Tektronix

전원 설계를 위한 오실로스코프 200% 제대로 사용하는 방법

오실로스코프 파워 솔루션과 파워 전용 프로브

Understanding Power

240/120V AC

12V DC

SMPS

440V AC

Large Motors

240/120V AC

Small Motors

400V AC

Wind Power

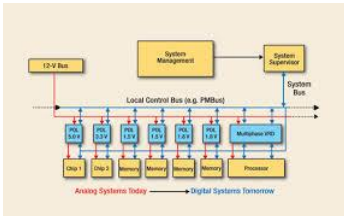
1500V DC

Solar Power

24V DC

250V AC

Inverters



12V DC

5/3.3/1.3V DC

DPM

Power Solutions : Hardware

- ISOVu Isolation Probe(TIVP)
- Power Rail Probe(TPR)
- 6 Series B MSO Oscilloscope

Elements of a Complete Power Solution

- Best in Class Acquisition System
  - Oscilloscope
- Best In Class Probing capability
  - Ability to meet new design needs
- Automated Application Software
  - Ease of Use
  - Repeatable
  - Report
- Complete Solution

All Great Measurements Start With Probing

- Choose adequate bandwidth for your signal
- Differential / Single-ended probes (ground referenced or not)
- Make sure probe is within its voltage operating range (safety!!)
- Low probe loading to reduce effects on circuit
- A probe that communicates to your scope ensures probe parameters are automatically captured
- Differential/Floating measurements measure the difference in voltage between two nodes
  - **Method 1**: Floating the Scope **(DO NOT DO THIS!)**
  - **Method 2:** Use two single-ended probes and scope math (CH1-CH2) to measure the difference
  - **Method 3:** Using an isolated input and an isolated probe.
  - **Method 4:** Using a differential probe/amplifier **(PREFERRED)**

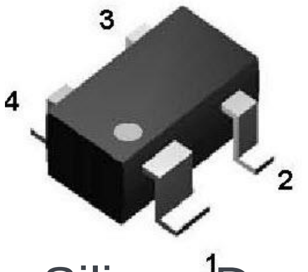
THDP0100 (± 6000 V / ± 6000 V, 100 MHz)

TCP0030A (1mA to 30 A, 120 MHz)

TIVP (+/- 3300V, ≤ 60kV, 1 GHz)

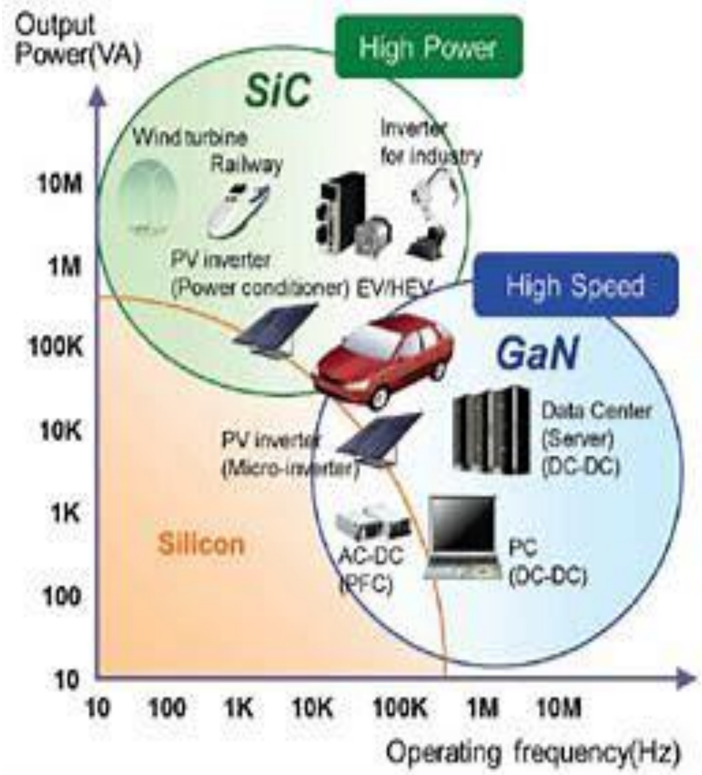
TPR4000 (<300uV Noise(20MHz, MSO6B), 4 GHz)

Wideband GAP devices getting into designs



Silicon Dual Channel MoSFET

Silicon Carbide Chip



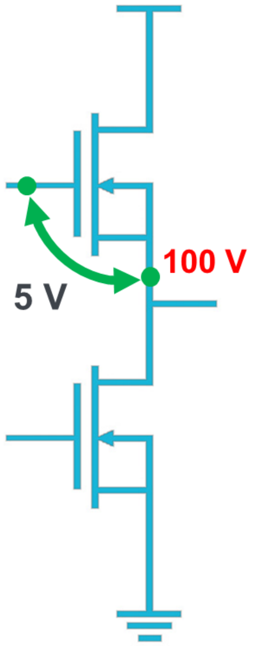
SiC for high power voltages (>1kV) with high current
= niche market

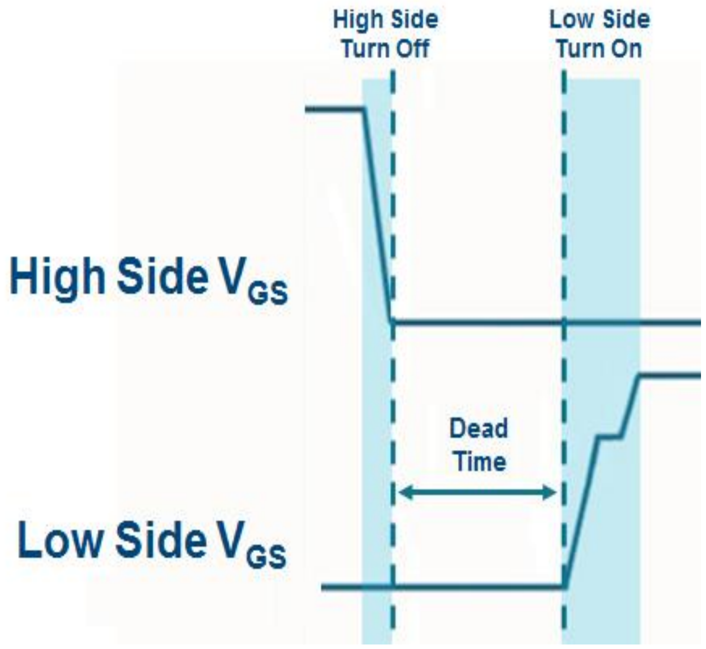
GaN on Si for high frequency at midrange voltages (<1kV, up to 100A)
= mass market

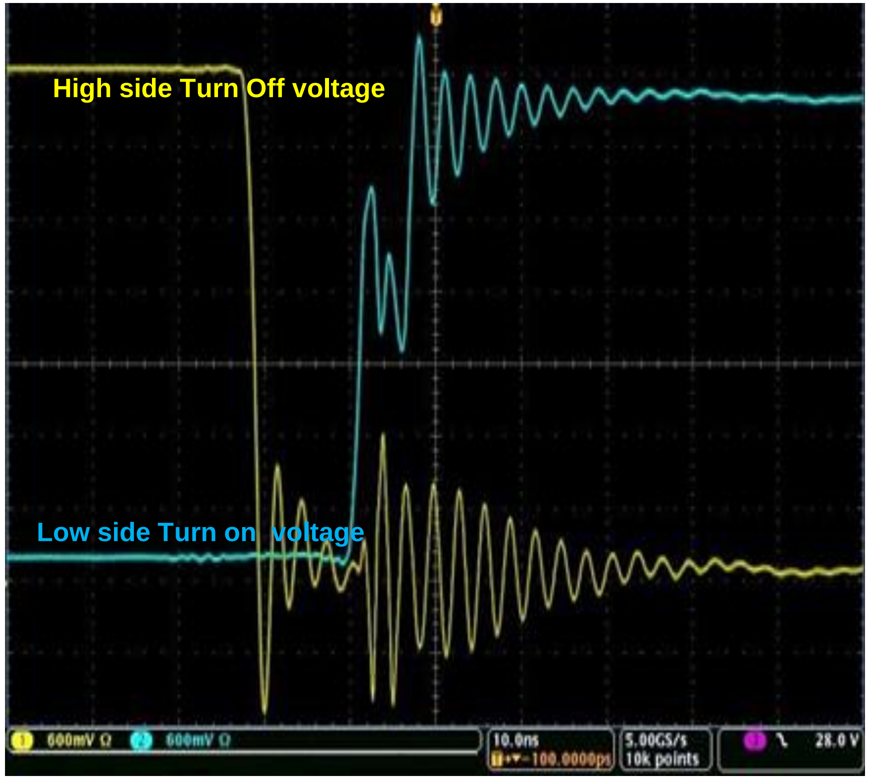
New Probing Challenges: Wide Bandgap Measurements

INTERACTION BETWEEN THE HIGH AND LOW SIDE

- Violation of specifications can lead to simultaneous conduction (it blows up), switch loss, loss of efficiency, and device degradation
- Parasitic coupling between switch node and both FETs



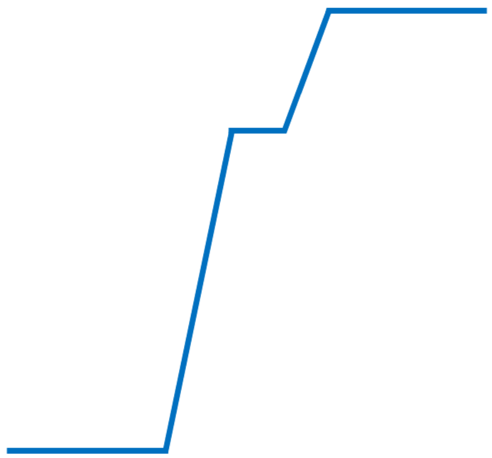




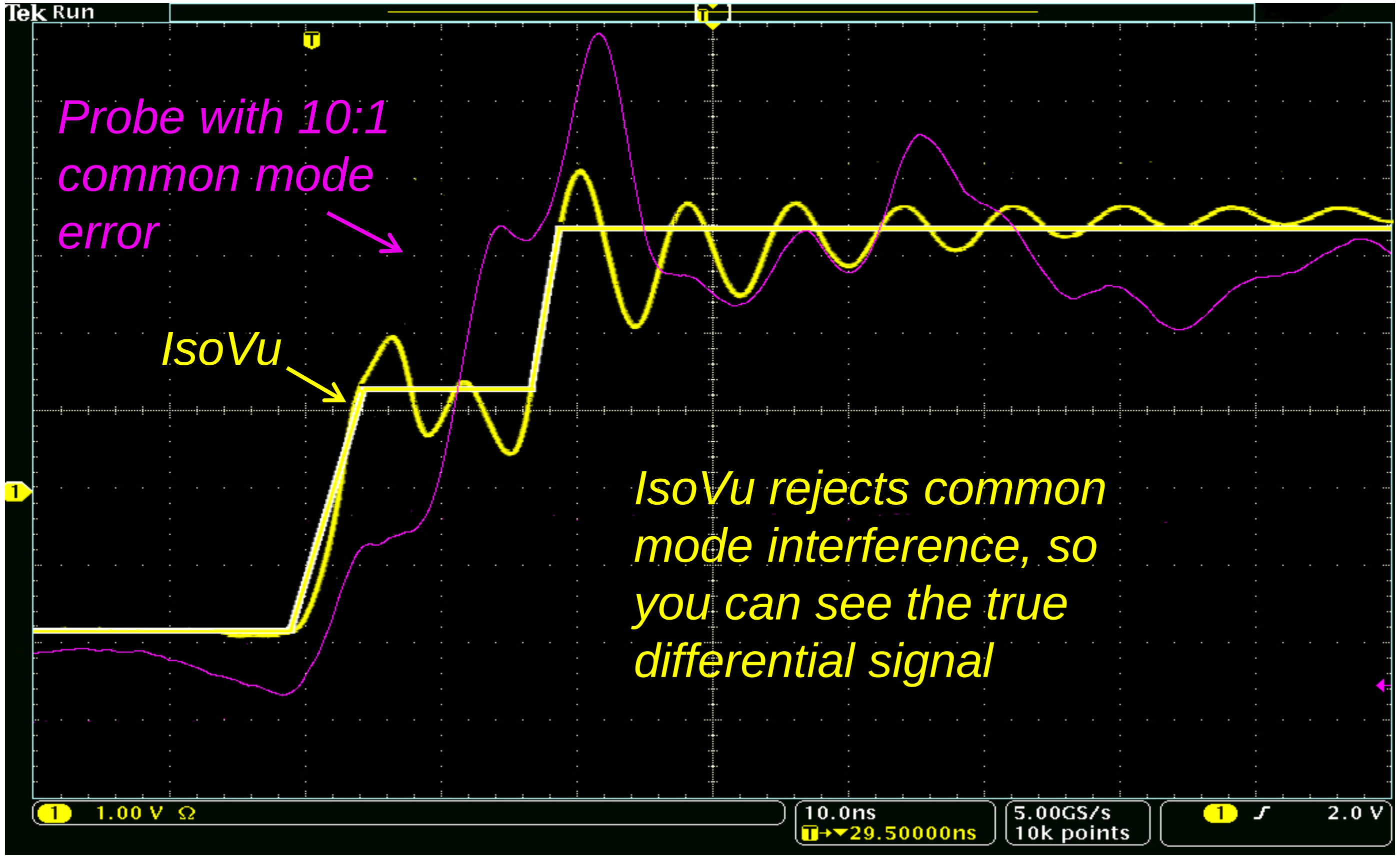
New Probing Challenges

DO YOUR WIDEBAND GAP MEASUREMENTS MATCH YOUR EXPECTED RESULTS?

- IsoVu gives you an accurate, repeatable measurement providing meaningful correlation with expected performance



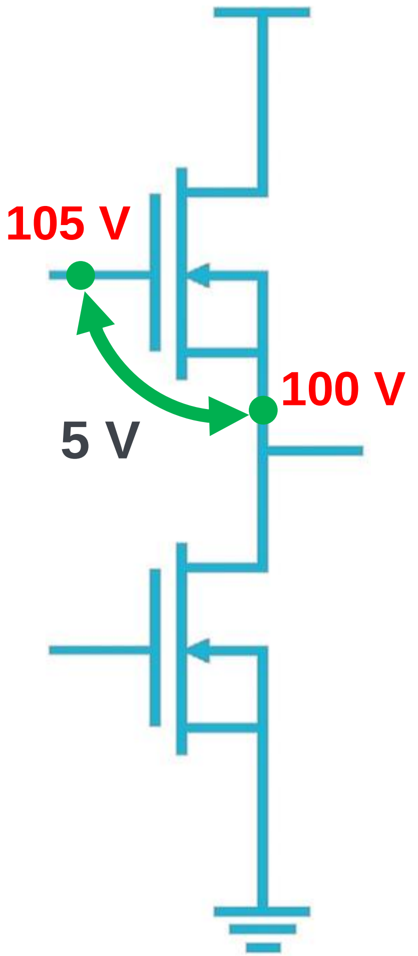
Expected Simulation Results

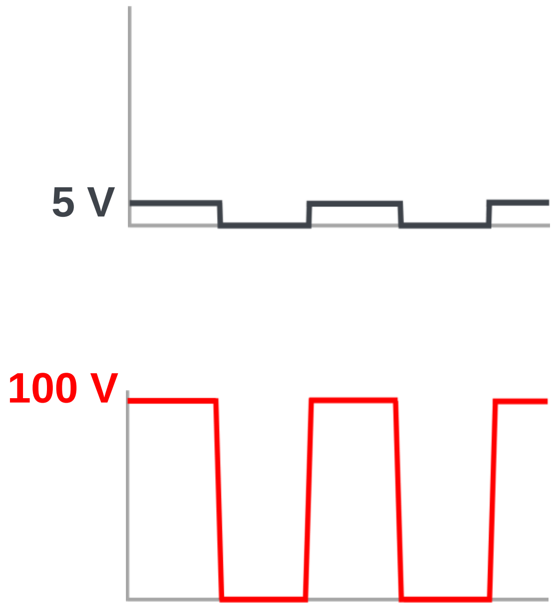


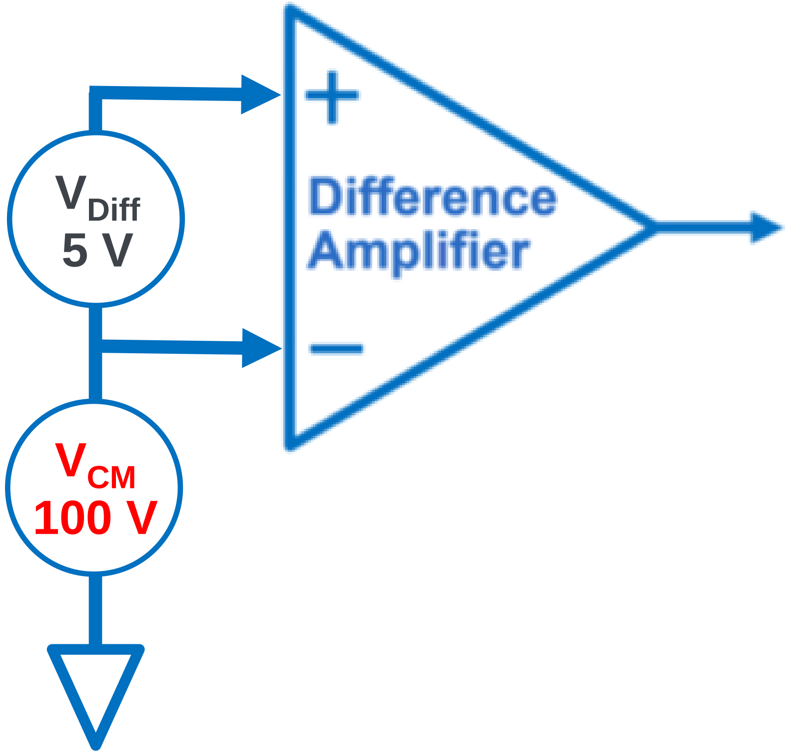
The Measurement Problem

CMRR IS A CRITICAL BUT OFTEN OVERLOOKED SPECIFICATION

Can a 5V differential signal be measured in the presence of 100V common mode signal?





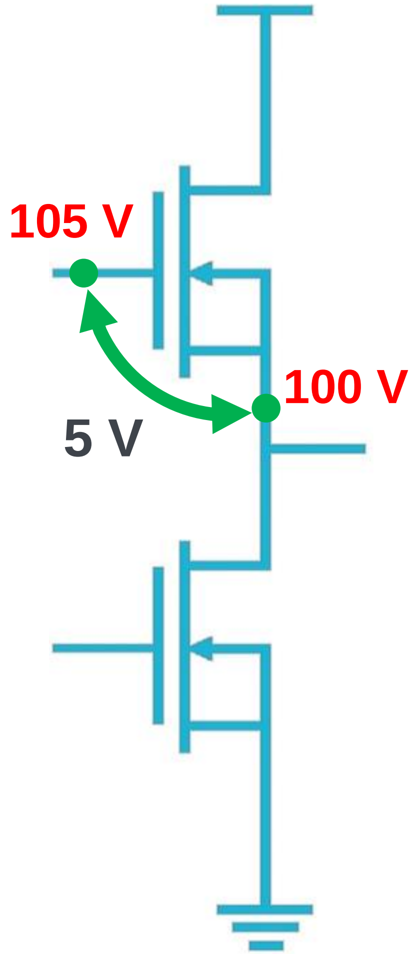


It depends on how much common mode error is in your measurement.
A probe's common mode rejection varies by:

- Magnitude of the common mode signal.
- Frequency content of the common mode signal.

IsoVu Solves the Common Mode Problem

MOST PROBES HAVE VERY POOR CMRR ABOVE A FEW MHZ



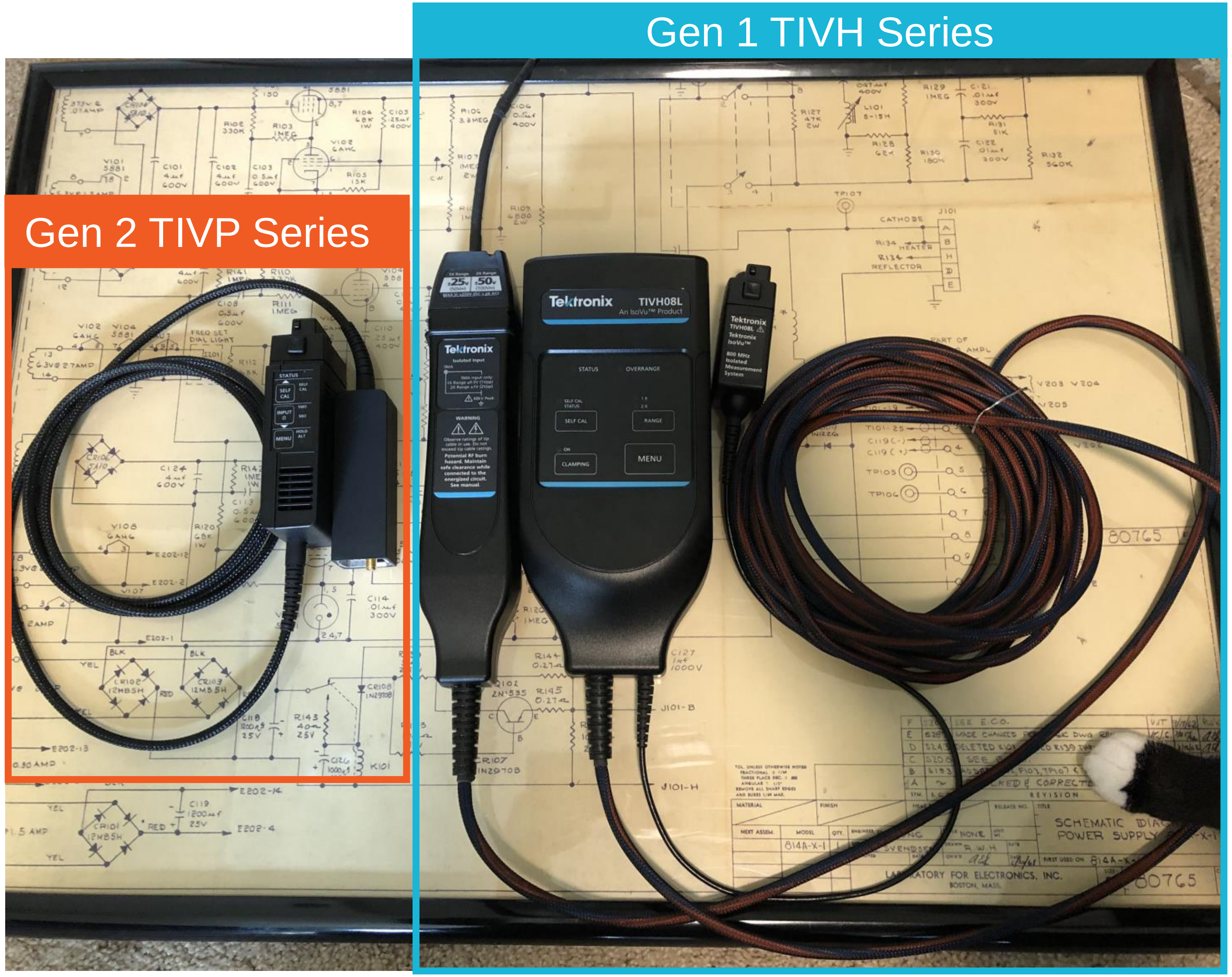
At 100 MHz, most probes have 20 dB or less common mode rejection. This is 10:1 common mode rejection.

- With 100 V common mode voltage, 20 dB or (10:1) common mode rejection is:
  100 V divided by **10** → **10 V error**

You can’t resolve 5V with 10V of error

IsoVu has 120 dB or 1 Million to 1 common mode rejection at 100 MHz
100 V divided by **1 Million** → **100 µV error**

IsoVu Gen 2 is 80% Smaller



TIVP vs. TIVH

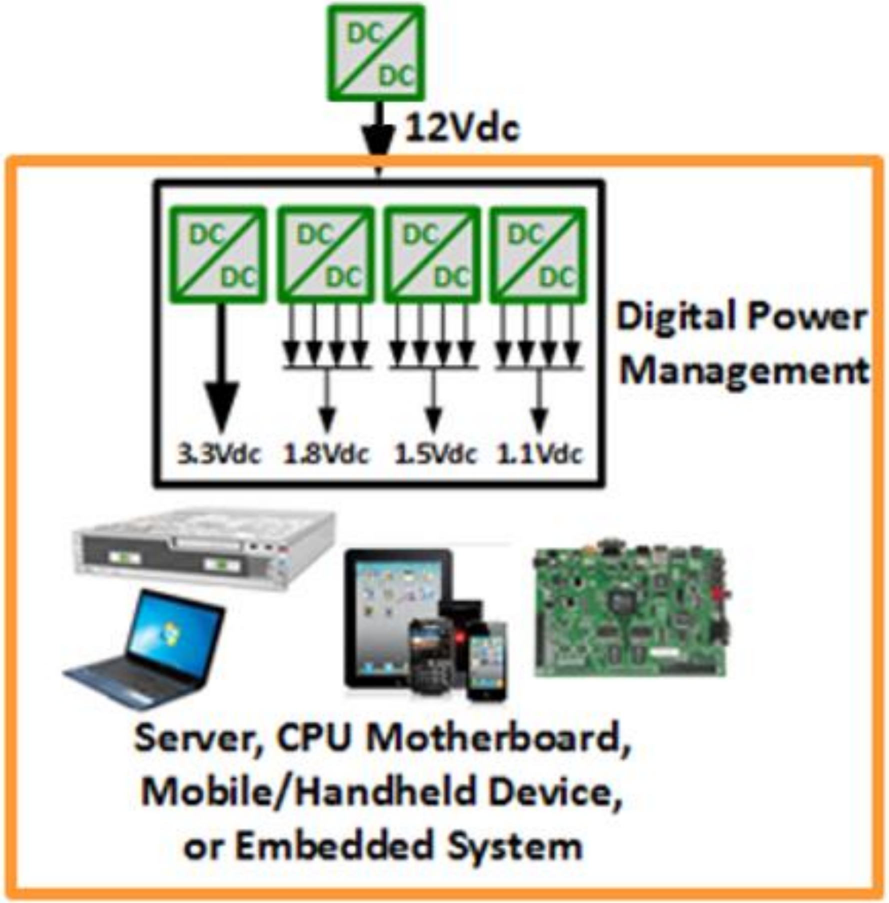
COMPARISON FACT SHEET

Key Specifications Comparison

	Tektronix TIVP	Tektronix TIVH
Applications	High Side V_{GS}, Wide Bandgap (GaN and SiC) characterization, SMPS optimization	High Side V_{GS}, Wide Bandgap (GaN and SiC) characterization, SMPS optimization
Bandwidth	200 MHz, 500 MHz, **1 GHz**	200 MHz, 500 MHz, 800 MHz
Risetime	450ps, 850ps, 2ns	450ps, 850ps, 2ns
CMRR @DC	160 dB	160 dB
CMRR @100 MHz	100 dB	100 dB
Diff. Voltage Range	Adjustable by Variable Gain. **up to 3.3kV***	Adjustable by Tip Attenuation. up to ±2.5kV
CM. Voltage Range	±60kV	±60kV
Offset Voltage Range	±2.5kV	±2.5kV
Noise (200mV – 3V measurements)	**$41.8mV_{pp}$**	$79.8mV_{pp}$
DC Gain Accuracy	**<2%**	3%
Input Impedance	10 MΩ || 3 pF	10 MΩ || 2 pF
Tips Required from 0V – 2500V	**4**	7
Temperature Range	0°C - 50°C (Probe head) 0°C - 85°C (Probe tip cable)	0°C - **70°C** (Probe head) 0°C - 85°C (Probe tip cable)
Oscilloscope Compatibility	4/5/6 Series MSO only	**All TekVPI Oscilloscopes** (including 4/5/6 Series MSO)

Digital Power Management

HIGH-PERFORMANCE SYSTEMS EVERYWHERE



- **Typical systems nowadays**
  - Processors, GPUs, SoCs, FPGAs
  - SerDes – High-speed data
  - Lots of power rails
  - Efficiency and heat management
  - Point of load power regulation and digital power management
- **Power integrity affected by noise**
  - Noise sources on power rails (frequencies can be quite high)
    - Cross talk from data signals, Coupling from clocks, Power supply switching noise (and harmonics)
  - What happens if power rails are noisy?
    - Jitter → bit errors, other reasons
  - Driving power rail specifications that require high accuracy ripple measurements

If not Passive probes, then what?

