Tektronix

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3-Phase Power Analysis

4 Series MSO Option 4-3PHASE Application Datasheet

The 4 Series MSO is available with up to 6 analog channels, making it well-suited for 3-phase power measurements. This three-phase analysis option (4-3PHASE) enables the 4 Series MSO to set up and perform the calculations needed to make key 3-phase power system measurements such as total power, harmonic distortion and phase parameters. The analysis package is ideal for design validation with flexible measurement trending and automatic reporting. Power converters often use Pulse Width Modulation (PWM) which complicates measurements since it is difficult to lock onto cycles. The analysis option includes filtering that provides stable measurements on PWM waveforms, while still providing the signal detail of a fast-sampling oscilloscope. Support for DC to three-phase AC converters make this package ideal for use in analyzing electric vehicle systems. Measurements are controlled using the 4 Series MSO's intuitive touch interface. 12-bit ADC's (up to 16- bit resolution in High Res mode) deliver accurate measurements and the three-phase power analysis software helps make measurements easier and repeatable.

Key features and specifications

- Quickly add and configure measurements through the intuitive drag and drop interface on the 4 Series MSO
- Accurately analyze three-phase PWM signals. A filtered PWM waveform is automatically calculated and may be displayed for reference
- Three-phase autoset automatically configures the oscilloscope for optimal horizontal, vertical, trigger, and acquisition parameters for acquiring three-phase signals
- Quickly perform common three-phase power measurements such as true, apparent and reactive power, and power factor
- Phasor diagrams indicate voltage and current phase relationships at a glance, as well as rms values and magnitudes at the fundamental frequency
- Measure three-phase harmonics to IEC 6100-3-2, IEEE-519, or custom limits
- Get mean, min, max, and standard deviations of key power measurement per acquisition or over many acquisitions
- Plot measurements over time trend within one acquisition or over multiple acquisitions
- Easily switch between line-to-line and line-to-neutral readings
- Automatically generate reports in MHT or PDF formats

Measurement overview

The three-phase analysis on the 4 Series MSO automates key electrical measurements which are grouped into the Electrical Analysis group. The measurements can be configured to measure the Input or Output wiring configuration.

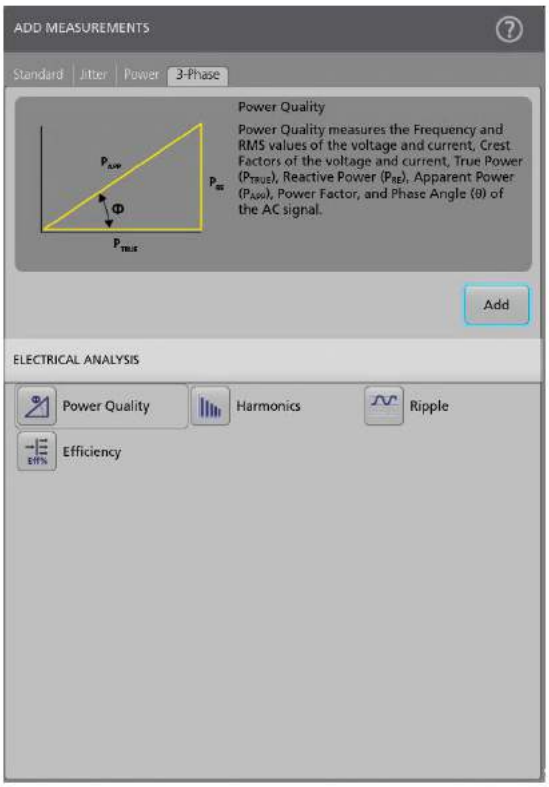


Figure 1: Three-phase analysis package on the 4 Series MSO

The measurements can be set to measure 1V1I (1-Phase-2-Wire), 2V2I (1-Phase-3-Wire), 2V2I (3-Phase-3-Wire), 1V1I (1-Phase-2-Wire DC), 3V3I (3-Phase-3-Wire), and 3V3I (3-Phase-4-Wire) to support various wiring configurations. Measurements can be performed line-to-line or line-to-neutral, to support delta or wye (star) configurations.

