
NATIONAL
INSTRUMENTS™

Agenda

Time	Topic	Presenter	Demo
8:30	**Welcome, Introductions and NI Semiconductor Update**	Peter	No
8:45	**Using a Modular Platform for Mixed-Signal Semiconductor Characterization** • Introduction to the NI PXI Platform • InstrumentStudio Software for Interactive PXI Measurements • ATE-Class PXI Digital Instruments • Live demonstration of DUT characterization using modular instruments	Tarek	Yes
10:15	**Coffee Break/Networking**		
10:30	**Introduction to NI's offering for RFIC Test Applications including 5G NR, DPD, ET and mmWave** • Addressing the FEM Test Challenges to LTE-Advanced Pro and 5G NR • Characterizing Multiband ET/DPD Modern Front End Modules • Challenges and Solutions for mmWave OTA Test	Udo	Yes
12:10	**NI-Ampleon Collaboration Project: Wideband Multi-port Characterization for Active Antenna Systems** • Motivation for collaboration: the Ampleon Perspective • Sub 6 GHz and mmwave Characterization Innovation: the NI Perspective	Sergio & Marc	No
12:30	Summary and wrap-up		

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Who are we?

- Peter Engelbracht: Account Manager, Semiconductor Test
- Udo Dehne: Business Development Manager, Semiconductor
- Marc Vanden Bossche: Chief RF Engineer, Network Analysis
- Tarek Safwan: Sr. Field Marketing Engineer, Semiconductor Test

Who are you?

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Purpose of this session

- Create a better understanding of NI's platforms used for Semiconductor Test
- Introduce our PXI Platform which is the core of all our solutions
- Introduce how our tools fit within your typical workflow and how you can leverage them
- Help you gain ideas on how to tackle the challenges you might face
- Align and identify future engagement opportunities
- Align and identify future event topics

Semiconductor Introduction and Update on Investment Directions

Peter Engelbracht

Account Manager - Semiconductor Industry

National Instruments

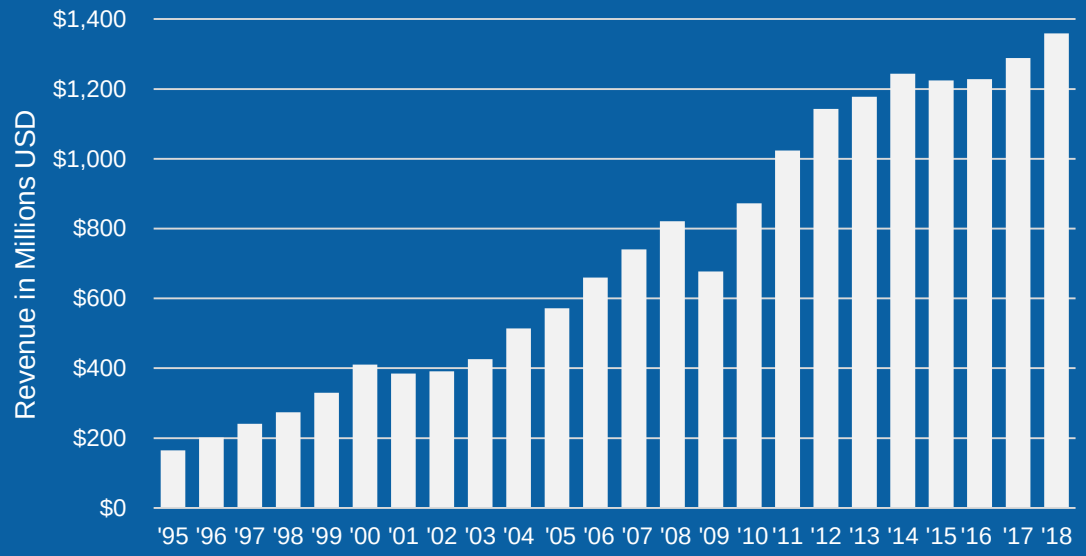
OPERATIONS IN
50+ COUNTRIES

$1.36
BILLION
IN 2018

35,000+
CUSTOMERS WORLDWIDE

16%
INVESTMENT IN R&D

Long-Term Track Record of Growth



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NI’s Core Strategic Vision

To Be the Leader in Software-Defined Automated Test and Automated Measurement Systems

Deliver value that gives our **customers** a competitive advantage.

Provide a differentiated platform for **software-defined** Automated Test and Automated Measurement systems.

Focus on customer segments that benefit from our platform’s **disruptive capabilities**.

Add **system-level** offerings to more fully meet customers’ enterprise wide challenges.

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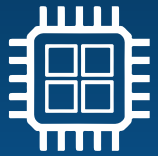

SEMICONDUCTOR

TRANSPORTATION

AEROSPACE/DEFENSE/
GOVERNMENT

PORTFOLIO

NI PLATFORM

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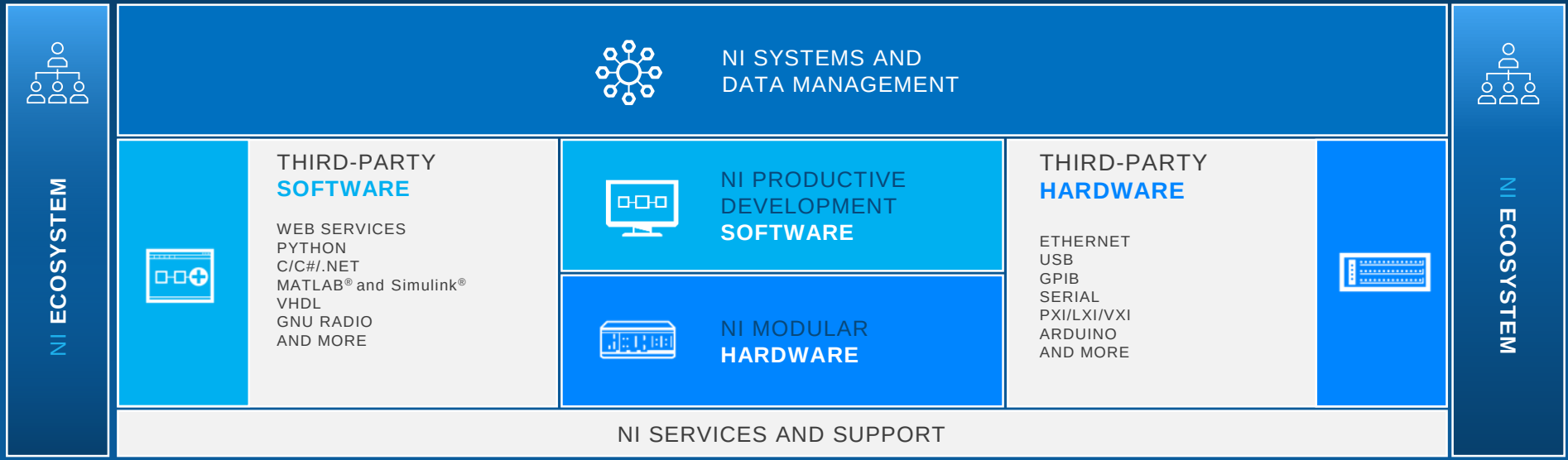
NI PLATFORM



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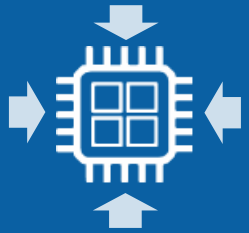
Semiconductor Realities Driving Test & Measurement



Smaller Footprint & Higher Complexity

Innovations in Sensing

Faster Design Cycles

Higher Analog Content & New Test Methodologies

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Semiconductor | Our Focus

FOCUSED APPLICATIONS

- RF/wireless (including 5G)
- Optoelectronics
- Mixed-signal

PLATFORM ADVANTAGES

- Common platform from lab to production
- Automation and standardization for lab test
- High measurement speed to lower cost of test
- Small footprint

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V&V Labs

- Designed for automation
- Optimized for test coverage
- Short test cycles

Characterization to Production

Same Platform

Reduce time to market and operational costs through

- Easier correlation
- Test IP reuse
- Proficiency on shared tools
- Common development and debug environments

Production Floor

- Designed for test cell
- Optimized for throughput
- Cost-effective

National Instruments is **uniquely positioned in the market** to serve the needs of semiconductor customers across lab and production environments with a common software and hardware platform.

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SEMICONDUCTOR TEST

NXP

5G Power Amplifier (PA) Testing with STS

“A few of our other business units have already adopted the NI Semiconductor Test System (STS) and it was some of their recommendations that first convinced our RF business unit to try it out for this massive MIMO application. I’m very pleased by the progress of course – in manufacturing, throughput is everything. Higher throughput means more devices shipped to our customers, faster, which fundamentally means business results.”

—David Reed, Executive Vice President of Global Operations, NXP

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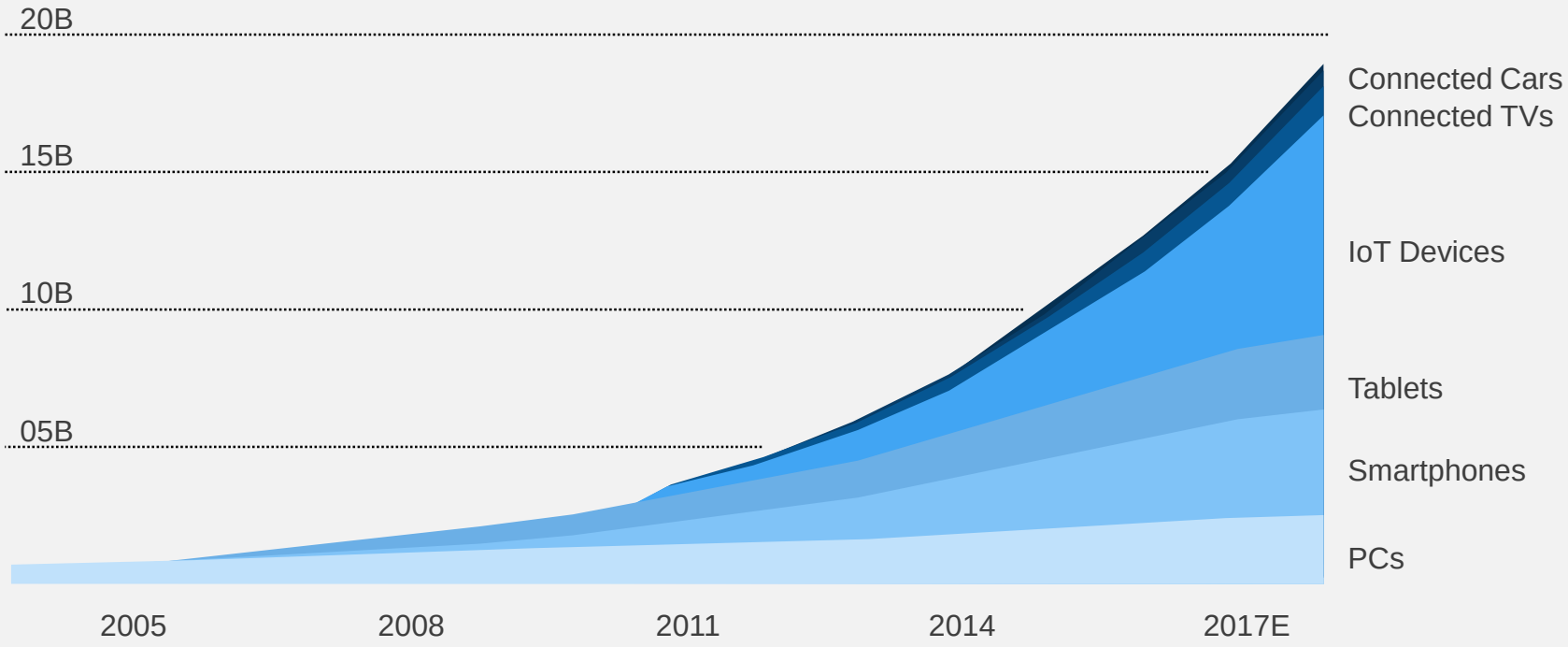
Introduction to the PXI Platform

Smarter Test From Characterization to Production

Tarek Safwan
Field Marketing, Semiconductor Test
National Instruments

The Big Bang of Smart Devices



Source: BI Intelligence Estimates

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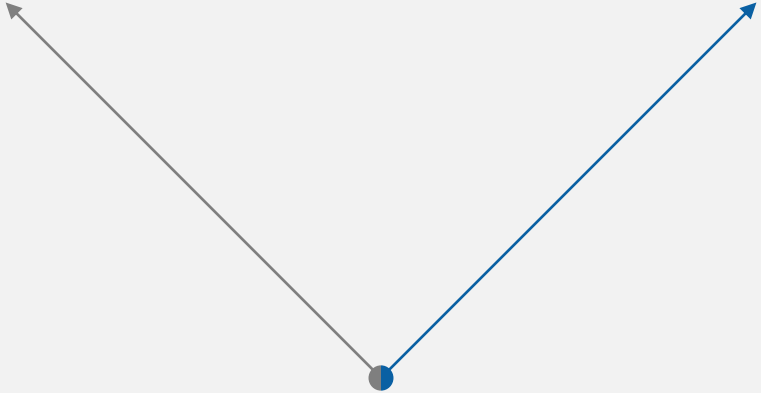
Vendor Strategies for Test and Measurement

CLOSED

- “Vendor knows best”
- Fixed functionality
- Closed ecosystem
- Customer pays



PLATFORM

- “Customer knows best”
- Customizable solution
- Open, vibrant ecosystem
- Customer designs

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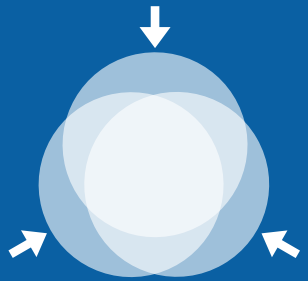
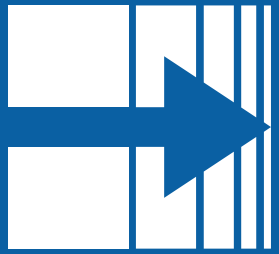
Unique Attributes of Smart Devices: Common Test Needs

CONVERGENCE



LOWER PRICE

RAPID CHANGE



- More functionality
- High reliability
- Lowest cost
- Short time to market

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Boxes Are Throttling Innovation

- Fixed Functionality
- Outdated Processors
- Communication Latency
- Little Data Streaming
- Closed Software

The old, closed approach to test just isn’t smart;
it can’t keep pace with innovation.

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Smarter Test System

- Open, Flexible Software
- Modular Hardware
- Vibrant Ecosystem
- “Customer Knows Best”

A smart test system is more than a fixed-functionality instrument; it is built for automation and customization.

PXI

Systems Alliance

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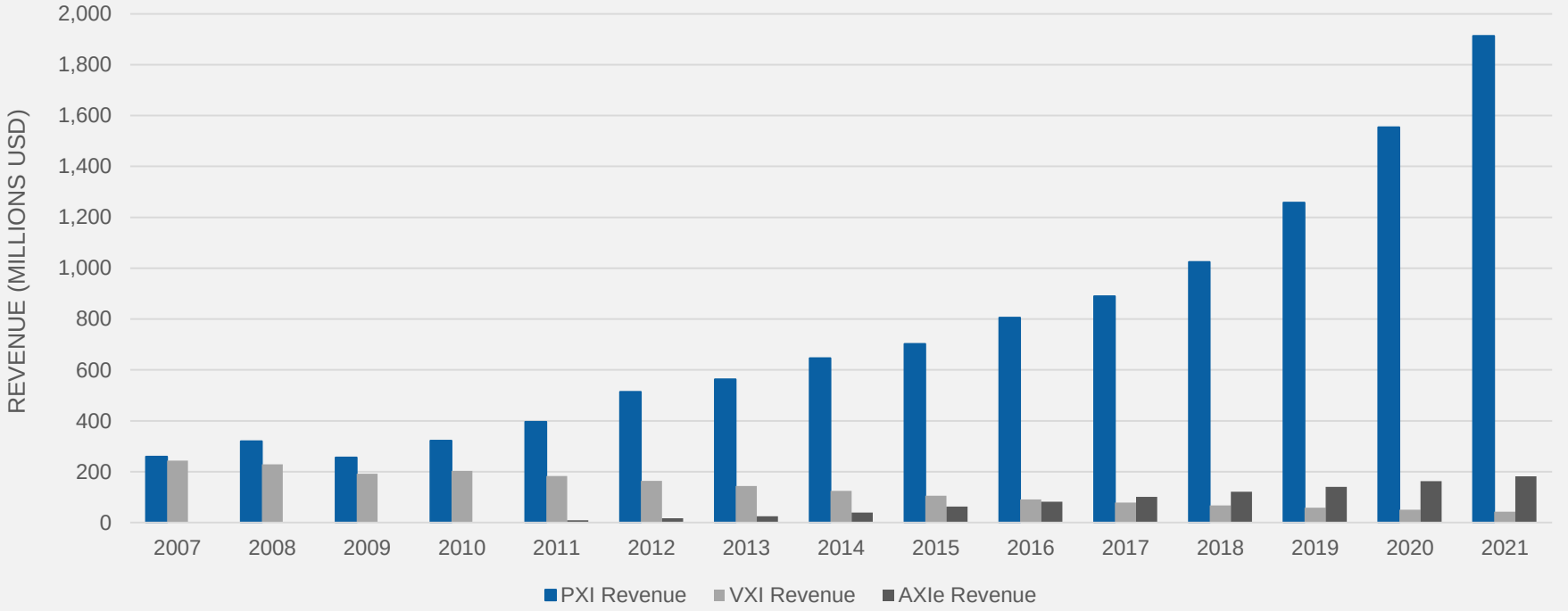
Characteristics of the Stable PXI Platform

- Founded in 1997
- 60+ Vendors
- 2000+ Modules
- Latest Technology
- Growing Market Share

Continued Innovation in PXI Platform



Source: Frost & Sullivan

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Anatomy of a PXI Test and Measurement System

Software

Test Management and Code Development
Code sequencing, database reporting, user management, operator interface, parallel execution, signal processing; LabVIEW, C/C++, .NET, Python

Timing and Synchronization

PXI Chassis
PCI Express Gen 3 throughput up to 24 GB/s, subnanosecond latency, P2P streaming, integrated triggering

Computer

PXI Embedded Controller
Windows and real-time OS options, Intel Xeon processing, peripheral ports, display output, integrated hard drive

Instrumentation

PXI Modules
DC to mmWave, oscilloscope, programmable power supply, switch/MUX, DMM, VSA, VSG, VST, AWG, SMU, DAQ

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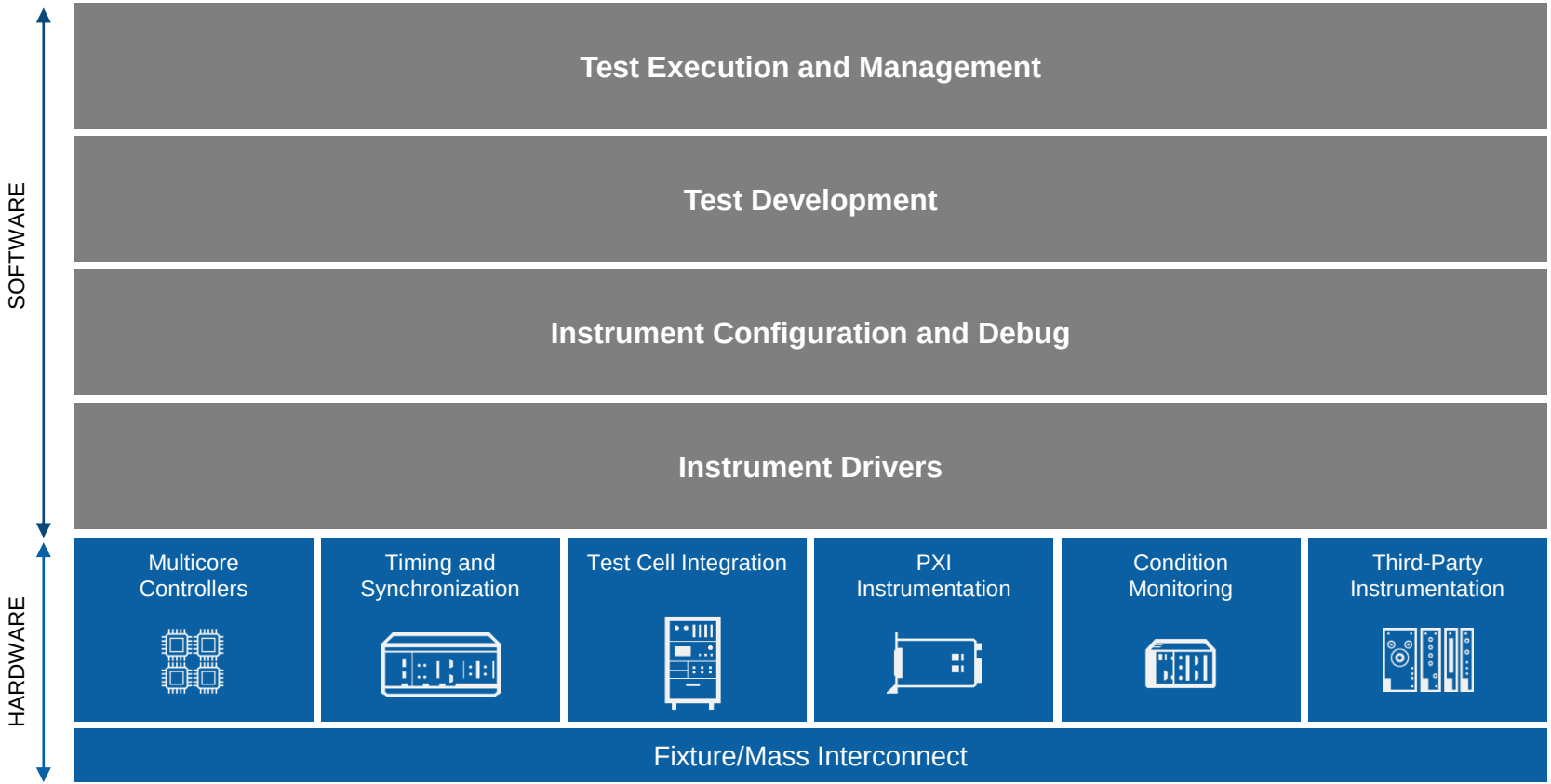
Architecture of an Automated Test System



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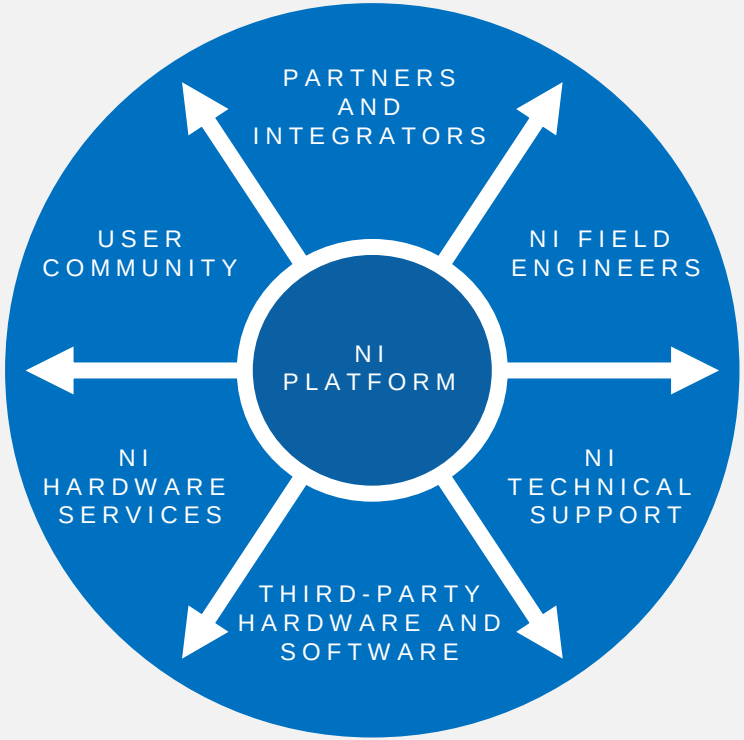
An Ecosystem Built on the NI Platform

300k+
Users

30+
Service Centers

350+
Software Toolkits



1000+
Partners

700+
Field Engineers

700+
Support Engineers

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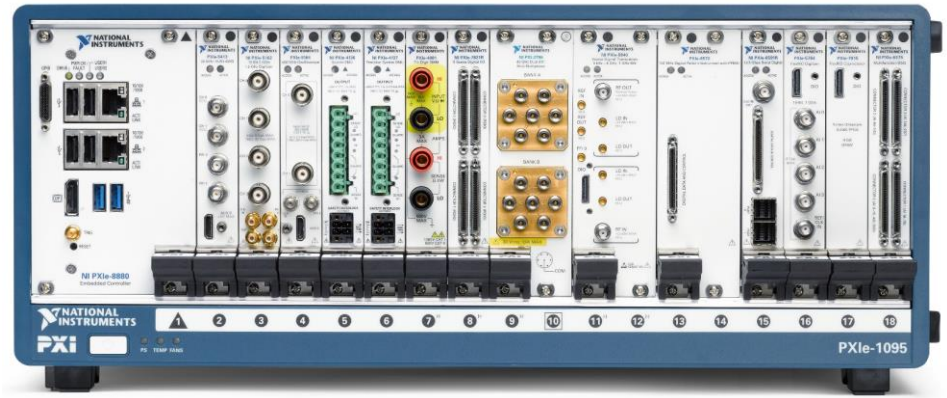
PXI Integrates All Instrumentation Protocols

Broad Modular Instrumentation Portfolio

DAQ and Control	Instrumentation	Interfaces
Multifunction I/O	Oscilloscopes	GPIB, USB, LAN
Counter/Timer/Clock	High-Speed Digital I/O	RS232/RS485
Digital I/O	DMM and SMU	CAN, LIN, DeviceNet
Analog Input/Output	Signal Generators	SCSI, Ethernet
Vision and Motion	Switching	VXI/VME
FPGA/Reconfigurable I/O	RF Analyzers and Generators	Boundary Scan/JTAG



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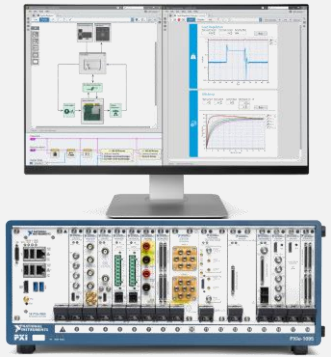

Advantages of PXI Instrumentation

- High Measurement Quality
- Low Latency and High Throughput
- Software-Defined Functionality
- Integrated Timing and Sync
- High-Performance Processing
- Reduced Size, Weight, and Power
- Complete Instrumentation Portfolio

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Industry-Leading Test and Measurement Platform

PXIe-5162
4 ch, 1.5 GHz,
10-bit digitizer

PXI-4081
7½-digit, 1 kV
precision DMM

PXIe-5668
26.5 GHz VSA with
765 MHz bandwidth

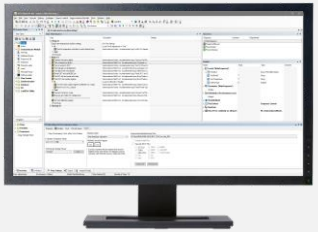
PXIe-4135
precision system SMU
10 fA sensitivity

PXIe-5840
6 GHz VST with
1 GHz bandwidth

PXIe-1095
PXI chassis
24 GB/s throughput

PXIe-8880
PXI Express controller
8-core Intel Xeon

LabVIEW
system design
software



TestStand
test management
software

PXIe-2543
6 GHz, 8 ch, solid-state
multiplexer

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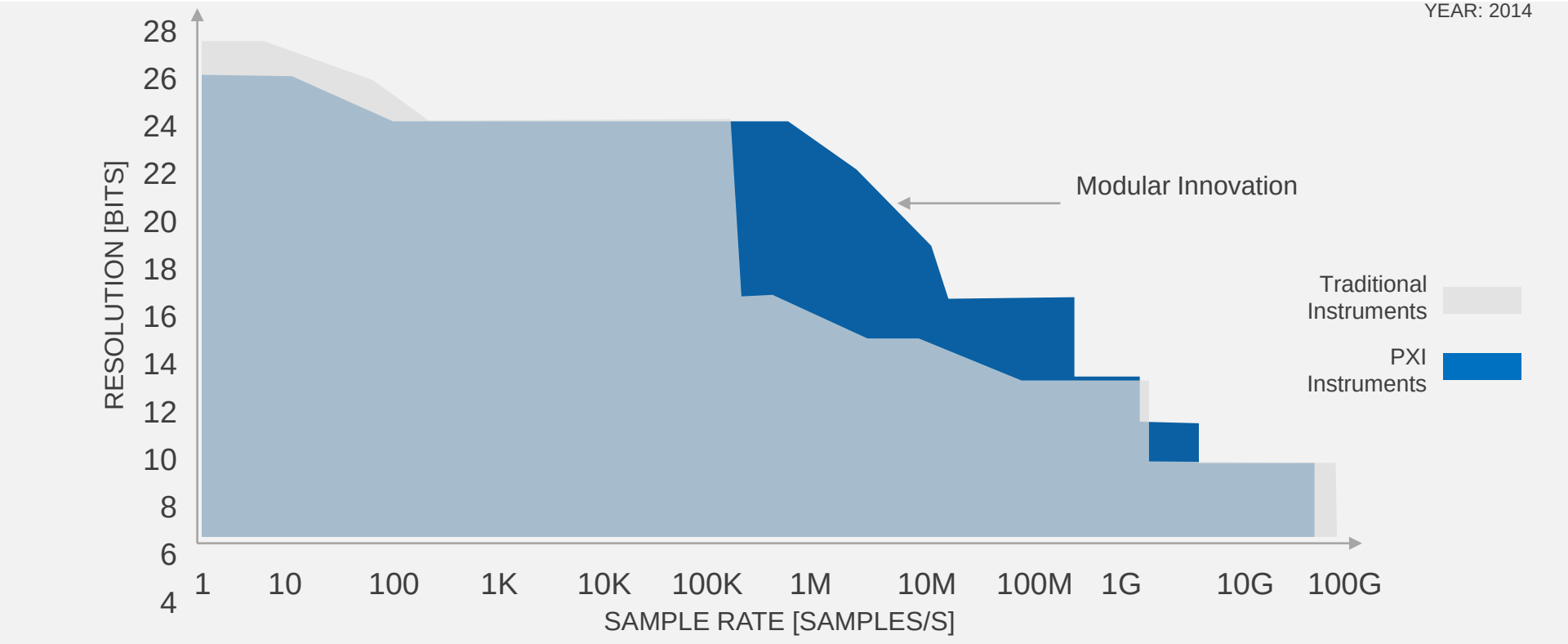
Trusted Measurement Quality



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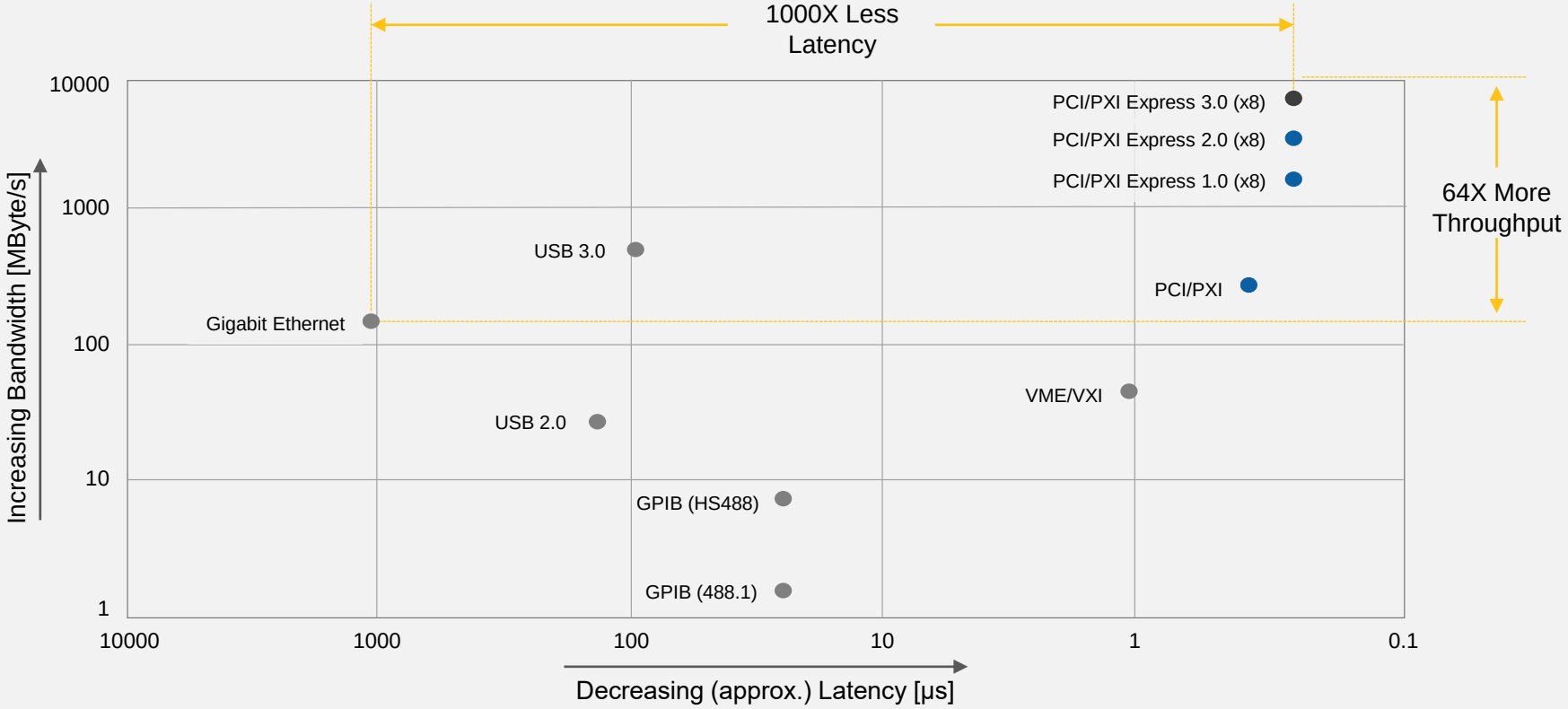
High Throughput and Low Latency With PXI



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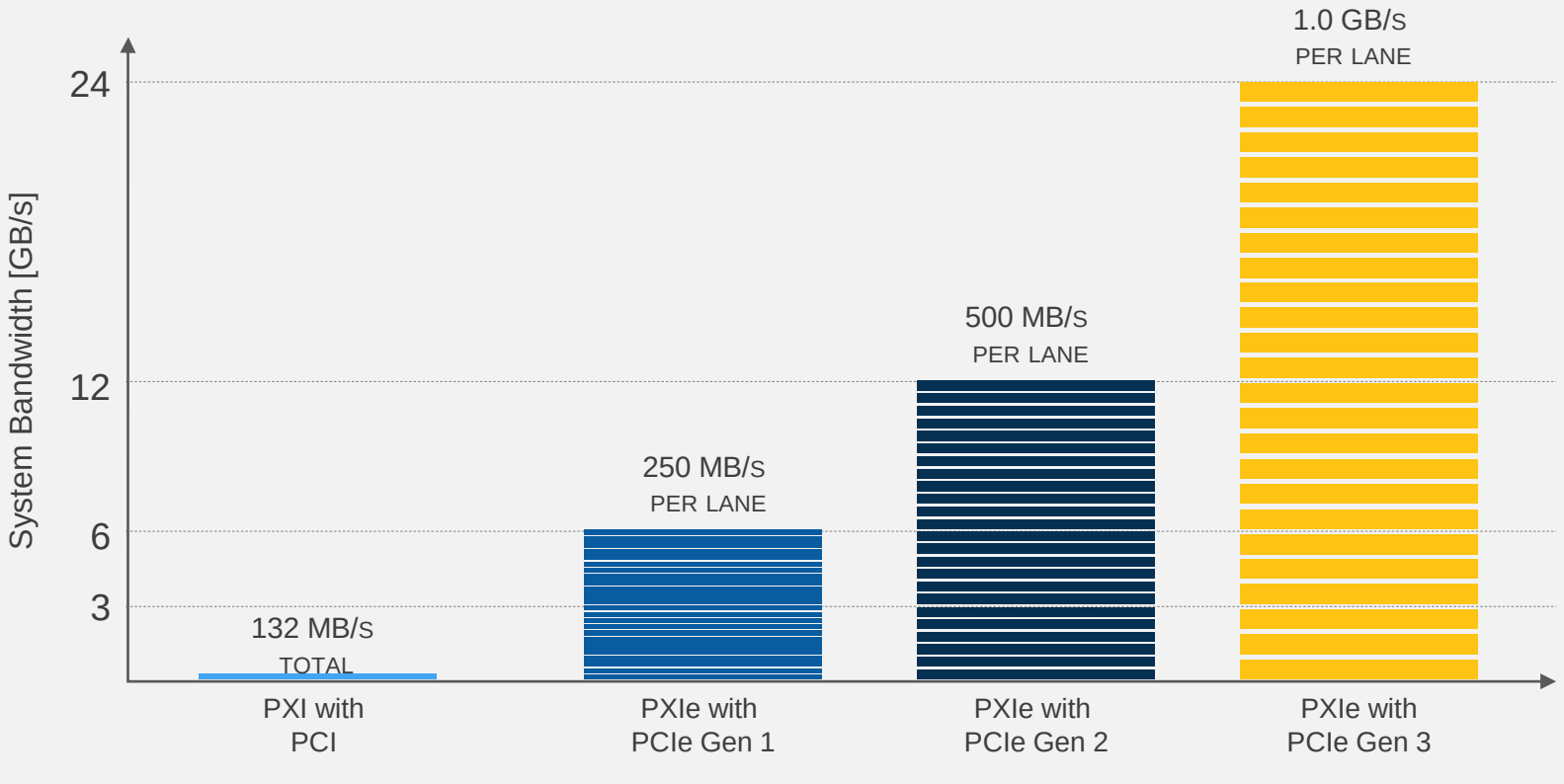
Continually Increasing System Bandwidth



