Direct Data Connectivity to the 89600 VSA (89601101C)

Introduction

Keysight's 89600 Vector Signal Analysis (VSA) software is used with confidence by many thousands of users to troubleshoot systems, validate product performance, and examine compliance for dozens of wireless standards, as well as automotive and aerospace/defense applications. Well known in test & measurement applications for acquiring IQ waveforms from hundreds of Keysight instruments, the VSA performs detailed signal analysis of those modulated waveforms, and presents the results, either through a visual GUI, or through a mature software API programming or SCPI commands. But what if you need VSA connectivity to your custom hardware or software?

With Keysight's Direct Data Connectivity to the 89600 Vector Signal Analysis software (option 89601101C), you can stream IQ data directly from your own software and hardware platform. This connectivity is available through two approaches: VITA-49/DIFI streaming for standardized network protocols, and the User Input API for custom software integration. This enables you to leverage Keysight's advanced measurement algorithms, intuitive visualization tools, and robust automation capabilities on a wide range of data sources, including:

- Data from the inside of your signal processing chain, such as the baseband IQ data from your own receiver (rather than a transmitter)
- Data from a preferred hardware receiver, including third party hardware
- Data from software streams, MATLAB™, simulated environments
- Data from large offline recording files
- Multi-channel data sources

The VSA software supports multiple connectivity options to access these data sources, including API programming (.NET or SCPI) and VITA-49 streaming over LAN.

With a state-of-the-art signal analysis software directly available in your application, you avoid the time and expense of needing to develop or support your own demodulation algorithms, plus you take advantage of the quality, interoperability, and standards compliance of the same software that Keysight uses on its own Test & Measurement platforms.

Say you are building a custom signal quality measurement solution leveraging in-house hardware or software that provides IQ data. You don't want to reinvent all the algorithms for signal processing to get relevant metrics, nor do you care to track the standards for the latest changes to the test models. You need great visualization to showcase many facets of your received signal. With the 89601101C Direct Data Connectivity, you can bring instrument grade metrology to your custom hardware solution. You can be assured that both you and your customers will have Keysight level customer care and great support for these continually evolving measurements.

Benefits of Direct Data Connectivity:

- Save custom solution development time.
- Track evolving wireless and cellular measurement standards.
- Compare your own receiver IQ data against reference Keysight spectrum analyzer IQ data.
- Apply Keysight measurement algorithms directly inside your signal processing chain.
- Showcase your own hardware performance (EVM, Power Spectrum, etc.) for early design wins.

Comparing Direct Data Connectivity and the Hardware Extension SDK

Although this technical overview focuses on Direct Data Connectivity (option 89601101C), Keysight offers another method for integrating custom hardware with the 89600 VSA software: the 89630B Hardware Extension SDK (HX SDK) with the 89601301C Multi-Vendor Hardware Connectivity. The HX SDK allows developers to create plug-ins that extend VSA's hardware support, so the VSA can control and acquire data from custom hardware as though it were a native Keysight instrument.

1. **Hardware Control and Integration**
   One of the biggest reasons to choose the HX SDK is the ability to control hardware settings—such as center frequency, bandwidth, triggering, and input level—directly from the VSA GUI. This provides a more integrated, analyzer-like user experience. In contrast, **Direct Data Connectivity** generally streams data from external sources, so you control most acquisition parameters outside the VSA user interface.

2. **Speed and Efficiency**
   The HX SDK can run in-process with the VSA, eliminating extra software layers. This setup often enables higher data throughput—especially if your hardware drivers are also running in-process. By comparison, the **User Input API** must transfer data from out-of-process, which can be less efficient for very high-throughput scenarios.

3. **Development Effort**
   In general, the HX SDK requires more specialized development work. However, it can sometimes be straightforward for certain use cases. Meanwhile, **Direct Data Connectivity** typically has a lower barrier to entry because it is already included with the VSA software and documented in the VSA help. That said, configuring the User Input API can still be complex for some scenarios—so "easier" or "harder" depends on the exact integration details.

When deciding between Direct Data Connectivity and the HX SDK, consider your application's requirements. If your primary goal is to stream data into the VSA for measurement, visualization, and automation, option 89601101C can be quicker to deploy. If you need deeper hardware control and in-process performance, the HX SDK may be more suitable. For further details on the HX SDK, refer to the **89601301C Multi-Vendor Hardware Connectivity** product description at https://www.keysight.com/products/89601301C.

Take VSA Connectivity to the Next Level

How do we get IQ data into a signal analysis toolbox? There are currently 3 ways.

1. Via direct hardware connection. With the PathWave Vector Signal Analysis 89600 VSA tool, you can connect to over 300 Keysight model numbers, ranging from digitizers to oscilloscopes to signal analyzers and even modular instruments. Once you've connected, the software feels like an extension of the instrument, so you can trigger on an event of interest (like an RF burst of power), and then later record your acquisitions to a binary file for postprocessing.
2. Through recording file playback. A waveform saved in MATLAB format, text, CSV, VITA-49, or various other binary formats can be recalled into the VSA software.
3. Direct Data Connectivity, which supports 2 main approaches:
    a. VITA-49/DIFI streaming for standardized digital IF data transfer over networks
    b. Custom hardware/software integration through the User Input API (.NET Framework 4.8 or .NET6+)

As shown in the figure below, flexibility in connectivity enables the VSA to test anywhere in the transmitter chain. Digital signal processing engineers can verify their baseband algorithms alongside RF systems engineers who can check the EVM floor of their ASIC.

