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# Analyzing Large Signal Phenomena and Crosstalk in Time and Frequency Domain and Avoiding Ground Loop Effects

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# Abstract

As electronic designs evolve, managing power fluctuations becomes increasingly challenging due to lower voltage levels and tighter component tolerances. With rising data rates, shrinking supply voltages, and higher integration densities, issues such as jitter, noise, frequency-dependent loss, reflections, and crosstalk are more common than ever. These factors can significantly affect power rails, resulting in voltage sag and ground bounce. Power rail disturbances, in return, have an increasing effect on signal integrity, particularly through power supply-induced jitter and amplitude noise. Thus, analyzing power integrity and the performance of the power delivery network (PDN) on a printed circuit board (PCB) is now an essential part of the digital design process.

In this session, you will learn more about:

•Analyzing large and small signal phenomena and the corresponding way of testing them

•Measuring PDN Crosstalk in the time and frequency domain

•Ground loop effects and how to avoid them

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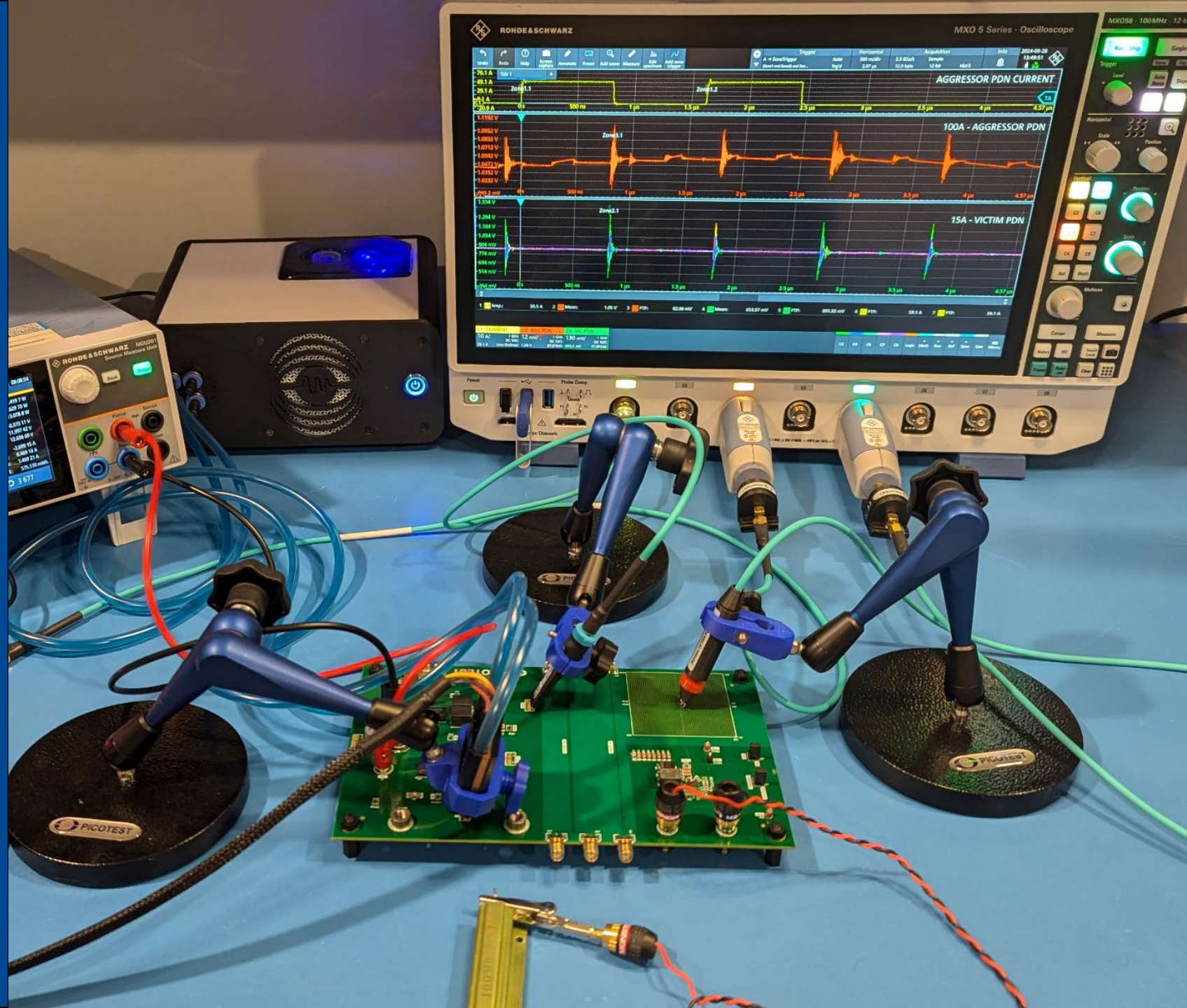
# ANALYZING LARGE SIGNAL PHENOMENA AND CROSSTALK IN TIME & FREQUENCY DOMAIN AND AVOIDING GROUND LOOP EFFECTS

AGENDA:

- WHY PDN CROSSTALK IS IMPORTANT
- USING ZONE TRIGGER ON MXO5
- PDN CROSSTALK ANALYSIS
- AVOIDING GROUND LOOPS
- LARGE VS. SMALL SIGNAL TESTING
- CONCLUSIONS



# WHY IS PDN CROSSTALK IMPORTANT

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- PDNs for ASIC packages and PCBs have an increasing number of power domains to supply power for multiple circuits on the die, or to multiple ASICs.
  - AMD Versal VPK180 evaluation board has 23 power domains on the PCB!
- Crosstalk occurs when electromagnetic energy from one signal (called the "aggressor") couples onto another signal (the "victim"), causing unwanted interference on the victim signal.
- Crosstalk can occur between any two conductors on your PCB including PDN to PDN.
- Crosstalk noise on the PDN can contribute to jitter and degrade performance of sensitive circuits such PLLs, clocks, RF signals, etc.

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# PDN CROSSTALK MEASUREMENT SETUP