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PXIe-1095

Industry's first chassis with 82 W of power and cooling in every slot

- 18-slot, 24 GB/s system bandwidth
  - 5 PXI Express hybrid slots, 12 PXI Express only (including one system timing slot)
- 2 hot-swappable, easily serviceable, 1,200 W power supplies
- 2 distinct, software-selectable cooling profiles
- Significant reduction in fan noise in 38 W profile
- Optional timing and synchronization upgrade
  - Built-in OCXO, external clock, and trigger routing

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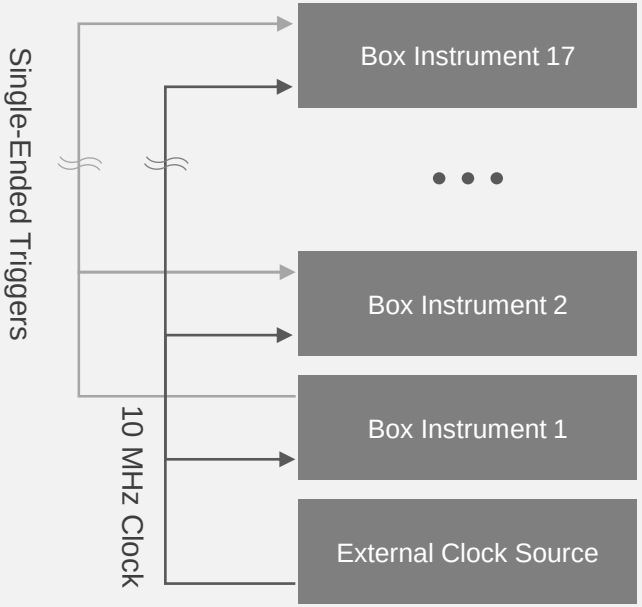
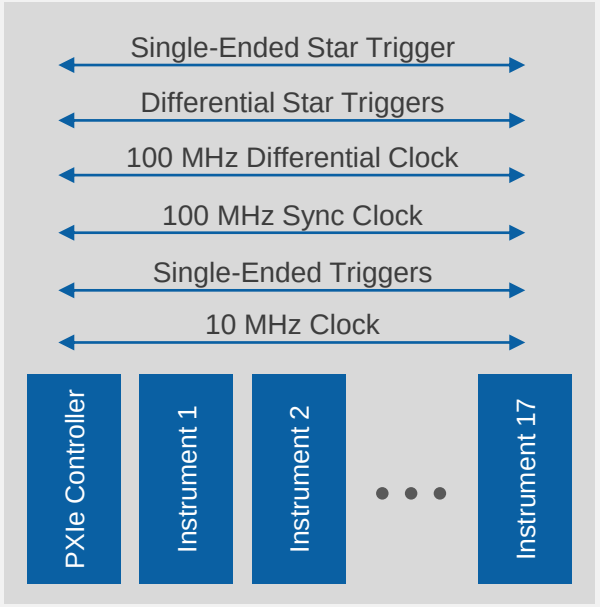
Advanced Timing and Synchronization With PXI



Box Instruments



PXI

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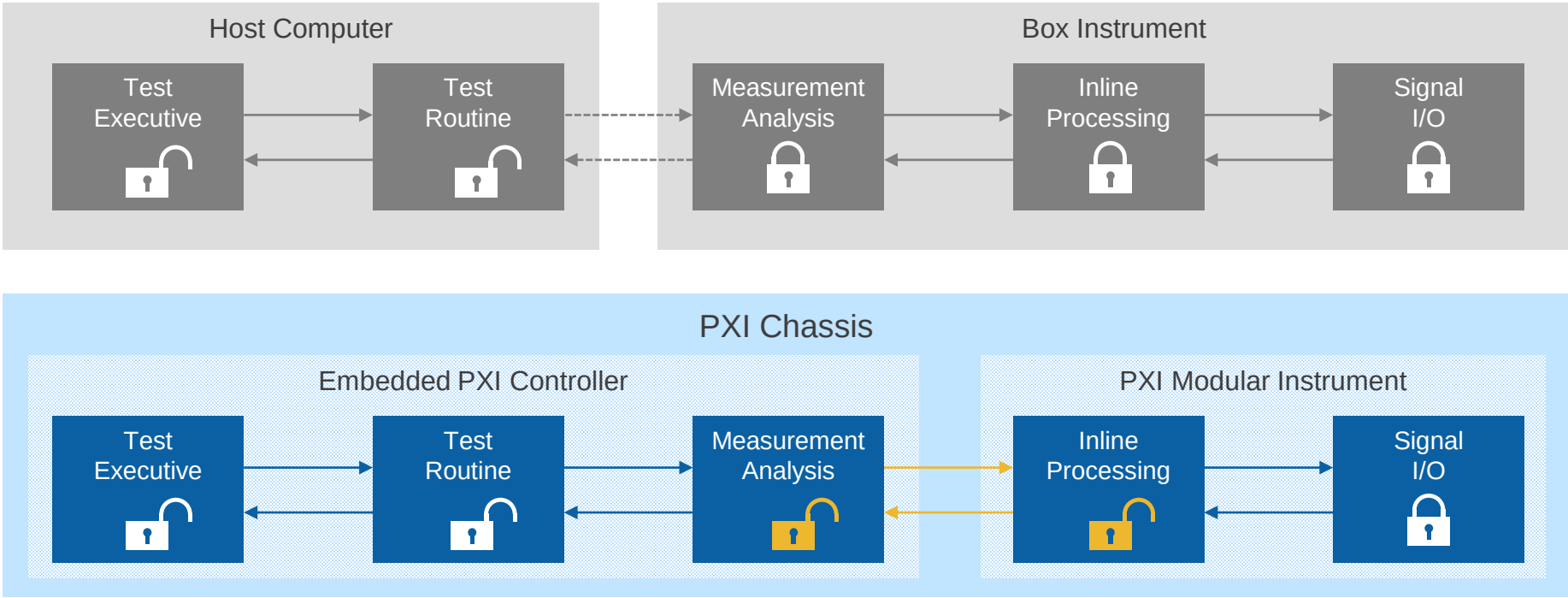
Highest Flexibility With Software-Defined Instruments



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Software-Designed Instruments

PXIe-5668
26.5 GHz, >765 MHz BW
RTBW vector signal analyzer

PXIe-5840
6 GHz VST with
1 GHz bandwidth

PXIe-5624
2 GS/s, 12-bit
IF digitizer

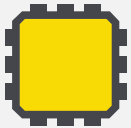
PXIe-6591/92
12.5 Gbps, 4–8 ch.
high-speed serial

PXIe-5170/71/72
250 MS/s, 14-bit, 4–8 ch.
oscilloscope

PXIe-7976
3.5 GB/s streaming
K410T K7 FlexRIO

"Fully functional instrument out of the box"

Customize functionality with



LabVIEW FPGA

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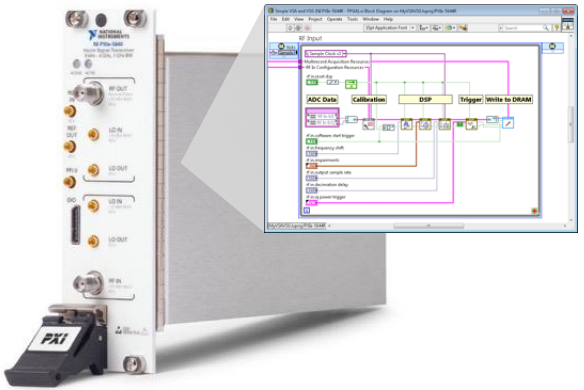
Second-Generation Vector Signal Transceiver

FEATURES AT A GLANCE

- User-programmable FPGA with LabVIEW
- 1 GHz of instantaneous bandwidth for advanced digital predistortion test and wideband signals
- Excellent accuracy enables measurement of 802.11ax error vector magnitude performance of -50 dB
- FPGA enables measurement speeds up to 10X faster than traditional instrumentation
- Small size and tight synchronization allow for up to 8x8 MIMO configuration in a single 18-slot chassis

APPLICATION AREAS

- Wireless test
- Semiconductor test
- Automotive radar



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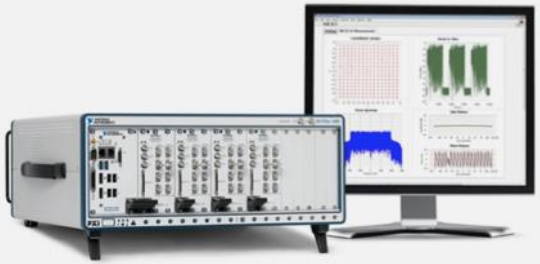
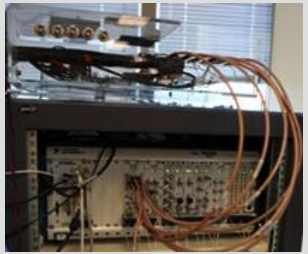
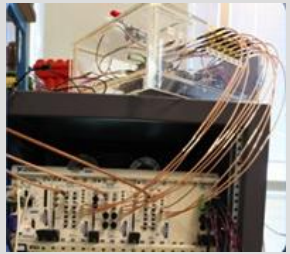
Qualcomm Reduces Test Times



Qualcomm ATHEROS

“We improved test speeds by more than 200X compared to traditional rack-and-stack instruments while significantly improving test coverage.”

	Previous	PXI Phase 1	PXI Phase 2
			
Technology	Traditional Box Instrumentation	NI PXI RF Instrumentation	NI Vector Signal Transceiver
Year	Early 2000s	2007	2012
Test Time Reduction	1X	10X	200X
WLAN Protocols Tested	802.11a 802.11b 802.11g	802.11a 802.11b 802.11g 802.11n	802.11a 802.11b 802.11g 802.11n 802.11ac

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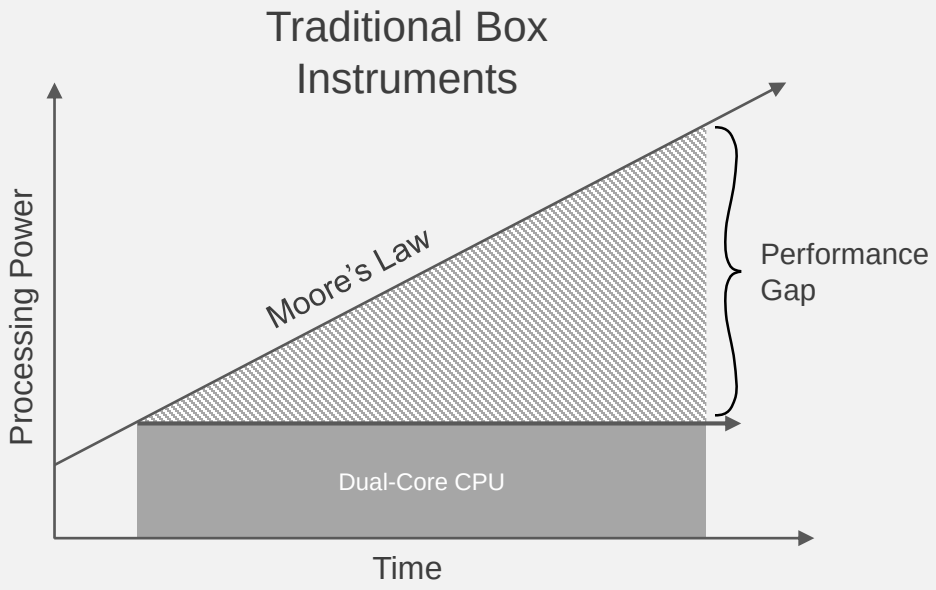
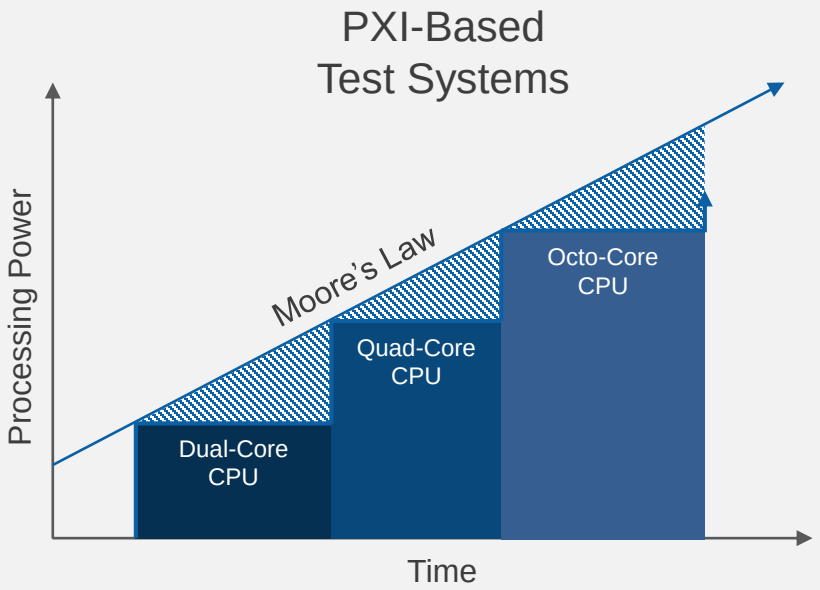
Reducing Test Times With Latest CPUs and FPGAs





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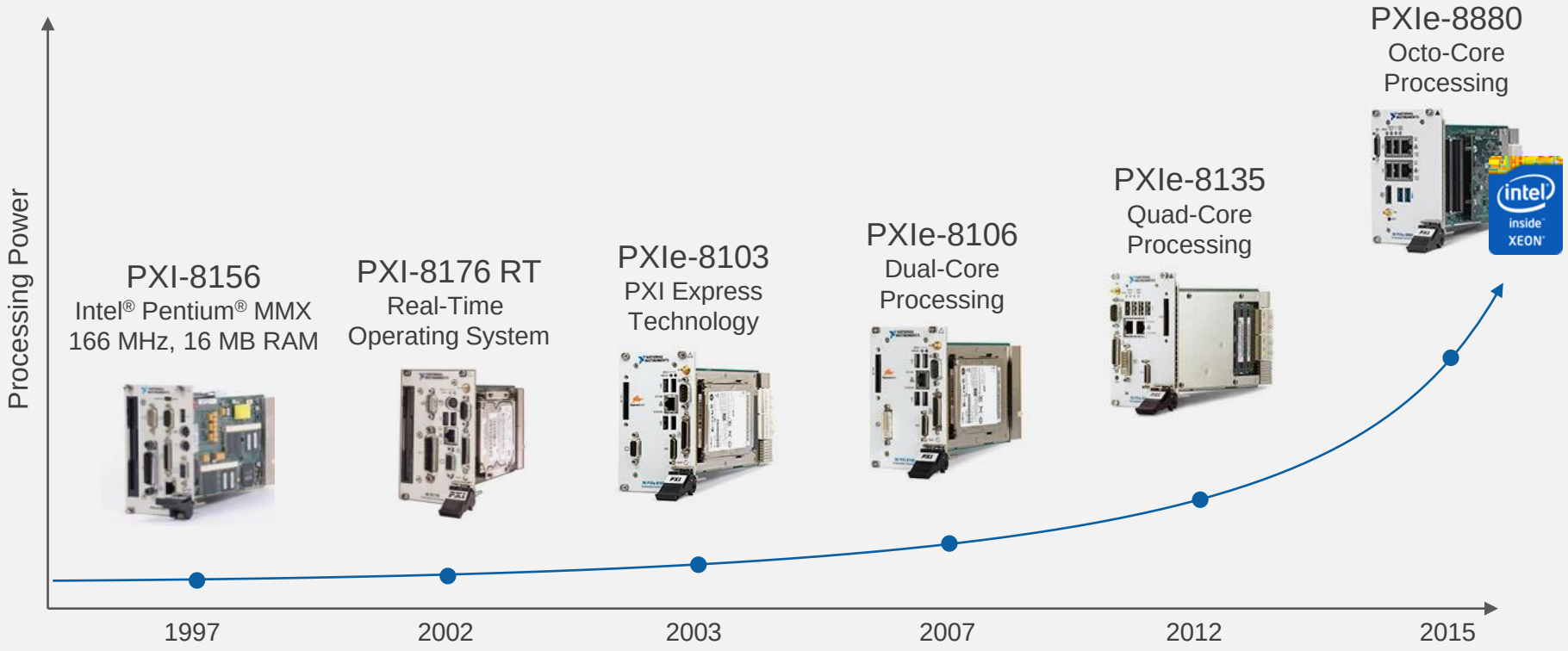
Industry-Leading NI PXI Controller Portfolio



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PXIe-8880 Embedded Controller

Embedded controller with Intel Xeon technology

- Intel® Xeon® E5-2618L v3 processor
- 2.3 GHz (base) and 3.4 GHz (Turbo Boost)
- 8 physical and 16 logical CPU cores
- 8 GB DDR4 1866 MHz RAM (standard); 24 GB max
- Up to 24 GB/s system bandwidth (each direction)
- 240 GB, 1.8 in. SSD hard drive
- Windows 7 64-bit or LabVIEW Real-Time OS
- PXI Express with PCI Express Gen 3 technology

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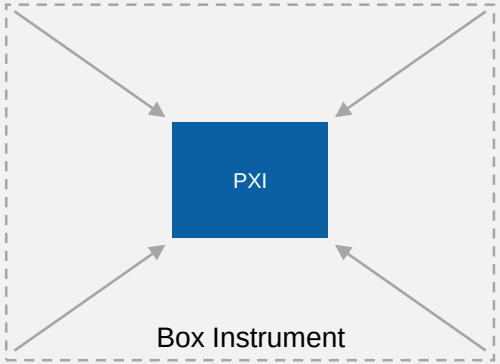
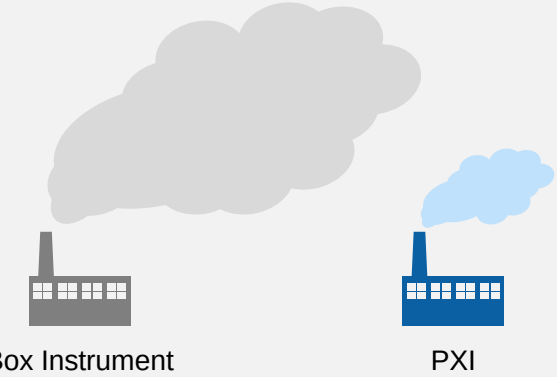
Reduced Overhead With PXI Form Factor



Size/Footprint

Weight/Portability



Power Consumption

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Analog Devices Reduces MEMS Test Cost

ANALOG DEVICES

“Using PXI and LabVIEW, we were able to test our MEMS devices at a fraction of the cost, weight, power consumption, and footprint of our previous ATE system.”

	Previous ATE	PXI System	Reduction
Cost	$450k	$40k	11X
Footprint	277 ft^3	1.75 ft^3	158X
Weight	4000 lb	60 lb	66X
Energy	10 kW	0.6 kW	16X

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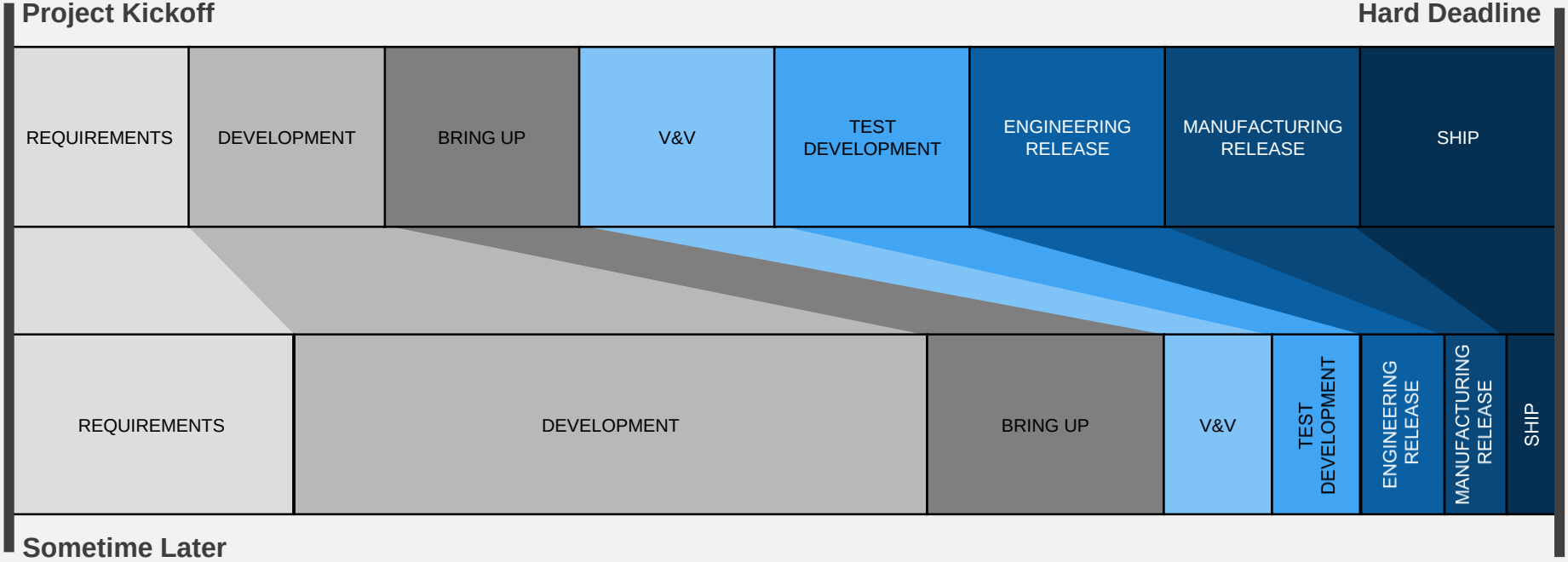
Using a Modular Platform for Mixed-Signal Semiconductor Characterization

Smarter Test From
Characterization to Production

Tarek Safwan
Field Marketing, Semiconductor Test
National Instruments

Does this ever happen to your projects?



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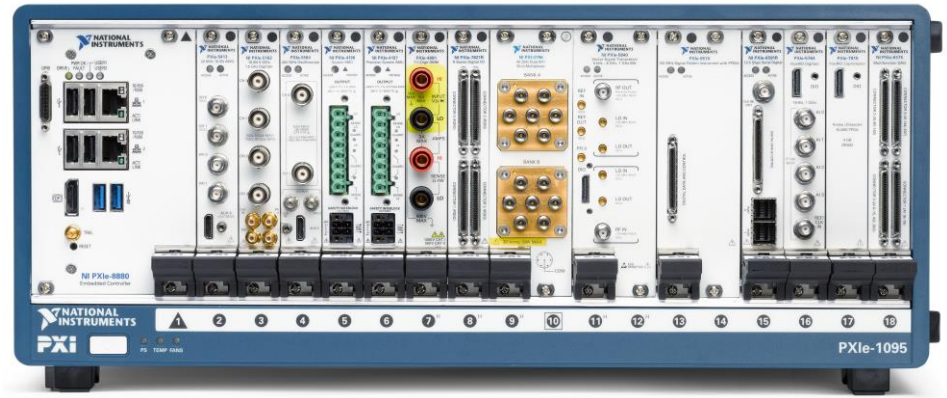
Broad Modular Instrumentation Portfolio

DAQ and Control	Instrumentation	Interfaces
Multifunction I/O	Oscilloscopes	GPIB, USB, LAN
Counter/Timer/Clock	High-Speed Digital I/O	RS232/RS485
Digital I/O	DMM and SMU	CAN, LIN, DeviceNet
Analog Input/Output	Signal Generators	SCSI, Ethernet
Vision and Motion	Switching	VXI-VME
FPGA/Reconfigurable I/O	RF Analyzers and Generators	Boundary Scan/JTAG



NATIONAL INSTRUMENTS

PXI Instrumentation for Mixed-Signal IC Test

NI Source Measure Units (SMUs)

- Broad IV range up to 200 V and 3 A (20 W DC)
- Pulse up to 10 A (500 W)
- Current resolution to 10 fA
- Max sampling to 1.8 MS/s
- NI SourceAdapt technology for fast settling in presence of capacitive loads
- Best-in-class channel density

NI Digital Pattern Instrument

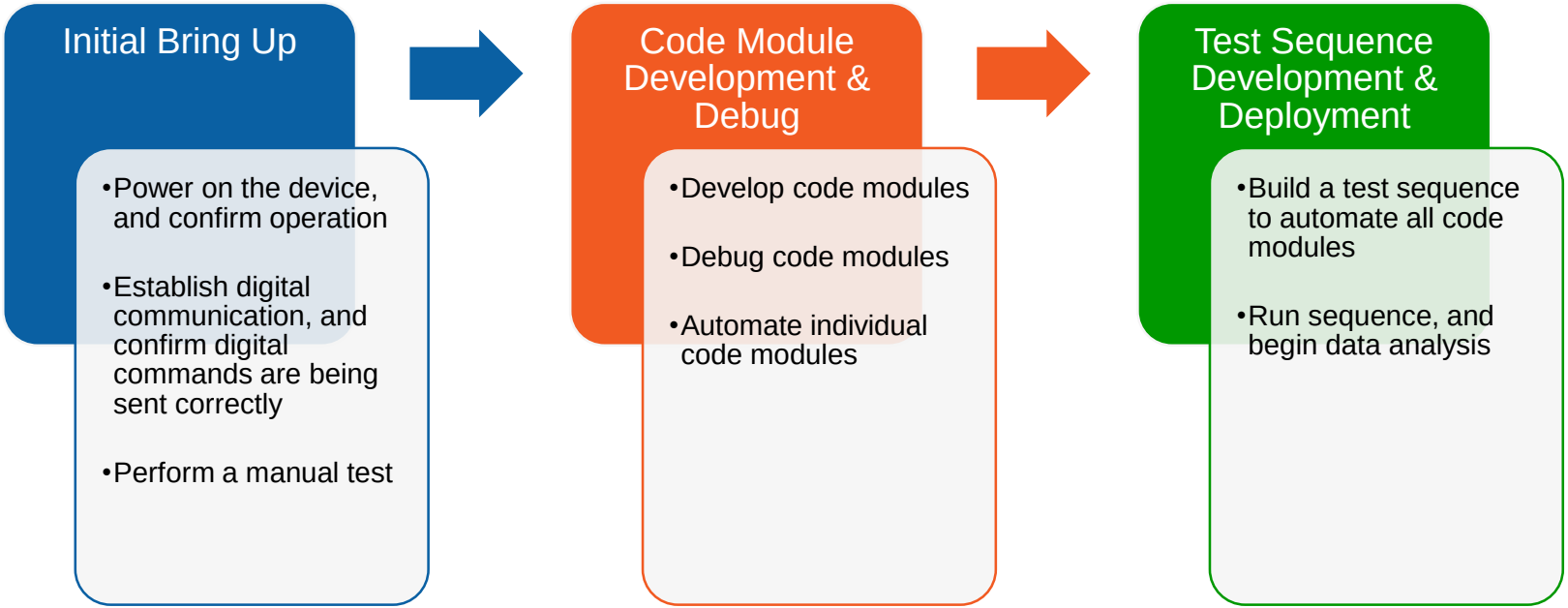
- ATE-class digital (with PPMU) in PXI
- Out-of-the-box Digital Pattern Editor software for configuration, interactive tests, and debugging
- Time sets, drive formats, opcodes, source and capture, history RAM, Shmoo

Other Instrumentation

- General-purpose analog and digital I/O for AC measurements and peripheral control
- General-purpose power supplies for peripherals
- Arbitrary waveform generators and oscilloscopes

NATIONAL INSTRUMENTS

Demo Workflow



Demo Workflow

InstrumentStudio

Power on Device, Confirm Operation

Confirm Commands From Digital Instrument

Perform Manual Test

Debug Test Code

Digital Pattern Editor

Establish DUT Communication

LabVIEW

Develop Test Code

Automate Single Test

NI TestStand

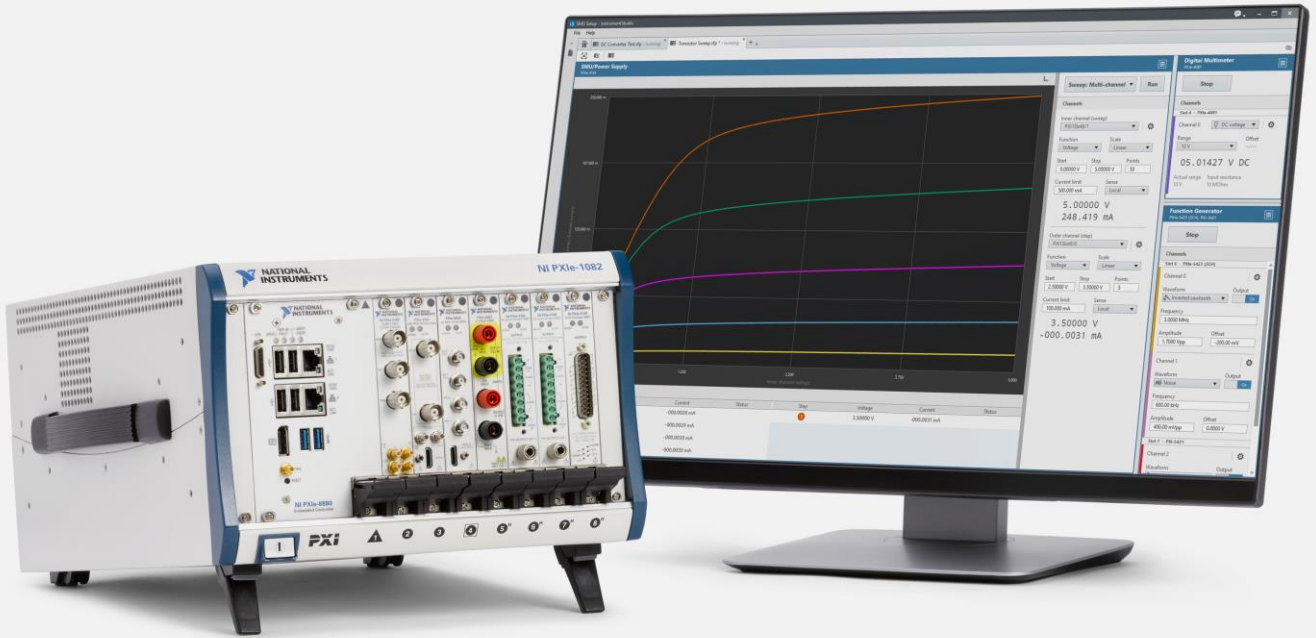
Build Sequence

Run Sequence and Begin Analysis

NATIONAL INSTRUMENTS

What is InstrumentStudio and why is it relevant to me?

It is all about adding an Integrated UI to the PXI Platform



NATIONAL INSTRUMENTS

InstrumentStudio™

Next-Generation Soft Front Panels for NI PXI Modular Instruments

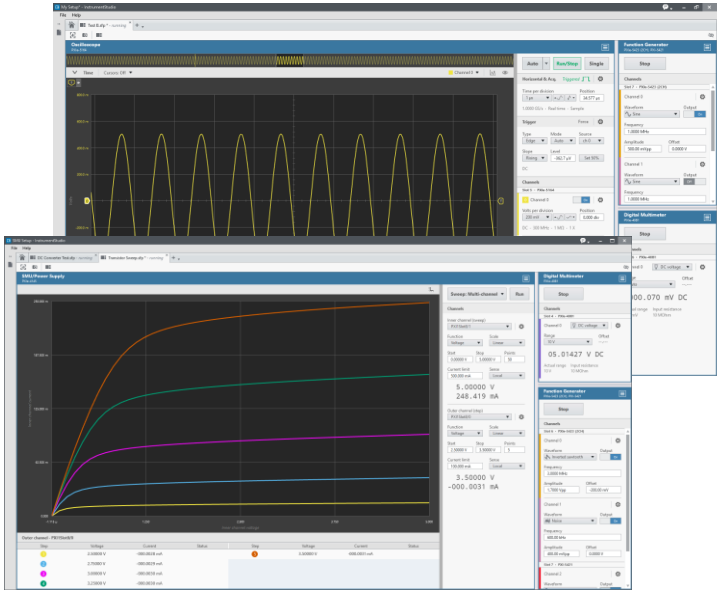
Access all your instruments in a single application
Take advantage of high-resolution monitors rather than small, integrated displays

Capture screenshots and export data
Store screenshots and measurement results from *all* your instruments with a single click

Share projects with colleagues and between systems
Use your projects to store your UI layout and instrument configuration for instant repeatability

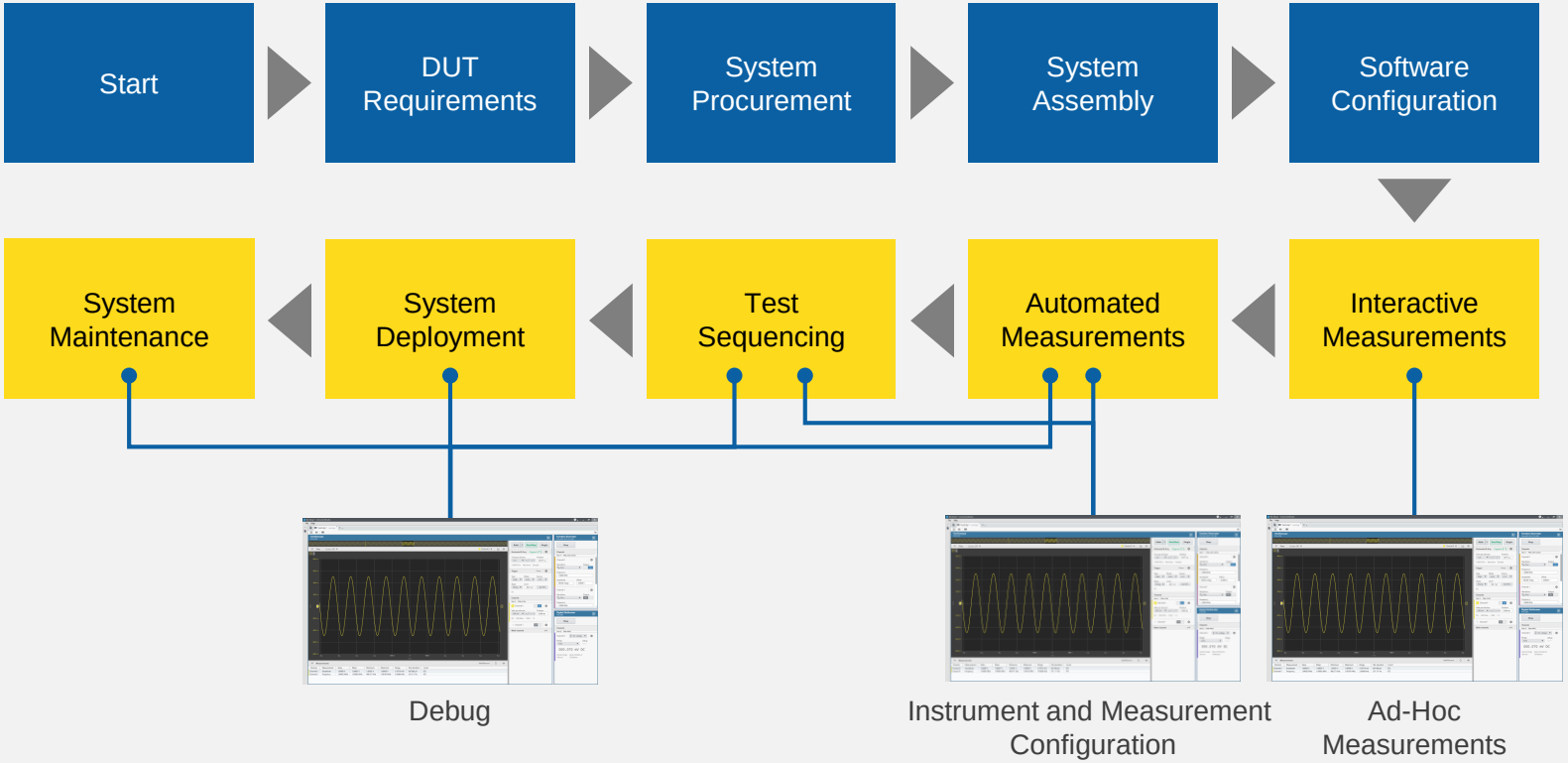
Export configurations for programmatic use
Minimize code development and guarantee measurement correlation

Monitor and debug automated test systems
Pause test sequences for debug or simply monitor your instruments while they are running



NATIONAL INSTRUMENTS™

Interactive Measurements in an Automated Workflow



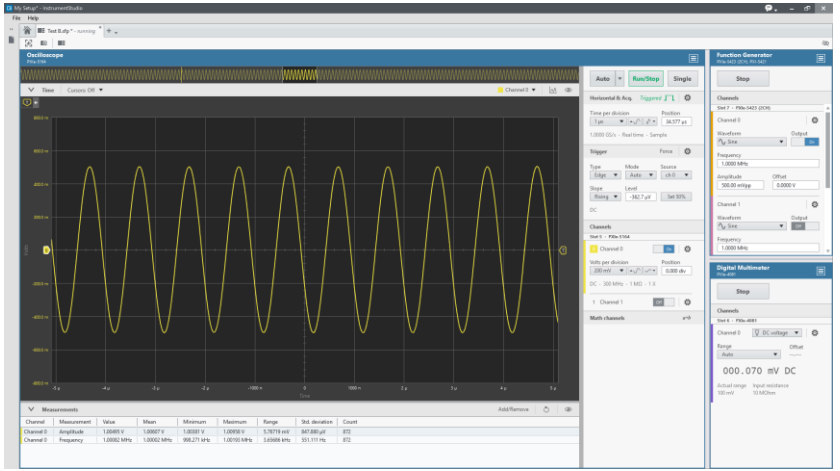
NATIONAL INSTRUMENTS

InstrumentStudio™ 2018

Oscilloscopes, AWGs and FGens, DMMs, SMUs, and Power Supplies

Enhanced interactive use

- Familiar but modern UI and UX with common functionality across instrument types
- Multi-instrument tabbed interface
  - Multidevice channel expansion within an SFP
  - One or many instruments per tab
  - Multiple tabs and multiple screens per instance
- Export data and screenshots
  - PNG, TDMS, clipboard
- Save UI configuration and share across systems



Streamlined transition from interactive to automated measurements

- Export instrument configuration for programmatic use

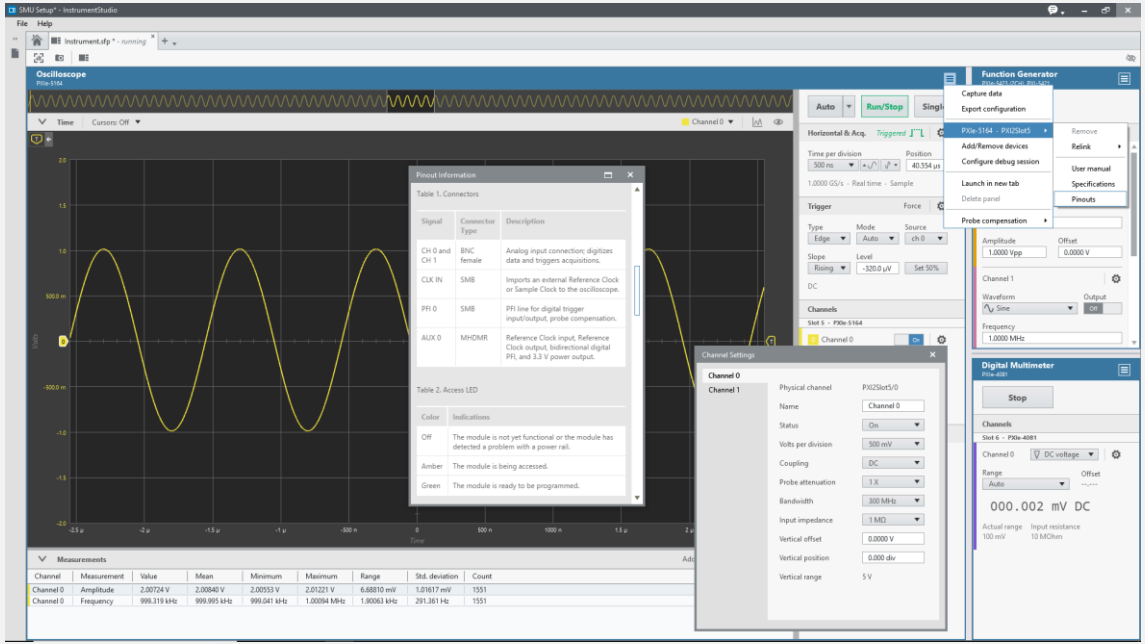
Simplified automated test system debug

- Debug driver session—monitor and control

NATIONAL INSTRUMENTS™

Oscilloscope: Configuration and Measurements

View device specifications and pinout from within the environment.



