from the subVI's File » VI Properties » Execution category to preserve this capability. See LabVIEW Help » Fundamentals » Managing Performance and Memory » Concepts » Suggestions for Using Execution Systems and Priorities » Simultaneously Calling SubVIs from Multiple Places for more information about reentrant VIs.

The final Initialization VI creates two sections. The Hardware Inputs section has eight output channels. The Hardware Enables section has eight input channels. We also create an input channel for the software trigger.
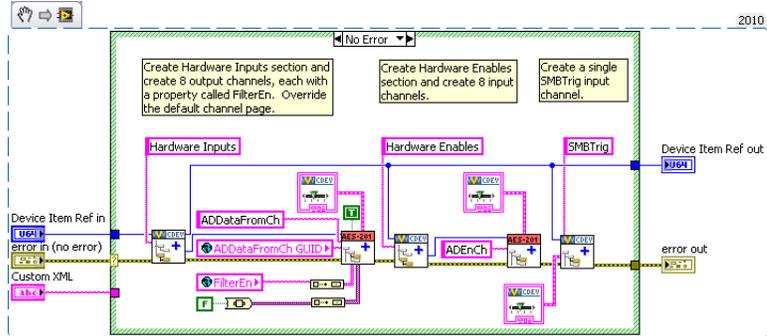
Now that the initialization routine is done, we'll turn our attention to the main page. We'll use a type definition combo box to set the range of the AES-201. Add the type definition to the custom device lvlib.
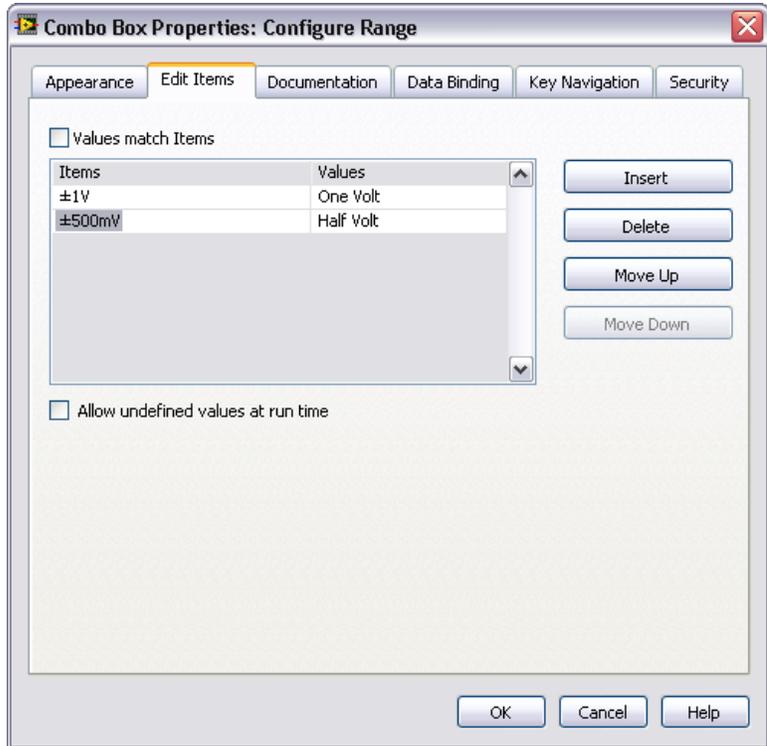
Modify the main page so the operator can set the range of the device. You don't have to override the main page with a custom page; you can simply modify the main page directly.

Add another string to the global variable for the `Range` property.
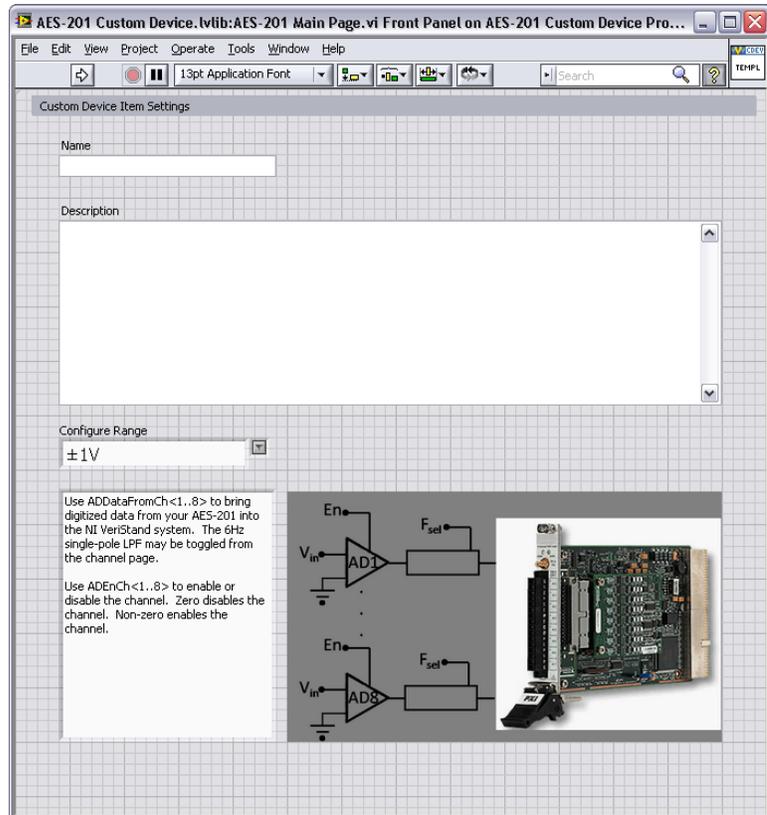
Add an event case to the main page that sets the range property when the operator changes the value of the control.
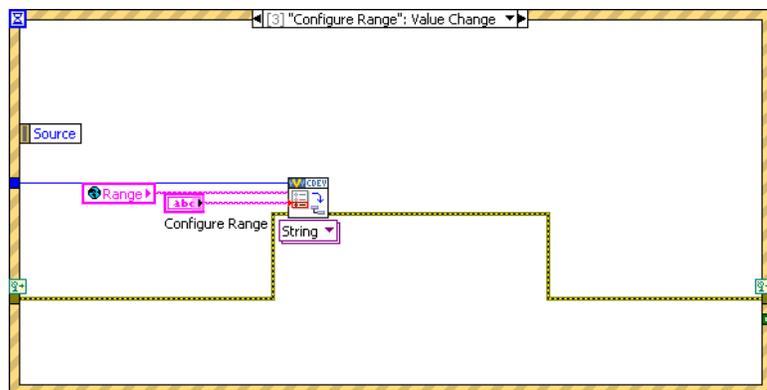
The engine will need some way to know how to address the board. Add another control so the operator can configure a `Resource Number`.
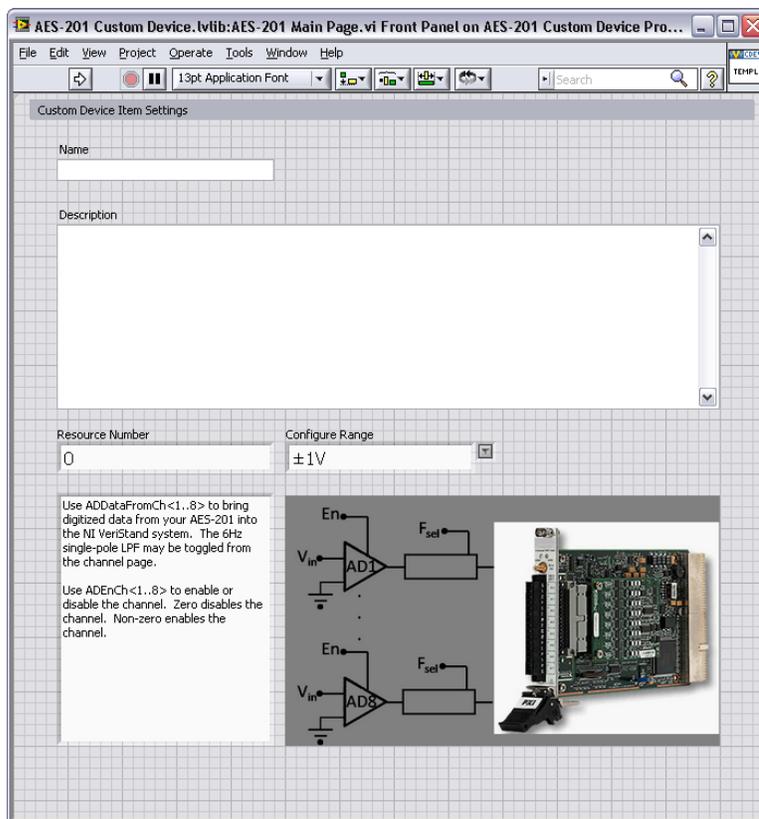
Many developers have asked for MAX integration/auto-discovery so the operator doesn't have to enter resource names manually. As of NI VeriStand 2010 this functionality does not exist. You can write your own discovery routine that populates available resources, or you can allow the operator to enter the resource name manually.

Add the event case to set the resource number property.
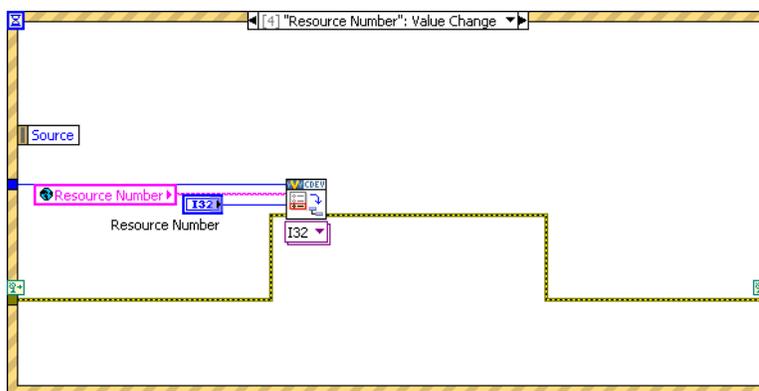
Read the device's resource name and range into the corresponding controls in the initialization frame, the same as you did for the extra channel page's filter property.

Remember, NI VeriStand stores state and provides the correct reference; the developer acts on the reference and modifies the state.
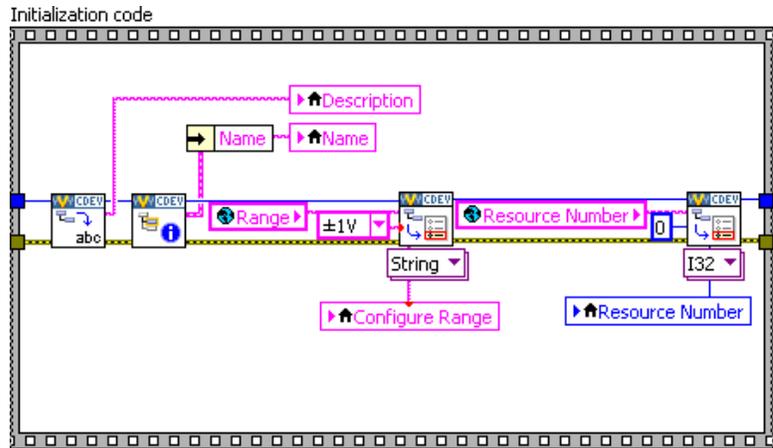
Build the custom device and inspect the hierarchy, sections, channels, main page and extra pages. Now we'll turn our attention to the RT Driver.
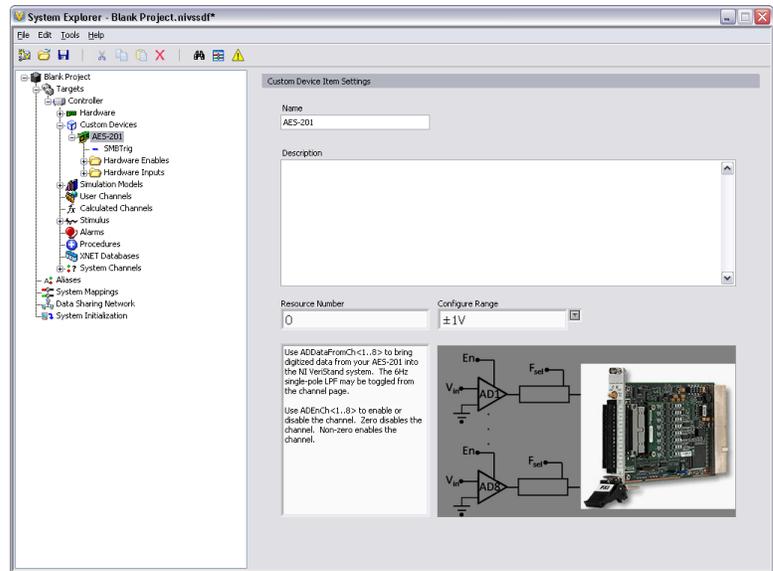

Build the Driver

The AES-201 comes with a simple LabVIEW API. We'll use the API to build the RT driver portion of the custom device.

Functions in the API call into the hardware dll. This is typical of a LabVIEW API. This paradigm requires the developer to post the dll to the execution host.

