connect

EMERSON | NI

Addressing Scalability, Modularity and Speed for Power Management IC (PMIC) Test

Jose Arteaga
Chief Offering Manager for Semiconductors and Electronics

EMERSON

Table of Contents

CONNECT

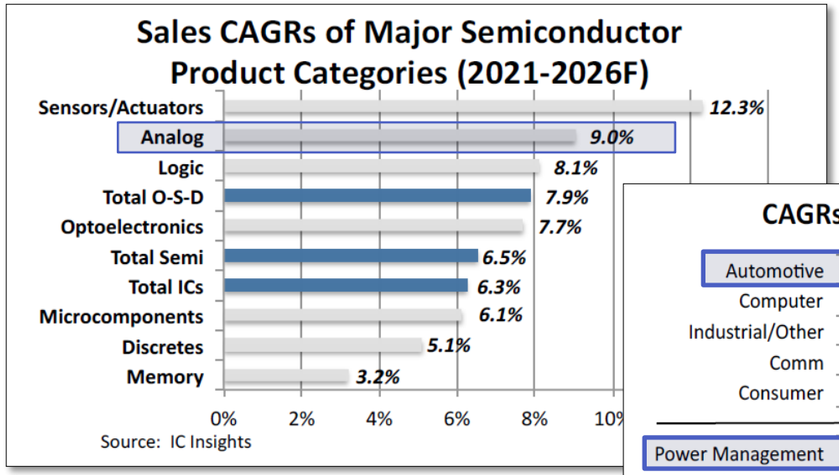
EMERSON | NI

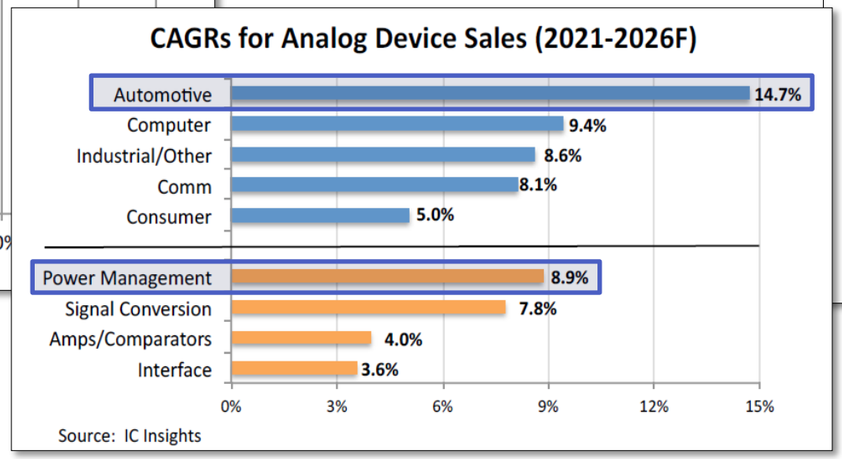
PMIC and Automotive | Semiconductor Growth Leaders

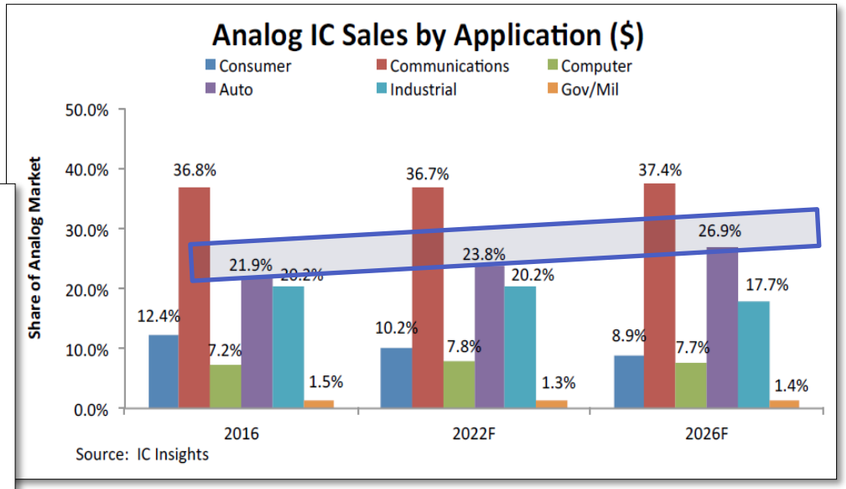
- **Analog ICs:**
  - Second highest growth product category in Semiconductor market
  - PMIC highest growth sub-type of analog ICs

By Application:

- Communications to maintain largest market share position ~37%
- Automotive poised for significant growth
  - Expected to make up for >25% of Analog IC market by 2026







PMIC Market | Trends & Challenges

- PMICs in **mobile, automotive, and industrial applications** driving needs for power density and efficiency

Top design considerations for today's PMIC landscape	
1. Increasing power density and efficiency	➢ Designers are required to squeeze more with less space, while increasing efficiency and thermal performance
2. Lowering cost – Electromagnetic Interference (EMI)	➢ Low EMI design can reduce filter size, cost, and complexity, especially in automotive and industrial applications
3. Lowering quiescent current – extend battery and shelf life	➢ Battery-operated systems are often in standby/sleep mode for long periods
4. Lowering Noise – Enhancing precision	➢ Excessive noise can harm sensitive applications and peripheral circuits (such as ADCs, AFEs, and clock sources)
5. Increasing Safety and Quality - Isolation between high and low voltage domains	➢ Good isolation management enhances system reliability, simplifies EMI compliance, and reduces form factors

EMERSON

Mobile PMICs | Trends & Validation Impact

*Extensive validation and testing needed for charger IC devices to ensure **performance**, **interoperability**, and **safety** meet industry standards*

Higher Power Delivery (Speed)

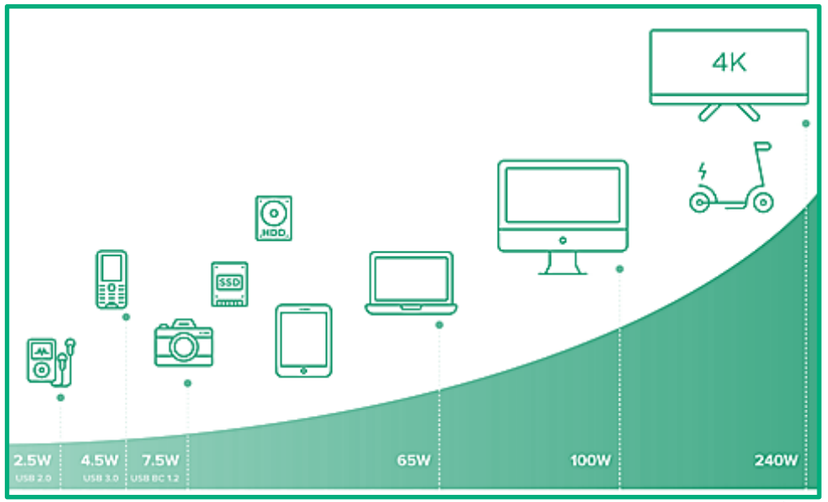
Trends:	Test impact:
1. Support for ~100W+ charging becoming commonplace 2. USB-PD 3.1 capable of 240W+	1. Capable HW up to 300W+ 2. Increased importance of temperature and safety testing