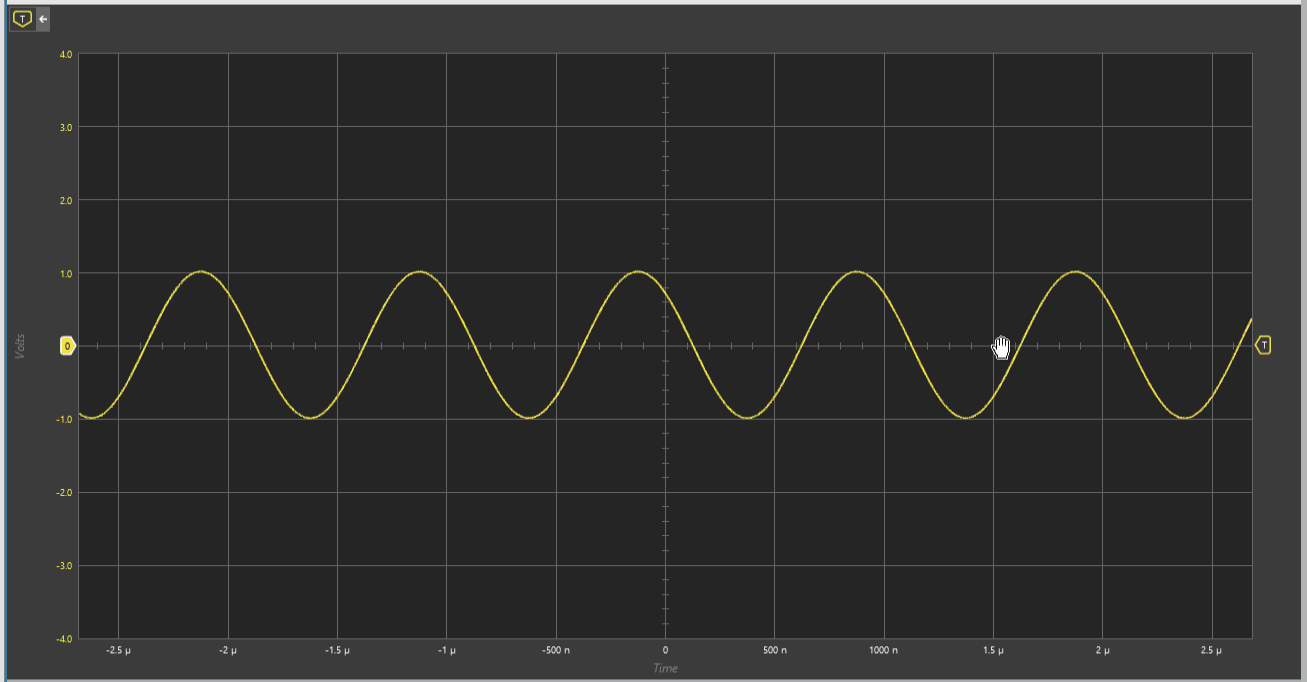
Untitled Project* - InstrumentStudio

File Help

Instrument.sfp * - running

Oscilloscope
PXIe-5164

Time | Cursors: Off | Channel 0



Measurements | Add/Remove

Channel	Measurement	Value	Mean	Minimum	Maximum	Range	Std. deviation	Count
Channel 0	Amplitude	2.01584 V	2.01501 V	2.01167 V	2.02019 V	8.52017 mV	1.49861 mV	87
Channel 0	Frequency	1.00018 MHz	999.947 kHz	998.943 kHz	1.00086 MHz	1.91638 kHz	399.002 Hz	87

Auto | Run/Stop | Single

Horizontal & Acq. Triggered

Time per division: 500 ns | Position: 28.376 µs

1.0000 GS/s · Real time · Sample

Trigger Force

Type: Edge | Mode: Auto | Source: ch 0

Slope: Rising | Level: 16.61 mV | Set 50%

DC

Channels

Slot 5 · PXIe-5164

Channel 0 — On

Volts per division: 1 V | Position: 0.000 div

DC · 300 MHz · 1 MΩ · 1 X

1 Channel 1 — Off

Math channels *a+b*

Function Generator
PXIe-5423 (2CH), PXI-5421

Stop

Channels

Slot 7 · PXIe-5423 (2CH)

Channel 0

Waveform: Sine | Output: On

Frequency: 1.0000 MHz

Amplitude: 1.0000 Vpp | Offset: 0.0000 V

Channel 1

Waveform: Sine | Output: Off

Frequency: 1.0000 MHz

Digital Multimeter
PXIe-4081

Stop

Channels

Slot 6 · PXIe-4081

Channel 0 — DC voltage

Range: Auto | Offset: --.---

000.065 mV DC

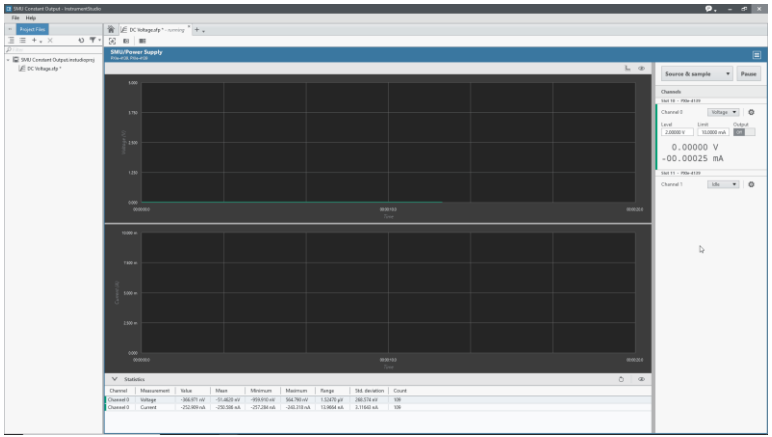
Actual range: 100 mV | Input resistance: 10 MOhm

InstrumentStudio™ 2018

Oscilloscopes, AWGs and FGens, DMMs, SMUs, and Power Supplies

Enhanced interactive use

- Familiar but modern UI and UX with common functionality across instrument types
- Multi-instrument tabbed interface
  - Multidevice channel expansion within an SFP
  - One or many instruments per tab
  - Multiple tabs and multiple screens per instance
- Export data and screenshots
  - PNG, TDMS, clipboard
- Save UI configuration and share across systems



Streamlined transition from interactive to automated measurements

- **Export instrument configuration for programmatic use**

Simplified automated test system debug

- Debug driver session—monitor and control

NATIONAL INSTRUMENTS™

SMU Constant Output - InstrumentStudio

File Help

Project Files

Filter

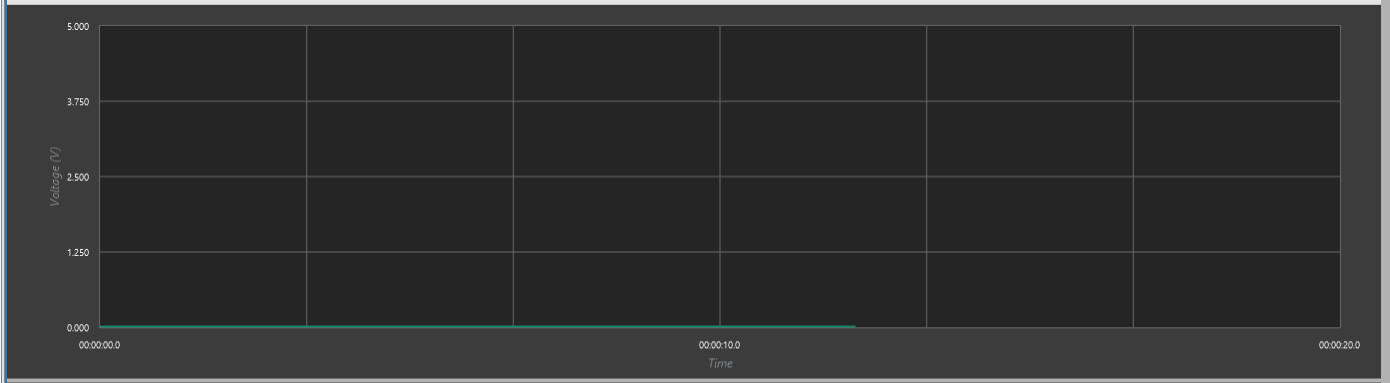
SMU Constant Output.instudioproj

DC Voltage.sfp *

DC Voltage.sfp * - running

SMU/Power Supply

PXIe-4139, PXIe-4139



Source & sample

Pause

Channels

Slot 10 · PXIe-4139

Channel 0 Voltage

Level 2.00000 V

Limit 10.0000 mA

Output Off

0.00000 V

-00.00025 mA

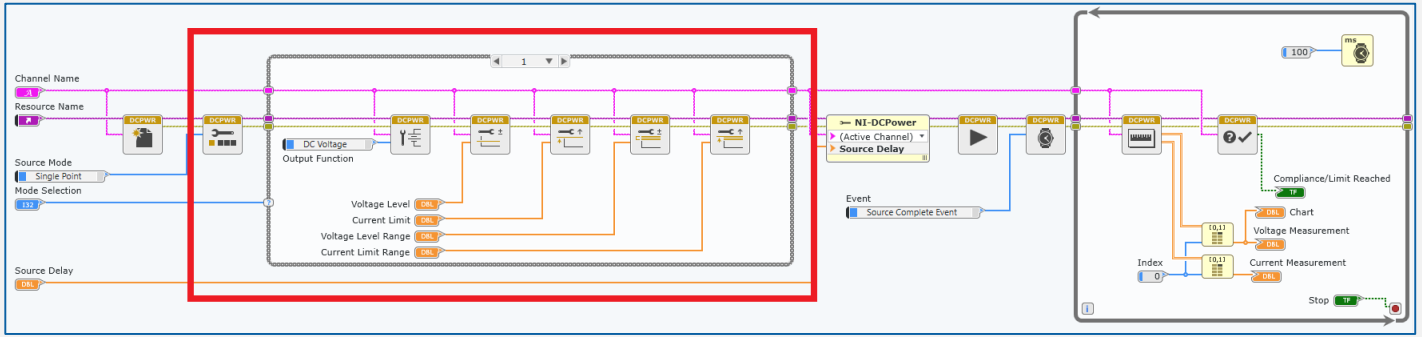
Slot 11 · PXIe-4139

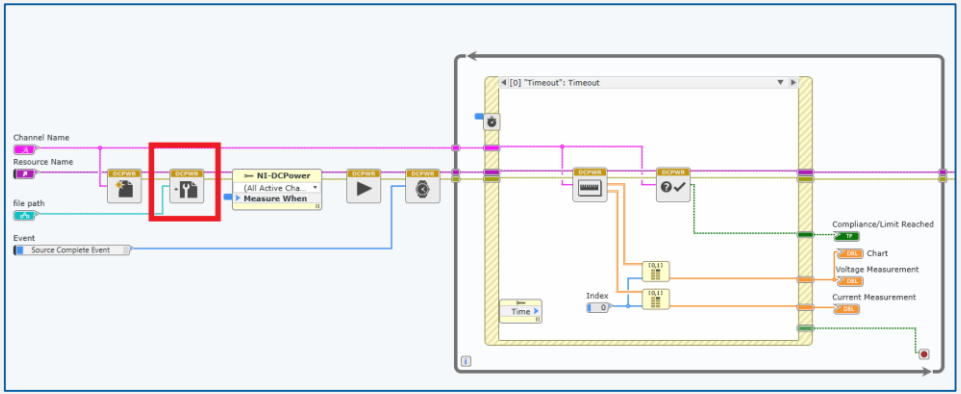
Channel 1 Idle

Statistics

Channel	Measurement	Value	Mean	Minimum	Maximum	Range	Std. deviation	Count
Channel 0	Voltage	-366.971 nV	-51.4620 nV	-959.910 nV	564.790 nV	1.52470 µV	268.574 nV	109
Channel 0	Current	-252.909 nA	-250.586 nA	-257.284 nA	-243.318 nA	13.9664 nA	3.11643 nA	109

Simplifying Your Code





NATIONAL INSTRUMENTS

NI-DCPower: Source and Sample Mode

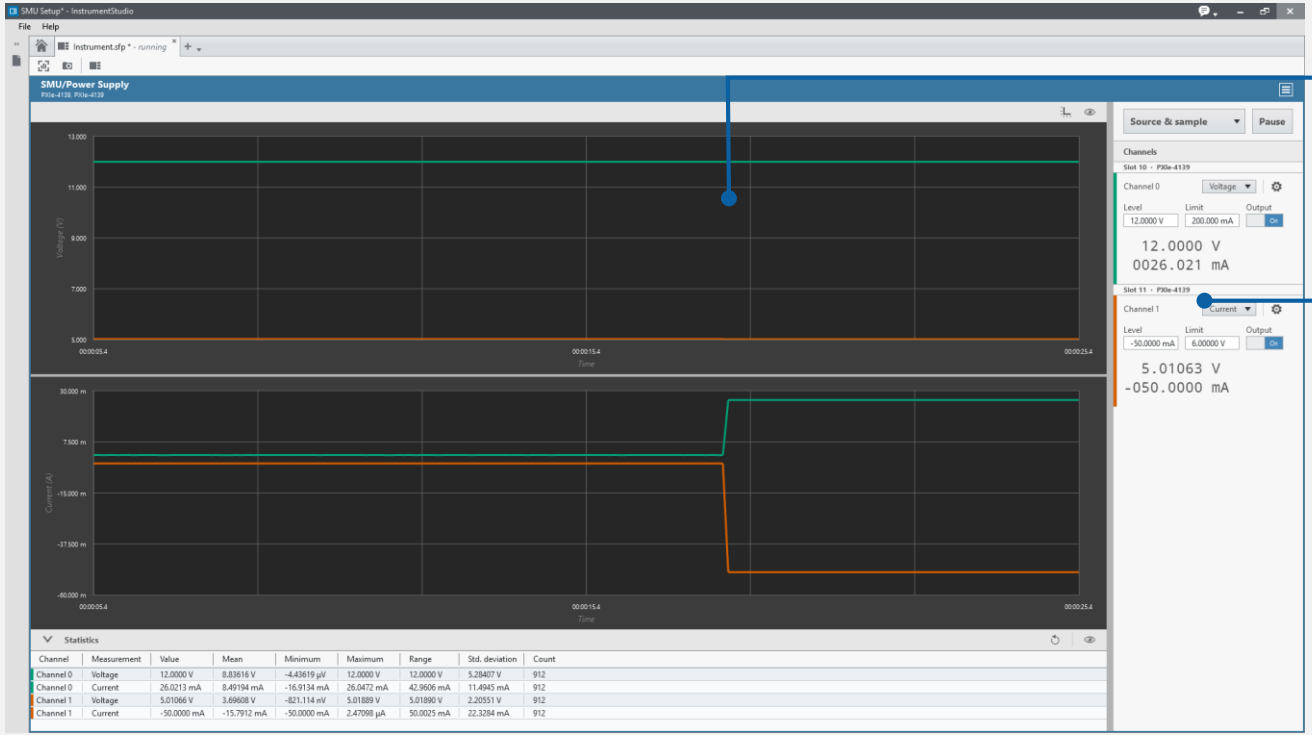
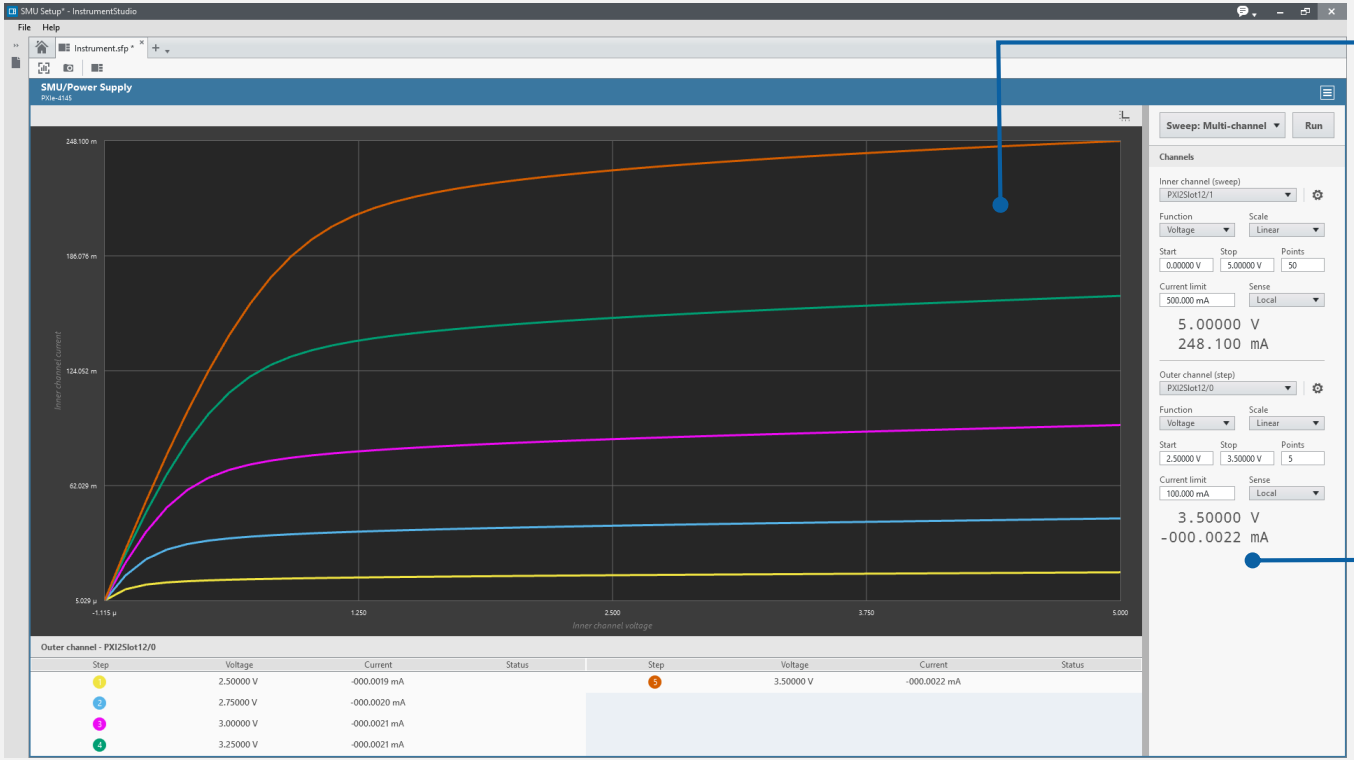


Chart voltage and current over time

Manage multiple devices in a single window

NATIONAL INSTRUMENTS

NI-DCPower: Sweep Mode



Run 1- or 2-channel sweeps

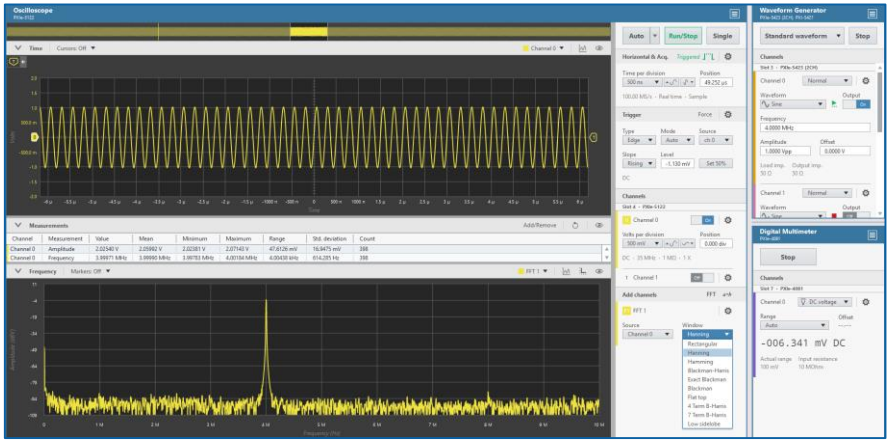
Access advanced timing and measurement settings

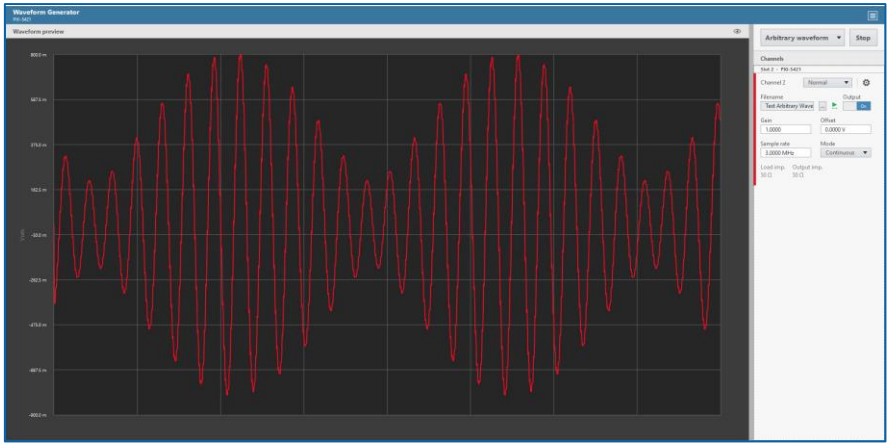
NATIONAL INSTRUMENTS

Recent / Planned enhancements with InstrumentStudio

InstrumentStudio™ 2018 SP2 Enhancements

- Oscilloscopes
  - Added FFT channels, frequency markers, and FFT measurements
  - Added two-channel measurements
- Waveform generators
  - Added support for arbitrary waveform generation mode
  - Added support for frequency list and sweep modes
- General
  - Added support for exporting instrument events to PXI chassis trigger lines
  - Added CSV file format for data capture

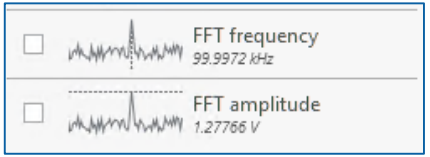


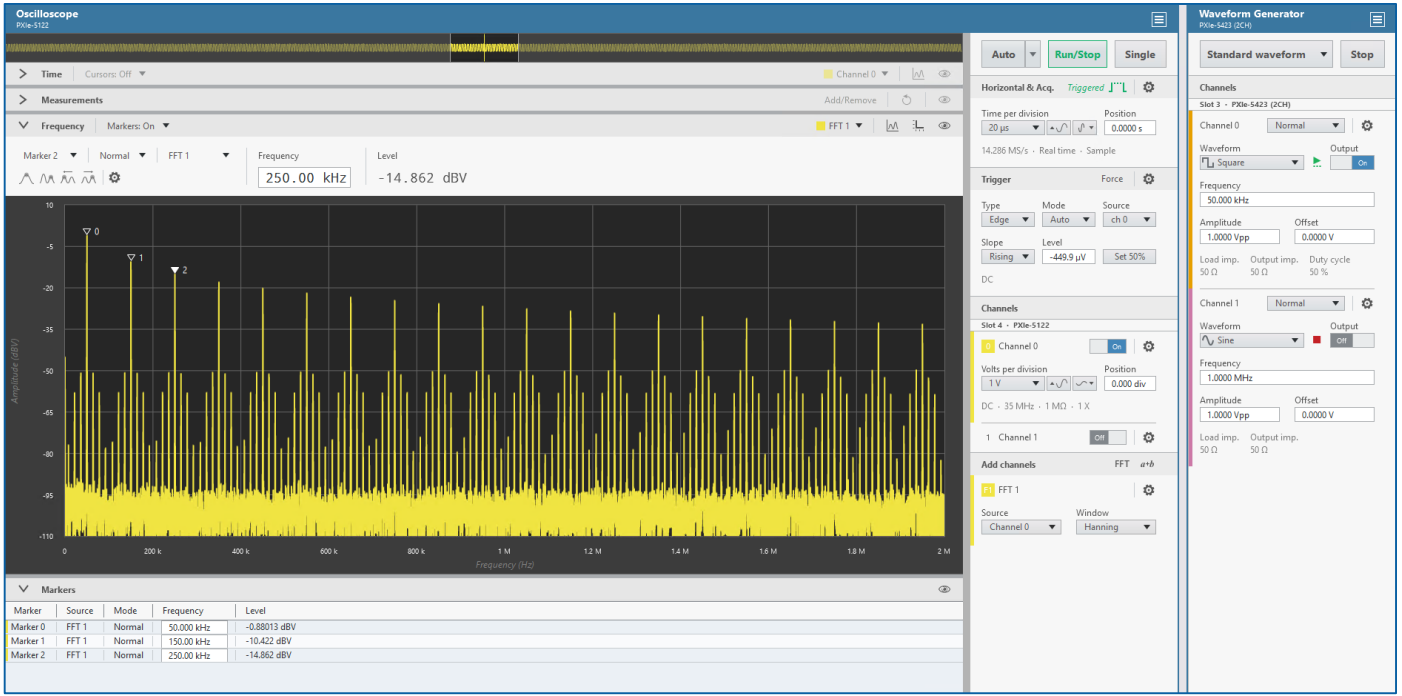


NATIONAL INSTRUMENTS

Oscilloscope Panel: FFT Channels

Plus frequency markers, peak search, and FFT measurements

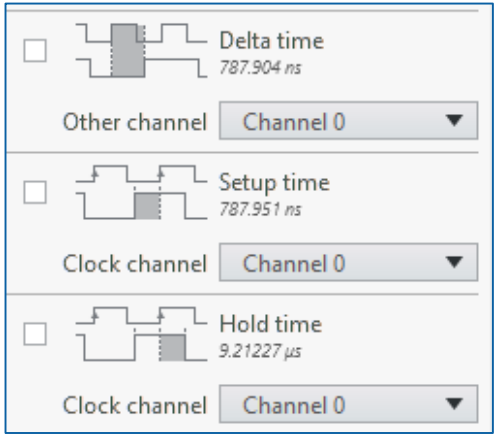


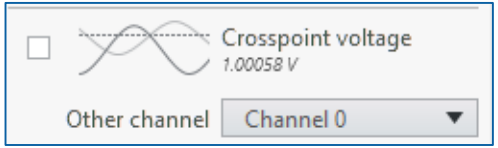


NATIONAL INSTRUMENTS

Oscilloscope Panel: Two-Channel Measurements

- Specify “other channel” to measure against primary channel
- Delta time, setup time, hold time, and crosspoint voltage

