3-Phase Power Analyzer

Oscilloscope Advanced Applications

User Manual

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1 Product Introduction

> **Document version**: 1.0.3 **Software version**: 00.01.00.01.05 **Application name**: 3-Phase Power Analyzer **Runtime environments**: Electron host (PC) mode / Offline mode **Last updated**: 2026-07-22

> **About hardware model information**: For the detailed specifications (bandwidth, sample rate, memory depth, voltage/current ranges, CAT rating, attenuation ratio, etc.) of the RIGOL oscilloscope models (DHO5000 / MHO5000 series) and probe models (PHA0150, PHA1150B, PHA2150B, PCA1030, PCA1150, PCA1500, PCA2030, PCA3030, PCA3031, RP1025D, RP1050D, RP1100D) mentioned in this guide, always refer to the **official RIGOL datasheets**. This guide provides selection recommendations and application mapping only.

1.1 Challenges of Three-Phase Power Measurement

Three-phase power systems are the backbone of modern industry — from grid distribution to motor drives, from PV inverters to energy-storage PCS, from EV chargers to data-center UPS. Accurate measurement and analysis of three-phase power involves a level of complexity far beyond single-phase measurement:

- **Multi-channel synchronization**: 6-channel (3V3I) synchronous acquisition requires the oscilloscope to digitize all voltage and current channels under the same sample clock. Any inter-channel time skew contaminates power factor, reactive power, harmonic phase and other calculations.
- **Diverse wiring topologies**: 3P4W (three-phase four-wire), 3P3W (three-phase three-wire two-wattmeter method), Delta, 1P2W (single-phase), DC and other wiring methods correspond to completely different channel role definitions and power-calculation paths — choosing the wrong wiring makes every result physically meaningless.
- **Phase-relationship sensitivity**: The core of a three-phase system is the 120° phase relationship. Incorrect phase sequence, mismatched V/I pairing, or uncalibrated deskew will distort the phasor diagram, PF, and per-phase P/Q/S results.
- **Multiple compliance frameworks**: IEEE 519, IEC 61000-3-2, GB/T 14549, EN 50160, DIN 40160, MIL-STD-1399, RTCA DO-160 and others use different scopes, limits and assessment methods. Engineers need a reliable way to perform pre-compliance checks during development.

1.2 Positioning of the 3-Phase Power Analyzer

The **3-Phase Power Analyzer** is a professional analysis application from RIGOL targeting three-phase power systems. It integrates the core functions of a traditional three-phase power analyzer — three-phase power quality, harmonic compliance, efficiency calculation and ripple spectrum — onto the oscilloscope platform. Combined with RIGOL high-voltage differential probes and current probes, engineers can perform a comprehensive evaluation of three-phase power systems without a dedicated power analyzer.

Core design philosophy: free engineers from manual phasor calculations, repeated standard lookups and results assembled across multiple instruments, so they can focus on what the measurements mean and how to improve the design.

1.3 Core Capabilities

Analysis domain	Sub-functions
Power Quality (PQ)	VRMS/IRMS, Vmag/Imag, simultaneous Fundamental/Wideband P/Q/S/PF, φ(I–V), Freq, VCF/ICF crest factor, three-phase summary, unbalance analysis (symmetrical components), phasor diagram, six-channel waveform display, Wh/VARh energy accumulation
Harmonics (HA)	DFT/FFT up to the 400th harmonic, THD-F, THD-R, TDD (IEEE 519), bar chart with limit lines, automatic Pass/Fail, CSV custom limit import, harmonic trend
Efficiency (EF)	Independent input/output wiring and channel mapping, ΣPin, ΣPout, η = ΣPout/ΣPin × 100%, Ploss, independent input/output power calculation, trend chart
Ripple (RP)	Line ripple, switching ripple, Vrms/Irms, VN-N/IN-N peak-to-peak, FFT spectrum with peak annotation, dominant frequency / dominant amplitude
Common support	Device search/connection, 7 standard wiring methods, shared measurement configuration, deskew V-V/V-I calibration, report export (HTML/CSV), offline waveform import, trend and statistics

1.4 Typical Application Scenarios

- **Three-phase inverters, VFDs, motor drives**: input/output power measurement, efficiency evaluation, harmonic analysis.
- **PV inverters, energy-storage PCS, EV chargers**: AC/DC conversion efficiency, grid-tie harmonic pre-compliance, DC-bus ripple.
- **Industrial grids or lab three-phase supply systems**: power-quality troubleshooting, unbalance analysis, fundamental-frequency monitoring.
- **DC buses and switching-supply outputs**: separating line ripple from switching ripple, locating dominant spectral peaks.
- **Pre-compliance checks before certification**: run desktop pre-compliance on the oscilloscope before sending to a certification lab, solving problems at the board level.