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

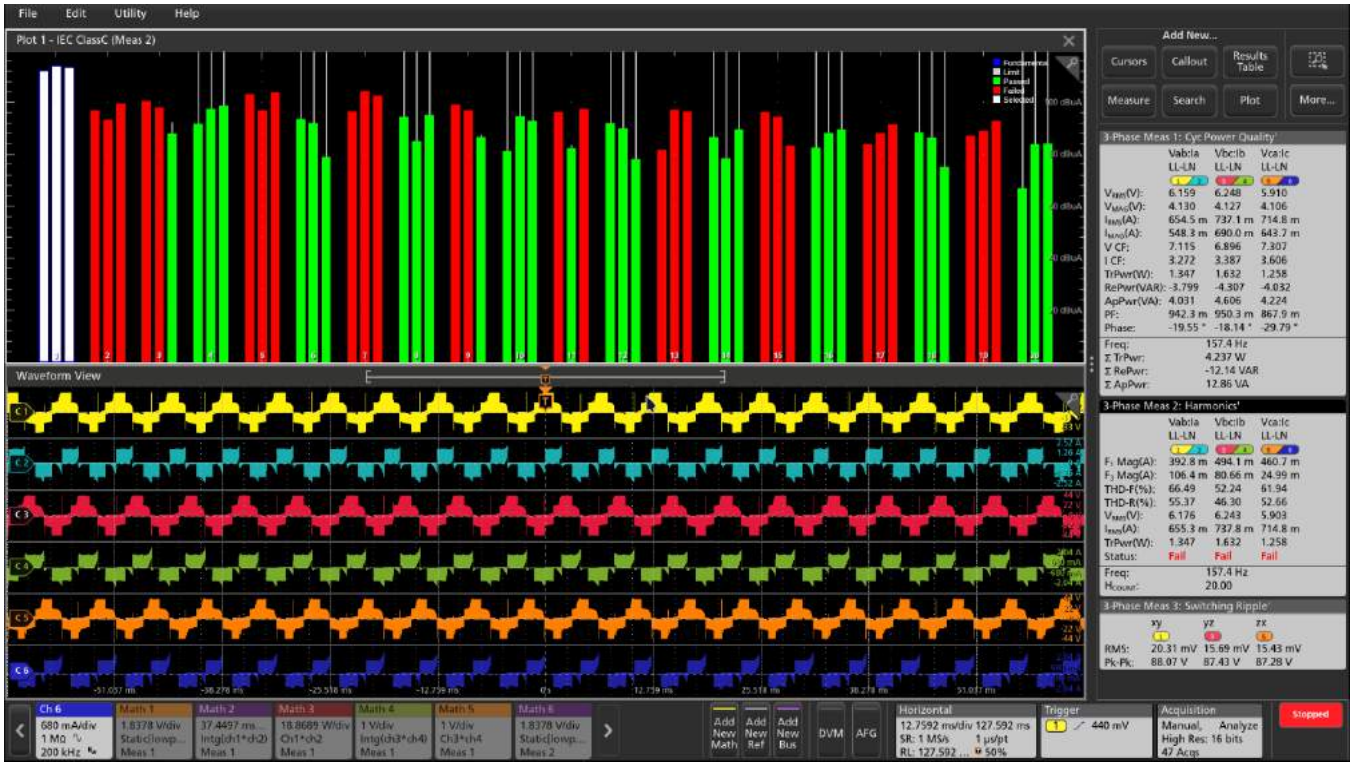


Figure 2: The harmonics plot indicates passing harmonics test results. Each set of bars contains results for phase A, B, and C for easy correlation. The set of green bars indicate a pass and the red bars indicate failure

The harmonics plot shows the test results for all three phases grouped so one can easily compare results among phases. For quick insight, harmonics bars are highlighted in green during a pass condition, and turn red when limits are exceeded.

Power quality

This measurement provides critical three-phase power measurements including

- Frequency and RMS magnitudes of voltage and current
- Crest factors of voltage and current
- PWM frequency
- Phase angle for each phase

It also displays the sum of true power, the sum of reactive power, and the sum of apparent power components.