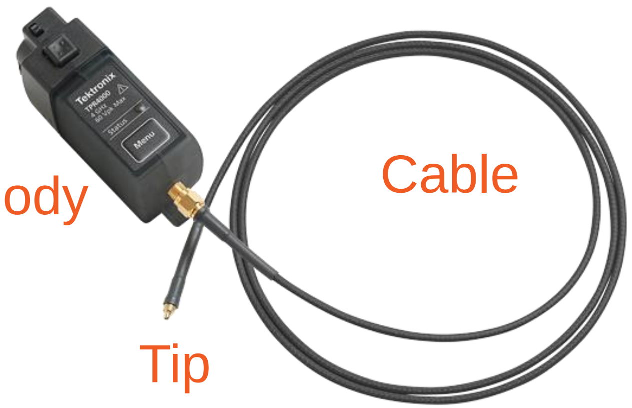
LARGER OFFSET VOLTAGE, WIDER DYNAMIC RANGE

- A specialized probe focused around Power Integrity testing
- Scope allows full bandwidth up to the probe bandwidth
- 60V DC maximum offset
- 1Vpk maximum AC signal
- DC level displayed on scope

Both the cars can go fast, but if you are looking for racing on a track, which one would you prefer? Why?

- Optimized for racing
- Better Aerodynamics
- Wider Tyres
- Lighter weight
- Fits only the race driver

You probably wouldn't buy this car for daily commute!

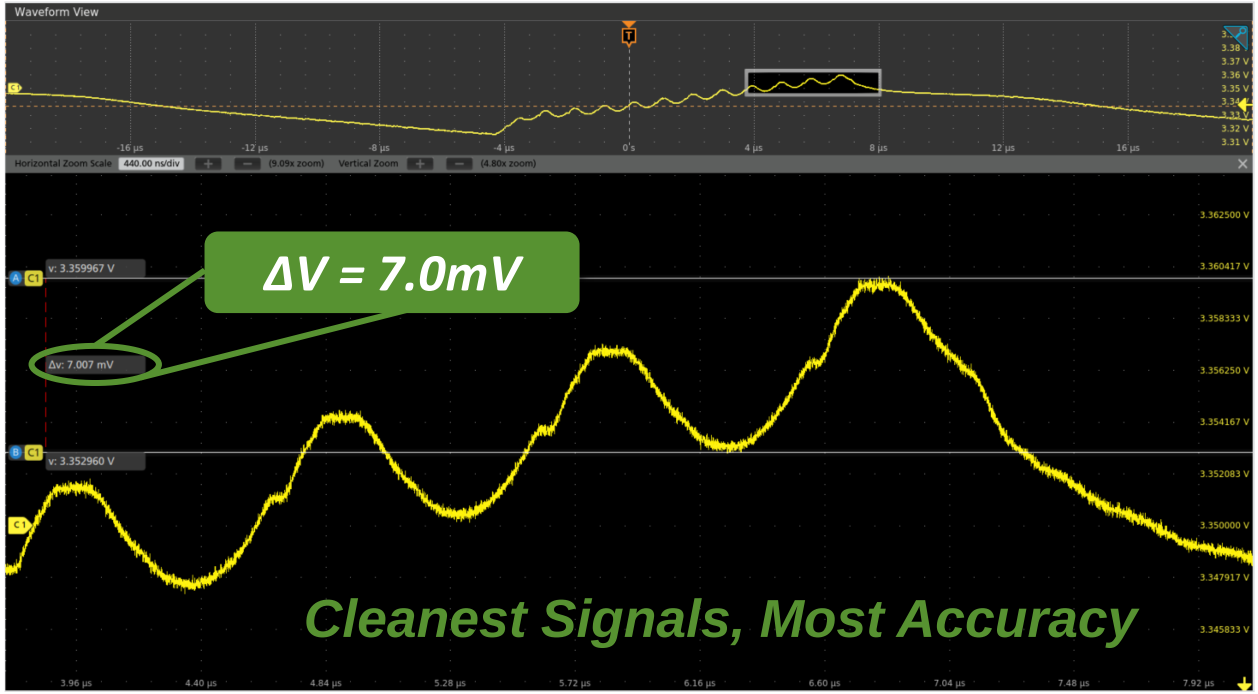


Power-Rail Probe vs. Passive Probes

WHAT POWER-RAIL PROBES SHOW THAT CAN'T BE SEEN WITH PASSIVE PROBES

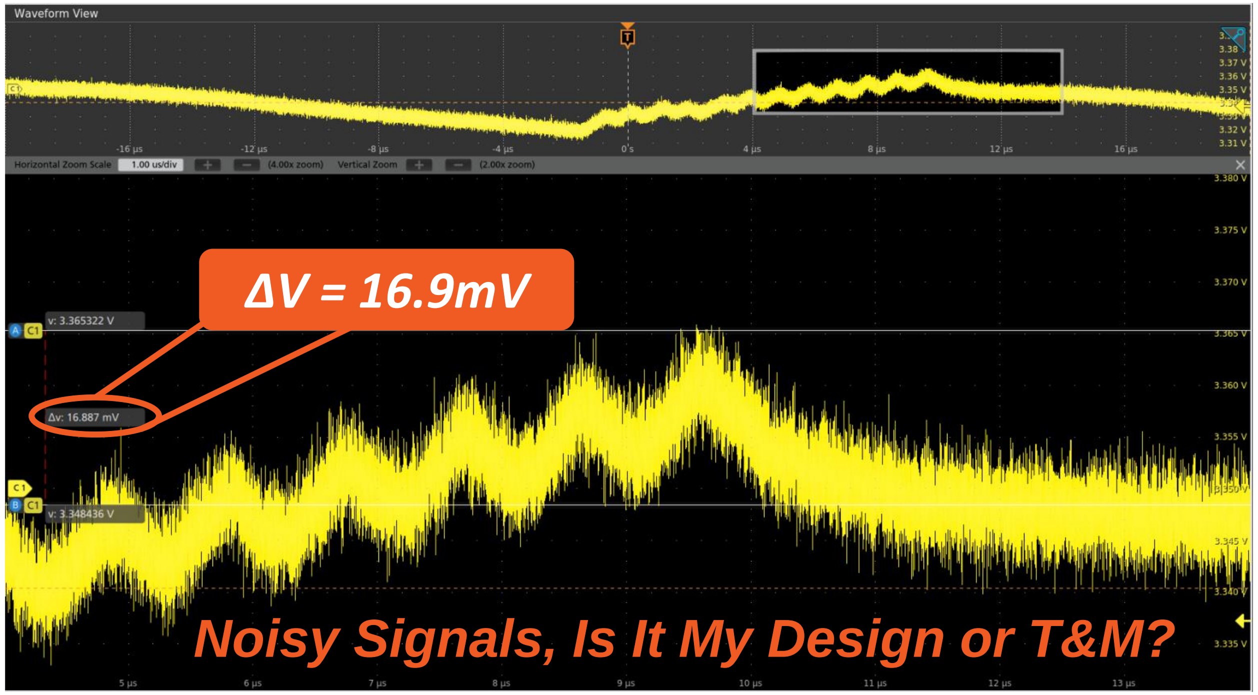
Ripple on 3.3V Rail with Power-Rail Probe

*(Using **1GHz** Bandwidth Limit & **6 Series** Oscilloscope)*



Ripple on 3.3V Rail with TPP1000 Passive Probe

*(Using **1GHz** Bandwidth Limit & **6 Series** Oscilloscope)*

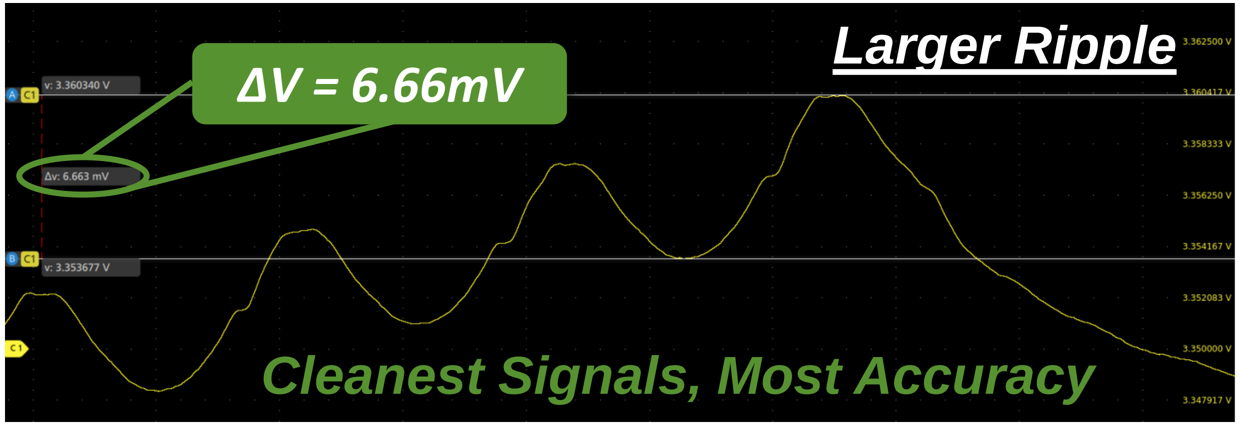


Power-Rail Probe vs. Passive Probes

WHAT POWER-RAIL PROBES SHOW THAT CAN'T BE SEEN WITH PASSIVE PROBES

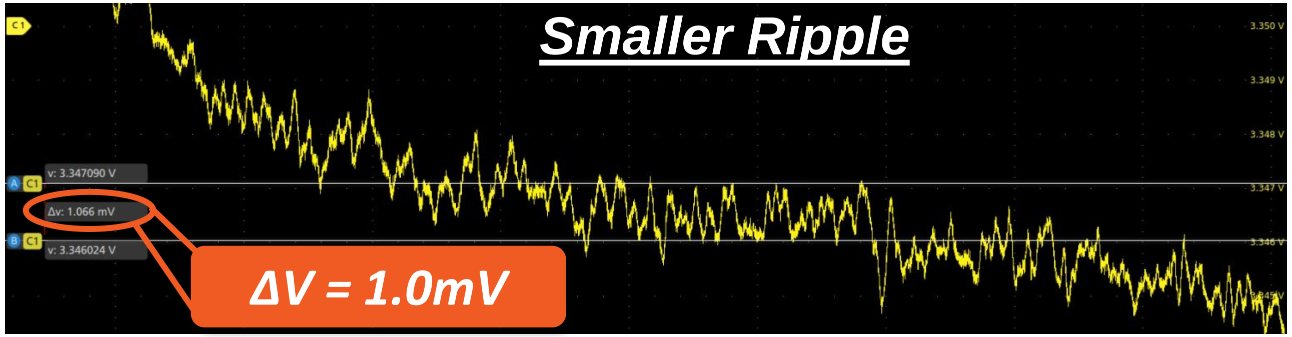
Ripple on 3.3V Rail with Power-Rail Probe

*(Using **20MHz** Bandwidth Limit & **6 Series** Oscilloscope)*



Ripple on 3.3V Rail with TPP1000 Passive Probe

*(Using **20MHz** Bandwidth Limit & **6 Series** Oscilloscope)*



Introducing The Power-Rail Probes

LARGER OFFSET VOLTAGE, WIDER DYNAMIC RANGE

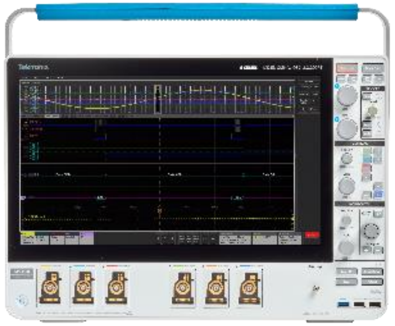
Specifications	TPR1000	TPR4000
Bandwidth	1 GHz	4 GHz
Offset Voltage Range	±60V	
Dynamic Range	±1V	
Input Resistance	50KΩ DC, 50Ω AC	
Input Coupling	DC, LF Reject	
Accuracy	1mV	
System Noise **(With 6 Series Scopes)**	$<300\mu V_{Peak\text{-}To\text{-}Peak}$ (With 20MHz Bandwidth Limit) $<1.3mV_{Peak\text{-}To\text{-}Peak}$ (At Full Bandwidth of Scope) Note: *With grounded input, set to maximum sensitivity of 1.3mV/Div*	
Attenuation	1.25x	
Connectivity & Accessories	New Browser, Solder-In & Snap-On	

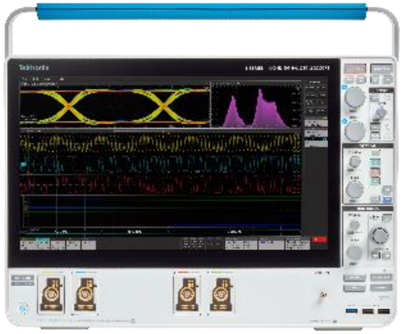
Note: Specifications are estimated and may change without notice

6 Series B MSO

POWER INTEGRITY SOLUTION AVAILABLE AT THE LAUNCH!

6 Series MSO	MSO64B	MSO66B	MSO68B
Bandwidth	1 GHz, 2.5 GHz, 4 GHz, 6 GHz, 8 GHz, 10 GHz		
FlexChannels	4	6	8
Analog Sample Rate (all channels)	25 GS/s *(Supports up to 10 GHz on all ch)*	12.5 GS/s *(Supports up to 5 GHz on >4 ch)*	
Analog Sample Rate (4 channels)	25 GS/s *(Supports up to 10 GHz on 4 ch)*		
Analog Sample Rate (2 channels)	50 GS/s *(Supports up to 10 GHz on 2 ch)*		
Maximum Digital Channels	32 (opt.)	48 (opt.)	64 (opt.)
Digital Sample Rate	25 GS/s		
Record length standard (all ch)	62.5 M		
Record length optional (all ch)	125 M, 250 M, 500 M, or 1 G		
Waveform Capture Rate	>500,000 wfms/s		
Arbitrary / Function Generator	50 MHz w/ 128 k Arbitrary memory (opt.)		
DVM	4-bit DCRMS, ACRMS, AC+DC (free with product registration)		
Operating System	Closed Embedded O/S (standard) on removable SSD Open Windows 10 O/S (opt.) on removable SSD		
Display	15.6 inch HD (1920 x 1080) capacitive touch		





System and Probe Noise Combo

IMPORTANT CRITERIA FOR POWER INTEGRITY

Baseline Noise:

- Open channel
- Probe connected with shorted output
- Vrms & Pk-Pk

MSO6 Channel:

- Pk-Pk – 466.2uV
- RMS – 50.05uV

MSO6 + TPR1000:

- Pk-Pk – 662.1uV
- RMS – 67.14uV

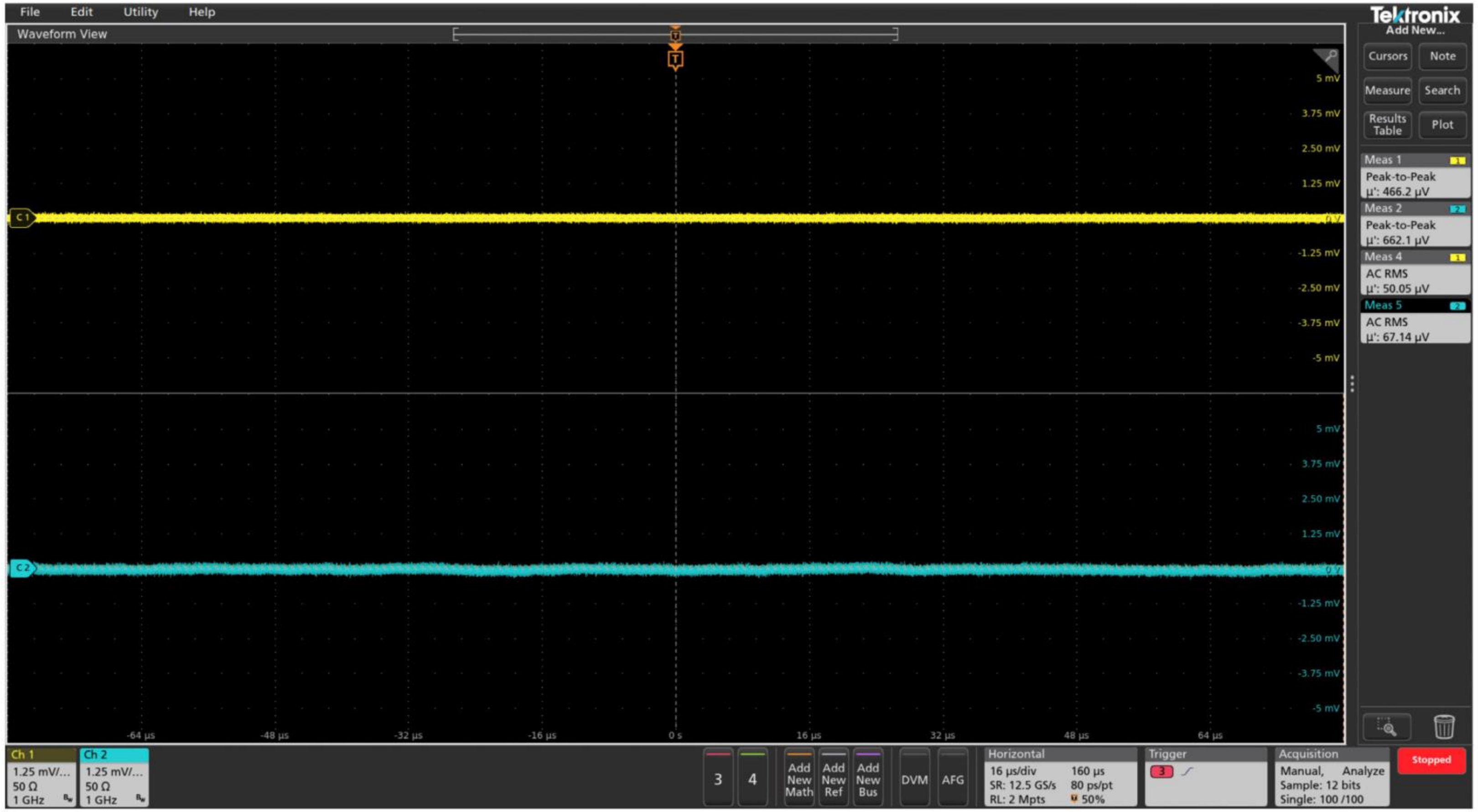


Figure 5. Channel 1 (yellow trace) is an oscilloscope channel with no input while channel 2 (blue trace) is a TPR1000 with its input shorted. Notice that at 1 GHz bandwidth the probe is only adding 17 μV of noise to the oscilloscope input.

Vertical Resolution Matters

12-BIT ADC AND HIGH RES MODE PROVIDE A MORE ACCURATE VIEW

- 12-bit analog-digital converter (ADC) delivers 16 times the resolution of conventional 8-bit ADC
- High Res mode delivers up to 16 bits of vertical resolution for finer view of lower frequency signals
- A unique DSP filter is applied at each sample rate. It limits bandwidth and thus, noise, providing a more accurate view of the signal
- Next generation front end amplifier reduces noise to help resolve small signal details
- ~4.5 dB lower noise from previous generation oscilloscopes

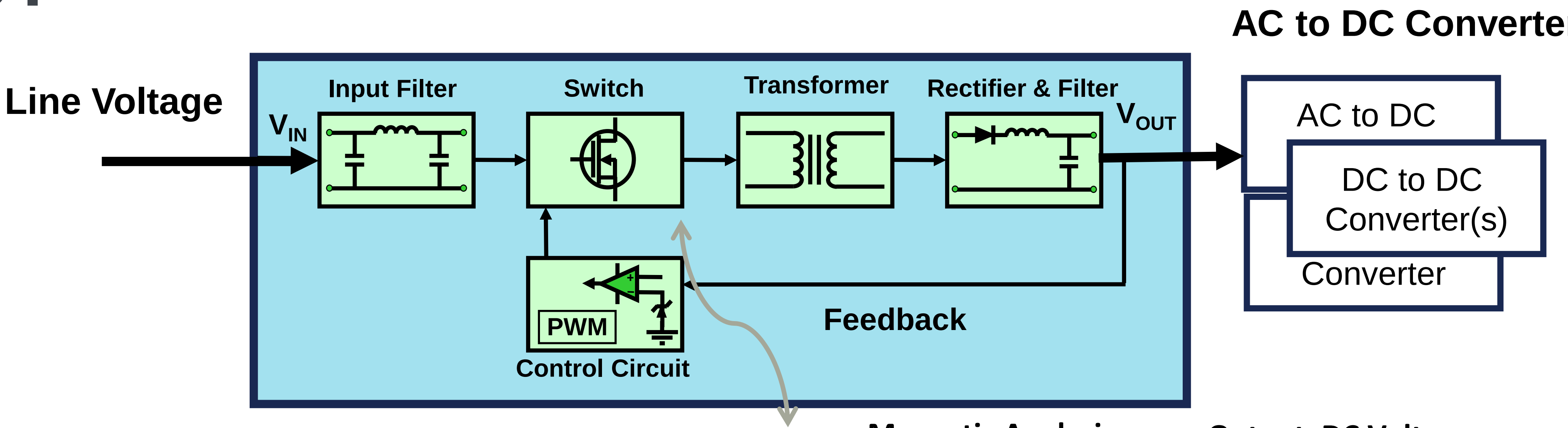
Power Solutions : Software

- Advanced Power Measurements(4/5/6-PWR)
- 3-Phase Analysis(IMDA)

Power Measurement Automation

- Automation gives the user application expertise
  - Algorithms and measurement techniques are automatically selected
  - Includes test limits for relevant industry standards
  - Simplifies probe deskew
- Automation ensures optimum setup for measurements
  - Automatically sets vertical scales, offsets, bandwidth limits, and triggering
  - Automatically sets horizontal scale, sample rate, and record length
  - Automatically selects acquisition mode (High Res), measurement thresholds, cursor gating
- Automation ensures consistent measurement technique
  - The application executes the same steps,
    in single-shot and repetitive operation
- Automation enables efficient documentation of measurement results
  - Create reports easily

Typical SMPS Circuit



- **Input / AC Power**
  - Current /Voltage Harmonics
  - Power Quality
  - Inrush Current
  - Input Capacitance
- **Active Components (Switch)**
  - Switching Loss
  - Safe Operating Area
  - d/dt
  - RDSon
- **Magnetic Analysis**
  - Magnetic Loss
  - Magnetic Property
  - Inductance
  - I vs. ∫V
- **Output DC Voltage**
  - Ripple
  - Efficiency
  - Turn on Time
  - Turn off Time
- **Frequency response Analysis**
  - Control Loop response(Bode Plot)
  - Power Supply Rejection Ratio (PSRR)
  - Impedance

Designers need the ability to access multiple test points and analyze them simultaneously to ensure quicker validation/testing cycles to meet faster GTM need.