Broad Ecosystem Support

Trend:	Test impact:
1. Growing need for charging ICs that support multiple protocols	1. Greater need for interoperability testing across devices 2. More protocols need to be tested

Intelligent Charging

Trend:	Test impact:
1. Intelligent charging that optimizes charging times and improve battery health 2. Smaller form factors	1. Increased importance of temperature and safety testing



USB-PD 3.1 pushing past 100W

Qualcomm quick charge 5 · CERTIFIED USB 240W/48V · SUPERVOOC · SAMSUNG Adaptive Fast Charging · IQ · PumpExpress by MediaTek

Wide variety of charging standards in market

EMERSON

PMIC Validation Challenges | User Feedback

Synchronization of instruments

Fast Slewing supplies and loads

Disparate tools/ instruments to cover all measurements/ devices

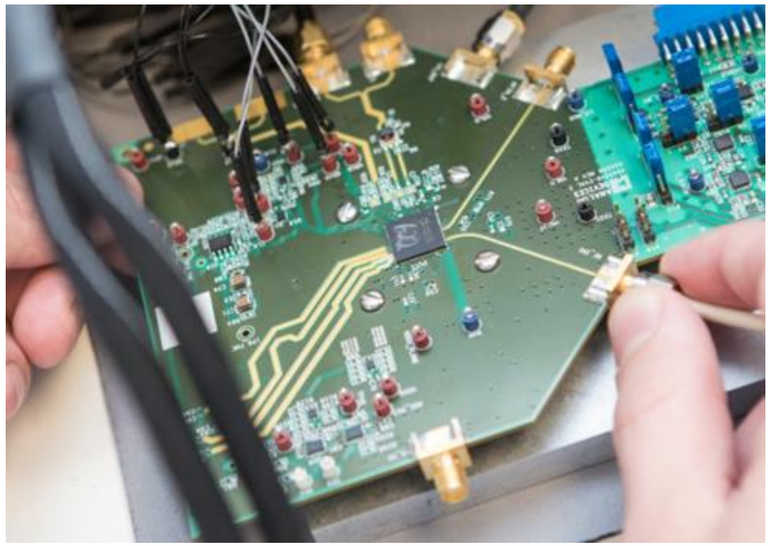
Programming experience in various languages
(LabVIEW, Python, C# .NET, etc.)

Lower capital cost of validation systems/ tools

Automation and debug for thousands of tests

Optimize measurement efficiency/ test time

Improve data management, correlation between teams



Measurements: *Efficiency, Accuracy, Line/Load Regulation, Shutdown Current, Quiescent Current, Line/Load Transient, and more…*

EMERSON

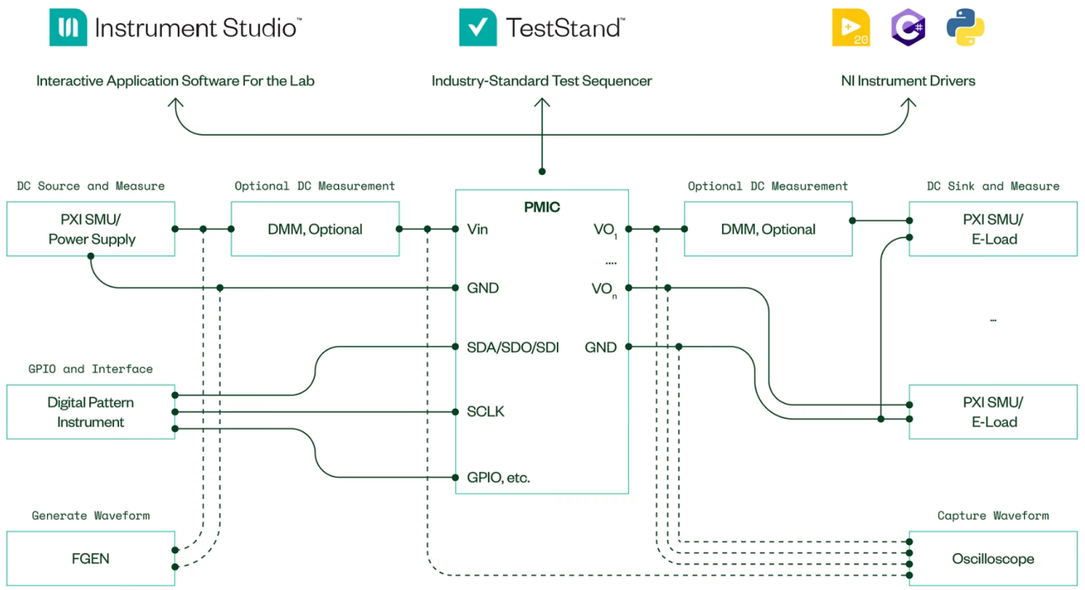
PMIC Validation Solutions

EMERSON

Power Management IC (PMIC) Validation Solution

HARDWARE

- Leverage high-performance instrumentation, including:
  - PXI Source Measure Units (SMUs)
  - PXI Power Supply, E-loads
  - PXI Digital Pattern Instruments
  - PXI Oscilloscopes
  - PXI Digital Multimeters (DMMs)
- Source and sink up to 300 W of power with high-performance DC instruments



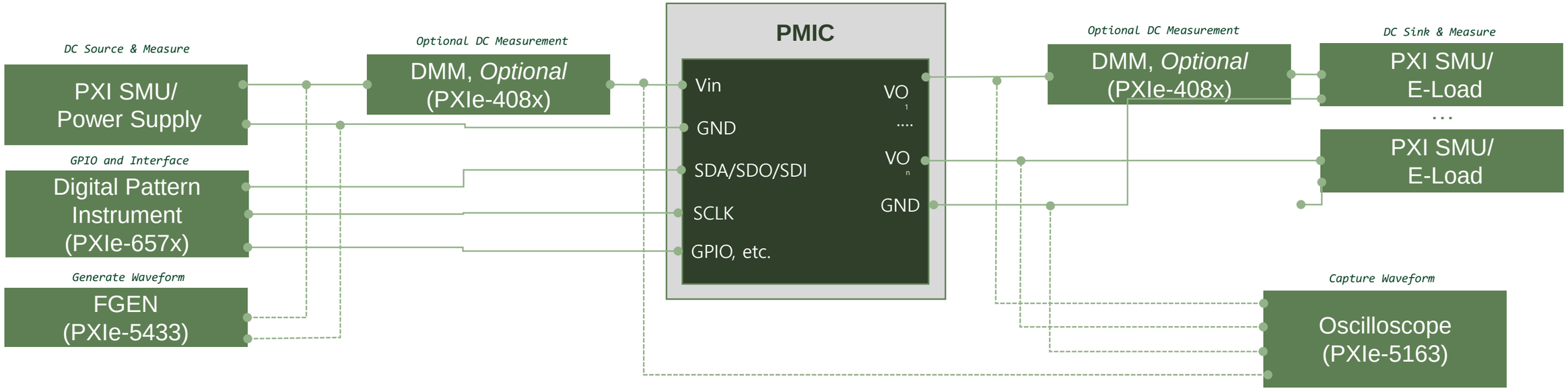
SOFTWARE

- Enable powerful engineering workflows between interactive tasks (bring-up, debug) and automated tasks (automated validation and characterization)
- Configurable instrument control with InstrumentStudio software panel
- Options to export configuration settings for automation with TestStand or LabVIEW
- Protocol Validation Software for I2C or SPI digital communication