1.5 Run Modes

Mode	Description	Typical use
Host (PC) mode	The app runs in an Electron environment and connects to the scope remotely over LAN	Remote control, shared instruments, automated testing
Offline mode	Import waveform files into Memory channels and run pure algorithmic analysis	Review, demo, algorithm validation, cross-team collaboration

1.6 Channel Role Requirements

Capability	Channel count	Description
Single-phase or DC measurement	2 channels	1 voltage + 1 current
Single-phase three-wire or three-phase three-wire 2V2I	4 channels	2 voltage + 2 current, two-wattmeter method
Three-phase 3V3I measurement	6 channels	3 voltage + 3 current, three-wattmeter method
Single-channel ripple measurement	1 channel	1 voltage ripple

> After connecting a real oscilloscope, the interface shows the channel count and sample rate reported by the device; when not connected, channel selection follows the default configuration.

1.7 Deployment Form

The 3-Phase Power Analyzer currently supports Electron host mode and offline mode. In host mode it connects to an oscilloscope remotely over LAN; in offline mode it analyzes imported waveform files.

2 Launching the Application

2.1 Launch Steps

1. Launch **3-Phase Power Analyzer** directly from the Windows **Start menu** or its **desktop shortcut**.
2. The app enters the main interface, showing the five-zone layout by default: Header + Left panel (device & navigation) + Center panel (measurement config) + Right panel (results) + Footer (status bar).
3. If you are in host mode, first connect to the target oscilloscope as described in §4.
4. Complete wiring selection and channel assignment as described in §6, then enter each analysis module.

2.2 Post-Launch State

Check item	Pass	On failure
Run-mode detection	Footer shows the run mode (host / offline)	Run mode is inferred from the current environment
Device capability read	Footer shows sample rate and channel count when connected	Shows "not connected" when no device