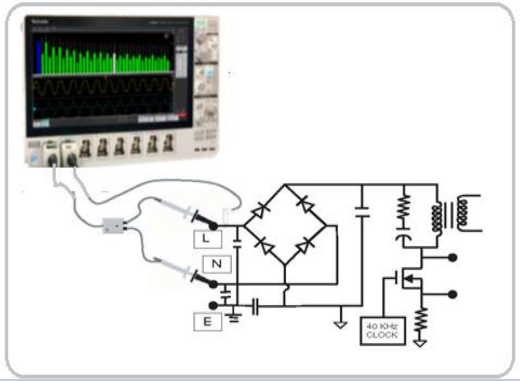
Advanced Power Measurements

OPTION 4/5/6-PWR

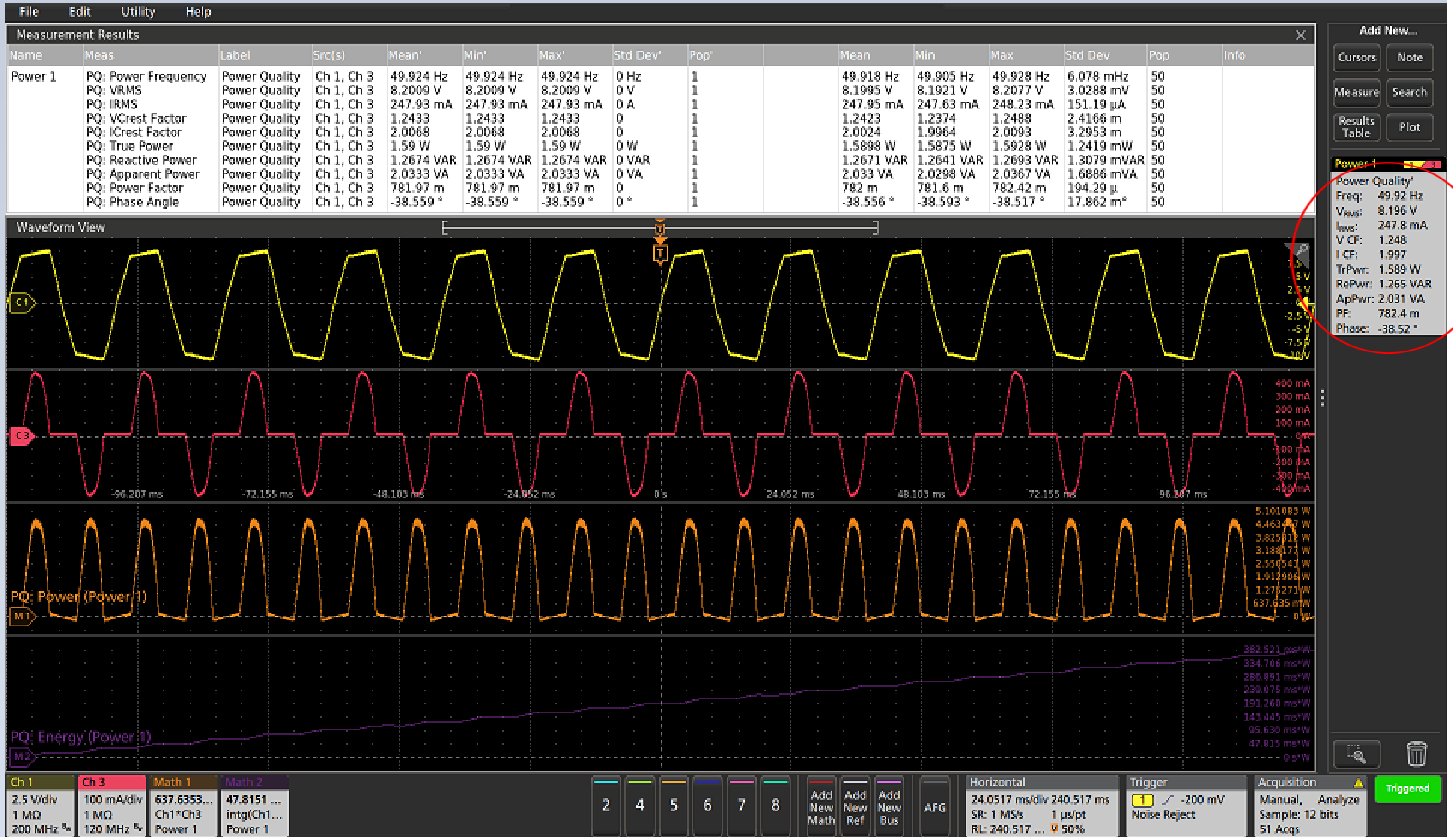
- Input Analysis
  - Power Quality
  - Harmonics
    - No standard
    - IEC61000-3-2
    - MIL-STD-1399
    - AM14
    - DO-160
  - Inrush Current
  - Input Capacitance
- Amplitude Analysis
  - Cycle Amplitude,
  - Cycle Top
  - Cycle Base
  - Cycle Peak-to-Peak
  - Cycle Maximum
  - Cycle Minimum
- Magnetic Analysis
  - Magnetic Loss
  - Magnetic Property
  - Inductance
  - I vs. ∫V
- Timing Analysis
  - Period
  - Frequency
  - Positive Duty Cycle
  - Negative Duty Cycle
  - Positive Pulse Width
  - Negative Pulse Width
- Switching Analysis
  - Switching Loss
  - SOA
  - dv/dt
  - di/dt
  - RDSon
- Output Analysis
  - Line Ripple
  - Switching Ripple
  - Efficiency
  - Turn on Time
  - Turn off Time
- Frequency Response Analysis
  - Control Loop response (Bode plot)
  - Power Supply Rejection Ratio (PSRR)
  - Impedance

Significance of Power Quality

THE BENEFITS OF GOOD POWER QUALITY

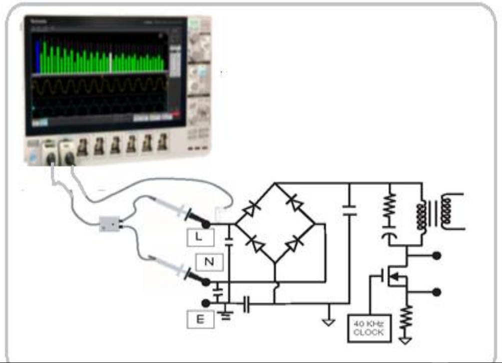


- Reduce the line & equipment current and losses and hence lower energy bills
- Improve Power Factor & avoid penalty for low power factor
- Prevent of malfunction of equipment
- Reduce the losses in equipment
- Increase the power equipment life



Significance of Harmonics

NON-IDEAL INPUT CURRENTS INCREASE BURDEN ON POWER GRID AND WASTE ENEGRGY



Harmonics can impact the efficiency of the system

In practice, loads are not always resistive

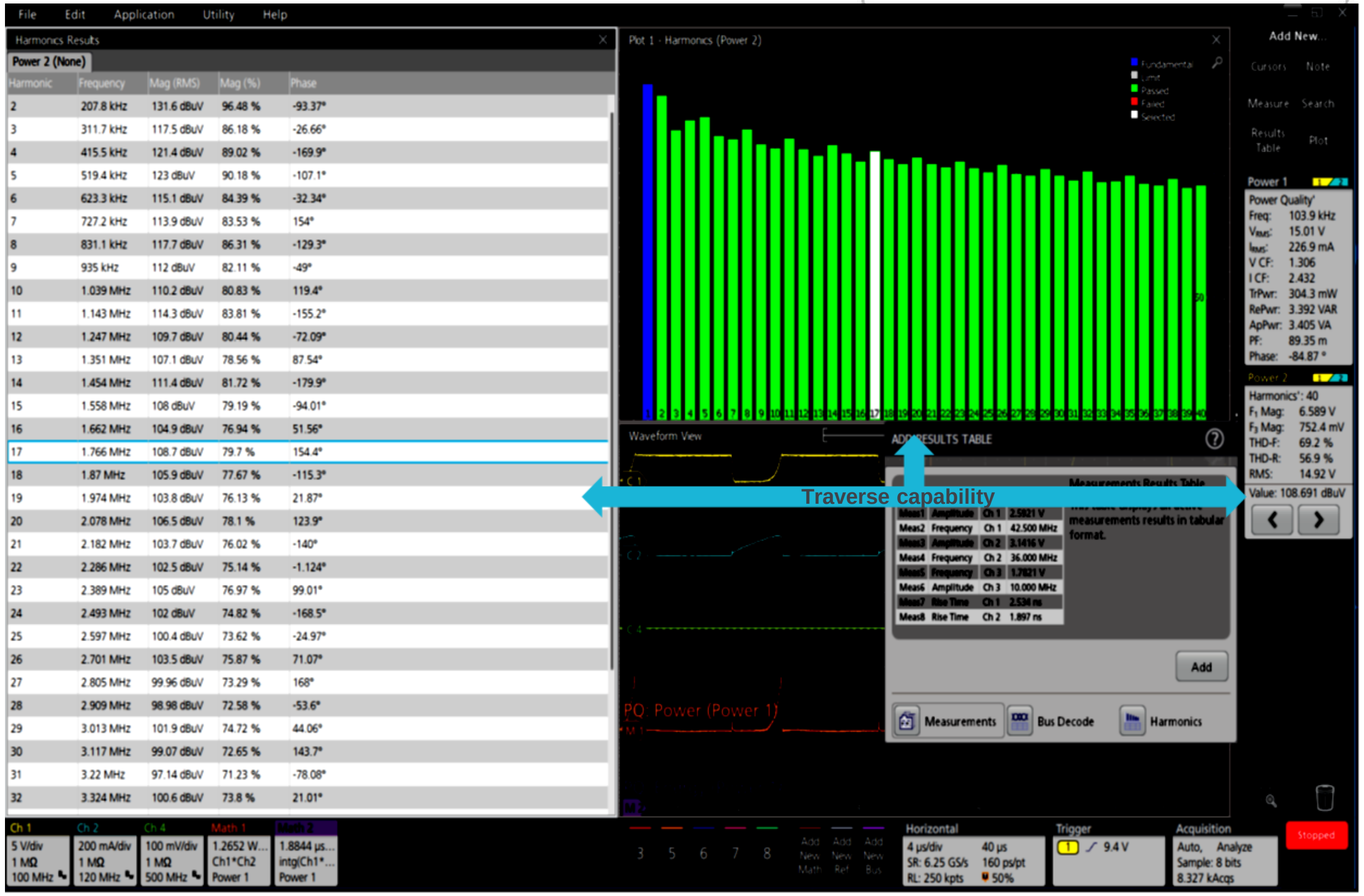
- AC-DC converters present non-linear impedance
- Power factor correction is complex

Various Standards of Current and Voltage Harmonics

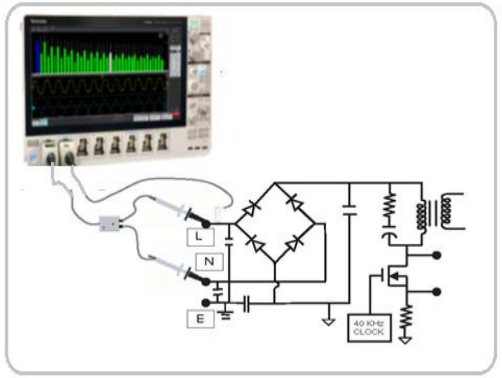
- 61000-3-2 [1]
- AM 14 [2]
- MIL 1399 [3]
- DO-160

User-defined harmonic order, can go up to 200th order and supports range filter for easy visibility

User can define custom limits and apply for the harmonics



Significance of Inrush current and Input Capacitance



INPUT CURRENT AND INPUT CAPACITANCE ARE KEY TO ENSURING DESIGN SAFETY

- **Inrush Current and Input Capacitance** measurements are important to ensure the design protection circuitry is in place.
- Power designers need insights to the peak current surge that needs to be handled for protection circuitry.
- Designers need to ensure the correct capacitor is used in the circuit which can handle the peak current surge effectively.
- Enables designers to traverse across cycles to identify and isolate problems effectively.

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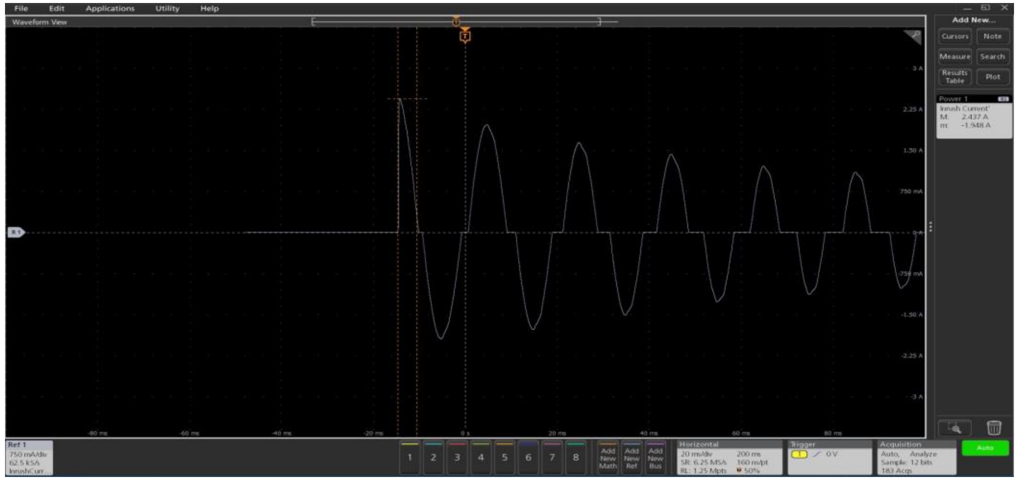
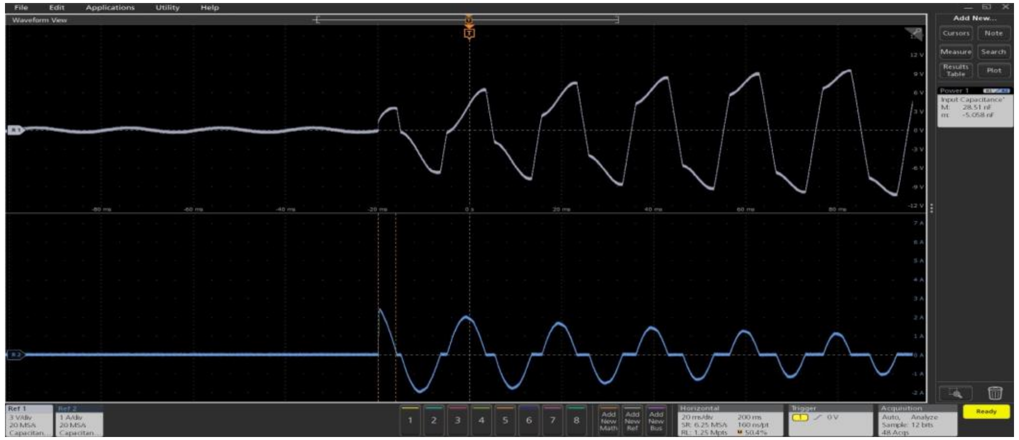


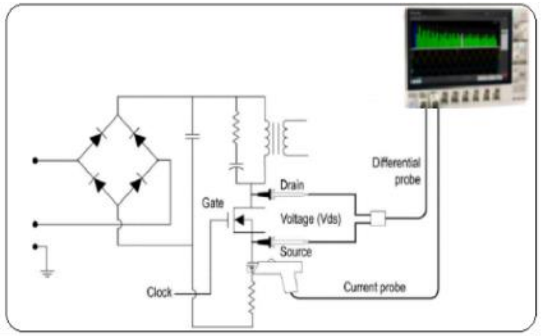


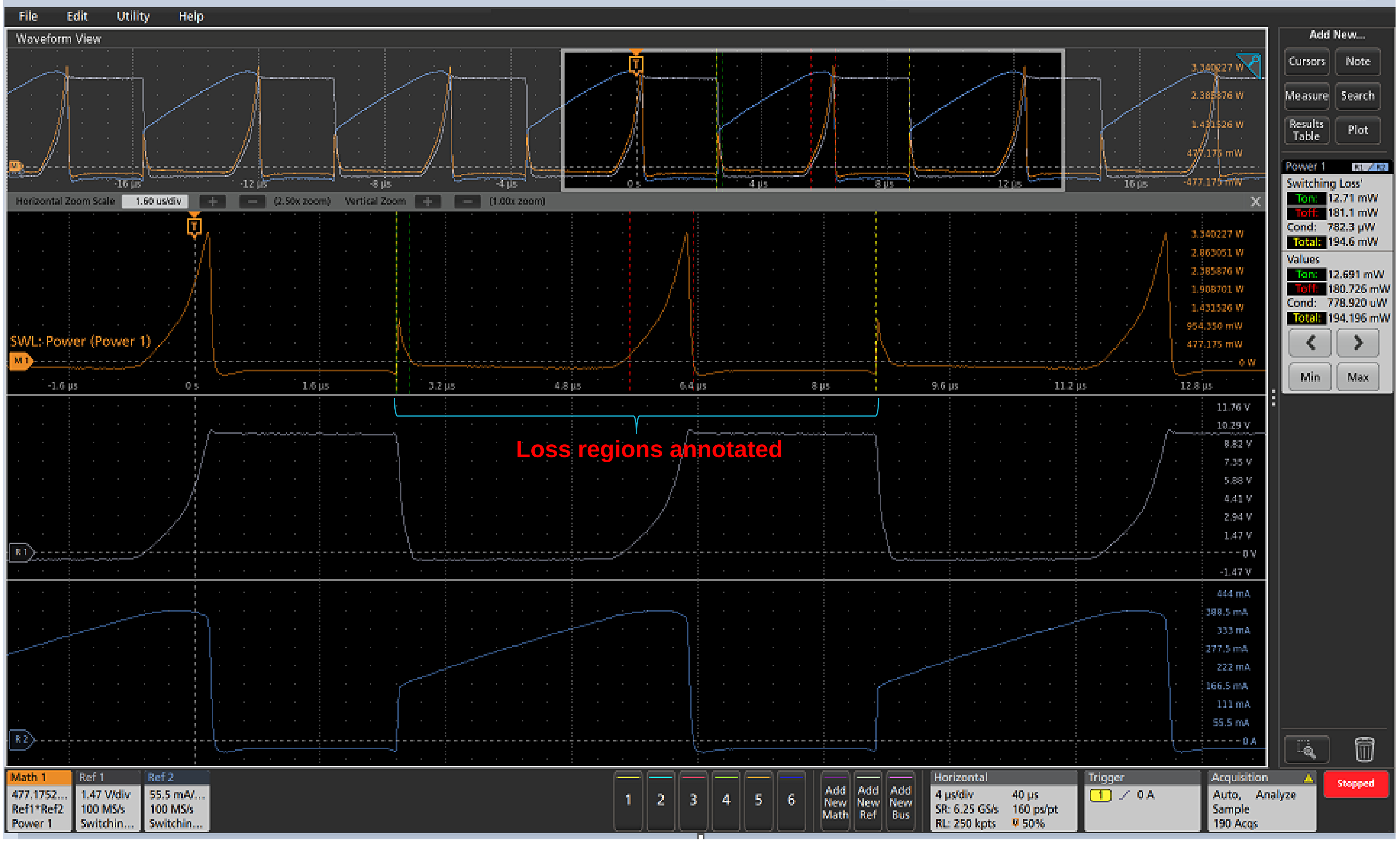
Switching Loss Measurements

- **Turn-on loss :**
  Energy losses when the switching device changes from its non-conducting state to its conducting state.

- **Conduction loss :**
  Losses in the switching device when it is in saturation.

- **Turn-off loss:**
  Energy losses when the switching device changes from its conducting state to its non-conducting state

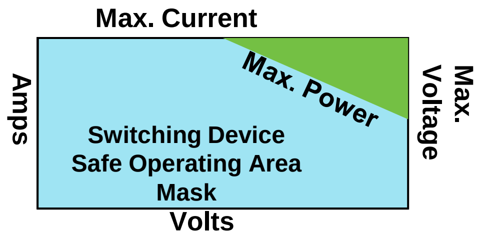


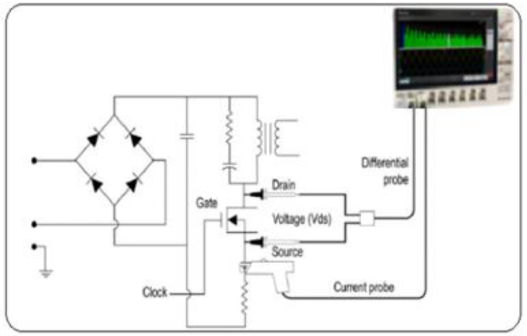


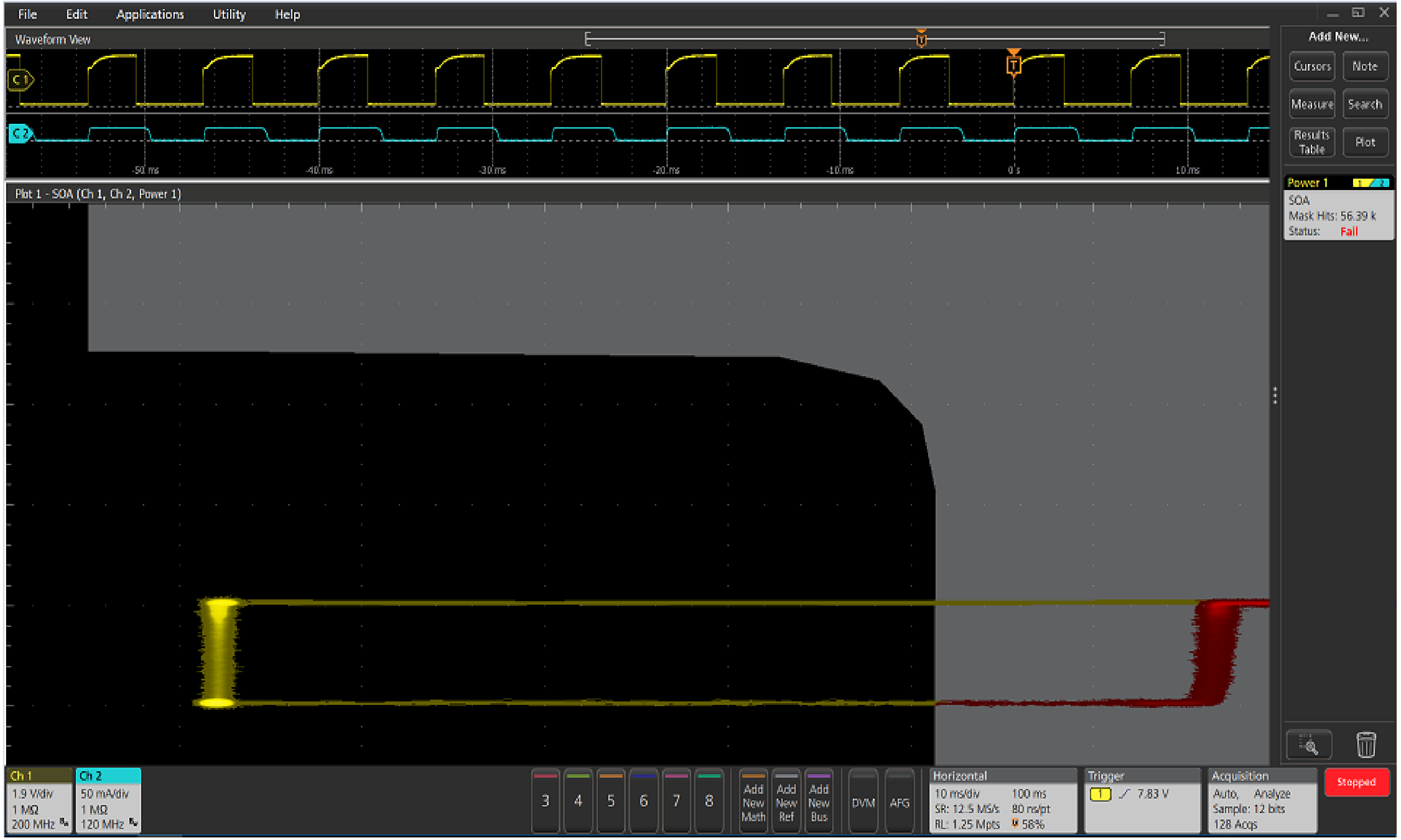
Switching Analysis

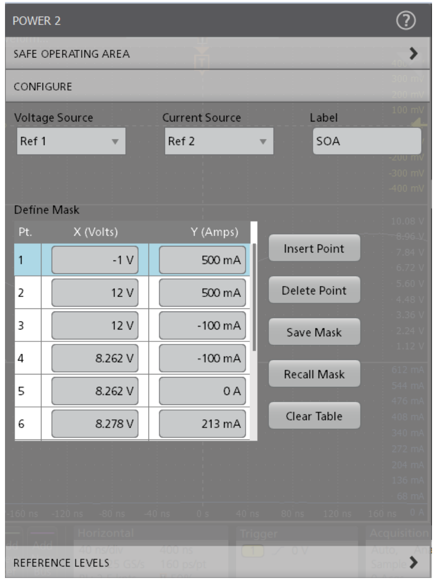
SAFE OPERATING AREA (SOA)

- Switching device operating region
- Plot of voltage versus current
- SOA mask is a graphic representation of the switching device's limits on a SOA plot

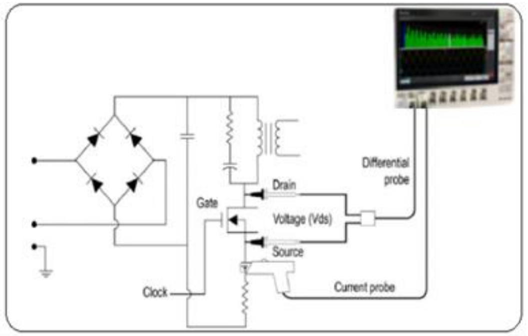






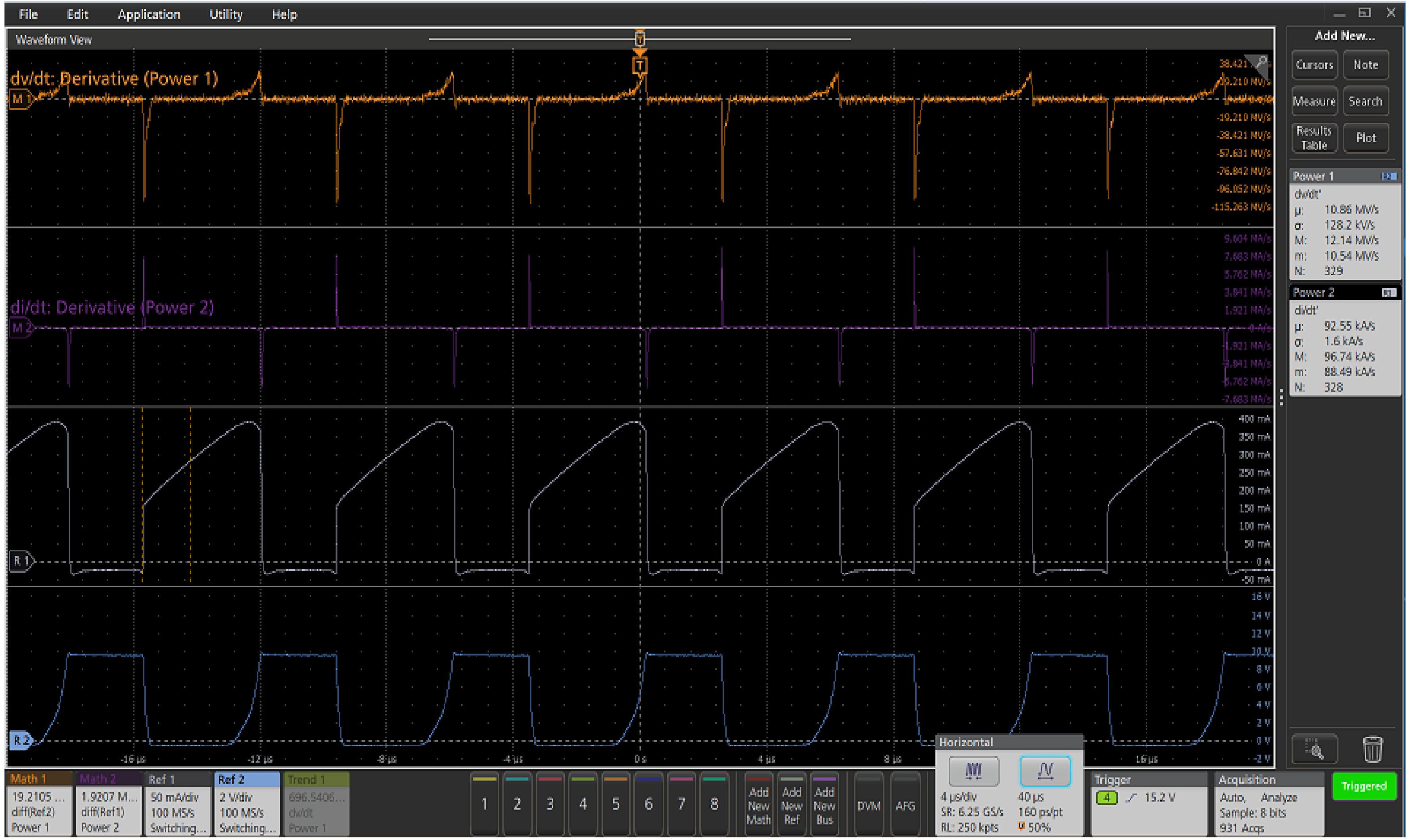


Switching Analysis



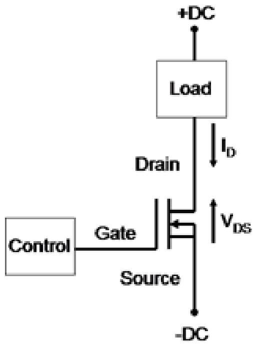
Di/dt and Dv/dt

- Rate of Change of Current and Voltage
- Need to look at the Slew rate of the Voltage and Current signals.
- Helps designers to optimize the rate of change of Current or Voltage signals to meet the fast switching design needs.
  - Ensures Loss is minimized