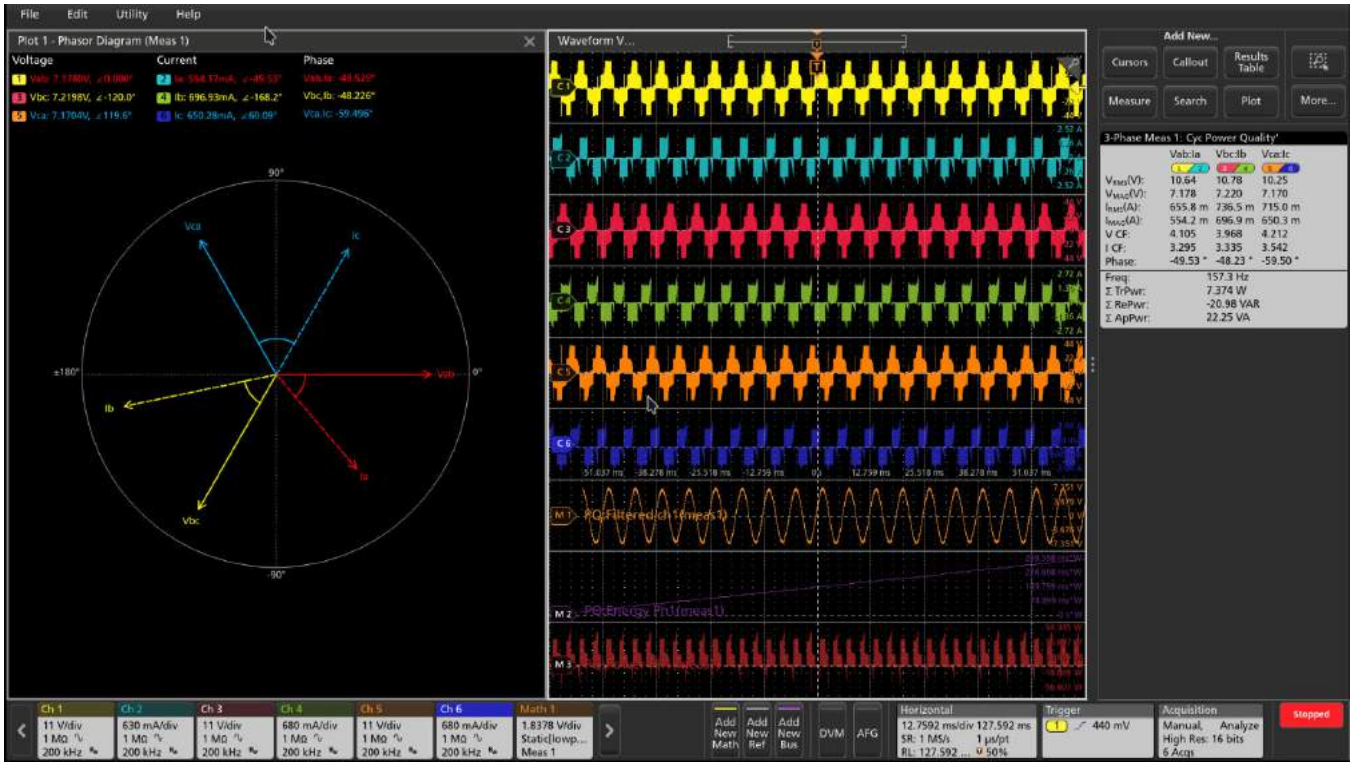
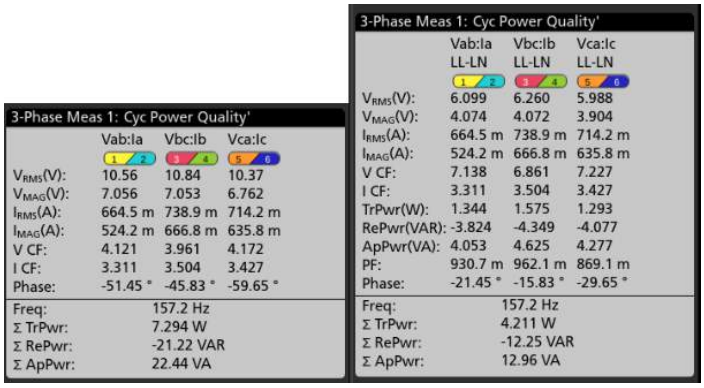