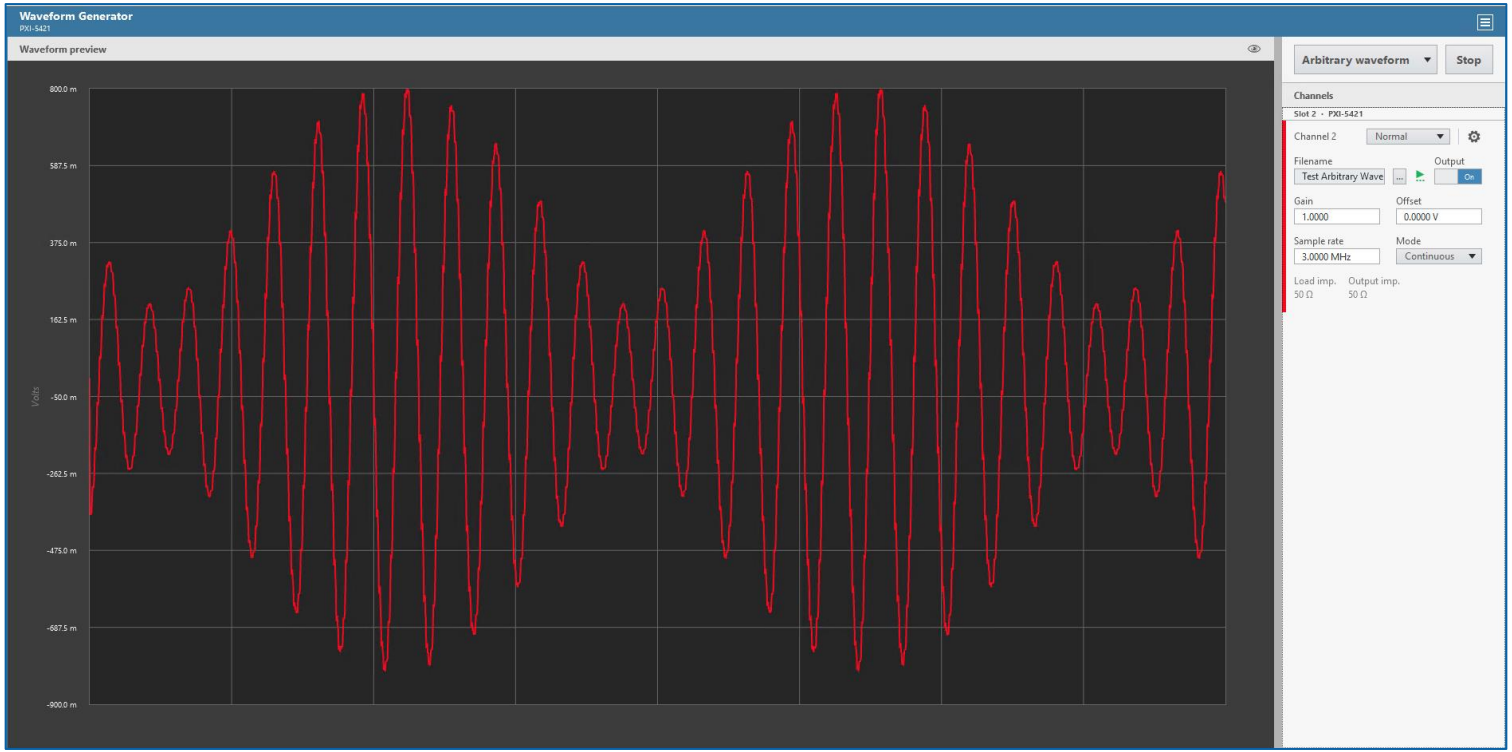




NATIONAL INSTRUMENTS

Waveform Generator Panel: Arbitrary Waveform Mode

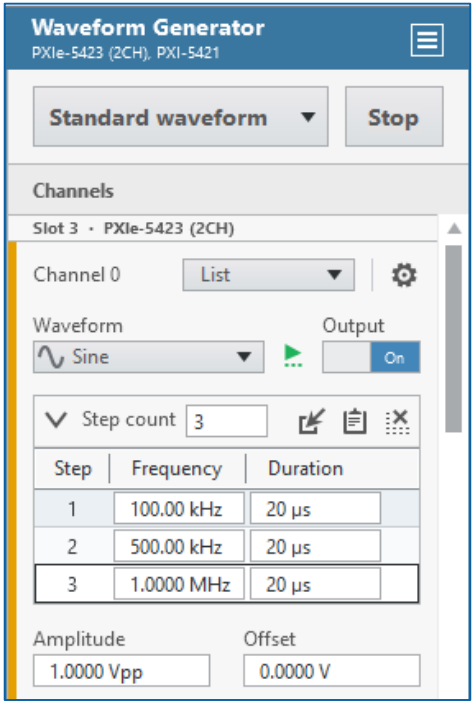
See a preview in the large panel view

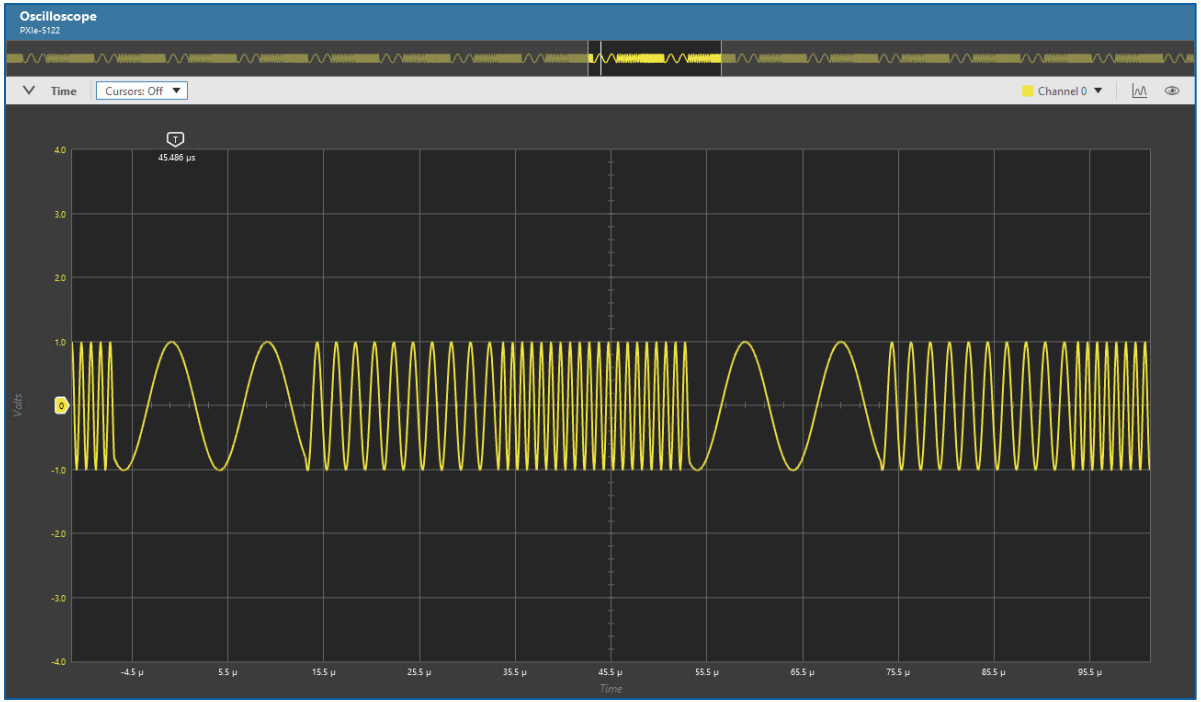


NATIONAL INSTRUMENTS

Waveform Generator Panel: List Mode

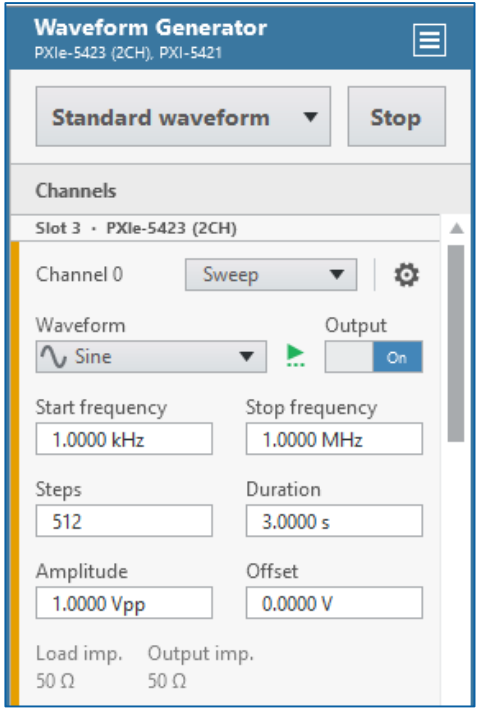
Specify a list manually or from file

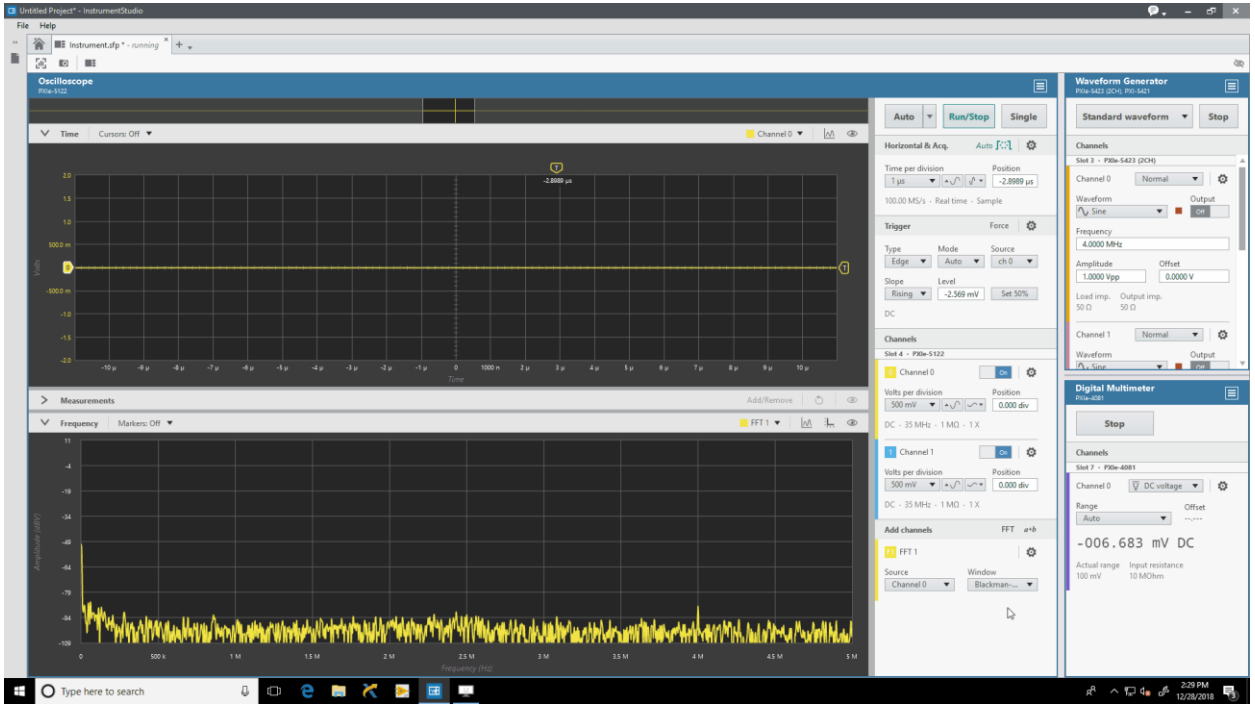




Waveform Generator Panel: Sweep Mode

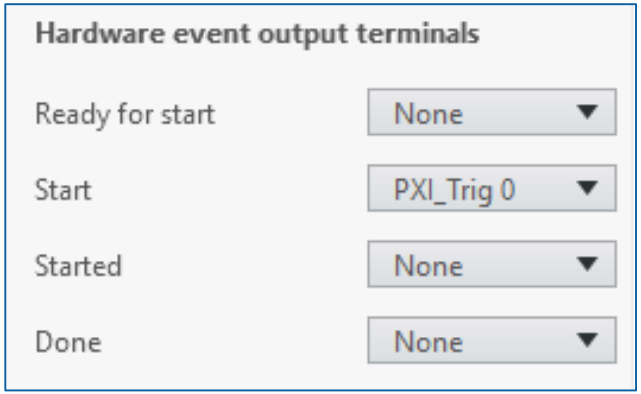
Animation: FGEN Sweep + Scope FFT

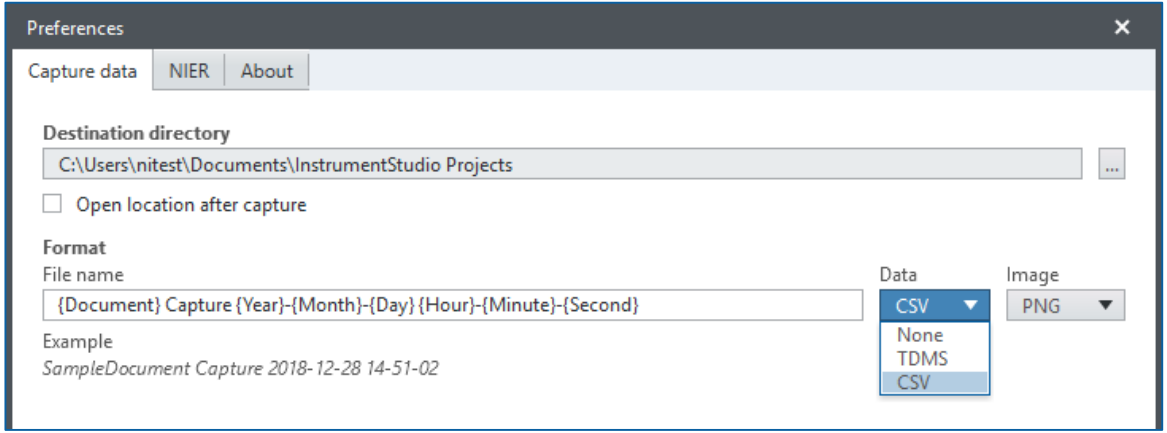




General: Instrument Event Export and CSV Data Capture

Export events to PXI chassis trigger lines. Choose between TDMS or CSV.

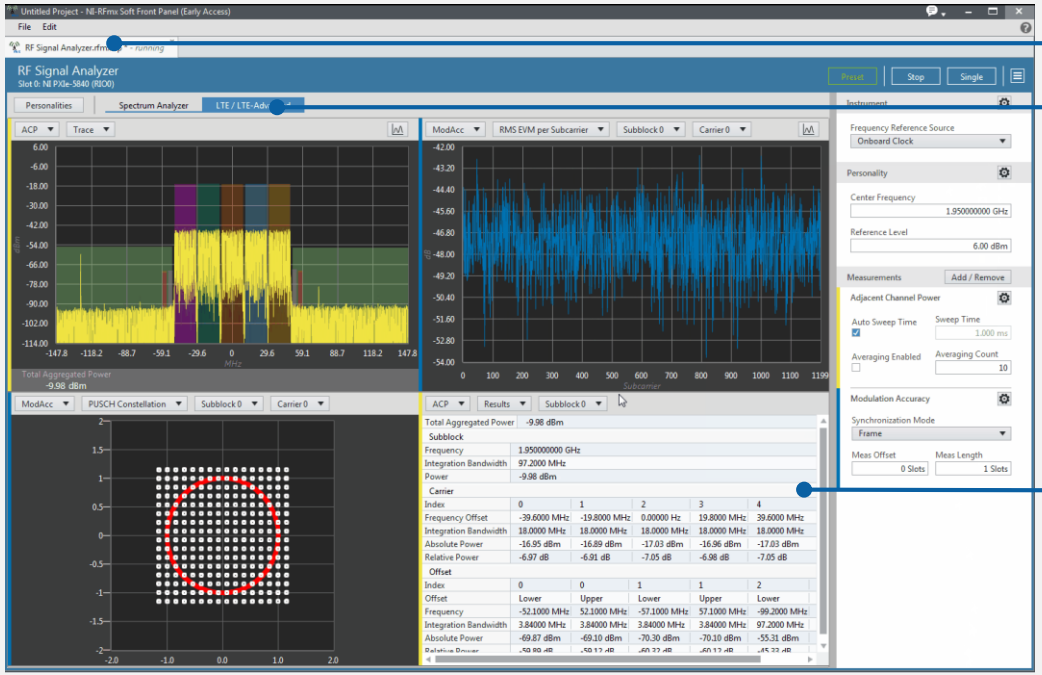




NATIONAL INSTRUMENTS

NI-RFmx Soft Front Panel: SpecAn and LTE/LTE-A

Similar interactive software for RF instrumentation



Multiple instances/tabs

Multiple personalities/standards

Multiple measurements and traces

NATIONAL INSTRUMENTS

FAQ

Installing InstrumentStudio

- Installs automatically with 18.1 drivers
- Or, download separately from Package Manager
  - This stand-alone version contains only the runtimes of the four drivers. You can use InstrumentStudio by itself, but you cannot perform operations that would require the API (config export to programming environments or debug monitor/control modes)

Supported hardware

- Any hardware (PXI, PCI, USB) that is supported by NI-SCOPE, NI-FGEN, NI-DMM, or NI-DCPower 18.1 or later; full hardware list at ni.com/instrumentstudio

Demo Workflow

InstrumentStudio

Digital Pattern Editor

LabVIEW

NI TestStand

Power on Device, Confirm Operation

Establish DUT Communication

Confirm Commands From Digital Instrument

Perform Manual Test

Debug Test Code

Develop Test Code

Automate Single Test

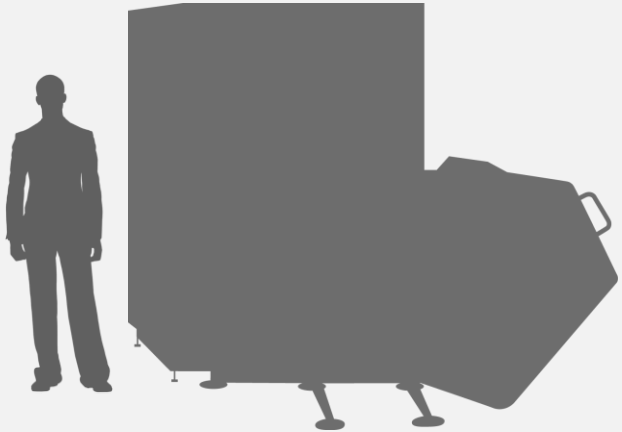
Build Sequence

Run Sequence and Begin Analysis

NATIONAL INSTRUMENTS

ATE Not Designed to Serve Validation

- Too expensive
- Custom cooling
- High-power connections
- Designated space in labs
- I/O options are fixed and aging
- Renting ATE from other groups
- Trying to partner overseas to use production ATE
- Lack of ATE availability limits test productivity



NATIONAL INSTRUMENTS

Lab Test System

ATE

Scalable ATE-Class Digital

Modular hardware

Timing and DC parametric measurements

ATE digital patterns

Production test speed

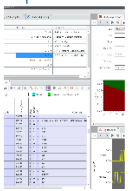
NATIONAL INSTRUMENTS

PXI Digital Pattern Instruments

PXIe-6570 and PXIe-6571

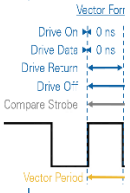
Built for Semiconductor Device Test

- RFICs and Transceivers
- Power Management ICs
- MEMS
- IoT Devices with Integrated MCUs and Sensors



ATE Development and Debug Features

- Digital Pattern Editor
- Source and Capture Memory
- History RAM, Digital Scope, Pin View, and System View
- Shmoo Plots



ATE Test Capability

- Time Sets and Edge Placement
- Opcodes
- Multi-site Support
- Integrated Per-Channel PPMU
- Up to 512 Synchronized Channels

NATIONAL INSTRUMENTS

PXI Digital Pattern Instruments: PXIe-6570 and PXIe-6571

	PXIe-6570	PXIe-6571*
Module Width	2 slots	1 slot
Active Load	24 mA	16 mA
Pin Electronics	Digital: -2 V to +6 V, 32 mA PPMU measure voltage: -2 V to +6 V, 32 mA PPMU force voltage: -2 V to +7 V, 32 mA	
Channels	32 per module	
	256 maximum in a synchronized subsystem	512 maximum in a synchronized subsystem
Maximum Vector Rate	100 MHz (10 ns minimum vector period)	
Maximum Data Rate	200 Mb/s	
Maximum Clock Rate	160 MHz**	
Pattern Timing	31 time sets 39.0625 ps edge placement resolution	
Drive Formats	Non-return (NR), return to low (RL), return to high (RH) (100 MHz max), surround by complement (SBC) (50 MHz max)	
Vector Memory Depth	128 M/channel	
Opcode Support	Flow control, sequencer flags and registers, signal, source and capture, subroutine	
Source and Capture Engines	Broadcast or site-unique Serial or parallel 8 per instrument	
SCAN Support	Flattened SCAN patterns, up to 128 M	

* Note that the PXIe-6571 requires a chassis with 82 W slot cooling capacity, such as the PXIe-1095. In STS, this requires the high-density test head revision.
** Clock rates >133 MHz will have a non-50% duty cycle.

NATIONAL INSTRUMENTS

A Modular Approach to Digital Test

Synchronized PXI Instruments

- Subnanosecond synchronization with other PXI modules
- Full suite of instruments from DC to mmWave

PXIe-8880 Controller

- Intel Xeon 8-core processor (2.3 GHz)
- 24 GB/s system bandwidth
- Up to 24 GB DDR4 1866 MHz RAM
- Gen 3 PCI Express technology

PXIe-6571 Digital Pattern Instrument

- 32 channels per module
- Up to 512 synchronized channels in digital subsystem
- 31 time sets
- 100 MHz vector rate
- 128 M vector memory

PXIe-1095 Chassis

- 18 PXI Express slots
- Up to 24 GB/s system bandwidth
- 82 W slot cooling capacity
- Peer-to-peer data streaming
- Gen 3 PCI Express technology

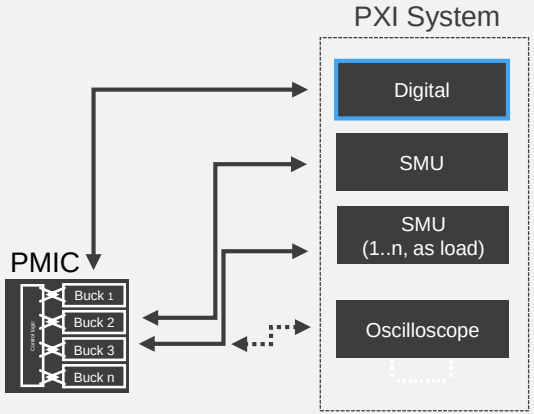
NATIONAL INSTRUMENTS

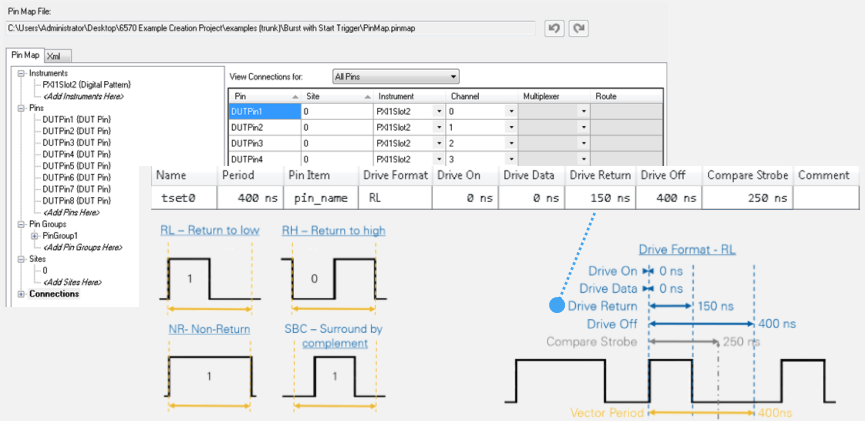
Digital: Consistent Terminology With ATE

- DUT-centric programming by pin
- Time sets with cycle-to-cycle edge placement and drive formats
- Pin electronics for edge placement and IV measurements

Why it matters

- Paradigm consistency paves the way for reuse (patterns, code modules) and easier correlation with production ATEs





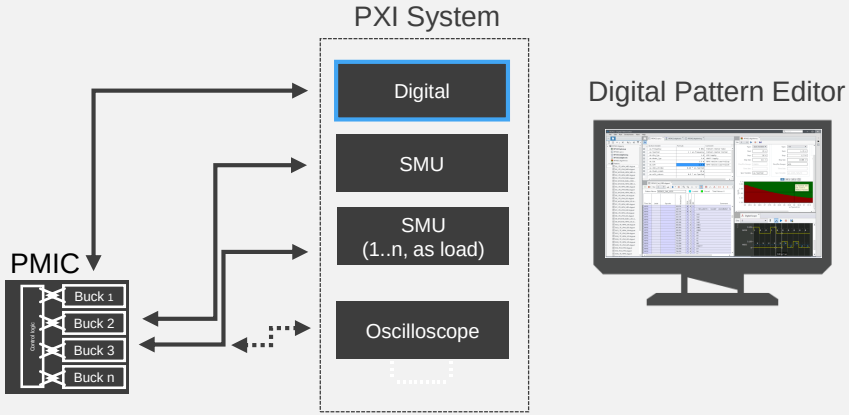
NATIONAL INSTRUMENTS

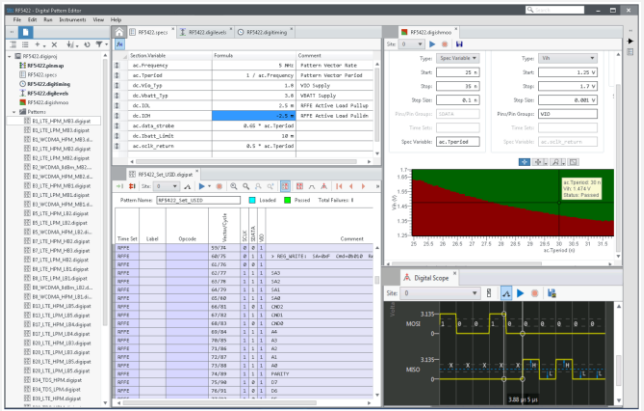
Digital: Pattern Editor Software

- Create, edit, and import digital test patterns
- Debug tools like History RAM and Digital Scope
- Shmoo plotting for margining and characterization

Why it matters

- Out-of-the-box functionality to import/create, debug, and burst patterns
- Go from configuration to test faster with out-of-the-box application software





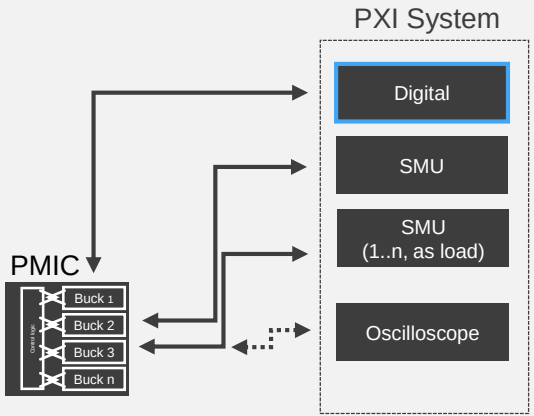
NATIONAL INSTRUMENTS

Digital: Test System Integration

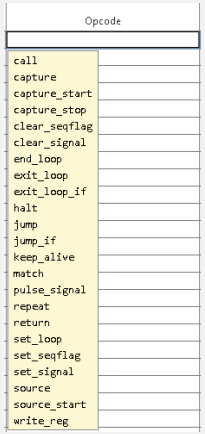
- Logical operations within patterns like looping, jumping, and matching
- Multimodule, cross-module, and cross-instrument operations

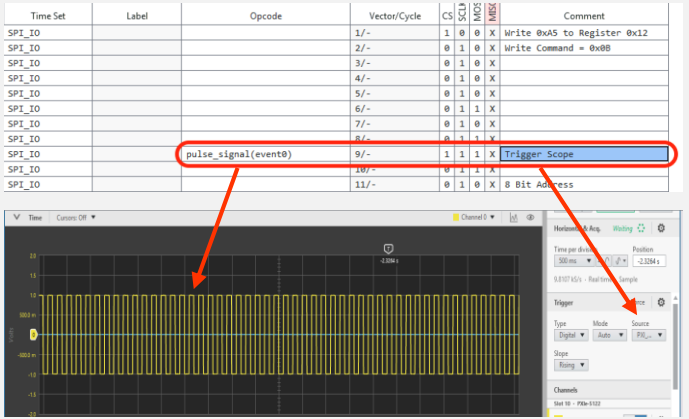
Why it matters

- Flexible execution of patterns including dynamic source and capture memory operations
- Integrated measurement capability of all instruments within a digital pattern

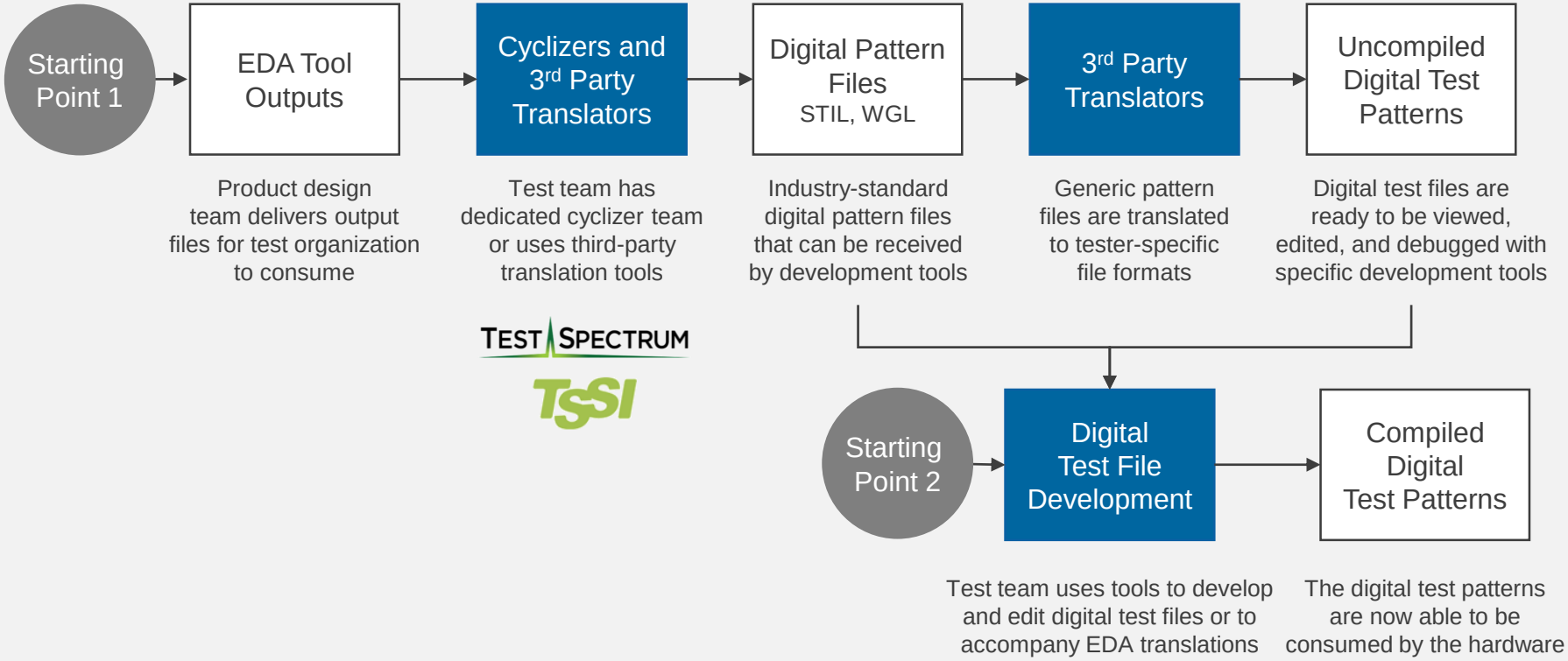


Digital Pattern Editor



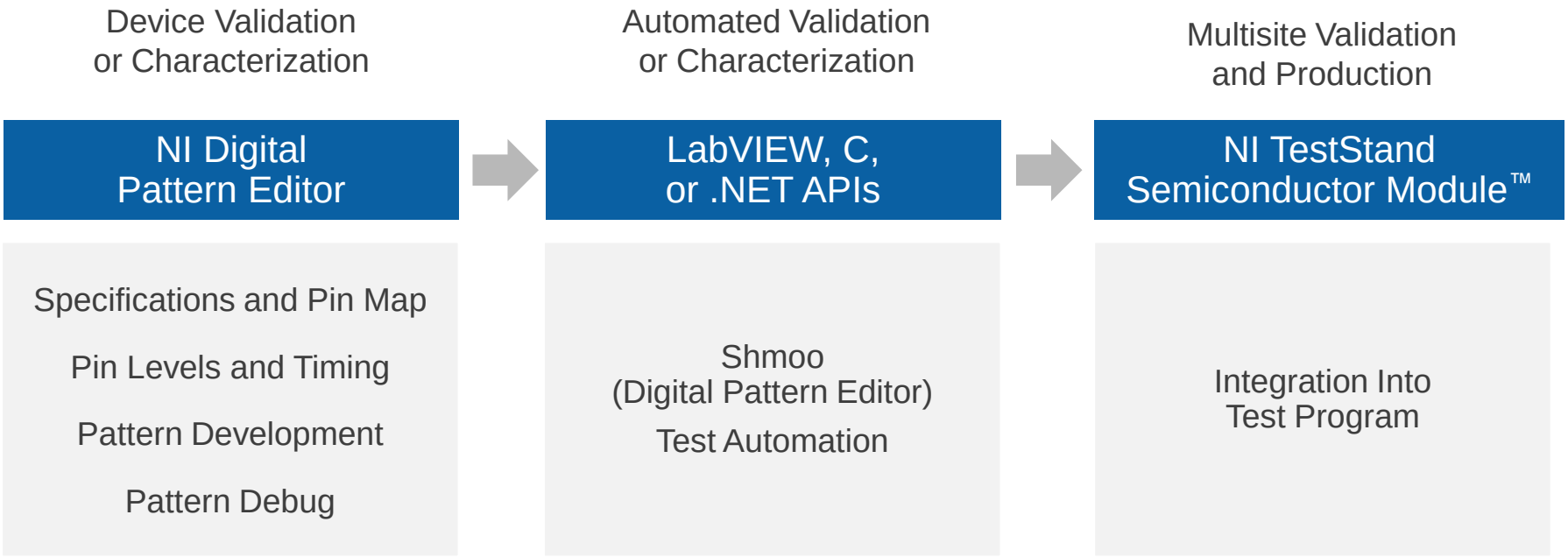


Semiconductor Digital Pattern Workflow



NATIONAL INSTRUMENTS

Test Engineer Workflow With NI



NATIONAL INSTRUMENTS

Goals of Validation Test

Take Accurate Measurements

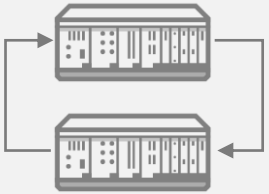
Develop Understanding of DUT Performance

Shorter Test Time With Less Effort

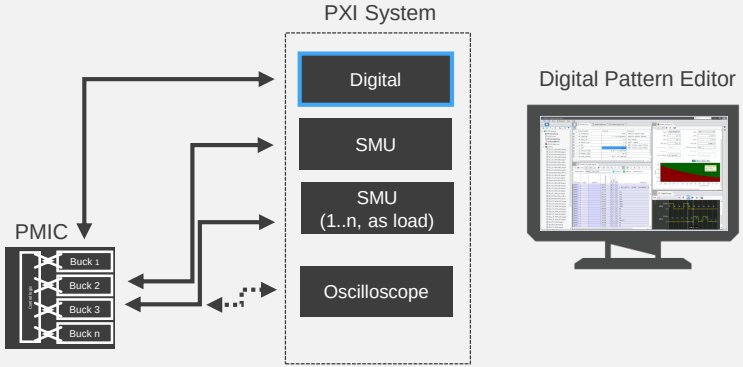
Characterization, Validation, Evaluation

Required Tools and Tasks

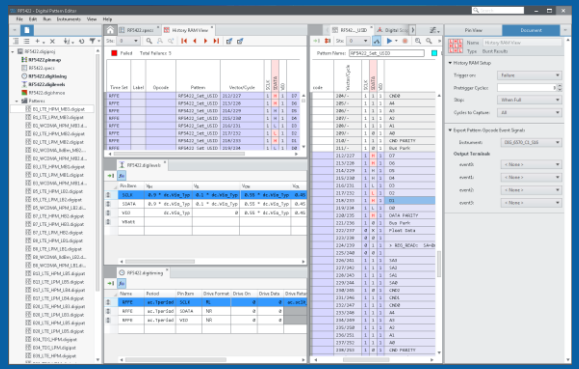
Shmoo Plots for Margining



Multiple-Instrument Automation



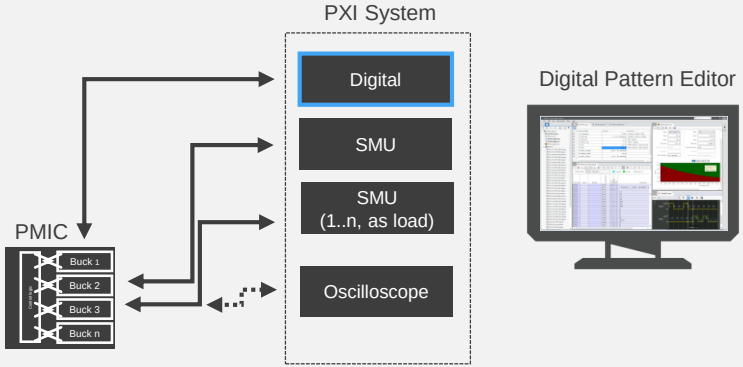
Digital Pattern Editor

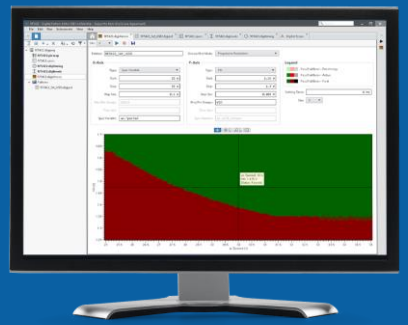


DEMO: Create and Edit Digital Patterns

- Develop digital patterns with the Digital Pattern Editor
- Create pin and channel maps
- Set specifications, timing, and levels
- Standard ASCII format for pattern files

NATIONAL INSTRUMENTS





DEMO: Debug Digital Patterns and Create Shmoo Plots

- History RAM overlay and viewer
- Pin and system views
- Digital scope
- Shmoo plot

NATIONAL INSTRUMENTS

Demo Workflow

InstrumentStudio

Digital Pattern Editor

LabVIEW

NI TestStand

Power on Device, Confirm Operation

Establish DUT Communication

Confirm Commands From Digital Instrument

Perform Manual Test

Debug Test Code

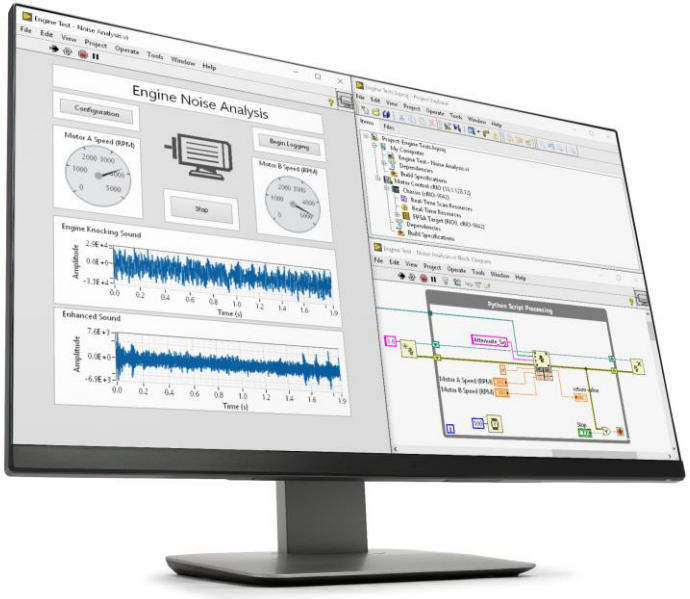
Develop Test Code

Automate Single Test

Build Sequence

Run Sequence and Begin Analysis

NATIONAL INSTRUMENTS



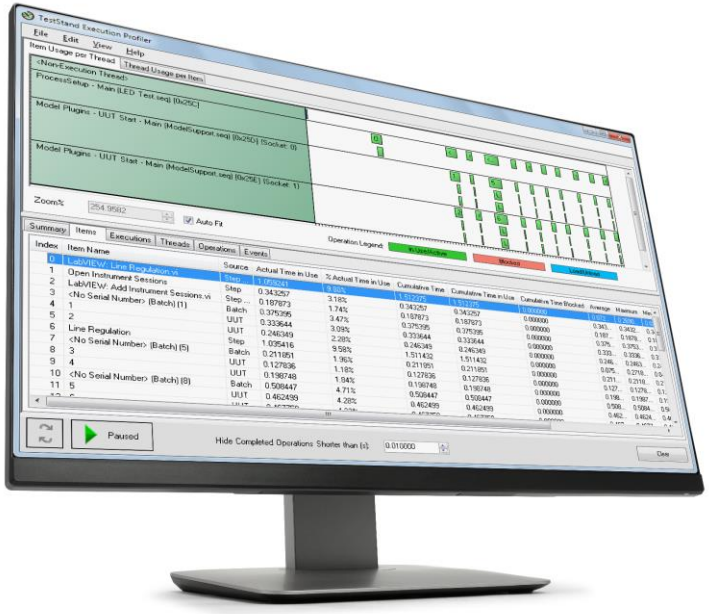
LabVIEW 2018 simplifies the design of distributed test, measurement, and control systems to decrease your time to market.

LabVIEW 2018

FEATURES AT A GLANCE

- Automate software building and execution with the LabVIEW Command Line Interface
- Natively call Python scripts with the Python Node
- Prototype FPGA code faster with improved floating-point operations, new compile tools, and LabVIEW FPGA 64-bit

NATIONAL INSTRUMENTS



Industry-Standard Test Management Software

TestStand

FEATURES AT A GLANCE

- Author, execute, and debug test sequences
- Leverage test code developed in any language
- Test many devices in parallel
- Generate reports
- Integrate with databases
- Extend the software to meet custom requirements
- Develop professional operator interfaces

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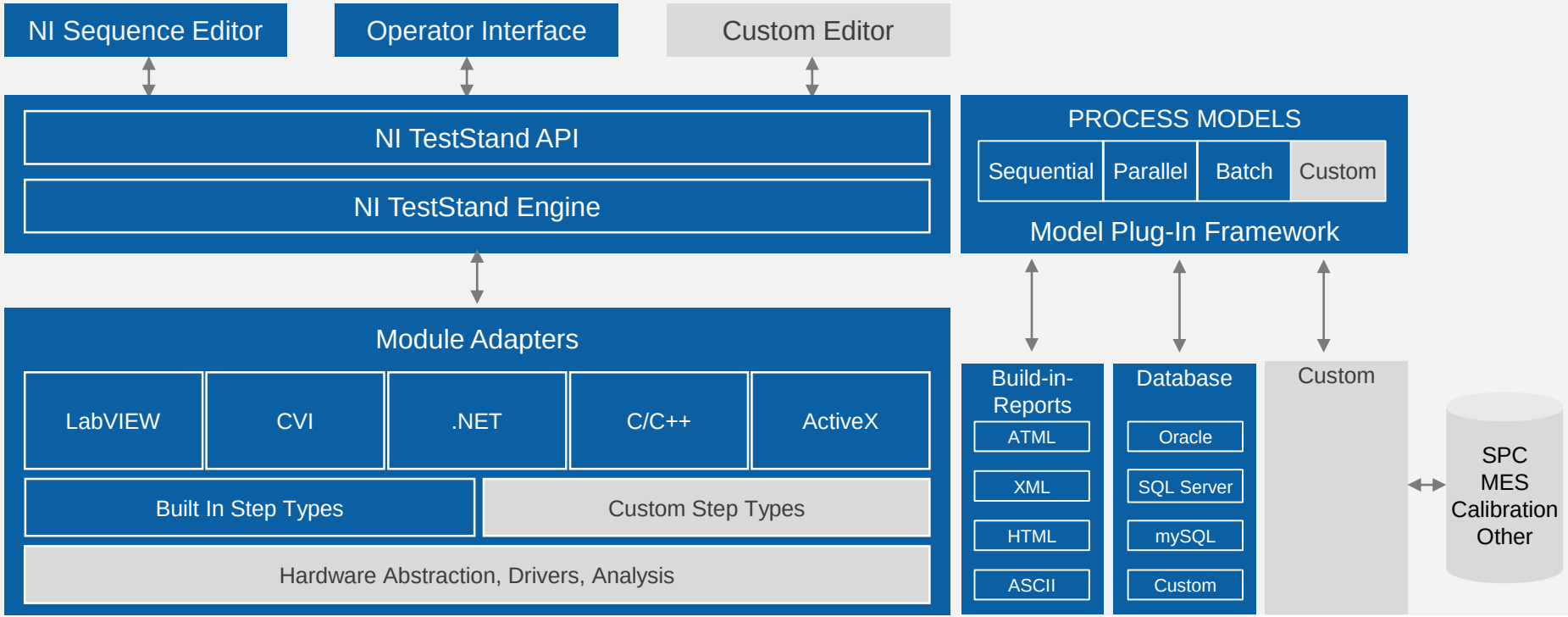
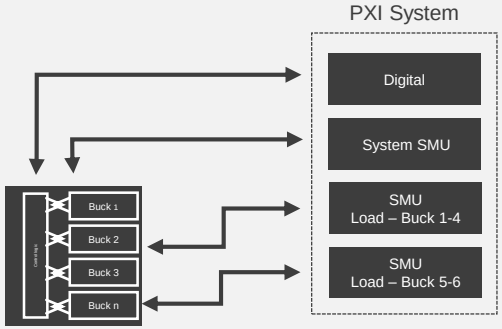
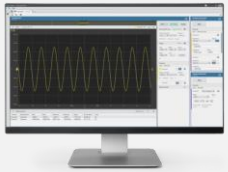
TestStand Architecture





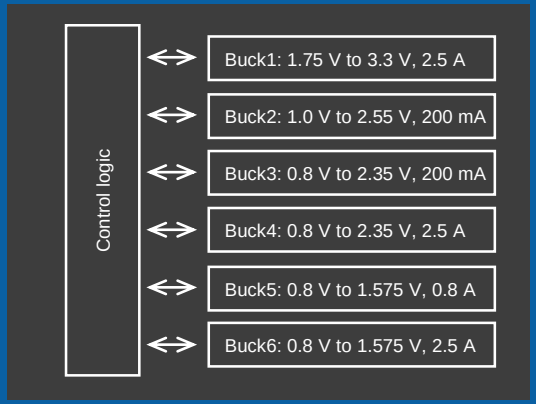


InstrumentStudio

LabVIEW

Digital Pattern Editor

NI TestStand



DEMO: Develop a Sample Automated Test Sequence for Power Efficiency and Load Regulation

- Use InstrumentStudio to confirm DUT functionality and debug
- Use Digital Pattern Editor to develop patterns to communicate with DUT
- Automate tests with LabVIEW
- Sequence numerous tests and generate reports with TestStand

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Agenda

Time	Topic	Presenter	Demo
8:30	**Welcome, Introductions and NI Semiconductor Update**	Peter	No
8:45	**Using a Modular Platform for Mixed-Signal Semiconductor Characterization** • Introduction to the NI PXI Platform • InstrumentStudio Software for Interactive PXI Measurements • ATE-Class PXI Digital Instruments • Live demonstration of DUT characterization using modular instruments	Tarek	Yes
10:15	**Coffee Break/Networking**		
10:30	**Introduction to NI's offering for RFIC Test Applications including 5G NR, DPD, ET and mmWave** • Addressing the FEM Test Challenges to LTE-Advanced Pro and 5G NR • Characterizing Multiband ET/DPD Modern Front End Modules • Challenges and Solutions for mmWave OTA Test	Udo	Yes
12:10	**NI-Ampleon Collaboration Project: Wideband Multi-port Characterization for Active Antenna Systems** • Motivation for collaboration: the Ampleon Perspective • Sub 6 GHz and mmwave Characterization Innovation: the NI Perspective	Sergio & Marc	No
12:30	Summary and wrap-up		

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Introduction to NI's offering for RFIC Test Applications

5G NR, DPD, ET and mmWave

Smarter Test From
Characterization to Production

Udo Dehne
Business Development Manager,
Semiconductor
National Instruments

FEM Test System

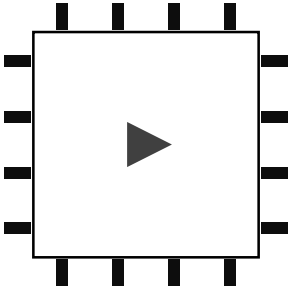
How could an efficient test system look like?