Example PXI Configuration: Multi-Channel PMIC

System Considerations

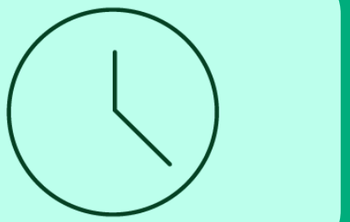
- NI system SMU functions both as load and as a precision power supply
- Available PXI switch for high-channel count or lower cost applications
- High precision signal generators and High pin count digital cards



Solution Advantages

- SMUs (413x) up to 40W and PSS (415x) and e-Load (4050) up to 300W
- For higher V/I needs Ganging configuration supported
- O-Scope (5163) for very fast transient load tests
- 6571 - 8Ch for DUT Control

PMIC Validation Solution | Value Proposition



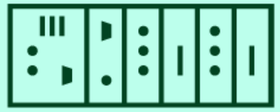
Exceptional measurement speed and performance

…through PXI data bandwidth & latency, PXI timing & synchronization, and custom transient tuning

Ability to scale with great cost per channel

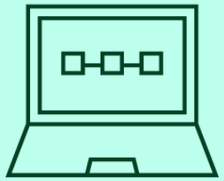
…for parallel multi-site or multi-channel

…great cost/ch for scopes <500MHz bandwidth



Breadth of portfolio

…Robust AC (Scope, FGEN), DC (SMUs, PSS, e-Loads), and Digital instrumentation – allowing a single platform for majority of validation needs



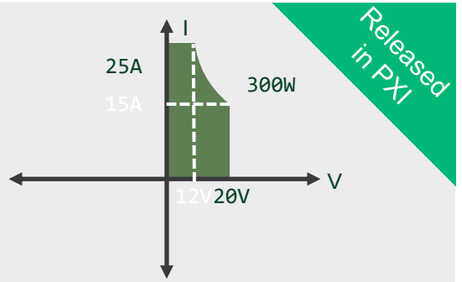
Seamless software ecosystem for full validation process

…enables use cases for interactive validation, automated validation, and data/ asset management

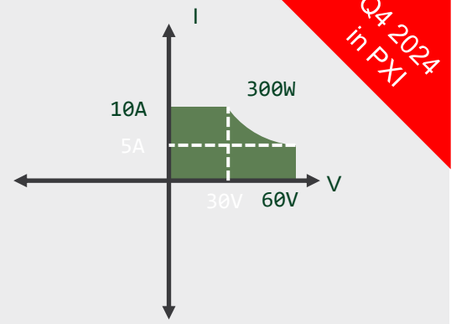
High-Performance 300 W PXI Power Instruments

- **Primary Application Targets:**
- Power management IC validation & test - General semiconductor & electronics test
- **300 W High-Performance PXI Power Supplies**
  - 1 channel, 2 PXI slots (requires auxiliary 48 V power)
  - PXIe-4151: Up to 20 V, 25 A (e.g. 20 V, 15 A or 12 V, 25 A)
  - PXIe-4150: Up to 60 V, 10 A (e.g. 60 V, 5 A or 30 V, 10 A)
- **300 W High-Performance PXI E-load**
  - 1 channel, 3 PXI slots
  - PXIe-4051: Up to 60 V, 40 A (e.g. 60 V, 5 A or 7.5 V, 40 A)
- **Common Features:**
  - 150 V CAT I isolation (max stacking voltage)
  - Simultaneous I & V measurements
  - DMM-like measurement accuracy
  - 1.8 MS/s sample rate & 100 kS/s update rate
  - Transient response tuning (SourceAdapt) - Advanced sequencing (per-step properties)

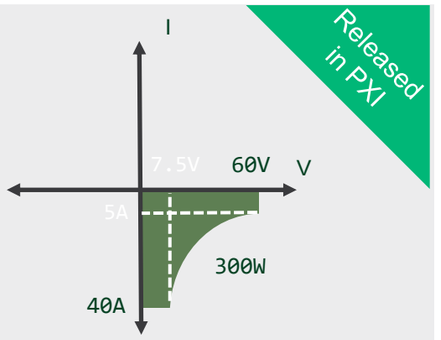
PXIe-4151
20 V, 25 A, 300 W Supply



PXIe-4150
60 V, 10 A, 300 W Supply



PXIe-4051
60 V, 40 A, 300 W E-load



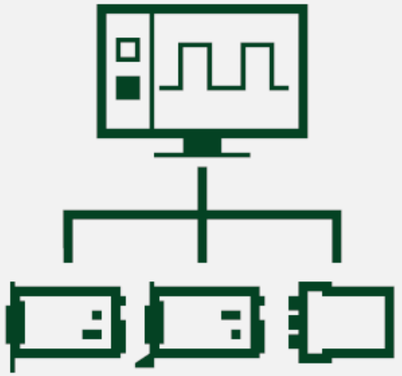
Benefits of NI’s 300 W PXI Instruments

Accuracy

NI’s 300 W PXI-based instruments offer high accuracy for output values and simultaneous, voltage and current measurements

Speed

NI’s PXI-based instruments are designed for fast operation and fast measurements to help you reduce test time and improve throughput



Timing & Synchronization

PXI-based instrument can be easily triggered and synchronized with other instrumentation, and can reuse existing code from NI SMUs

Comparing Types of Programmable Power Instruments

“Basic” Power Supplies & E-loads

- More affordable (more Watts per $)
- Minimal or no measurement capabilities
- Accuracy of ~1% for setpoint
- Burdensome timing & synchronization options
- Basic programming API & minimal documentation
- Lacking application software for interactive tasks

NI RMX-41xx Power Supplies & E-loads

High-Performance Power Supplies & E-loads

- Premium power instruments
- Simultaneous DMM-class I & V measurements
- Accuracy of ~0.0x% (setpoint & measurements)
- Integrated PXI-class timing & synchronization
- Robust API, example programs, & documentation
- InstrumentStudio support for interactive actions

NI PXIe-415x Power Supplies & PXIe-405x E-loads

EMERSON | NI

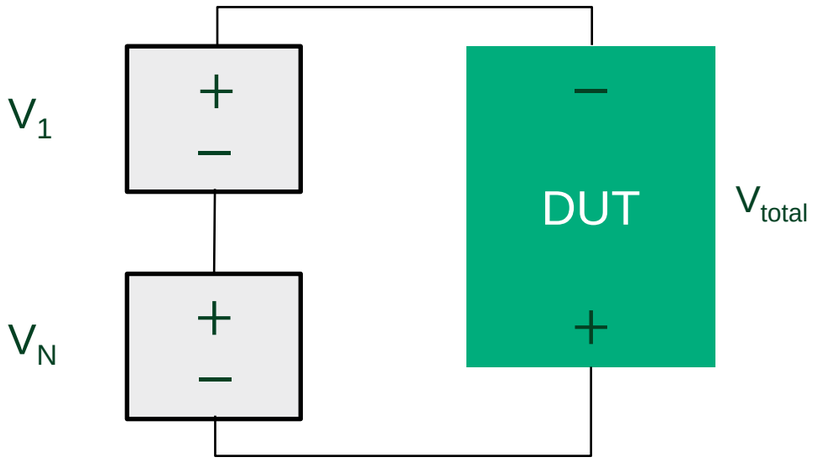
Can I Combine Channels for Higher Voltage/Current?