Figure 3: The power quality measurement provides an in-depth insight into the three-phase signals with a oscilloscope-based phasor diagram

In addition, in the Line-Neutral configuration, this measurement displays True power, Reactive power, and Apparent power components of all three-phases. Voltage and current vectors are displayed on a phasor diagram so you can quickly judge the phase shift for each phase and the balance among phases. Each vector is represented by an RMS value and the phase is computed using the Discrete Fourier Transform (DFT) method.

Figure 4: Configure Power quality measurement as Input or Output. Optionally convert Line-Line to Line-Neutral configuration mathematically without physical connection changes.



3-Phase Meas 1: Cyc Power Quality'

	Vab:Ia	Vbc:Ib	Vca:Ic
	1 / 2	3 / 4	5 / 6
V_{RMS}(V):	10.56	10.84	10.37
V_{MAG}(V):	7.056	7.053	6.762
I_{RMS}(A):	664.5 m	738.9 m	714.2 m
I_{MAG}(A):	524.2 m	666.8 m	635.8 m
V CF:	4.121	3.961	4.172
I CF:	3.311	3.504	3.427
Phase:	-51.45 °	-45.83 °	-59.65 °
Freq:	157.2 Hz		
Σ TrPwr:	7.294 W		
Σ RePwr:	-21.22 VAR		
Σ ApPwr:	22.44 VA		

3-Phase Meas 1: Cyc Power Quality'

	Vab:Ia LL-LN	Vbc:Ib LL-LN	Vca:Ic LL-LN
	1 / 2	3 / 4	5 / 6
V_{RMS}(V):	6.099	6.260	5.988
V_{MAG}(V):	4.074	4.072	3.904
I_{RMS}(A):	664.5 m	738.9 m	714.2 m
I_{MAG}(A):	524.2 m	666.8 m	635.8 m
V CF:	7.138	6.861	7.227
I CF:	3.311	3.504	3.427
TrPwr(W):	1.344	1.575	1.293
RePwr(VAR):	-3.824	-4.349	-4.077
ApPwr(VA):	4.053	4.625	4.277
PF:	930.7 m	962.1 m	869.1 m
Phase:	-21.45 °	-15.83 °	-29.65 °
Freq:	157.2 Hz		
Σ TrPwr:	4.211 W		
Σ RePwr:	-12.25 VAR		
Σ ApPwr:	12.96 VA		

Figure 5: Power quality test results in Line-Line mode (left) and in the Line-Neutral mode (right)

Efficiency

Efficiency measures the ratio of the output power to input power (DC-in AC-out, 2V2I configuration, and 1V1I industrial configuration). The efficiency measurement leverages all 6-channels of the 4 Series MSO and computes the overall system efficiency (1 voltage and 1 current source on the input side, and 2 voltage and 2 current sources on the output side).

Ripple analysis

Ripple is residual or unwanted AC voltage on a DC power supply. In a three-phase converter system, it is typically measured on the DC bus. This measurement helps to understand how efficiently the signal is getting converted from AC-DC on the input side, and the impact of unwanted components on the PWM signal on the output side.

Dynamic measurements using Trend analysis

A common requirement in three-phase analysis is the need to look at the system response over longer test times to monitor the DUT behavior over varying load conditions. Trends provide insight into interdependency between different parameters like voltage, current, power, frequency, and their variance based on the load conditions.

Figure 6: The Time trend and Acq trend plots on the Power quality measurement enables monitoring parameters over longer records.