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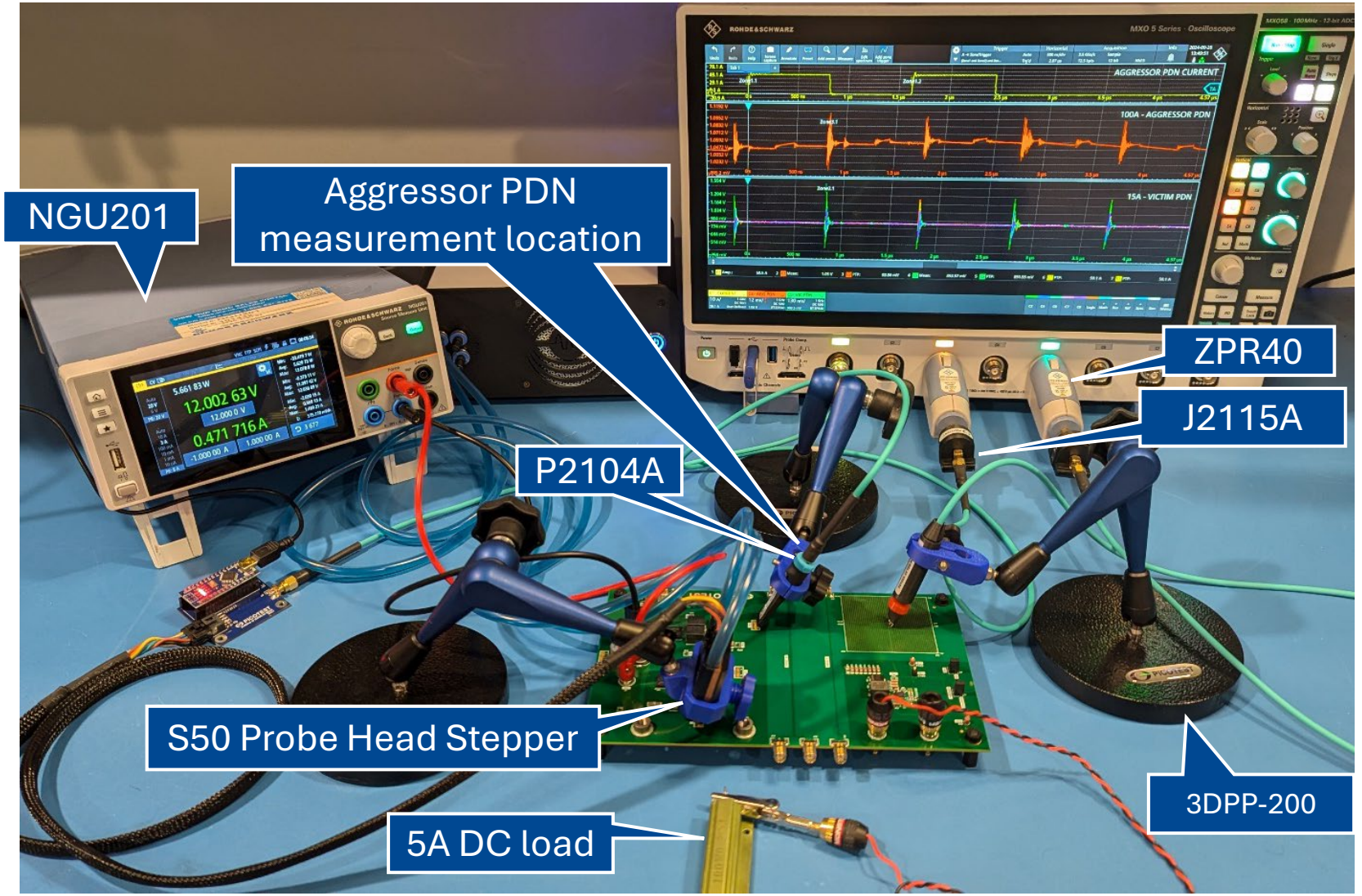


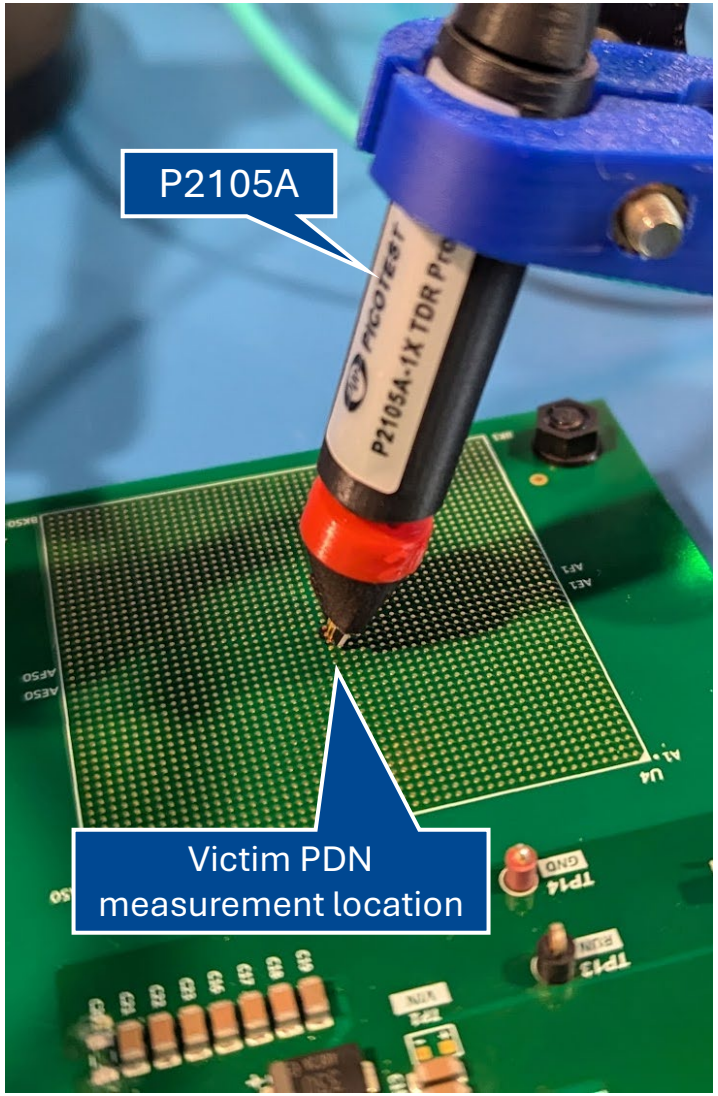


[Picotest S50 Demo Board | Signal Edge Solutions]

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# MEASUREMENT RESULT – 5A DC LOAD ON VICTIM PDN