Yes

- ✓ Works best for resistive loads (requires more customization for highly reactive loads)
- ✓ Only combine channels of the same instrument ***Model*** (e.g., multiple PXIe-4151s)
- ✓ Each channel must be programmed separately and results must be analyzed separately

For Higher **Voltage**

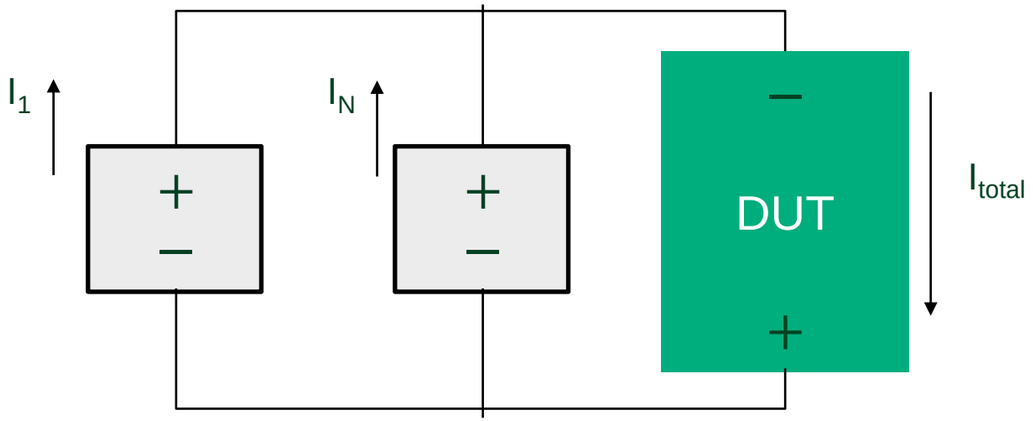
- Channels can be combined in series (**Stacked**)
- Do NOT exceed isolation voltage (150V)



$$V_1 + \cdots + V_N = V_{total} \leq V_{isolation}$$

For Higher **Current**

- Channels can be combined in parallel (**Ganged**)
- No limit on maximum current
- Other limitations may apply (e.g., wire gauge)



$$I_1 + \cdots + I_N = I_{total}$$

EMERSON | NI

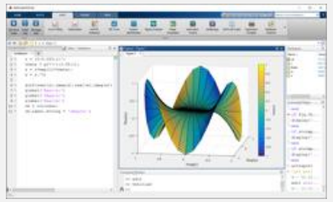
2024

Why IC Bring up & Validation is Critical?

EMERSON | NI

Semiconductor Test Solutions that Scale From Lab to Production

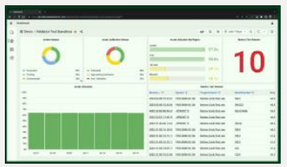
Modeling and Simulation → Validation and Characterization → High Volume Manufacturing → Quality and Reliability



Faster transition to test with off the shelf instrument models

Accelerate time to market with scalable, modular PXI and software-connected workflows

Lower cost of manufacturing with the flexible, fungible Semiconductor Test System



Improve asset management, quality and yield with SystemLink and O+ analytics

NI's comprehensive, connected approach leverages a common software, hardware and data platform to drive engineering efficiency across the semiconductor value chain

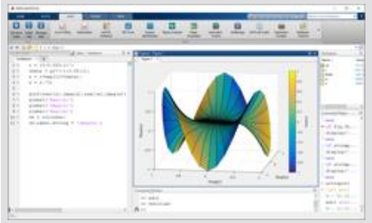
EMERSON | NI

NI Semiconductor Test Solutions
Driving Engineering Efficiency From Lab to Production

Simulation & Modeling → Silicon Bring-up & Validation → Characterization → Production Test → Quality & Reliability

Accelerate Productivity Across Product Lifecycle

Simulation & Modeling



Validation & Characterization

High Volume Manufacturing

Product Quality & Reliability

SAME Software SAME Instrumentation SAME Data

Software Investments in Design-to-Test Workflow Optimization & Data Analytics

NI Value Proposition for IC Validation

Shrink Time to Market

Bring up and Debug

Same Hardware

Same Measurement Science (Meas. IP Libraries)

Same Software

Automated Validation

Behavioral Modeling & Simulation → Simulation & Verification → Silicon Bring-up & Validation → Characterization → Production Test