Modify the custom device to package the dll with the custom device and deploy it to the execution host.
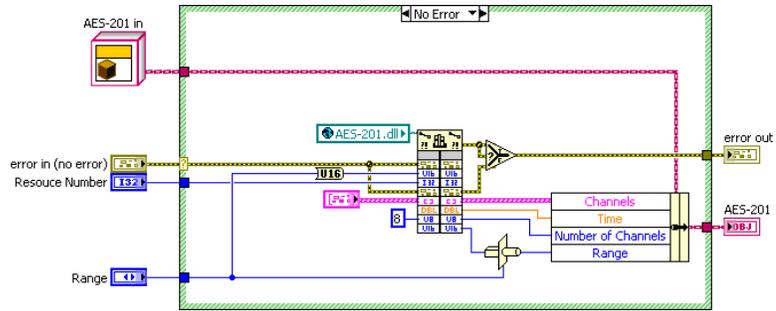

Add Custom Device Dependencies

Shared libraries are typically .dll files on Windows/PharLap operating systems and .out files on VxWorks systems. If you're building a custom device for a Compact RIO execution host, you'll be working with .out files. See KnowledgeBase 4LRA4IQ0: What Operating System is my Real-Time Controller Running and Why for more information.

There are two parts to packaging dependencies. The first part is to incorporate the dependency into the LabVIEW Project.

Add the dll to the custom device LabVIEW library.

Modify the configuration's source distribution by adding the dll to the Always Included list.
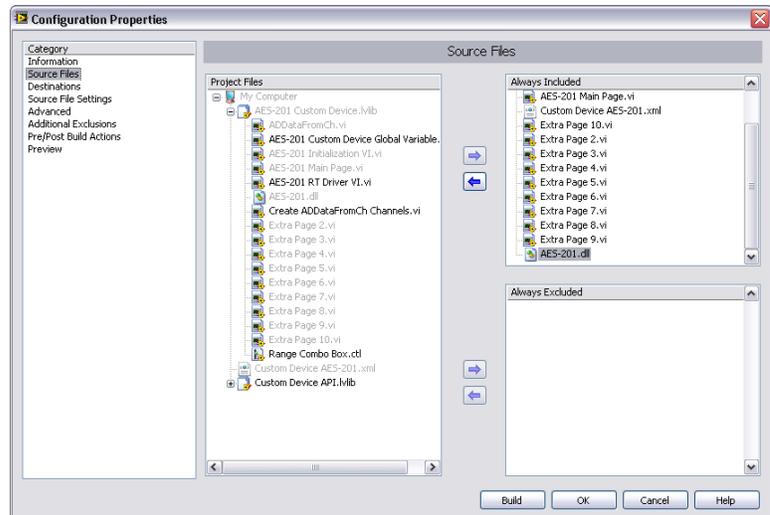
Note the location of the Support
Directory. In this case it's
`C:\Documents and
Settings\All
Users\Documents\National
Instruments\NI VeriStand
2010\Custom Devices\AES-
201\Data.`
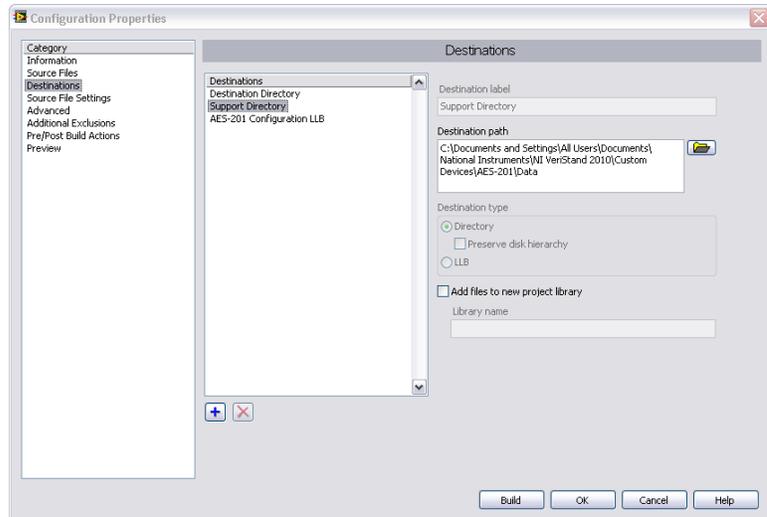
Set the destination directory for the
dll to the Support Directory.

Now when you build the
configuration, LabVIEW sends the
dll to the support directory.
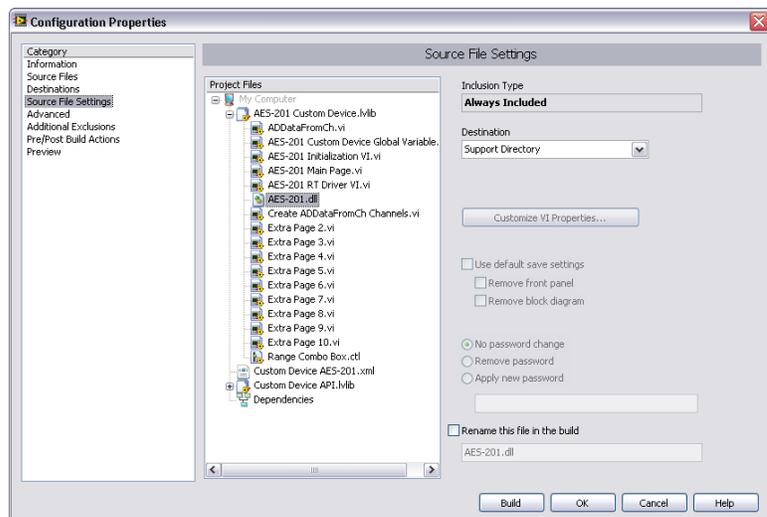
The second part in packaging dependencies is to incorporate the dependency into the custom device. Use Add Custom Device Dependencies to deploy the library to the execution host.

NI VeriStand – Add Custom Device Dependencies VI
Owning Palette: Dependencies VIs

Adds dependencies to a custom device.
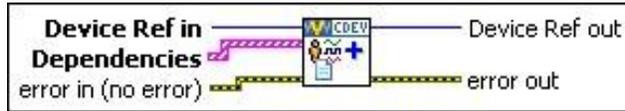
U64		**Device Ref in** is the NI VeriStand reference to the custom device.	
[...]		**Dependencies** is an array of Custom Device File Dependency controls.	
	[...]	**Path** is the path and file name of the dependency	
	[...]	**Type** is absolute or relative to one of NI VeriStand's built-in file paths. See the What is a Custom Device for a list of built-in file paths.	
	[...]	**RT Destination** specifies the directory and file name of the dependency on the execution host	
	TF	**Force Download** terminal must be false.	
	[...]	**SupportedTarget** specifies the target operating systems that will receive the dependency	
	abc	**Version**	
[...]		**error in** describes error conditions that occur before this node runs. This input provides standard error in functionality.	
U64		**Device Ref out** is a duplicate of the Device Ref in.	
[...]		**error out** contains error information. This output provides standard error out functionality.	

There are several other VIs in the NI VeriStand Dependencies VIs palette that operate on custom device dependencies. These functions do what you'd expect given their names.

☐ Dependencies VIs » Get Custom Device Dependencies
☐ Dependencies VIs » Reset Custom Device Dependencies

Add the custom device dependency to the Initialization VI.
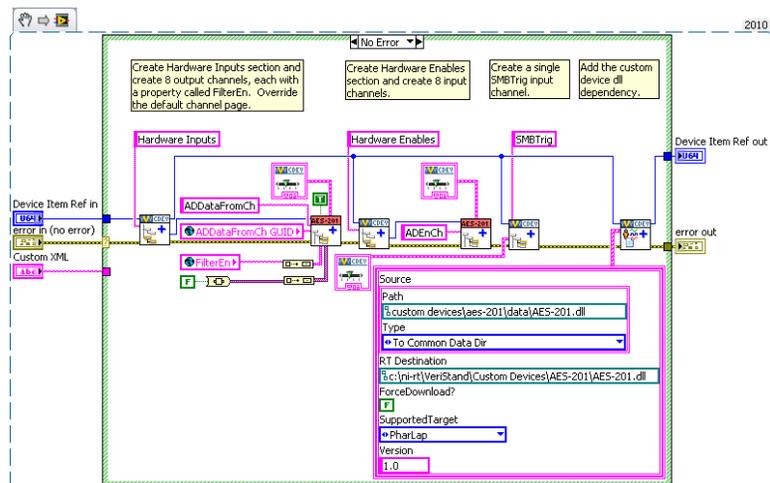
As a result, the Initialization VI adds the dll to the project's dependency list when it runs.

You must have some way to direct the engine to the dll on the execution host. One way is to deploy the dll to a folder in RT's search path (`C:\ni-rt\system` by default).
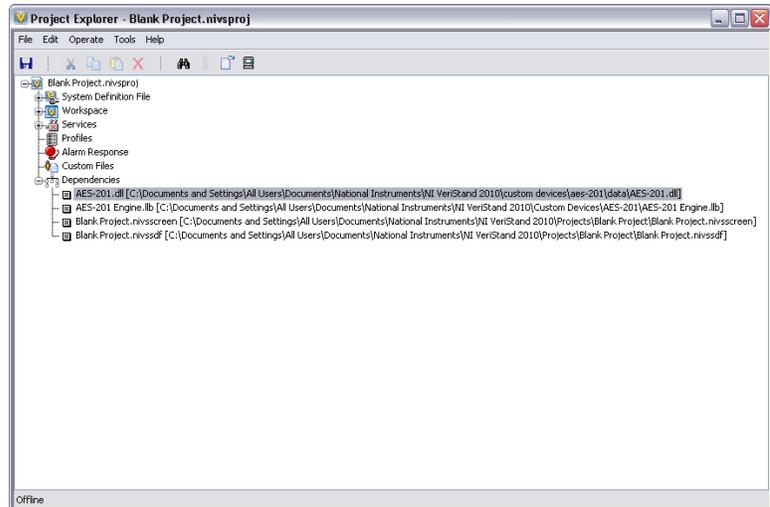
A better way is to use a global variable that points to the absolute path of the dll on the execution host.
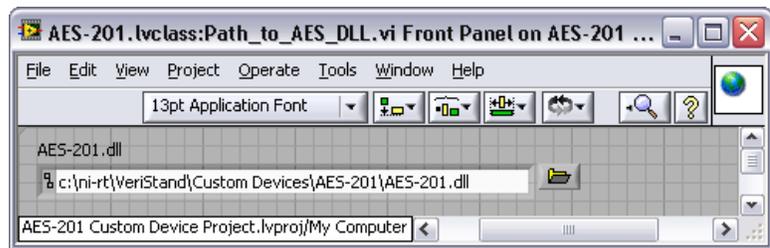
Deploy the dll to `C:\ni-rt\VeriStand\Custom Devices\<Custom Device Name>\<library>.dll`. This is more maintainable.

Read the range and resource number properties from the custom device reference. Recall that you must read the property from the correct item, and we set these properties to the top-level device reference. Call the AES-201 API to initialize the board according to the property values.

| Read item property | Coerce the property value to a data for the API | Call the hardware API |
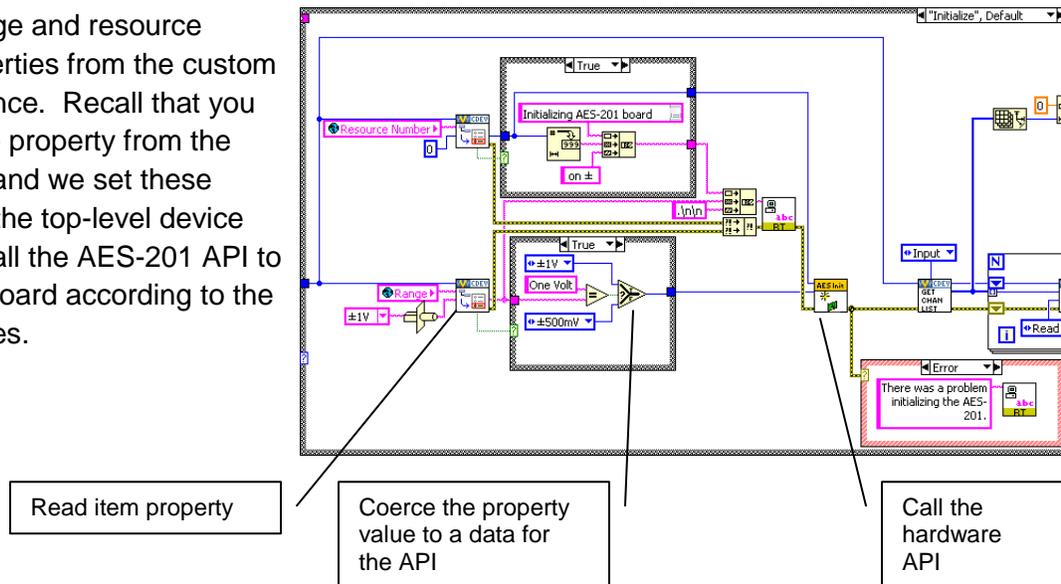
Remember, if the operator didn't trigger the event to set the property, there won't be a property to read. Instead of throwing an error, default to the value of your choice and call the API accordingly.

It might be nice to tell the operator what's going on. Print a few strings to the console. See the Printing to the Console section for more information.