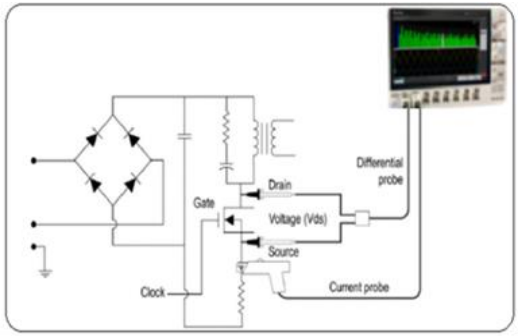
Switching Analysis– $RDS_{(on)}$

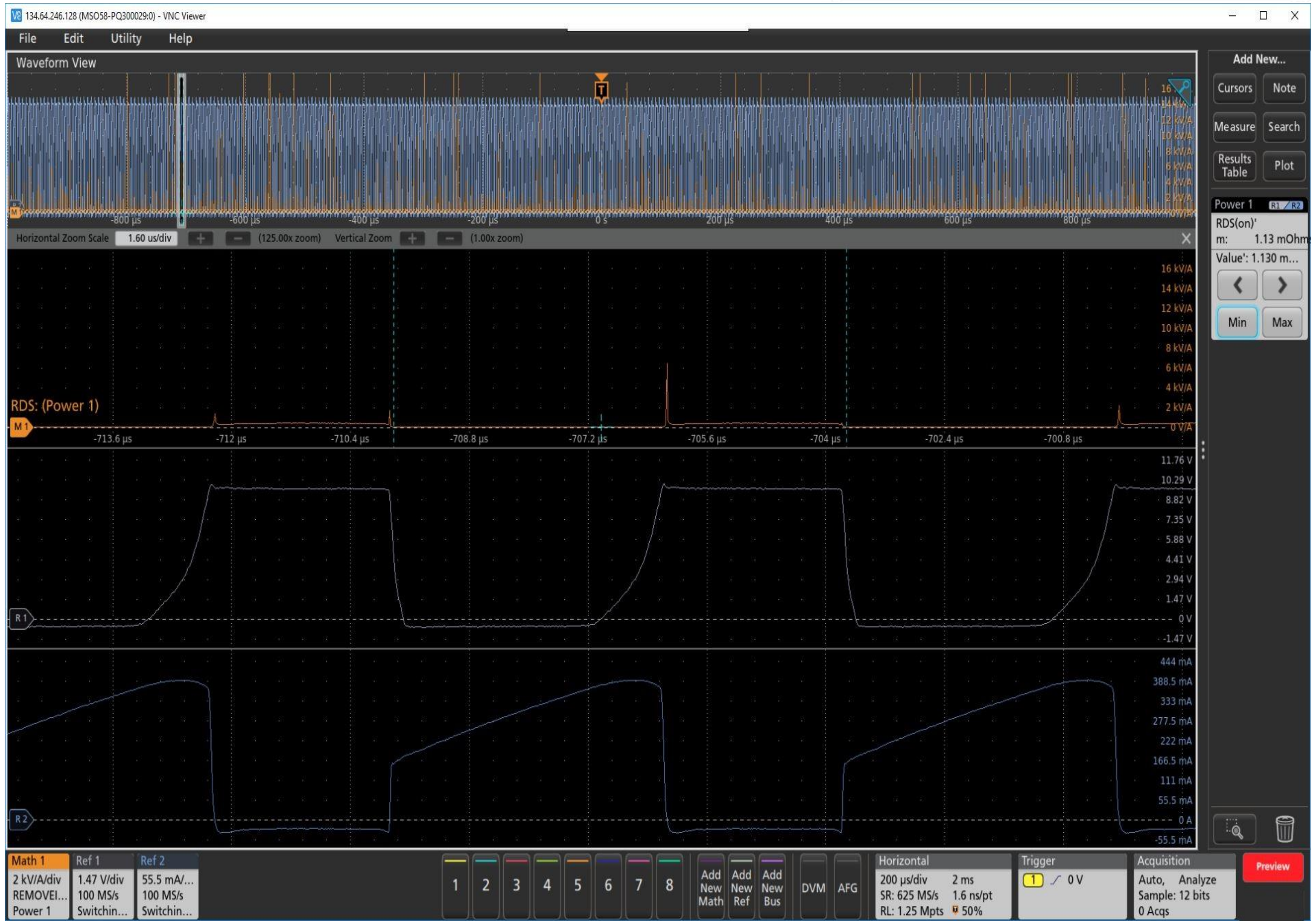
- This **updated** measurement provides a simple way to verify the minimum dynamic on-resistances in switching devices. $R_{DS(on)}$ is simply voltage divided by current



- Measurement is gated during conduction regions

- Spikes in time trend are where current approaches zero





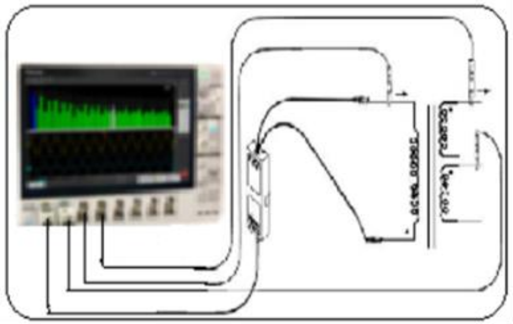
Magnetic Analysis

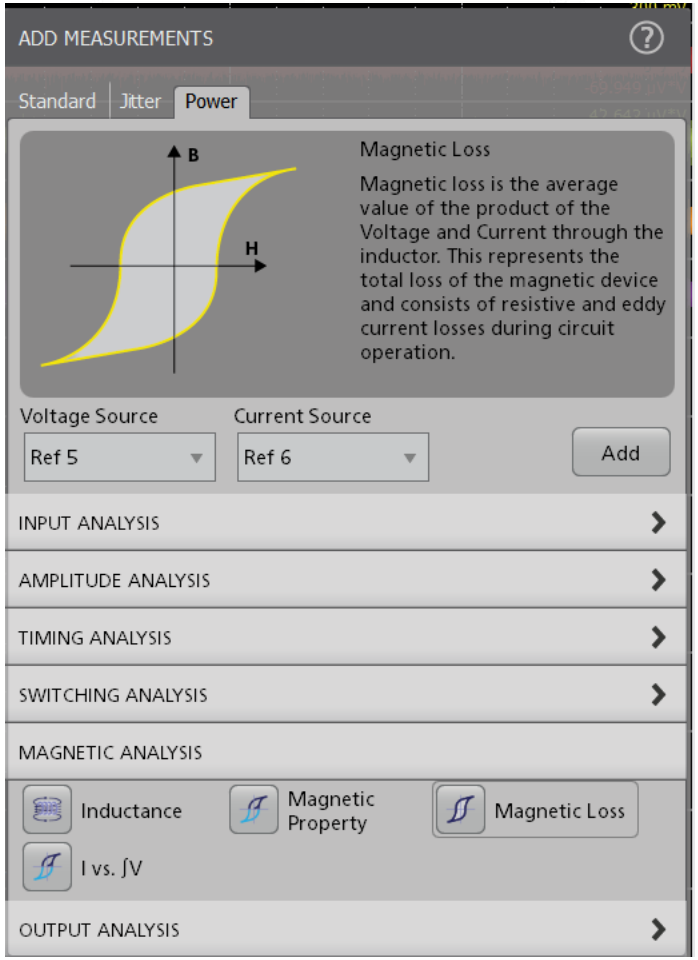
Computing Power Loss at the Magnetic Component

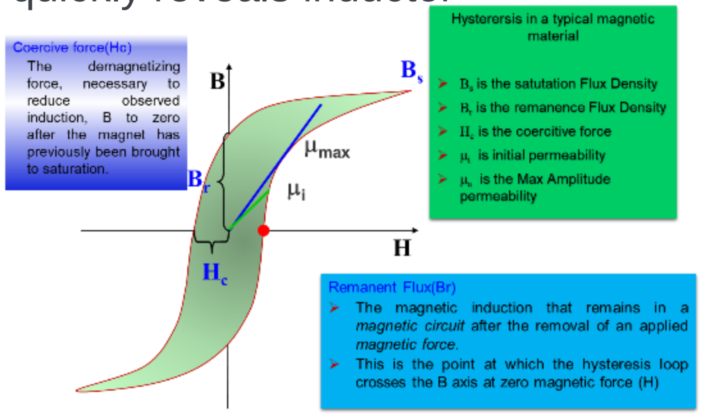
- **Aim is to reduce power dissipation in the core area**
  - In a typical Power conversion circuit, the inductor and transformer will dissipate power
  - Affects power efficiency and causing thermal runaway.

Methods of monitoring the behavior of the core

- LCR meter- simulation
- B-H curve, because the B-H curve quickly reveals inductor behavior in a power supply

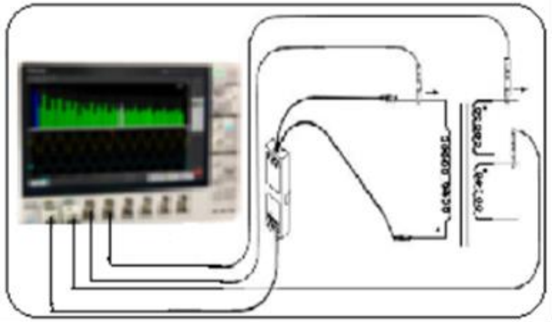






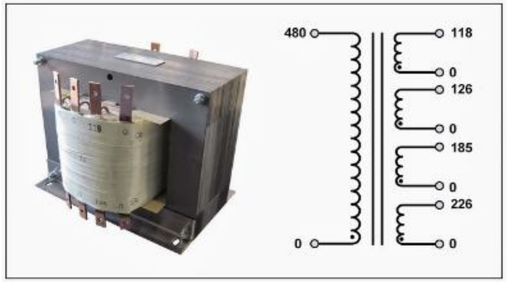
Magnetic Analysis

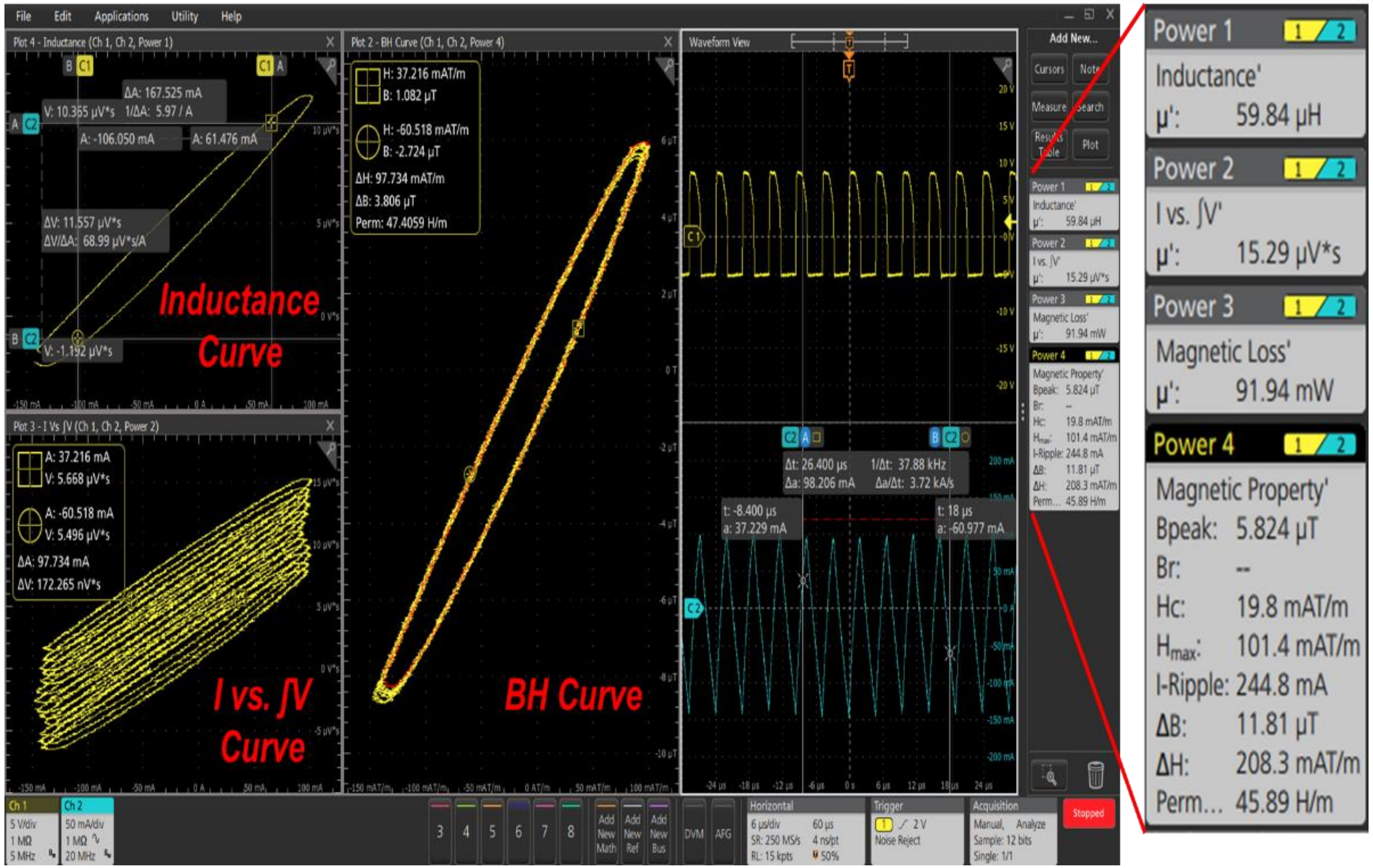
Computing Power Loss at the Magnetic Component



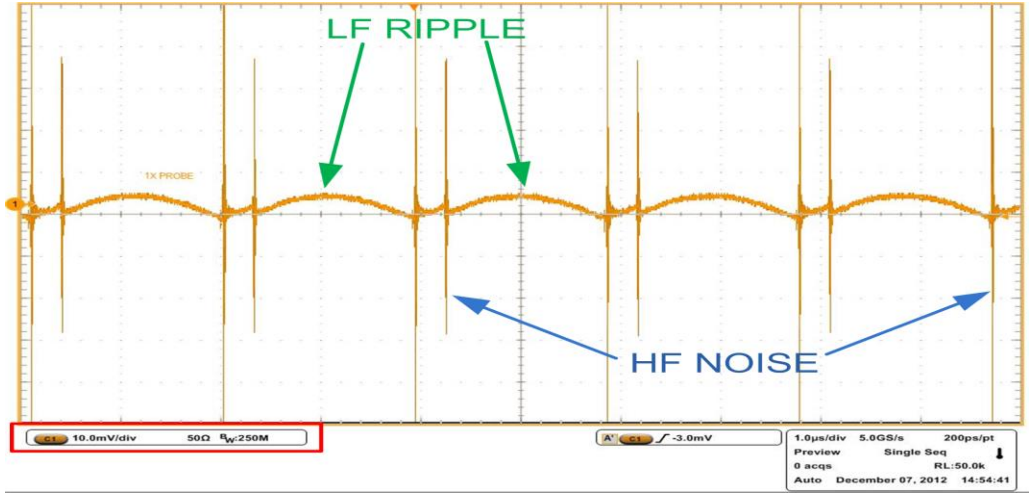
- Magnetic Property (BH Curve)
- Inductance
- I Vs Int V
- Magnetic Loss
  - **Get insight to Total Magnetic Loss**
  - **Derive Core Loss from vendor's data sheet**
  - **Solve for Copper Loss**
- **Ability to test multiple secondary windings in one go - ensures faster test times**

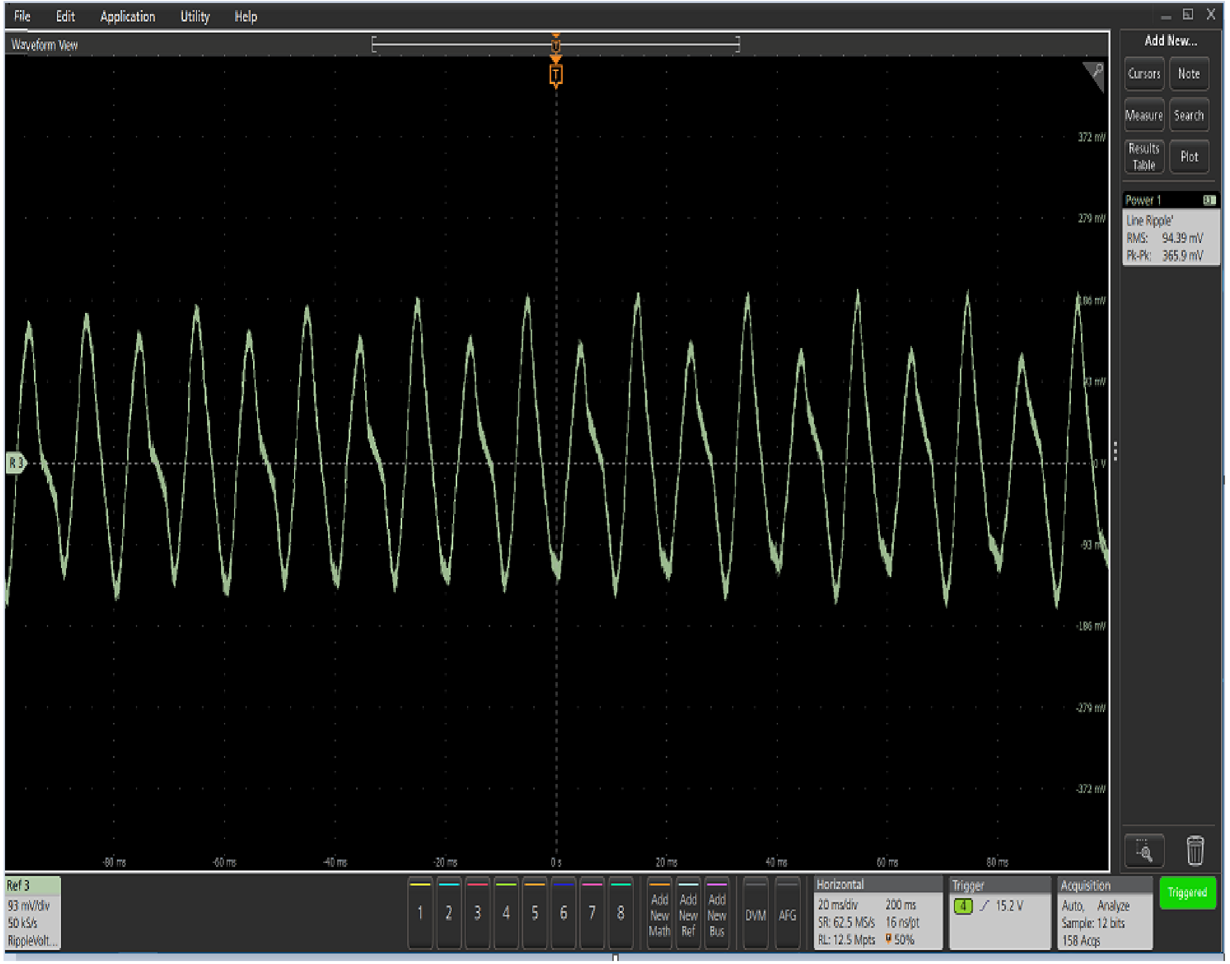
$$TotalPowerLoss = PowerLoss_{L1} + PowerLoss_{L2} + PowerLoss_{L3} + \cdots$$



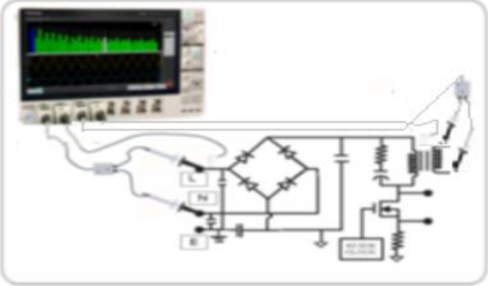


Significance of Ripple

- Need to look at the output voltage ripple on the power supply's output or load.
- Ripple is the AC voltage that is superimposed onto the DC output of a power supply. Linear power supplies usually see a ripple that is close to twice the line frequency, whereas switching power supplies may see a switching ripple in the hundreds of kHz.
- The output voltage ripple has two components: Low Frequency "ripple" and High Frequency "noise".
- 



Power Efficiency

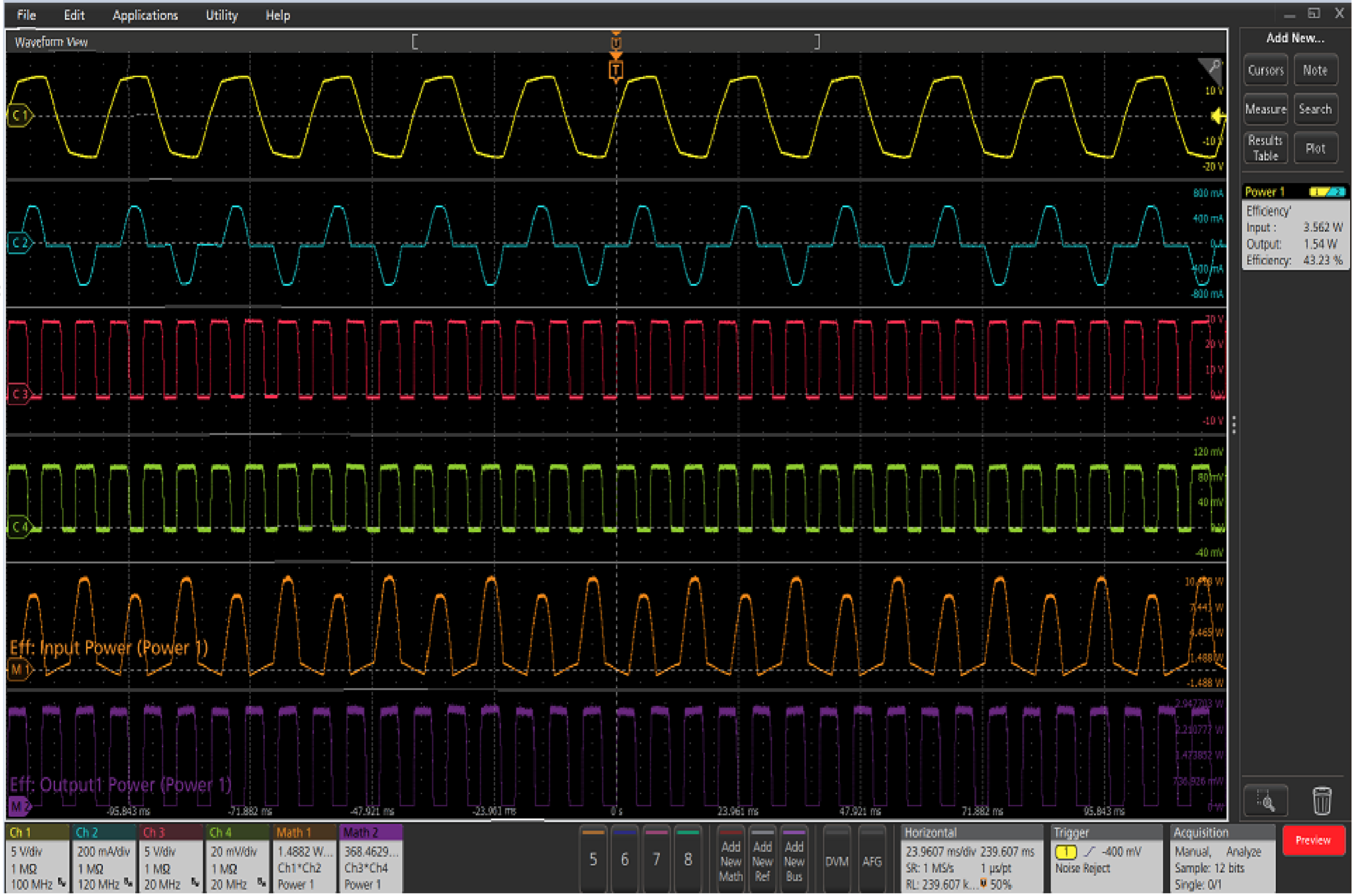


- Efficiency is a measure of how much power at the input appears at the output.
    - **less waste.**
- **Conserve energy** - considered technologically **“green”.**

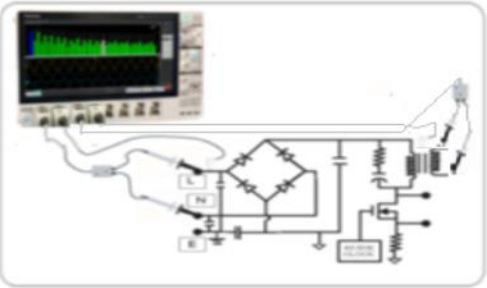
- **Power supply efficiency** has a direct effect upon the **upper limit of output power** given **a package size** and mode of **cooling.**

- **Energy Efficient products**

- **Test multiple output products in ONE go-FASTER TIME TO MARKET**



Power Efficiency



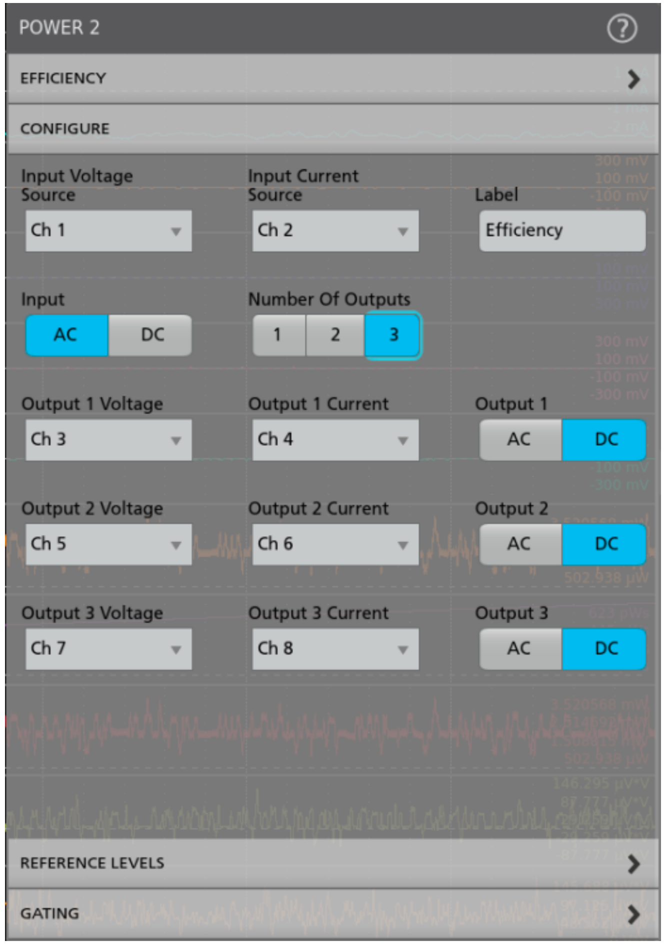
- Efficiency measurement capability increases with channel count of instrument and **the updated flexibility to configure each output independently.**