Software Investments in Design-to-Test Workflow Optimization & Data Analytics

EMERSON | NI

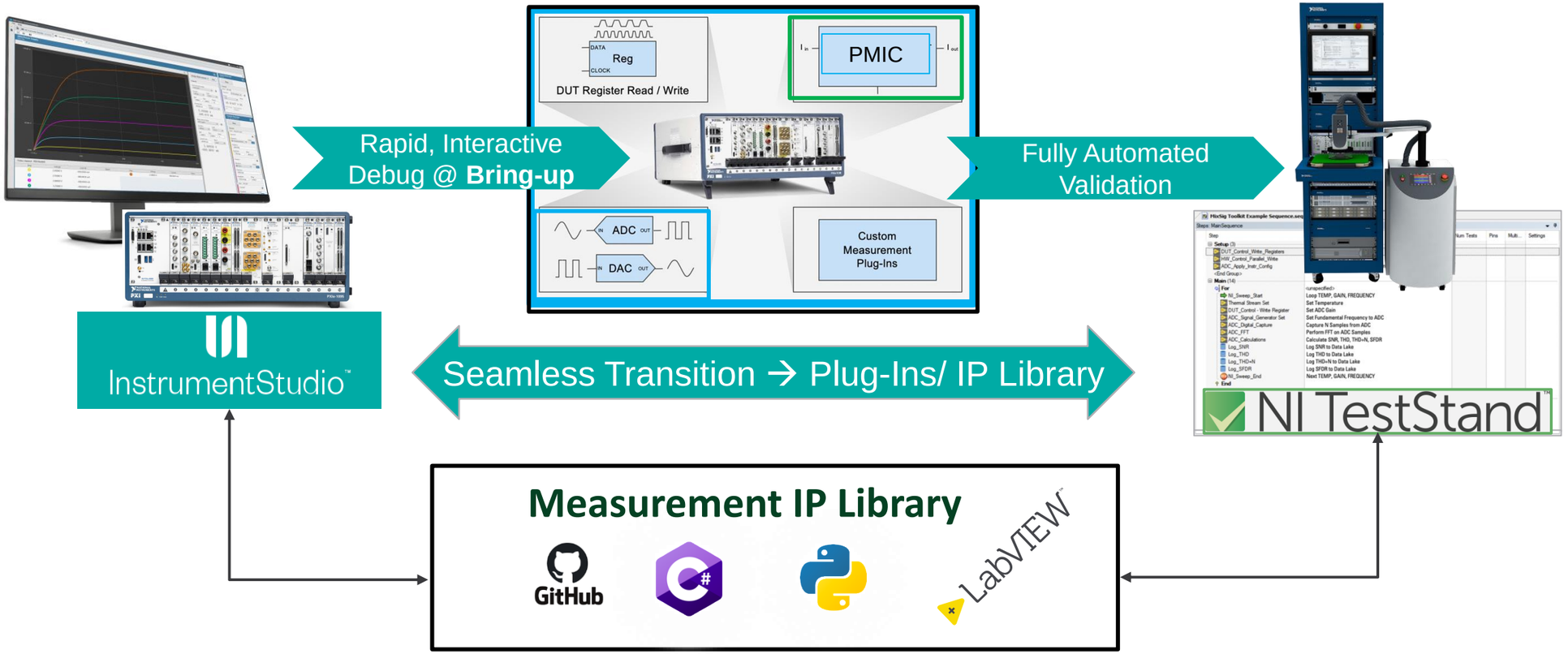
Measurement IP Library

Merging Interactive bring-up and automated validation

EMERSON

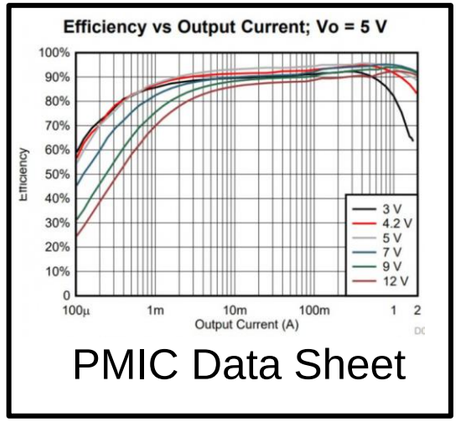
NI CONNECT 2024 AUSTIN

From Interactive Bring-up to Fully Automated Validation



- To enable a flow from Silicon Bring-Up and Debug to Fully Automated Validation with Seamless Transition.
- Open-Source Plugins included on new version of InstrumentStudio®. Python & Labview SW examples, distributed by GitHub Repo
- Accelerate Growth in Semi with out-of-the-box capability / IP measurements.

Key PMIC Parameters visualized as Data Sheet



PMIC Data Sheet

InstrumentStudio™

Seamless Transition → Plug-Ins/ IP Library

NI TestStand™

Rapid, Interactive Debug @ **Bring-up**

Measurement IP Library

GitHub

LabVIEW

Fully Automated Validation

EMERSON

Measurement IP Library for Power Management

Measurement IP Library

Open Source: A set of SW Examples (Labview and Python) for test IP on the most critical **Power Management Devices Specs** using familiar formats and standard visualization found in data sheets. Library uploaded in GitHub.

Plug-ins for Instrument Studio: Use all the features already available in InstrumentStudio Front Panels, adding these key measurements for interactive debug and seamless integration on Test Stand sequencer for fully automated validation

Scalable Platform: This Power Management library is the baseline to scale across different DUT configurations, spec limits to “brake” the IC. This requires either NI support, customer expertise in LV or Python or working with a Solutions Provider.

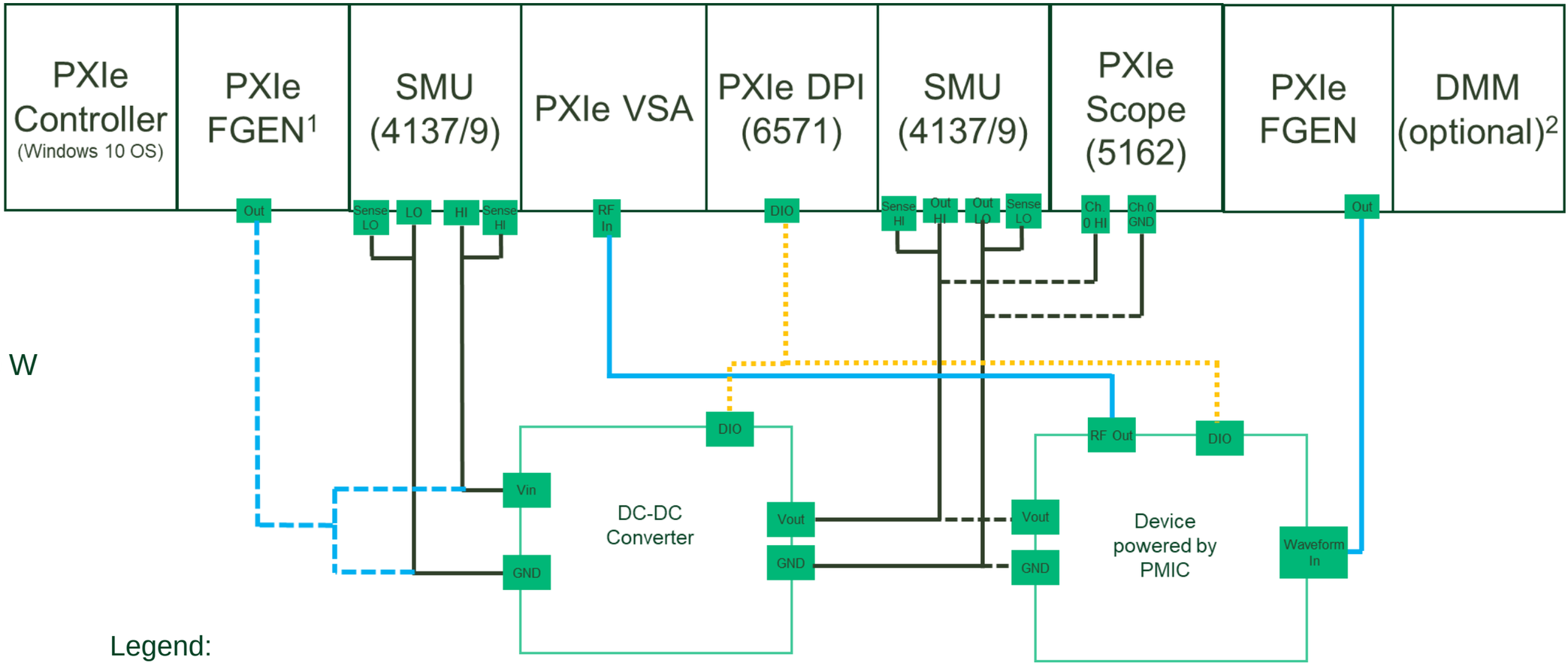
Targeted DUTs: DC/DC Converters, LDOs, etc.