Use a default value if the property is not found.
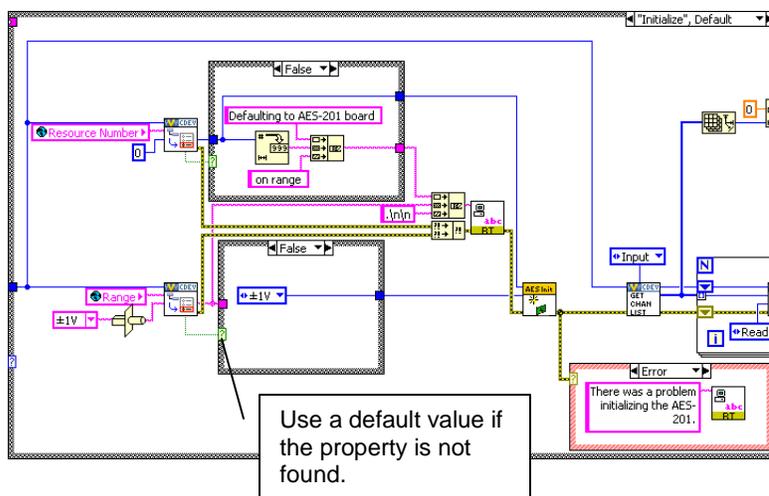
The inline HW custom device uses a feedback node to pass state data between states. Add the AES-201 state data to the feedback node's cluster. If you're not familiar with LabVIEW Objects, it's sufficient to know that this LabVIEW object represents all the state data needed to use the AES-201 in subsequent states.
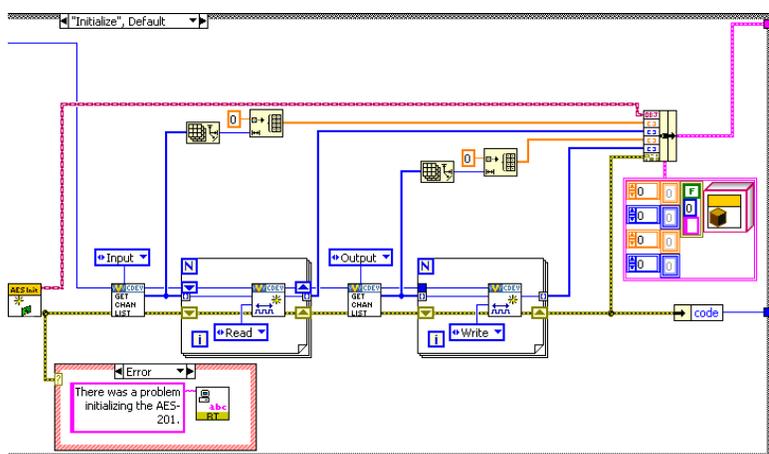
Add the input and output channel references to the state data cluster.

The input channel references

The input channel *data* references
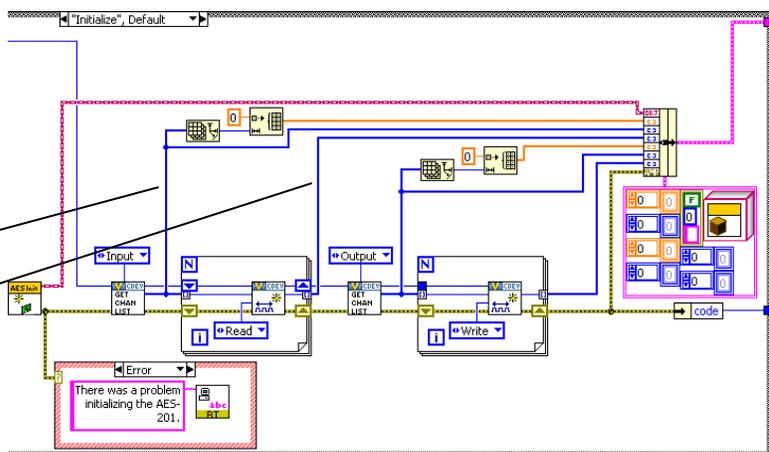
The output channels are for `ADDataFromCh<1..8>`. Check the filter property on each output channel reference and call the AES-201 API to set the filter accordingly.

Return FALSE if the property is not found.
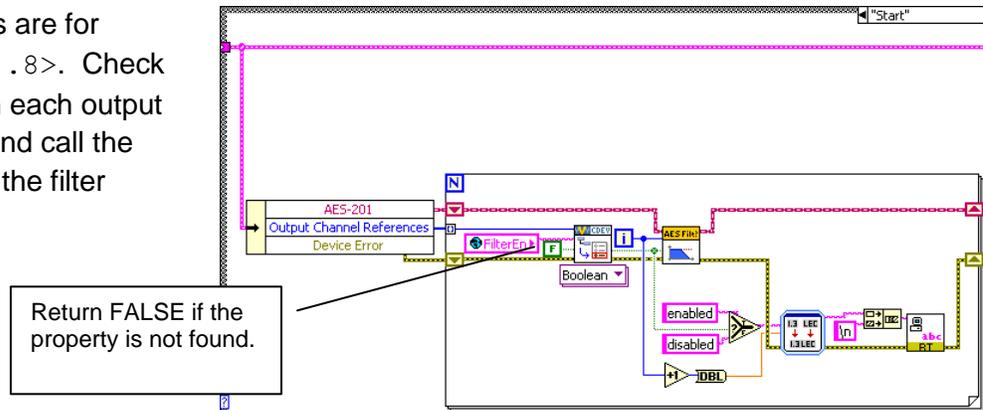
After the custom device has been configured and deployed, NI VeriStand will no longer exchanged property information between the host computer and execution host. Since we implemented the filter as a property, we'll call the AES-201 API in the Start case. If the operator wants to toggle the filter, he must reconfigure the device in System Explorer.

Now that we've configured the hardware, we'll request an A/D sample. For this custom device, the Read Data from HW case is nicely suited for this operation.
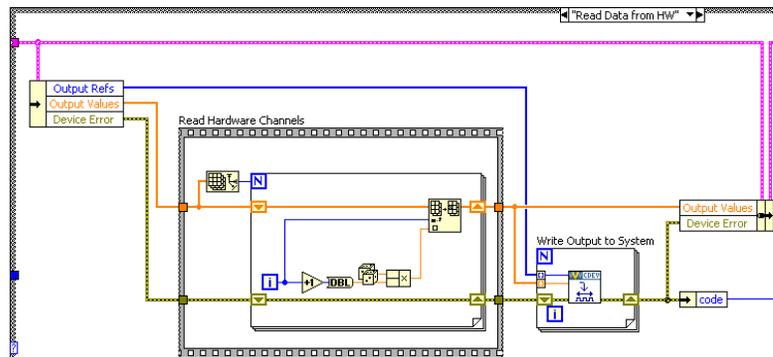
Replace the Read Hardware Channels frame with the API call to digitize. Convert the 32-bit raw data to DBL data depending on the range of the AES-201.

Query the range   Digitize   Convert to DBL
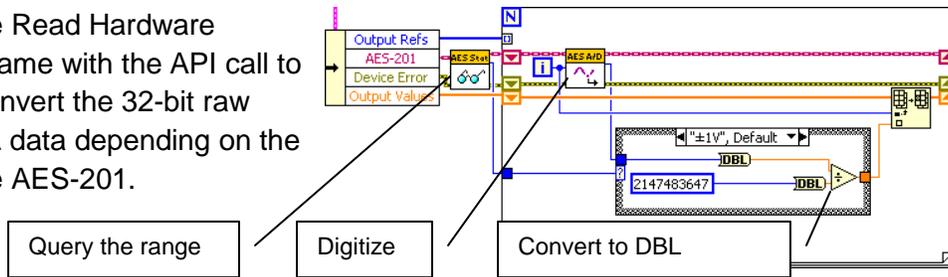
Send the channel data to the rest of the NI VeriStand system by writing to the Output Reference.

Write NI VeriStand Channels
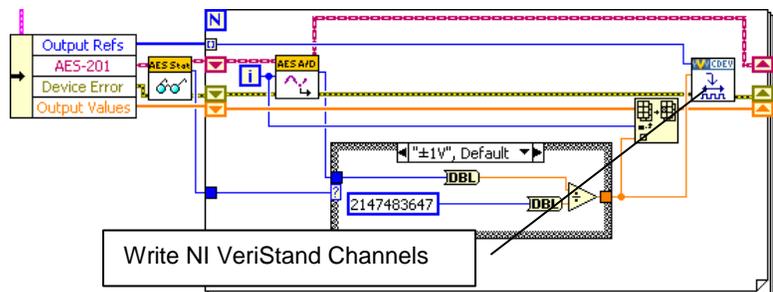
For flat hierarchies, the reference array corresponds *one-to-one* with channels as they were created on the host computer. In other words, the first channel created is the 0'th element of the array.

For non-flat hierarchies, the reference array corresponds *top-down and one-to-one* with channels as they were created. In other words, channels at the highest level of the hierarchy appear first in the array, then subsequent levels' channels appear in the array in the order they were created.

Robust custom devices do *not* depend on any particular order of channel references. Unique properties or GUIDs should be used to ensure the driver VI operates on the correct channel.

The AES-201 inputs are enabled by default. Build the custom device, enable filtering on all channels, add it to a new system definition and deploy the project.

You should see messages on the console indicating the non-default configuration. This is a good sanity check.
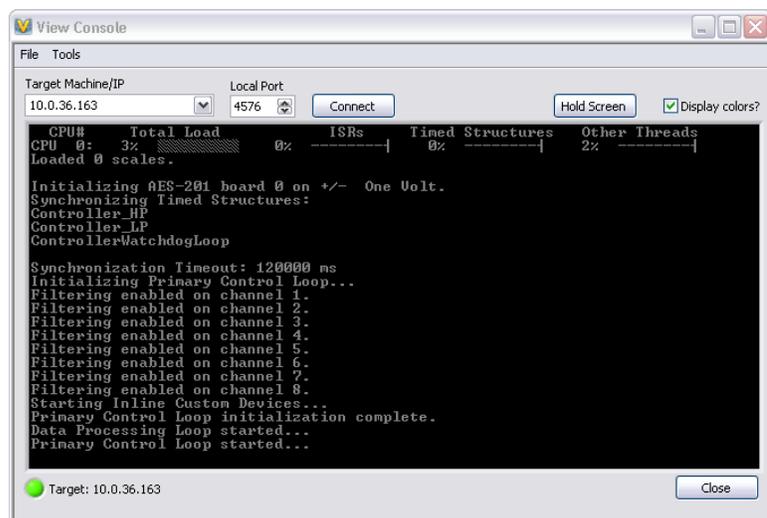
Map the ADDataFromCh<1..8> channels to a simple graph and make sure they display the expected signals.
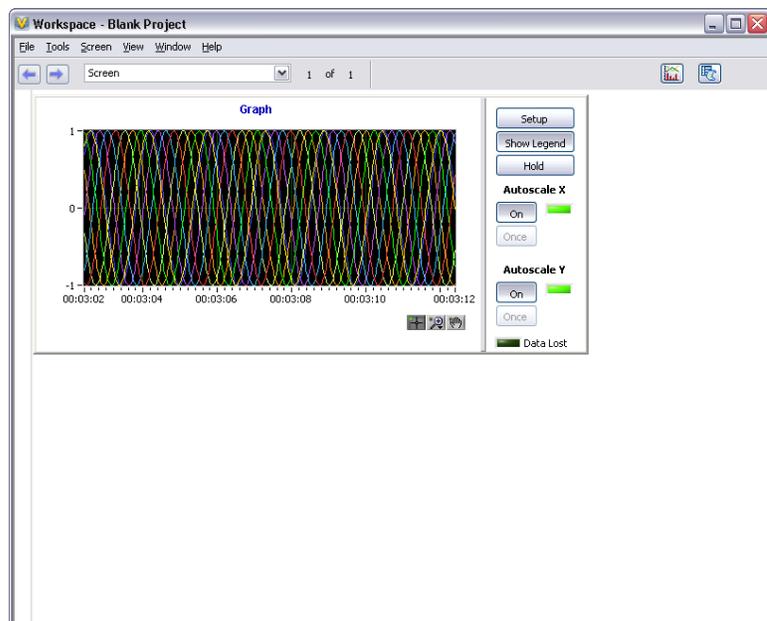
Now we'll process the software
enable channels. For this custom
device, the Write Data to HW case
is nicely suited.
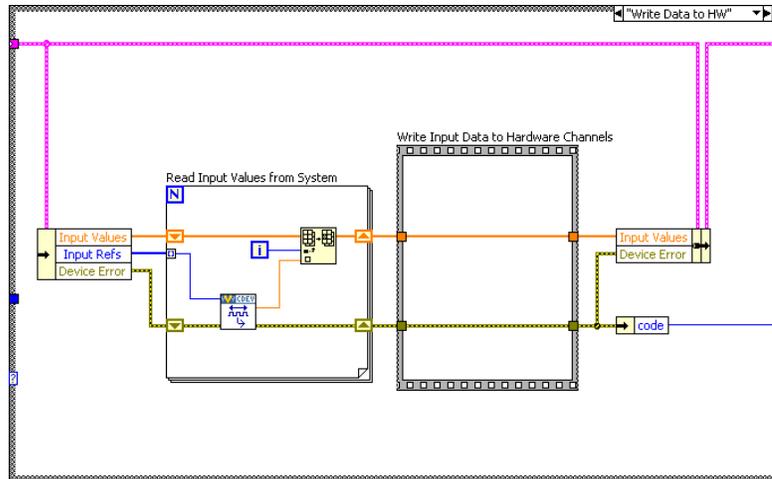
The `SWTrig` channel is *higher* than
the `ADEnCh<1..8>` input channels
*in the hierarchy; even though it
was created last, it's the first
channel in the input channel
reference array*. We'll skip the
`SWTrig` channel reference for
now, and read the 8 enable
channels.
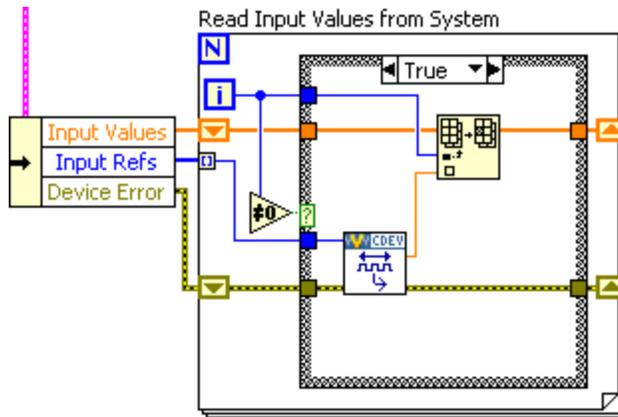
Make a call to the AES-201 only if
the enable channel value has
changed. Enable the hardware
channel if the NI VeriStand channel
does not equal zero.