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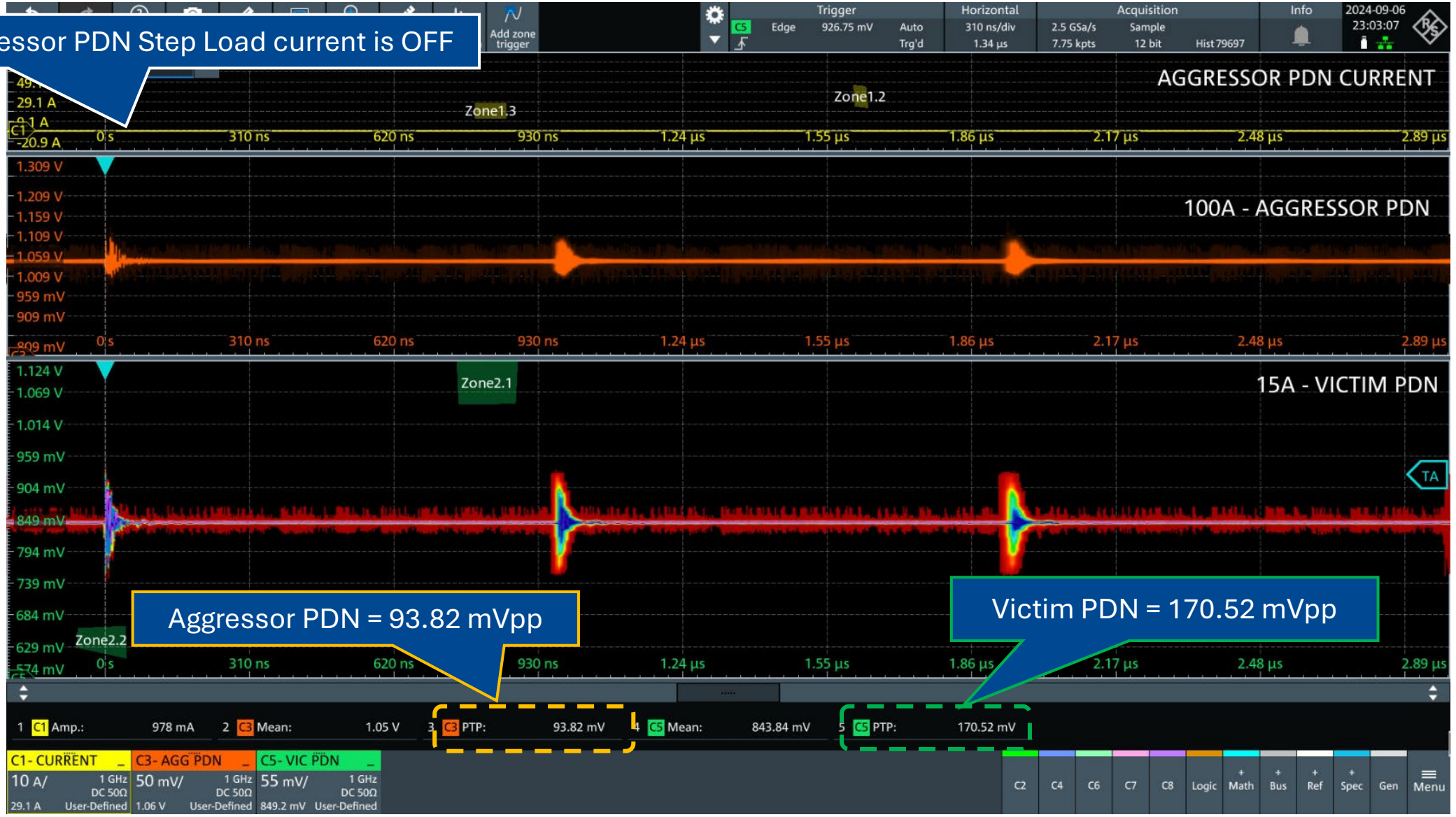


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# ZONE TRIGGER SETUP TO MEASURE PDN CROSSTALK

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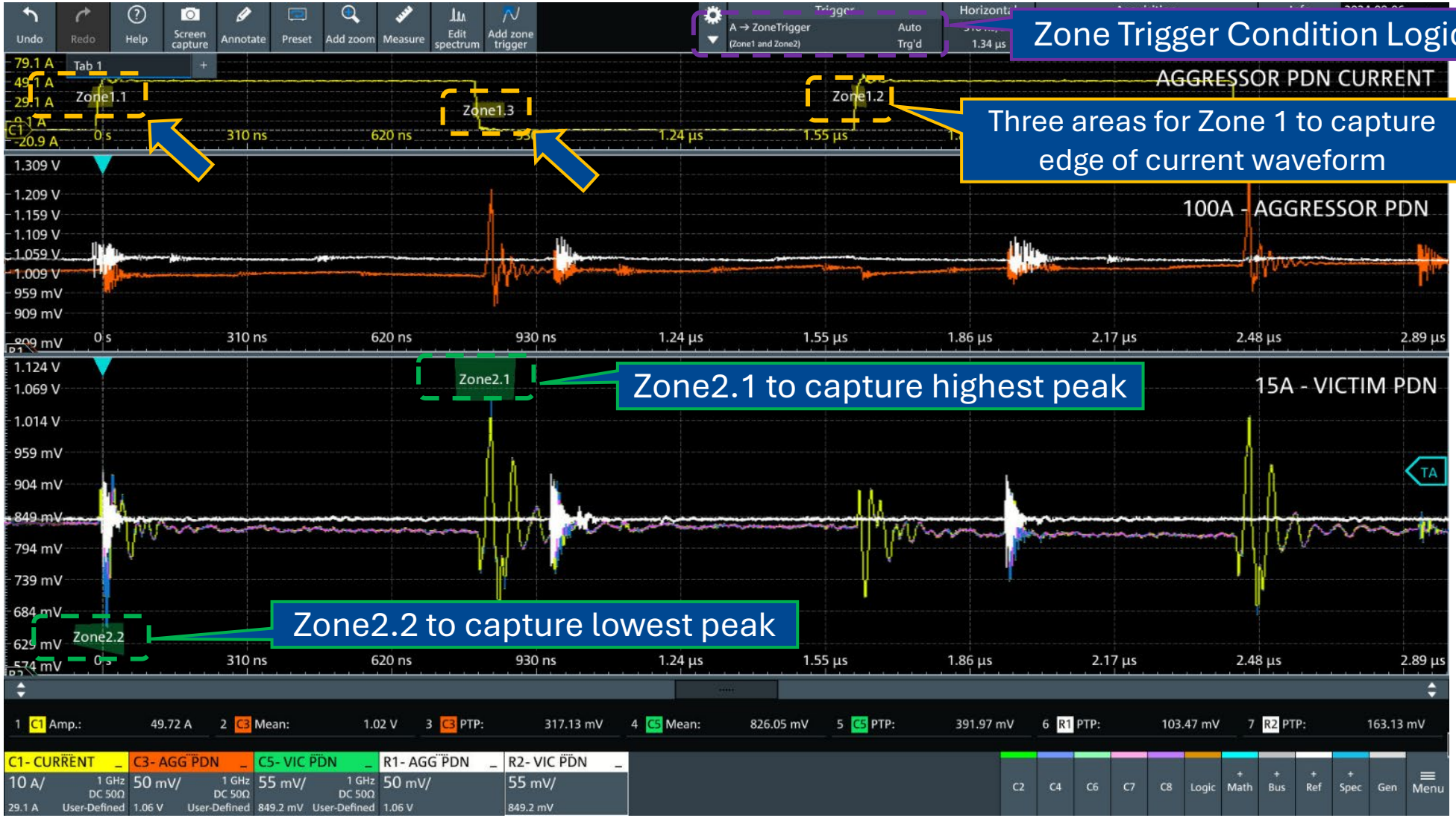
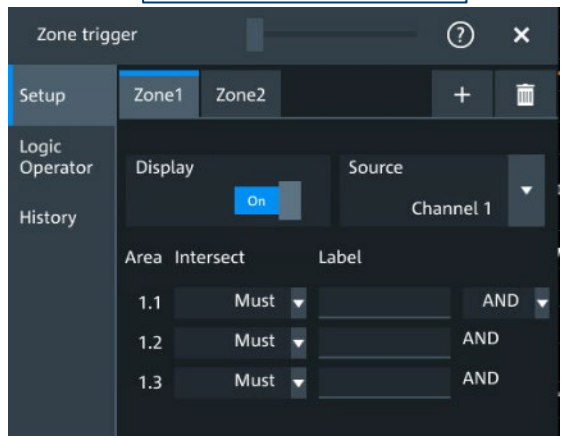
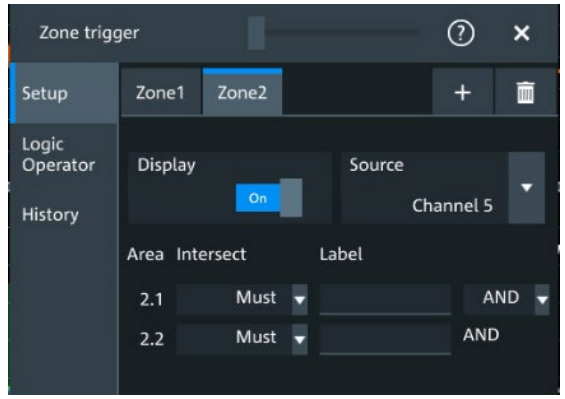



## Zone1 Setup




## Zone2 Setup




Zone Trigger is used to accurately measure three (3) non-synchronized signals

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# PDN CROSSTALK – 50A PULSED LOAD


228.84 mVpp increase in voltage noise on Victim PDN due to PDN crosstalk!

