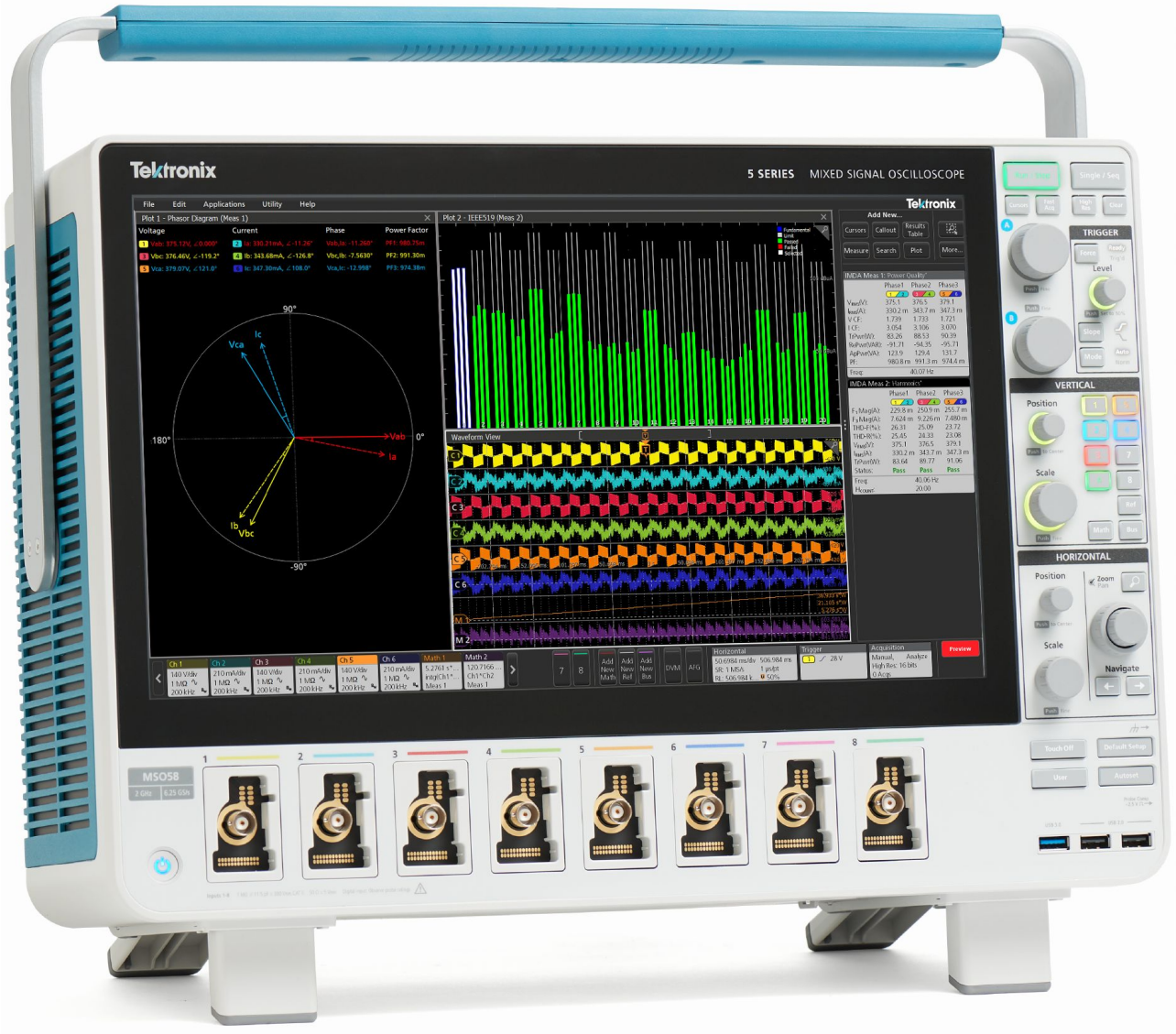
3-Phase Inverter Motor Drive Analysis

5 Series MSO Option 5-IMDA Application Datasheet

Get more visibility into your inverters, motors, and drive systems



Measurements and analysis on three-phase power systems are inherently more complex than on single-phase systems. Although oscilloscopes can capture voltage and current waveforms with high sample rates, further calculations are required to produce key power measurements from the data. Power converters based on Pulse Width Modulation (PWM), such as variable-frequency motor drives, further complicate measurements since filtering and triggering on PWM signals are challenging. Yet for most validation and troubleshooting, understandably their oscilloscope is the instrument of choice for designers. Special software, designed to automate power analysis on inverters, motors, and drives, greatly simplifies important three-phase power measurements on PWM systems and can help engineers get faster insights into their designs. The Inverter Motor Drive Analysis (IMDA) solution from Tektronix helps engineers design better and more efficient three-phase motor drive systems, taking full advantage of the advanced user interface, six or eight analog input channels, and 'High Res' mode (16 bits) on the 5 Series MSO. The IMDA solution provides fast, accurate, and repeatable results for electrical measurements on industrial motors and drive systems for AC induction motors, permanent magnet synchronous motors (PMSM), and brushless DC (BLDC) motors. It can be configured to measure DC to three-phase AC converters, such as those used in the electric vehicles.