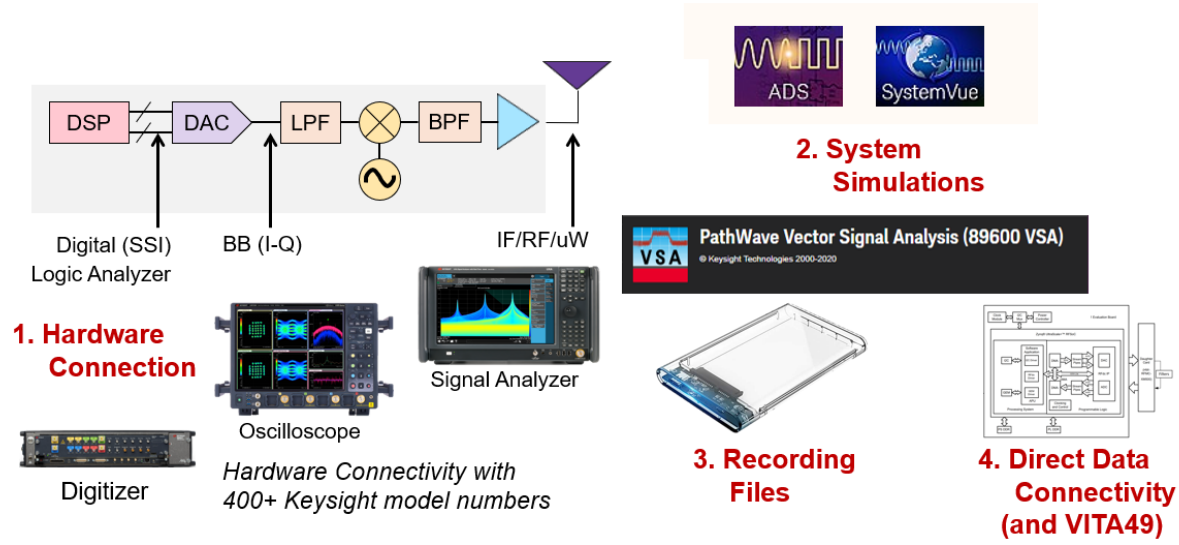


Figure 1. Comprehensive Signal Analysis Workflow: Hardware Connection, System Simulations, Recording Files, and Direct Data Connectivity to custom hardware or software.

While you would normally choose hardware control or recording file playback, there are certain situations where Direct Data Connectivity is the right way to go. In the following section, we will discuss the different types of direct data connectivity options available (VITA-49 versus User Input API) and when to use each.

Choosing Your Approach for Direct Data Connectivity

Before diving into the technical details, consider your implementation needs:

Choose **VITA-49/DIFI streaming** if you:

- Need standardized digital IF data transfer
- Work with satellite communications or ground station applications
- Want to leverage industry-standard protocols
- Need plug-and-play compatibility with DIFI hardware

Choose the **User Input API** if you:

- Need custom test solution integration
- Require programmatic control over VSA measurements
- Have unique hardware interfaces
- Need deep integration with existing software

Digital Intermediate Frequency Interoperability (DIFI/VITA-49) Data Streaming Over LAN

The satellite communications industry is adopting new digital standards that make ground stations - the earth-based equipment that communicates with satellites - more flexible and easier to upgrade. The Digital IF Interoperability (DIFI) standard helps by defining common ways for equipment to exchange digitized radio signals over standard computer networks, much like how the Internet uses standard protocols to connect different devices.

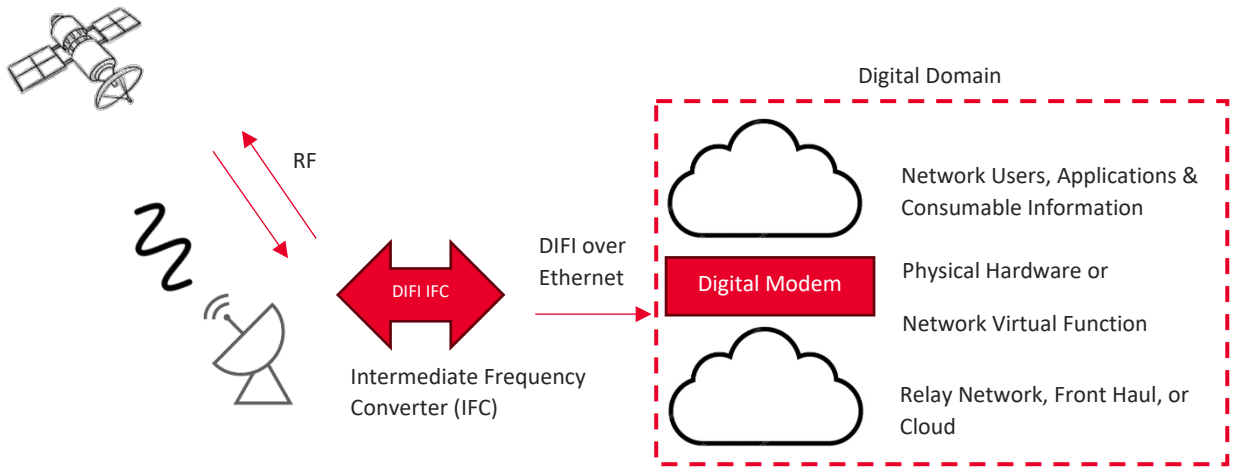


Figure 2: The DIFI ecosystem: from satellite signals to digital applications. DIFI standardizes how RF signals are converted and transported across digital networks.