Agenda

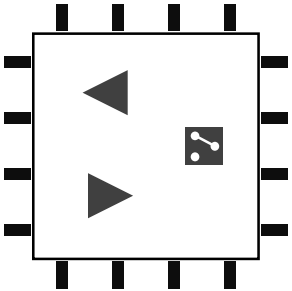
- Trends and Challenges
- RF Hardware
  - Sub-6
  - 6 GHz Band
  - mmWave
- RF Software
  - Demo 1: Sub-6 5G/NR PA test
- PA/FEM Test (DPD, ET)
  - Demo 2: Sub-6 5G/NR PA test with DPD
- OTA

Trends & Challenges

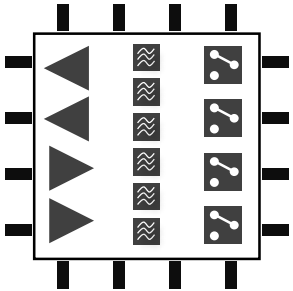
Increasing Component Complexity



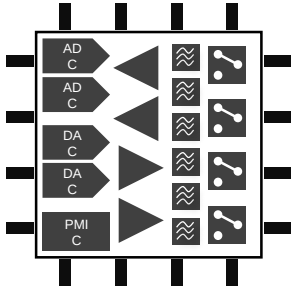
2005
PA



2010
FEM



2015
Multiband FEM



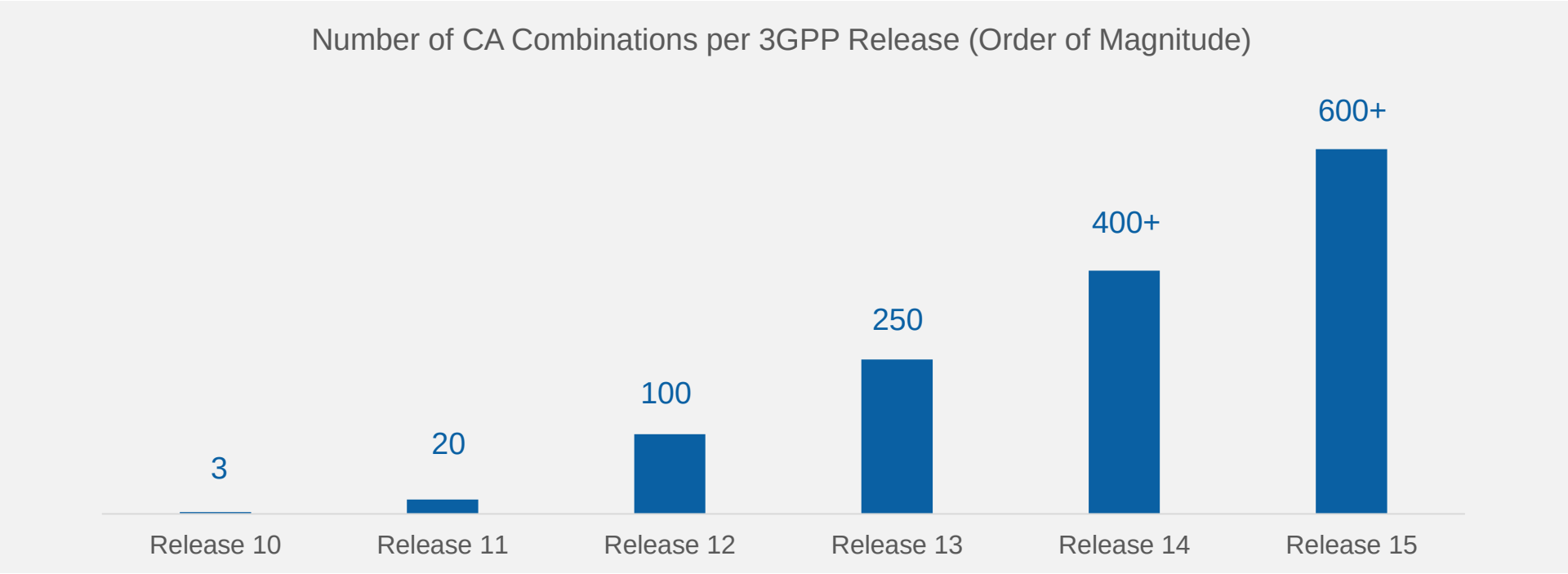
2020
Integrated Radio

"Multiple versions of the same LTE device are required to accommodate the worldwide proliferation of cellular bands—40 already and counting. The problem gets even worse when you consider the different band combinations required to support LTE-Advanced carrier aggregation."

QUALCOMM®

More Test Cases Than Ever

Carrier and band combinations in every new 3GPP release increase the total number of valid test scenarios



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A Smarter Approach

Labs

- Designed for automation
- Optimized for measurement quality
- Fast test cycles

Same Platform

- Maximize Leverage
- Code, setup, training
- Simpler correlation
- Faster test cycles
- Lower cost

Production Floor

- Designed for test cell
- Optimized for throughput
- Cost effective

Sub-6GHz Hardware

Key Innovations for PA Test

NI Vector Signal Transceiver (VST)

- FPGA-based servoing for measurement acceleration
- Up to 1 GHz instantaneous bandwidth for wide range of wireless technologies
- R&D-grade measurement performance with up to -50 dB EVM for 802.11ax

NI Source Measure Units (SMUs)

- Broad IV range: 200 V (20 W), 3 A (10 A pulse)
- Current resolution to 10 fA
- Max sampling to 1.8 MS/s
- NI SourceAdapt technology for fast settling in presence of capacitive loads
- Best-in-class channel density

NI Digital Pattern Instrument

- ATE-class digital (with PPMU) in PXI
- Out-of-the-box Digital Pattern Editor software
- Time sets, drive formats, opcodes, source and capture, history RAM, Shmoo

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High-Performance PXI RF Instruments

PXIe-5840 Vector Signal Transceiver	
Frequency Range	9 kHz to 6 GHz
Maximum Bandwidth	1 GHz
Maximum Output Power	+20 dBm
802.11ax EVM	-50 dB (with external LO)

PXIe-5668R Vector Signal Analyzer	
Frequency Range	20 Hz to 26.5 GHz
Maximum Bandwidth	765 MHz
Phase Noise	-129 dBc/Hz (1 GHz, 10 kHz offset)
RMS Noise Floor (without pre-amp)	< -155 dBm/Hz (1 GHz) < -148 dBm/Hz (26 GHz)

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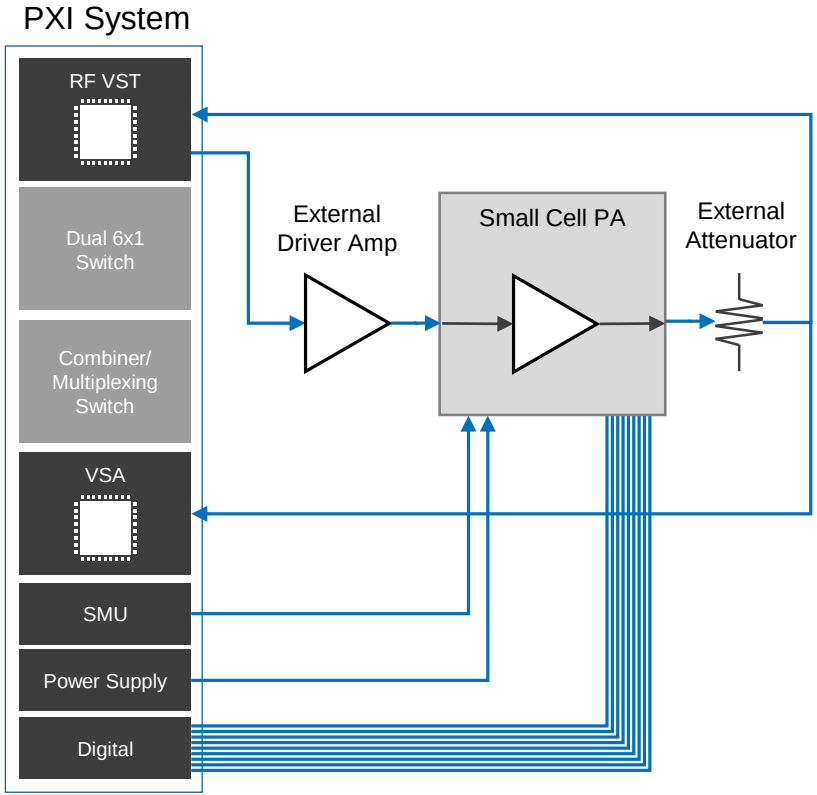
Typical Test System for 5G-NR BTS PA



Required System Components

- RF Vector Signal Transceiver (VST) combines 6 GHz VSG and VSG into single module
- 26.5 GHz VSA (PXIe-5668R) for high-dynamic range ACLR and harmonics
- SMU's offer up to +/- 10 A current sourcing and current sensitivity down to +/- 10 fA
- External Power Supply offer up to 1500W, max voltage of 650V, and max current of 150A

Optional System Components

- Wide range of switching topologies including multiplexor, combiner/splitter, and SPDT for multi-band PA/FEMs.
- Arbitrary waveform generator (AWG) for dynamic power supply testing scenarios

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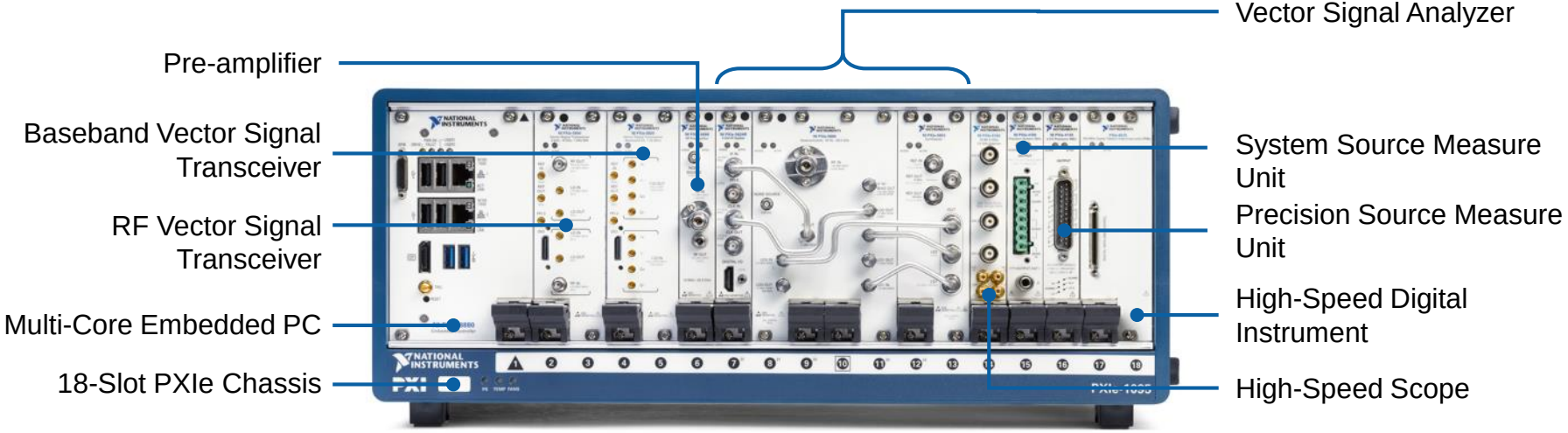
RFIC Validation Test Solution for <6 GHz 5G NR FEM



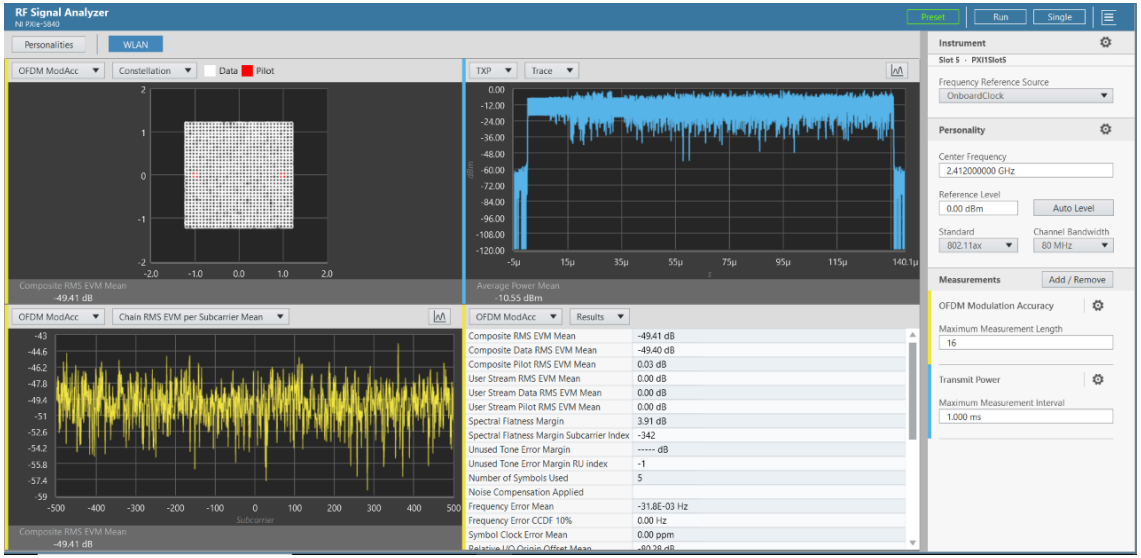
- Characterize and validate NR FEMs operating up to 6 GHz with 1 GHz of real-time bandwidth
- Generate and analyze standard-compliant 5GNR waveforms
- Evaluate device performance with Envelope Tracking under multiple Digital Pre-distortion models.
- Synchronize MIPI RFFE DUT control with analog measurements

6 GHz Band (5.925 – 7.125 GHz) Hardware For WiFi6 and NR-U

Q3 2019

6 GHz Band Extension - NI PXIe-5830/31 12/21 GHz VST

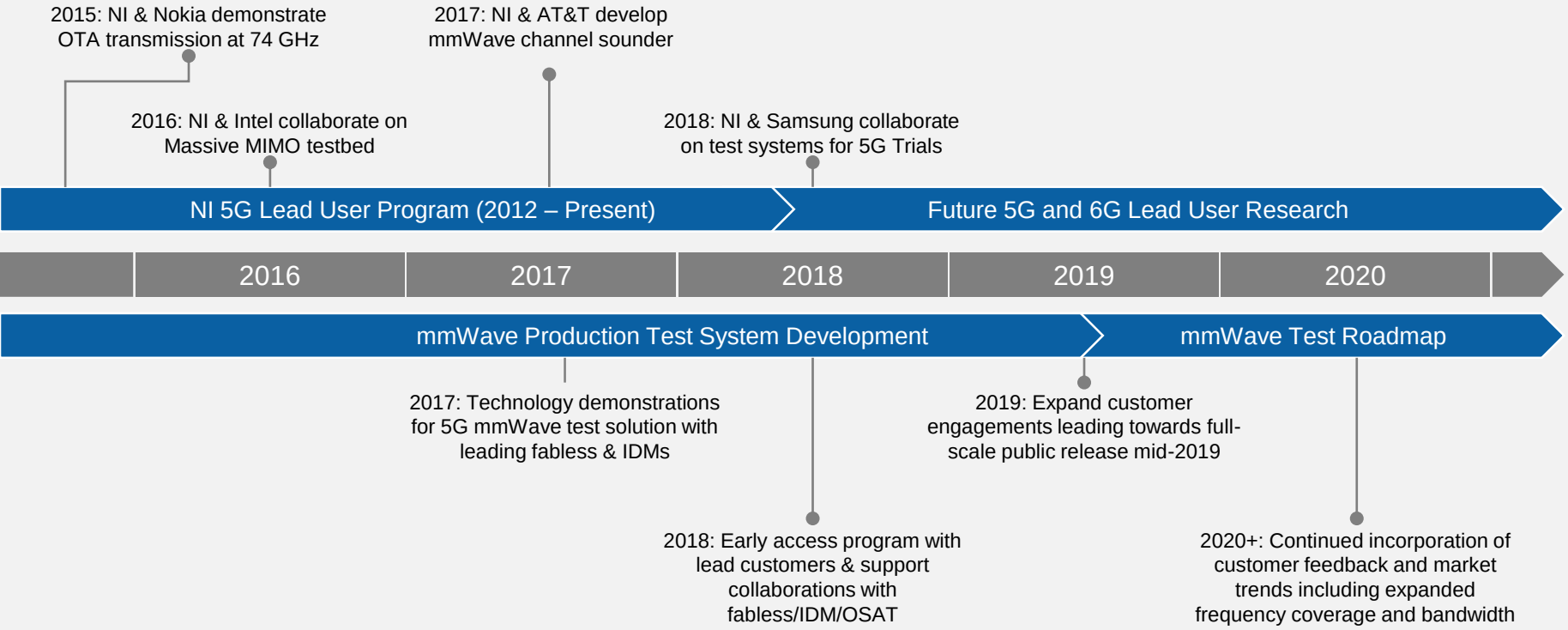
- 5.0 GHz to 12/21 GHz Frequency Coverage for Unlicensed Bands
- 1 GHz Bandwidth for LTE-A Pro LAA, NR-U, Wi-Fi 6 and UWB



PXIe-5820 PXIe-3621/22

mmWave Hardware

5G mmWave Test Timeline



Transition of mmWave Technology

Challenges in mmWave Applications:

- Handling multi-port devices
- Features & testing optimized for characterization and production
- OTA in case of integrated antennas or packages with antennas
- High port-count due to integrated switching/multiplexing
- High levels of device features/functionality/integration
- Cost of tests

Use of mmWave so far

- Specific / niche applications
- Low-mid volumes
- Low-mid level of integration
- Slow speed
- Single / rel. simple packages
- Manageable tests
- Expensive / higher price “accepted”

Use of mmWave from now on

- Consumer applications, thus high-volume production
- Other frequency bands
- High level of integration
- Test Speed matters
- Advanced packaging
- Complex tests
- “Low costs” / cost & time pressure from market

NI 5G Test: A Platform Approach

Sub-6 GHz

mmWave

PXI
- Simple I/O insertion scalable port counts
- Tight timing and synchronization
- high throughput data movement

LabVIEW FPGA
- Custom and NI supplied IP
- Ultimate instrument flexibility
- Hardware timed measurements

RFmx
- Standards compliant measurements
- Parallel high performance processing
- Approachable yet flexible API

Vector Signal Transceiver Architecture

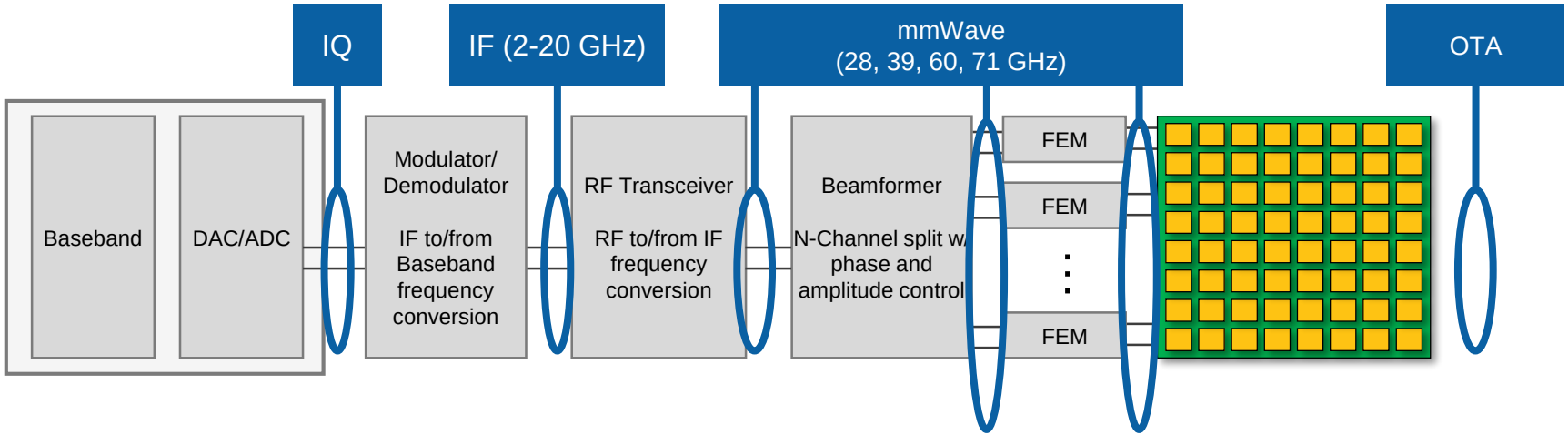
Wide BW DACs and ADCs + Integrated FPGA for real-time processing and measurement acceleration

- High linear Tx power for high PAPR signals
- 9 kHz – 6.5 GHz contiguous frequency range
- Clock synchronization and signal sharing for MIMO
- Low slot count modules for high channel density
- Cellular and WiFi for coexistence testing

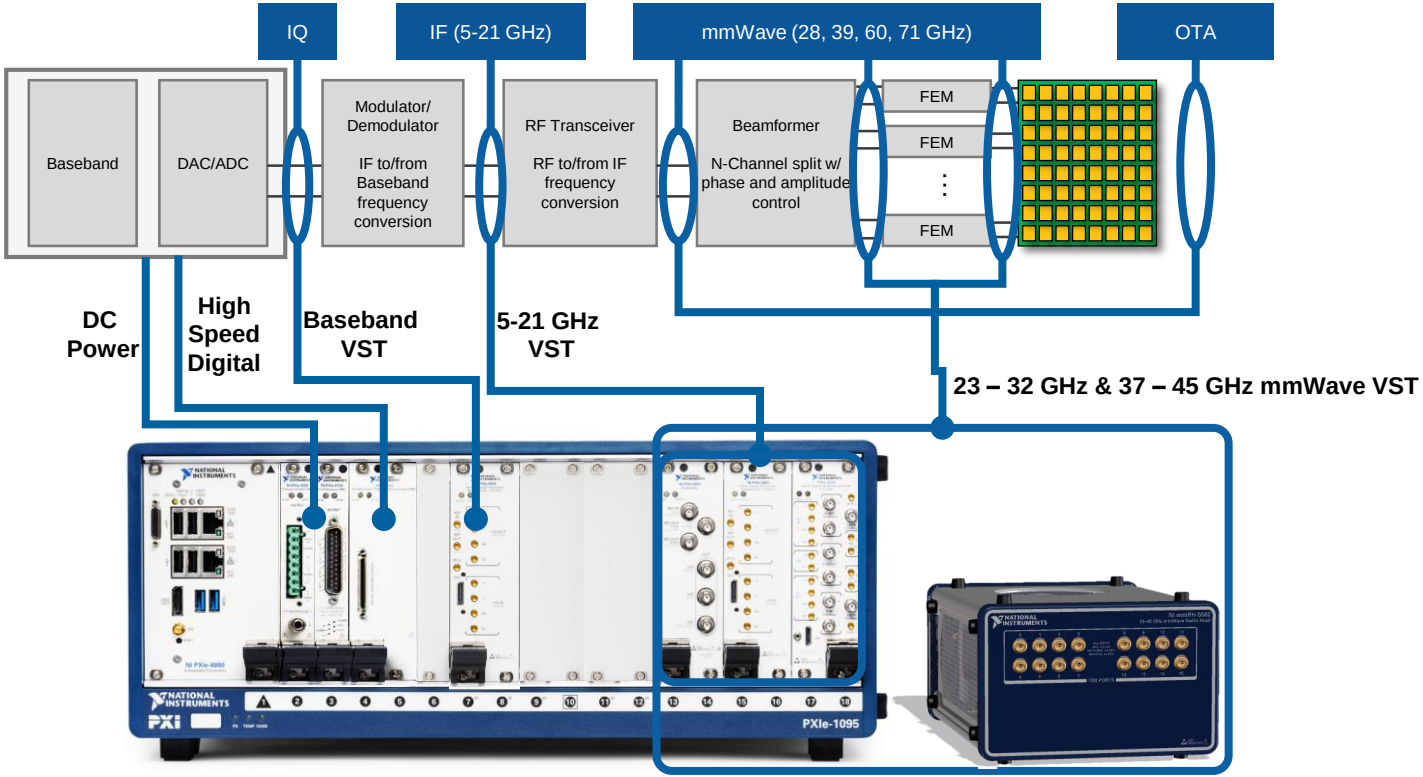
- Flexible test port configurations (Dig, BB, IF, RF)
- Targeted mmWave frequency extensions for flexible frequency scaling and port expansion
- Leveraged capital with common baseband/IF
- Simple integration to cabled and OTA configurations

mmWave IC Architectures Vary by Application

- Application level requirements dictate extent of functional integration in IC designs
- Early deployments will validate appropriate architectures and integration
- Test solutions must be flexible to scale by architecture and frequency



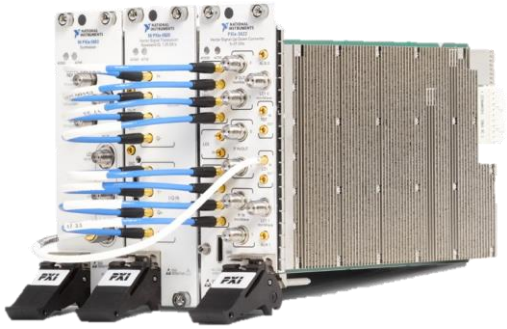
5G Measurements That Scale to Fit



Interface every point in your DUT with one system.

Two High-Performance PXI VST Instruments

5-21 GHz VST	
Frequency Range	5 to 21 GHz
Maximum Bandwidth	1 GHz
Maximum Output Power	+12 dBm
5G NR EVM (*preliminary*)	-44 dB



mmWave VST	
Frequency Range	23 – 32 GHz / 37 – 45 GHz
Maximum Bandwidth	1 GHz
Maximum Output Power	+17 dBm
5G NR EVM (*preliminary*)	-41 dB

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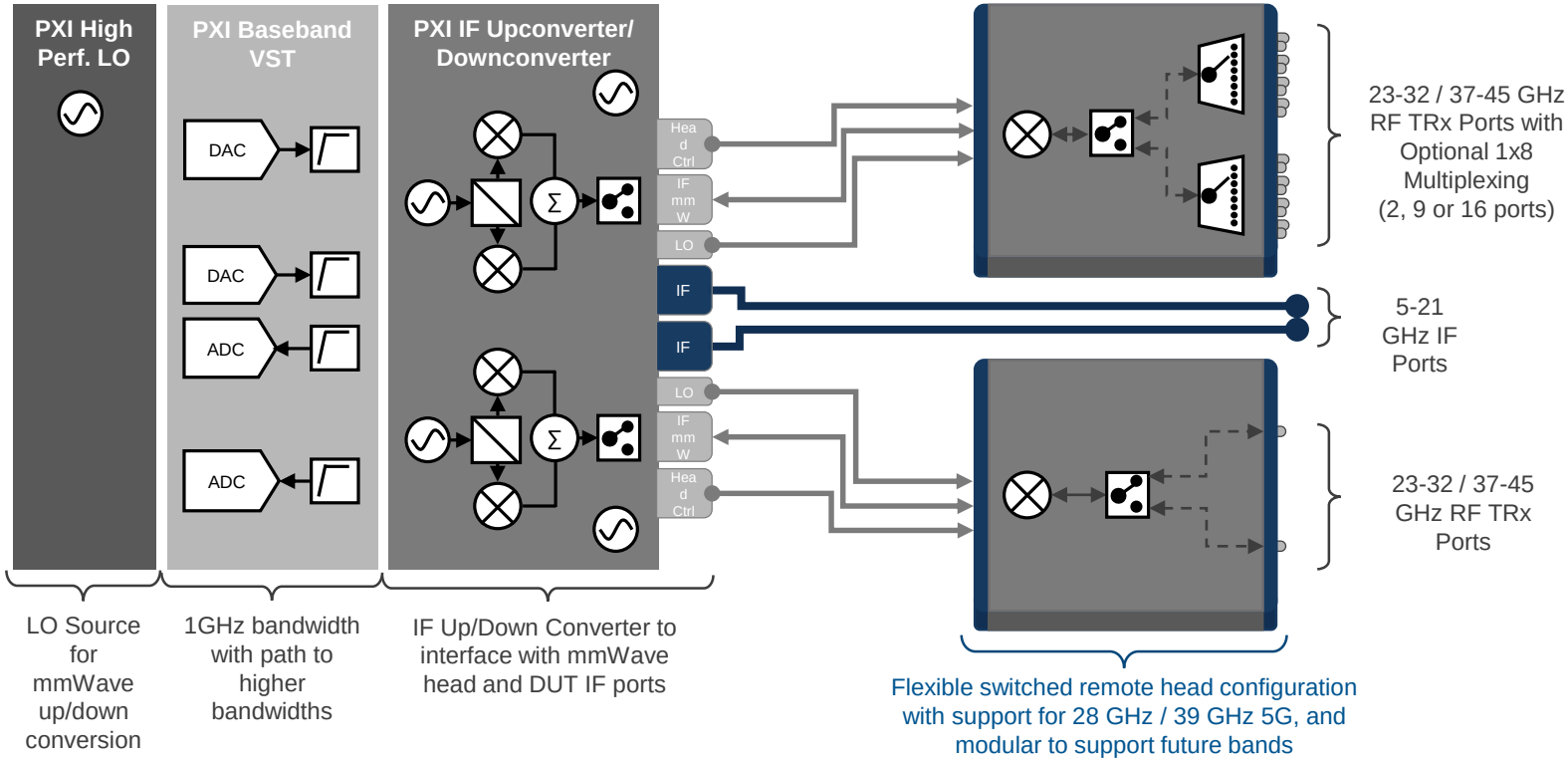
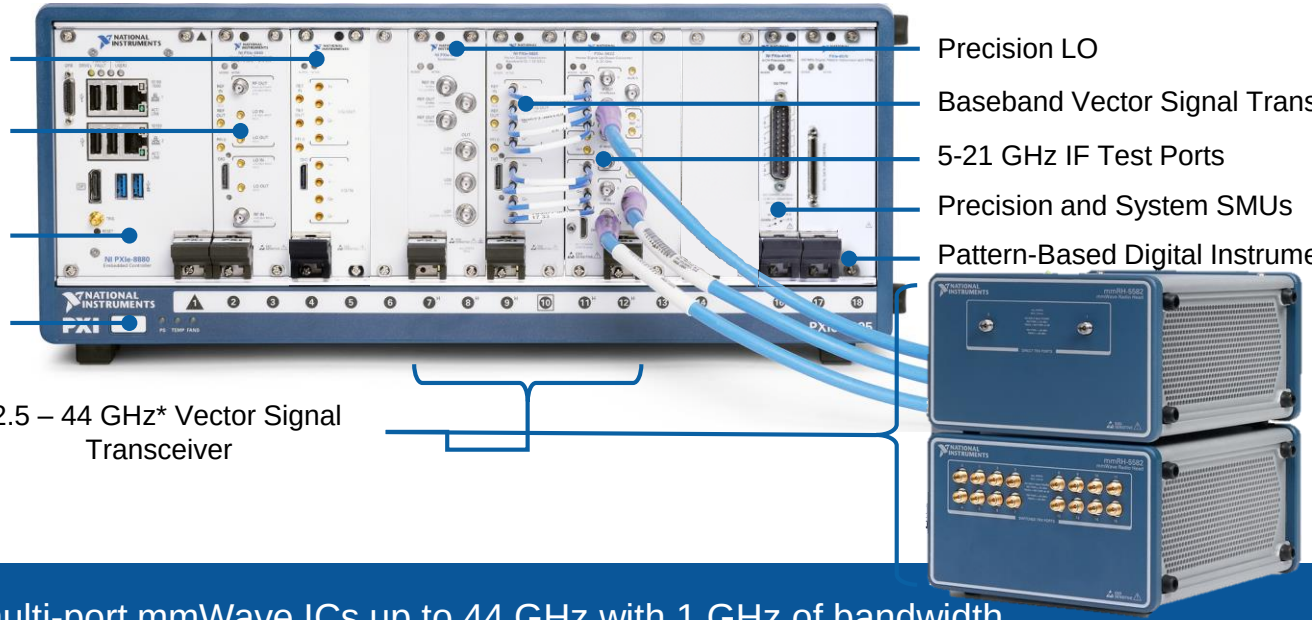
mmWave VST Architecture

Modular system architecture scales with evolving performance, configurations and standards



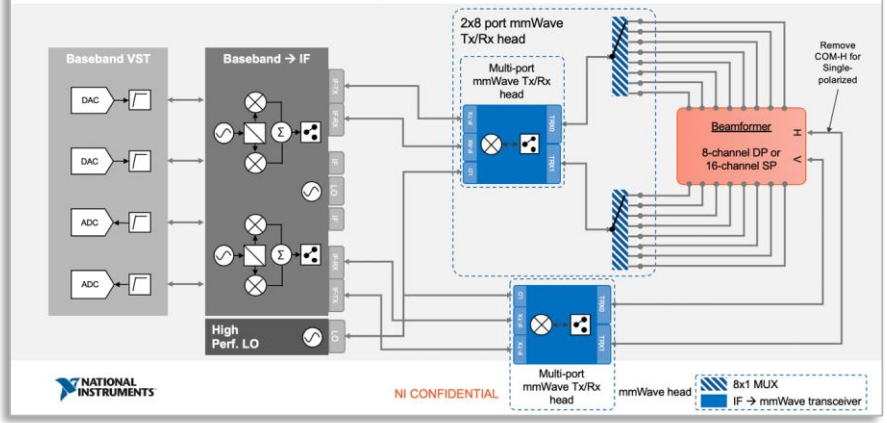
RFIC Validation Test Solution for >6 GHz RFICs