Key features and specifications

- Accurately analyze three-phase PWM signals used to drive AC induction, BLDC, and PMSM motors.
- Unique oscilloscope based phasor diagrams indicate V_{RMS}, I_{RMS}, V_{MAG}, I_{MAG}, and phase relationships at a glance for the configured wiring pairs.
- Debug motor drive designs by viewing the drive input/output voltage and current signals in the time domain simultaneously with the phasor diagram.
- Three-phase Autoset feature configures the oscilloscope for optimal horizontal, vertical, trigger, and acquisition parameters for acquiring three-phase signals.
- Measures harmonics per the IEEE-519 standard or using custom limits.
- Measures drive system efficiency using the 2V2I (two wattmeter) method.
- Quickly add and configure measurements through the intuitive drag and drop interface on the 5 Series MSO.
- Analyze Inverter and Automotive three-phase designs for DC-AC topology.
- Supports 1-Phase-2Wire (1V1I) and 1-Phase-3Wire (2V2I) under the AC-AC Industrial configuration.

Measurement overview

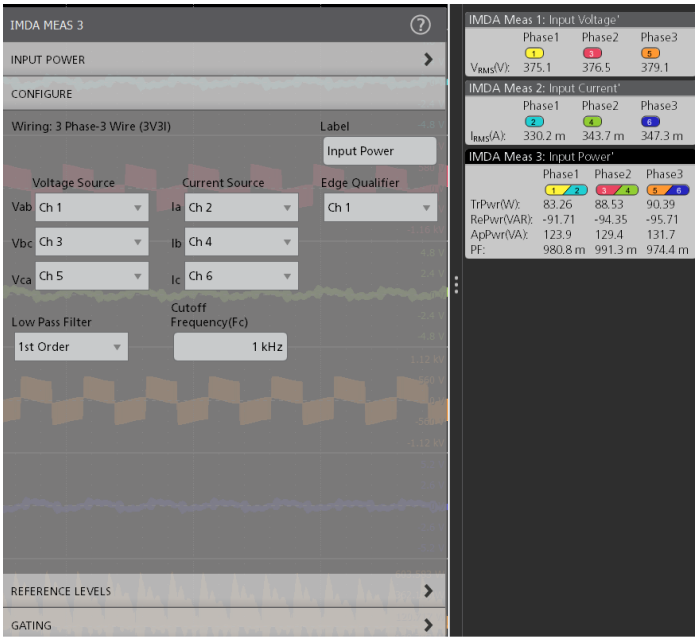
Three-phase power converters such as variable frequency drives require a range of measurements during the design process. The Inverters, Motors, and Drives Analysis package for the 5 Series MSO automates key electrical measurements which are grouped into three categories:

- Input analysis
- Output analysis
- Ripple analysis

Each of these sections include key measurements which are critical to a motor design.

Input analysis

Input analysis includes the basic measurements used in most power equipment designs. The 5-IMDA solution automatically measures the current, voltage, and power values for different wiring configurations. The measurements can be set to measure 1V1I (1-Phase-2Wire), 2V2I (1 Phase - 3 Wire), 2V2I (3 Phase - 3 Wire) or 3V3I (3-Phase-3Wire), and 3P4W (3-Phase-4Wire) to support various supply and motor configurations. Measurements can be performed line-to-line or line-to-neutral, to support delta or wye configurations.