In this ecosystem, satellites transmit RF signals to a DIFI intermediate frequency converter (IFC), which transforms these signals into standardized digital data streams carried over Ethernet. This digital data can flow through various network infrastructure - including relay networks, front haul, or cloud - before

reaching a digital modem, which may be either physical hardware or a network virtual function (NVF). The digital modem extracts payload data that network users and applications can consume.

The VSA software supports these DIFI/VITA-49 formats in two ways: The base platform (89601200C) can analyze saved DIFI data files (*.vita49 format). The direct data connectivity option (89601101C) can capture and analyze selected streams of VITA-49 data streams as they flow across the network.

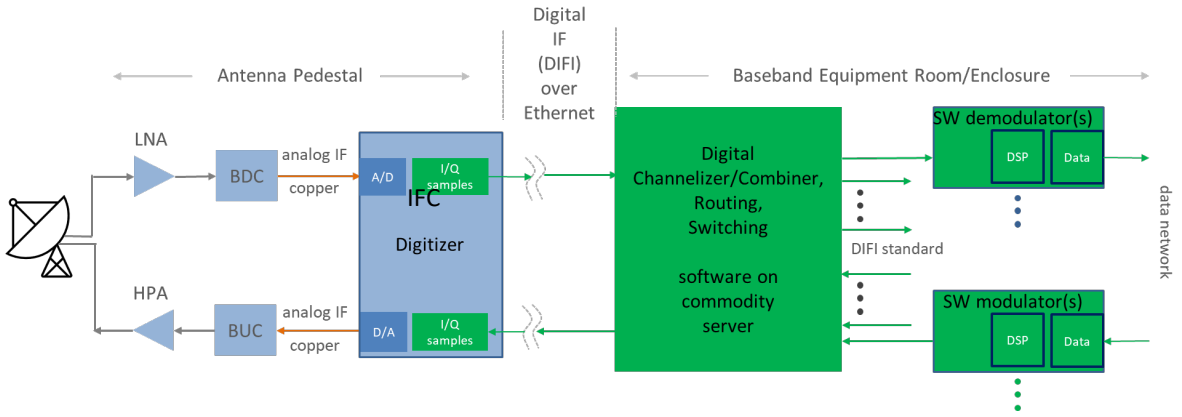


Figure 3. Block diagram of a modern ground station. Radio signals are processed through the antenna (left) where they are amplified and converted to digital form. The digital signals then travel over Ethernet using the DIFI standard to processing equipment in the baseband room (right), where software demodulators extract the information.

Figure 3 shows a detailed implementation of how a modern ground station works with DIFI. At the antenna site, radio signals from satellites are amplified, converted to lower frequencies, and digitized. These digital signals then travel over standard Ethernet networks to processing equipment that can be located anywhere - at the same site, in a different facility, or even in the cloud. This separation of antenna hardware from signal processing enables more efficient use of ground station equipment.

For a thorough testing of DIFI, Keysight provides an end-to-end solution. The VXG-C M9484C vector signal generator creates high-rate analog DVB-S2X test signals. These signals feed into the IFC which converts them to DIFI format. The 89600 VSA software, operating as a DIFI/VITA-49 analyzer, then analyzes the resulting DIFI streams directly from the Ethernet, providing deep insight into signal quality through demodulation and vector analysis. This capability extends beyond satellite standards to support DVB-S2X, custom modulation, 5G, and other formats, enabling thorough validation of DIFI implementations across diverse applications.

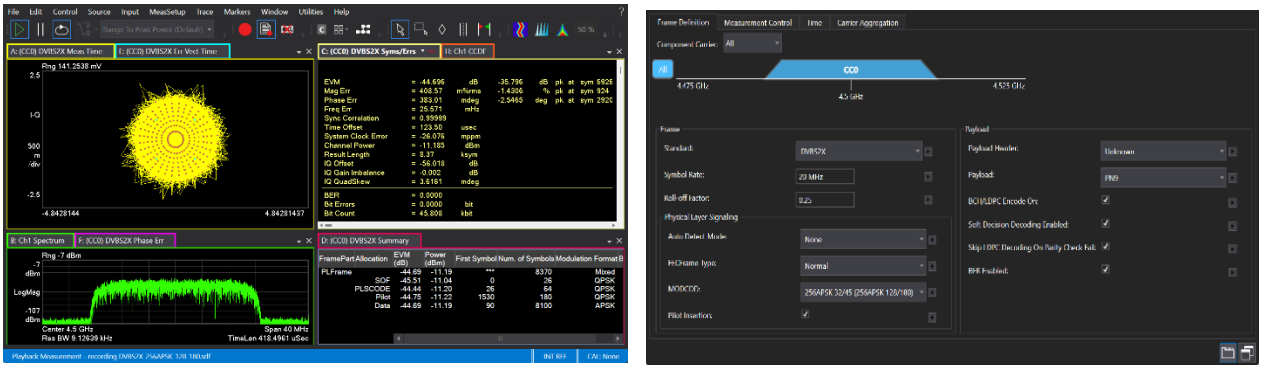


Figure 4: Demodulation of a DVB-S2X 256 APSK signal on our DIFI / VITA-49 analyzer mode at 20 Gbps.