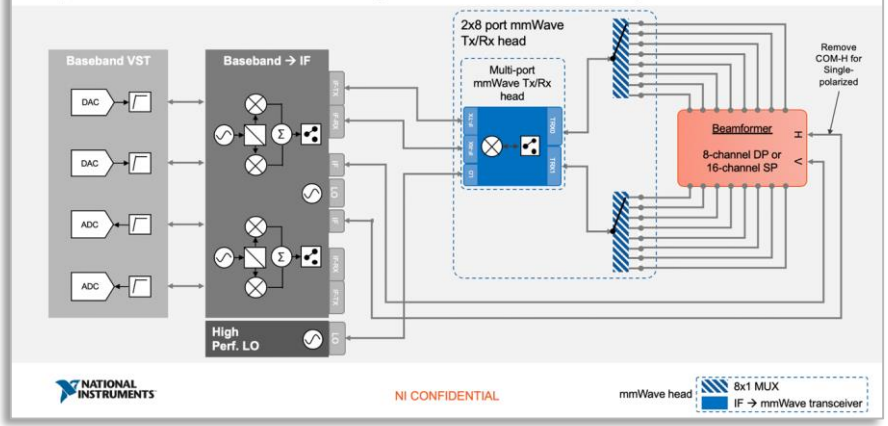
- Characterize multi-port mmWave ICs up to 44 GHz with 1 GHz of bandwidth
- Generate and analyze standard-compliant 5G NR mmWave waveforms
- Evaluate device performance under multiple Digital Pre-distortion models
- Synchronize MIPI RFFE DUT control with analog measurements

*Frequency range differs for Tx and Rx:
- Tx frequency range: 22.5 – 31.3 GHz / 37 – 44 GHz
- Rx frequency range: 22.5 – 44 GHz

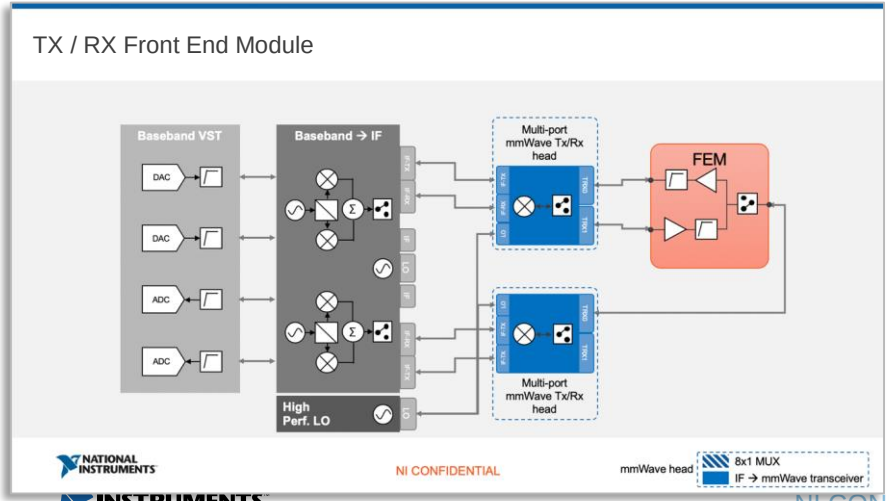
Up to 8-ch – Dual Polarized or 16-ch Single Polarized RF-RF Phased Array



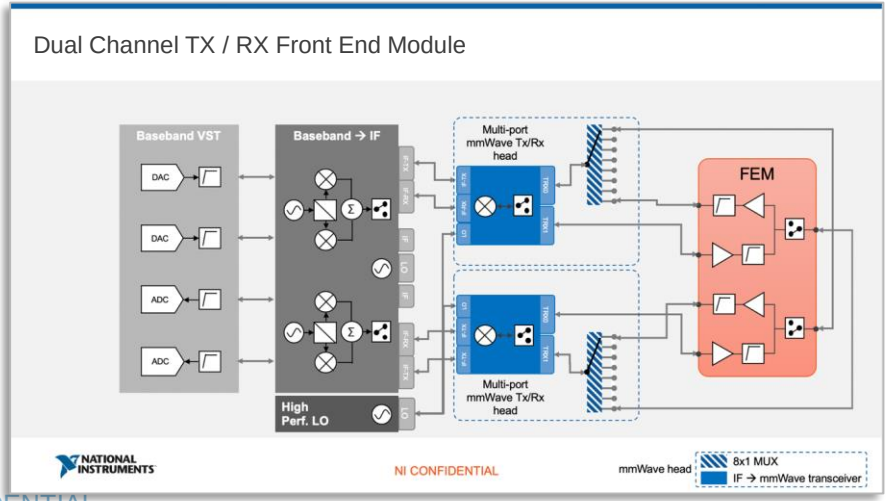
Up to 8-ch – Dual Polarized or 16-ch Single Polarized IF-RF Phased Array



TX / RX Front End Module



Dual Channel TX / RX Front End Module



Common Solution from Characterization Lab to ATE

System Highlights

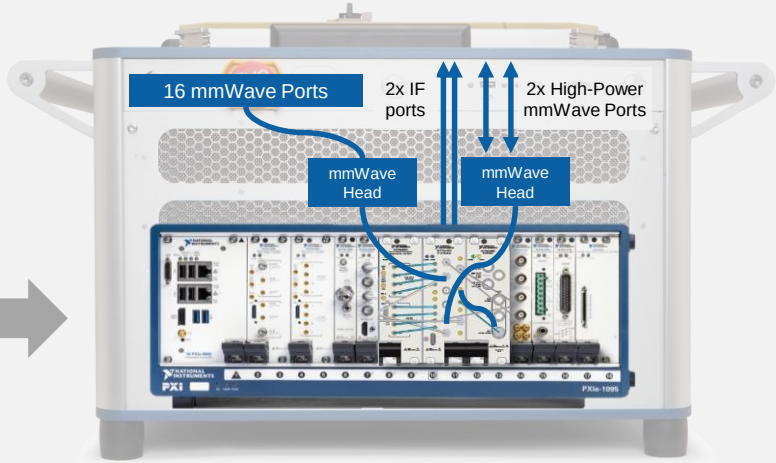
- Identical signal chain
- Identical RFmx measurement software
- Scales with DUT needs
  - Software upgrades with evolving wireless standards
  - Modular mmWave heads for new bands

5G mmWave Characterization System

mmWave heads with Dual 8-Port Solid State Switch

PXI System with mmWave VST

5G mmWave Production ATE



PXI Simplifies Data Correlation Through Standardization

PXI, LabVIEW, TestStand

STS Standardized Docking and Cabling Interface

NI PXI

NI ATE Core Configurations

NI STS T1

NI STS T2

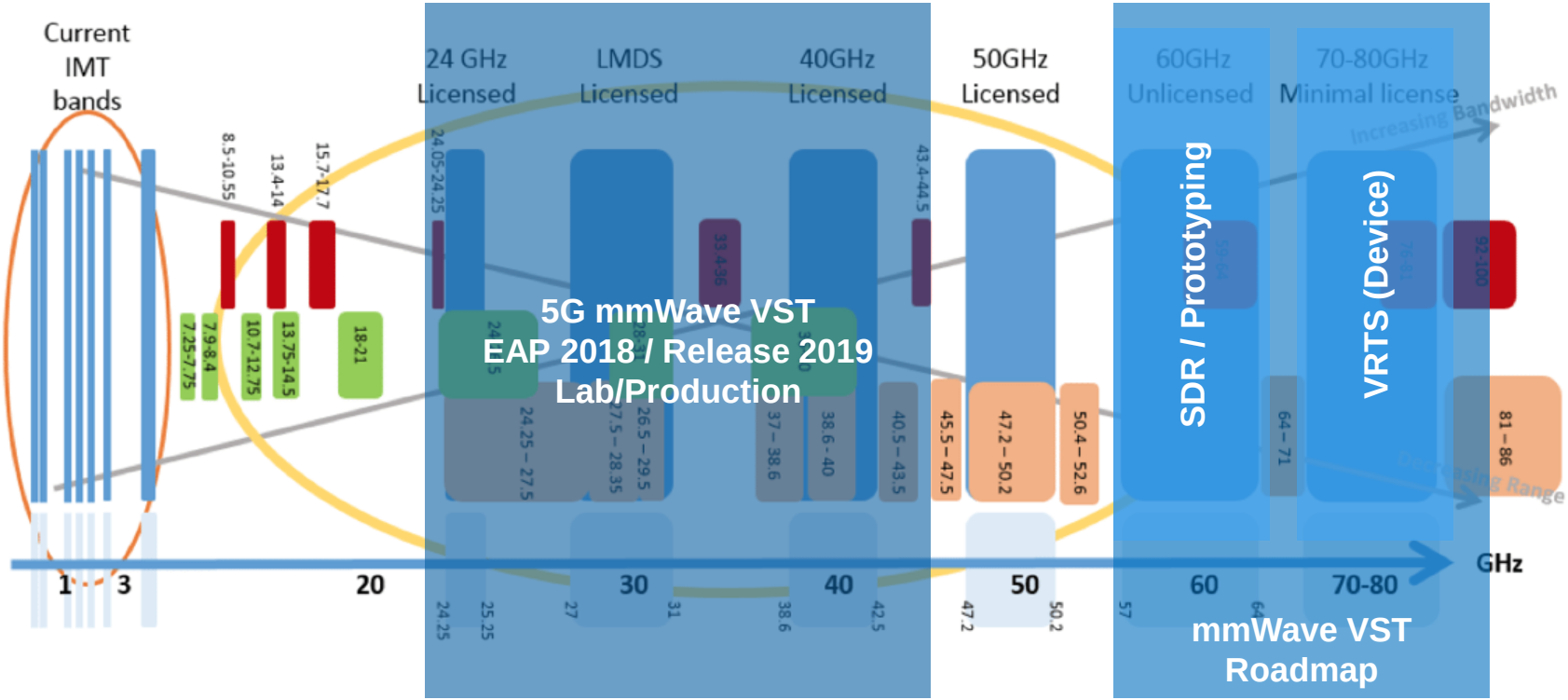
NI STS T4

Typical for Characterization

Typical for Production

NATIONAL INSTRUMENTS

NI's mmWave Band coverage



RF Measurement Software

NI RF Test Software Offerings

RFmx General Purpose
- Waveform Creator
- SpecAn
- Demod
- Noise Figure

RFmx Cellular
- 5G NR
- LTE/LTE-A/LTE-A Pro, NB-IoT/eMTC
- W-CDMA/HSPA/HSPA+
- GSM/EDGE/EDGE+
- TD-SCDMA, cdma2000, EV-DO

Connectivity Test Toolkits
- WLAN 802.11a/b/g/j/p/n/ac/ax
- WLAN 802.11af/ah
- Bluetooth
- FM Radio

Partner Toolkits
- ZigBee, Z-Wave, Wi-Sun
- UWB
- GNSS
- Digital Video Broadcast
- Base Station Test
- XM

RFIC Test Software
- Envelope Tracking (ET)
- Digital Predistortion (DPD)
- Power-Added Efficiency (PAE)
- Dynamic EVM (DEVM)

Measurement Acceleration
- FPGA Power Servo
- Fast ACP
- User FPGA Extensions

Why NI is Different
- ✓ Best in class measurement speeds
- ✓ No RF waveform encryption
- ✓ Transferrable licenses

NATIONAL INSTRUMENTS

NI-RFmx: Soft Front Panels and Automation API for RF Measurements

ACCURATE

High-performance measurements for 5G New Radio, LTE-A Pro, and more

Optimized measurement performance correlated to traditional box instruments

FAST

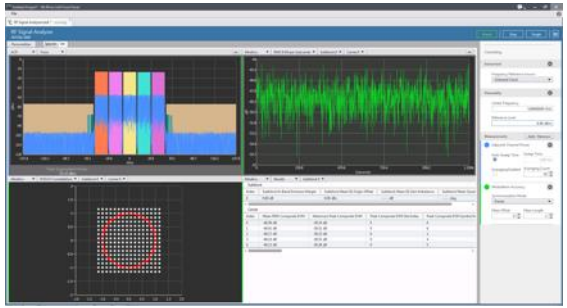
Industry-leading measurement speeds using the latest processor technologies

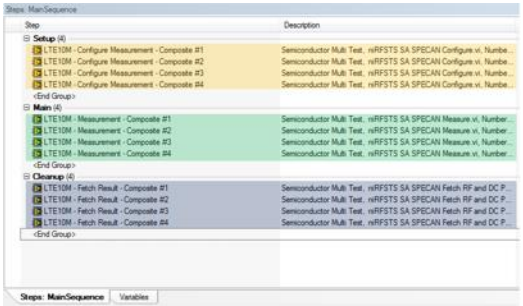
Easy-to-program multi-threaded measurements for test time reduction

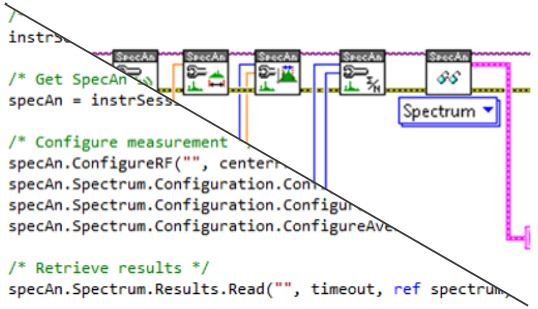
SIMPLE

Measurement-centric API with single-session interoperability

Hundreds of automation examples in LabVIEW, C/C++, and .NET







NATIONAL INSTRUMENTS LabVIEW

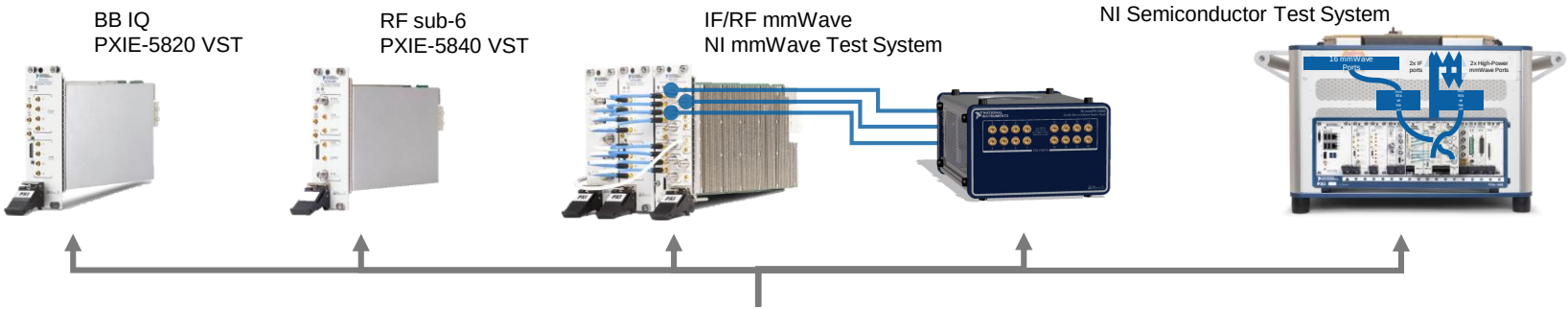
TestStand™

C/C++

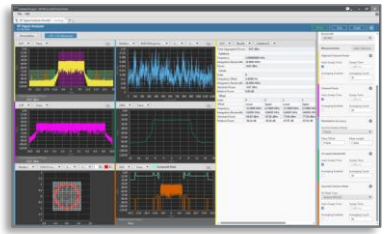
Microsoft® .NET

NATIONAL INSTRUMENTS™

NI-RFmx: Single Measurement Driver for Any Test Interface



NI-RF*mx*

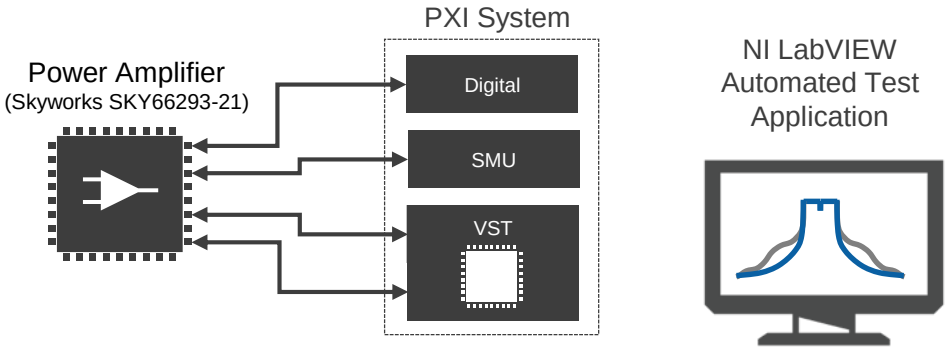


NATIONAL INSTRUMENTS LabVIEW

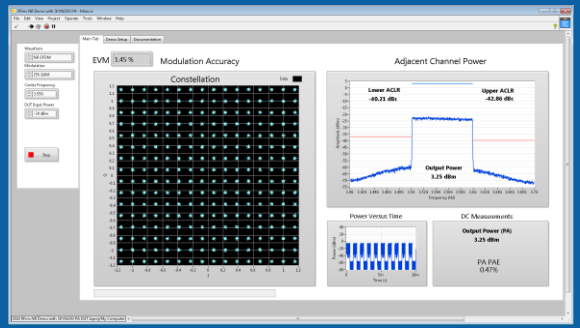
C/C++

Microsoft® .NET

Demo: Sub-6 5G/NR PA Test



Demo: Testing a PA Using 5G NR Waveforms



- LabVIEW-based example application for device validation
- Includes 5G NR and LTE waveform generation
- Measures EVM, ACP, and PAE of the DUT

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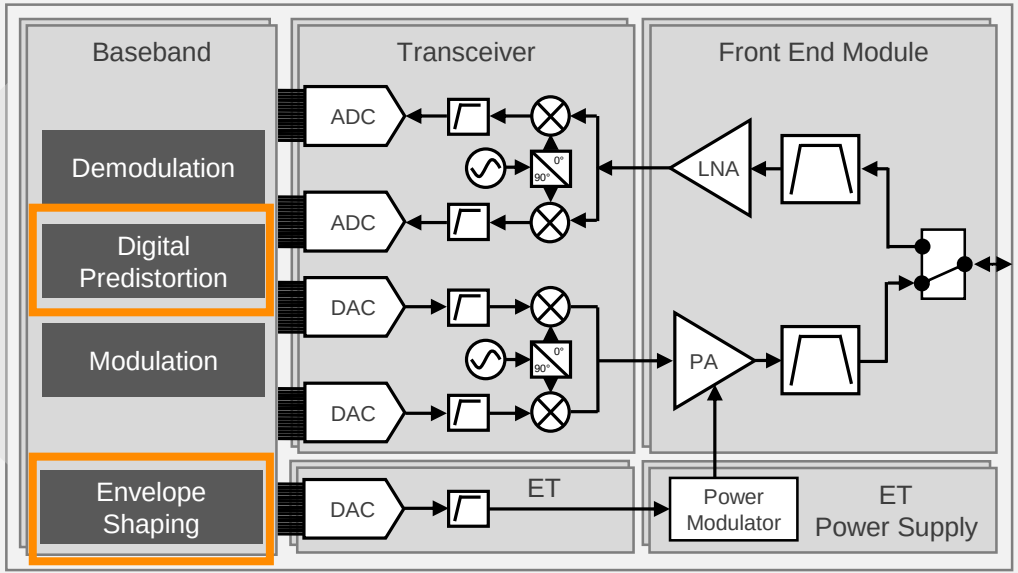
PA/FEM Test

Front-End Modules in a Modern Radio

- Multimode, multiband
- APT and ET capable
- Integrated digital controller

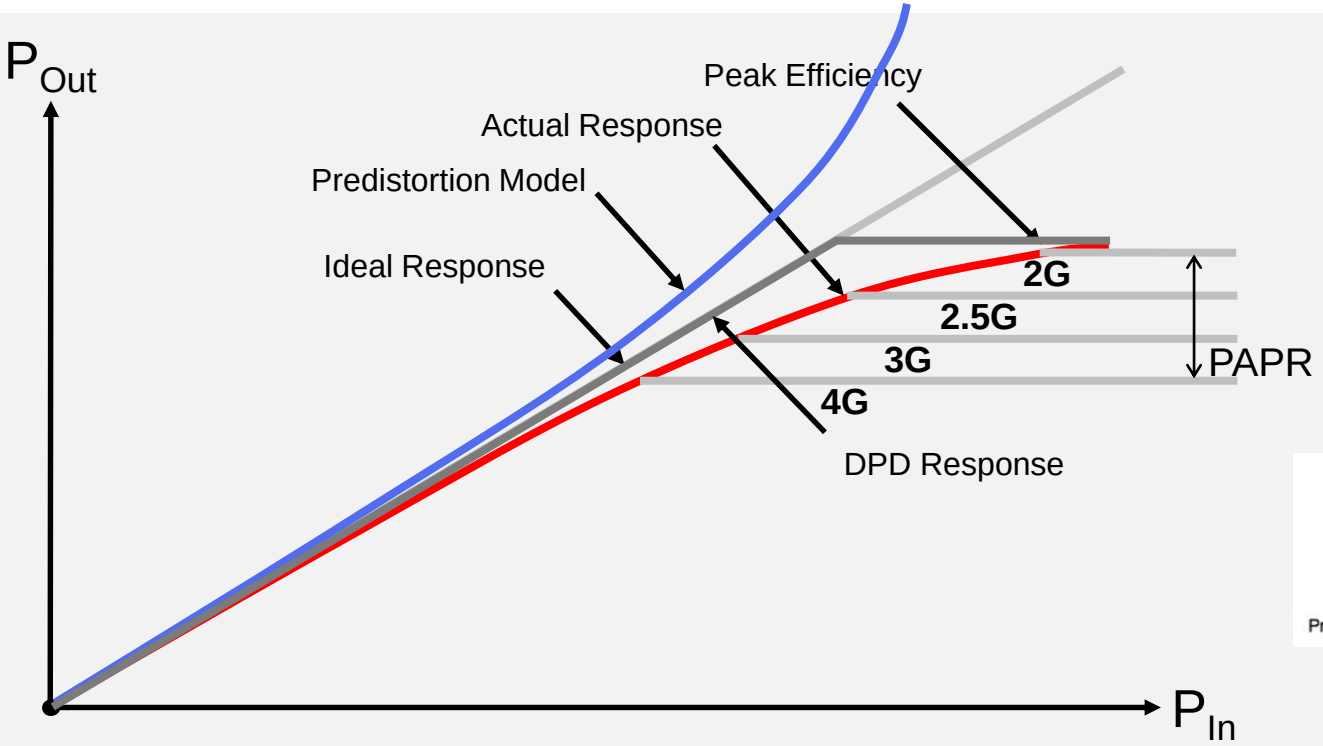
Modern Radio Design



NATIONAL INSTRUMENTS

DPD - Digital Predistortion

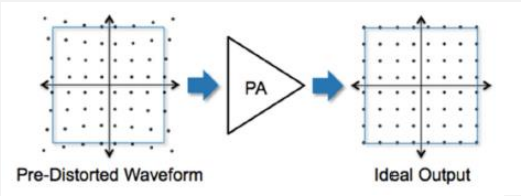
Effects of Nonlinearity and Digital Predistortion (DPD) on High PAPR



A nonlinear gain response introduces amplitude (AM-AM) and phase (AM-PM) distortion to signals with changing power over time

This distortion increases for signals with higher Peak to Average Power Ratio (PAPR)

If the nonlinear response of a PA is known, we can pre-distort the input signal so that the resulting amplified signal is undistorted



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PA Linearization Methods

Simple Lookup Table (LUT)

- Approach: Measure AM-AM/PM and apply numerical inverse
- Benefit: Computational simplicity
- Drawback: Limited bandwidth for PA's with memory effects

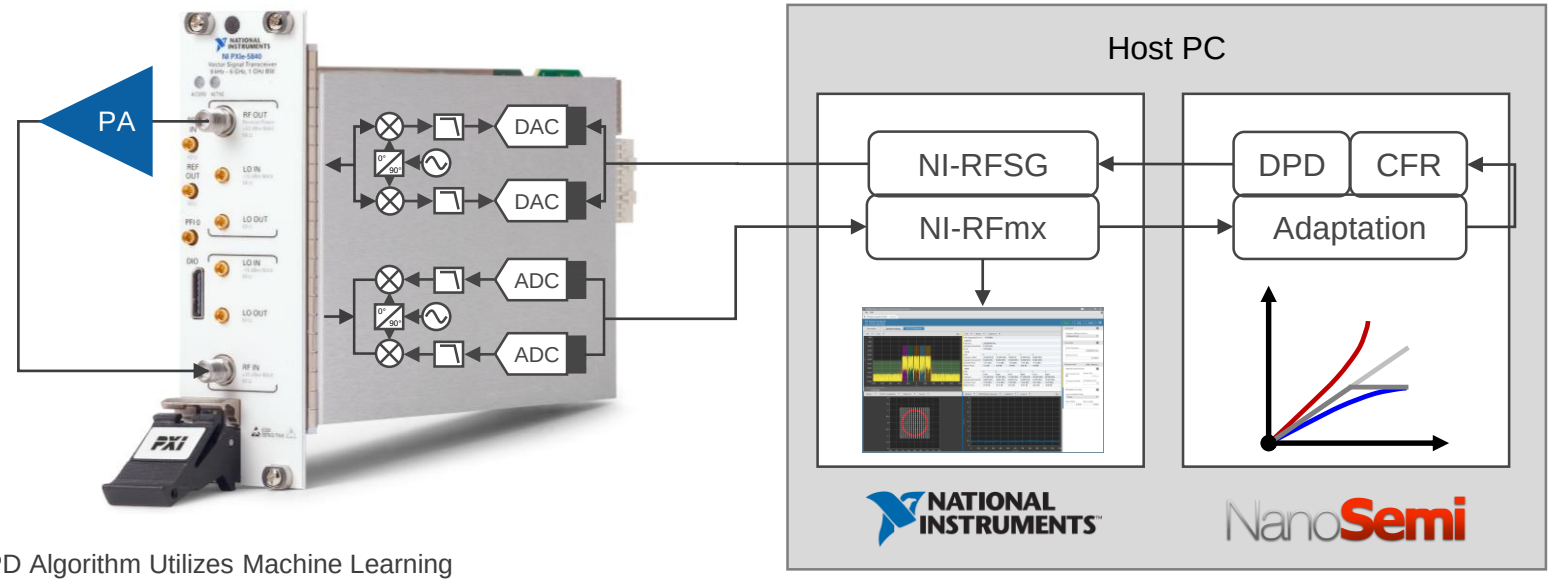
Memory Polynomial Model

- Approach: Correlate and solve for pre-distortion memory matrix
- Benefit: Significant EVM & ACP benefit when used with wideband signals such as LTE-A and 802.11ac
- Drawback: Computational complexity

Generalized Memory Polynomial

- Approach: MPM expansion to correct high memory effects with additional lead and lag terms that model the correlation between the signal and its time shifted envelope
- Benefit: Improved MPM performance for PAs exhibiting high memory effects
- Drawback: Computational complexity

NI + NanoSemi High Performance DPD Linearization



- DPD Algorithm Utilizes Machine Learning
- Corrects up to 400 MHz signal bandwidth with NI VST, with contiguous or non-contiguous carriers for 5G NR, LTE-Advanced, and Wi-Fi
  - Improves EVM by up to 30 dB
  - Corrects ACLR by up to 40 dB
  - Increase power efficiency by up to 3x
- Rapid adaptation and convergence
- Automatically characterizes and models signal chain including PA

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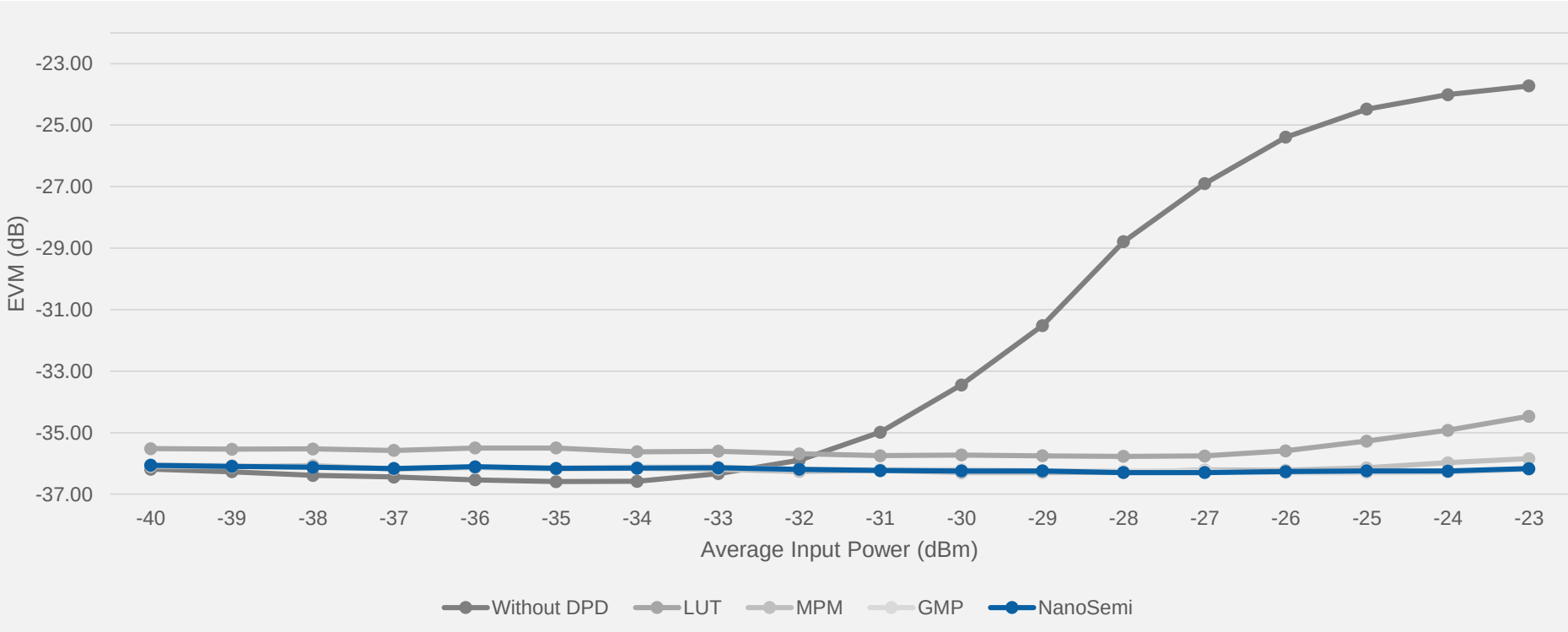
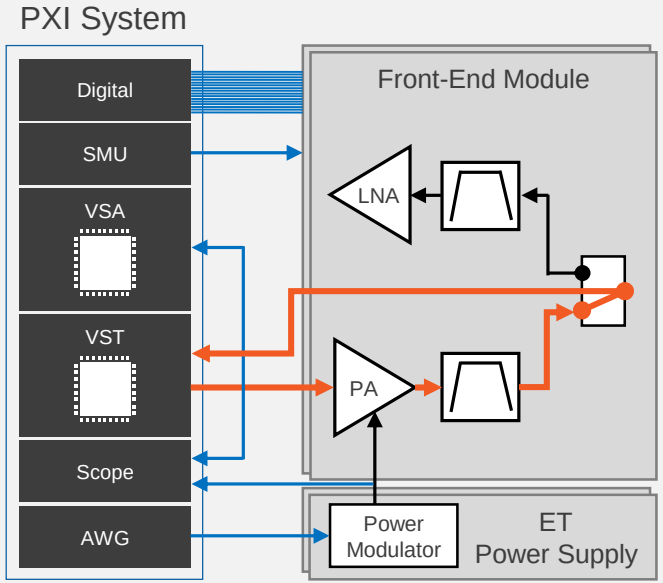
DPD Effect on Error Vector Magnitude



NI Front-End Module Test With DPD

- VST with 1 GHz instantaneous generation and analysis bandwidth
- Free NI-RFmx SpecAn with LUT, MPM, and GMP DPD models
- Free RFIC Test Software with DPD automation examples

1. Generate reference waveform and acquire distorted waveform
2. Create pre-distortion model by comparing reference waveform to distorted waveform
3. Apply DPD to reference waveform using pre-distortion model
4. Generate pre-distorted waveform and make measurements



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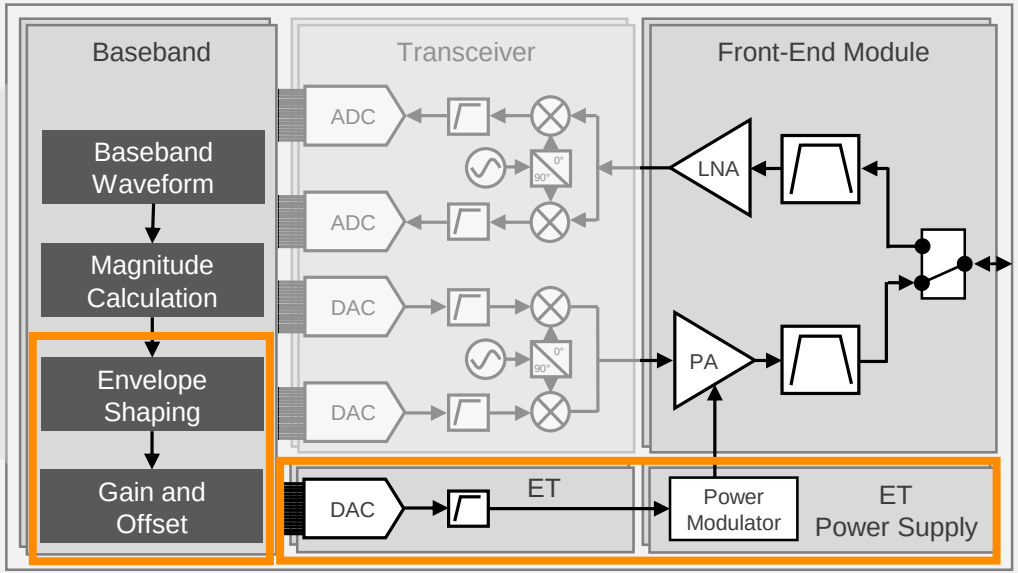
Envelope Tracking (ET)

Baseband Processor in Envelope Tracking Scenario

- Envelope based on baseband absolute magnitude
- Needs to be shaped and adapted to PA's efficiency curve
- Needs to account for envelope tracking power supply transfer function

Modern Radio Design



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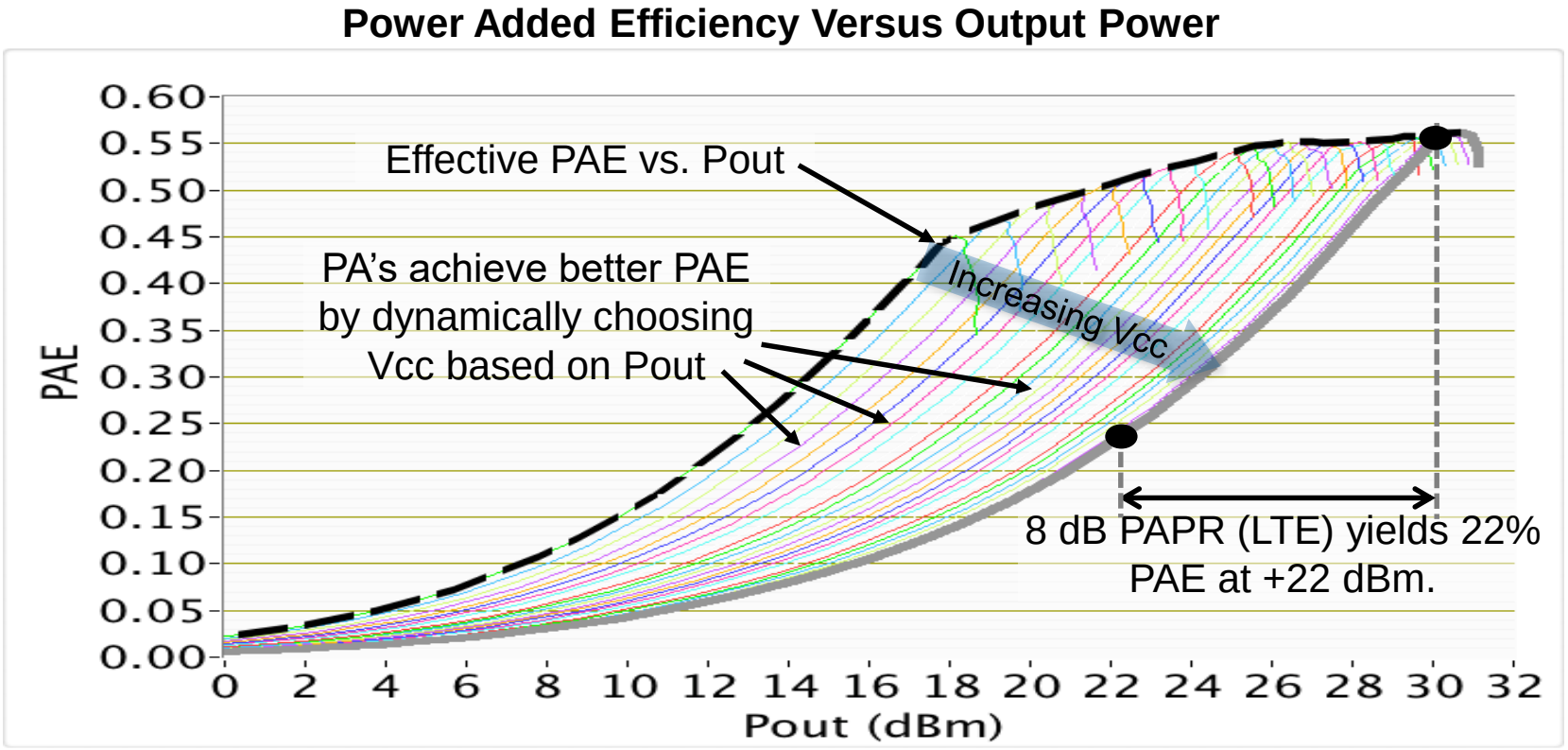
Peak PAE is Dependent on VCC