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# PDN CROSSTALK – NOISE SPECTRUM WITH 50A PULSED LOAD

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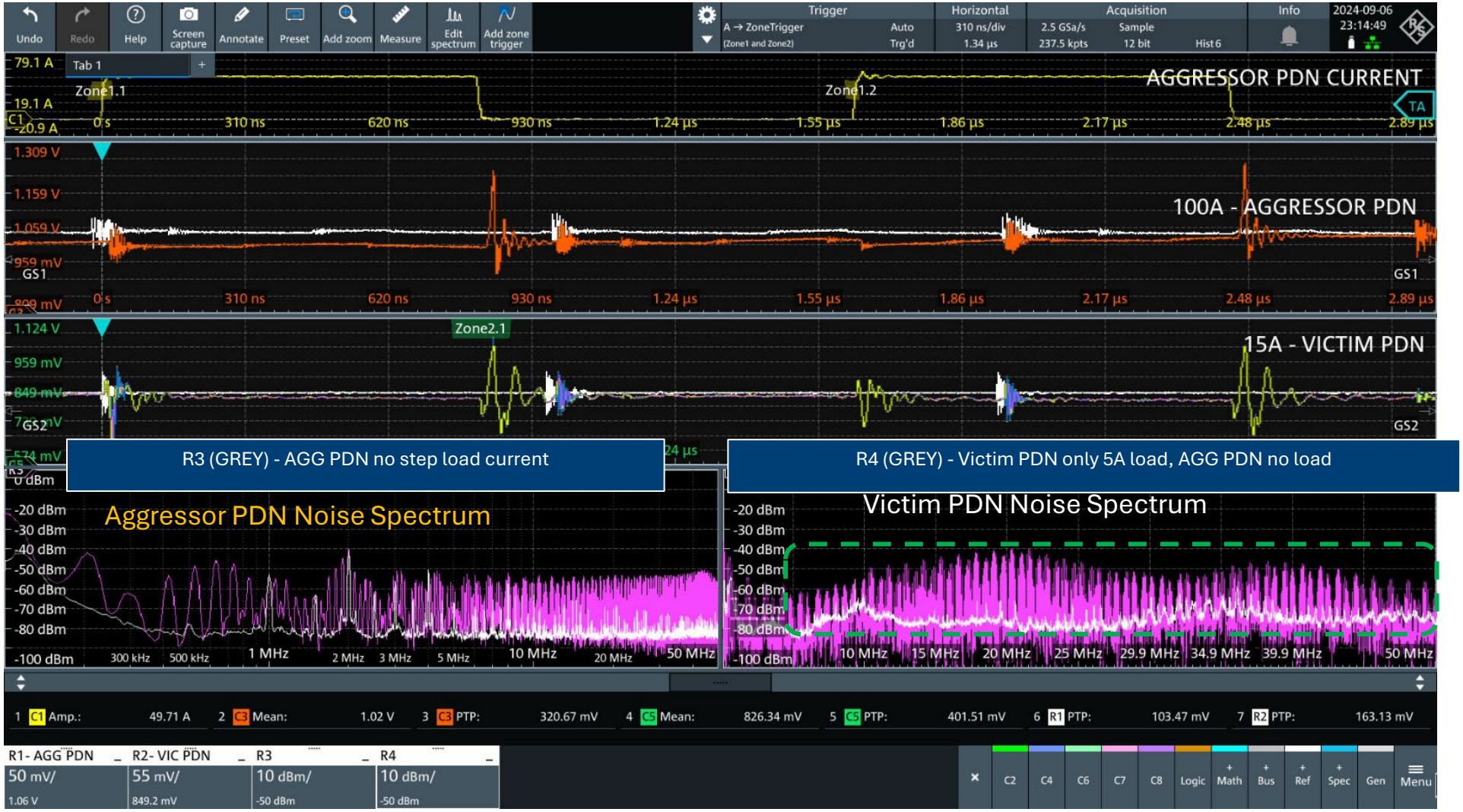


10 dB to 30 dB increase in noise from 100 kHz to 50 MHz due PDN crosstalk

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# THE SOLUTION TO THE GROUND LOOP PROBLEM

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## Previous measurements did NOT have ground loops