Power Management Library List	DC/DC Converters	LDOs
Line Regulation	✓	✓
Efficiency/Load Regulation	✓	✓
Output Voltage accuracy	✓	✓
Ripple	✓	
Load Transient Response	✓	✓
PSRR	✓	✓
Multi-channel Output accuracy, Crosstalk in Multichannel PMIC	✓	✓
300W PSS/e-Load Channel Ganging Multi point Sweep Voltage/Current	✓	✓
300W PSS/e-Load Channel Ganging : Line Reg, Load Reg, Transient Load	✓	✓
Ramp-up time	✓	✓

EMERSON | NI

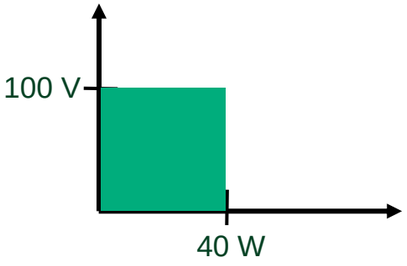
PMIC Key Instruments Supported by Library

PXI Test System Block Diagram – Lower Power DUTs



DUT Limits:

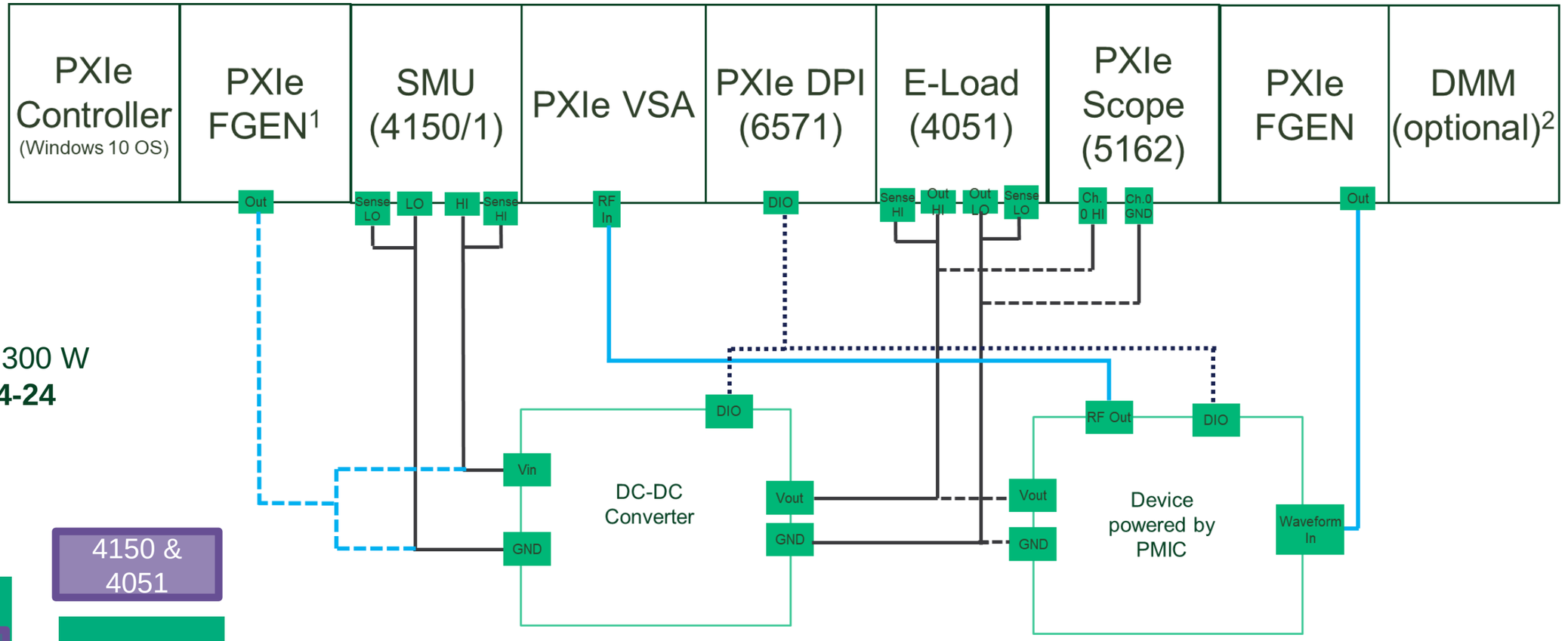
- Max Vin = 100 V
- Max Pin & Pout = 40 W
- **Available Now**



Legend:

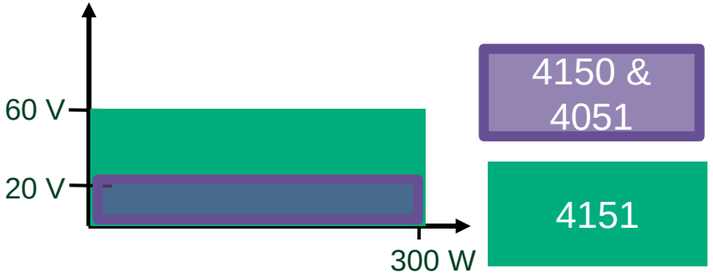
- Power in/out
- Analog Waveforms/RF
- Digital I/O
- (dotted) Optional Connection

PXI Test System Block Diagram – Higher Power DUTs



DUT Limits:

- Max Vin = 60 V
- Max Pin & Pout = 300 W
- **Available Now/Q4-24**



Legend:

- Power in/out
- Analog Waveforms/RF
- Digital I/O
- (dotted) Optional Connection

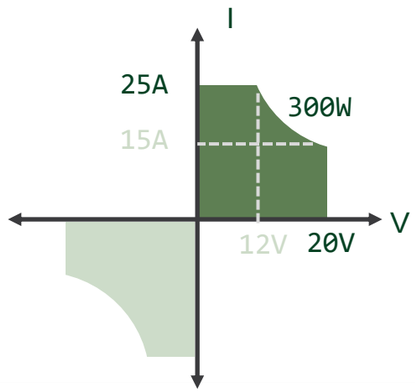
Released

High-Perf. 20 V, 300 W PXI Power Supply

2-slot PXI Power Supply with DMM-like Measurement Accuracy

- PXIe-4151 20 V, 25 A, 300 W Programmable Power Supply
  - 20 V up to 15 A
  - 25 A up to 12 V
  - 150 V CAT I Isolation
- Ranges
  - Current: 25 A, 1 A, & 100 mA ranges (up to 10 nA resolution, 0.03% + 30 µA accuracy)
  - Voltage: Full scale and 6 V ranges (up to 1 µV resolution, 0.022% + 500 µV accuracy)
- Simultaneous current and voltage measurements
- Floating design can be manually inverted for negative V & I (i.e. Quadrant III)
- Down-programmer stage “pulls” the output down with reverse current source
- Output Noise: 20 mVpk-pk & < 6 mV_{rms}
- Requires auxiliary power input (48 V, ~400 W)
- Will work in any PXI Express chassis, but limited to 22 A in 38 W chassis