To validate the DIFI protocol in Vector Signal Analyzers (VSA), we need both a way to generate test signals and verify their reception.

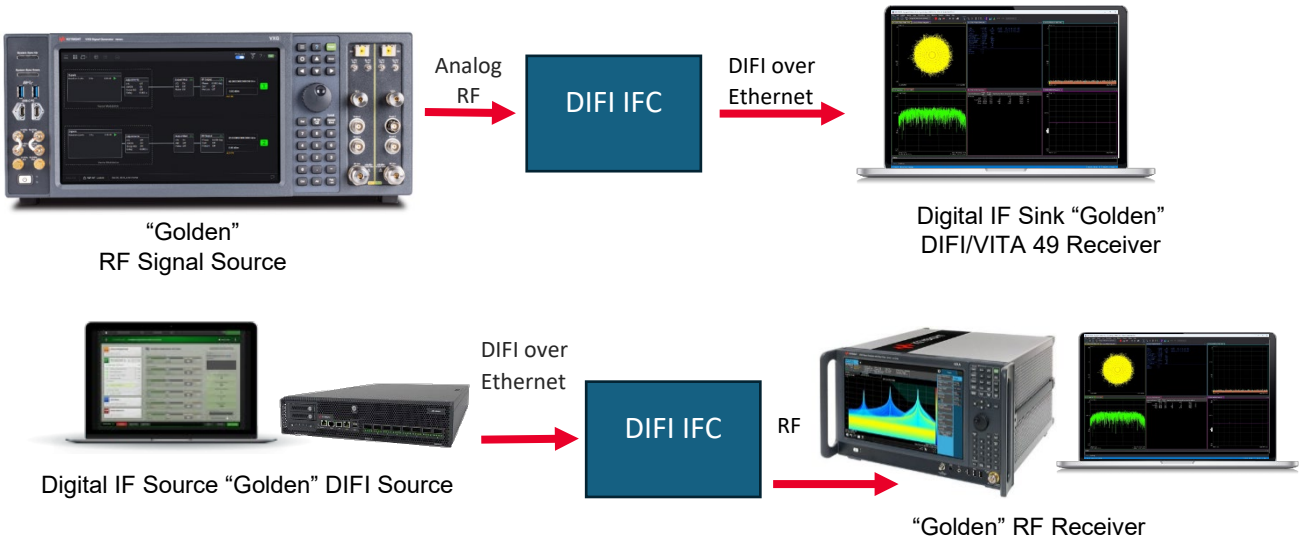


Figure 5: Golden reference signal workflow, connecting analog and digital sources to DIFI-enabled receivers.

The 89600 VSA supports complete testing of DIFI implementations in both conversion directions:

RF to DIFI Testing:

- An RF signal originates from a signal generator or DUT transmitter
- The VSA with a signal analyzer could measure the original RF signal (not shown above)
- VSA analyzes the converted DIFI stream

This verifies signal fidelity through the RF-to-DIFI conversion process

DIFI to RF Testing:

- DIFI packets are generated based on the target IQ modulation technology.
- The VSA can directly analyze the DIFI stream content before RF conversion (not shown above)
- After DIFI-to-RF conversion, VSA with a signal analyzer measures the RF signal

This enables validation of the entire signal chain from DIFI packets through RF output

This bidirectional test capability allows engineers to validate DIFI packet generation and conversion accuracy, verify signal quality at both digital and RF domains, ensure specification compliance throughout the signal chain, and troubleshoot conversion artifacts or signal degradation.

Live VITA-49 Stream Analysis Capabilities

Starting with VSA 2024 U2, the VSA software introduces VITA-49 streaming support through Direct Data Connectivity Option 89601101C. This capability enables users to directly analyze VITA-49 data streams in real-world applications. It is configured through the Instrument Manager (accessible via Utilities --> Hardware menu), providing:

- Integrated stream configuration within the VSA software interface

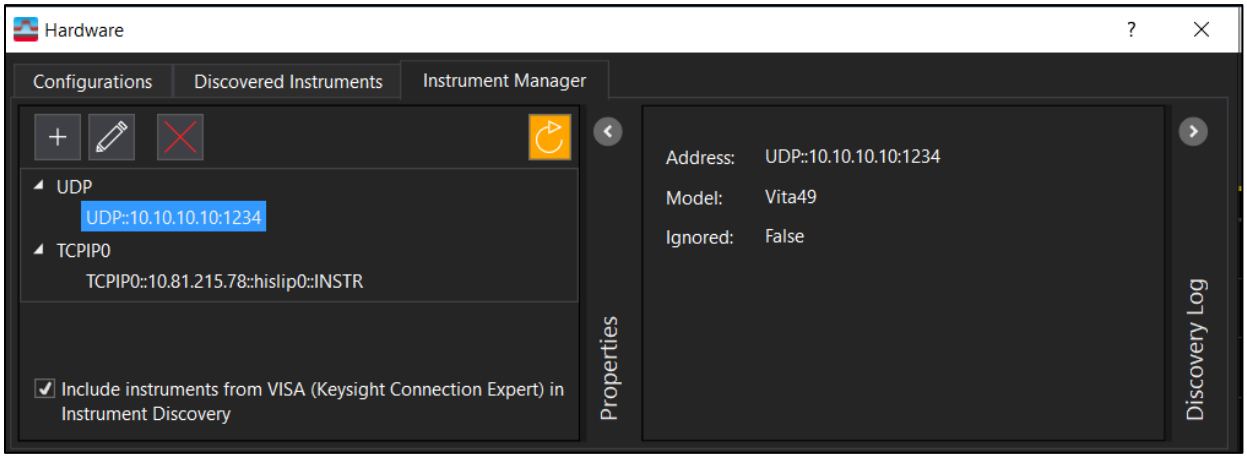
- Direct LAN connectivity without requiring external libraries
- Support for VITA-49 streaming

The VSA software supports two VITA-49 capture modes:

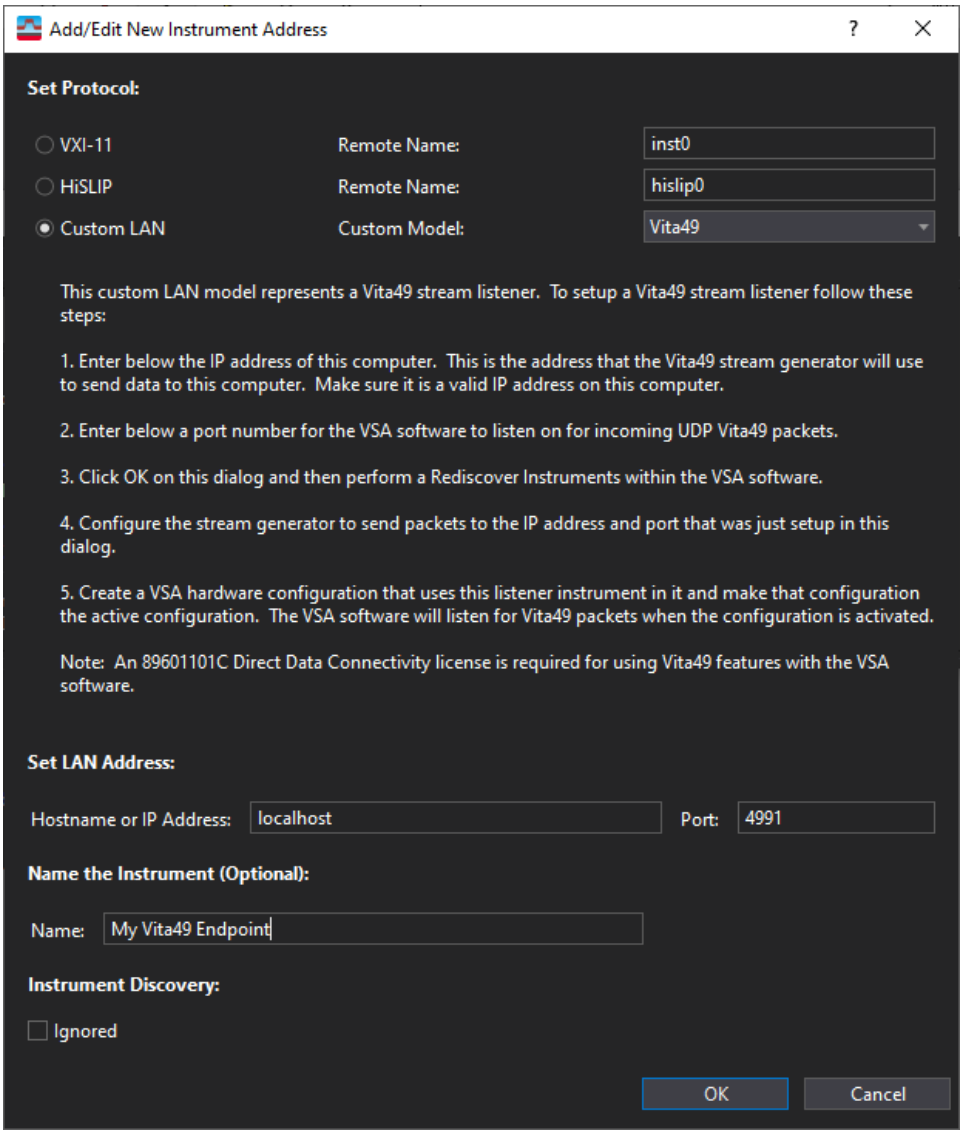
1. Single Capture Mode, which attempts to maintain data continuity within each individual capture, restarting the capture if packet gaps are detected within that capture period.
2. Segmented Mode, which captures data in segments and continues operation even when packets are dropped between segments. While gaps between segments may occur based on system performance, this mode is useful for long-term RF spectrum monitoring applications where continuous data is not required.