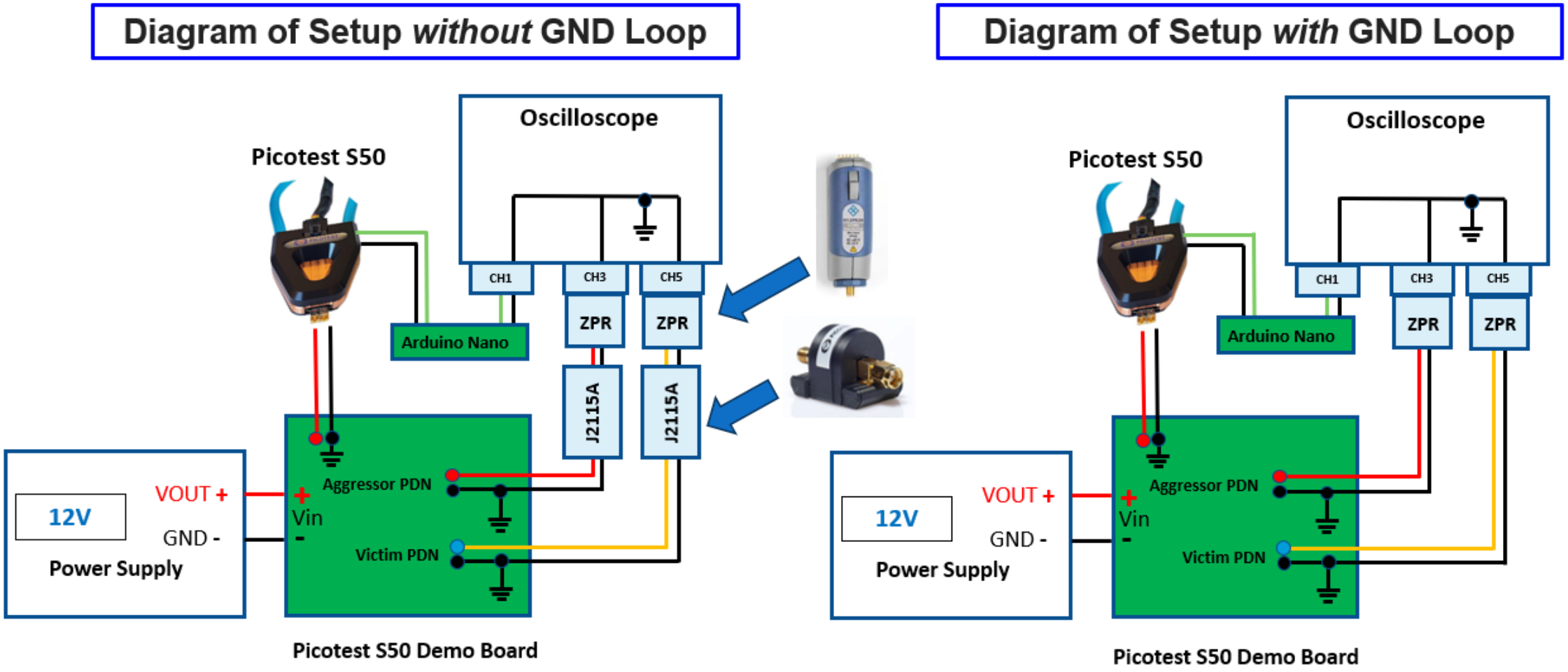


Image Source: Dannan, B. Sandler, S. (2024, Aug 21) Correcting Ground Loop Errors in Multi-Channel Oscilloscope Measurements with Power Rail and other Single-Ended Probes. EDICon 2024.

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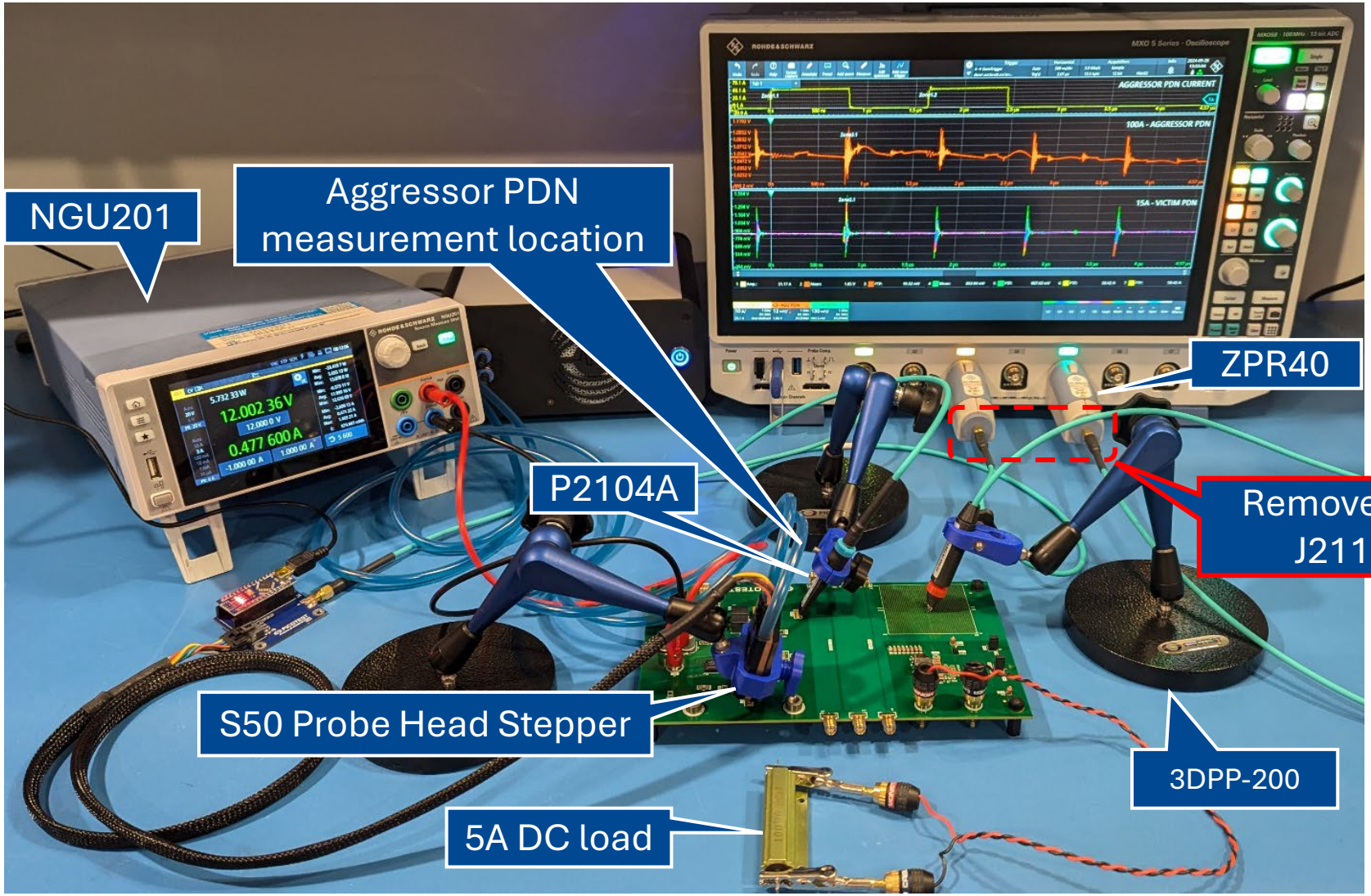
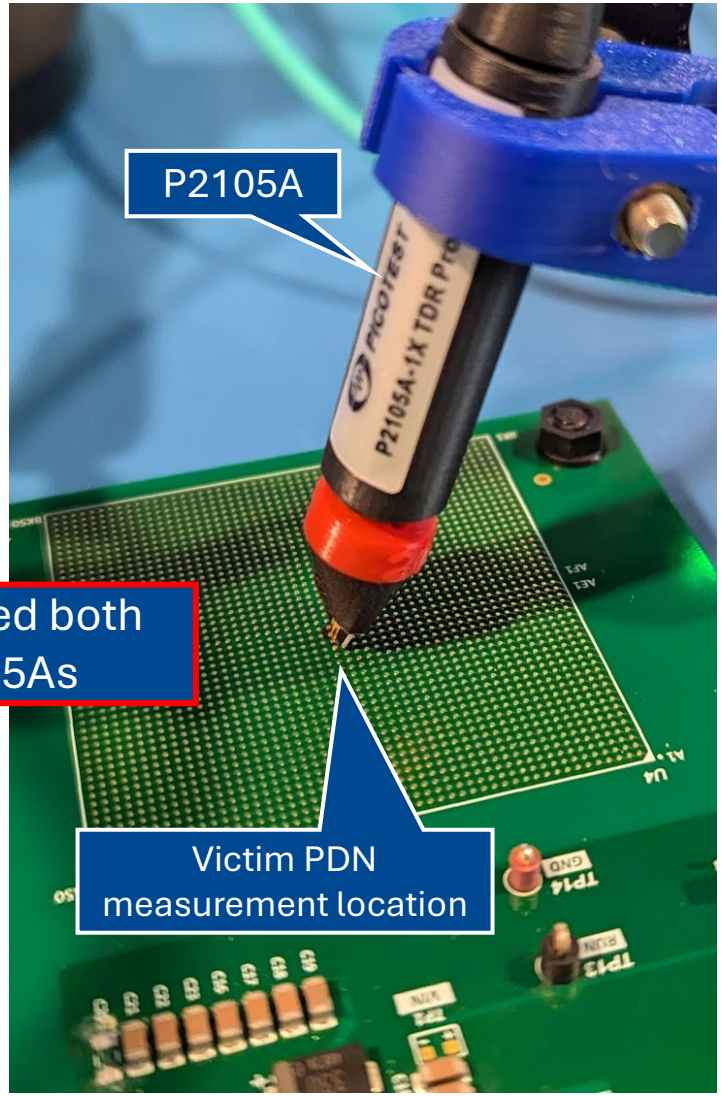
# MEASUREMENT SETUP WITH GROUND LOOPS