- 4-channel scope
  - 1 input, 1 output

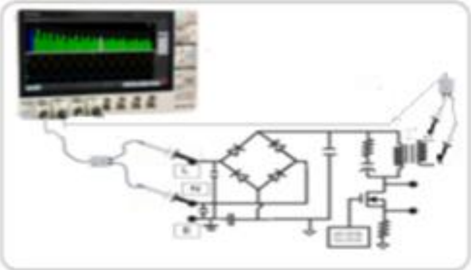
- 6-channel scope
  - 1 input, 2 outputs

- 8-channel scope
  - 1 input, 3 outputs

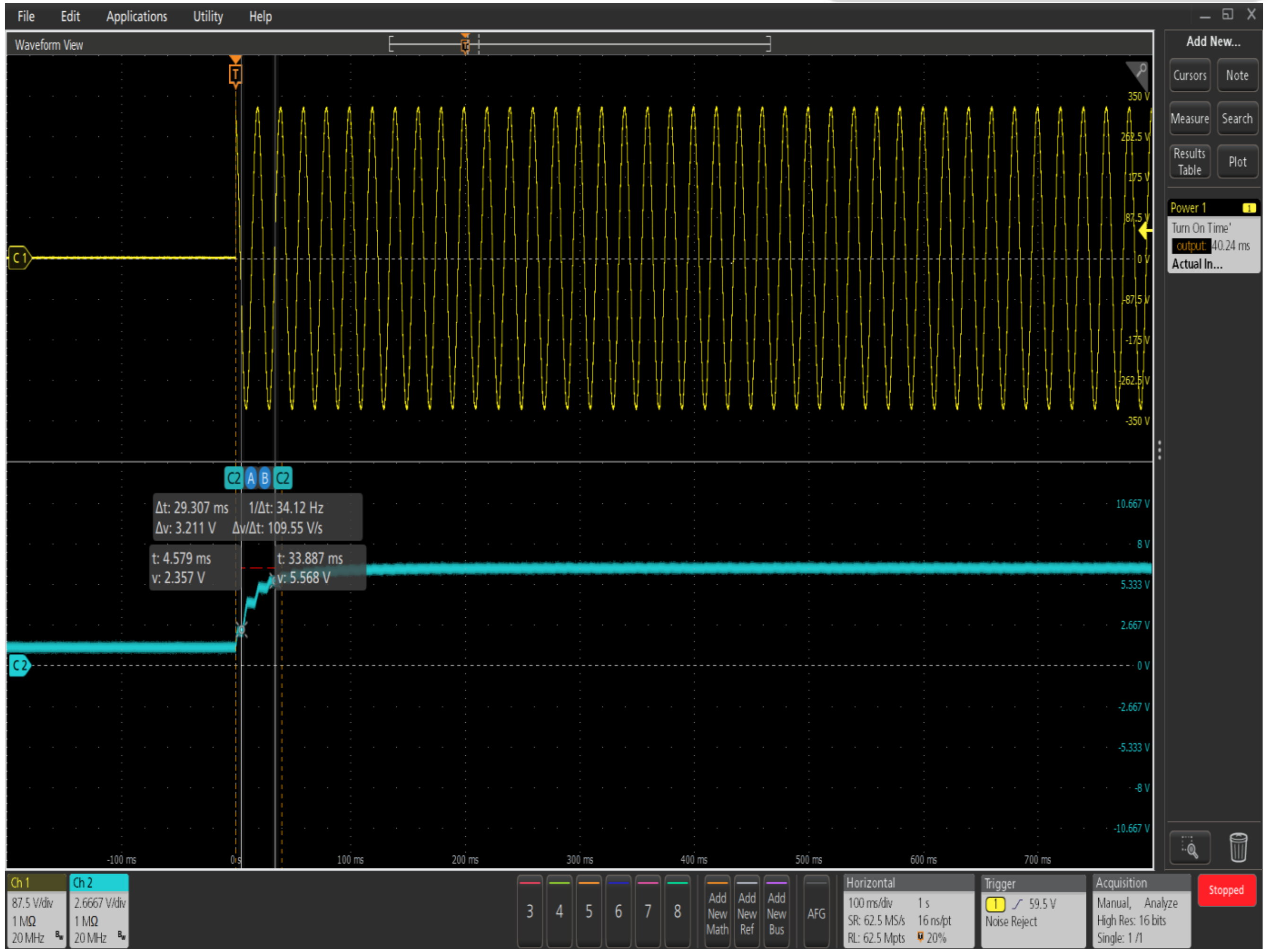
1-input, 3-output device



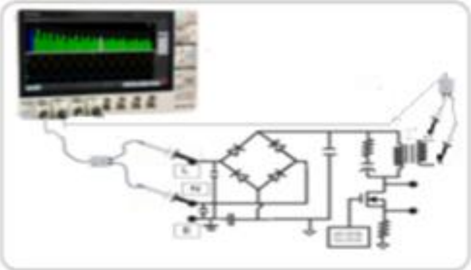
Significance of Turn on Time



- **Turn on Time** is the time taken to get the output voltage of the power supply after the input voltage is applied.
- The timing and sequencing of power supply outputs during turn-on is critical to the reliable operation of the end-products.
- Supports testing of up to 7 outputs (MSO58) simultaneously there by enabling system testing and faster validation times.



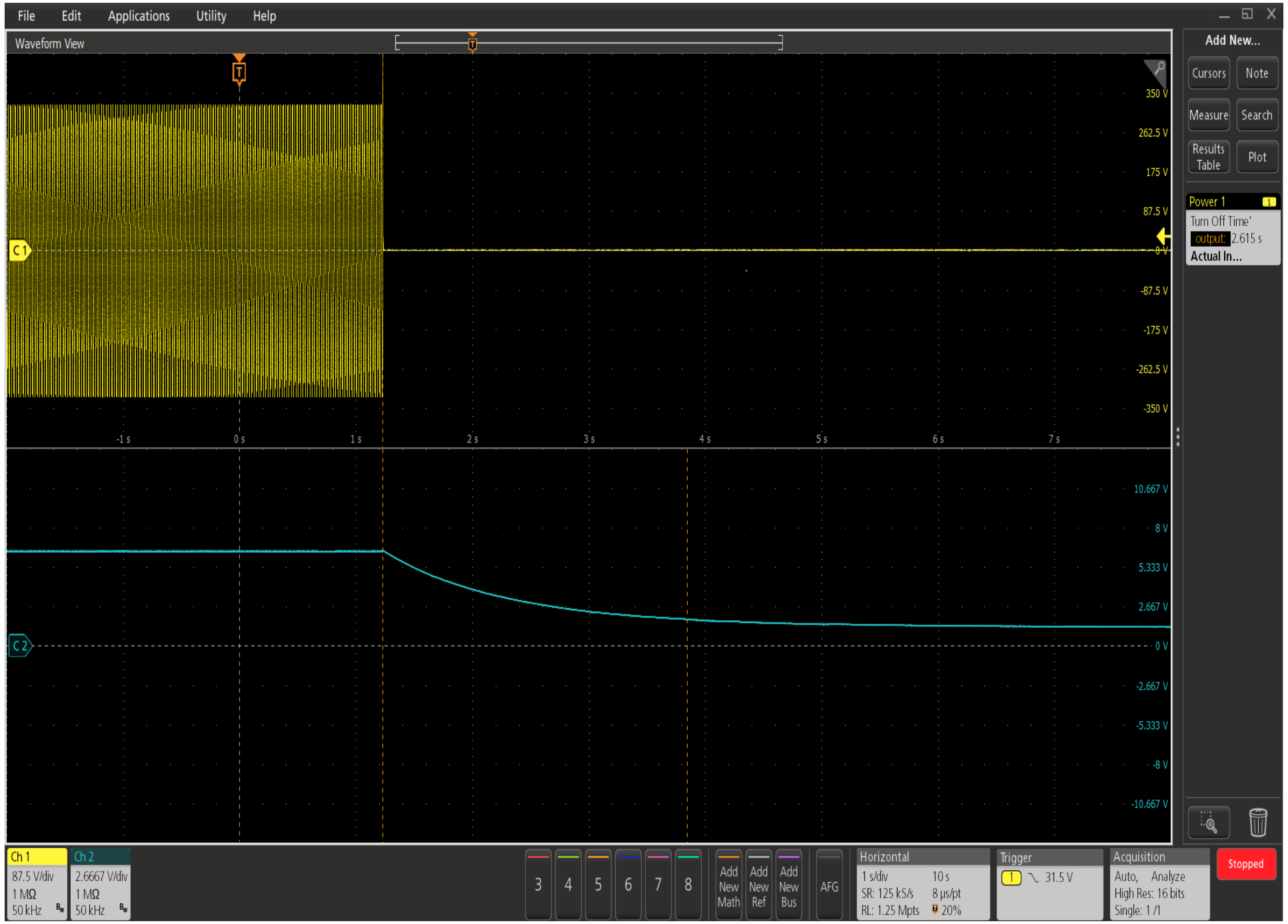
Significance of Turn off Time



- **Turn off Time** is the time taken to get the output voltage of the power supply close to zero after the input voltage is removed.

- The timing and sequencing of power supply outputs during turn-off is critical to the reliable operation of the end-products.

- Supports testing of up to 7 outputs (MSO58) simultaneously there by enabling system testing and faster validation times.



Frequency Response Analysis

- Frequency Response Analysis
  - Control Loop Response(Bode Plot)
  - Power Supply Rejection Ratio(PSRR)
  - **Impedance**

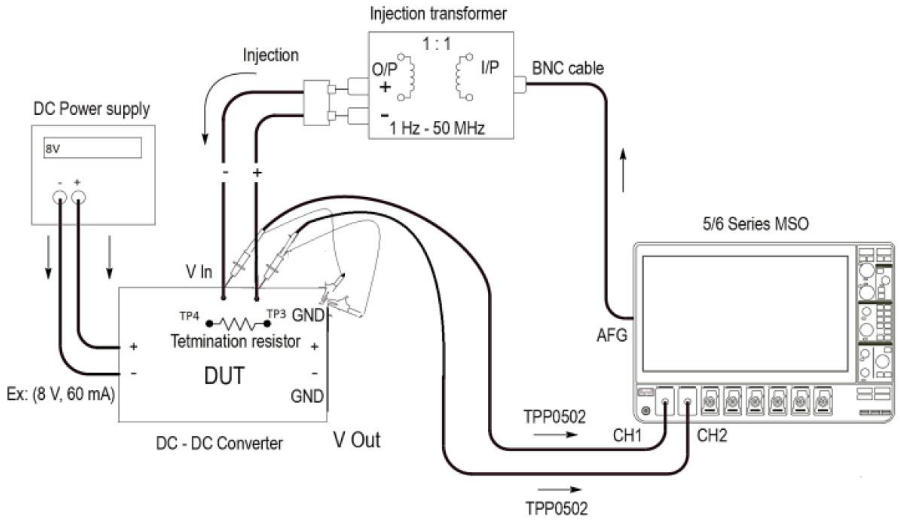
These are typically performed using stand alone Frequency Response Analyser or VNA.

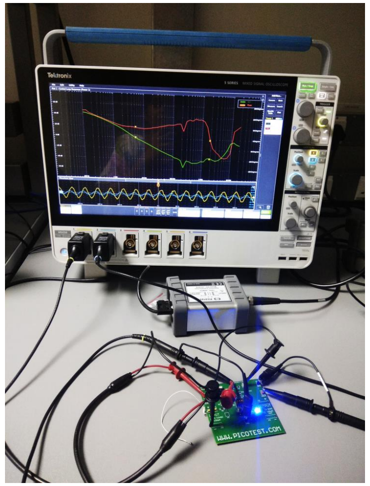
- Customer Pain Points
  - Separate test setup.
  - Long test times as the Frequency Response Analyers or VNAs are shared.

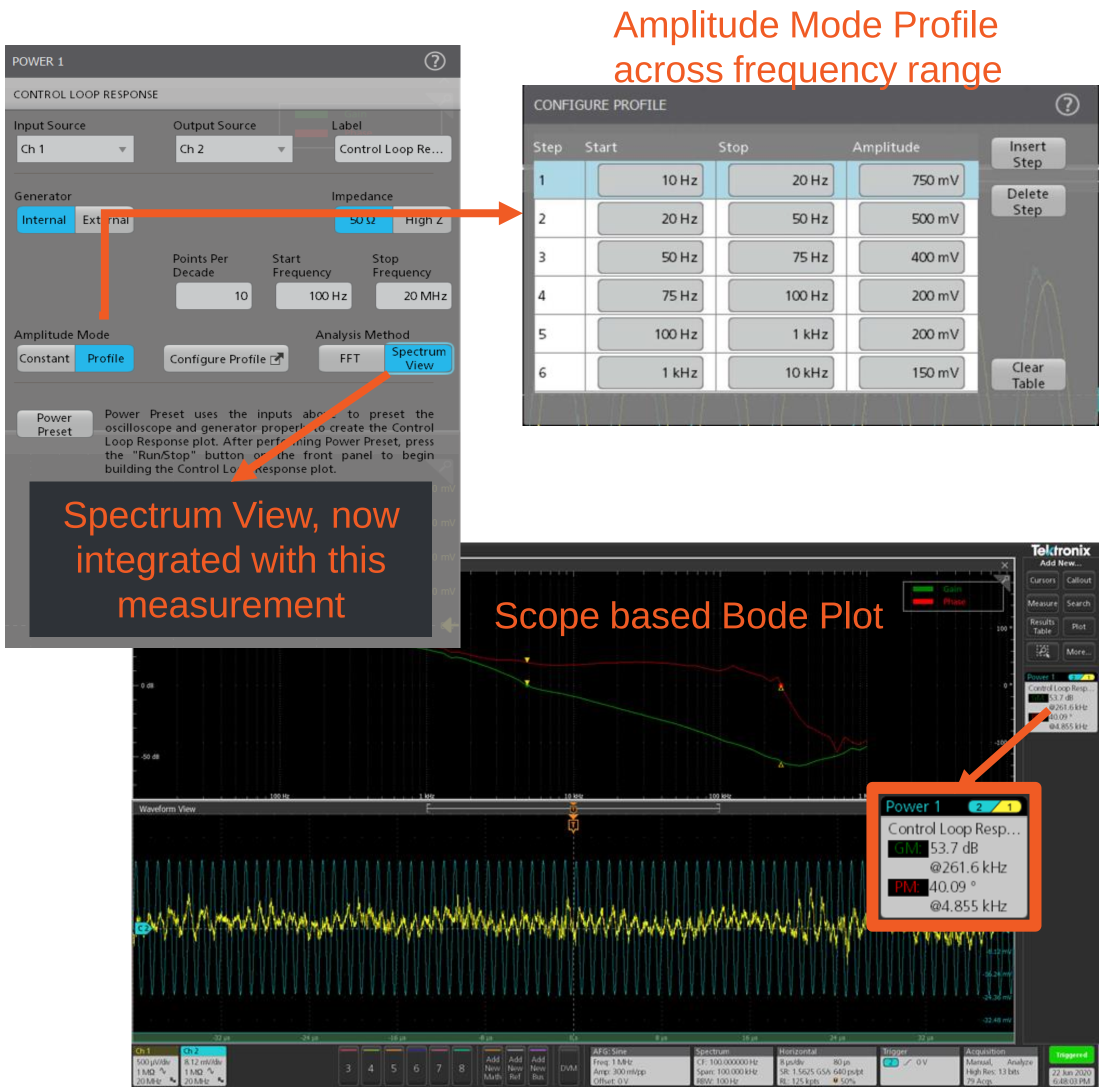
Tektronix Method – Control Loop Response

Measurement System

- 4/5/6 Series MSO Scope
- AFG (from the scope or external)
- 2 TPP0502 Probes
- Injection Transformer (Picotest)



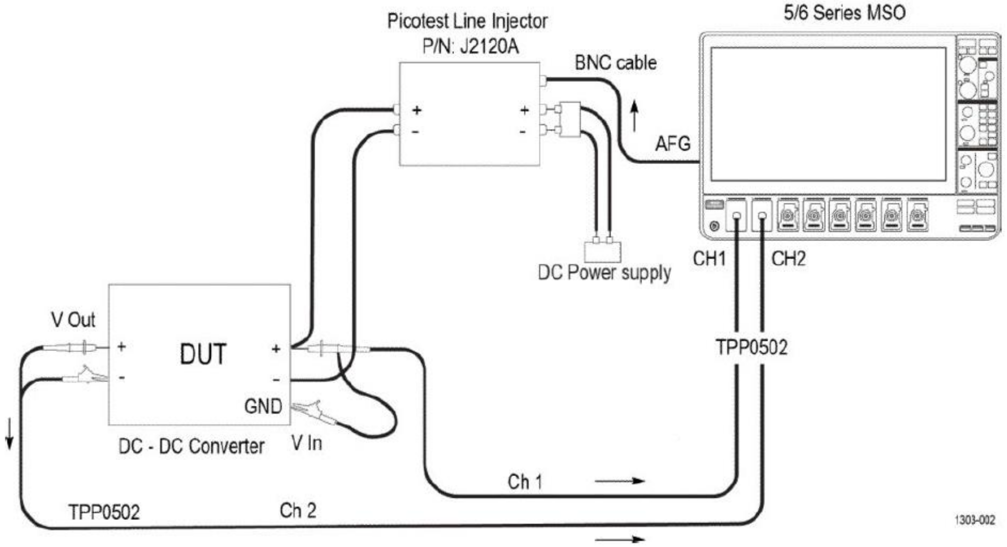


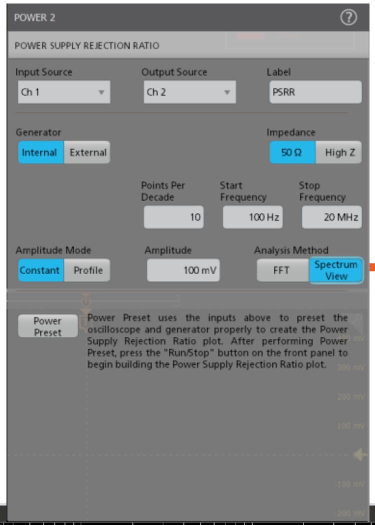


Tektronix Method – PSRR

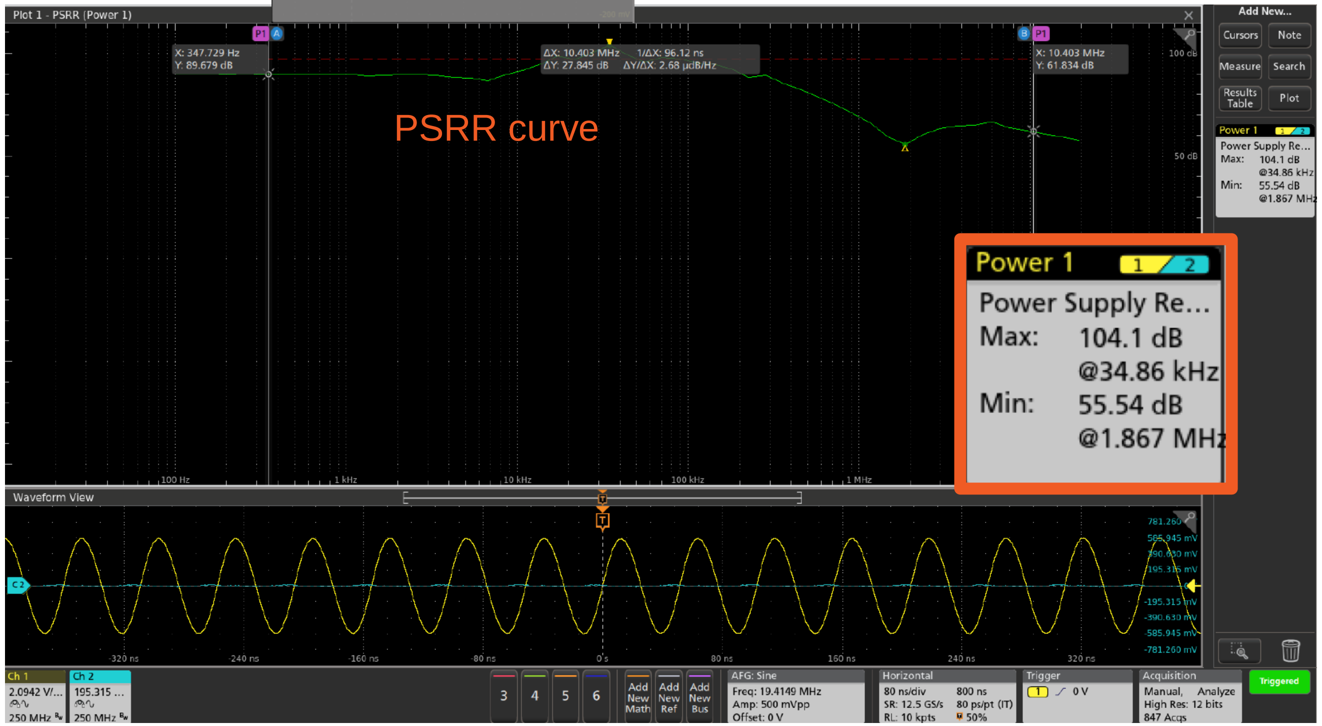
Measurement System

- 4/5/6 Series MSO Scope
- AFG (from the scope or external)
- 2 TPP0502 Probes
- Programmable DC Power Supply
- Line Injector (Picotest)





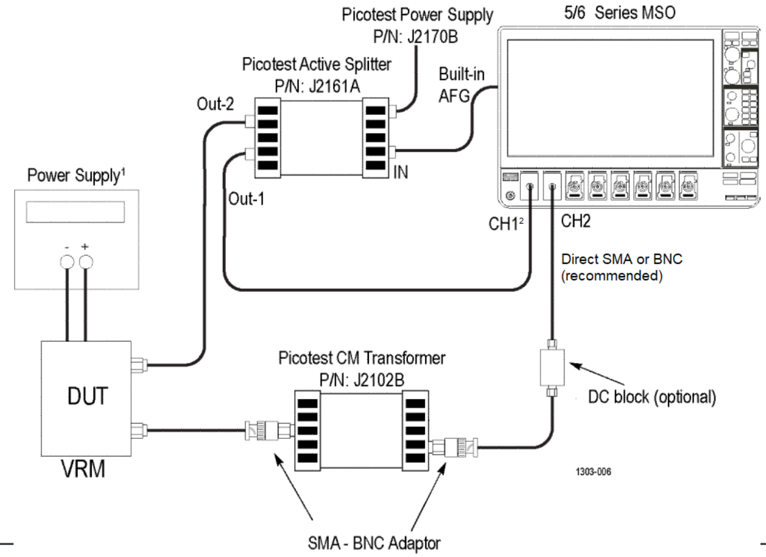
Spectrum View, now integrated with this measurement

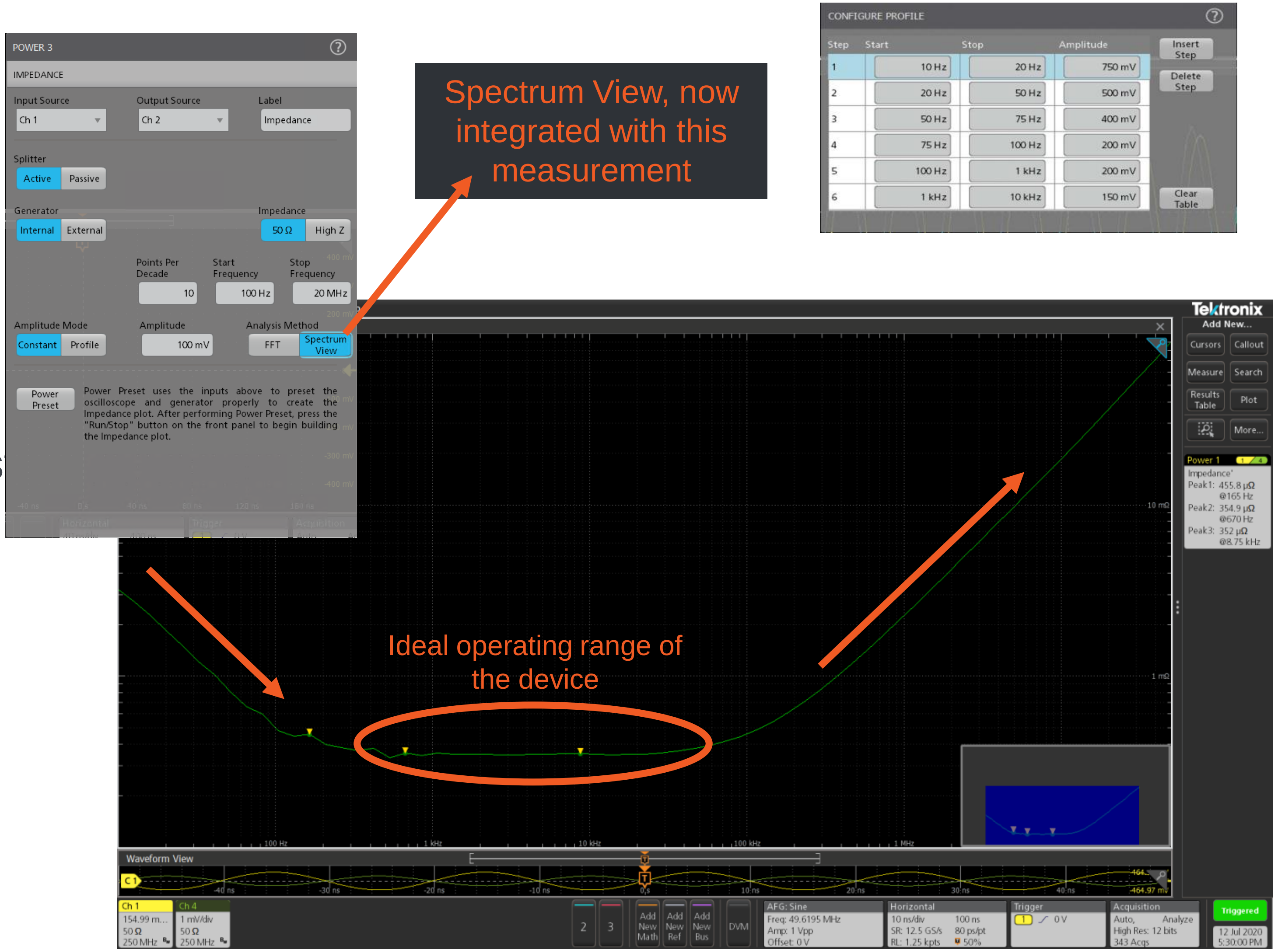


Tektronix Method – Impedance

Measurement System

- 4/5/6 Series MSO Scope
- AFG (from the scope or external)
- Direct SMA or BNC
- Power Supply (Picotest)
- Active Splitter (Picotest)
- Common-mode Transformer (Picotes





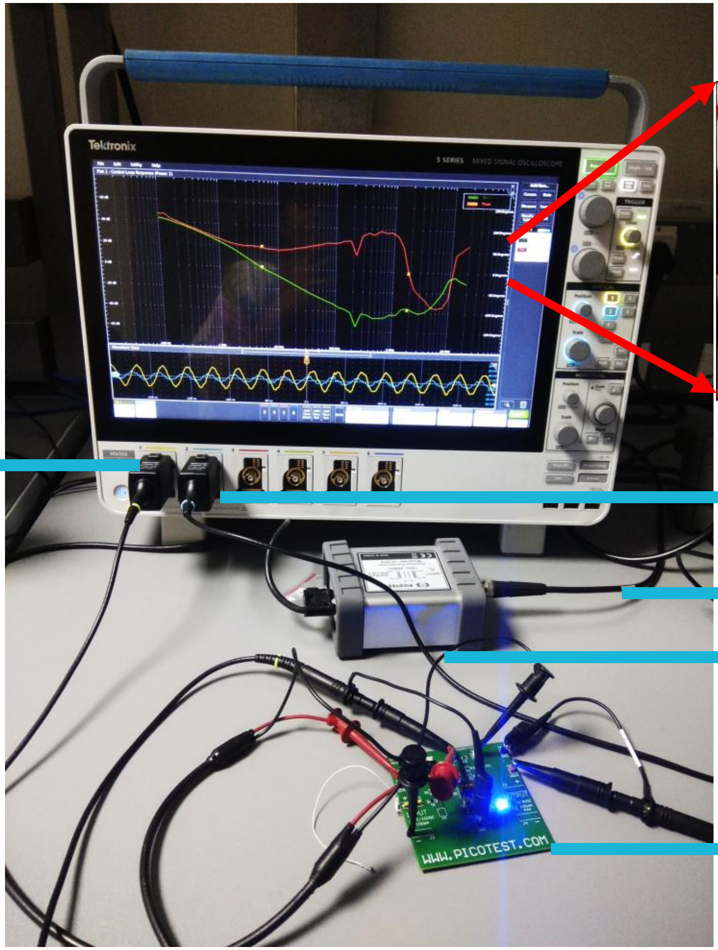
¹Source of power supply can be a DC power supply unit or USB connector
²It is recommended to use DC block at CH2 of the oscilloscope, if there is a DC offset in the signal.