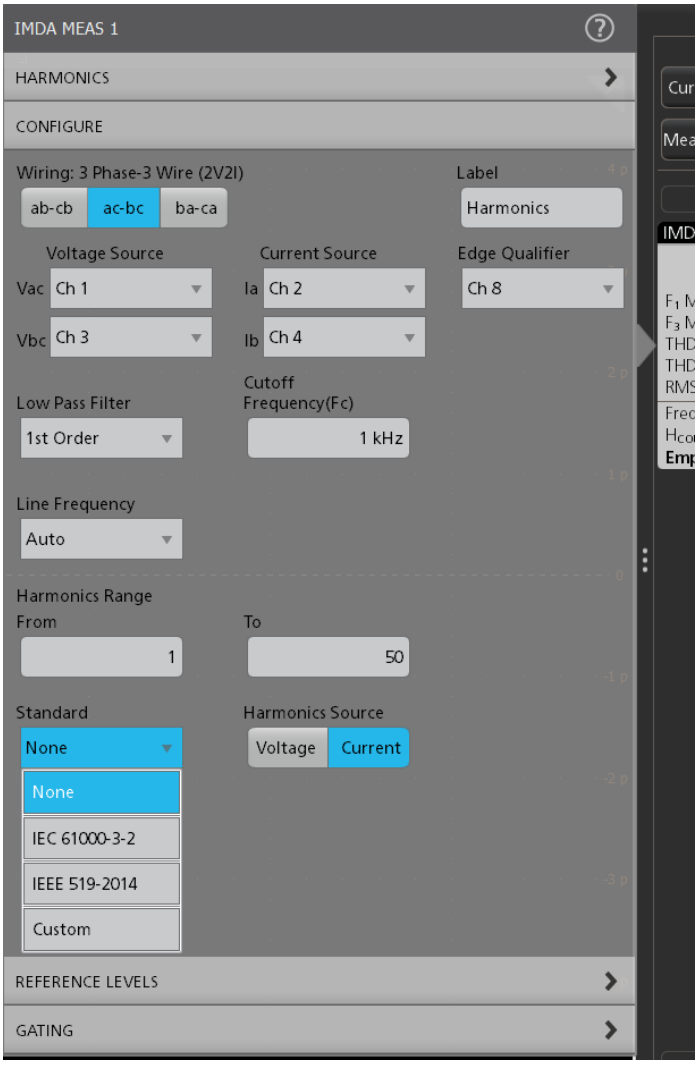


Input analysis wiring configuration

Harmonics

Power waveforms are rarely textbook sinusoids. Harmonics measurements break down non-sinusoidal voltage or current waveforms into their sinusoidal components, indicating the frequency and amplitude for each component.

Harmonics analysis can be performed up to 200th harmonic order. The maximum harmonic order can be set to suit your needs by specifying the range in the measurement configuration. THD-F, THD-R and fundamental values are measured for each phase. Measurements can be evaluated against the IEEE-519 or IEC 61000 3-2 standard, or custom limits. Test results can be recorded in a detailed report indicating pass/fail status.

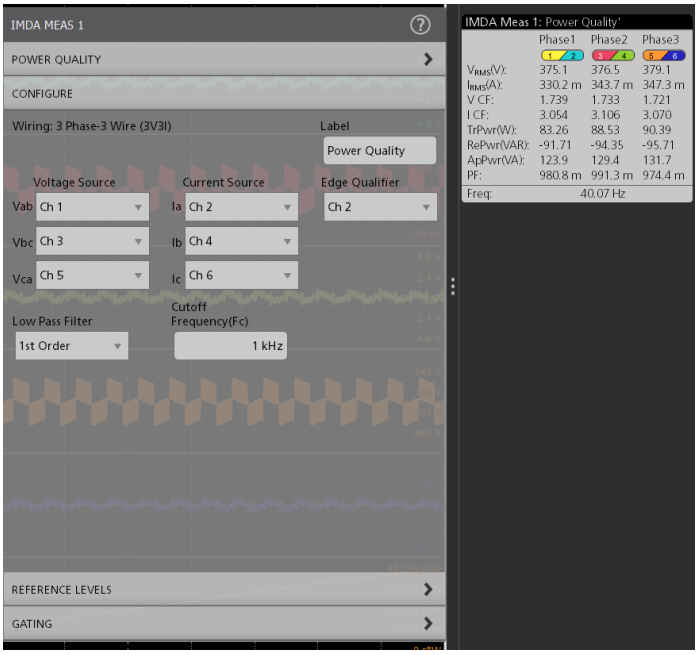


Compare harmonics measurements against industry standards or custom limits

Power quality

This group provides critical three-phase power measurements including: frequency and RMS magnitudes of voltage and current, crest factors of voltage and current, PWM frequency, true power, reactive power, apparent power, power factor, and phase angle for each phase.

Voltage and current vectors can be displayed on a phasor diagram so you can quickly judge phase shift for each phase and the balance among phases. Each vector is represented by an RMS value and phase is computed using the DFT method.



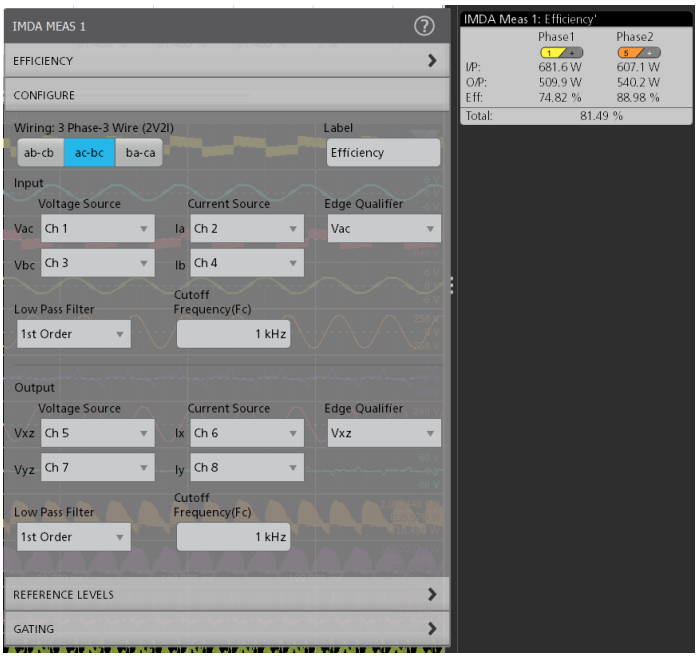
Easily configure the settings to get insight into the power quality