Skip the `SWTrig` channel

Only call the API if the enable channel has changed value
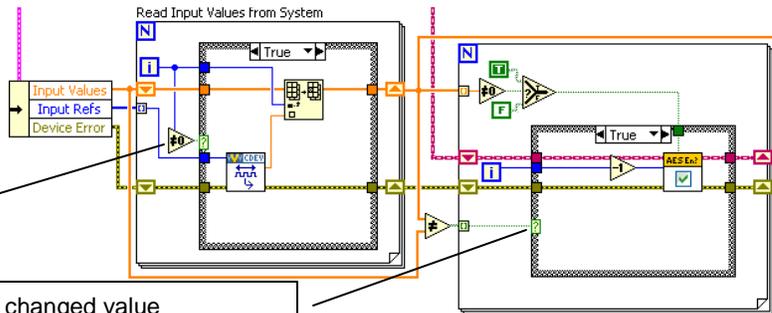
Channel Change Detection

You can build change detection into the custom device engine so it doesn't perform actions if
the data hasn't changed. This will cause differing execution times depending on data. Some
may consider this *jitter;* but it isn't the literal sense of the word unless the code *fails* to meet
determinism requirements. And as long as you don't fail a requirement, saving time is never
bad.
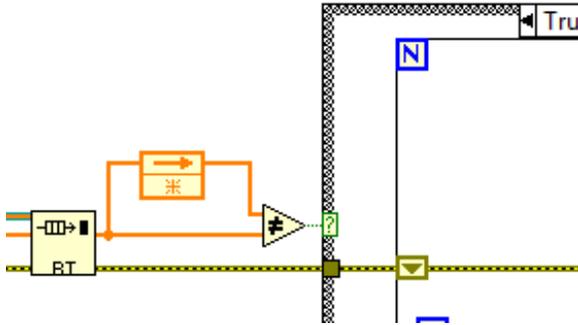
Figure: Simple Change Detection   **Figure: Change Detection with Tollerance**
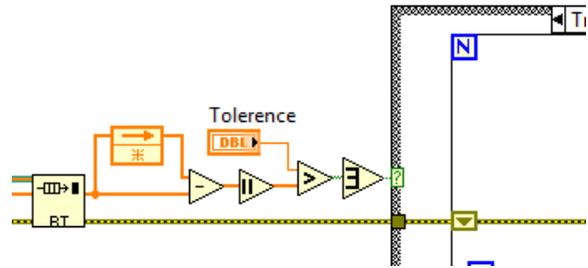
There are a variety of methods for doing change detection. We'll briefly discuss two methods. Simple change detection can fail due to floating point precision issues. See NI Developer Zone Tutorial: An Introduction to Floating-Point Behavior in LabVIEW for more information about how computers handle floating point numbers.

Change detection with tolerance works-around the precision issues. Make sure to use tolerances that avoid false triggers.

Rebuild the device and add 8 Boolean controls to the workspace. Map each control to the corresponding `ADEnCh<1..8>` channel.
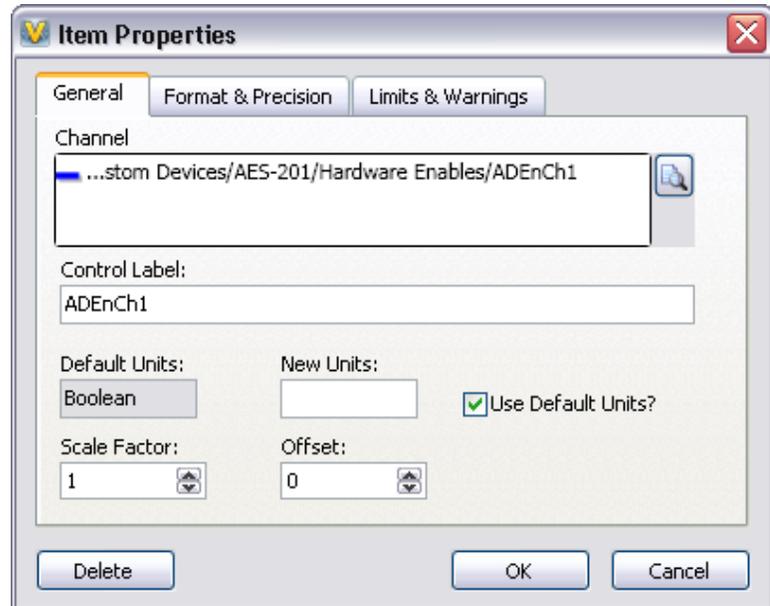
You should now be able to toggle
the channels on and off from the
workspace. In this contrived
example, disabled channels hold
the last sample.
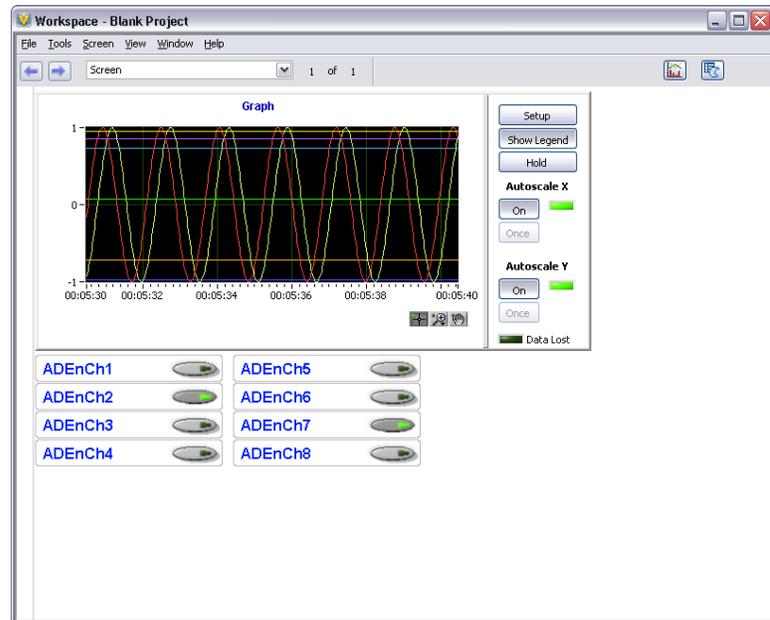
Since we thoroughly planned the AES-201 custom device before we started writing code, it was
fairly straightforward to implement the device. Planning is key. The next section of the
document will cover some debugging and benchmarking techniques.

Debugging and Benchmarking
Debugging and benchmarking is a normal process of code development. There are a variety of
ways to debug and benchmark custom devices.

LabVIEW Debugging Techniques
Custom devices are written in LabVIEW code. Therefore it's possible to develop, test and
debug in LabVIEW before running the Custom Device Template Tool. In other words, you can
use LabVIEW's built-in debugging techniques during development; and merge the LabVIEW
code into the custom device framework after it matures.

Since the custom device is one of many parts of the system definition, the behavior of the
LabVIEW code within the custom device framework will likely differ from the stand-alone
LabVIEW application, *especially in regards to timing*. As a result, you should benchmark the
custom device inside of the NI VeriStand Engine.

Once added to the system definition, custom devices have been fully integrated into NI
VeriStand's context. As a result, LabVIEW's built-in debugging techniques are no longer
available. Several techniques are available for debugging and benchmarking the custom
device.

Console Viewer

A subcomponent of NI VeriStand RT Engine is the RT Console Viewer. You can install it to the execution host using Measurement and Automation Explorer. When installed, the component runs a small UDP daemon allowing the operator to view the console from a utility called the RT Console Viewer. You can access the RT Console viewer from NI VeriStand » Workspace » Tools » Console Viewer.
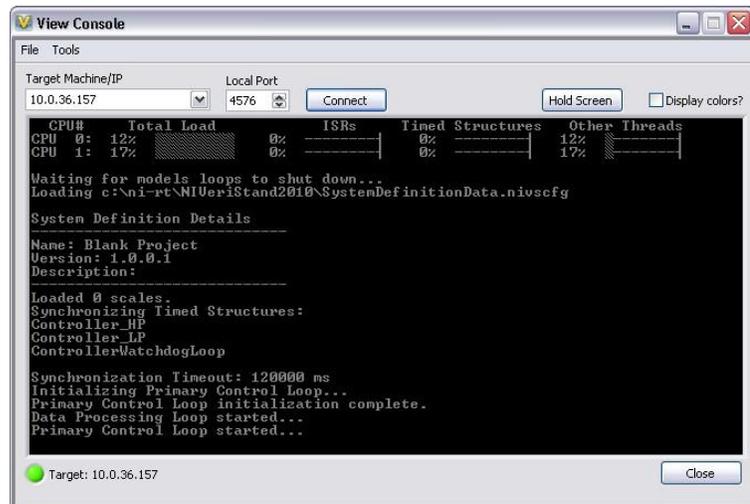
Figure: RT Console Viewer

The Console Viewer will show the system definition and the resulting CPU usage. The viewer is also useful for displaying debugging messages. The console viewer provides a periodic snapshot of utilization. CPU spikes and transients will probably be unobservable. If the system is very busy, it may not update the console viewer at all. You can use other debugging methods for a more accurate indication of resource utilization.

As the name implies, the RT Console viewer is only available on real-time targets. The RT Console Viewer is also available as a stand-alone add-on to LabVIEW Real-Time. See NI Developer Zone Tutorial: Remotely View Console Output of Real-Time Targets for more information.

Printing to the Console

Printing to the console is often all that's needed to debug an application.

Printing With NIVS Debug String VI

The recommended method of printing to the console is to use Print NIVS Debug String VI. You can download the VI from NI Community » NI VeriStand Add-Ons » Documents » Print NI VeriStand Debug String.
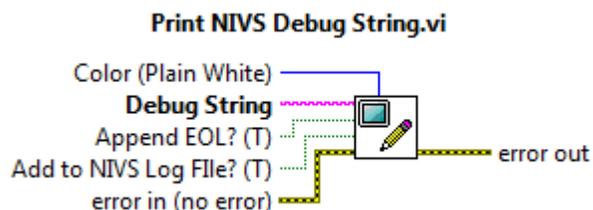
This VI works on both Windows and RT execution hosts. It has an optional input to change the color of the text. It also has an optional input to append the string to the NI VeriStand log file.

Printing With ni_emb.dll

The NIVS Debug String VI is not available in NI VeriStand 2009. You'll find `ni_emb.dll` in `<labview>\Targets\NI\RT\vi.lib`. This dll contains a stub function called **`PrintStringToConsole`**. Calling this function sends a string to the RT console. Configure the function to run in any thread using the C calling convention. The return type is void and it has a C String pointer input constant. You'll find this function wrapped in a VI in the same folder

in `rtutility.llb\RT Debug String.vi`. Since `ni_emb.dll` is a stub dll, it's not necessary to deploy this VI to the RT target. The stub exists so the **PrintStringToConsole** function does not return an error when called on Windows.

If you do not want to call `ni_emb.dll` on a Windows OS, you can use a Conditional Disable Structure around the dll. See NI Developer Zone Tutorial: Using the Conditional Disable Structure for more information.
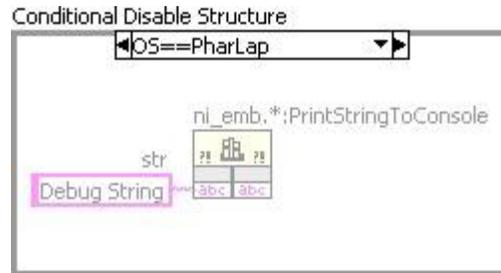
Figure: Disable `ni_emb.dll` for non-Windows Operating Systems

You may find NI Developer Zone Example Program: DebugInfo.vi: Polymorphic VI for Showing Debug Information on an RT System useful for printing non-string data to the console window. You should be aware of the overhead incurred by calling this function. KnowledgeBase 3EK88SOH: Can I Use the RT Debug String In My Time-Critical Loop outlines a few caveats and best practices for using the **PrintStringToConsole** function, such as using **\r** in a Slash Code string constant to avoid scrolling the screen.

Distributed System Manager
You can use the NI Distributed System Manager (DSM) to monitor the CPU and memory resources of an RT target. You must install System State Publisher on the RT target. This component runs a small daemon that publishes the system state to DSM. See NI Distributed System Manager for LabVIEW 2010 Help » System Manager Overview » System Manager Overview » Monitor RT target resources for more information.