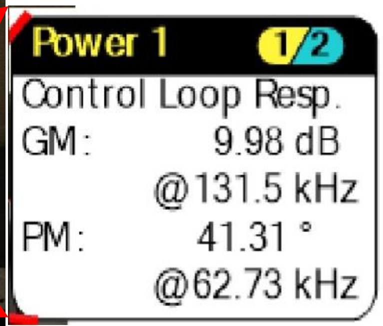
BODE plot , PSRR and Impedance Tektronix 1 BOX Solution

- **MSO4/5/6** series with built-in AFG OR

  External AFG31000 series.

- 2#TPP0502 probes
- 1#TPR1000/TPR4000 probe or P6150
- External components
  - Pico test injector
  - Isolation transformer
  - Programmable Power Supply(for PSRR)





DUT input

DUT output

AFG output

Picotest Injection transformer

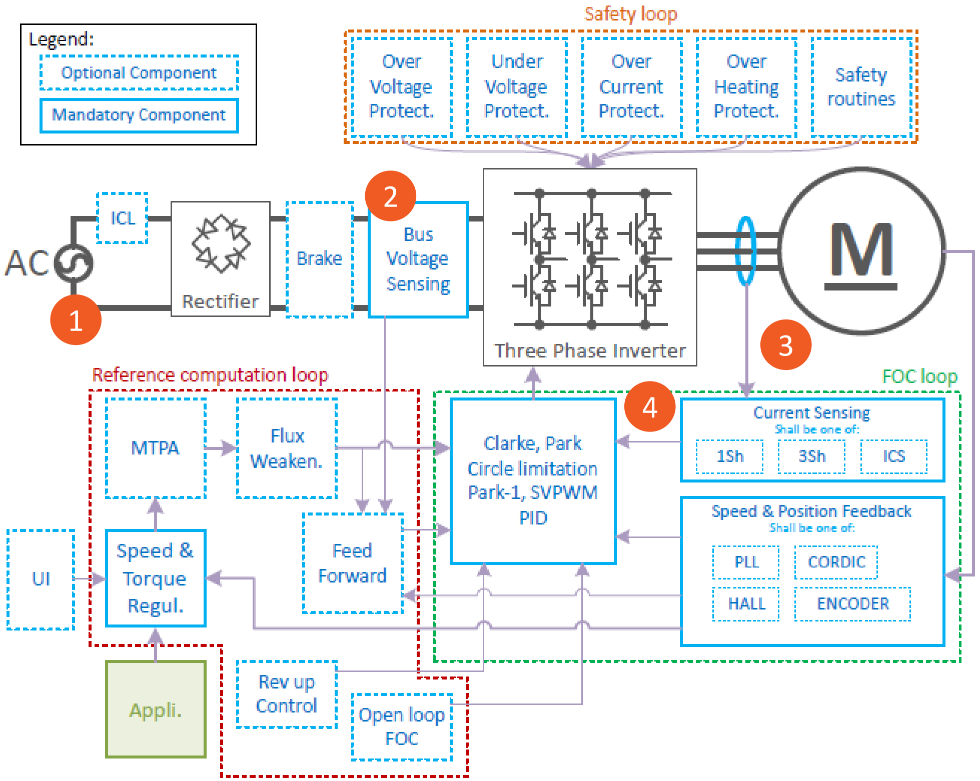
DUT

Motor Drive System

PAIN POINTS

- 1. Input (AC-DC)
- 2. DC-DC Bus
- 3. Inverter (DC-AC)
- 4. Control Logic

Figure 9. Motor control software subsystem overview

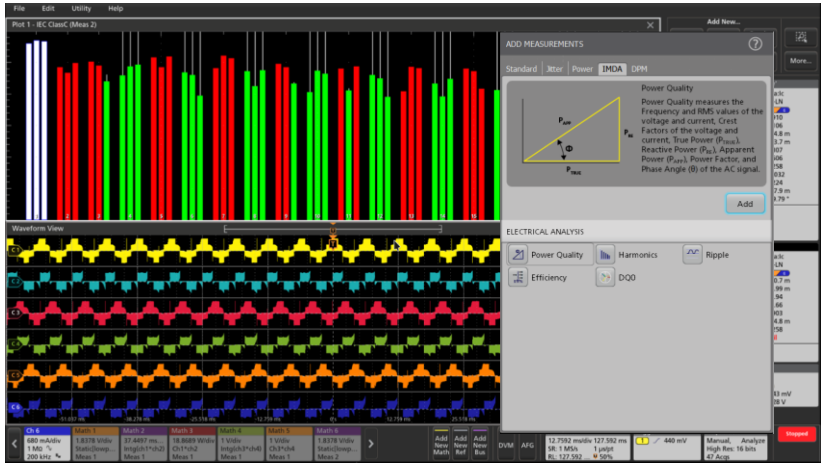


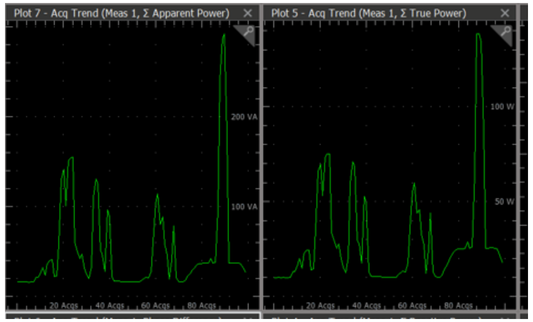
- Power Quality
- Ripple
- Efficiency
- Harmonics
- Dynamic Tests
- FOC Loop (DQ0)
- Mechanical (Speed, Direction, Torque)

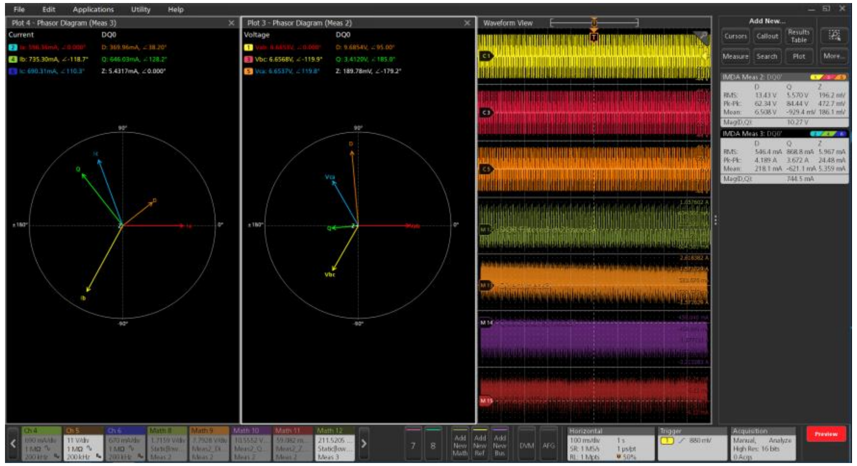
3-Phase and Inverter Motor Drive Analysis

OPTION: 5/6-IMDA, 4-3PHASE

- Single or three phase (AC/DC) Input/Output Analysis
- Static Measurements
- Dynamic Measurements
  - Time-Trend plots per Acq, and across multiple Acqs
- 3-Phase Harmonics
- Phasor diagrams
- Control Logic analysis (industry first)
  - Using Direct Quadrature Zero (DQ0) Transform
- Power Quality
- Efficiency
- LL-LN Mathematical Conversion

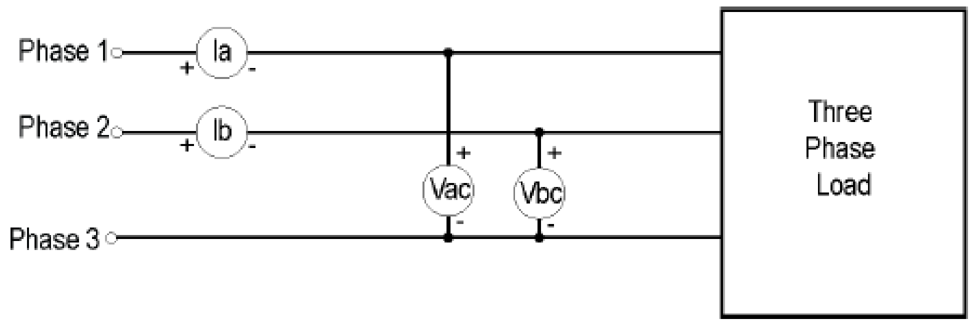




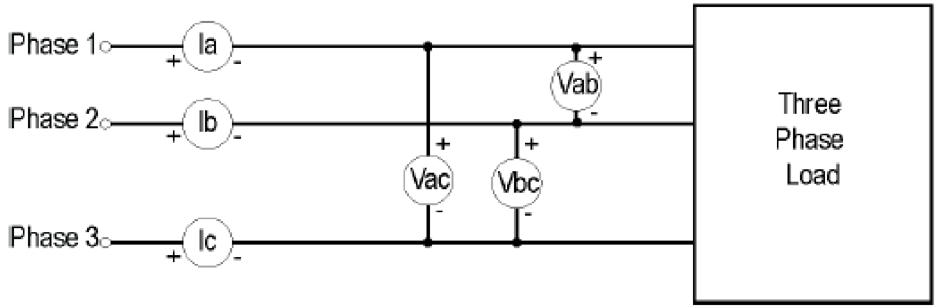


Configurations

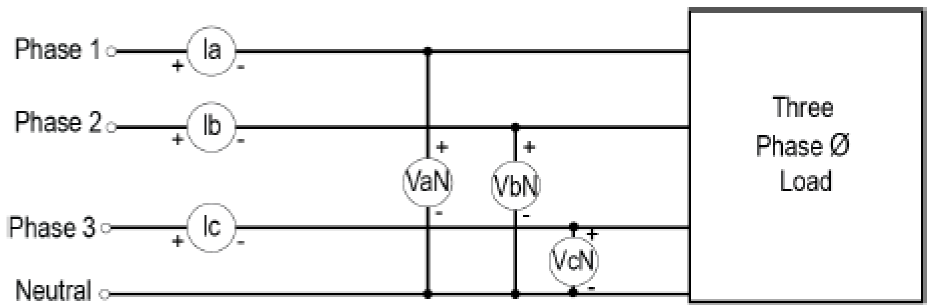
2V/2I, 3-Phase, 3-Wire



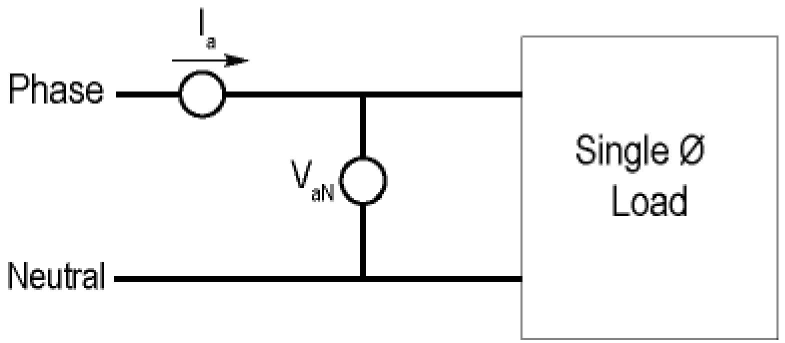
3V/3I, 3-Phase, 3-Wire (Delta)



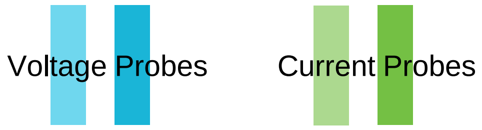
3V/3I, 3-Phase, 4-Wire (Star, Wye)



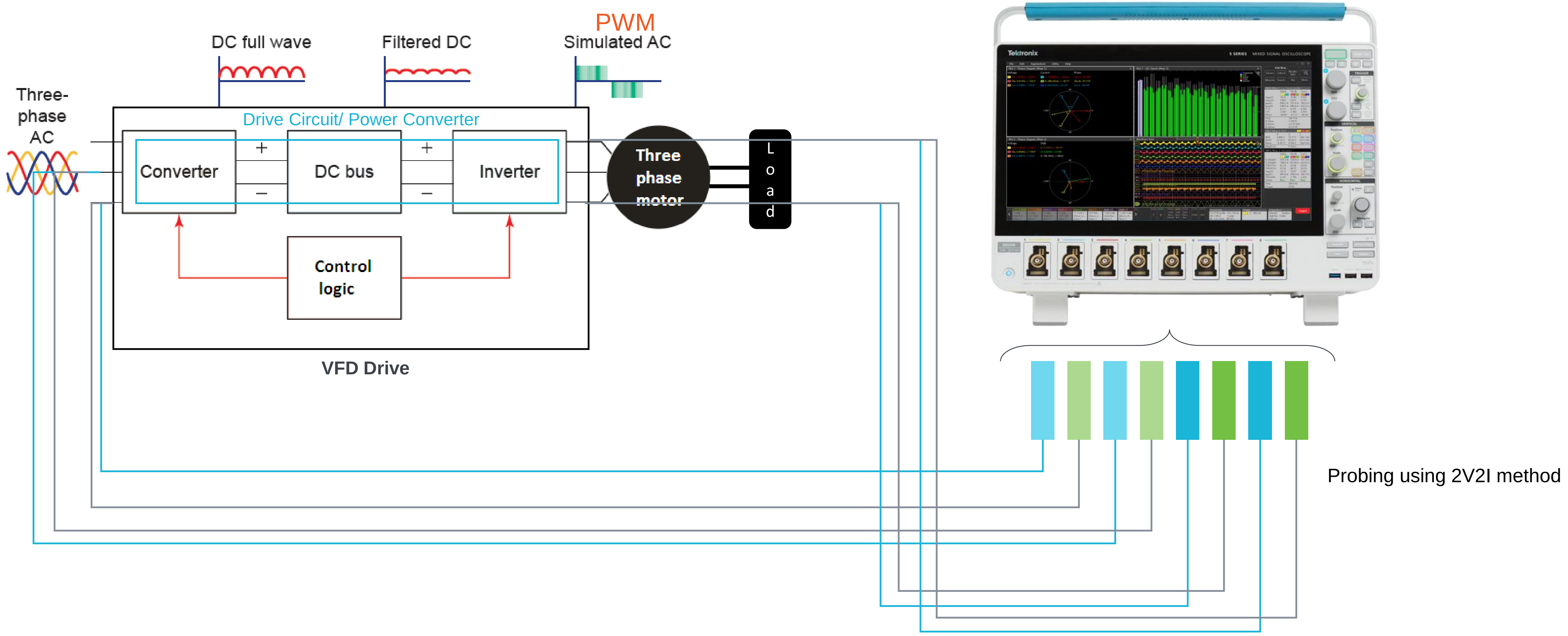
1V/1I, 1-Phase, 2-Wire



Typical Motor Test Setup



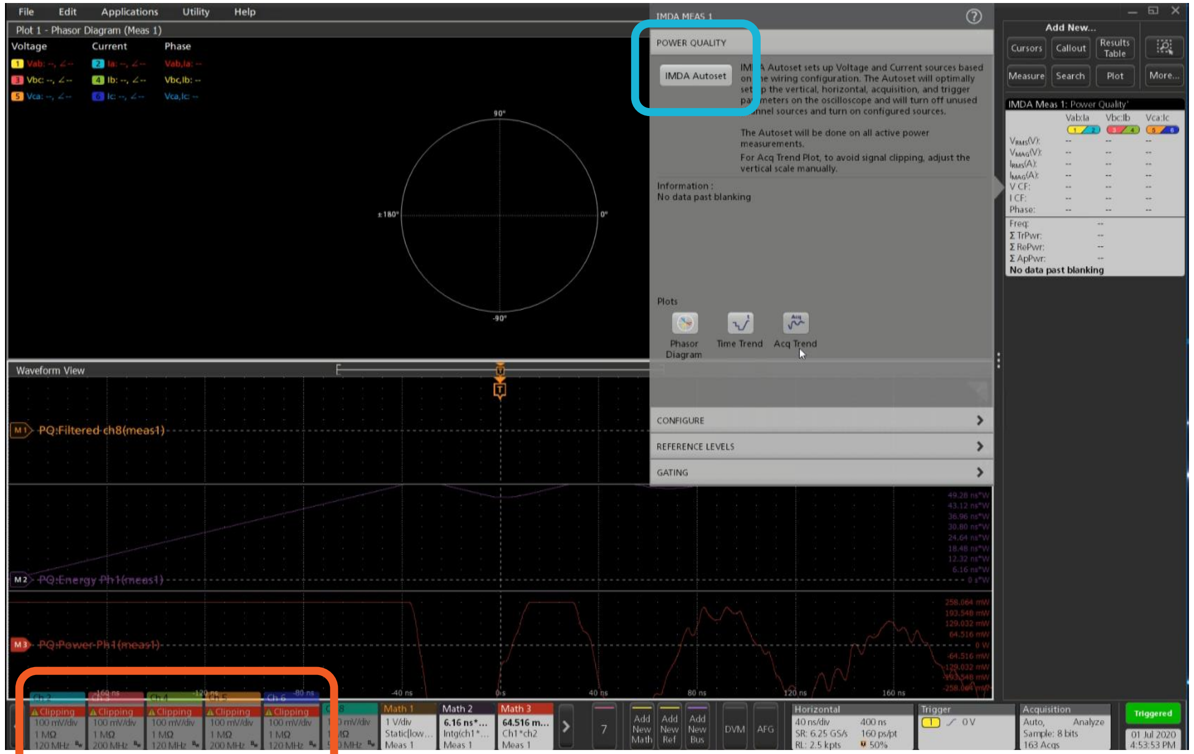
PROBING FOR EFFICIENCY MEASUREMENT USING 2V2I CONFIG



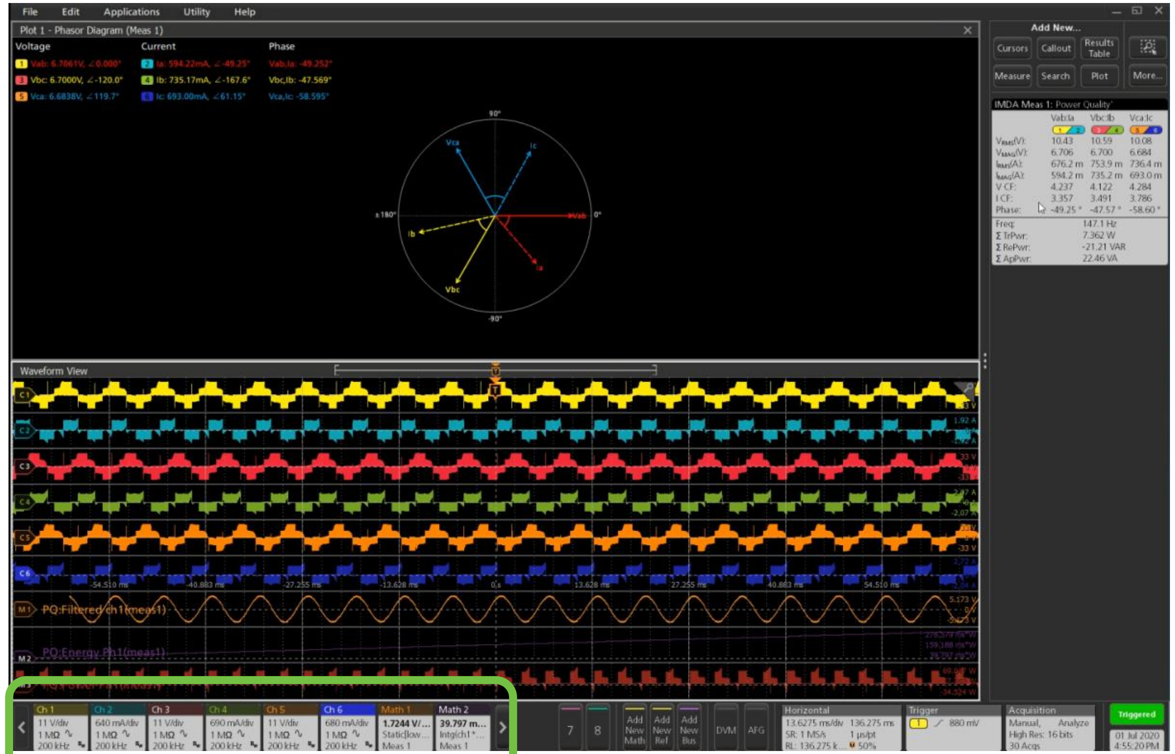
IMDA Autoset

AUTOSET THE VERTICAL DYNAMIC SCALE FOR PWM SIGNALS WITH A 1-CLICK

2. IMDA Autoset Button (available in every measurement)



1. Channels clipping initially

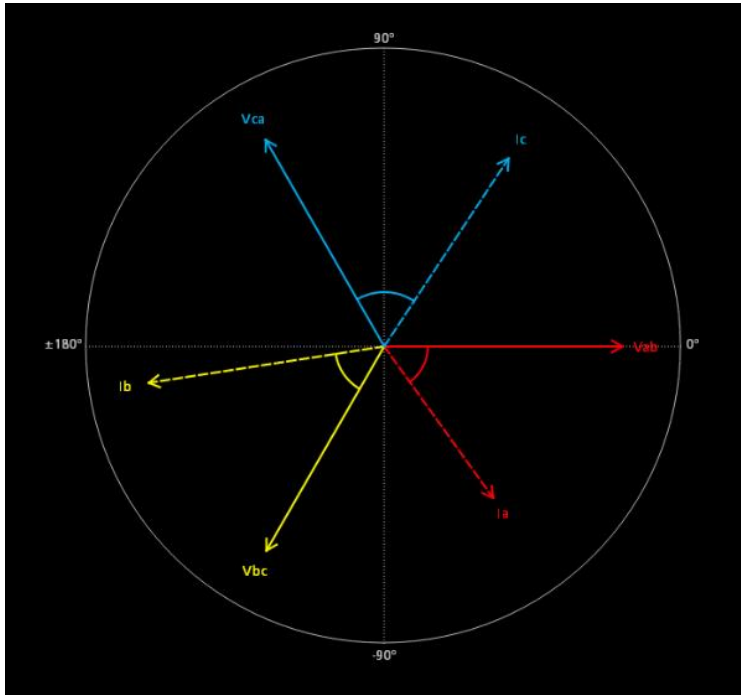


3. No clipping; channels setup optimally based on the motor PWM signal levels

IMDA Autoset is a unique feature of IMDA that sets the scope up for optimal horizontal time base snf Record Length based on the motor operating frequency. The number of cycles are important for FFT algorithm to compute the magnitude and phase values for the Phasor diagram. Also, many sub-measurements on the Power Quality can build a good result statistics using these settings.