Output analysis

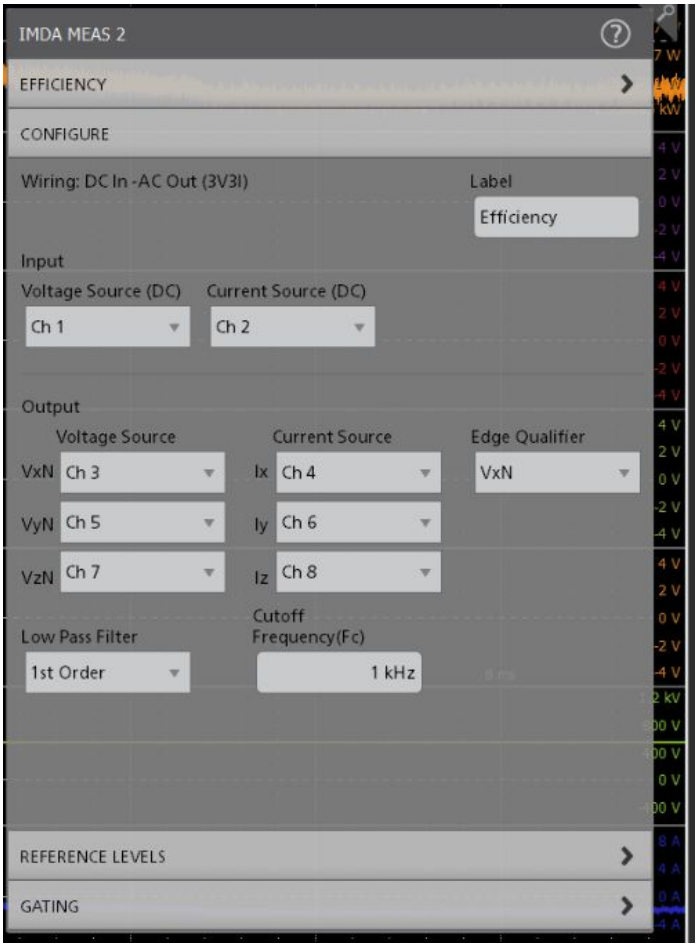
This group of measurements can help calculate the overall performance of the motor drive system.

Efficiency

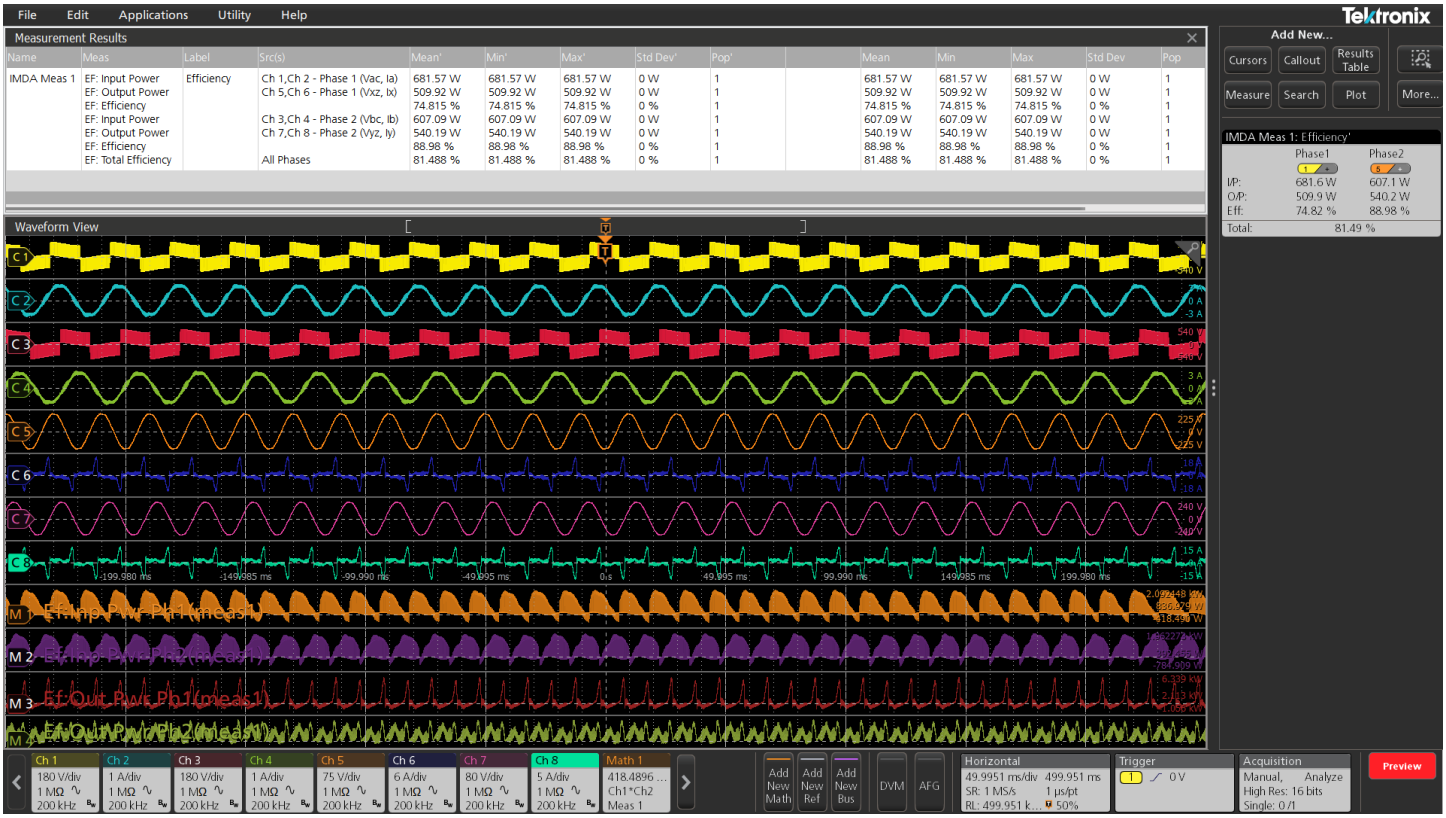
Efficiency measures the ratio of the output power to input power for respective input and output V and I pairs. By using the 2V2I method, three-phase efficiency may be measured using eight oscilloscope channels (2 Voltage and 2 Current sources on the input side and 2 Voltage and 2 Current sources on the output side). The solution calculates efficiency at each phase and the total (average) efficiency of the system.