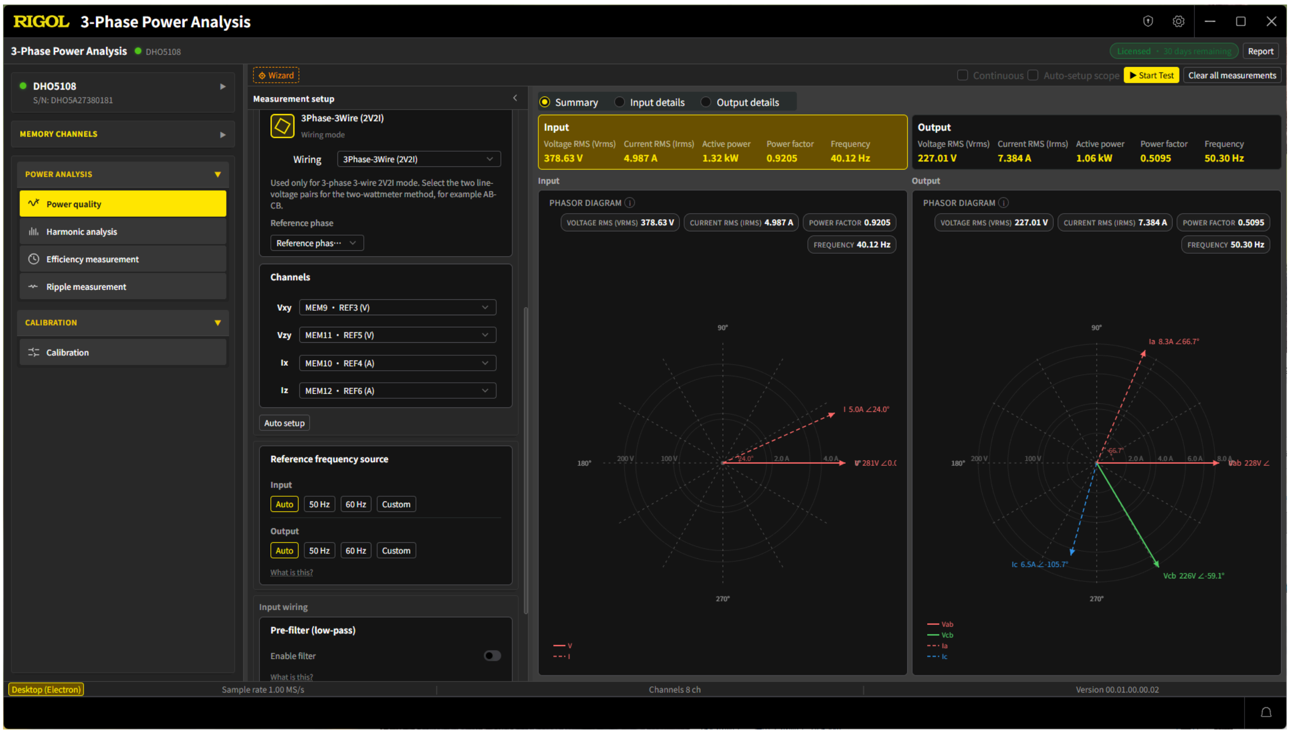
3 Main Interface Tour

3.1 Overall Layout

The main interface uses a five-zone workspace layout: **Header + Left + Center + Right + Footer**.

Zone	Function
Header	App title, connection-status indicator, Report (report export), Snapshot (debug snapshot), Settings
Left	Device Connection, Memory-channel management, Power Analysis (PQ / HA / EF / RP), and Utility (Deskew calibration and waveform preview)
Center	Shared measurement config card (Wiring + Channel Assignment, always visible) + the current module's dedicated config panel
Right	Waveform charts, phasor diagram, harmonic bar chart, FFT spectrum, result cards, statistics tables and trend views
Footer	Run-mode badge, sample rate, resolution, channel count, app version