[Picotest S50 Demo Board | Signal Edge Solutions]

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# PDN CROSSTALK – 50A PULSED
## GND LOOPS VS. NO GND LOOP


**Victim PDN has 369.9 mVpp increase PDN crosstalk noise with GND LOOP!**

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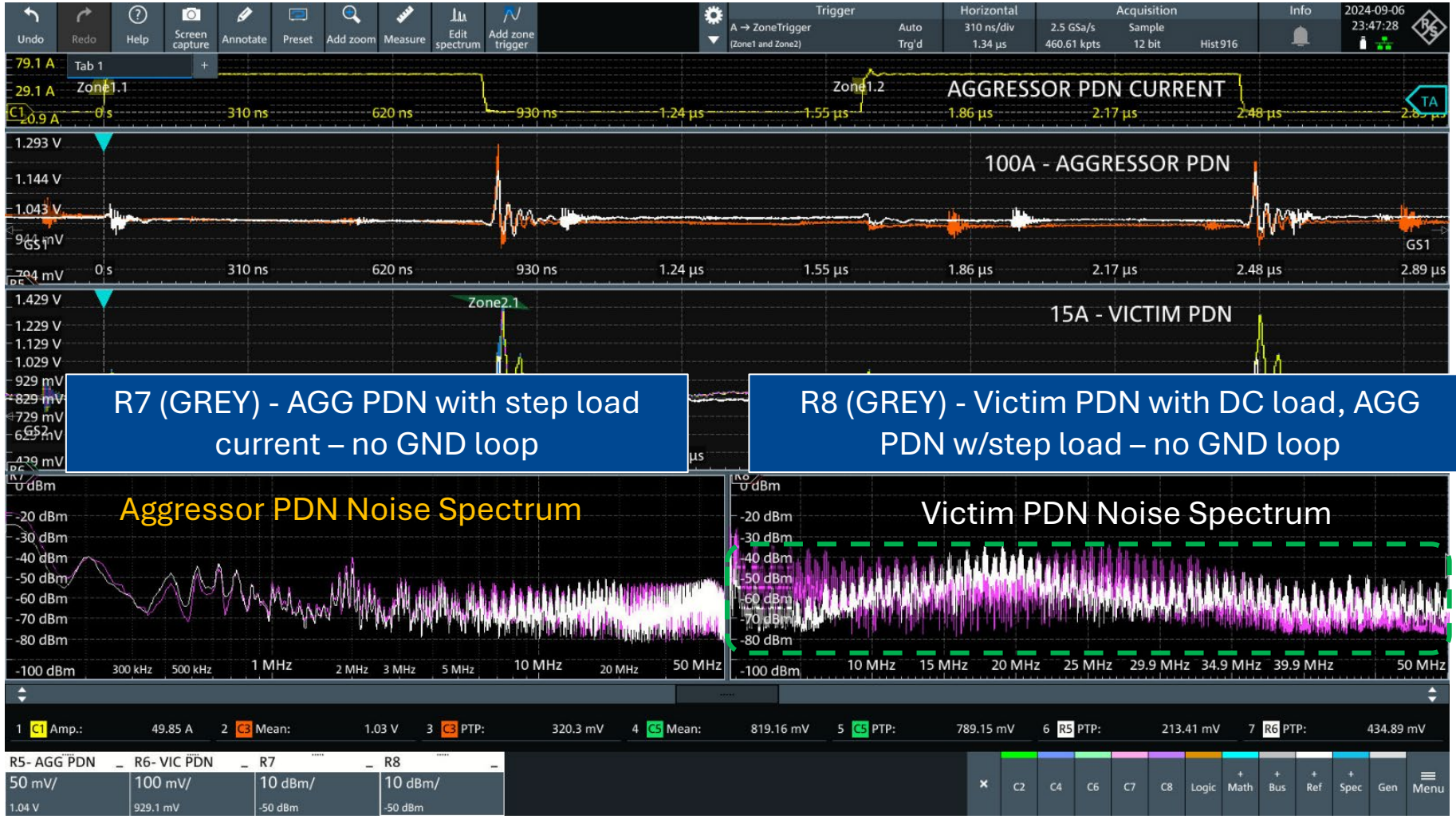
# NOISE SPECTRUM WITH 50A PULSED LOAD
## GND LOOP VS. NO GND LOOP




10 dB to 30 dB increase in crosstalk noise with the GND loop!

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# LARGE VS. SMALL SIGNAL MEASUREMENT VALIDATOIN

- Measurement Equipment
  - Invest in high-quality measurement equipment before trying to make these types of measurements
- Small signal vs Large signal
  - **Small signal** represent relatively constant signals and typically have small variations around a nominal operating point (DC)
    - Valuable for assessing PDN stability and noise margins
  - **Large signal** focuses on phenomena such as transient, step response, voltage droop
    - Stored energy in the inductor can also cause large signal effects
  - Small signal represents a linear region of the control loop whereas large signal is non-linear response

Reference: Sandler, S., Dannan, B., Barnes, Ezra, I., Ni, Y. (2024, January) Design, Simulation, and Validation of a 2000-Amp Core Power Rail. DesignCon 2024.

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# LARGE VS. SMALL SIGNAL MEASUREMENT TESTING

- **Small signal testing focuses on relatively constant signals with small variations such as:**
  - Impedance
  - PSRR
  - Bode plot
- **Large signal testing focuses on phenomena such as:**
  - Transient
  - Step response
  - Voltage droop – a decrease in voltage during sudden increase in current
  - Power delivery during peak power demand
  - Large signal impedance can be observed when using a Picotest in-socket load using a high current sine wave
- **Power integrity includes everything from the power supply to the load.** PDN design & validation is specific to each application!
  - This means → PDN validation requires both large signal and small signal measurements

Source: Sandler, S., Dannan, B., Barnes, Ezra, I., Ni, Y. (2024, January) Design, Simulation, and Validation of a 2000-Amp Core Power Rail. DesignCon 2024.