Configure wiring and filters to perform efficiency measurements for an Industrial motor



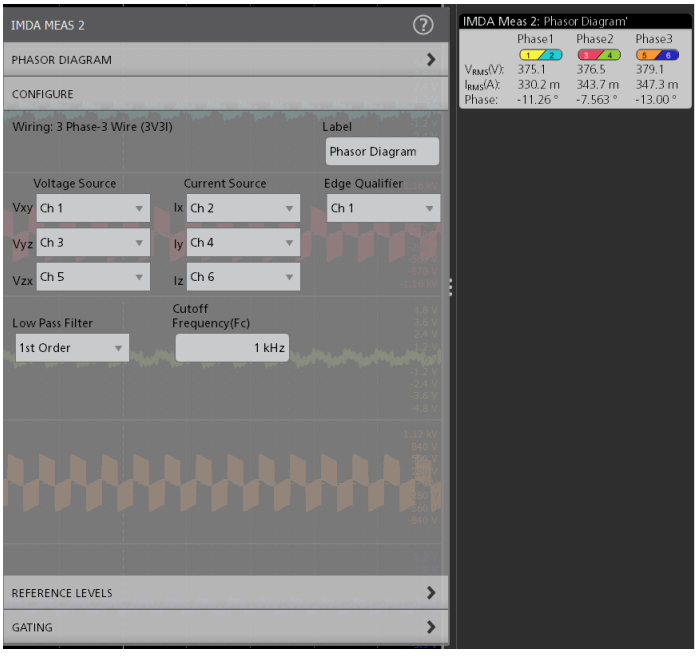
Configure wiring and filters to perform efficiency measurements for a DC-AC topology



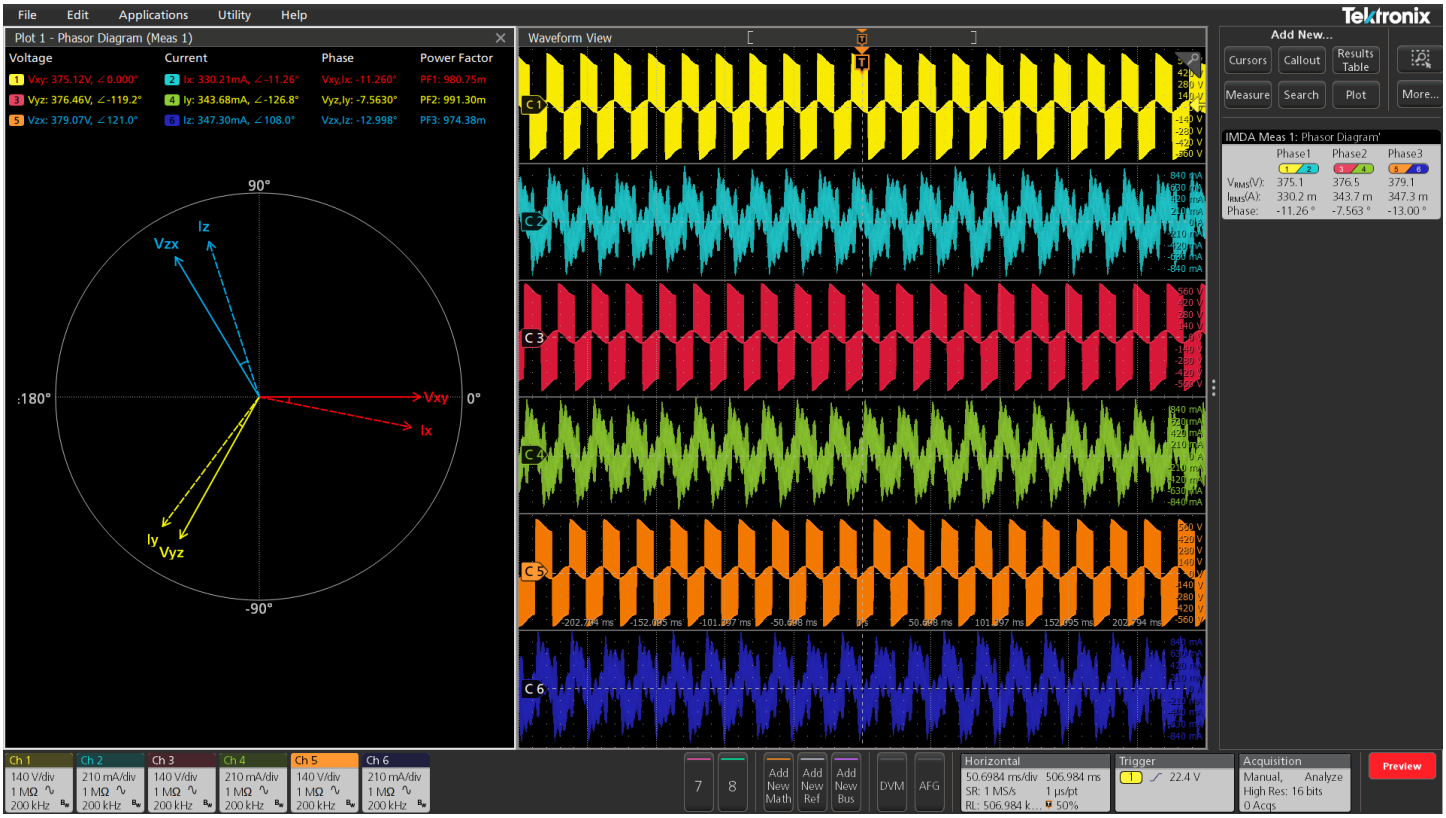
Get complete insight into the overall system efficiency