Interface illustration

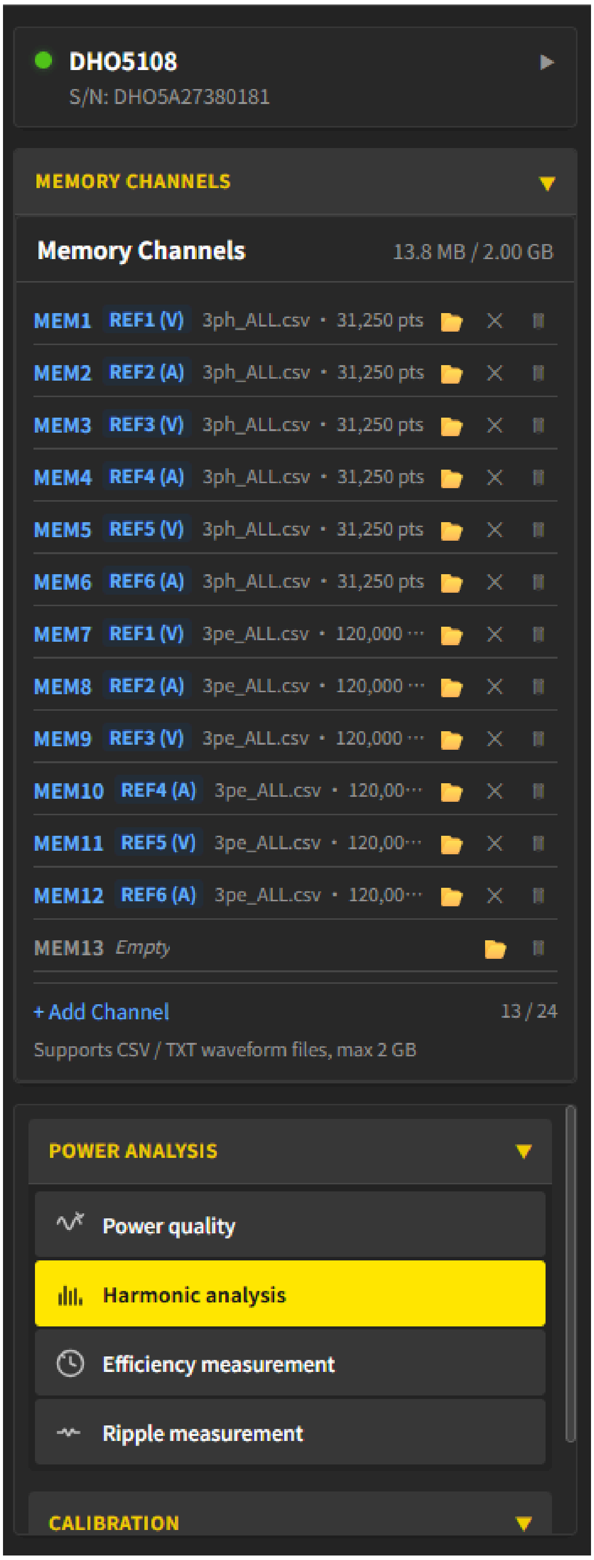


Main interface five-zone layout

3.2 Left Panel: Device and Modules

Element	Function
Device Connection	Select VISA address, scan devices, connect/disconnect, show device IDN
Memory channels	Import `.csv` / `.txt` / `.bin` waveform files as offline data sources
Power Quality (PQ)	Three-phase power quality analysis: RMS, simultaneous Fundamental/Wideband P/Q/S/PF, phasor, waveform, energy accumulation, unbalance
Harmonics (HA)	Harmonic analysis: THD/TDD, bar chart, compliance verdict, CSV standard import
Efficiency (EF)	Efficiency measurement: independent input/output configuration, total efficiency, power loss
Ripple (RP)	Ripple measurement: line/switching ripple, time-domain metrics, FFT spectrum

Interface illustration: left panel showing the device connection and Memory channel area expanded



Left panel: device connection and memory channels

3.3 Connection Status Indicators

State	Color	Meaning

Not connected	Gray	No device or no device selected
Connecting	Yellow	Establishing connection or retrying
Connected	Green	Device available, measurement allowed
Error	Red	Connection lost, device fault, or capability read failed

3.4 Common Structure of Analysis Panels

Each analysis panel typically contains the following elements:

Element	Description
Config card	The current module's wiring, channel assignment, standard selection, filter, frequency and other parameters
Start Analysis / Stop	Start one analysis or stop continuous analysis
Continuous	Toggle for continuous acquisition and statistics accumulation
Auto Setup	When checked, invoke the scope's auto-setup before starting analysis (online mode only)
Result card	Highlights key KPIs such as PF, THD, η, VN-N
Result table	Shows per-phase parameters, three-phase summary, statistics (Mean/Min/Max/Std/Cnt), Pass/Fail status
Chart area	Waveform chart, phasor diagram, harmonic bar chart, FFT spectrum, trend chart

3.5 Mouse Interaction

- **Waveform/chart**: drag → pan; scroll wheel → horizontal zoom.
- **Chart hover**: shows the instantaneous value, frequency or statistics summary at that data point.
- **Result-row click**: cross-highlights with the bar chart/waveform (harmonics, etc.).
- **Splitter drag**: adjust the width of the left panel (240–360 px), center panel (320–560 px) and right panel; double-click a splitter to restore the default size.

4 Instrument Connection and Offline Data

4.1 Online Mode: Connecting the Oscilloscope

4.1.1 Steps

1. Confirm that the oscilloscope is reachable via its VISA address (LAN or USB).
2. Select or scan for the device in **Device Connection** on the left panel:
    - Click Scan to launch background device discovery;
    - Status updates in real time: a green badge for RIGOL devices, gray for others or no response;
    - Select the target VISA address and click **Connect**.
3. On success, the header connection status turns green and the footer shows the device model, sample rate and channel count.

4.1.2 Connection Failure Handling

If the connection fails:

- Confirm the PC and oscilloscope are on the same subnet, or that the VISA driver is correctly installed;
- Disable the PC firewall or open ports 5025 / 111 / 5555;
- Ping the PC IP from the oscilloscope to verify bidirectional connectivity;
- Restart the oscilloscope's LAN service.

4.2 Offline Mode: Importing Waveform Files

Suitable for: on-site waveform review, remote collaboration, algorithm validation, demos and training.

4.2.1 Steps

1. Click the import button in the **Memory channels** area on the left panel.
2. Select a waveform file.

Supported formats:

Format	Extension	Description
RIGOL binary	`.bin`	RIGOL binary format
Generic CSV	`.csv`	Time-amplitude text
Generic text	`.txt`	Generic text format

3. For multi-channel files, assign file channels to Memory slots in the import dialog.
4. Map Memory channels to roles such as Va, Ia, Vb, Ib in the channel mapping.
5. Enter the PQ, HA, EF or RP module and click **Start Analysis** to run the analysis.