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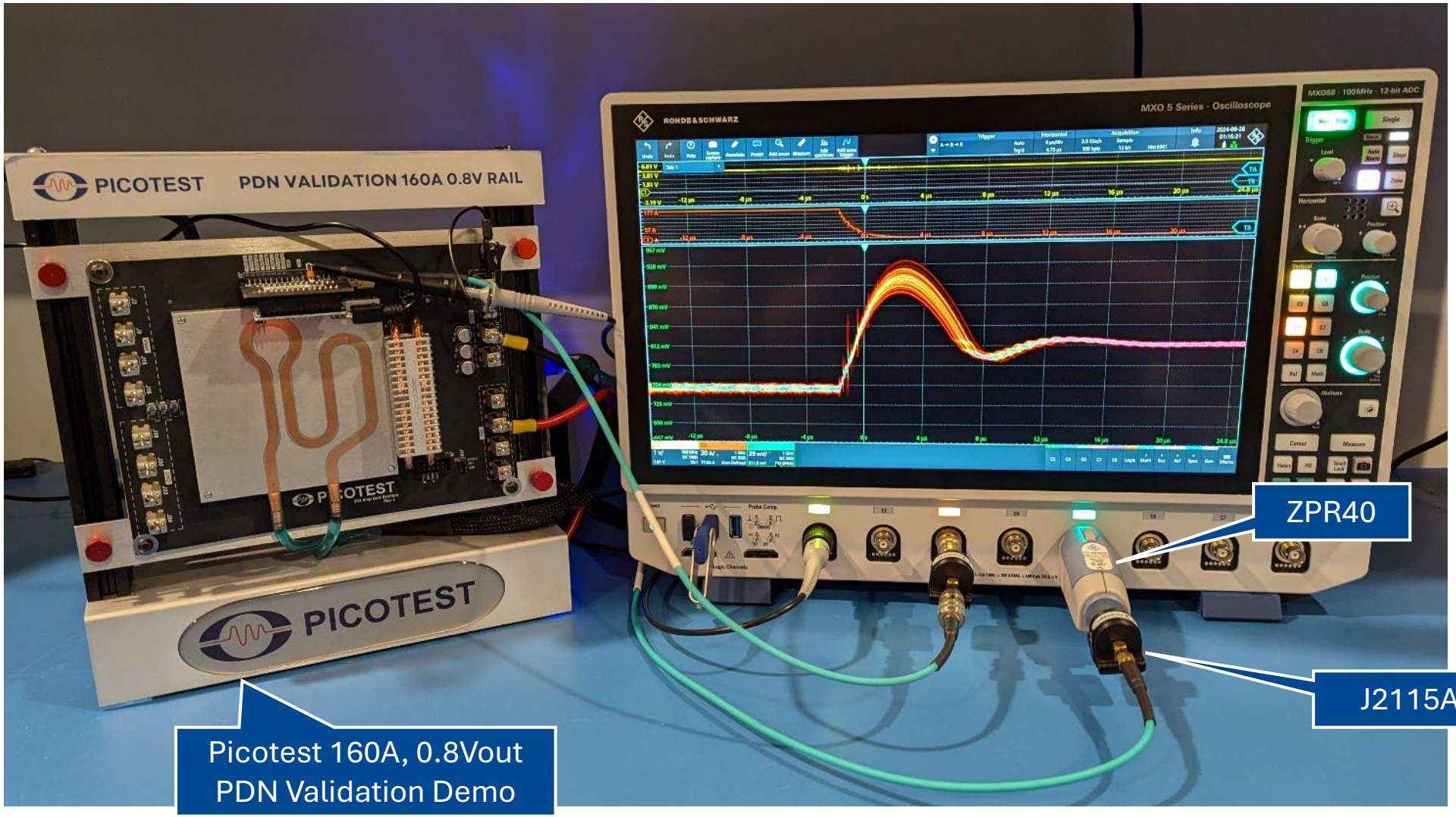
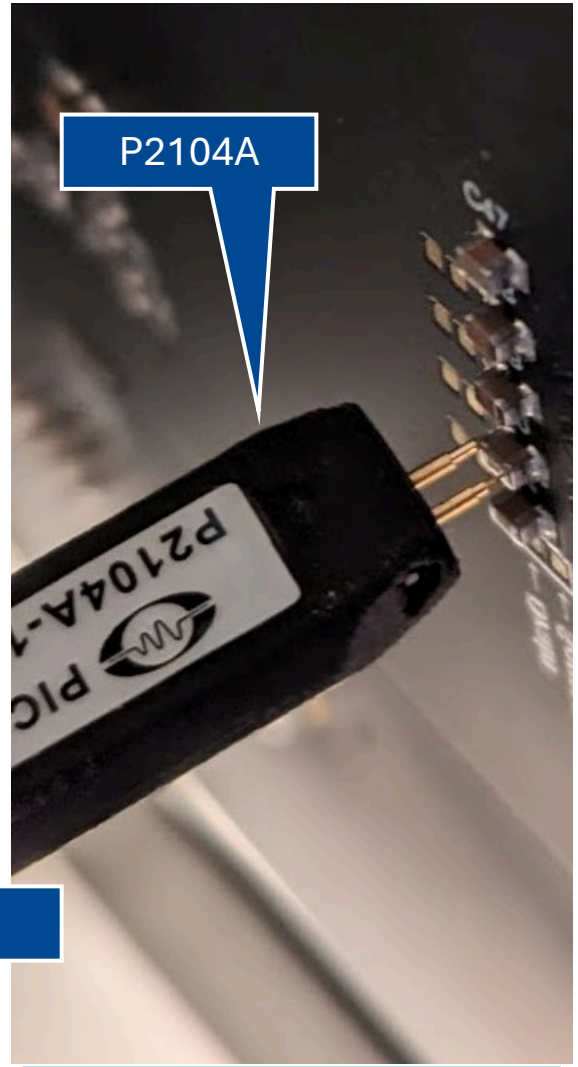
# LARGE SIGNAL MEASUREMENT SETUP




**CH5 - P2104A Probe on C50**
**Located on back of Demo Board**

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# LARGE SIGNAL PHENOMENA SEQUENTIAL TRIGGER SETUP

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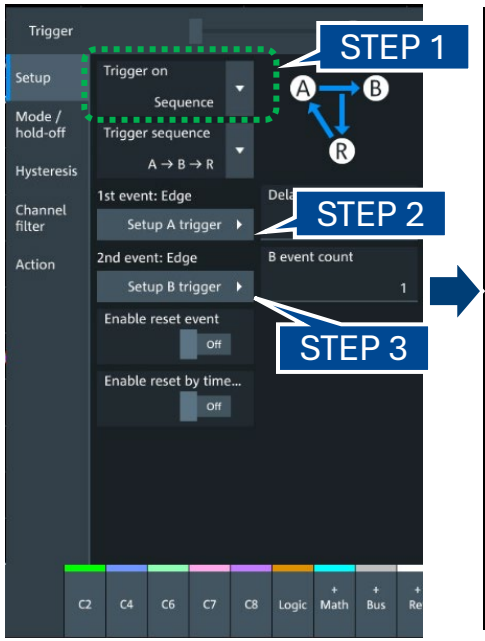
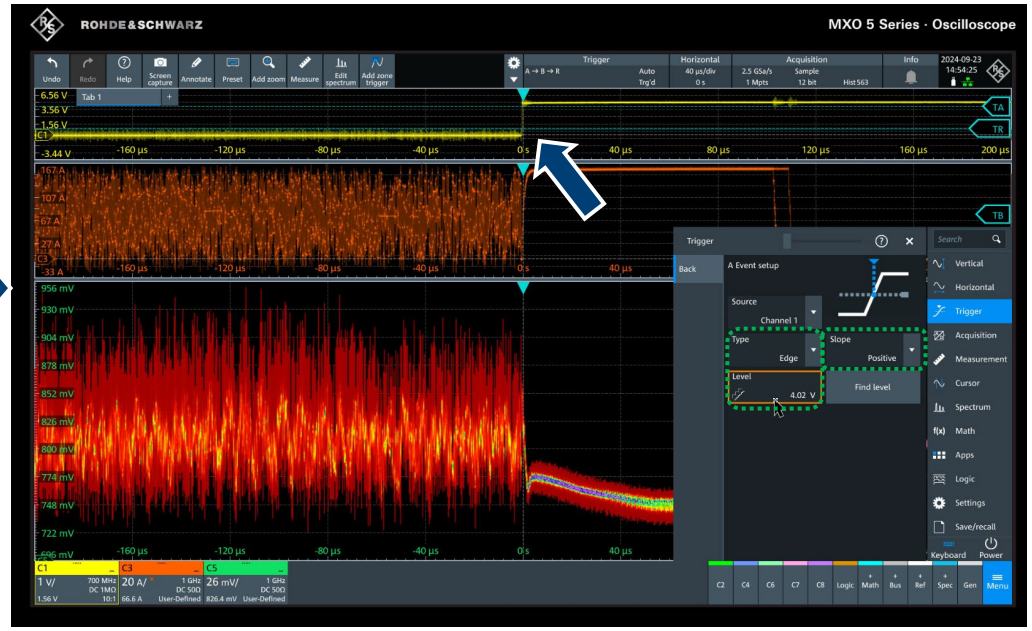
**To setup sequential trigger, open trigger menu and follow these steps….**