PXIe-4151

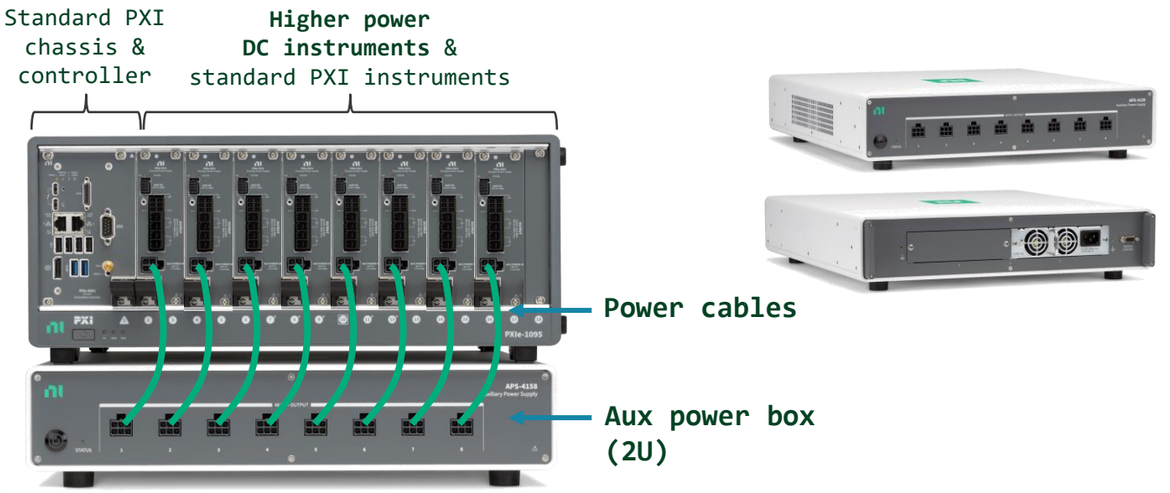


Requires ~400 W, 48 V auxiliary power input

EMERSON

PXIe-4150/1 Auxiliary Power

To source 300 W in the PXI form factor, the PXIe-4150/1 requires 48 V auxiliary power input



APS-4158/9 2U Multi-Channel Auxiliary Power Supply [Released]

- Ideal for systems with multiple (up to 8) PXIe-4150/1 supplies
- Provides clean, bulk 48 V power to the front of the PXI instrument
- Options for 800 W or 1,600 W of usable power per aux. power supply
- Requires simple power budgeting* for max instantaneous power across all connected PXIe-4150/1 units
- For example, with a 1,600 W aux. power supply, you can:
  - Supply 5 PXIe-4150/1 units with the full 300 W each
  - Supply 8 PXIe-4150/1 units with an average of 200 W each

Use 48 V Bulk Power from Other NI System Infrastructure

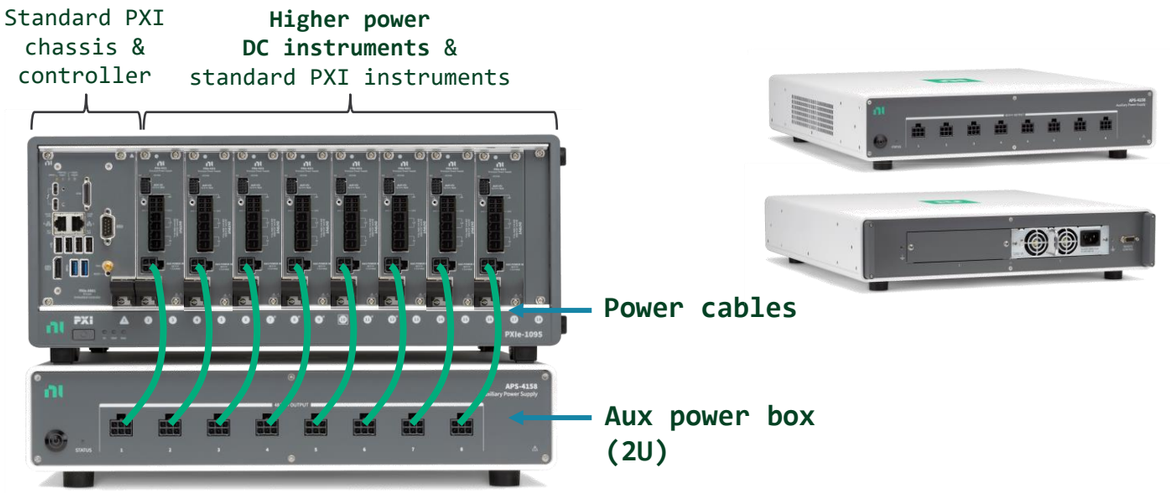
- NI is adding support for the PXIe-4150/1 in the Semiconductor Test System (STS) and will use an internal 48 V bulk power rail
- Additionally, NI's next generation of Smart Rack solutions will provide more bulk power distribution and could support this use case

**Simple power budgeting provides a conservative estimate of usable power available to connected PXIe-415x.*

EMERSON | NI

PXIe-4150/1 Auxiliary Power

To source 300 W in the PXI form factor, the PXIe-4150/1 requires 48 V auxiliary power input



APS-4158/9 2U Multi-Channel Auxiliary Power Supply [Released]

- Ideal for systems with multiple (up to 8) PXIe-4150/1 supplies
- Provides clean, bulk 48 V power to the front of the PXI instrument
- Options for 800 W or 1,600 W of usable power per aux. power supply
- Requires simple power budgeting* for max instantaneous power across all connected PXIe-4150/1 units
- For example, with a 1,600 W aux. power supply, you can:
  - Supply 5 PXIe-4150/1 units with the full 300 W each
  - Supply 8 PXIe-4150/1 units with an average of 200 W each

Laptop-style Power Brick Under Development

- Recent innovations in wide bandgap GaN power semiconductors have led to commercially available, fully enclosed, and passively cooled AC-DC power supplies with enough power to support the full range of a single PXIe-4150/1 channel
- This option was not available at project kickoff, but we are researching options for productizing a laptop-style power brick that can provide enough power for a single PXIe-415x (up to 300 W)
- More ideal for low-channel-count systems and evaluations

**Simple power budgeting provides a conservative estimate of usable power available to connected PXIe-415x.*

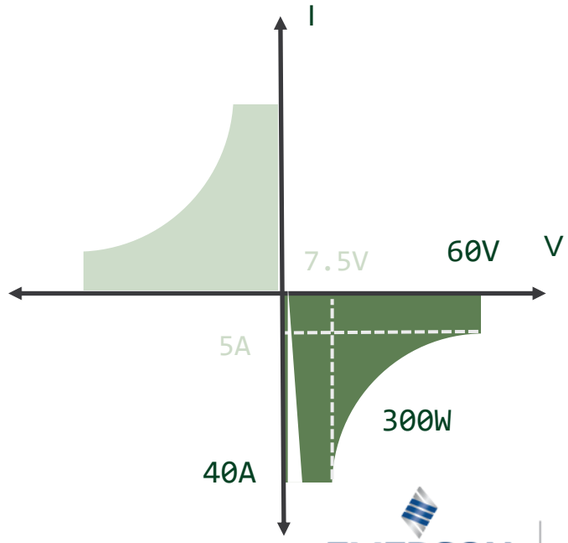
Released

High-Performance 300 W PXI Electronic Load

3-slot PXI E-load with DMM-like Measurement Accuracy

- Max sink power = **300W**
  - **60V, 40A**
  - 150 V CAT I Isolation
- Phase 1 Modes (Released): Constant voltage (CV), constant current (CC)
- Phase 2 Modes Constant resistance (CR), constant power (CP)
- Ranges
  - Current: Full scale and 4 A ranges (10 µA resolution, 0.05% + 700 µA accuracy)
  - Voltage: Full scale and 6 V ranges (1 µV resolution, 0.03% + 600 µV accuracy)
- Programmable slew rate (CC mode)
- Simultaneous current and voltage measurements
- Floating design can be manually inverted to operate in quadrant II
- Pulsing API (up to DC boundary, does not extend I-V reach)
- Will work in any 58W or 82W PXI Express chassis, but will require the PXIe-1095, PXIe-1092, or PXIe-1084 for full 300W capabilities
- Will be limited to 150 W in a 58 W chassis