Phasor diagram

The measurement displays the magnitude and phase angle between Voltage(V) and Current(I) vectors in a phasor plot. The V and I vectors depend on the wiring configuration.



Easily configure the voltage and current inputs to display phasor diagrams



Unique scope based phasor diagram feature provides the relation between the voltage and current vectors

Ripple analysis

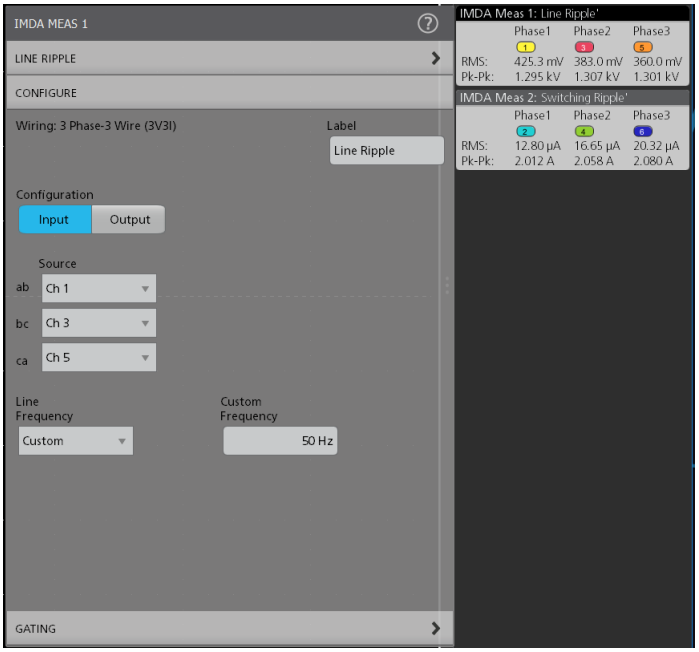
Ripple is defined as the residual AC voltage on a constant DC component (offset). Typically, the ripple component is often small in magnitude relative to the DC component.

The solution measures two types of ripple:

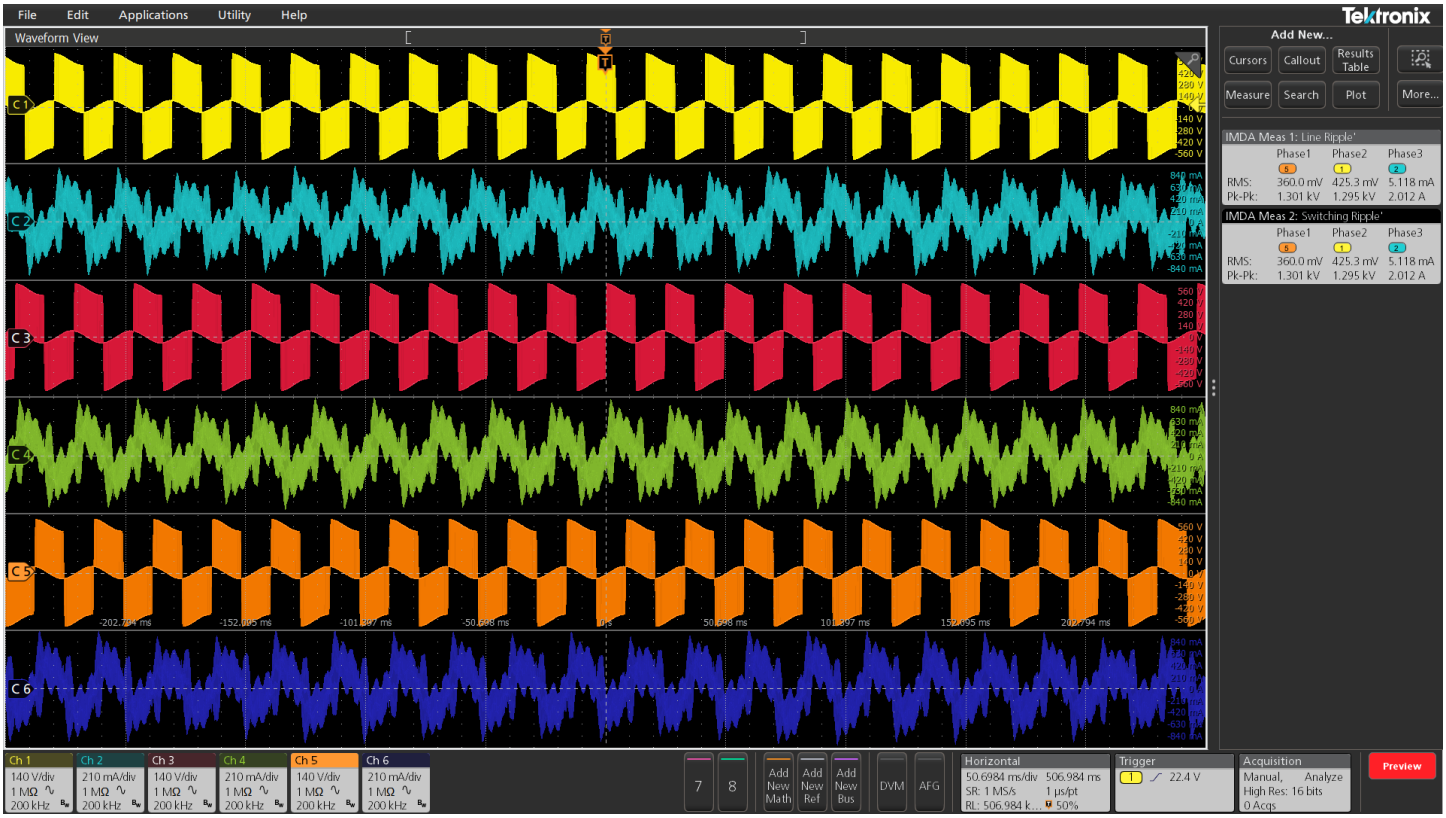
- Line ripple
- Switching ripple

Line ripple: The line ripple measures the RMS at the configured line ripple frequency and the peak-to-peak value of the time domain waveform for the configured phases.

Switching ripple: The switching ripple measures the RMS at the configured switching ripple frequency and the peak to peak value of the time domain waveform for the configured phases.



Ripple analysis configuration can be set to look into line and switching ripple



Detailed ripple analysis being carried out on all three-phases

Report generation

The 5-IMDA software simplifies data collection, archiving, documentation of your design, and development process. It supports the report generation in MHT, PDF or CSV formats with pass/fail results for easy analysis.

Measurement Report Tektronix

Monday February 3 2020 10:54:56

Setup Configuration

Scope Details			
Scope Model Number	**Scope Serial Number**	**TekScope Version**	**Scope Calibration Status**
MSO58	Q100118	1.24.6	Pass

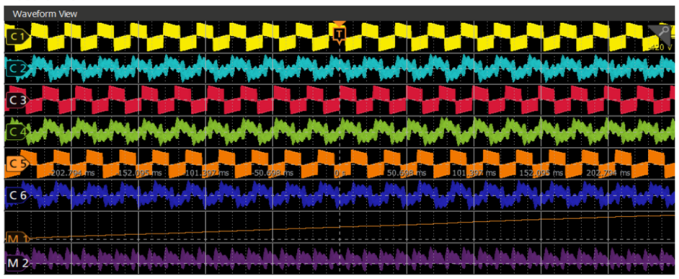
IMDA High Level Configuration

Measurement Type	Wiring	Connection	L-L to L-N
Industrial	3 Phase-3 Wire (3V3I)	Line-to- Line	False