Power Quality

- Ability of electrical equipment to consume the energy being supplied to it
- Power Quality measurement provides a complete dashboard insight into the Current, Voltage and Power values at any instance
- Power Quality measurement calculates:
  - Frequency and RMS values of the voltage and current
  - Crest Factors of the voltage and current
  - Operating PWM frequency
  - True Power (TrPwr)
  - Reactive Power (RePwr)
  - Apparent Power (ApPwr)
  - Power Factor (PF)
  - Phase Angle (θ) per phase of the signals



Analyzing Noisy Motor Waveforms

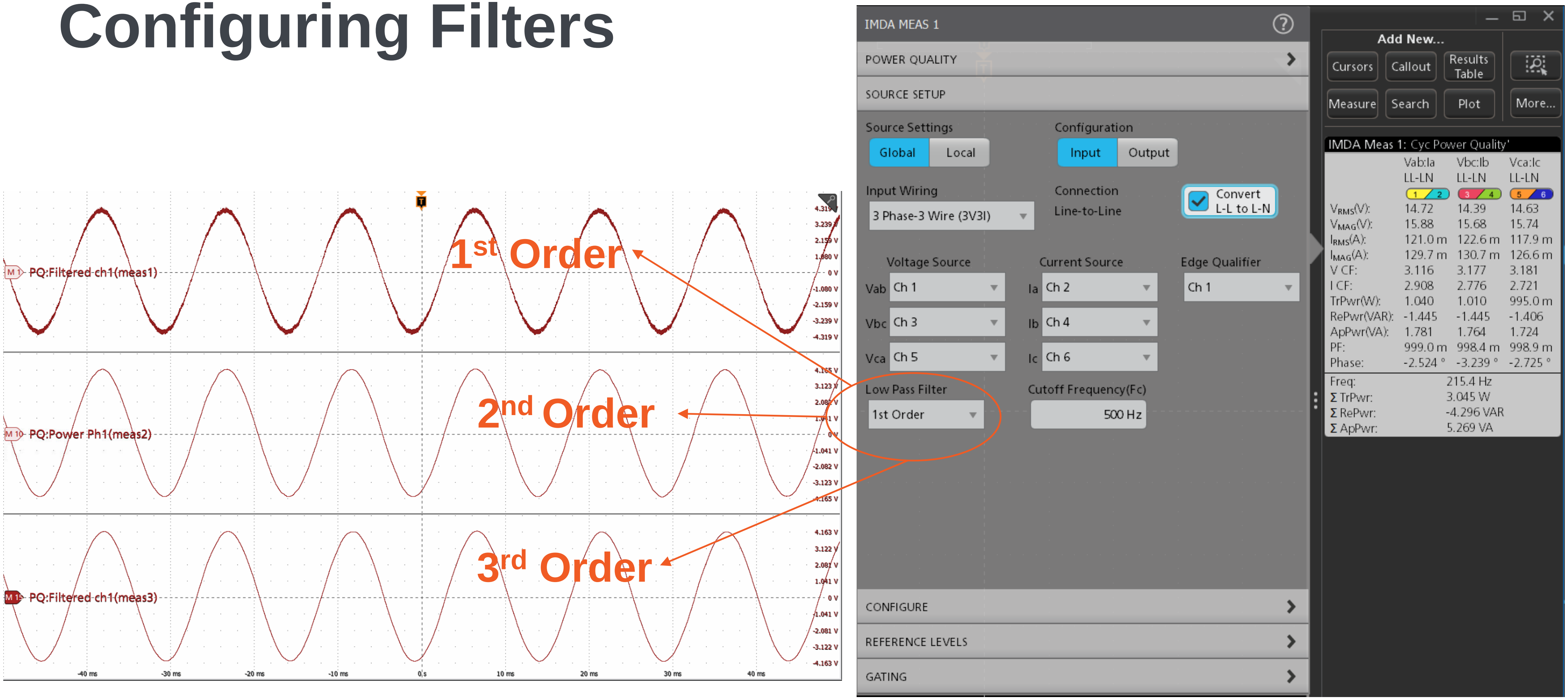
Why, Filters?
In the case of highly noisy motor waveforms, we need to likely find that some adjustment of the Low Pass Filter (LPF) cutoff, and Hysteresis settings are important and necessary to be applied.
User can then view the low-pass-filtered edge extracted as a MATH output waveform.

Why, Edge Qualifier?
Edge signal selection is critical to the correct operation of the IMDA, as it determines the zero crossings of the PWM edges at which measurements are performed. The motor signals are PWM in nature and we need to extract the edges using the Edge Qualifier. Typically, the edge extracted from the PWM would be the signal that most closely represents a sine wave, although it is not absolutely necessary to use a sine wave always.

The choice of the Edge source requires some thought prior to beginning the motor drive set up, and perhaps a visual observation of the filtered edge MATH waveform is necessary to achieve accurate power measurement results.

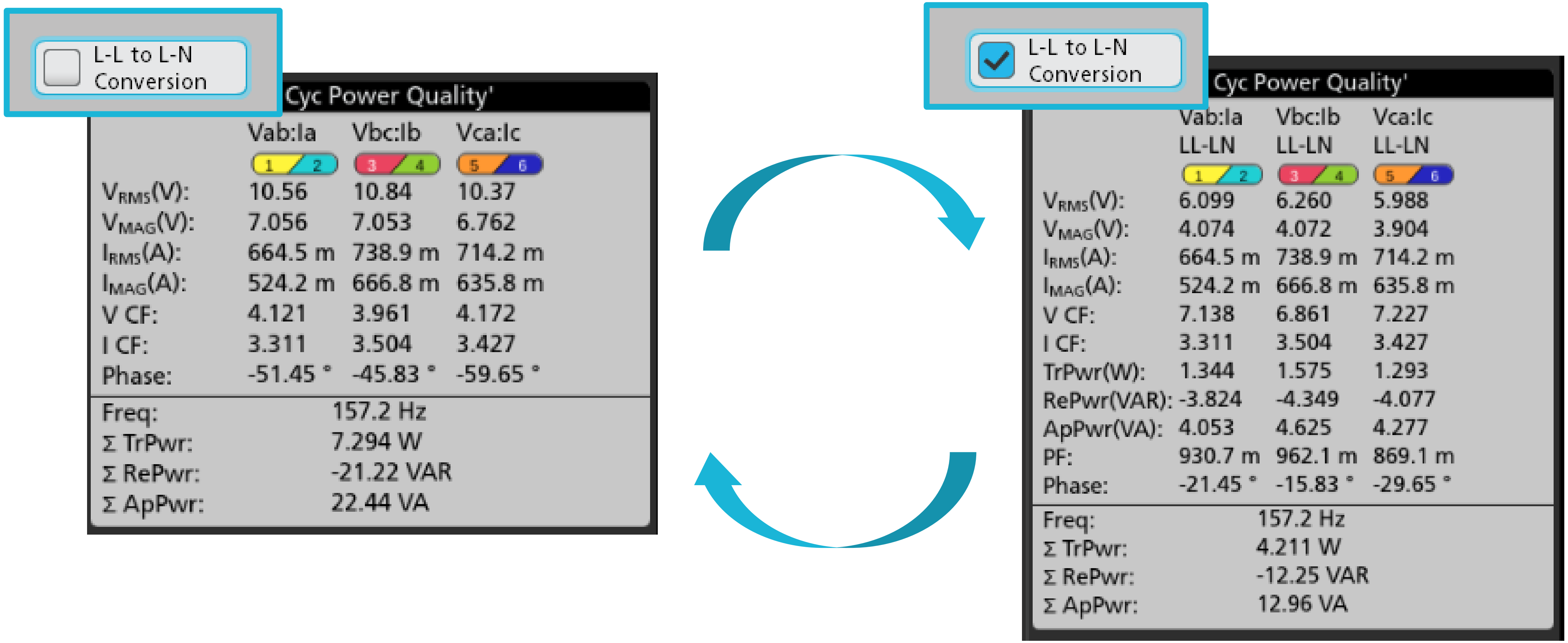
Note: The user is expected to provide a good source that is less noisy in nature as edge source, to get precise edge transitions. LPF rejects harmonics such as 5^{th} order and 7^{th} order harmonics. The LPF needs a low cut off frequency like the 500Hz to 1KHz. Such LPF may cause some significant phase shift which must be compensated.

Configuring Filters



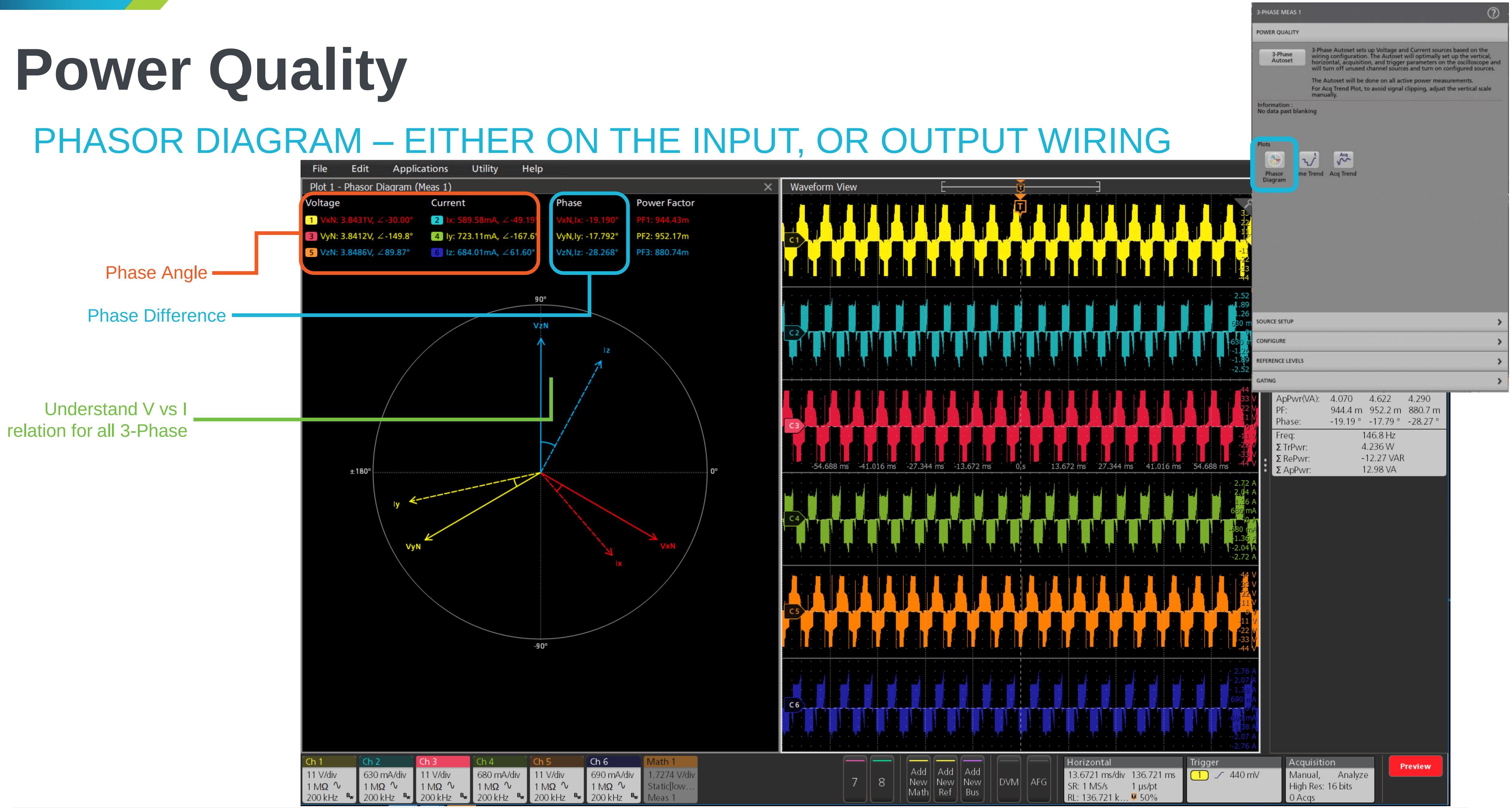
Power Quality

LINE-LINE TO LINE-NEUTRAL MATHEMATICAL CONVERSION



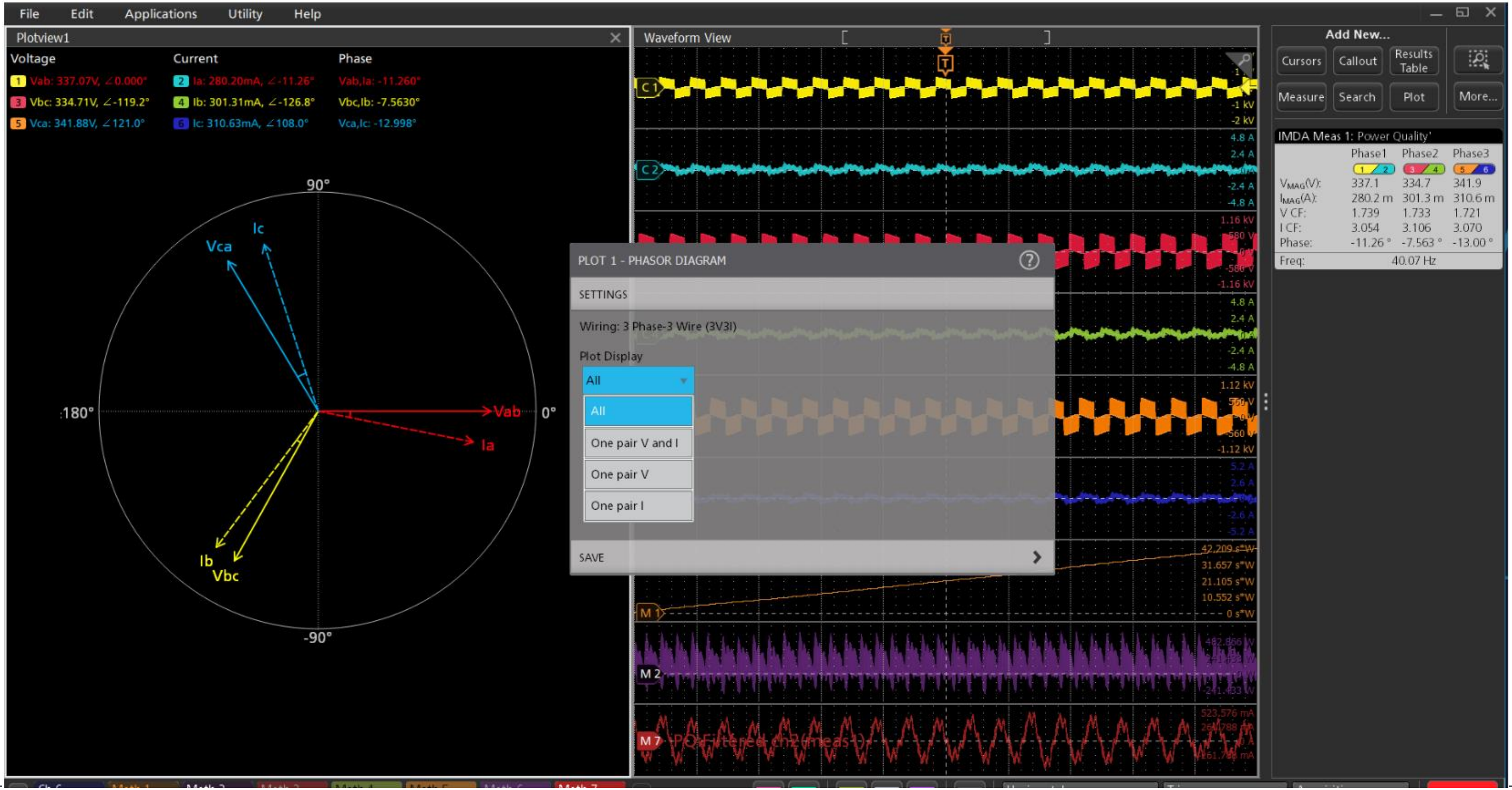
Power Quality

PHASOR DIAGRAM – EITHER ON THE INPUT, OR OUTPUT WIRING



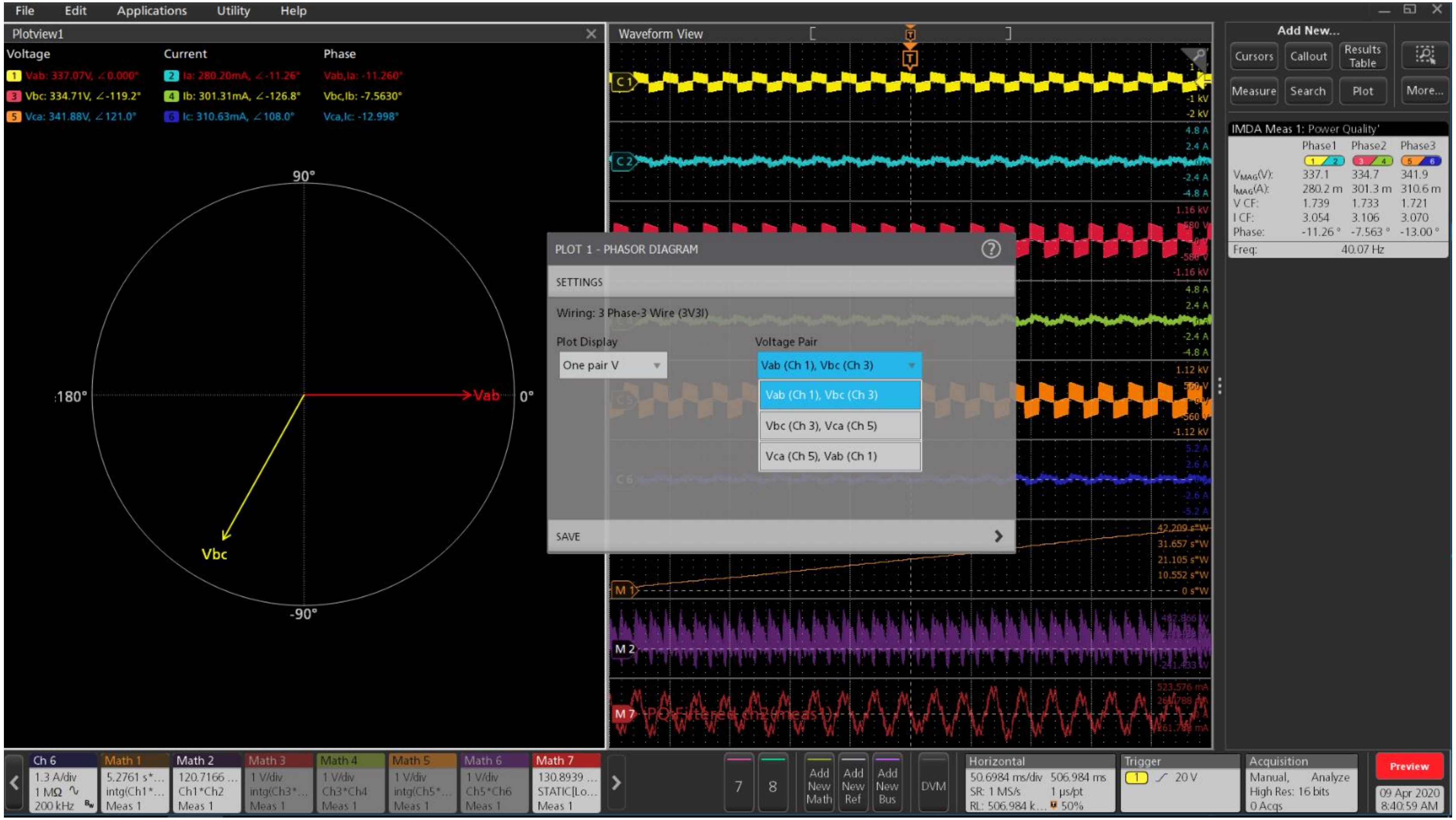
Power Quality

CONFIGURABLE OPTIONS



Power Quality

CONFIGURABLE OPTIONS

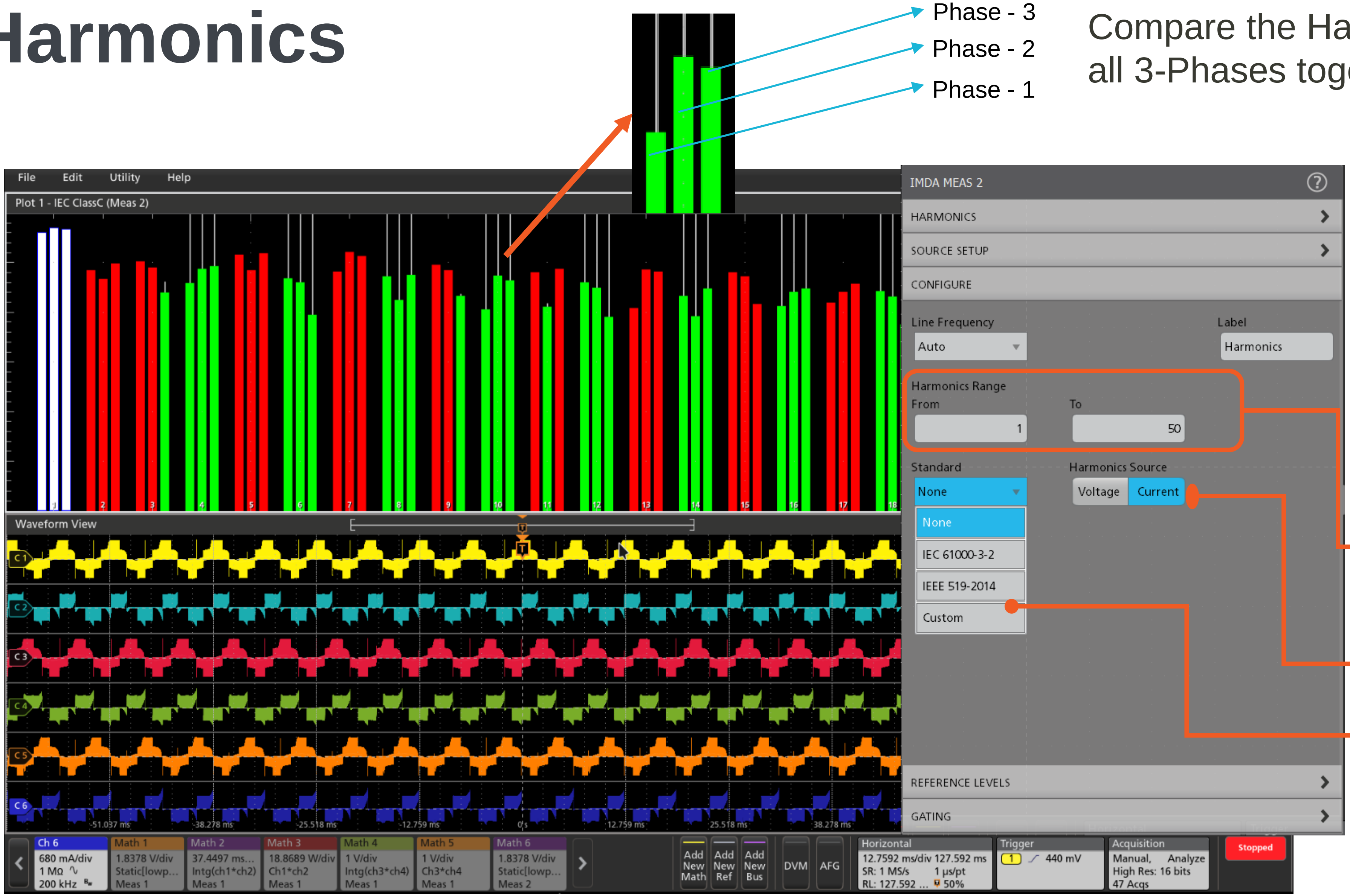


Harmonics

- Harmonics can impact the efficiency of the system
  - Can result in heating of coils, misfiring of VFDs, etc.
- Displays 3-Phase Harmonics side-by-side for easy correlation
- The solution computes many important sub-measurements such as THD-F, THD-R and fundamental values per phase
- User-defined harmonic order, can go up to 200th order and supports range filter for easy visibility
- Support IEEE-519/IEEE-61000 standard, useful for motor designs with pass/fail status. This helps for pre-compliance testing.
- User can define custom limits and apply for the harmonics.

Harmonics

Compare the Harmonics of all 3-Phases together



Grey bars indicate the Harmonics limit as per the standard selected

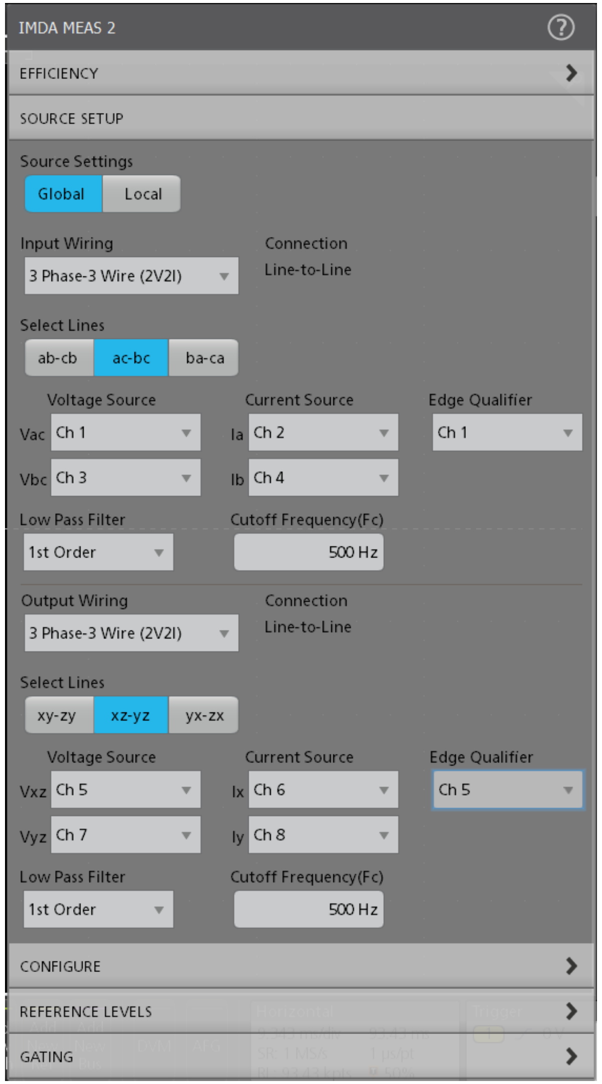
Green – PASS

Red – FAIL

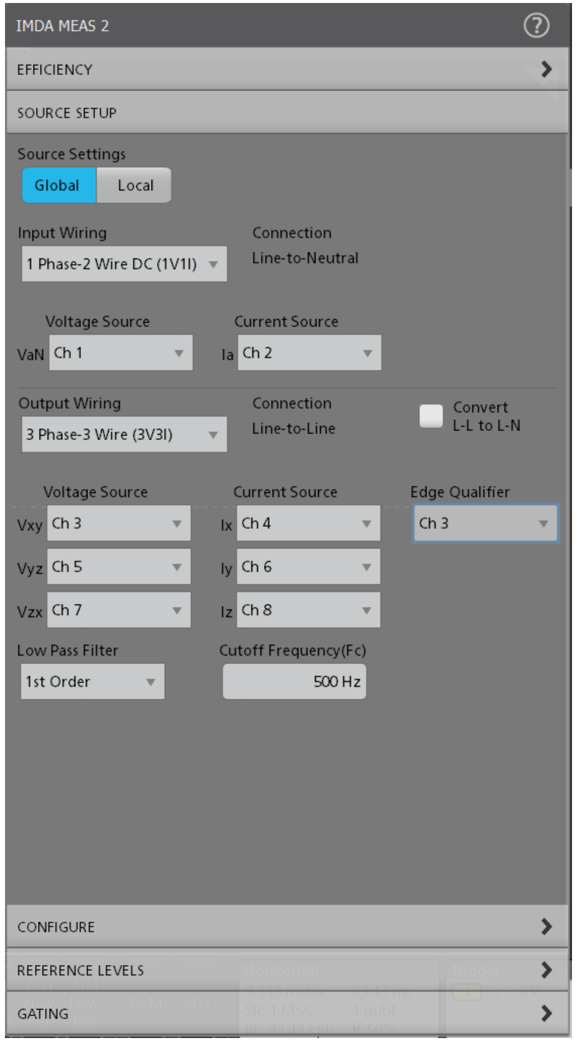
Specify custom limits which is user defined values

Efficiency

- Efficiency measures the ratio of Output Power to Input Power
- Calculates Efficiency at each phase, and total efficiency (average) of the system
- IMDA supports 2V2I (2-Wattmeter method) which requires all 8 scope channels for performing efficiency measurement.