> When Memory channels are used, **Continuous** and **Auto Setup** are disabled — this is normal behavior for offline analysis.

5 Pre-Measurement Preparation

5.1 Safety Notes

- Confirm that the system voltage and current under test match the probe ratings.
- The CAT rating, bandwidth and range of differential voltage probes and current probes must meet the test conditions.
- Before connecting to three-phase power equipment, confirm the wiring diagram, phase sequence, grounding point and isolation method.
- When measuring high-voltage or high-current systems, follow lab safety practices and use compliant protective equipment.
- Three-phase systems may have multiple voltage reference points (neutral, ground, DC-bus negative, etc.); confirm the reference potential before wiring to avoid short circuits or ground loops.

5.2 Recommended Preparation Workflow

1. Choose voltage and current probes suited to the system under test (see Appendix D).
2. Connect the oscilloscope and confirm all channels have stable signals.
3. Select the module in the left panel, then choose the correct wiring in the center panel (see §6.1).
4. Complete the channel mapping and confirm the voltage/current roles match the physical connections.
5. Run Deskew in **Calibration** (see §12) to correct inter-channel time skew between voltage and current.
6. Check **Auto Setup** in the analysis toolbar if you want the scope to auto-set before analysis.
7. Click **Start Analysis** to begin.

5.3 Signal Quality Checks

Anomaly	Possible cause	Suggested action
Clipped waveform	Vertical scale too small, probe range insufficient	Increase range or change probe
No signal on a phase	Wiring error, probe not clamped, channel off	Check wiring and channel switch
Abnormal phase sequence	A/B/C channel mapping error	Adjust channel mapping, confirm with phasor diagram
Negative PF or power	Reversed current direction, V/I pairing error	Check current-probe arrow direction and channel pairing
Severe PF or three-phase power anomaly	Deskew not calibrated	Run deskew then re-measure
Unstable harmonic results	Insufficient acquisition length, fundamental detection failed	Increase record length or set line frequency manually

Efficiency > 100%	Channel mapping, probe ratio, power direction, or sign-convention error	Check configuration and waveform (see §9.6)

5.4 Preparation Items Specific to Three-Phase Measurement

- **Phase-sequence confirmation**: after connecting the three-phase system, use the phasor diagram to confirm the phase sequence (positive sequence should be A→B→C counterclockwise).
- **V/I pairing**: each phase's voltage and current channels must correspond to the same phase, otherwise PF and per-phase power are meaningless.
- **Unified reference potential**: when using multiple differential probes, ensure each probe's reference matches the defined potential under test.
- **Unbalance estimate**: before measurement, visually inspect the waveforms to judge whether the three-phase amplitudes are roughly similar; severe unbalance should first prompt a wiring check rather than an instrument check.

6 Shared Measurement Configuration

All analysis modules share one measurement configuration at the top of the center panel. PQ, HA, EF and RP share the wiring method and channel assignment; the EF module additionally provides independent Input Wiring and Output Wiring configuration.

6.1 Wiring Methods

The wiring method determines the number of channel roles and the power-calculation path. The app provides the following 7 standard wiring methods:

Wiring method	Short name	Default channel roles	Power-calc method	Typical use
3Phase-4Wire (3V3I)	3P4W	Va/Vb/Vc + Ia/Ib/Ic	Three-wattmeter	Three-phase four-wire systems (with neutral)
3Phase-3Wire (2V2I)	3P3W	Vab/Vbc + Ia/Ib	Two-wattmeter (Blondel's theorem)	Three-phase three-wire systems (no neutral)
3Phase-Delta (3V3I)	3V3A	Vab/Vbc/Vca + Ia/Ib/Ic	Three line-voltage/line-current synthesis	Delta-connected loads
1Phase-2Wire (1V1I)	1P2W	V + I	Single-phase power P = V × I × PF	Single-phase two-wire (input or output side)
1Phase-3Wire (2V2I)	1P3W	Va/Vb + Ia/Ib	Split-phase power synthesis	Single-phase three-wire systems
DC (1V1I)	DC	Vdc + Idc	P = V × I	DC bus or DC output
Single-channel ripple (V)	RP_1CH	V	Ripple analysis	Single-channel voltage ripple measurement