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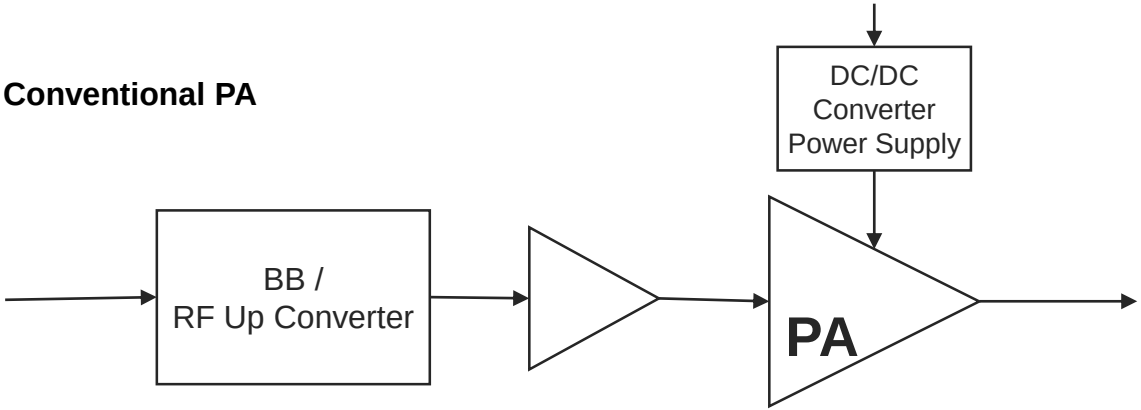
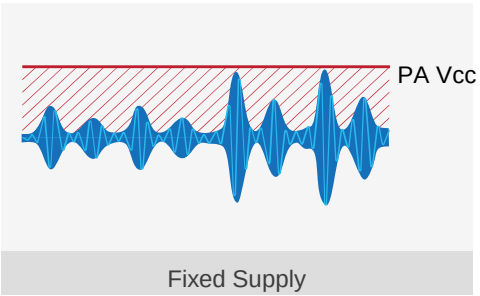
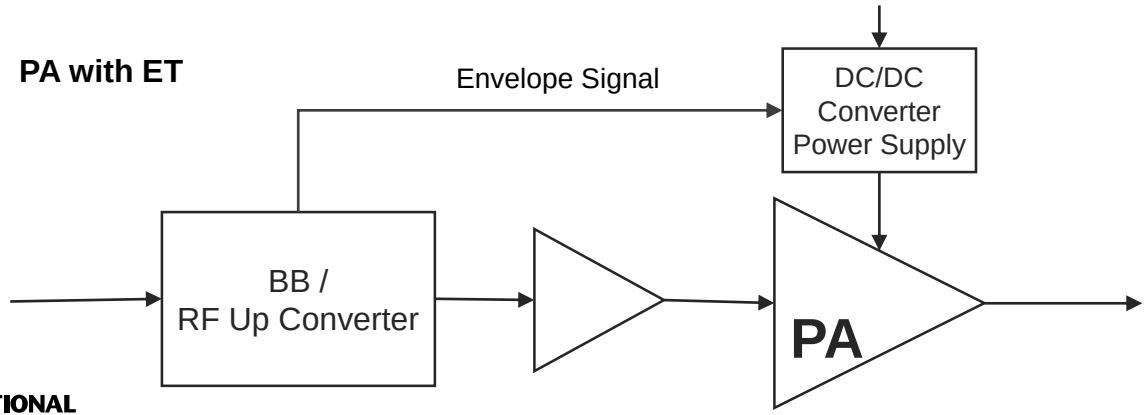
Envelope Tracking Principle (ET)

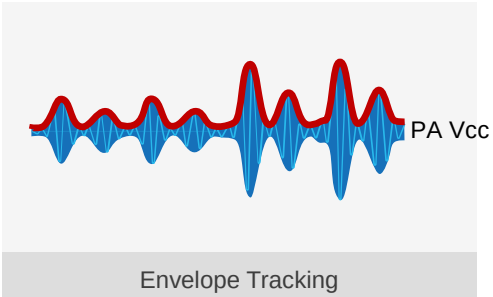
Conventional PA





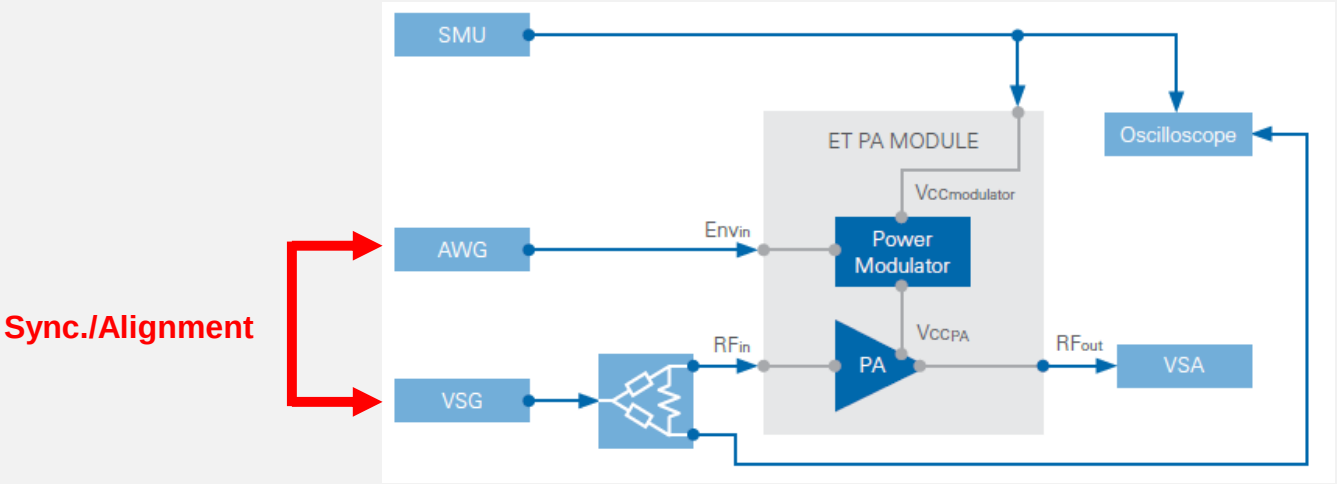
PA with ET



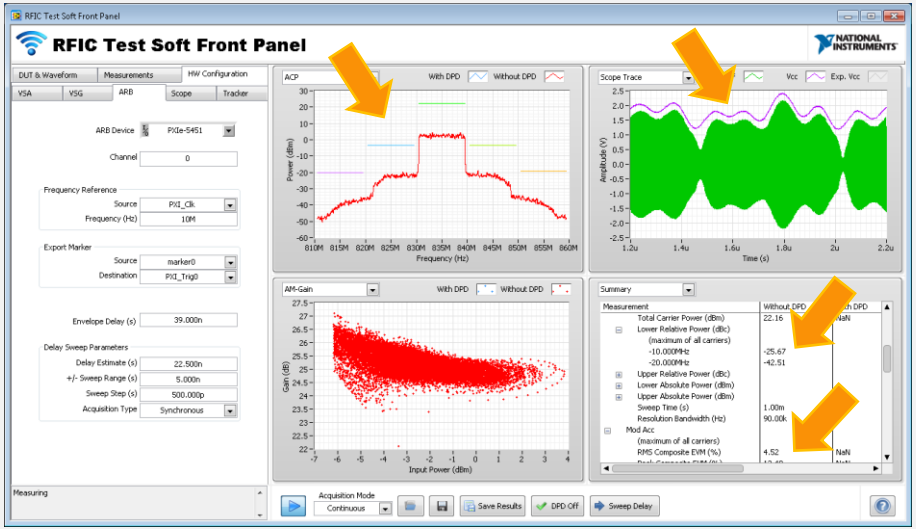


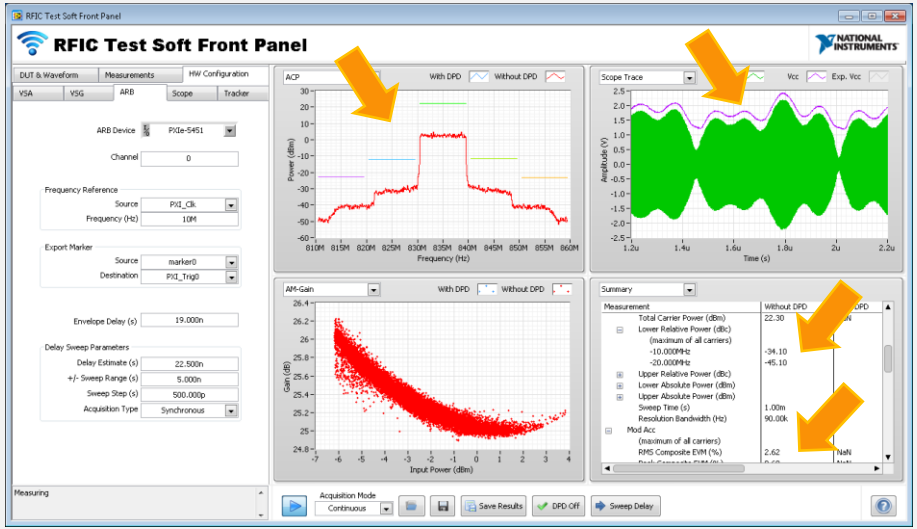
Typical PA Test under DPS Conditions

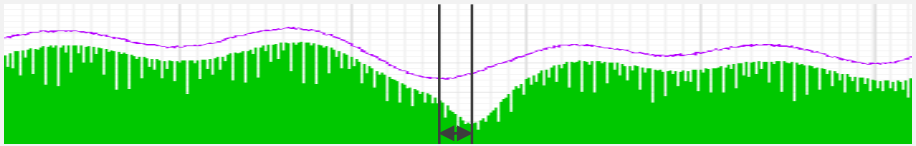
- Linearization (GMP)
- Synchronization
- Alignment of supply voltage with RF stimulus signal

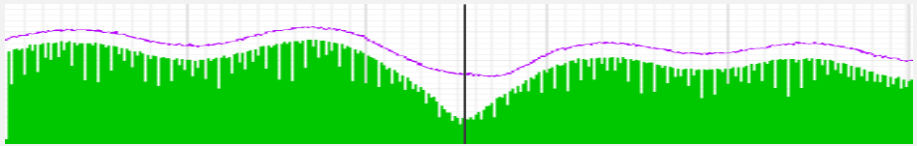


How Much Does Synchronization Matter?









20 ns misalignment → 4.5% EVM

<1 ns misalignment → 2.6% EVM

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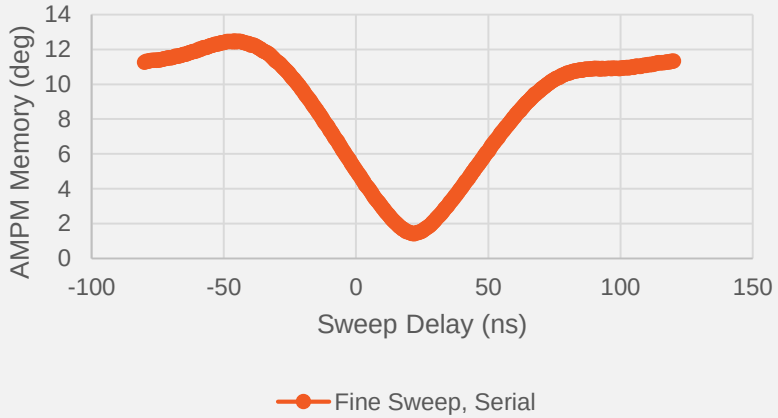
* Typical synchronization performance is < 100 ps due to N-TClk

Delay Sweeps

- Because propagation delays depend on device paths and test parameters, alignment is generally done before each test case
- Identify ideal timing alignment by the sweeping delay between RF and envelope to find the point of maximum performance (ACLR, EVM, or RMS memory)
- FPGA delay adjustment, NI-RFmx overlapped measurements, and optimized sweep routines can reduce measurement time

Fine Sweep (9.0 sec serial, 3.5 sec pipelined)



Coarse, Then Fine Sweep (0.85 sec pipelined)

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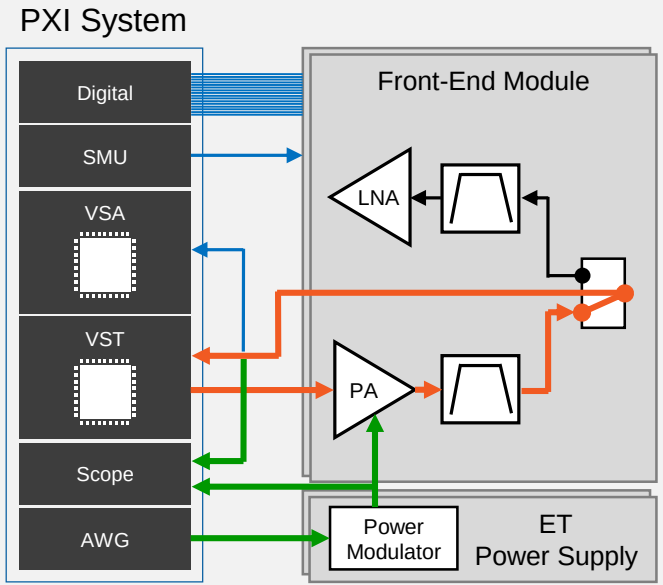
NI Front-End Module Test With Envelope Tracking

- <1 ns out-of-the-box synchronization between RF and envelope
- On-the-fly RF and envelope delay adjustment
- Free RFIC Test Software with envelope tracking examples

1. Create envelope waveform from pre- or post-DPD RF waveform
2. Generate synchronized RF and envelope waveforms
3. Find optimal delay between RF and envelope signals
4. Make measurements



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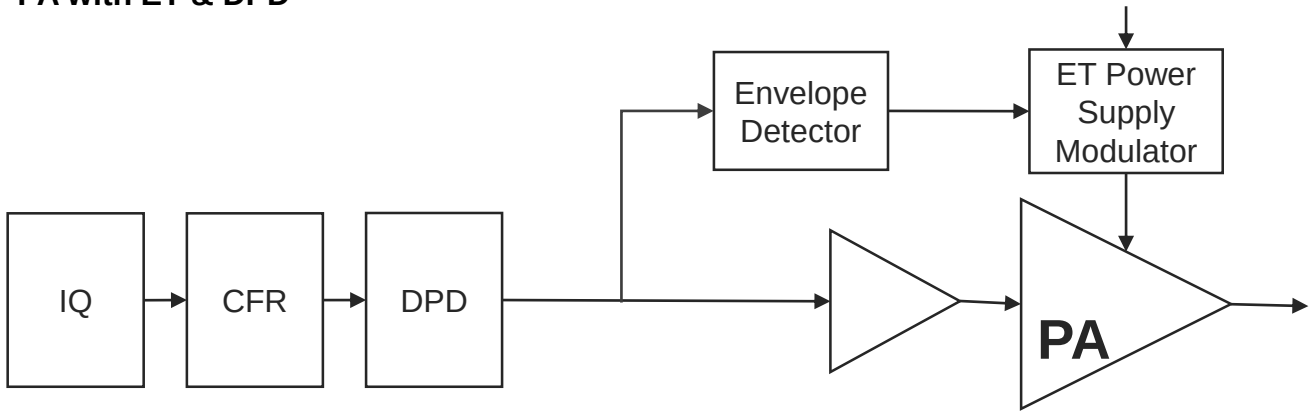
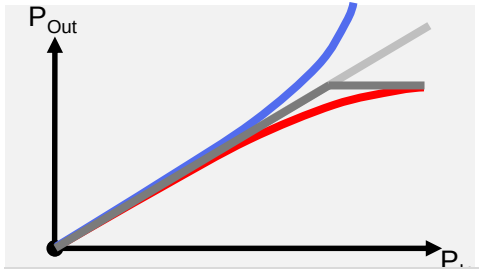
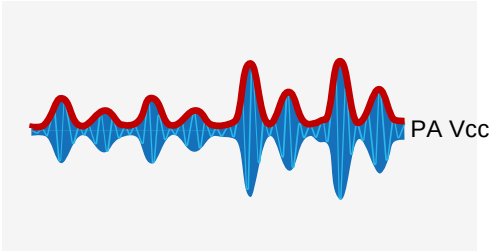
Combination of ET & DPD

PA with ET & DPD



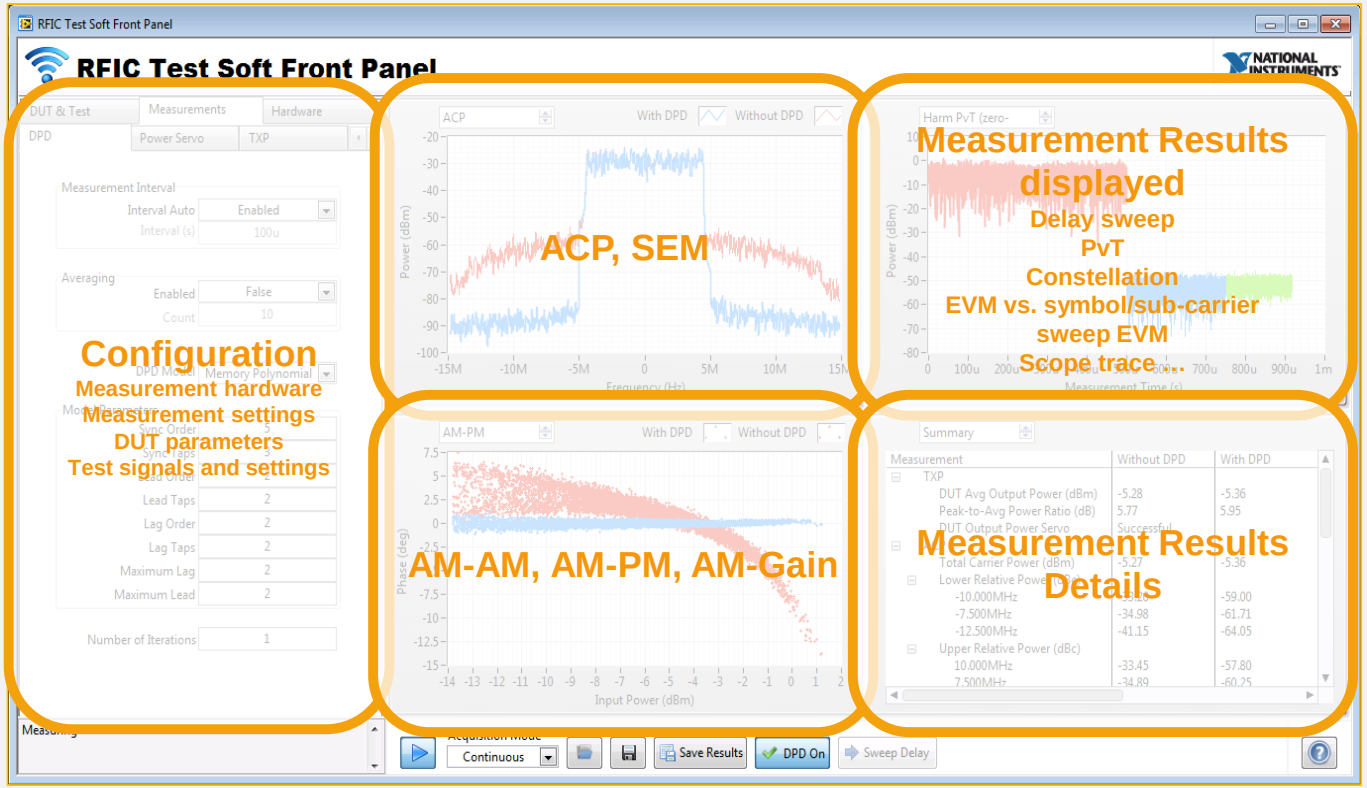


Digital Pre-Distortion



Envelope Tracking

RFIC Test Software



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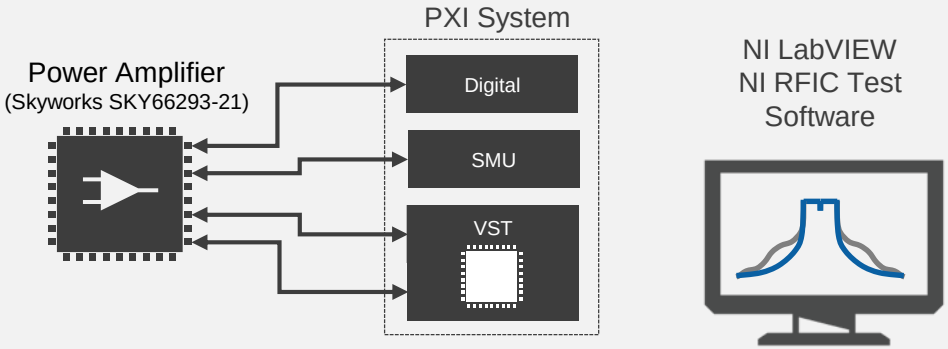
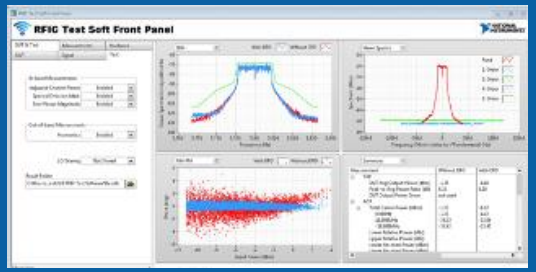
Demo: Sub-6 5G/NR PA Test with DPD





Demo: Power Amplifier (PA) Test With DPD

- Based on RFIC Test Software
  - Purpose-built soft front panel for RFIC test
  - Ideal for quick DUT validation while custom test app is in dev
- DPD examples for LTE and WLAN
- 3rd, 5th, or 7th Order predistortion on 80 MHz or 160 MHz WLAN signal

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OTA

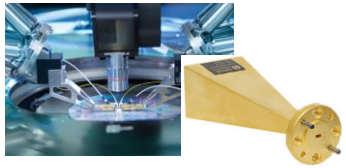
OTA Test Challenges

Building OTA Test Systems Entails Addressing…

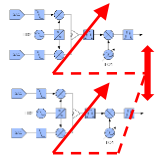
Measurement algorithms & speed

UID	Uncertainty source	Uncertainty value	Distribution of the probability	Di
	Stage 2: DUT measurement			
1	Positioning misalignment	0.50	Rectangular	
2	Measure distance uncertainty	1.00	Rectangular	
3	Quality of quiet zone (NOTE 2)	1.50	Actual	
4	Mismatch (NOTE 3)	1.30	Actual	
5	Absolute antenna gain uncertainty of the measurement antenna	0.00	Normal	
6	Uncertainty of the RF power measurement equipment (NOTE 4)	2.16	Normal	
7	Phase curvature	0.00	U-shaped	

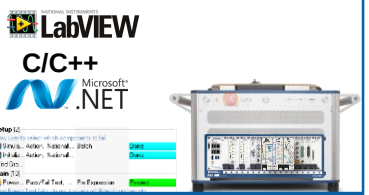
Measurement uncertainty budget



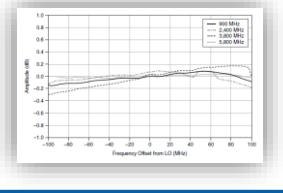
Fixtures, Probers, Antennas
(Accessories that affect cal.)



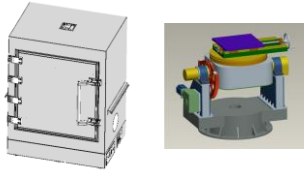
DUT calibration and adjustment



mmWave instrumentation



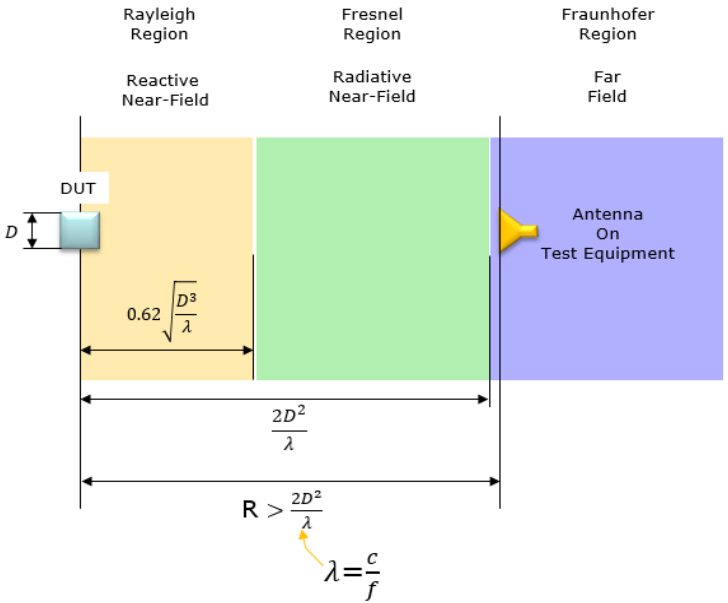
Test system calibration



Accessories
(Chambers and Positioners)

Customer education

Near Field (NF) and Far Field (FF)



Source: www.sharetechnote.com

Why Far Field:

- Field pattern in FF is more stable and predictable and less sensitive to small surrounding components
- Angular field distribution is essentially independent of the distance from the antenna and the radiation pattern can be approximated with spherical wave-fronts
- One can safely assume that the wave front going through the receiving antenna is almost planner

→ most of measurement can be done “easily” and reliably

- But other methods like IFF or NF make sense in case of larger objects like complete mobile phone, larger antenna array or the like, otherwise we have to deal with huge chambers incl. high path loss
- See also 3GPP TR 38.810, 5.3 Test method applicability

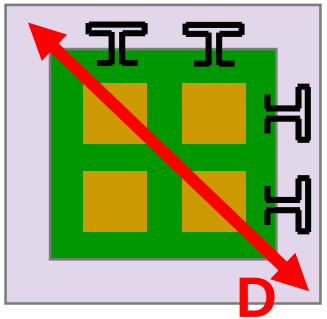
Far Field Distances and Free Space Path Loss

$R > 2D^2/\lambda$, $\lambda = c/f$

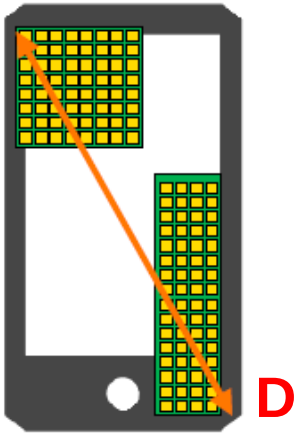
$FSPL = 20 \log_{10}(d) + 20 \log_{10}(f) + 20 \log_{10}(4\pi/c) - G_{Tx} - G_{Rx}$

D in m	Frequency in GHz	λ in m	FF Distance (R) in m	FSPL in dB
0,05	**28**	**0,0107**	**0,47**	**54,83**
0,10	28	0,0107	1,87	66.82
0,15	**28**	**0,0107**	**4,20**	**73,85**
0,20	28	0,0107	7,47	78,85
0,25	28	0,0107	11,67	82,72
0,30	28	0,0107	16,81	85,89
0,05	**39**	**0,0077**	**0,65**	**60,52**
0,10	39	0,0077	2,60	72,56
0,15	**39**	**0,0077**	**5,85**	**79.60**
0,20	39	0,0077	10,41	84,61
0,25	39	0,0077	16,26	88,48
0,30	39	0,0077	23,42	91,65

d = Distance between the antennas.
f = Frequency
G (Tx) = The Gain of the Transmitting Antenna.
G (Rx) = The Gain of the Receiving Antenna.
c = Speed of light in vacuum (Meters per Second)
D = DUT diameter
λ = Wave length



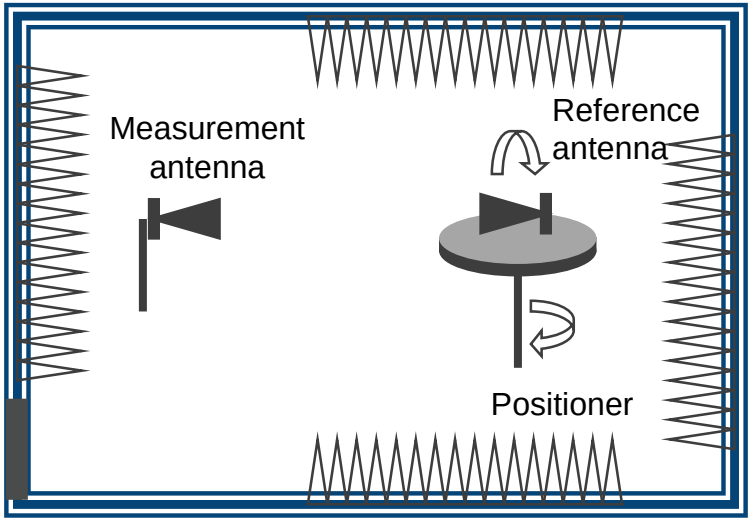
D < 0.05 m



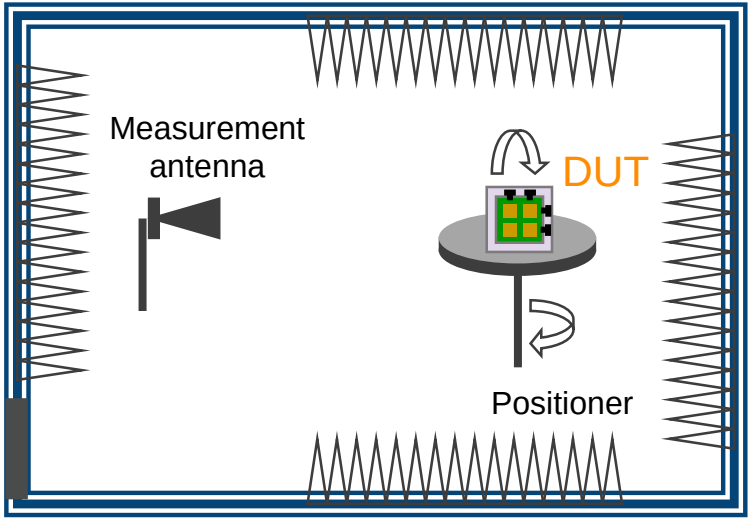
D ~ 0.15 m

OTA Uncertainties

Stage 1: Calibration measurement
Measurement Equipment (system cal uncertainty)
Phase centre offset of calibration
Reference antenna: absolute gain uncertainty
Reference Antenna positioning misalignment
Positioning misalignment of Ref and Cal Antennas
Pointing missalignment of Ref and Cal Antennas
Influence of cross-polarization distortion
Quality of Quiet Zone
Reference antenna feed cable loss measurement



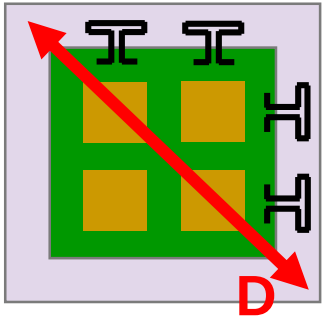
Stage 2: DUT measurement
Measurement Equipment (system cal uncertainty)
Positioning misalignment
Measurement Distance
Phase Curvature
Mismatch
Signal Analyzer Absolute Uncertainty
Reference antenna: absolute gain uncertainty
Influence of cross-polarization discrimination
Quality of Quiet Zone
Modulation Error (flatness, others)



OTA Measurements

Measurements

- Antenna Measurements
  - Effective Isotropic Radiated Power (EIRP)
  - Total Radiated Power (TRP)
- 3GPP Measurements
  - Output Power (EIRP)
  - Adjacent Channel Leakage Ratio (TRP)
  - Spectral Emissions
  - Modulation Accuracy
  - Sensitivity
- RFFE Measurements
  - P1dB
  - Intermodulation
  - Noise Figure
  - DPD

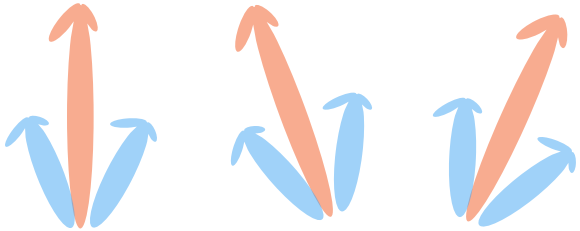


In process of definition

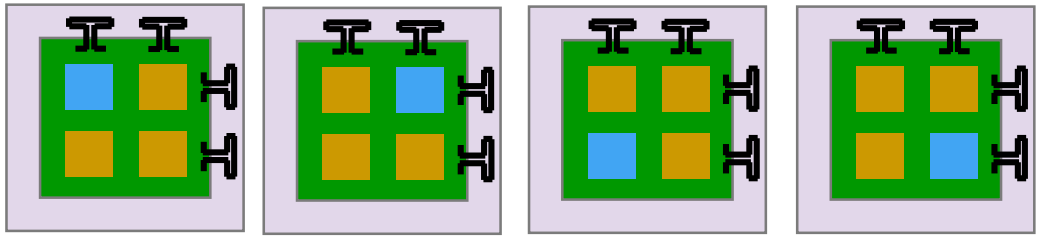
Might be of interest as well

Antenna Array Tx Testing Procedure

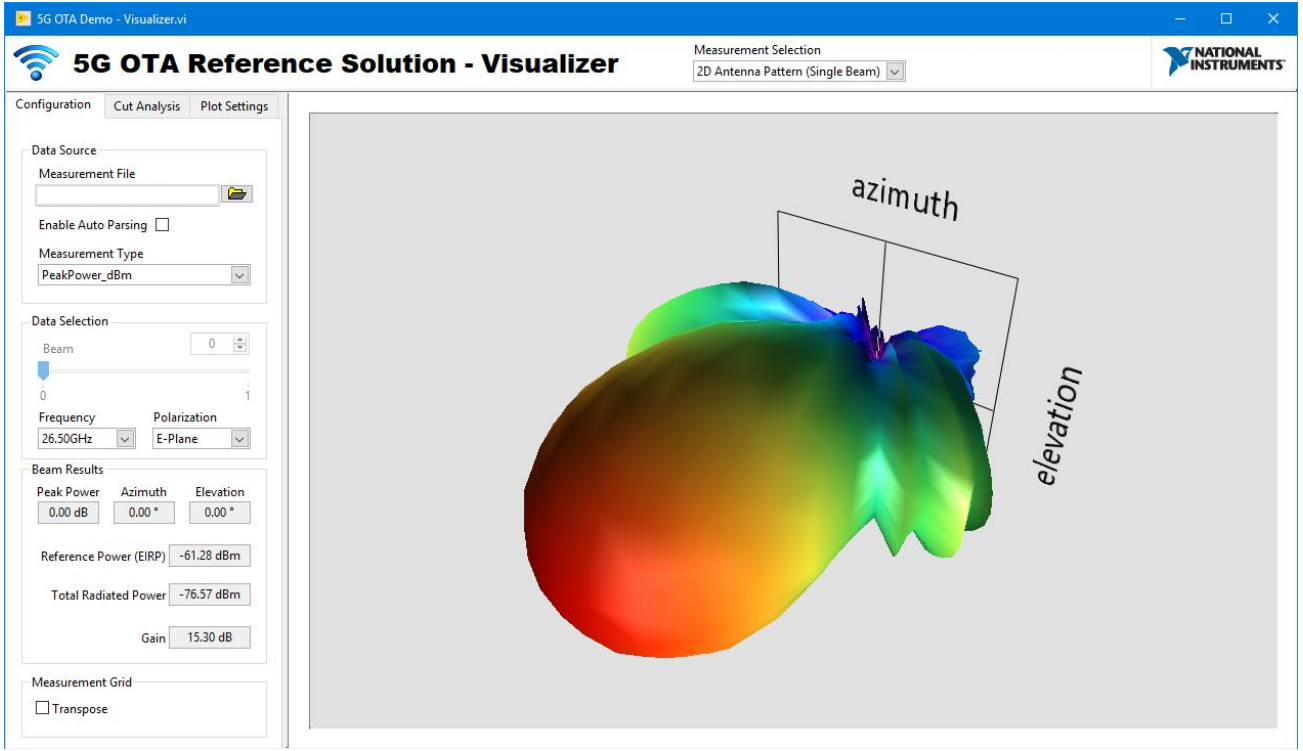
- Spatial Scanning, Beam #1 … N, measurement of joint
  - EVM
  - ACLR
  - OOB
  - X-point antenna gain



- Sequential Test of each transceiver + antenna patch #1 … M
  - EVM
  - ACLR
  - OOB
  - Individual antenna gain