System State Publisher provides a periodic snapshot of utilization. Spikes and transients in CPU utilization will probably not be observable. If the system is very busy, it may not update DSM at all. You can use other debugging methods for a more accurate indication of resource utilization.

System Channels
NI VeriStand includes dozens of system channels. System channels provide information about what's going on under the hood of NI VeriStand. Several of these system channels are useful in benchmarking and debugging.

Table of Debugging and Benchmarking System Channels

System Channel	Description
HP Count	The number of times the Primary Control Loop reported being late.
HP Loop Duration	The duration of the Primary Control Loop in nanoseconds.
LP Count	The number of times the Data Processing Loop reported being late.
Model Count	The number of times the models have not completed their execution in time.

If the value of the `count` channels increase over time, the execution host is not achieving the desired loop rates. You can use the system channels in conjunction with an *alarm* or *procedure* to handle the event.

System Monitor Add-on
The NI VeriStand System Monitor is a Custom Device that tracks memory resources and CPU usage on an RT target running the NI VeriStand Engine. Set the update rate (Hz) in System Explorer to determine how often the custom device checks CPU and memory usage and sends them to the corresponding channel. The NI VeriStand System Monitor can only be used on an RT target. The custom device returns an error if you target it to a Windows system.

Real-Time Execution Tracing
NI VeriStand 2010 provides built-in support for using the NI Real-Time Execution Trace Toolkit to create trace logs for low-level debugging. The NI Execution Trace Toolkit is required to view the log. The execution trace provides the finest grain thread and timing details of all the debugging tools. See LabVIEW Execution Trace Toolkit Help » Viewing Trace Sessions to learn about the information the tool provides.

The execution trace will start capturing when System Definition » Targets » Controller » System Channels » `Trace Enabled Flag` becomes non-zero. When `Trace Enabled Flag` becomes zero again, it finalizes the execution and stores the execution trace log file on the target at `C:\ni-rt\NIVeriStand2010\ExecutionTraces\`. If you have the Execution Trace Log Viewer open on the execution host, the target will send the log to the viewer over Ethernet. The following channels may be used with the execution trace.

Table of RT Execution Tracing Channels

Channel Name	Function
Detailed Tracing Flag	Specifies whether detailed execution tracing is enabled on the RT target. This channel corresponds to the Detailed Tracing terminal.
Thread Tracing Flag	Specifies whether thread execution tracing is enabled on the RT target. This channel corresponds to the Thread Tracing terminal.
Trace Buffer Size	Specifies the size in bytes of the execution trace buffer on the RT target. This channel corresponds to the Buffer Size terminal.
Trace Enabled Flag	Specifies whether execution tracing is currently active on the RT Target.
VI Tracing Flag	Specifies whether VI execution tracing is enabled on the RT Target. This channel corresponds to the VI Tracing terminal.

In NI VeriStand 2009, you could obtain an execution trace by using the Real-Time Trace Toolkit Add-on.

Additional Debugging Options for NI VeriStand

Upon request, National Instrument may provide advanced debugging tools to help you resolve certain custom device issues. These tools are a last resort when all other debugging options have been exhausted. Please contact National Instruments for more information.

Table of Debugging and Benchmarking Techniques

Technique	Useful For	Granularity	Caveats
LabVIEW's Built-in Debugging Tools	Debugging	N/A	• Useful before the LabVIEW code has been merged into the custom device framework • LabVIEW debugging hooks do affect timing • Execution highlighting drastically affects VI timing
Console Viewer	Debugging Benchmarking CPU	Low	• Periodic snapshot of utilization, transients and spikes may be missed • Requires the RT Console Viewer daemon
RT Debug String	Debugging	N/A	• Incurs overhead, especially when the console window requires a redraw
Distributed System Manager	Benchmarking CPU Benchmarking RAM	Medium	• Periodic snapshot of utilization, transients and spikes may be missed • Requires the System State Publisher daemon
System Channels	Benchmarking timing	High	• Knowledge of the operator's System Definition is required to make good use of the system channels for benchmarking
System Monitor Add-on	Benchmarking CPU Benchmarking RAM	High	• This add-on is an asynchronous custom device. The higher you configure the custom device loop rate, the more overhead it adds.
Real-Time Execution Tracing	Debugging Benchmarking	Ultra High	• Execution trace logs contain a vast amount of detailed information. They require a good deal of domain expertise to interpret. • Using the tool effectively requires starting and stopping the trace directly around the period of interest.
Additional Debugging Options	Debugging		• Must request from NI • NI must approve its use • Considered a last resort only

Distributing the Custom Device

After you build, debug, validate, and benchmark the custom device, you'll probably want to package it for operators and other developers to use. We'll briefly cover a manual distribution process. As with a generic application, you may streamline distribution by building an installer. See LabVIEW 2010 Help » Fundamentals » Building and Distributing Applications » Creating Build Specifications » Building an Installer (Windows) for more information.
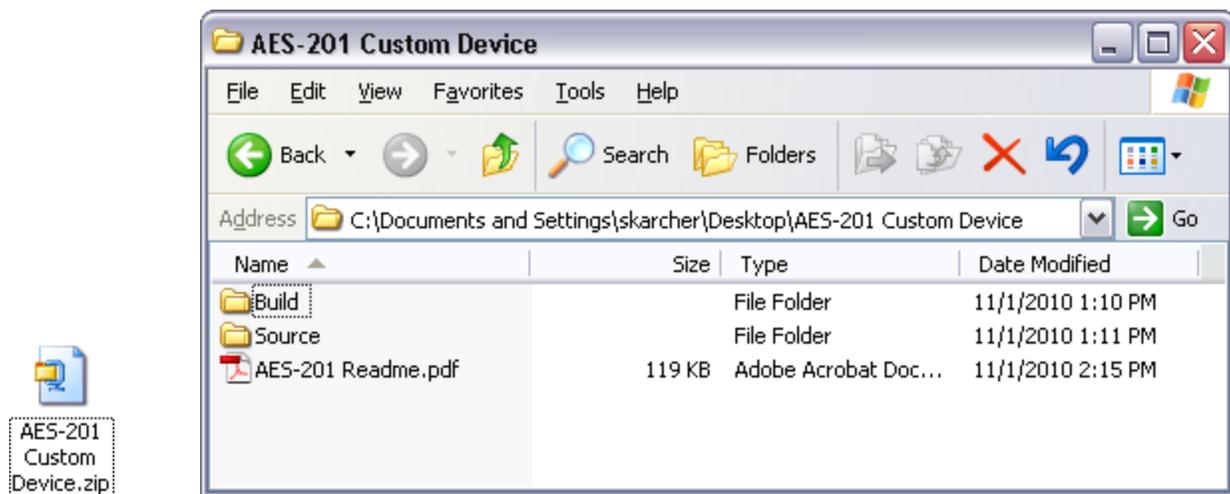
Figure: AES-201 Distribution and Folder Hierarchy

We recommend distributing the custom device by copying the necessary files into a simple folder hierarchy. The top-level folder should contain a Readme file and two folders: `Build` and `Source`. By copying the contents of the `Build` folder to NI VeriStand's `<Common Data>\Custom Devices\`, the operator can add the custom device to his system definition.

The `Source` folder should contain the LabVIEW Project used to create the custom device and any supporting libraries and dependencies required to build the custom device. For example, you'll want to ship the AES-201 custom device with the LabVIEW API and hardware dll.

> ⚠️ Do not include the Custom Device API.lvlib files with the distribution. You do not want to replace the library on the operator's machine, and you do not want to change the library linking on your machine.

The Readme file should contain instructions for installing, licensing, using, and modifying the custom device. It should also contain contact information if you plan to support the device, or a disclaimer if you don't plan to support the device. The Readme file is a good place to put any benchmarking information you've obtained.

You cannot directly use an NI VeriStand 2009 custom device in NI VeriStand 2010 or vice versa, so it's important to include version information for the custom device.

Custom Device Tips and Tricks

This section contains a hodgepodge of tips and tricks when developing custom devices.

Custom Device Engine Events

After a custom device has been deployed, data is exchanged via custom device channels. If channels are insufficient or overly cumbersome, you may implement your own communication mechanism. NI VeriStand also provides access to its own TCP pipe so you don't have to maintain the connection. NI VeriStand's pipe facilitates readable text and byte array data.

In the custom device API you'll find NI VeriStand - Register Custom Device Engine Events VI. This VI provides three dynamic events that may be registered in any VI with a reference to the custom device.

1. Shut Down
2. Message (Byte Array)
3. Message (string)
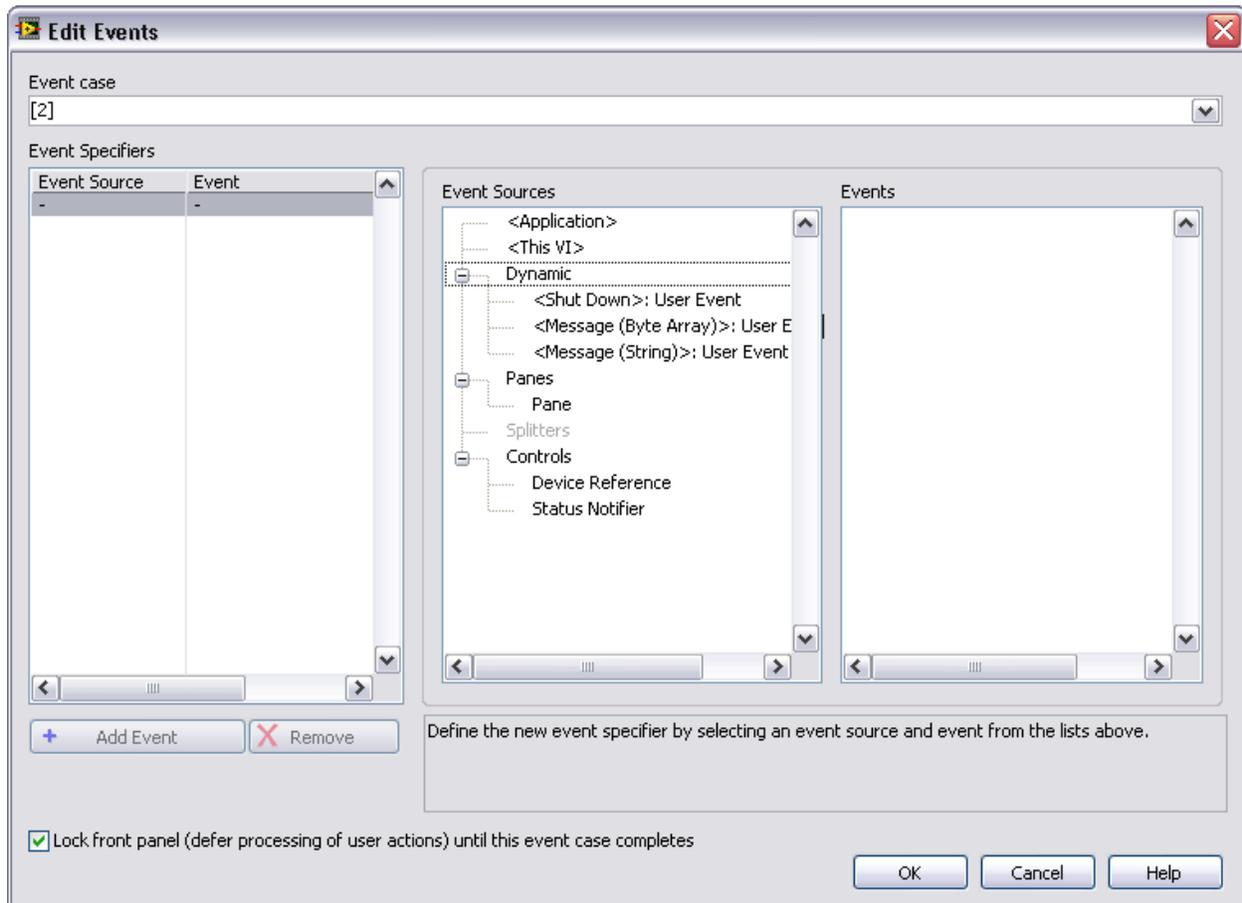
Figure: Registering for NI VeriStand Dynamic Events