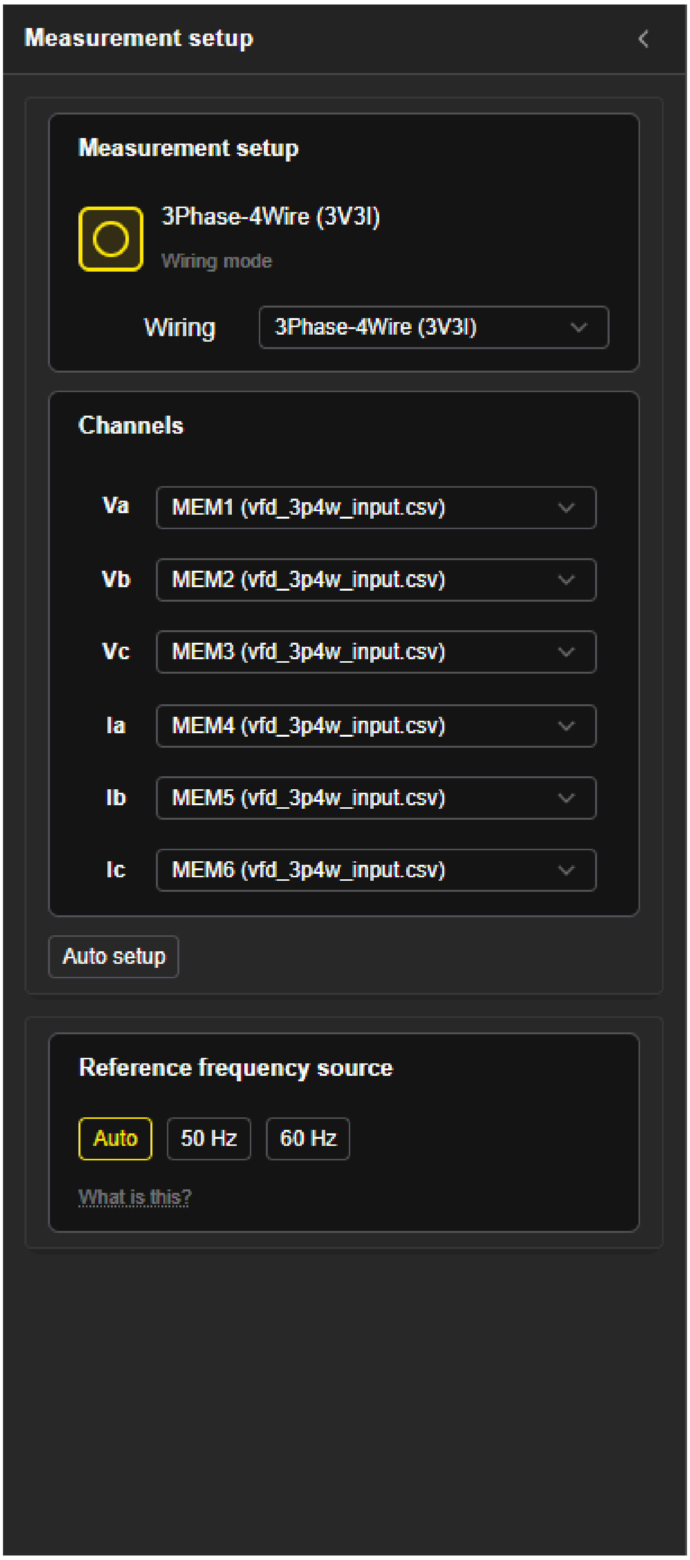
6.2 Channel Assignment

1. Choose the wiring method in **Wiring**.
2. In **Channel Assignment**, select a physical channel (CH1–CHn or MEM1–MEMn) for each voltage/current role.

3. Check whether the same channel is assigned more than once — duplicate assignment affects measurement results.
4. For three-phase three-wire or delta wiring, confirm whether the voltage labels are line voltage or phase voltage:
   - 3P3W uses two line voltages Vab, Vbc and two line currents Ia, Ib;
   - 3V3A uses three line voltages Vab, Vbc, Vca.

5. Save the configuration or continue with the current session configuration.

Interface illustration: center-panel shared measurement configuration (wiring + channel assignment)



Shared measurement config: wiring and channel assignment

6.3 Config-Card Auto Setup

Config-card **Auto Setup** rebuilds the default channel mapping for the selected wiring; toolbar **Auto Setup** configures the connected oscilloscope before **Start Analysis** and is unavailable with Memory channels.