Three-phase solution offers two unique trend plots on the power quality measurement to support such requirements – TimeTrend and Acq Trend plots. Each plot has its advantages and can be used to plot any of the power quality measurements. The Time Trend plot shows the measured value per cycle, or for an acquired waveform (a record), while the Acq Trend plot shows a mean of the measured value per record, over multiple acquisitions. The acquisition count is set by the user during the test configuration. This allows users to capture long records of data to perform deep record analysis and understand the dynamic behavior of the system response. The plots can be saved as a CSV file for offline analysis.

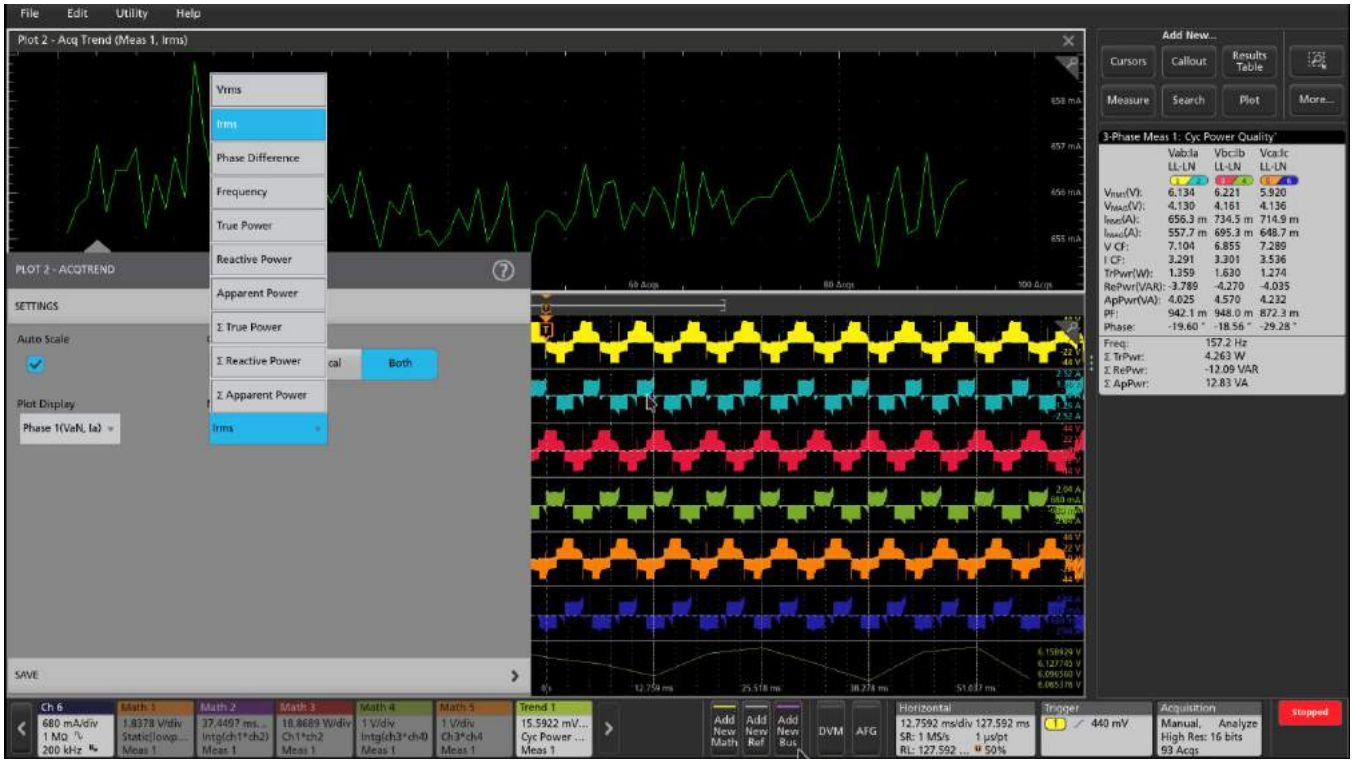
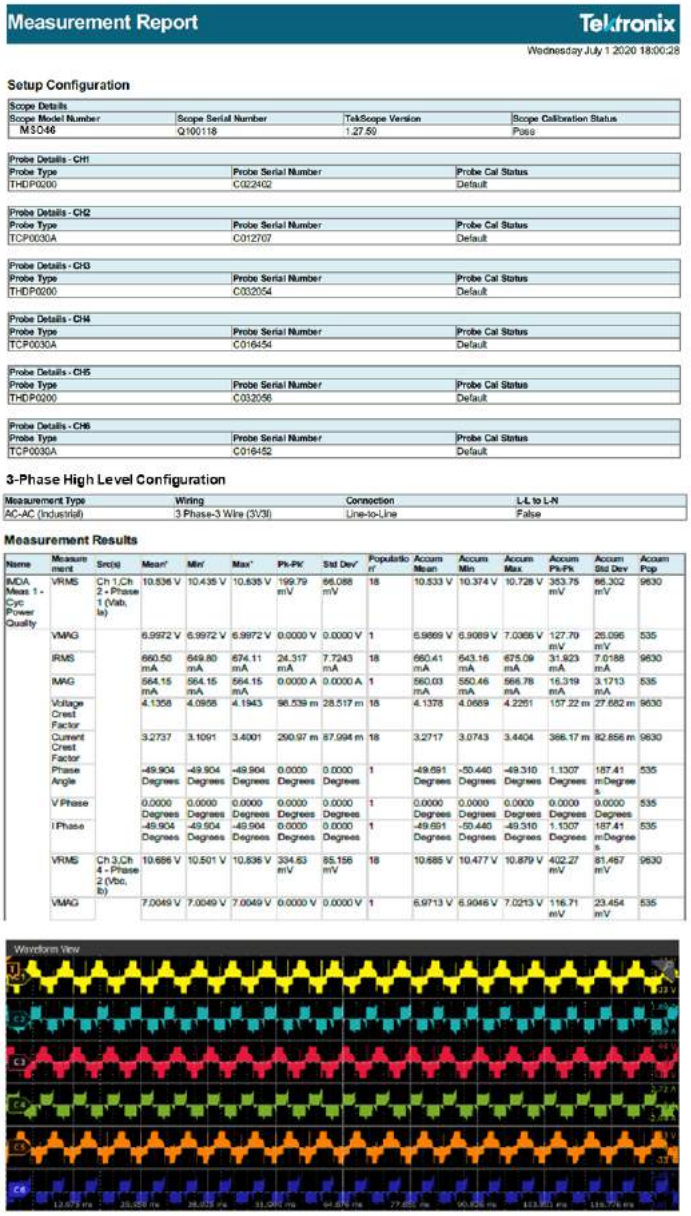