These two capture modes allow users to balance between detailed analysis needs and system performance constraints, making VITA-49 stream analysis practical in real-world applications. Once configured, VITA-49 streams can be analyzed using the full suite of VSA measurements, including:

- Custom OFDM (with 89601BHFC license)
- Digital Demodulation (with 89601AYAC license)
- DVB-S2/S2X analysis (with 89601DVBC license)
- 5G NR testing (with 89601BHNC license)
- Power Spectrum analysis (with 89601PSMC license)



(a) The VSA Instrument Manager providing centralized hardware configuration where a UDP endpoint can be defined for a VITA-49 stream.



(b) Detailed VITA-49 stream settings available under the Custom LAN protocol, showing key parameters like IP address and port configuration

Figure 6. VSA Vita 49 Stream Configuration, parts (a) and (b)

The VSA software provides two separate interfaces for managing VITA-49 connectivity:

1. The Instrument Manager (shown in part a) displays the current list of instruments organized by protocol, including any VITA-49 UDP Endpoints that have been defined.
2. Part (b) reveals the specific UDP endpoint settings needed, such as IP address and port number, when defining a VITA-49 instrument within the VSA instrument manager.

The creation and management of hardware configurations is done in the separate Configurations tab, where a configuration is made by picking from the list of discovered instruments. A VSA measurement must be connected to a specific hardware configuration, which may consist of one or more instruments

depending upon what hardware is being connected to. For detailed information about supported VITA-49 packet types, field configurations, and achievable bit rates, please refer to the VSA help documentation.

VSA Integration with FieldFox Handheld Spectrum Analyzer with VITA-49 Streaming

The VSA software seamlessly integrates with Keysight's FieldFox handheld spectrum analyzer for VITA-49 streaming. The FieldFox can capture IQ data, encapsulate it as VITA-49 streams, and transfer it directly to a PC running the VSA software. This enables remote signal analysis of field-captured data.

To configure VITA-49 streaming on the FieldFox, use the following SCPI commands:

```
:INST “SA”                          // Choose the SA mode
:SENS:MEAS:IQAN STR                 // Choose the IQ streaming measurement
IQST:DHOS "<destination_ip>"        // Set target IP address for streaming
IQST:DPOR <port_number>             // Set destination port (default: 4991)
IQST:VITA:MRIP?                     // Query max rate (should be ~1000)
IQST:STAR                           // Start streaming
IQST:STOP                           // Stop streaming when needed
```

Once streaming is configured on the FieldFox, the VSA software can connect to this stream through the Instrument Manager interface by creating an instrument that uses the same IP address and port number specified in the SCPI commands.

The Need for a User Input API

There are situations when the VSA must receive data and provide signal analysis as a part of a larger test system. Perhaps the measurement receiver is a custom hardware solution. Perhaps a chipset vendor needs to set many parameters (even thousands) on their chip, exercise the transmitter and check signal accuracy using the VSA. In such scenarios, there is no hardware extension for the VSA to control the data acquisition. Then what about using recording files? Well, dealing with individual IQ data files can be slow and cumbersome, as different filenames might represent different permutations of input parameters to the chipset. Who wants to manage 100s of IQ data files?

As shown in Figure 7, RF SoC's have now evolved to where IQ data may be extracted directly from an evaluation board with LAN connectivity.

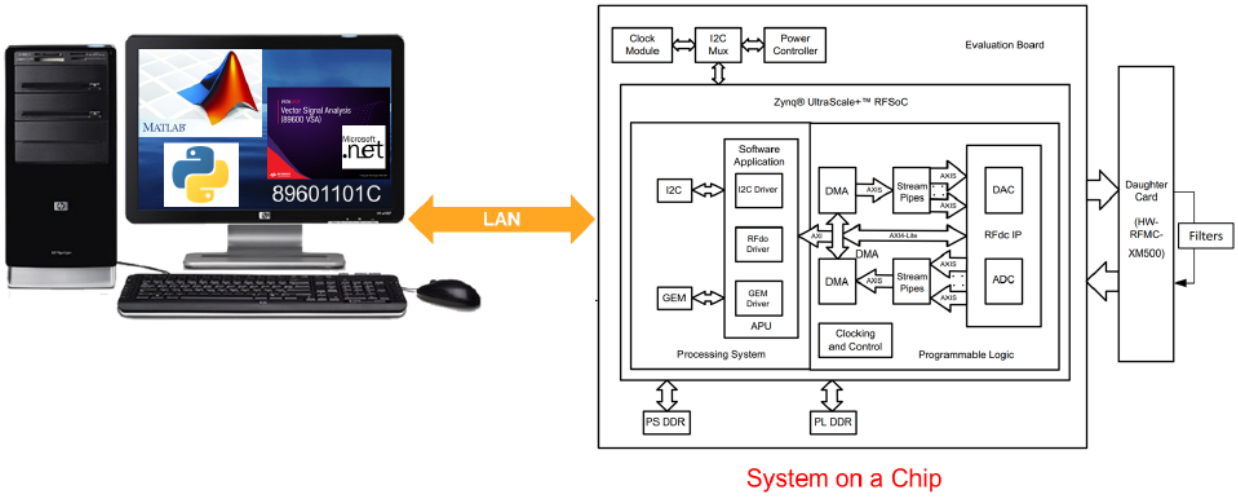


Figure 7. Connectivity diagram for RF SoC Test, which could be well applied to FPGA's, base stations, O-RAN radio units, etc. (Block diagram source: Xilinx ZCU111 User Guide)

You can furthermore benefit from the **User Input API** in the following additional use cases.