Name	Measurement	Src(s)	Mean'	Min'	Max'	Pk-Pk'	Std Dev'	Population'	Accum Mean	Accum Min	Accum Max	Accum Pk-Pk	Accum Std Dev	Accum Pop
IMDA Meas 1 - Power Quality	VRMS	Ch 1,Ch 2 - Phase 1 (Vab, Ia)	375.12 V	375.12 V	375.12 V	0.0000 V	0.0000 V	1	375.12 V	375.12 V	375.12 V	0.0000 V	0.0000 V	1
	IRMS		330.21 mA	330.21 mA	330.21 mA	0.0000 A	0.0000 A	1	330.21 mA	330.21 mA	330.21 mA	0.0000 A	0.0000 A	1
	Voltage Crest Factor		1.7386	1.7386	1.7386	0.0000	0.0000	1	1.7386	1.7386	1.7386	0.0000	0.0000	1
	Current Crest Factor		3.0543	3.0543	3.0543	0.0000	0.0000	1	3.0543	3.0543	3.0543	0.0000	0.0000	1
	True Power		83.258 W	83.258 W	83.258 W	0.0000 W	0.0000 W	1	83.258 W	83.258 W	83.258 W	0.0000 W	0.0000 W	1
	Reactive Power		-91.713 VAR	-91.713 VAR	-91.713 VAR	0.0000 VAR	0.0000 VAR	1	-91.713 VAR	-91.713 VAR	-91.713 VAR	0.0000 VAR	0.0000 VAR	1
	Apparent Power		123.87 VA	123.87 VA	123.87 VA	0.0000 VA	0.0000 VA	1	123.87 VA	123.87 VA	123.87 VA	0.0000 VA	0.0000 VA	1
	Power Factor		980.75 m	980.75 m	980.75 m	0.0000	0.0000	1	980.75 m	980.75 m	980.75 m	0.0000	0.0000	1
	Phase Angle		-11.260 Degrees	-11.260 Degrees	-11.260 Degrees	0.0000 Degrees	0.0000 Degrees	1	-11.260 Degrees	-11.260 Degrees	-11.260 Degrees	0.0000 Degrees	0.0000 Degrees	1
	V Phase		0.0000 Degrees	0.0000 Degrees	0.0000 Degrees	0.0000 Degrees	0.0000 Degrees	1	0.0000 Degrees	0.0000 Degrees	0.0000 Degrees	0.0000 Degrees	0.0000 Degrees	1
	I Phase		-11.260 Degrees	-11.260 Degrees	-11.260 Degrees	0.0000 Degrees	0.0000 Degrees	1	-11.260 Degrees	-11.260 Degrees	-11.260 Degrees	0.0000 Degrees	0.0000 Degrees	1

Views

Time Domain View



Global Configuration

Gating	Jitter Separation Model	Dual Dirac Model	Display Unit Type	Standard Reference Levels	Jitter Reference Levels	Lock RJ
None	SpectralOnly	PCIExpress	Seconds	Every Acquisition	First Acquisition	false

Reference Levels Configuration

Ref Levels	Ch1, Ch2, Ch3, Ch4, Ch5, Ch6
Ref Level Type	Global
Base Top Method	MinMax
RiseHigh	90%
RiseMid	50%
RiseLow	10%
FallHigh	90%
FallMid	50%
FallLow	10%
Hysteresis	10%

A sample IMDA test report file with summary, details, and corresponding images

Specifications

Wiring Configuration	1V1I (1-Phase-2Wire), 2V2I (1 Phase - 3 Wire), 2V2I (3 Phase - 3 Wire), 3V3I (3-Phase-3Wire), and 3P4W (3-Phase-4Wire)
L-L to L-N Conversion	Applicable for 3 Phase-3 Wire (3V3I) [1]
Input Analysis	Power Quality, Harmonics [2], Input Voltage, Input Current and Input Power
Ripple Analysis	Line ripple, Switching ripple (for Industrial), and Ripple (for Automotive)
Output Analysis	Efficiency [3], Phasor Diagram
Three-phase Autoset	For all measurements
Plots	Phasor diagram and harmonics bar graph [4]
Report	MHT and PDF format, Data export to CSV format
Degauss/Deskew (static)	Automatic detection of probes, Auto Zero. User can deskew voltage and current probes, degauss the current probe from the menus for each channel
Source support	Live analog signals, reference waveforms, and math waveforms

1 For 3 Phase-4 Wire (3V3I) the connection is always Line to Neutral and for 3 Phase-3 Wire (2V2I), it is Line to Line.

2 Supports Custom limits

3 For 2V2I wiring

4 Range filter as part of measurement configuration.

Ordering information

Models

Product	Options	Supported instruments	Bandwidth available
New instrument order option	5-IMDA	5 Series MSO (MSO56, MSO58)	• 350 MHz • 500 MHz • 1 GHz • 2 GHz
Product upgrade option	SUP5-IMDA	5 Series MSO (MSO56, MSO58)	
Floating license	SUP5-IMDA-FL	5 Series MSO (MSO56, MSO58)	

Recommended probes

Probe model	Description	Quantity
TCP0030A	Current Probes	3 for 3V3I wiring [5]
THDP0200 or TMDP0200	High Voltage Differential Probes	3 for 3V3I wiring [5]

Tektronix is registered to ISO 9001 and ISO 14001 by SRI Quality System Registrar.

Product(s) complies with IEEE Standard 488.1-1987, RS-232-C, and with Tektronix Standard Codes and Formats.

Product Area Assessed: The planning, design/development and manufacture of electronic Test and Measurement instruments.

5 For performing efficiency measurement, four quantities are required.

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For Further Information. Tektronix maintains a comprehensive, constantly expanding collection of application notes, technical briefs and other resources to help engineers working on the cutting edge of technology. Please visit www.tek.com.

21 Apr 2020 48W-61649-1