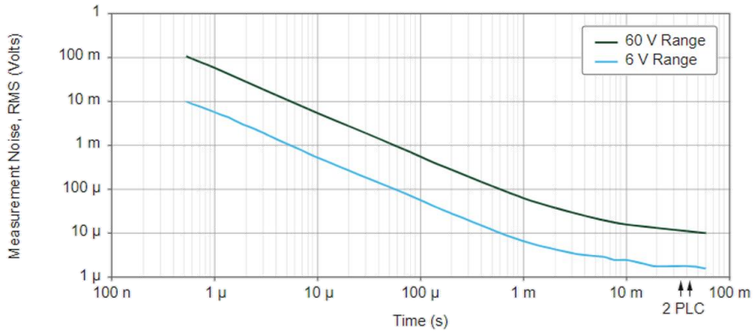
PXIe-4051

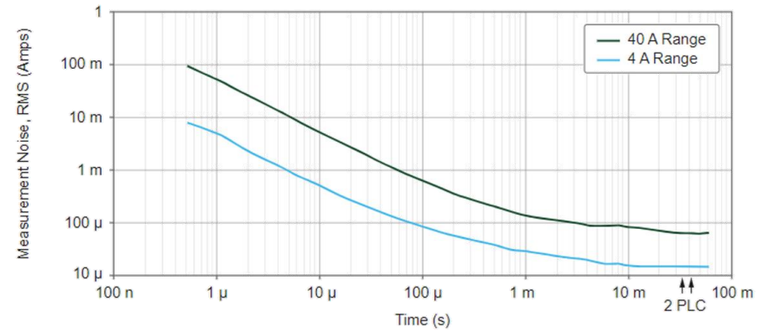


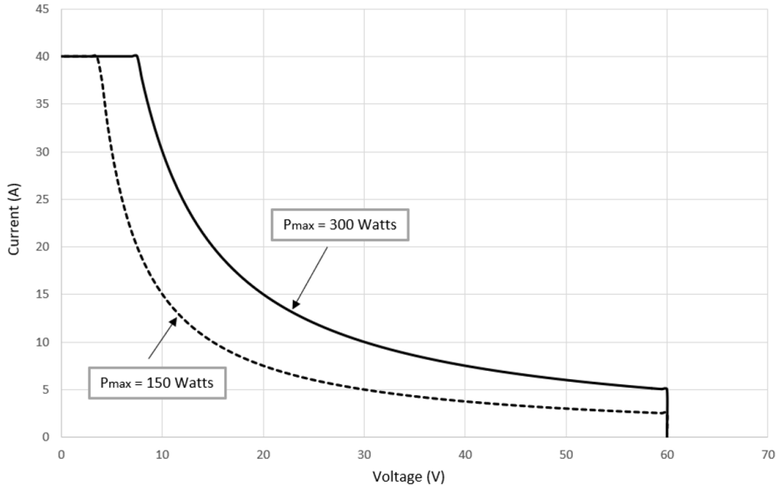
EMERSON | NI

PXIe-4051 | Spec Summary

- Sample Rate: 1.8 MS/s
- Update Rate: 100 kS/s
- Voltage:
  - 6 V range: 1 µV resolution, 0.03% + 600 µV accuracy
  - 60 V range: 10 µV resolution, 0.03% + 6 mV accuracy
- Current Accuracy:
  - 4 A range: 10 µA resolution, 0.05% + 700 µA accuracy
  - 40 A range: 100 µA resolution, 0.07% + 13 mA accuracy
- Minimum Operating Voltage:
  - Minimum input resistance (Rmin): 12.5 mΩ
  - Minimum 500 mV for full 40 A operation
  - Linear current derating between 0 V & 500 mV (Vin/Rmin)
- Max Slew Rate*:
  - DC current: 10 µs rise time, 3 A/µs
  - DC voltage: 103 µs rise time, 0.38 V/µs or 380 kV/s
- Power & Cooling Requirements:
  - Requires PXIe-1084, PXIe-1092, or PXIe-1095 for full 300 W
  - Limited to 150 W in 58 W chassis (other than PXIe-1084)
  - Will not work in 38 W chassis







*Slew rate depends on SourceAdapt settings and system setup. With proper tuning performance values may increase

PMIC Validation | More on Oscilloscopes

- **±50 V is the maximum voltage range for NI PXI Scopes**
  - Must use probes with 10x/100x attenuation for DUTs with voltages beyond ±50 V

- **Core PMIC measurements that need a scope:**
  - Capturing line/load transients that require a faster SR than 1.8 MS/s
  - Noise, ripple/PSRR
  - Start up sequence and shut down sequence for DC-DC converters
  - OVP/UVP/OCP/UCP when fast sampling rate is needed
  - LED dimming test
  - Gate driver propagation delay, rise time, fall time, and pulse width distortion

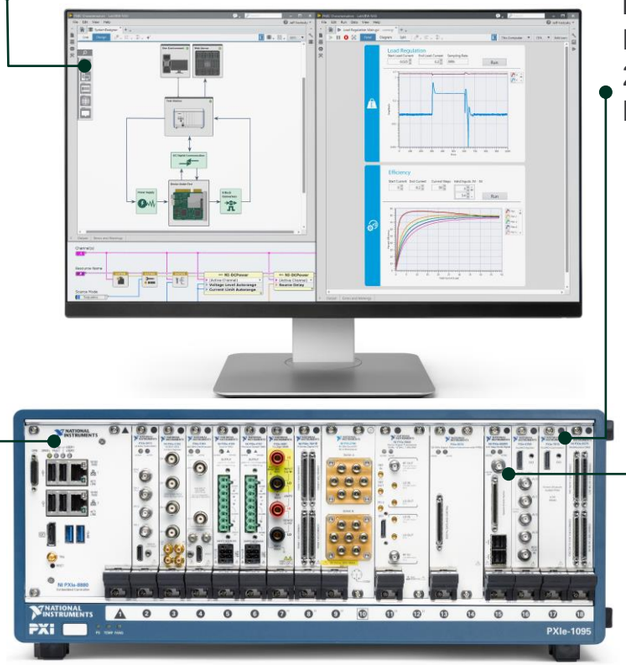
Q&A

CONNECT
2024 AUSTIN

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