**STEP 1 - Under Trigger On > Select Sequence**





**STEP 2**
**Select > Setup A Trigger**
**Select > ‘Edge’ Type & ‘Positive’ Slope**
**> Adjust Level on rising Edge of CH1**

**STEP 3**
**Select > Setup B Trigger**
**Select > ‘Edge’ Type & ‘Negative’ Slope**
**> Adjust Level on falling edge of CH3**

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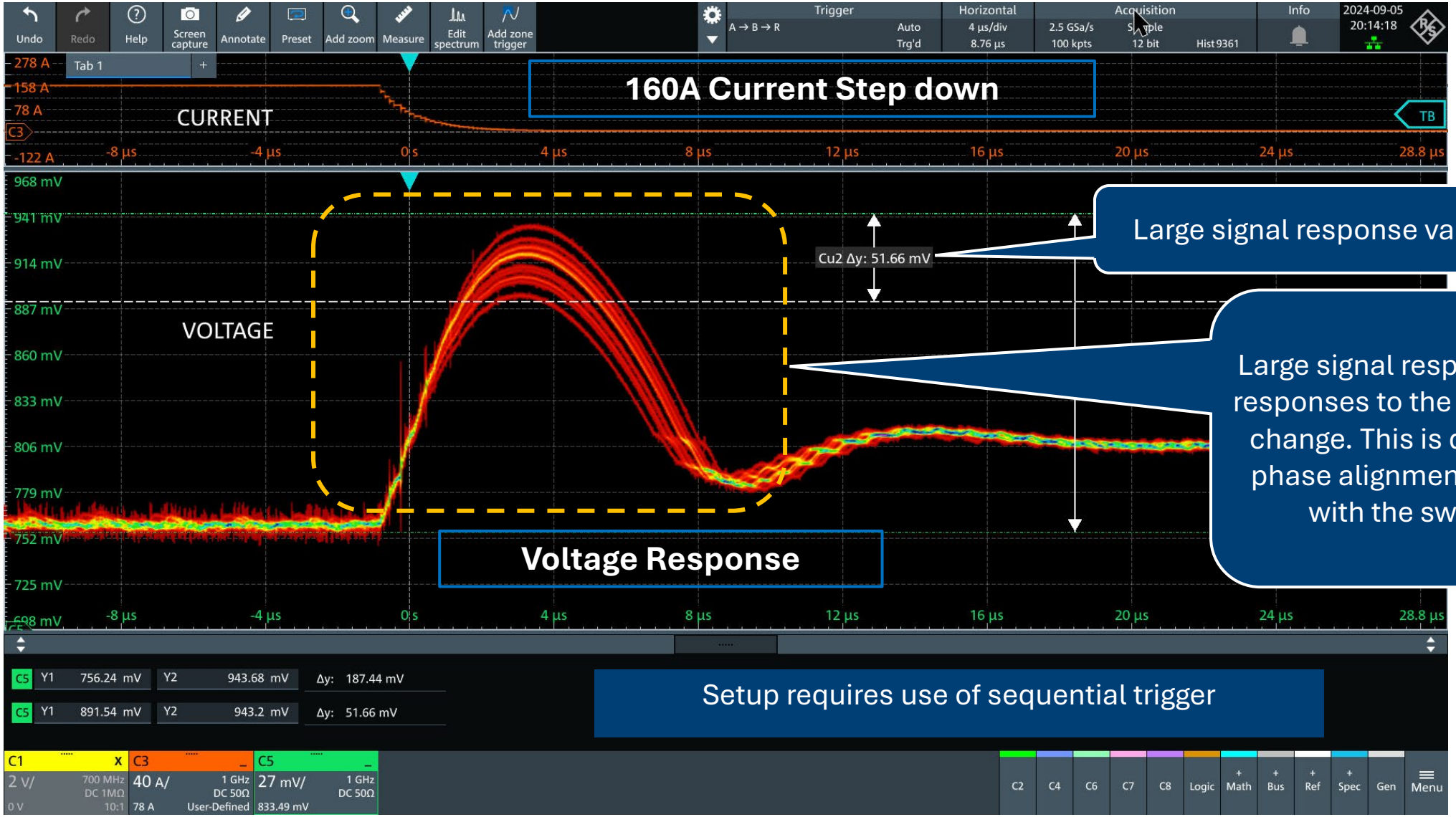
# LARGE SIGNAL PHENOMENA – DUE TO 160A STEP CHANGE

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# LARGE SIGNAL PHENOMENA – DUE TO 160A STEP CHANGE


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# CONCLUSIONS AND WRAP-UP

- **PDN validation requires both large signal and small signal measurements**
- **Ground loops are everywhere and can impact your measurement significantly!**
  - Use a Common mode isolator such as the J2115A or J2102B to break the ground loop
- Important to validate PDN design at multiple frequencies, to assess large signal response and PDN crosstalk performance
- The S50 browser probe format allows ‘Go / no-Go’ large signal testing
- Precise and repeatable load current control allows characterization/validation of power rail:
  - PDN Crosstalk
  - Thermal performance
  - EMI
- Easy to create forced PDN response with various patterns:
  - Pseudo random, long dwell, long pattern, sine or pulse

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# REFERENCES


1. R&S MXO 58 Oscilloscope - 2GHz BW | Signal Edge Solutions
2. Picotest P2105A 1-Port Low Noise TDR - Ripple Browser Probe | Signal Edge Solutions
3. Picotest P2104A 1-Port Transmission Line PDN Probe | Signal Edge Solutions
4. Picotest P2105A Probe-Based Stepper (S10) | Signal Edge Solutions
5. Picotest Water-Cooled Head Stepper <50A (S50) | GaN-enabled | Signal Edge Solutions
6. Picotest S50 Demo Board | Signal Edge Solutions
7. Picotest J2115A | Signal Edge Solutions


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