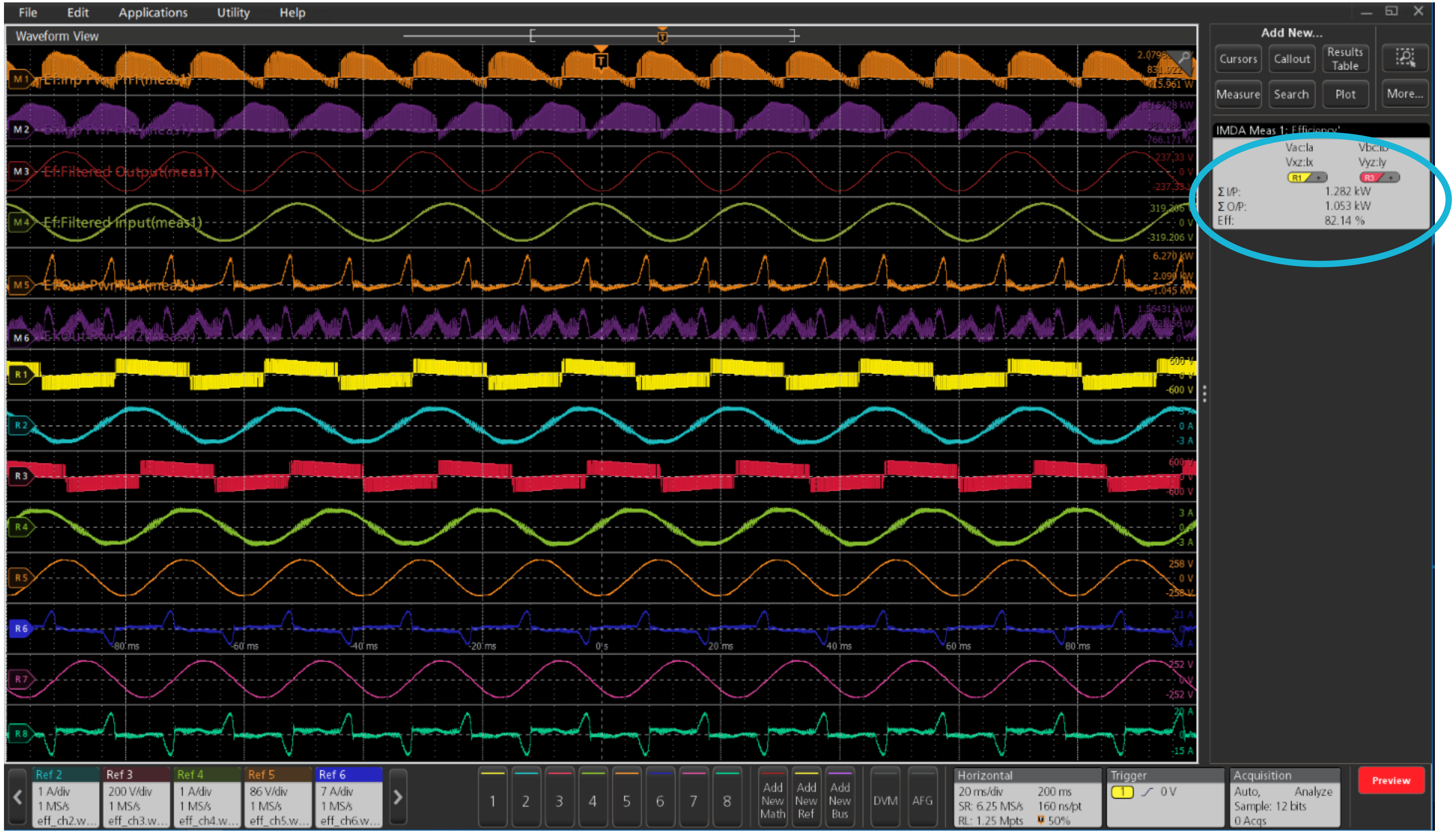
3-Phase Efficiency (AC-AC)



3-Phase Efficiency of Inverters (DC in – AC out)

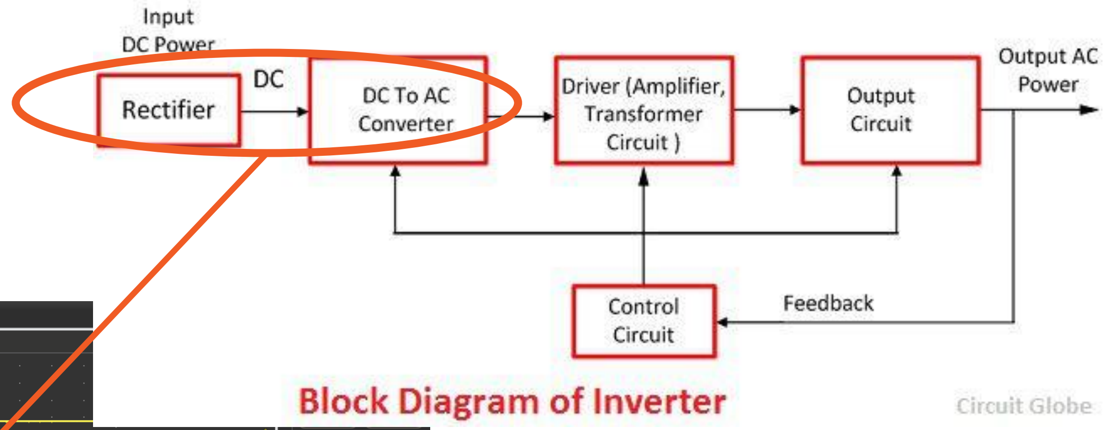
Efficiency

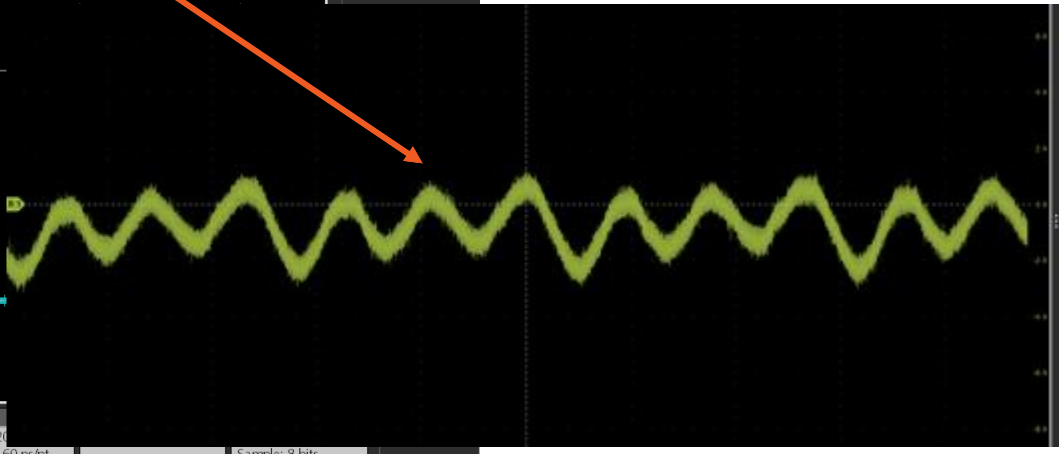
2V2I METHOD



Ripple Analysis

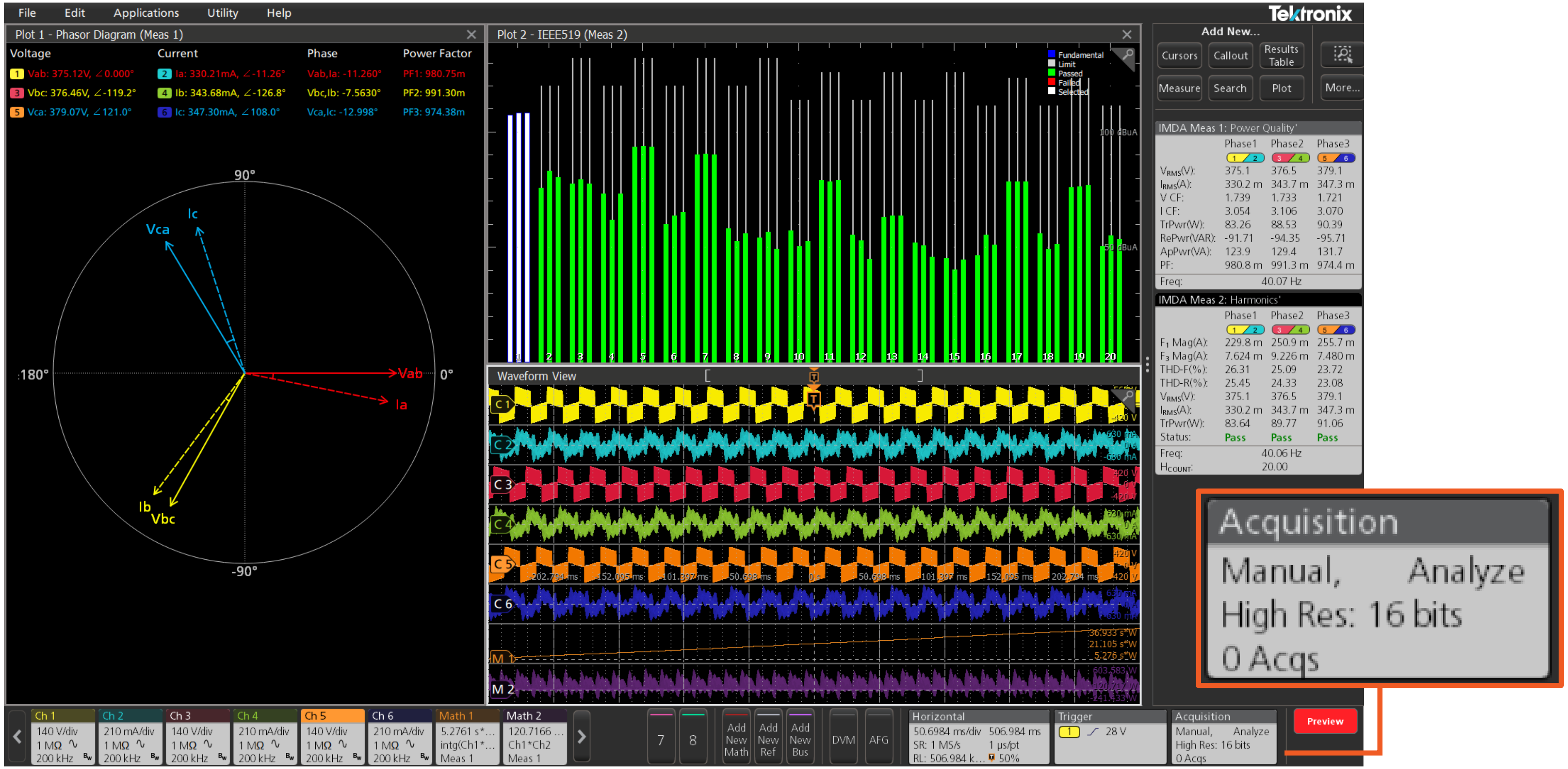
DC BUS – INVERTER INPUT





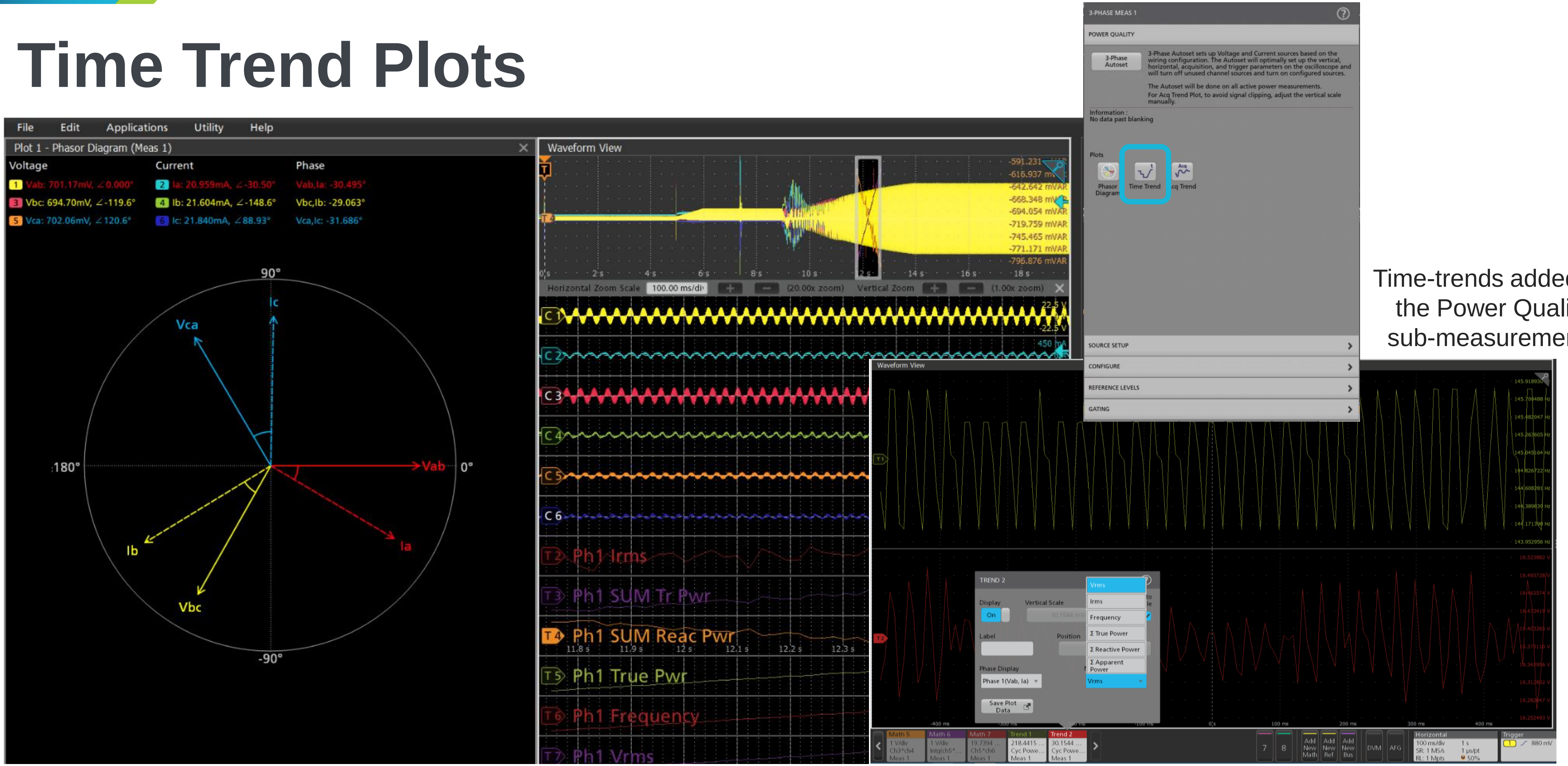
Ripple is generally measured at the switching side of the Half or a Full bridge rectifier.

Make Accurate Measurements



Measurements are performed in 16 bits High Res mode which provides high accuracy

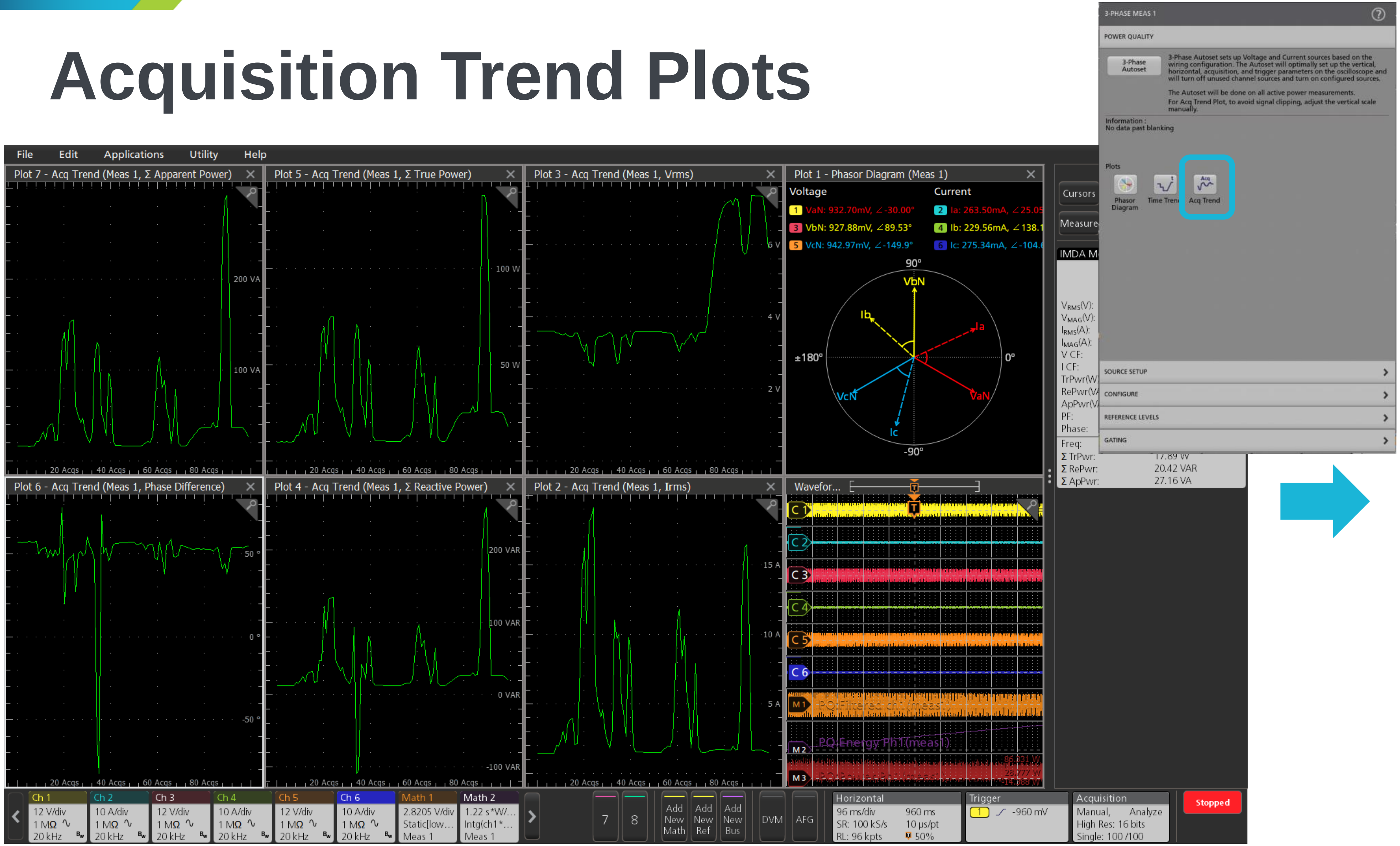
Time Trend Plots



Time-trends added on the Power Quality sub-measurements

Analyze how your motor drive measurements change over time in a long deep memory acquisition. This also allows you to zoom and window your measurements to any part within the acquisition.

Acquisition Trend Plots

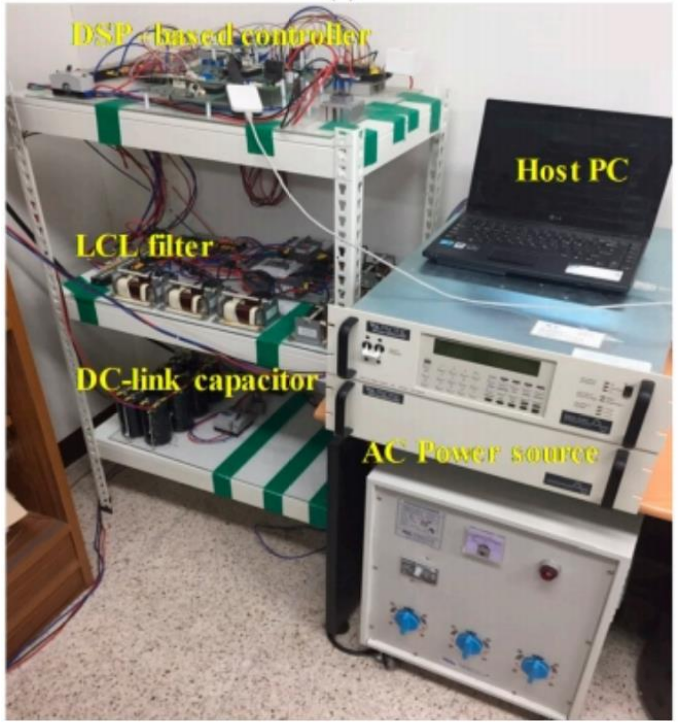


Plot data saved into a CSV file for post processing

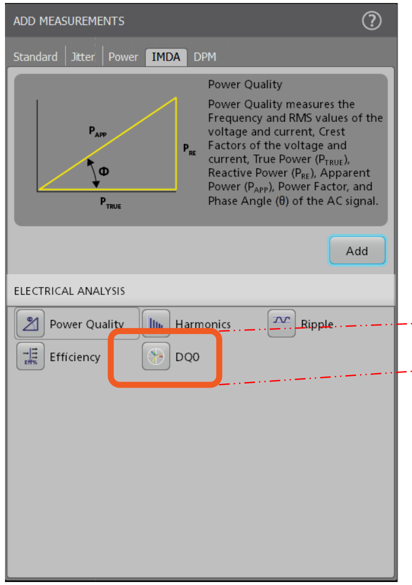
	A	B	C	D
1	Date	Time	Acqs	Value(V)
2	7/3/2020	03:41.5	1	10.5563
3	7/3/2020	03:42.0	2	10.5726
4	7/3/2020	03:42.4	3	10.5638
5	7/3/2020	03:42.7	4	10.5645
6	7/3/2020	03:43.0	5	10.5589
7	7/3/2020	03:43.2	6	10.5696
8	7/3/2020	03:43.5	7	10.5741
9	7/3/2020	03:43.8	8	10.5636
10	7/3/2020	03:44.1	9	10.5587
11	7/3/2020	03:44.4	10	10.5794
12	7/3/2020	03:44.7	11	10.5626
13	7/3/2020	03:45.0	12	10.5679
14	7/3/2020	03:45.3	13	10.5584
15	7/3/2020	03:45.5	14	10.5587
16	7/3/2020	03:45.8	15	10.575
17	7/3/2020	03:46.1	16	10.5586
18	7/3/2020	03:46.3	17	10.5496
19	7/3/2020	03:46.6	18	10.5496
20	7/3/2020	03:46.9	19	10.5669
21	7/3/2020	03:47.1	20	10.5683
22	7/3/2020	03:47.4	21	10.5566
23	7/3/2020	03:47.6	22	10.5682
24	7/3/2020	03:47.8	23	10.5555
25	7/3/2020	03:48.1	24	10.5536
26	7/3/2020	03:48.3	25	10.5623
27	7/3/2020	03:48.5	26	10.565

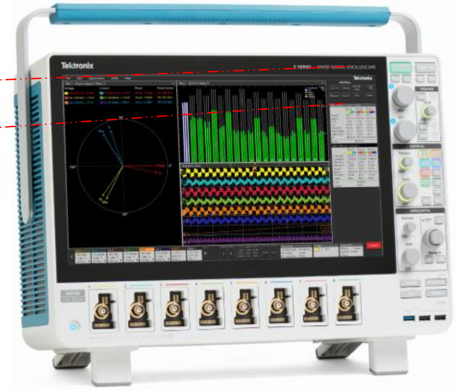
Analyze how your motor drive measurements change over multiple acquisitions effectively turning it into data logger.

Simplify testing with IMDA DQ0



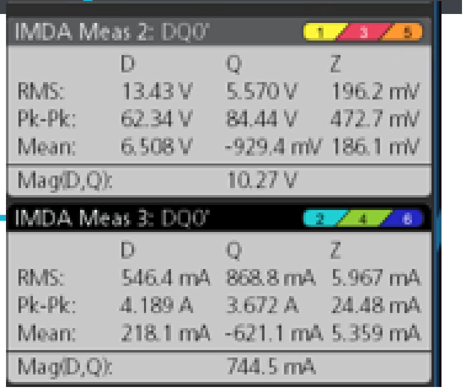
General Customer’s DQ0 Test Setup
(Hardware Intensive)





Tektronix 1-Box
DQ0 Solution!

D-Q-0 scalar results

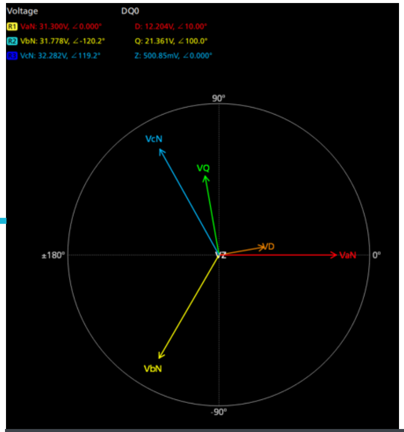


IMDA Meas 2: DQ0

	D	Q	Z
RMS:	13.43 V	5.570 V	196.2 mV
Pk-Pk:	62.34 V	84.44 V	472.7 mV
Mean:	6.508 V	-929.4 mV	186.1 mV
Mag(D,Q):		10.27 V	

IMDA Meas 3: DQ0

	D	Q	Z
RMS:	546.4 mA	868.8 mA	5.967 mA
Pk-Pk:	4.189 A	3.672 A	24.48 mA
Mean:	218.1 mA	-621.1 mA	5.359 mA
Mag(D,Q):		744.5 mA	



D-Q-0 on the
Phasor Diagram

Summary

POWER PROBLEMS SOLVED WITH A 1-INSTRUMENT SOLUTION

Power measurement

Oscilloscope

Spectrum analyzer

Power Analyzer

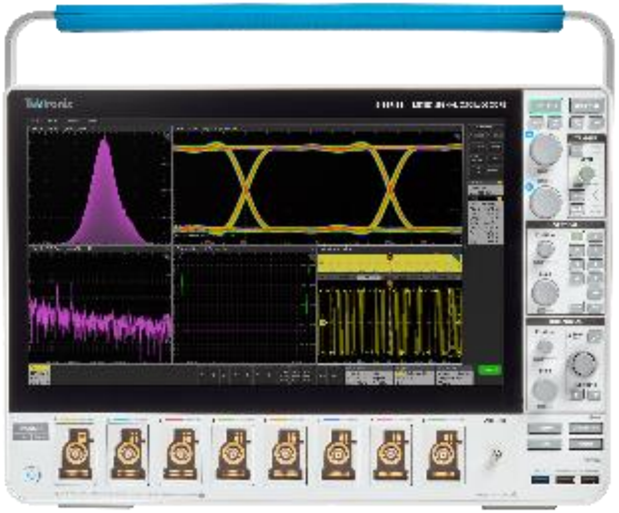
Function generator

Frequency response analyzer

L C R meter

Impedance analyzer

VNA



- Detailed Power Analysis : AC-DC, DC-DC (PWR)
- Power Integrity testing (DPM)
- 3-Phase Analysis
- Wide Bandgap characterization
- DC-AC Inverter Block Analysis
- Power Sequencing on Multi-rails
- Spectrum View to identify the source of Ripple
- Isolate issue between SI and PI testing
- PDN Impedance
- Frequency Response Analysis - Bode Plots
- PSRR
- Multi-channel scope with built-in AFG

Thank You