The two `message` events fire when some code calls NI VeriStand – Send Custom Device Message VI.
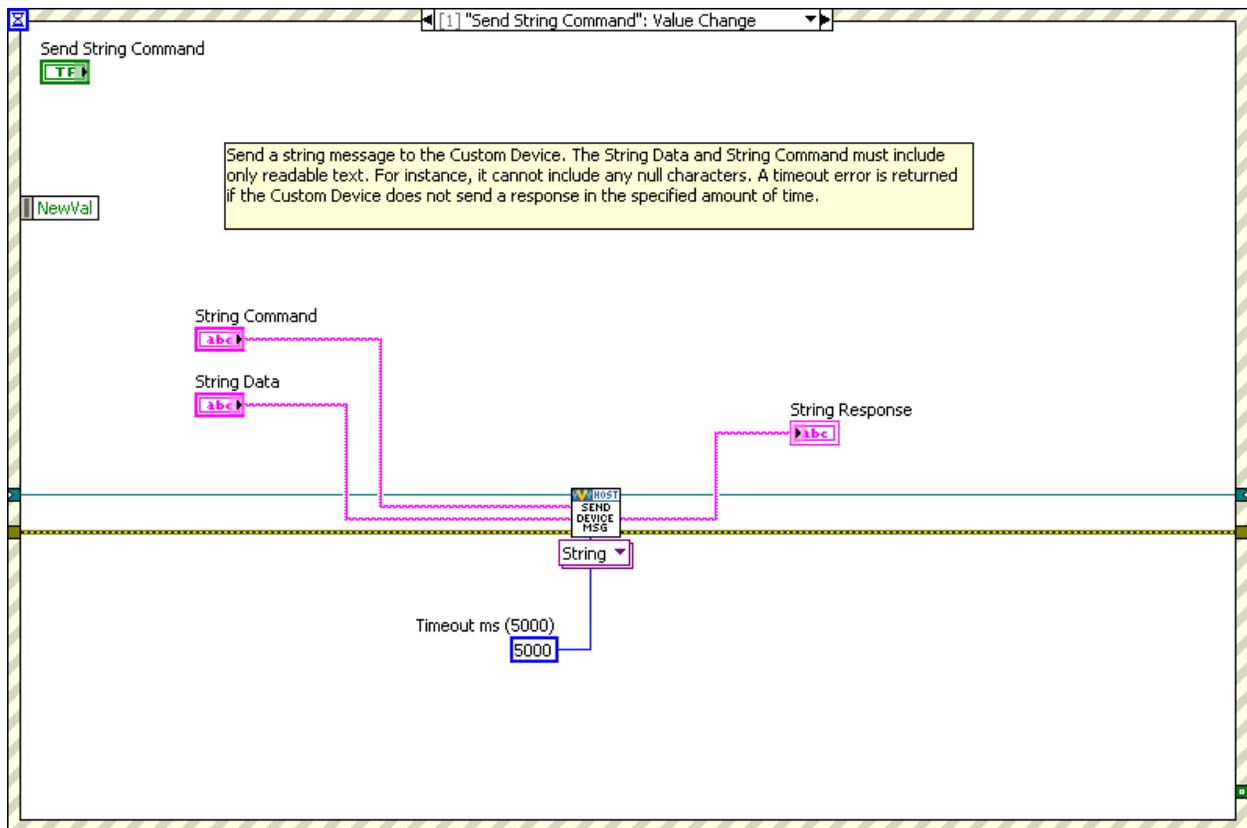
Figure: Sending a Message to NI VeriStand's Dynamic Message Events

There is an example of using the dynamic event pipe in `<labview>\Examples\NI VeriStand\Custom Devices\Communication Example\Communication Example Custom Device Project.lvproj`.

Block Writing and Reading

For inline hardware and inline model custom devices with a large number of channels, it's more efficient to read and write channel data using block data references. Use the following VIs to work with block data references. Custom Device API.lvlib » Templates » RT Driver VIs » Inline » Inline Driver Utilities » Channel Data References » NI VeriStand…

- Get Channel Block Data References
- Get Channel Values by Block Data Reference
- Set Channel Values by Block Data Reference

Recall the Initialization code that generates a list of output channel references.

Channel data references

Instead of output channel references, obtain block references to the output channels. Modify the state data cluster accordingly.

Block data references

In the first version of the custom device, we auto-indexed each channel data reference.

Auto indexing channel data references
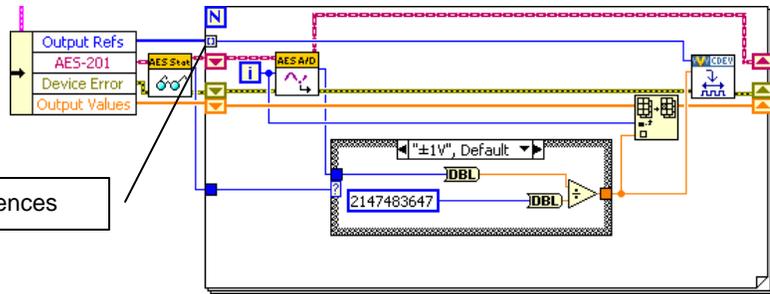
Modify the code to write the block reference instead. Notice the channel block data references are written en-mass outside the loop rather than channel-by-channel within the loop.

Writing block data references
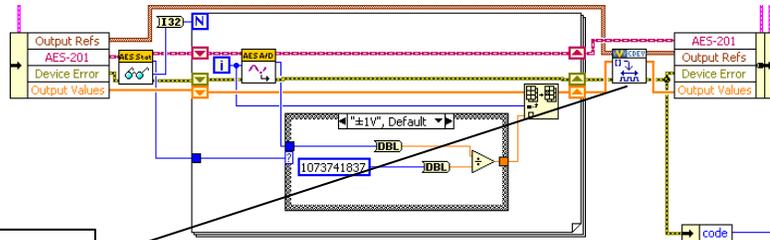
Working with String Constants

During custom device development, strings are used for property names and GUIDs. These strings are case-sensitive and, in the case of GUIDs, long and prone to typos. To facilitate working with these, consider using either LabVIEW Global Variables or a type definition Combo Box control. When using the global variable, ensure that you have set the correct default value for the control. When using the Combo Box control, uncheck the **Values match Items** box on the Edit Items tab of the Properties dialog box.

⚠️ The Combo Box control does not auto-update from its type definition. Completely populate the control before using it on the block diagram.

Custom Error Codes

You may build custom error codes for your custom device by using the General Error Handler VI or the Error Code File Editor. See LabVIEW 2010 Help: Defining Custom Error Codes in Test Files for more information. If you use an error file, you must move the file to NI VeriStand's error folder. By default, this folder is located at `<Program Files>\National Instruments\VeriStand 2010\project\errors\English`. You should add the error file as a project dependency. If applicable, deploy the file to the error directory on the RT system, located at `\NI-RT\SYSTEM\errors\english` for PharLap and VxWorks targets.

Utility VIs

The NI VeriStand developers have assembled a library of useful utility VIs in `<vi.lib>\NI Veristand\Custom Device Tools\Custom Device Utility Library\Custom Device Utility Library.lvlib`. The VIs in this library are documented in LabVIEW's Context Help window. Here is a list of the utility VIs.

- Add Sections Recursively by Relative Path
- Advanced Browsing Dialog
- Get All Channels
- Get Channel FIFO Buffer Index

- Get Item Ref by Relative Path
- Get Multiple Dependent Node Refs
- Get Next Unique Label
- Get Target Ref
- Highlight Node in System Explorer
- Not a Ref
- Ref Constants
- Report Final Error Status
- Search for All Items by GUID
- Search for All Items by Name
- Search for All Items by Property
- Search for Item by GUID
- Search for Item by Name
- Search for Item by Property
- Search for Item
- Set Multiple Dependent Node Refs

Sort Channels by FIFO Location

NI VeriStand – Get Channel FIFO Buffer Index VI returns the FIFO buffer index for the input or output channel reference. Use this function for Asynchronous Custom Device channels to determine what index to read or write in the FIFO arrays. The VI also returns which FIFO Buffer (Input or Output) the channel will be located in. This function is only intended for Asynchronous Custom Devices.

Consider a custom device to read an arbitrary list of DAQmx thermocouple inputs. One way to accomplish the task would be to read *all* the hardware channels, cycle through the list of custom device channels looking for the `channel` property, and write the associated hardware channel value that corresponds to the custom device channel.

A superior way to accomplish the task is to sort the channel references in the order they appear in the custom device FIFO, and configure the DAQmx task so the thermocouple channels are read in the same order as they appear in the FIFO.
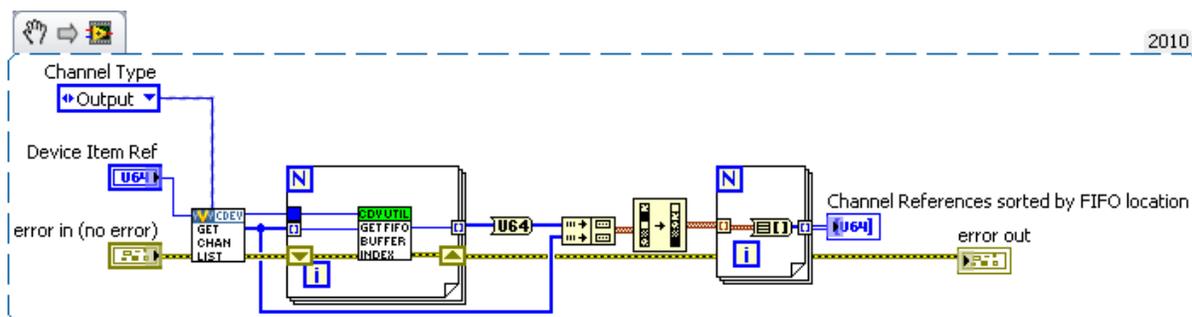
Figure: Sorting Asynchronous Custom Device Channels by their Order in the FIFO
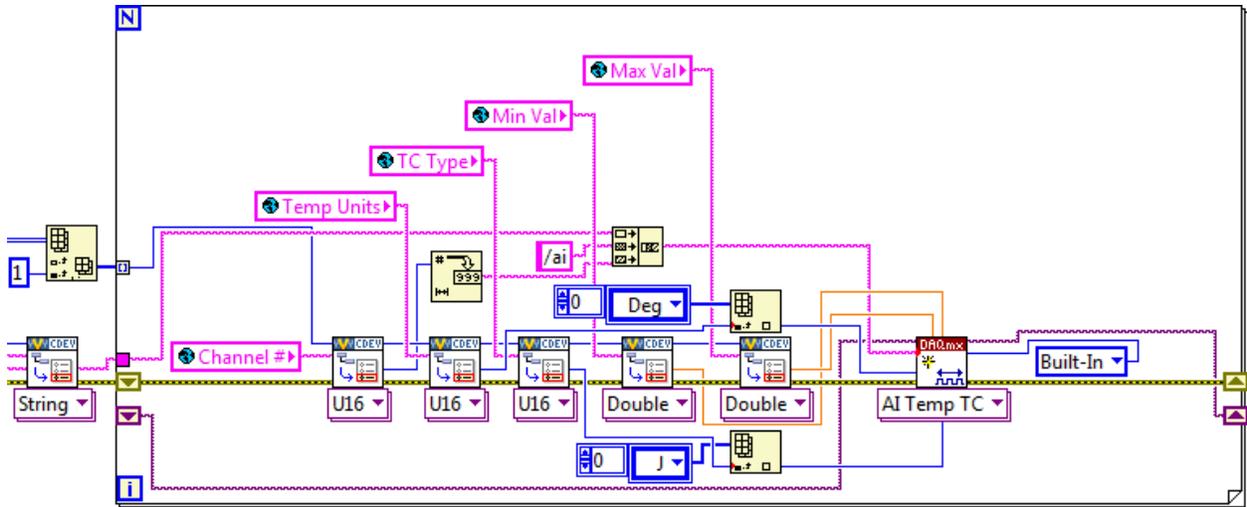
Figure: Adding Channels to a DAQmx Task by their Order in the Custom Device FIFO

There are several advantages of this architecture. The operator is free to add/remove/reorder channels how he pleases, only the desired channels are configured, and writing data to the custom device FIFO becomes naturally efficient.
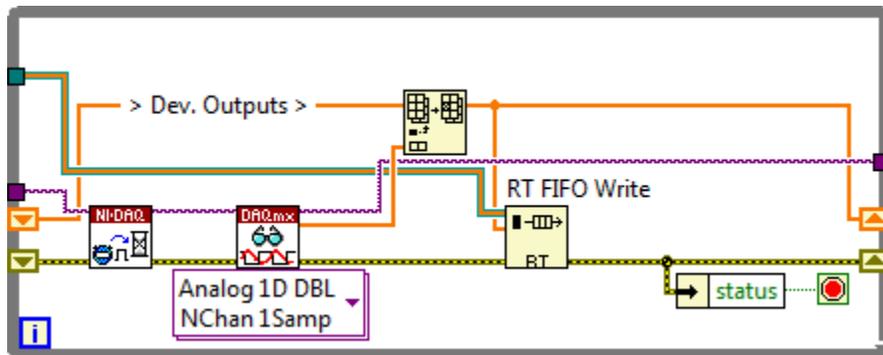
Figure: Writing Multiple Hardware Channels Directly to the Custom Device FIFO

The hardware data returns from the DAQmx driver in the same order as the channel references in the asynchronous custom device FIFO.

Triggering Within the Custom Device

There are many cases where you want to run code in the custom device when an event occurs. By comparing the AEEnCh<1..8> channel values to the previous iteration, we implemented simple value-triggering.