- Parametric testing of RF SOCs and transceivers by programmatically controlling chip settings and analyzing IQ data in closed-loop operation
- Spectral monitoring systems with on-demand VSA analysis based on anomaly detection
- Wireless chipset performance validation by routing on-chip ADC data directly to VSA algorithms for analysis
- Deep-dive pulsed signal analysis on terabyte-scale recordings by processing select time segments through the VSA

API Architecture and Implementation Overview

While VITA-49/DIFI streaming provides standardized network protocols for digital IF data, many applications require deeper integration with custom hardware or software. The **User Input API** addresses these needs through direct programmatic control of bidirectional communication between the data provider (your application) and the VSA software. To make best use of this functionality, it's important to understand the key architectural components—connection configuration, data pushing, and connection monitoring—and how they interact.

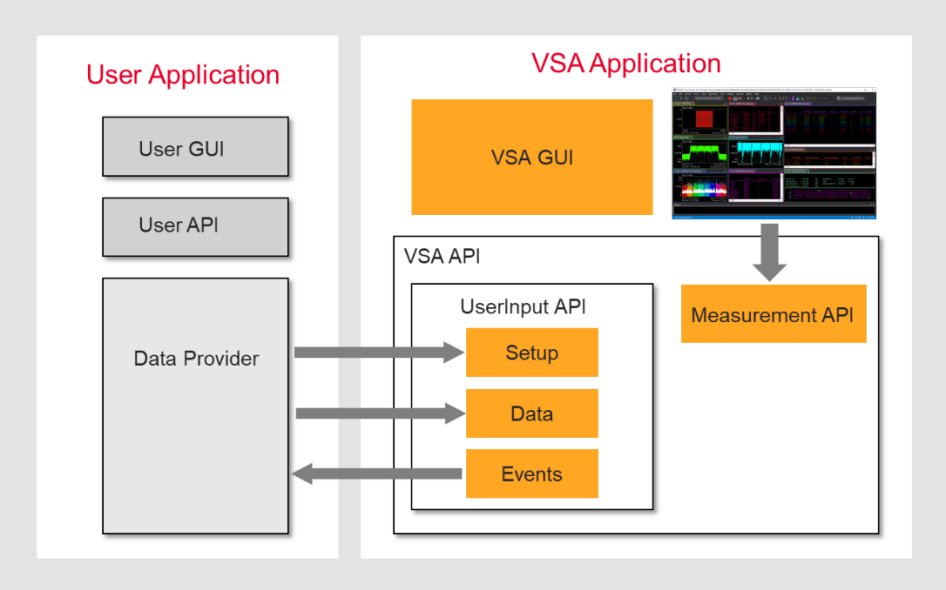


Figure 8. API Data Flow Architecture, showing the bidirectional communication between user application in the VSA software.

Connection Configuration

The data provider configures the connection using the **UserInputSetup** API, which defines fundamental properties of your incoming data stream such as sample rate, center frequency, channel count, and maximum data points per acquisition. These properties tell the VSA software exactly what to expect from your data source.

For optimal measurement results, it's important to configure these properties *before* setting up specific measurements in the VSA, as they determine what measurements are possible. For example, if you plan to make narrow resolution bandwidth measurements, you'll want to ensure your UserInputSetup specifies sufficient data points to support the desired frequency resolution. Once configured, these settings remain in effect for subsequent measurements until explicitly changed by the user.

Data Flow Management

Once set up, the data provider sends measurement data to the VSA via the **UserInputData** API, which supports:

- Up to eight input channels of either complex envelope or baseband data

- Both contiguous (gapless) and non-contiguous data streams, which is especially useful for scenarios like circuit simulation or transient-event capture

Data are submitted in blocks, and multiple blocks can form a single time record. The VSA stores incoming data in a first-in-first-out (FIFO) buffer, separate from the measurement process that consumes this data. This separation means the FIFO buffer may accumulate more data than needed for a single measurement. To maintain precise control over your measurement process, the API provides a method to clear the FIFO buffer after obtaining your measurement results.

To manage this data flow effectively, the API offers **two** approaches:

- **Polling:** Monitor the **UserInput status bit** to check if the VSA is ready for more data or still processing the existing submission.
- **Event-Driven:** Implement an **event handler** that fires an event when the VSA is ready for additional data. This approach can streamline your overall data flow management.

For precise control, you can query the VSA using **UserInputData.RequiredSamples** to see how many data points are needed to satisfy the current measurement operation.

Development Resources

For detailed API documentation and programming guidance, the VSA software provides extensive online resources:

- Complete UserInput API reference documentation at helpfiles.keysight.com
- Well-annotated example programs installed with the VSA software
- Programming examples in multiple languages including C#, Python, and MATLAB

These resources are designed to help you quickly implement direct data connectivity in your application.