Spatial Measurements – 3D Radiation Pattern



Shows how power is distributed in space around the DUT/AUT

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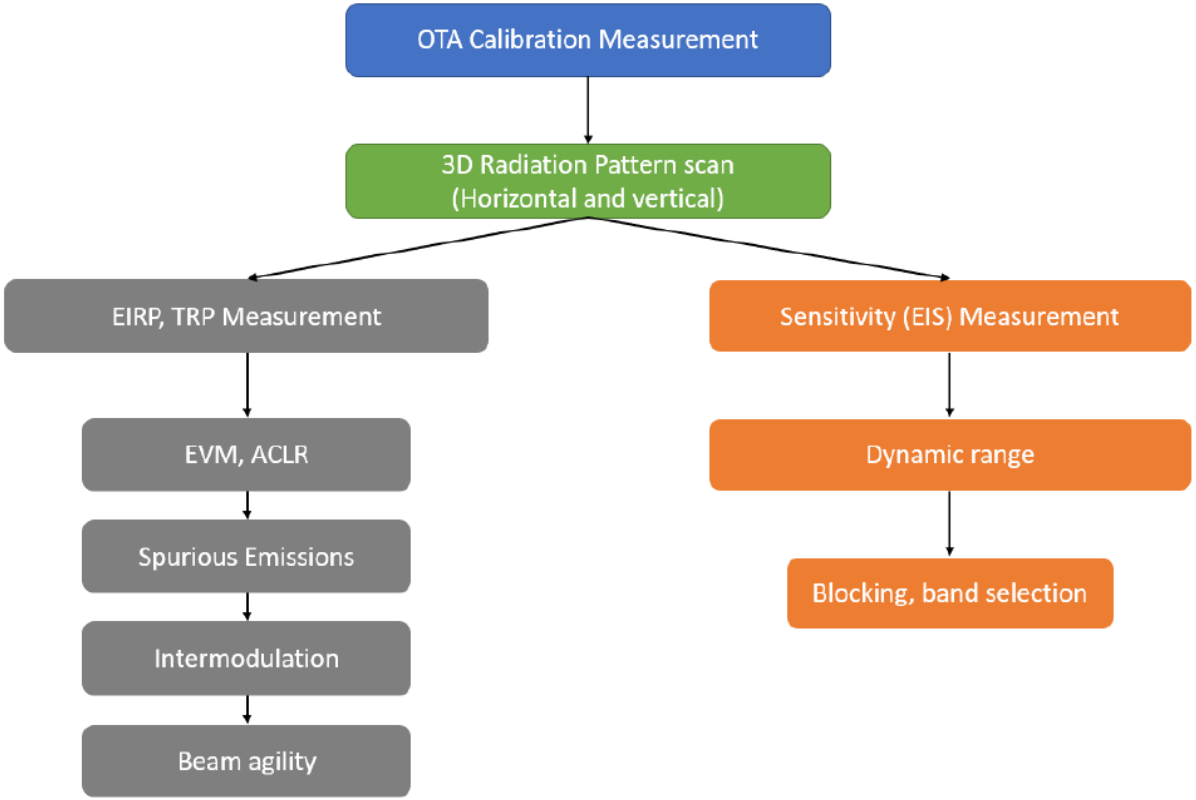
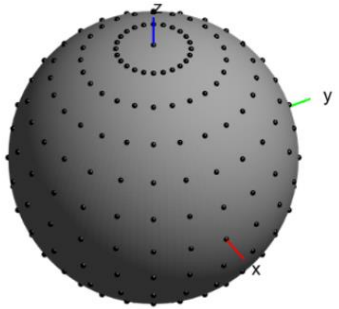
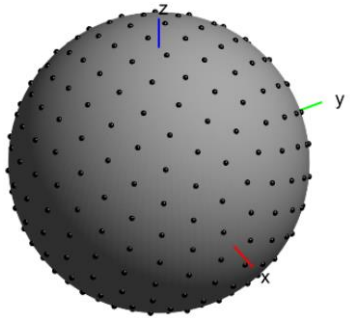
Spatial Test Procedure





Constant Step Size Grid (266 points)

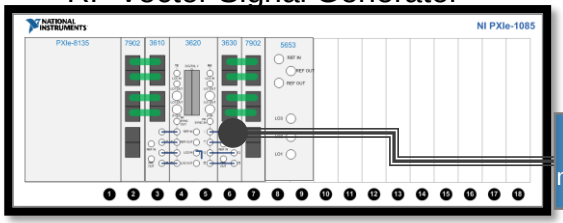


Constant Density Grid (266 points)

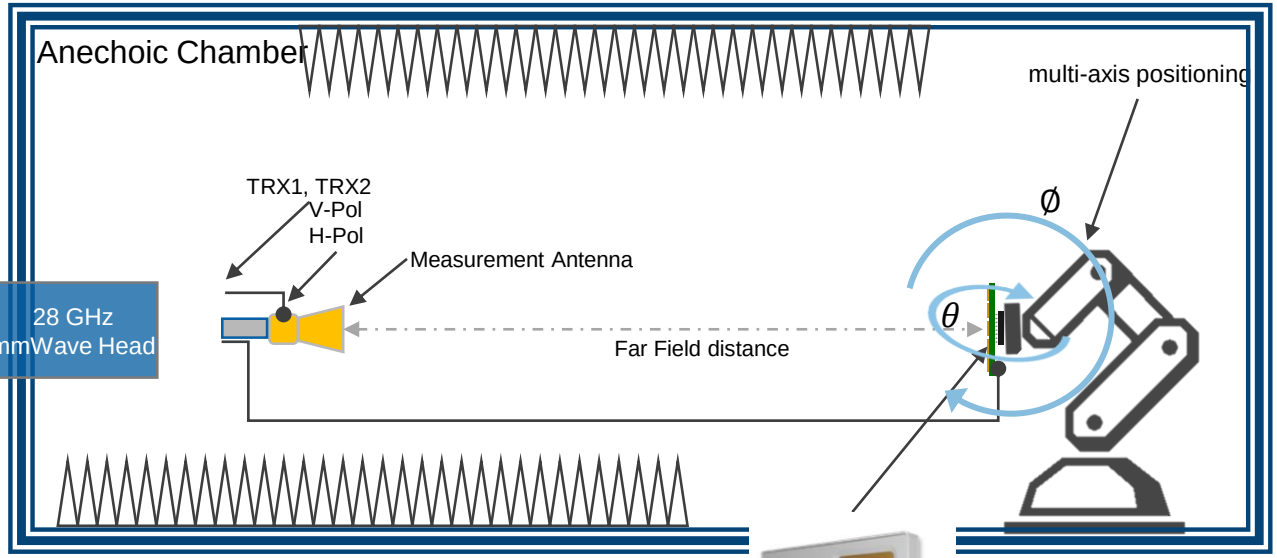
OTA Setup

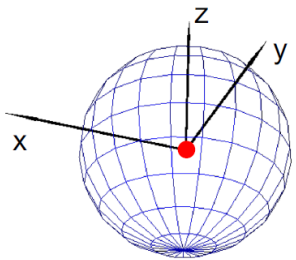
OTA System Setup: Hardware Option 1

Instrument
- RF Vector Signal Analyzer
- RF Vector Signal Generator



28 GHz mmWave Head





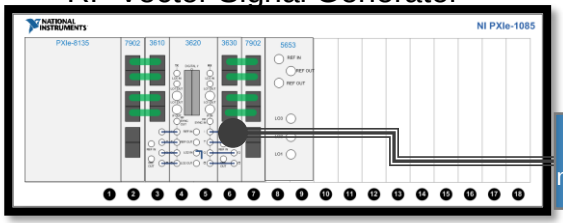
$\theta = Horizontal = Azimuth$

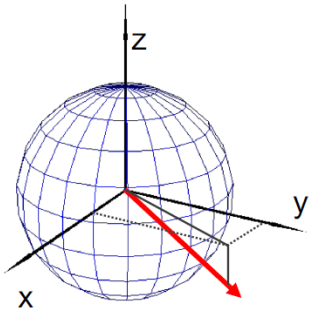
$\emptyset = Vertical = Elevation$

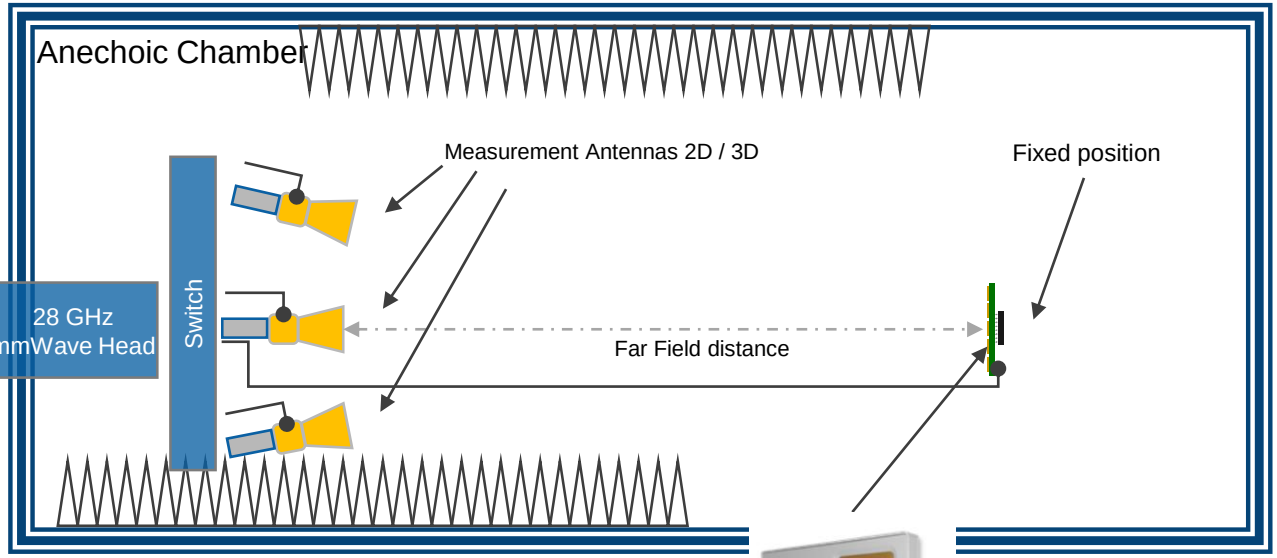
28 GHz phased array

OTA System Setup: Hardware Option 2

Instrument
- RF Vector Signal Analyzer
- RF Vector Signal Generator







28 GHz phased array

NI OTA Setup

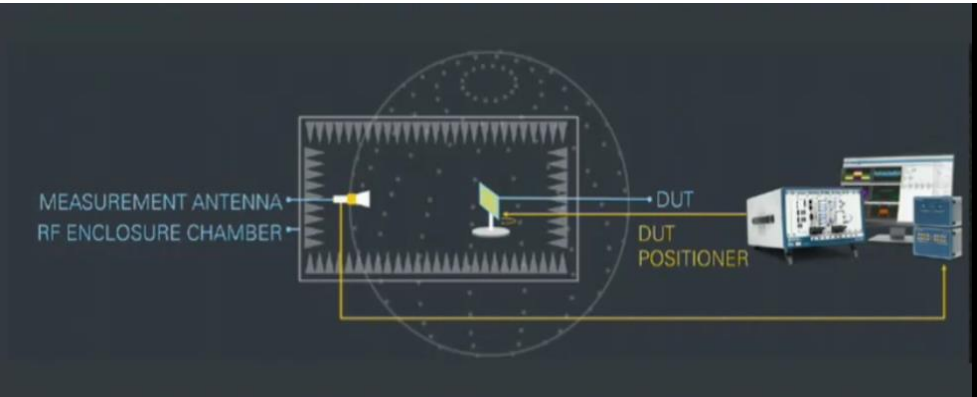
NI mmWave VST OTA Reference Solution - Highlights

Details:

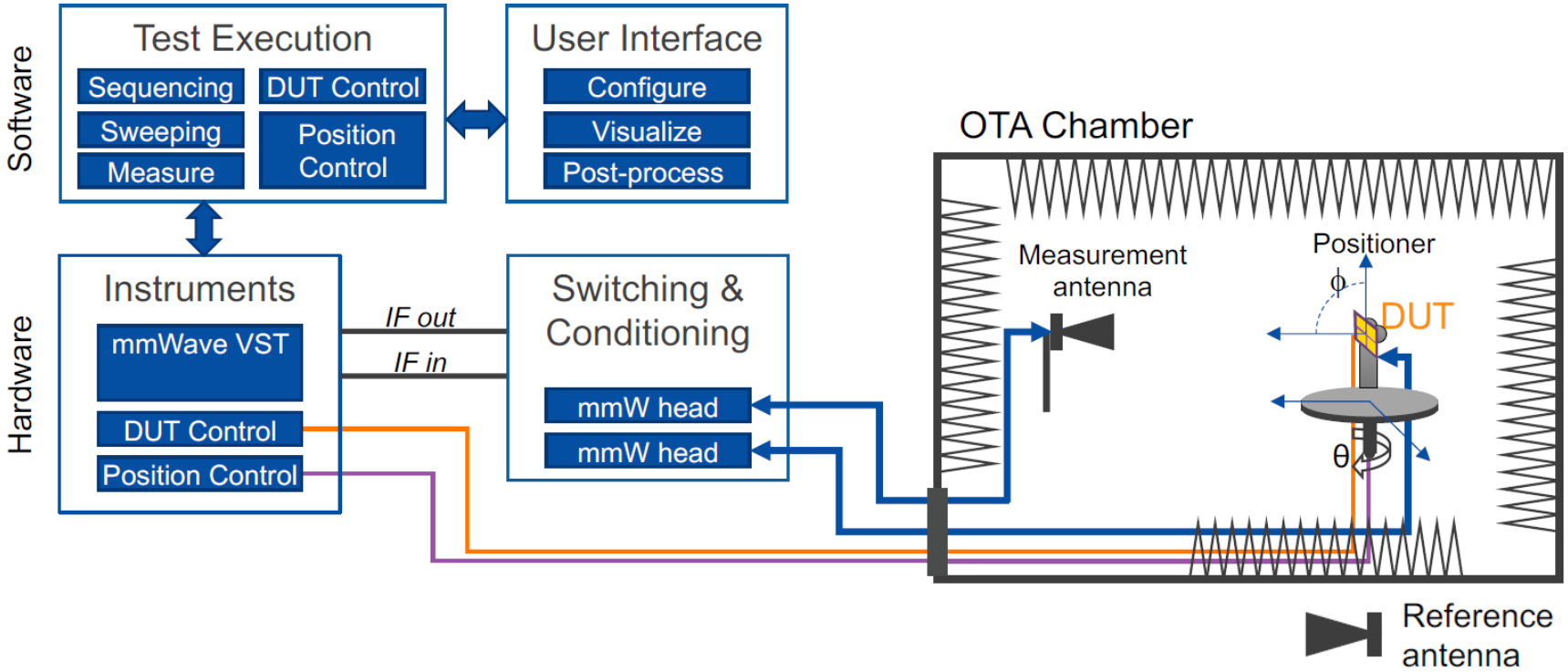
- DUT: Beamformer
- Application: Lab characterization
- Test type: Spatial scanning with patented HW-timed solution

Highlights:

- Capital Cost improved up to 2.5 – 3x
- Measurement Speed up to 15x faster (6 min vs. 23 sec per DUT)
- Equipment Size Reduction 5x smaller
- CW and modulated signal tests



NI mmWave VST OTA Reference Solution - Setup



NI mmWave VST OTA Reference Solution - Parts

The OTA reference solution includes:

- mmWave VST for high-bandwidth waveform generation and analysis
- RF anechoic chamber for far-field measurements with high accuracy (φ, θ) positioners using real-time motion control
- RF-transparent thermal enclosures for characterization of DUTs over temperature (if required)
- mmWave high-gain antennas, cables, and accessories

Over-the-Air Test, 15x Better than Current Solutions

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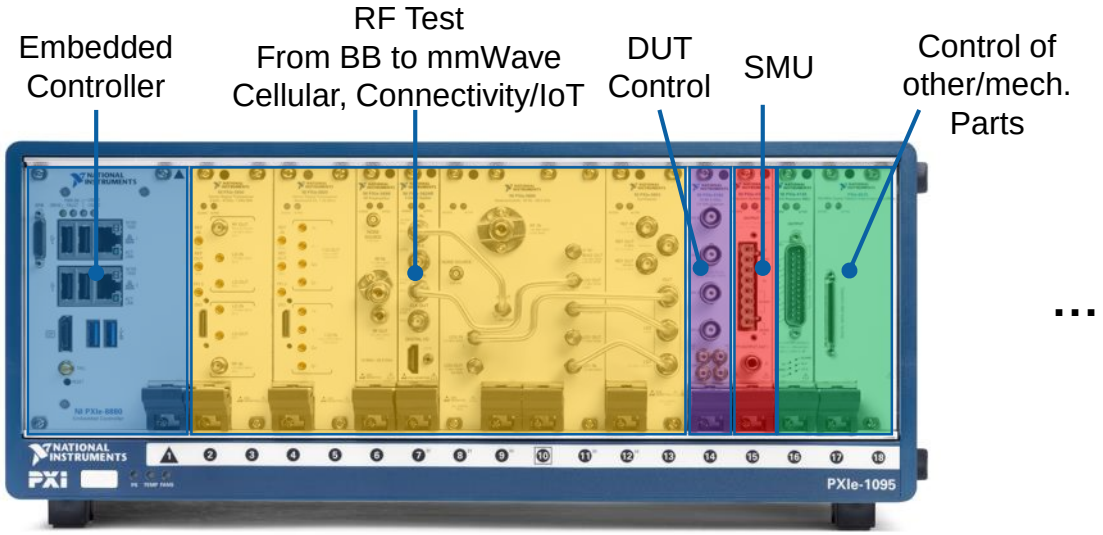
Conclusion

FEM Test System

How should an efficient test system look like?

FEM Test System



- Combine RF and DC / analog and digital measurements and controlling functions in a PXI chassis
- Synchronize instruments tightly incl. mechanical parts
- Use cutting-edge test speed in characterization, V&V or production
- Be prepared for new requirements

Questions?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Agenda

Time	Topic	Presenter	Demo
8:30	**Welcome, Introductions and NI Semiconductor Update**	Peter	No
8:45	**Using a Modular Platform for Mixed-Signal Semiconductor Characterization** • Introduction to the NI PXI Platform • InstrumentStudio Software for Interactive PXI Measurements • ATE-Class PXI Digital Instruments • Live demonstration of DUT characterization using modular instruments	Tarek	Yes
10:15	**Coffee Break/Networking**		
10:30	**Introduction to NI's offering for RFIC Test Applications including 5G NR, DPD, ET and mmWave** • Addressing the FEM Test Challenges to LTE-Advanced Pro and 5G NR • Characterizing Multiband ET/DPD Modern Front End Modules • Challenges and Solutions for mmWave OTA Test	Udo	Yes
12:10	**NI-Ampleon Collaboration Project: Wideband Multi-port Characterization for Active Antenna Systems** • Motivation for collaboration: the Ampleon Perspective • Sub 6 GHz and mmwave Characterization Innovation: the NI Perspective	Sergio & Marc	No
12:30	Summary and wrap-up		

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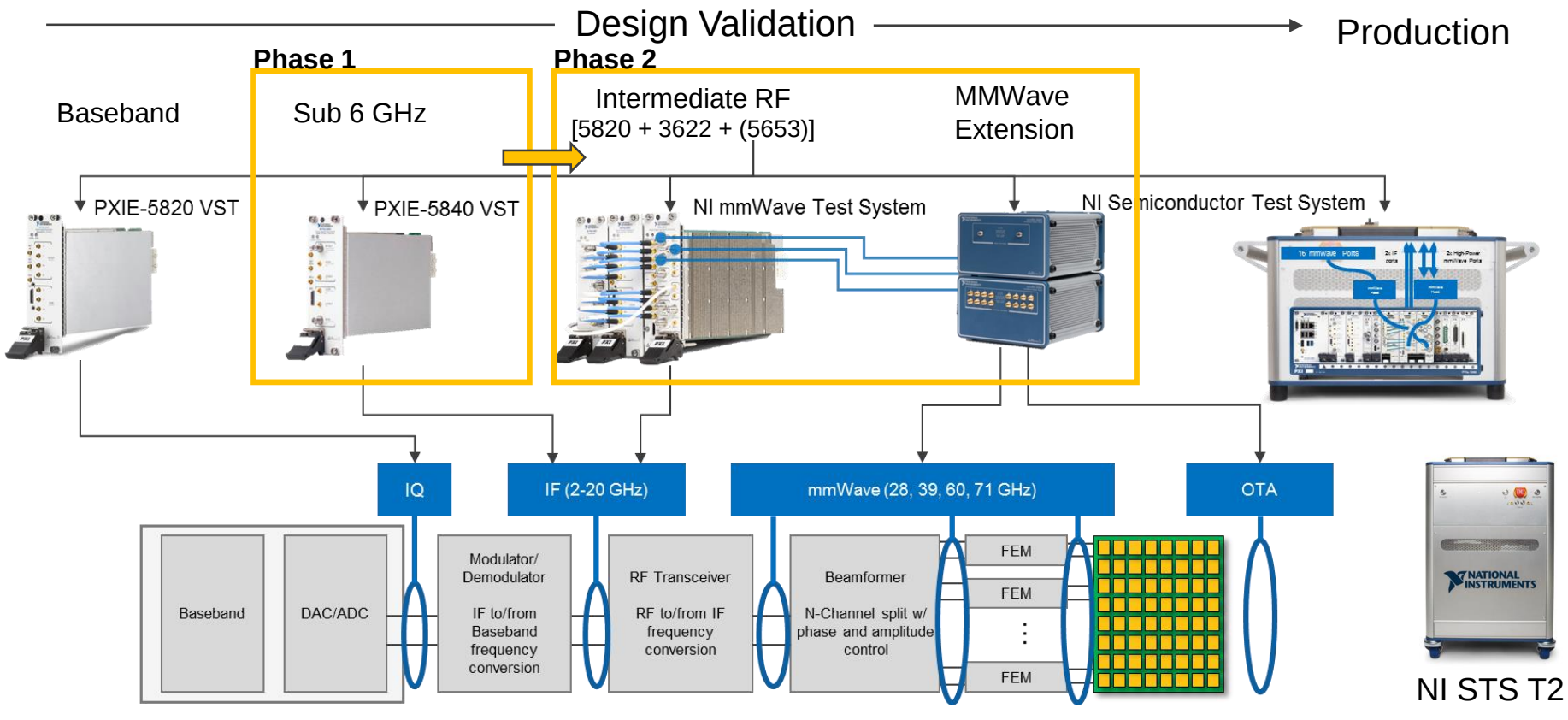
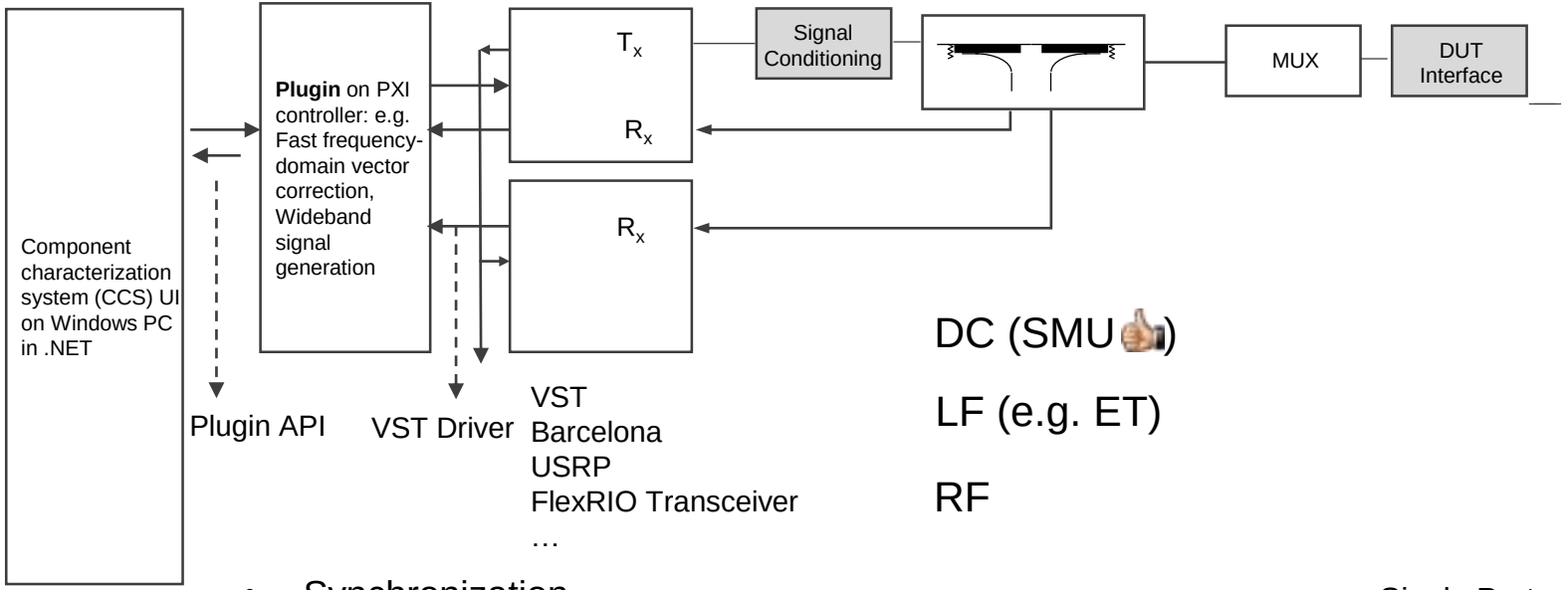
Wideband Multi-Port Conductive Characterization for Active Antenna Systems

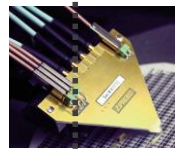
- Sub 6 GHz and mmwave Characterization Innovation: the NI Perspective -

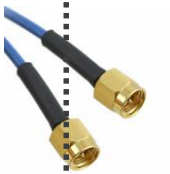
Platform Selection : VST - based

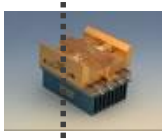


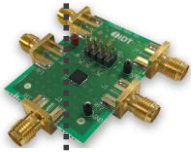
Core Building Block with Stimulus/Response System Calibration

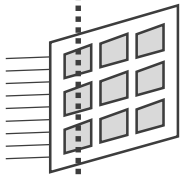










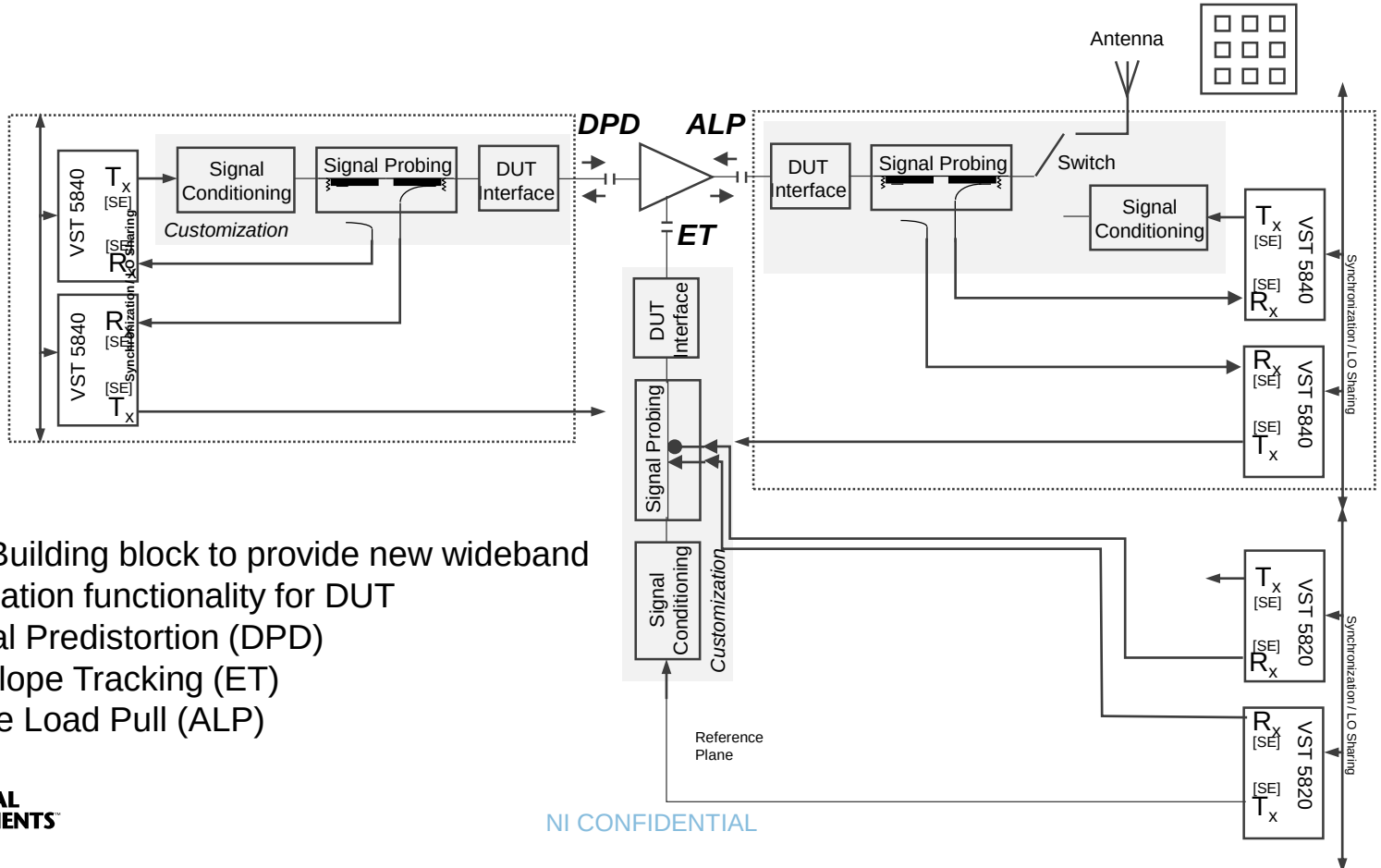


- Synchronization
- Phase Coherency in Tx and Rx
- Fast Error Correction of Modulation Signals

Single Port
Multi Port
System Cal

- Signal reconstruction at DUT

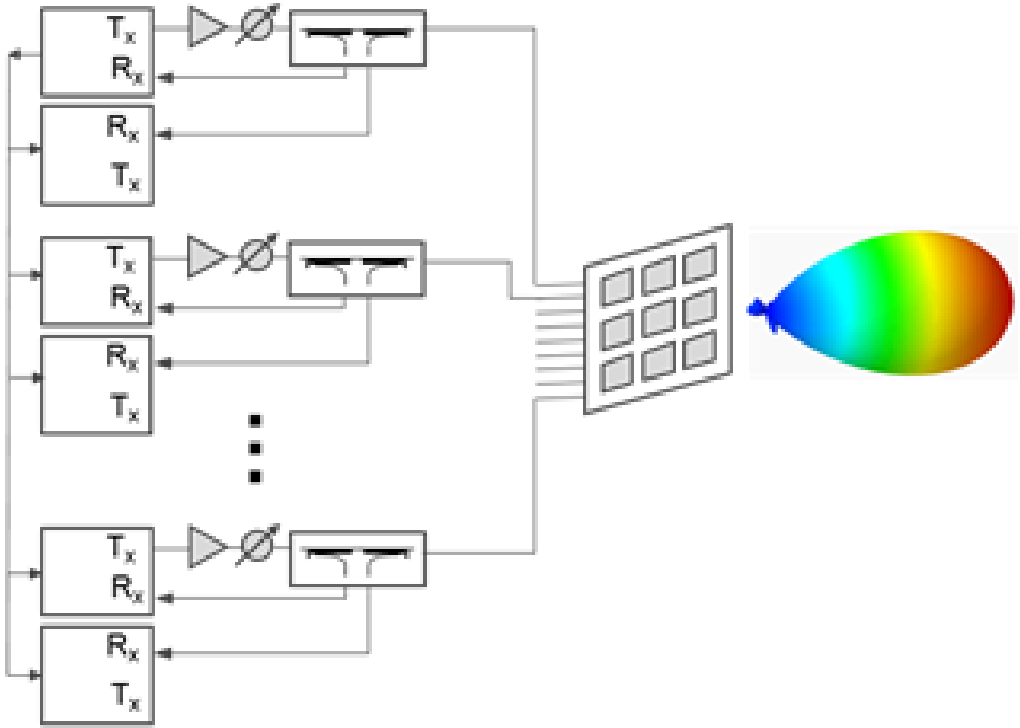
Setup for on-wafer Device Characterization (< 6 GHz)



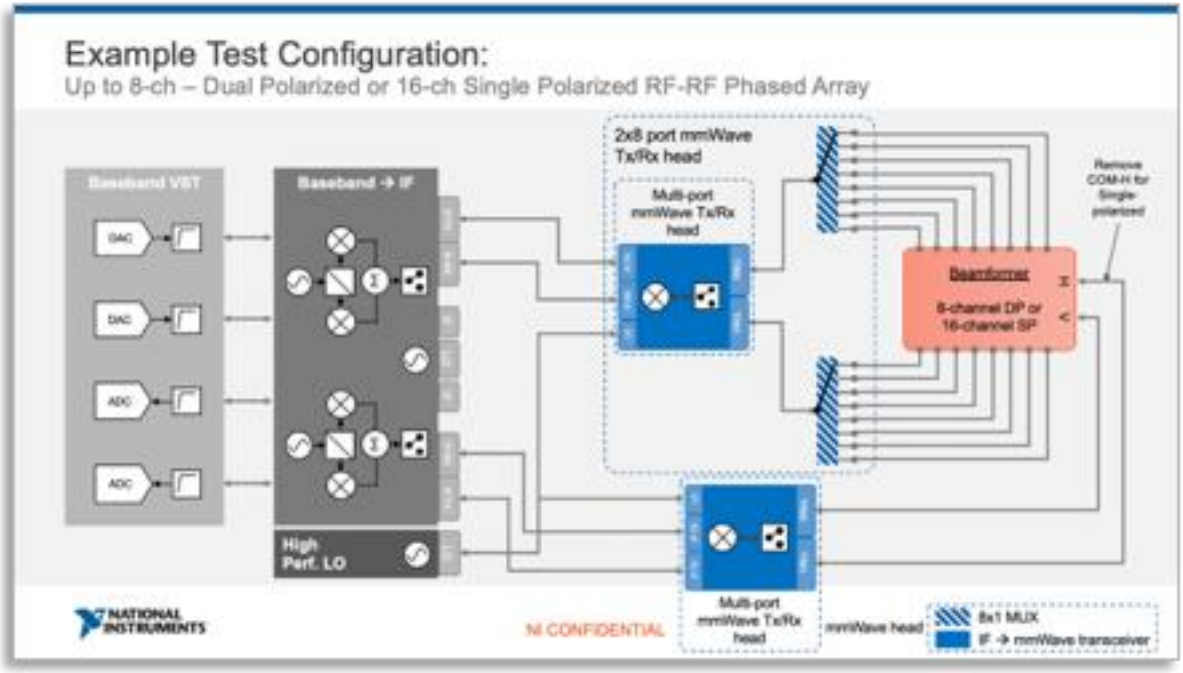
- Use Core Building block to provide new wideband characterization functionality for DUT
  - Digital Predistortion (DPD)
  - Envelope Tracking (ET)
  - Active Load Pull (ALP)

Setup for System-level Characterization (< 6 GHz)

Scaling up to 9 antennas (each with one PA)



Phase 2: Migration to MMwave Setup



Adapted for

- Active loadpull (HW signal routing)
- Wideband vector calibration and error correction (SW)
- ET and DPD capability (SW)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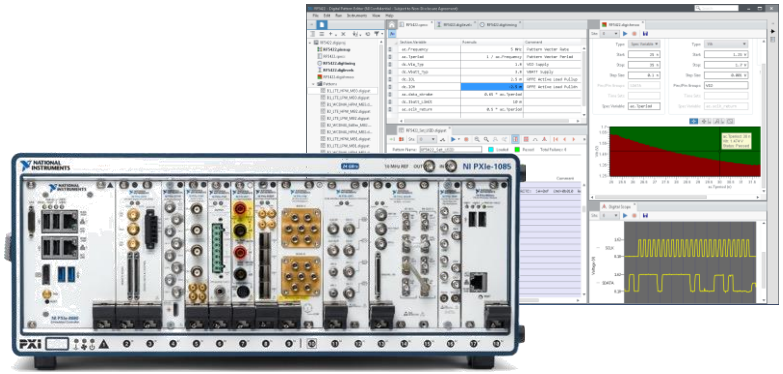
Leadership in Standardized Lab V&V

Core Needs: Test coverage, test speed, and time to market

Approach: Automate for speed & coverage, standardize for reuse

Why Choose NI? Faster development and optimization of test sequences with the most productive, integrated hardware and software toolchain

- Over 500 high-accuracy PXI Modules from DC to mmWave
- 300K+ members in NI's software community utilizing support and training
- Highly extensible to 3rd party hardware and programming languages



500+
NI PXI SYSTEMS SOLD TO SEMICONDUCTOR CHARACTERIZATION EACH YEAR

intel	Intel Mobile Communications division speeds measurements by 5X with LabVIEW and PXI
ST ERICSSON	ST-Ericsson Reduces Semiconductor Test Time by 10X With LabVIEW and NI PXI RF
qorvo	Qorvo Reduces Characterization Time of RF Power Amplifiers by 10X with PXI & LabVIEW
ANALOG DEVICES	Analog Devices Reduces MEMS Test Costs by 11X with PXI and LabVIEW
CIRRUS LOGIC	Improving Validation With a LabVIEW-Based Interactive Framework
Texas Instruments	TI's Standardized Infrastructure Built On NI TestStand, LabVIEW, and PXI
ON Semiconductor	NI PXI for Semiconductor Validation Achieves Performance Improvements, 3X Cost Savings
Melexis	Worldwide Standardization of Semiconductor Characterization Test at Melexis
amu	Automated Characterization of Analog-to-Digital Converters Using PXI and LabVIEW
MICROCHIP	Designing Highly Scalable Semiconductor Validation Systems With PXI and LabVIEW

NI as a Global System Supplier

200,000	PXI chassis shipped since 1997
50,000	PXI systems deployed globally into high-volume manufacturing
15,000	PXI systems deployed in semiconductor labs (design, V&V, and char.)
5,000	PXI systems deployed in semiconductor production
500	STS semiconductor production systems deployed since 2014

Diverse Applications

RF Front Ends	RF Transceivers	IoT Devices
Mixed-Signal ICs	MEMS Devices	Optoelectronics
Package and Wafer Test		

Diverse Deployment Locations

Integrated Device Manufacturers	OSATs	Test Houses

Summary

NI's #1 growth opportunity is semiconductor lab and production test

NI is rapidly increasing investment in semiconductor and STS and evolving our organization to better serve customer business needs

NI values our relationship

- Continued investment drives mutual benefit
- Open collaboration promotes future growth
- Your feedback makes NI better at what we do

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- 100+ demos from 50+ exhibitors on the exposition floor
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