A useful VI for triggering is Signal Processing » Point by Point » Other Functions » Boolean Crossing Point by Point.
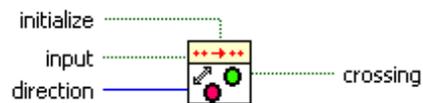
Figure: Boolean Crossing PtByPt VI

Recall the Write Data to HW state that reads NI VeriStand Channels. Add code to check the software trigger.
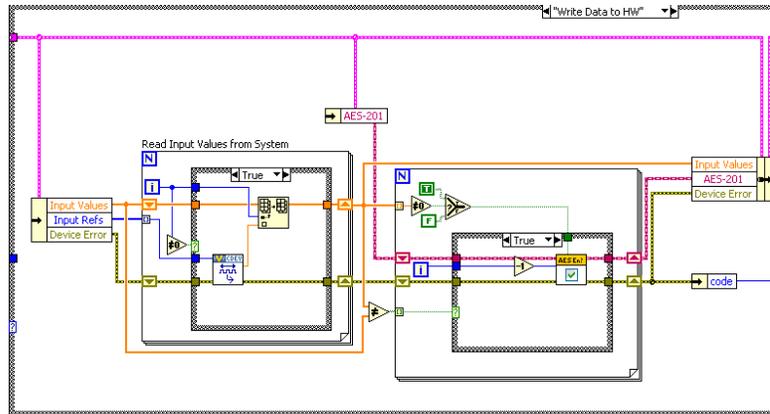
Check the `SWTrig` channel for a transition and handle the transition accordingly.
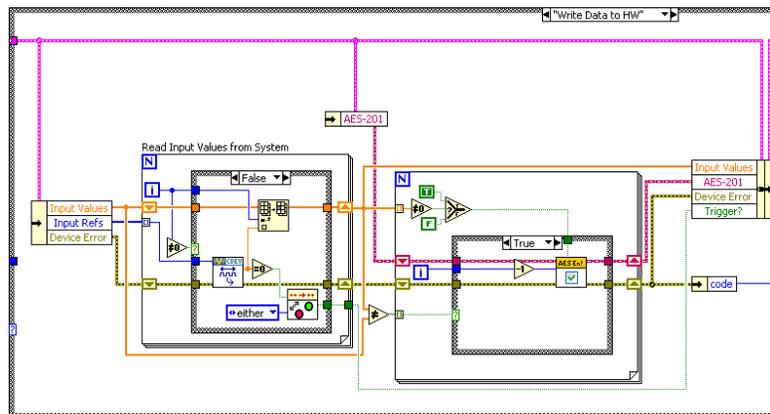
This triggering VI is most useful in asynchronous custom devices that do not execute in line with the PCL. An asynchronous device might iterate multiple times in a single iteration of the PCL, but this triggering VI will only assert on the desired edge of the transition.

Adding Extra Pages After Creating the Custom Device Project

If your Custom Device requires additional pages for sections or channels, you should specify their names in the **Extra Page Names** control of the Custom Device Template Tool before you generate the LabVIEW project for the device. The tool ensures that the appropriate references are available to the page, the necessary declarations go into the Custom Device XML file, and the Build Specification deploys the page to the correct location.

There are two telltale signs that an extra page has not been added correctly to a custom device. The first is the default section or channel page loads into System Explorer instead of the expected extra page. The second is an error from System Explorer similar to **Custom Device Page Error: The following Custom Device page VI is not executable. The VI might not be found at the correct location, or it is missing dependencies that it requires to run. Please contact the Custom Device vendor for more information on this problem**.

In order to add a new page after the framework has been generated, you must manually perform all the actions the tool performs.

⚠️ Perform the following operations from the LabVIEW Project Explorer.
Incorrect changes to the Custom Device's XML file can corrupt the System Definition in NI VeriStand.

☐ Ensure the device gets the appropriate device reference. The NI VeriStand API requires the correct Node Reference input. The NI VeriStand system is responsible for passing this reference to the page. There's a VI Template in `Custom Device API.lvlib\Templates\Subpanel Page VI\Page Template.vit` for this purpose. Another way to ensure the new page gets the correct Node Reference is to copy a page generated by the Custom Device Template Tool, such as the Main page.

☐ Create the page section in the custom device XML file. The Custom Device's XML file tells the System Explorer how to load the device's files.
   1. Open the XML file from the Project Explorer window.
   2. Locate the **Pages** section.
   3. Copy the information between Main Page's **Page** and **/Page** declarations.
   4. Paste the section immediately below the **/Page** declaration that closes the Main Page section.
   5. Change the **eng**, **loc,** and Path tags for the new page.
   6. Change the GUID to match the extra page's GUID you created.
   7. Save and close the XML file.

☐ Modify the configuration build specification. The Custom Device Template Tool scripts two Build Specifications that put the custom device files in the necessary format and location for System Explorer.
   1. Open the configuration's build specification dialog box.
   2. In **Source Files**, expand the lvlib for your device.
   3. Add the new page to the **Always Included** section.
   4. In **Source Files Settings**, select the new page in the **Project Files** tree and change the **Destination** to **Custom Device <*Name*> Folder**.
   5. Click **OK** to close the build specification.
   6. Save the LabVIEW project.

You must rebuild the Configuration and Engine build specifications to deploy the changes. You may then use the extra page as if it were generated by the Custom Device Template Tool.

The Custom Device Template Tool is open source. If you have any questions about what the tool does, you can refer to the code as you would any other VI.

Custom Device XML
The full set of features that can be implemented with custom device XML tags are undocumented. Refer to the XML schema file (`<common data>\Custom Devices`) to discover what features may exist. Features are shown as tag names. Consider the following example line from the `Custom Device.xsd` file.

```
<xs:element minOccurs="0" name="ActionVIOnDelete" type="Path" />
```

A Line from the Custom Device XML Schema File

The name of this tag is `ActionVIOnDelete`. Adding this tag to the custom device XML runs a VI when the operator deletes the item from System Explorer. While these features are undocumented, the XML is fairly intuitive. You may find experimenting with the custom device XML easier in an empty custom device. Assistance implementing the features may be obtained by contacting National Instruments VeriStand technical support.

It may be helpful to explore NI VeriStand's built-in components for examples on implementing XML features. The built-in components are found in `<application data>\System Explorer\System Explorer Definition Files`.

If a tag is opened, use the format `</tag_name>` to close the tag. If a tag must be specified but has no value, you may use the format `<tag_name />` to open and close the tag at the same time. This format has the same effect as `<tag_name>tag value</tag_name>`.

Delete Protection
You can add **`<DeleteProtection>true</DeleteProtection>`** to any section in the custom device XML to disallow deleting the item from the configuration tree in System Explorer.

Limiting Occurrences of the Custom Device
If it doesn't make sense to have more than `N` instances of the custom device in a single System Definition, you can limit the number of instances by adding **`<MaxOccurrence>N</MaxOccurrence>`** to the custom device XML underneath the device type.

Rename Protection
There may be cases when you depend on a custom device item to have a certain name, and you'd like to prevent the operator from renaming the item. Add **`<DisallowRenaming>true</DisallowRenaming>`** below the `</Name>`tag for any page to prevent the operator from renaming the item.

Action VIs
There are a variety of actions that can trigger a VI to run.

- `OnDelete`
  - Executes on the deletion of a node in the system definition
- `OnLoad`
  - Executes on the creation of a new node or load of an existing nod in the system definition
- `OnSystemShutdown`
  - Executes on system explorer close or current system definition close
- `OnSave`
  - Executes on save of system definition
- `OnDownload`
  - Executes when the system definition is downloaded to the target. This VI is called after compile is complete and binary files have been created. Writing to memory should not be performed in this VI. The VI can be used to read from memory and download additional files as needed
- `OnPaste`
  - Executes when a node is pasted within the system definition
- `OnTargetTypeChange`

Executes on change of target type in the system definition

- OnDeleteRequest

  Executes on the delete request before deletion of node in system definition

- OnCompile

  Executes when the system definition is compiled during deployment. The system definition will only be compiled during deployment if there is not a good compile cache available on the host. This happens when the system definition file has been moved on disk or when changes have been made.

These VIs are useful if you need to make checks or perform cleanup operations after something happens. The template VIs for these actions are found in the Custom Device API library.

Run-Time Right-click Menu
You can add right-click functionality in System Explorer to any custom device item. Underneath the `</Item2Launch>` tag for any page, add the following framework.

```
</Item2Launch>
<RunTimeMenu>
  <MenuItem>
    <GUID>GUID</GUID>
    <Type>Type_Enum</Type>
    <Execution>Execution_Enum</Execution>
    <Position>Position_Enum</Position>
    <Behavior>Behavior_Enum</Behavior>
    <Name>
      <eng>Extra Page Name</eng>
      <loc>Extra Page Name</loc>
    </Name>
    <Item2Launch>
      <Type>To Common Doc Dir</Type>
      <Path>...\Configuration.llb\Extra Page Name.vi</Path>
    </Item2Launch>
  </MenuItem>
</RunTimeMenu>
```
Custom Device XML Right-Click Framework

- **GUID**

  A unique GUID for the extra page
- Type_Enum

  Describes the type of right-click item
  - **Action** (default) runs the VI silently in the background, i.e. carry out a pre-configured task and exit
  - **VI** runs the VI in interactive mode displaying the front panel
- Execution_Enum
  - **silent** runs the VI silently in the background
  - **modal** runs the VI as a modal window
  - **floating** runs the VI as a floating window
- Position_Enum
  - **centered** (default) centers the window on the default monitor on launch
  - **mouse pointer** puts the font panel origin at the mouse pointer on launch
- Behavior_Enum
  - **None**

- o **OpenFrontPanel** (default)

Dynamic Buttons
Dynamic buttons are tied to the page and are displayed in the menu area of System Explorer. One the page goes out of memory and a different page (with a different GUID) is loaded, dynamic buttons disappear. Underneath the `</RunTimeMenu>` tag for any page, add the following framework.

```
<RunTimeMenu/>
<ButtonList>
  <Button>
  <ID>A unique button ID</ID>
  <Glyph>
    <Type>To Application Data Dir</Type>
    <Path>System Explorer\Glyphs\abc.png</Path>
  </Glyph>
  <Type>Type_Enum</Type>
  <ReferencedGUID></ReferencedGUID>
  <ButtonText>
    <eng>Button Text</eng>
    <loc>Button Text</loc>
  </ButtonText>
  <Caption>
    <eng>Button Caption</eng>
    <loc>Button Caption</loc>
  </Caption>
  <TipStrip>
    <eng>Button Tip</eng>
    <loc>Button Tip</loc>
  </TipStrip>
  <Documentation>
    <eng></eng>
    <loc></loc>
  </Documentation>
  </Button>
</ButtonList>
```
Custom Device Dynamic Button Framework

- Type_Enum
    - Action runs the VI silently in the background, i.e. carry out a pre-configured task and exit
    - Dialog
    - Page
    - Notification send a notification to the currently loaded page and pass the unique button ID
    - Separator add a visual separator to the toolbar

In the custom device LabVIEW Project, you'll find Custom Device API.lvlib » Utility » NI VeriStand – Enable Dynamic Button and Disable Dynamic Button.vi to enable/disable the button based on the unique button ID.

Upgrading VeriStand 2009 Custom Devices to 2010
While custom devices are written in LabVIEW, they depend on NI VeriStand's framework to behave as native tasks within the engine. Changes to NI VeriStand's framework require changes to the LabVIEW code. Mass compiling NI VeriStand 2009 custom devices in LabVIEW 2010 does not account for these changes; it simply saves the VIs in the new version of LabVIEW. As a result, mass compiling alone does not upgrade the custom device to NI VeriStand 2010. The following instructions assume that you have access to the custom device LabVIEW source project.

- ☐ Open the custom device source project in LabVIEW 2010
- ☐ Mass compile the source directory
- ☐ Update the build destinations

- o Open the build specification for the configuration
- o Select the Destinations category in the Configuration Properties window
- o Highlight the custom device name in the Destinations list
- o If necessary, direct the Destination Path control to the correct custom device folder for your operating system. Make sure the Destination type is still LLB
- o Follow the same steps for the engine's build specificaiton
- ▢ Rebuild the configuration and engine source distributions
- ▢ Add the custom device to an NI VeriStand 2010 system definition – this automatically mutates the XML file

The original XML file is renamed to Vers0_0_0_0<Custom Device Name>.xml. The mutation is necessary due to several changes in the XML schema definition.

One major change is the alias name of the destination folder of custom devices. The actual source folder of custom devices has not changed (`<Common Data>\Custom Devices`) whereas the alias has. In NI VeriStand 2009 this folder was called `<Type>To App Data Dir</Type>`. In NI VeriStand 2010 it has been changed to `<Type>To Common Doc Dir</Type>`. Due to this change, the alias of the application data directory (`C:\Documents and Settings\All Users\Application Data\National Instruments\NI VeriStand 2010`) was changed from `<Type>To App Data Dir</Type>` to `<Type>To Application Data Dir</Type>`.

The folder structure has been changed, which can affect custom devices that have referenced internal NI VeriStand glyphs in their XML file. If the custom device glyphs are incorrect after the mutation, change the glyph's location alias from `<To Common Doc Dir>` to `<To Application Data Dir>`.