Figure 7: The Acq Trend plot enables user to monitor system behaviour over long records. Choose from a range of parameters of the Power quality measurement to plot the trend data. The Acq Trend of Irms plotted over 93 acquisitions is shown in green.

Report generation

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



Measurement Report — Tektronix

Wednesday July 1 2020 18:00:28

Setup Configuration

Scope Details			
Scope Model Number	Scope Serial Number	TekScope Version	Scope Calibration Status
MSO46	Q100118	1.27.59	Pass

Probe Details - CH1		
Probe Type	Probe Serial Number	Probe Cal Status
THDP0200	C022402	Default

Probe Details - CH2		
Probe Type	Probe Serial Number	Probe Cal Status
TCP0030A	C012707	Default

Probe Details - CH3		
Probe Type	Probe Serial Number	Probe Cal Status
THDP0200	C032054	Default

Probe Details - CH4		
Probe Type	Probe Serial Number	Probe Cal Status
TCP0030A	C016454	Default

Probe Details - CH5		
Probe Type	Probe Serial Number	Probe Cal Status
THDP0200	C032056	Default

Probe Details - CH6		
Probe Type	Probe Serial Number	Probe Cal Status
TCP0030A	C016452	Default

3-Phase High Level Configuration

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

Measurement Results

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 - Cyc Power Quality	VRMS	Ch 1,Ch 2 - Phase 1 (Vab, Ia)	10.836 V	10.435 V	10.835 V	199.79 mV	66.088 mV	18	10.533 V	10.374 V	10.728 V	353.75 mV	86.302 mV	9630
	VMAG		6.9972 V	6.9972 V	6.9972 V	0.0000 V	0.0000 V	1	6.9869 V	6.9089 V	7.0366 V	127.79 mV	26.096 mV	535
	IRMS		660.50 mA	649.80 mA	674.11 mA	24.317 mA	7.7243 mA	18	660.41 mA	643.16 mA	675.09 mA	31.923 mA	7.0188 mA	9630
	IMAG		564.15 mA	564.15 mA	564.15 mA	0.0000 A	0.0000 A	1	560.03 mA	560.46 mA	566.78 mA	16.319 mA	3.1713 mA	535
	Voltage Crest Factor		4.1358	4.0958	4.1943	98.539 m	28.517 m	18	4.1378	4.0689	4.2251	157.22 m	27.682 m	9630
	Current Crest Factor		3.2737	3.1091	3.4001	290.97 m	87.994 m	18	3.2717	3.0743	3.4404	366.17 m	82.856 m	9630
	Phase Angle		-49.904 Degrees	-49.904 Degrees	-49.904 Degrees	0.0000 Degrees	0.0000 Degrees	1	-49.691 Degrees	-50.440 Degrees	-49.310 Degrees	1.1307 Degrees	187.41 mDegrees	535
	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	535
	I Phase		-49.904 Degrees	-49.904 Degrees	-49.904 Degrees	0.0000 Degrees	0.0000 Degrees	1	-49.691 Degrees	-50.440 Degrees	-49.310 Degrees	1.1307 Degrees	187.41 mDegrees	535
	VRMS	Ch 3,Ch 4 - Phase 2 (Vbc, Ib)	10.686 V	10.501 V	10.836 V	334.63 mV	85.156 mV	18	10.685 V	10.477 V	10.879 V	402.27 mV	81.467 mV	9630
	VMAG		7.0049 V	7.0049 V	7.0049 V	0.0000 V	0.0000 V	1	6.9713 V	6.9046 V	7.0213 V	116.71 mV	23.454 mV	535

Figure 8: A sample three-phase test report with setup details, test summary, test results, and images

Specifications

Wiring configuration	1V1I (1-Phase-2-Wire), 2V2I (1-Phase-3-Wire), 2V2I (3-Phase-3-Wire), 3V3I (3-Phase-3-Wire), and 3P4W (3-Phase-4-Wire)
L-L to L-N conversion	Applicable for 3-Phase-3-Wire (3V3I)[1]
Electrical analysis	Power quality, Harmonics[2], Ripple, Efficiency[3]
Three-phase autoset	For all measurements
Plots	Phasor diagram, Time Trend, Acq Trend, 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 test limits.
3 Efficiency is supported on specific wiring configuration only.
4 Range filter as part of measurement configuration.

Ordering information

Models

Product	Options	Supported instruments	Bandwidth available
New instrument order option	4-3PHASE	4 Series MSO (MSO46)	200 MHz, 350 MHz, 500 MHz, 1 GHz or 1.5 GHz
Product upgrade option	SUP4-3PHASE		
Floating license	SUP4-3PHASE-FL		

Software bundles

Bundle options	Supported instruments[5]	Description
4-PRO-POWER-1Y	4 Series MSO	1 Year Pro Power Bundle for 4 Series MSO
4-PRO-POWER-PER	4 Series MSO	Perpetual License Pro Power Bundle for 4 Series MSO
4-PRO-AUTO-1Y	4 Series MSO	1 Year Pro Automotive Bundle for 4 Series MSO
4-PRO-AUTO-PER	4 Series MSO	Perpetual License Pro Automotive Bundle for 4 Series MSO
4-ULTIMATE-PER	4 Series MSO	Perpetual License Ultimate Bundle for 4 Series MSO

Recommended probes

Probe model	Description	Quantity
TCP0030A	Current probes	3 for 3V3I wiring
THDP0200 or TMDP0200	High voltage differential probes	3 for 3V3I wiring

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] 3-Phase Power Analysis requires a 6 channel instrument.