7 Power Quality (PQ)

7.1 Background and Engineering Significance

Power Quality is the core module of three-phase power analysis, answering the most fundamental operating-state questions of a three-phase system:

- **How much power is supplied?** P (active), Q (reactive), S (apparent) per phase and for the three-phase total
- **What are the load characteristics?** PF (power factor), phase angle, crest factor
- **Is the three-phase balanced?** Unbalance ratio, negative-sequence component
- **Is the system frequency stable?** Fundamental-frequency monitoring
- **How much energy has been consumed?** Wh, VARh

Whether you evaluate grid supply quality, validate inverter output characteristics, or monitor the input state of a motor drive, the PQ module is the starting point of all three-phase analysis.

7.2 Measurement Principles

The current release displays active power, apparent power, reactive power and power factor together in each result cell, ordered as **Fundamental/Wideband**. Fundamental quantities use only the fundamental components; Wideband quantities use the complete acquired waveform in the analysis window and therefore include harmonics and waveform distortion.

Quantity	Formula/definition	Unit
True RMS	`Vrms = √mean(v²)`, `Irms = √mean(i²)`	V / A
Fundamental amplitude	Vmag/Imag, given by the FFT amplitude at the fundamental	V / A
Fundamental active power	`P1 = V1rms × I1rms × cos[ϕ(I-V)]`	W
Wideband active power	`Pwb = mean(v × i)`	W
Fundamental apparent power	`S1 = V1rms × I1rms`	VA
Wideband apparent power	`Swb = Vrms × Irms`	VA

Quantity	Formula/definition	Unit
Fundamental reactive power	`Q1 = -V1rms × I1rms × sin[ϕ(I-V)]`, signed	var
Wideband reactive power	Signed Wideband reactive result reported by the application, including harmonic and distortion effects	var
Fundamental power factor	`PF1 = P1 / S1 = cos[ϕ(I-V)]`	-1 to 1
Wideband power factor	`PFwb = Pwb / Swb`	-1 to 1
Crest factor	`CF = Peak / RMS`	—

> **Phase angle and reactive-power sign**: the UI defines `ϕ(I-V) = ϕI1 - ϕV1`. Fundamental reactive power must therefore be written as `Q1 = -V1rms × I1rms × sin[ϕ(I-V)]`; the unsigned `√(S²-P²)` cannot replace signed reactive power. The Wideband reactive-power sign follows the application's power-direction and phase convention.

7.3 Entering PQ

1. Click **Power Quality (PQ)** in the left panel.
2. Confirm the center-panel wiring method and channel mapping are correct.
3. Choose Auto, 50 Hz or 60 Hz in **Frequency Source**.
4. Check **Continuous** (continuous acquisition) or **Auto Setup** as needed.
5. Click **Start Analysis**.

7.4 Main Configuration Items

Config item	Description
Wiring	Choose the wiring method (3P4W / 3P3W / 3V3A / 1P2W / 1P3W / DC)
Channel Assignment	Choose CH or MEM channels for voltage/current roles
Frequency Source	Auto (extracted from the waveform) / 50 Hz / 60 Hz
Continuous	Continuous acquisition with statistics update
Auto Setup	Invoke the scope auto-setup before starting analysis

7.5 Interpreting Results

7.5.1 Per-Phase and Summary Parameters

In paired power results, the value before the slash is **Fundamental** and the value after the slash is **Wideband**. Read the result table as follows:

- **Paired values:** Active power, Apparent power, Reactive power and Power factor are shown as Fundamental/Wideband.
- **Single values:** Voltage RMS, Current RMS, Vmag/Imag, φ (I–V), Frequency and VCF/ICF each have one result.
- **Σ summary:** the system aggregation follows the selected wiring; not every item is a simple arithmetic sum of visible branches.
- **Other results:** Wh/VARh are resettable energy accumulations; Unbalance reports the ratio and negative-sequence component.