NI VeriStand 2010 has introduced the knowledge of operating systems (Windows, Pharlap and VxWorks). Existing custom device XML files get mutated to `PharLapWindows`. `PharLapWindows` is the default if the tag is not specified in the XML. The 2010 Custom Device Template Tool creates the tag by default. If an operator wants to run the custom device on VxWorks, he has to modify the custom device XML file. A good start to get an idea how this works is the Embedded Data Logger that ships with NIVS 2010.

```
<CustomDeviceVI>
  <SourceDistribution>
    <Source>
      <SupportedTarget>PharlapWindows</SupportedTarget>
      <Source>
        <Type>To Common Doc Dir</Type>
        <Path>Custom Devices\National Instruments\Embedded Data Logger\Embedded Data
Logger - Engine - PharLap.llb\Embedded Data Logger RT Driver VI.vi</Path>
      </Source>
      <RealTimeSystemDestination>c:\ni-rt\NIVeriStand2010\Custom Devices\National
Instruments\Embedded Data Logger\Embedded Data Logger - Engine - PharLap.llb\Embedded
Data Logger RT Driver VI.vi</RealTimeSystemDestination>
    </Source>
    <Source>
      <SupportedTarget>VxWorks</SupportedTarget>
      <Source>
        <Type>To Common Doc Dir</Type>
        <Path>Custom Devices\National Instruments\Embedded Data Logger\Embedded Data
Logger - Engine - VxWorks.llb\Embedded Data Logger RT Driver VI.vi</Path>
      </Source>
      <RealTimeSystemDestination>c:\ni-rt\NIVeriStand2010\Custom Devices\National
```

```
Instruments\Embedded Data Logger\Embedded Data Logger - Engine - VxWorks.llb\Embedded
Data Logger RT Driver VI.vi</RealTimeSystemDestination>
    </Source>
  </SourceDistribution>
</CustomDeviceVI>
```
Excerpt from the Embedded Data Logger XML Showing Two Separate LLBs

If the custom device's LabVIEW source project is unavailable, the following process will update
the NI VeriStand 2009 custom device to 2010.

- ☐ Open the configuration and engine LLBs and look for all custom VIs and controls
- ☐ Save all custom VIs and controls to a new location
- ☐ Create a new LabVIEW Project and add the custom device API library
- ☐ Create a new custom device library
- ☐ Add the custom files to the LabVIEW library
- ☐ Recreate the source distributions for the configuration and engine LLBs
- ☐ Build the new LLBs

This goal of this process is to link the custom VIs to the NI VeriStand 2010 VIs and controls
instead of the old resources in the LLBs.

Beyond the Template Frameworks
The Custom Device Template Tool provides a convenient starting point for most custom
devices; it reduces the opportunity for error; and it contains build specifications that deploy the
custom device to the correct location on disk. Now that you've seen the tool in action, you
should know that it's completely unnecessary. The `<vi.lib>\NI VeriStand\Custom
Device API\Cutom Device API.lvlib` library contains all the template VIs, type
definitions and functions needed to make a custom device.

There's no hard requirement for an Initialization and Engine library, or any of the VIs you've
seen that are part of these libraries (Main, Initialization, RT Driver). NI VeriStand will deploy a
custom device according to any properly formatted XML file, so long as the controls and
indicators provided by the appropriate VI template(s) are maintained.

One of the best resources for ideas about custom device architecture are the devices that
already exist. You may come across the following framework.

Inline Custom Device with Asynchronous Threads
Inline custom devices execute within the PCL. The device is guaranteed an opportunity to
publish and consume data to/from NI VeriStand in each iteration of the PCL. A major caveat of
inline devices is the potential for the device to introduce latency into the PCL. An asynchronous
custom device may synchronize its Timed Loop to the PCL, achieving a pseudo-synchronous
loop. Two caveats of pseudo-synchronous loops are they are not guaranteed to iterate once
per iteration of the PCL and they are not guaranteed to iterate deterministically with respect to
the PCL.

It may suite your needs to launch asynchronous worker thread(s) from an inline custom device.
The inline device is responsible for communicating channel data to/from NI VeriStand, and the
worker is responsible for nondeterministic operations on the channel data. RTFIFOs are best-
suited for communicating between the inline device and the worker(s). You'll find an example of

this architecture in the Embedded Data Logger custom device that ships with NI VeriStand 2010. If you look in the Initialize case of `Embedded Data Logger - Engine - PharLap.llb\Embedded Data Logger RT Driver VI.vi`, you'll see the inline device launch an asynchronous loop.
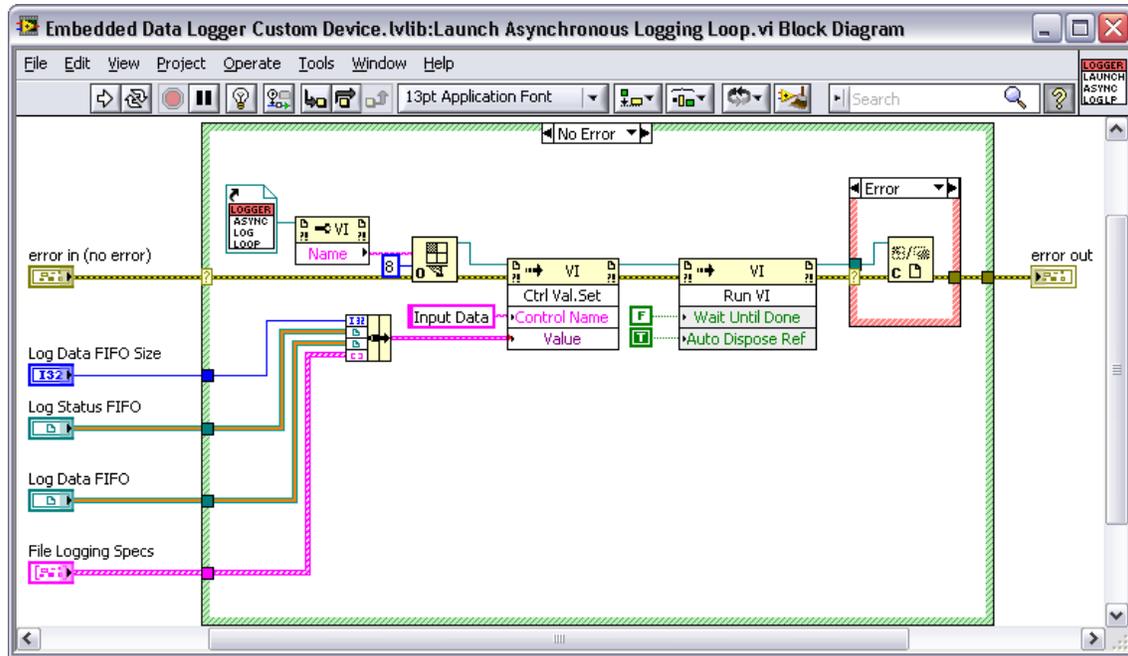

Figure: Launching an Asynchronous Worker Thread from an Inline Device

One RT FIFO is used to communicate information from the asynchronous worker to the inline custom device in the Read Data from HW case.
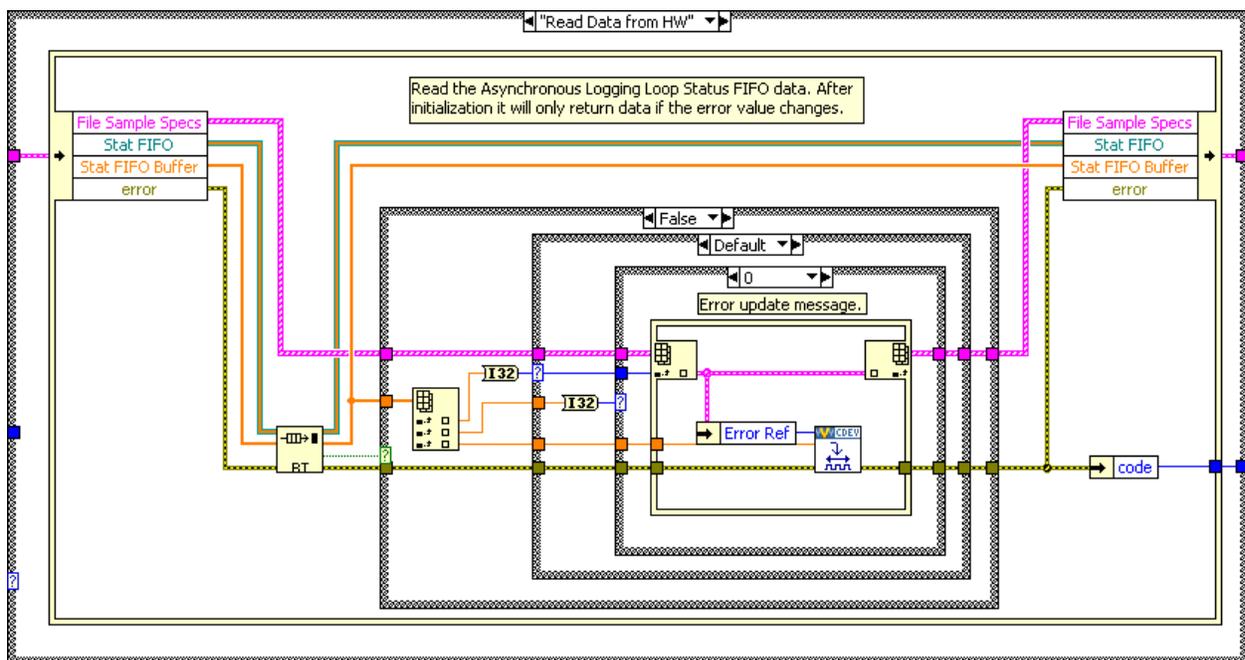

Figure: Communicating from the Asynchronous Worker to the Inline Device

Another RT FIFO is used to communicate channel values to the asynchronous worker.
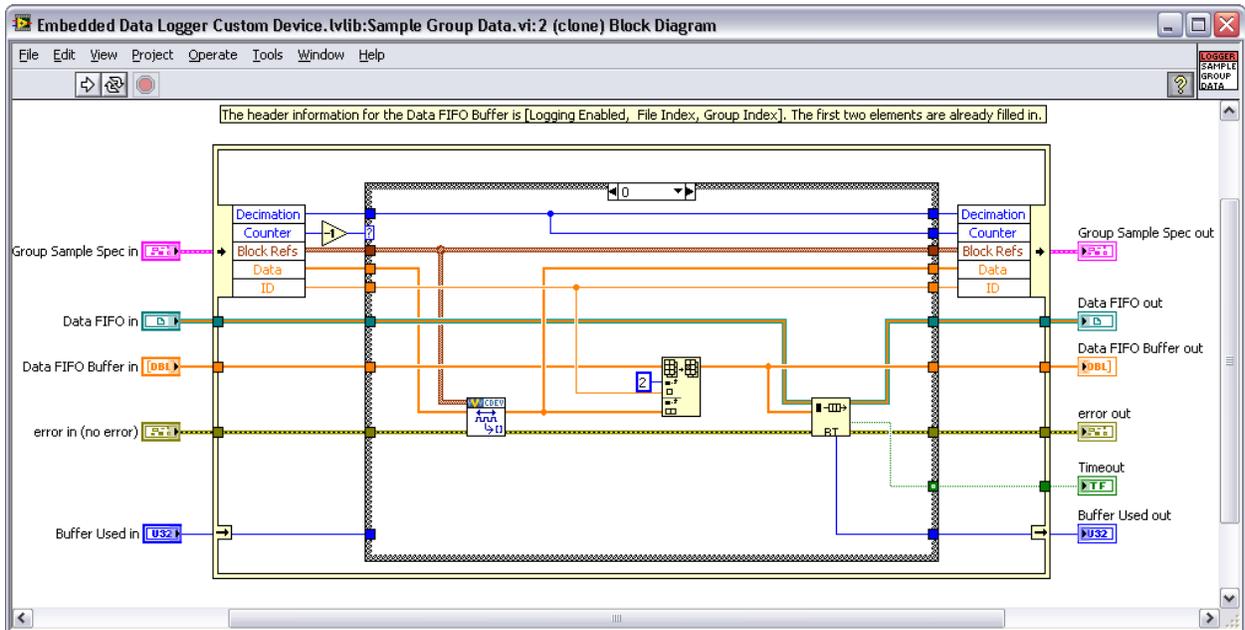

Figure: Communicating from the Inline Device to the Asynchronous Worker

This architecture works-around the caveats of the inline device and the pseudo-synchronous device. A caveat of this architecture is the data must be consumed from the RT FIFOs at an acceptable rate or the mechanism will overflow. In the RT logging custom device, the developer tallies the number of "missed points" when this happens, but does not abort logging.

Custom Device Development Job Aid

- Do you Need a Custom Device?
  - Have you tried to meet specification with built-in NI VeriStand features?
  - Do you need to support 3rd Party Hardware?
  - Do you need an unsupported measurement or generation mode?
  - Do you need to implement a feature?
    - Is a custom device the best customization mechanism for the feature?
  - Have you checked that a custom device doesn't already exist
- Custom Device Risk Analysis
  - Do you have the appropriate LabVIEW application development experience?
  - Do you have LabVIEW Real-Time application development experience?
  - Do you have an NI VeriStand operator background or understanding?
  - If you need to support hardware, does an RT compatible driver exist?
  - Can you test and debug on a system representative of the operator's system?
- Planning
  - Channels (DBL)
    - Pass data from the custom device to the system
    - Pass data from the system to the custom device
    - Pass dynamic properties
  - Properties (any data type)
    - Pass configuration data from execution host to target on one time basis
    - Use within the RT driver to pass around information
  - Hierarchy
    - Use the minimum number of sections
    - Make the hierarchy well-organized, intuitive, and user friendly
  - Extra Pages
    - One for each channel or section that requires other than the default page
    - Create a few extra just in case
  - Type
    - Select the type based on the timing requirements of the custom device
    - Plan the type before executing the Custom Device Template Tool
    - Some devices require multiple RT Driver VIs
- Implement
- Debug and Benchmark
  - Console Viewer
  - RT Debug String
  - System State Publisher
  - System Channels
  - System Monitor Add-on
  - Real-Time Execution Tracing
  - "Other" debugging options from NI
- Distributing the Custom Device
  - Source
  - Build
  - Readme