Prerequisites

To use this API, make sure you meet the following requirements:

- **.NET Framework 4.8** or **.NET 6.0+** (both supported)
- **.NET IDE Requirements:** Visual Studio 2019 or greater (Visual Studio 2022 for .NET6+)
- **Minimum VSA Licensing:** 8960120xC and 89601101C
- **PC Requirements:** Refer to the VSA help page for specific hardware and OS prerequisites

Examples of User Input API Integration

One implementation of Direct Data Connectivity can be seen in our EDA tool integration. To demonstrate this capability, let's look at a simulation workbench implemented in SystemVue, as shown in Figure 9. This RF simulation includes configurable system components such as noise density and amplifier characteristics. Through direct data connectivity, the 89600 VSA software can analyze the simulated signal in real-time as parameters are adjusted.

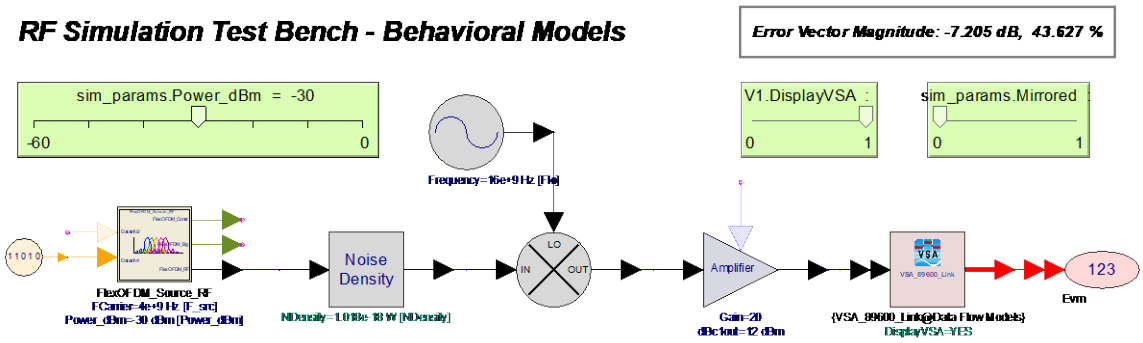


Figure 9. Direct data connectivity to PathWave System-Level Design (SystemVue). Various parameter settings may be studied to see their effect on signal quality.

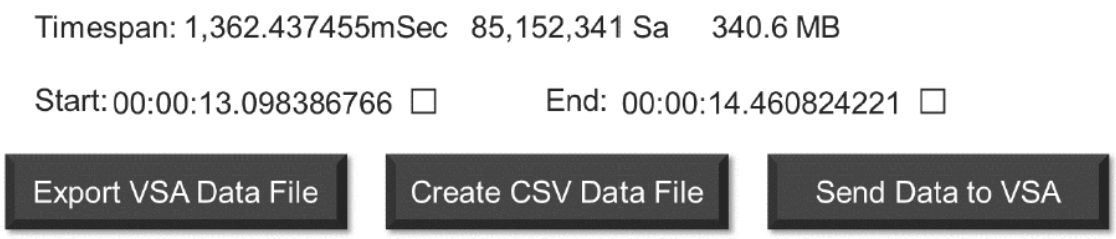
The test bench illustrates several key capabilities:

- Interactive power level adjustment (-60 to 0 dBm range shown)
- Noise density modeling
- Amplifier characteristics
- Real-time VSA measurement updates

This is but a very simple example. A systems engineer can interactively modify simulation parameters while observing their impact on signal quality through the VSA's extensive measurement capabilities. This enables rapid evaluation of design choices and system tolerances without the need for physical hardware.

As a second example, User Input API connectivity enables analysis of specific time segments from a RAID array storing radar pulse data. In this solution:

1. A high-speed digitizer captures down-converted RF signals, recording pulses in IQ time domain
2. The captured data is stored in a RAID array
3. Analysis software catalogs the dataset with pulse descriptor words
4. Selected time segments can be sent directly to the VSA software for detailed analysis leveraging a custom integration that facilitates seamless data transfer.



Conclusion

The 89600 VSA's Direct Data Connectivity capabilities provide two powerful approaches for integrating Keysight's advanced measurement science into your test solutions:

VITA-49/DIFI Streaming

- Standardized digital IF data transfer over networks
- Seamless integration with modern ground station equipment
- Support for emerging satellite communications standards
- Flexible deployment options from local analysis to cloud processing
- Complete compatibility with industry-standard DIFI conversion hardware

User Input API

- Direct integration with custom hardware and software platforms
- Programmatic control over measurement parameters
- Support for up to 8 channels of complex or baseband data
- Real-time analysis capabilities
- Flexible data handling for both continuous and triggered acquisitions

These complementary technologies enable you to:

- Integrate VSA analysis capabilities directly into your test systems
- Analyze signals anywhere in your signal processing chain
- Automate complex measurement scenarios
- Validate designs from simulation through production testing

As covered at the start, VITA-49/DIFI streaming is optimal for standardized digital IF applications, while the User Input API serves custom integration needs. Your choice should align with your system architecture and integration requirements.

Getting Started

- For VITA-49/DIFI streaming, begin with the Instrument Manager configuration tool
- For API development, explore the example programs in the VSA help system
- Contact Keysight support for guidance on your specific application needs

As digital transformation continues to reshape RF testing, the VSA's flexible connectivity options position it as a versatile tool for both current and future test needs. We invite you to explore these capabilities and share your experiences as we continue enhancing the platform to meet evolving industry requirements.