The following example shows the current AB, CB and Σ format, beginning with the paired power values:

Parameter	AB	CB	Σ
Active power Fundamental/Wideband	137.37 W/180.07 W	121.17 W/102.18 W	258.54 W/282.25 W
Apparent power Fundamental/Wideband	150.09 VA/463.32 VA	156.00 VA/465.51 VA	306.09 VA/804.39 VA
Reactive power Fundamental/Wideband	-60.48 var/-426.89 var	98.25 var/454.16 var	37.77 var/27.27 var

The remaining results and statistics rows are:

Parameter	AB	CB	Σ
Voltage RMS (Vrms) (L-L)	189.38 V	188.41 V	—
Current RMS (Irms)	2.446 A	2.471 A	—
φ (I–V)	23.76°	-39.04°	—
Frequency	119.51 Hz	119.51 Hz	119.51 Hz
Power factor Fundamental/Wideband	0.9152/0.3887	0.7768/0.2195	0.8447/0.3509
Power factor · Mean	0.9152	0.7768	—
Power factor · Std dev	—	—	—
Active power · Mean	137.37 W	121.17 W	258.54 W
Active power · Std dev	—	—	—

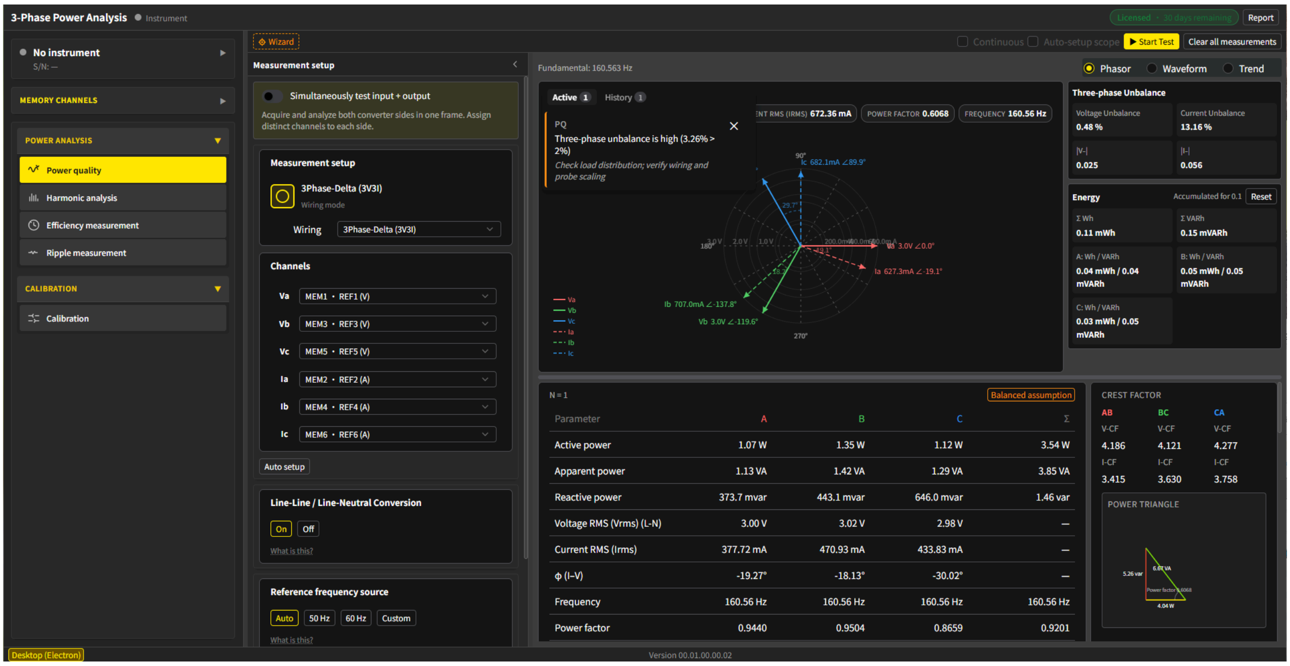
> **Reading the example**: ΣP and ΣQ happen to equal the algebraic AB+CB sums in this data set, but Wideband ΣS is not the simple sum of the two visible Wideband S values. Always use the Σ result reported by the application. `–` means not applicable, unavailable, or that no valid statistics result is currently available. Mean and Std dev are separate statistics rows, not part of the slash-separated pair.

7.5.2 Phasor Diagram

- Displays the fundamental vectors of voltage (solid arrows) and current (dashed arrows), helping confirm phase sequence, amplitude and phase relationships.
- Under normal positive-sequence three-phase, voltage vectors should be arranged in 120° symmetry rotating counterclockwise.
- When the phase sequence is wrong, a phase is missing, or amplitudes are severely unbalanced, the chart area shows a hint.

Interface illustration: PQ phasor diagram + per-phase/summary power results

> The phasor screenshot illustrates the interface layout. Use the Fundamental/Wideband result table in this section as the authority for current power fields and display order.

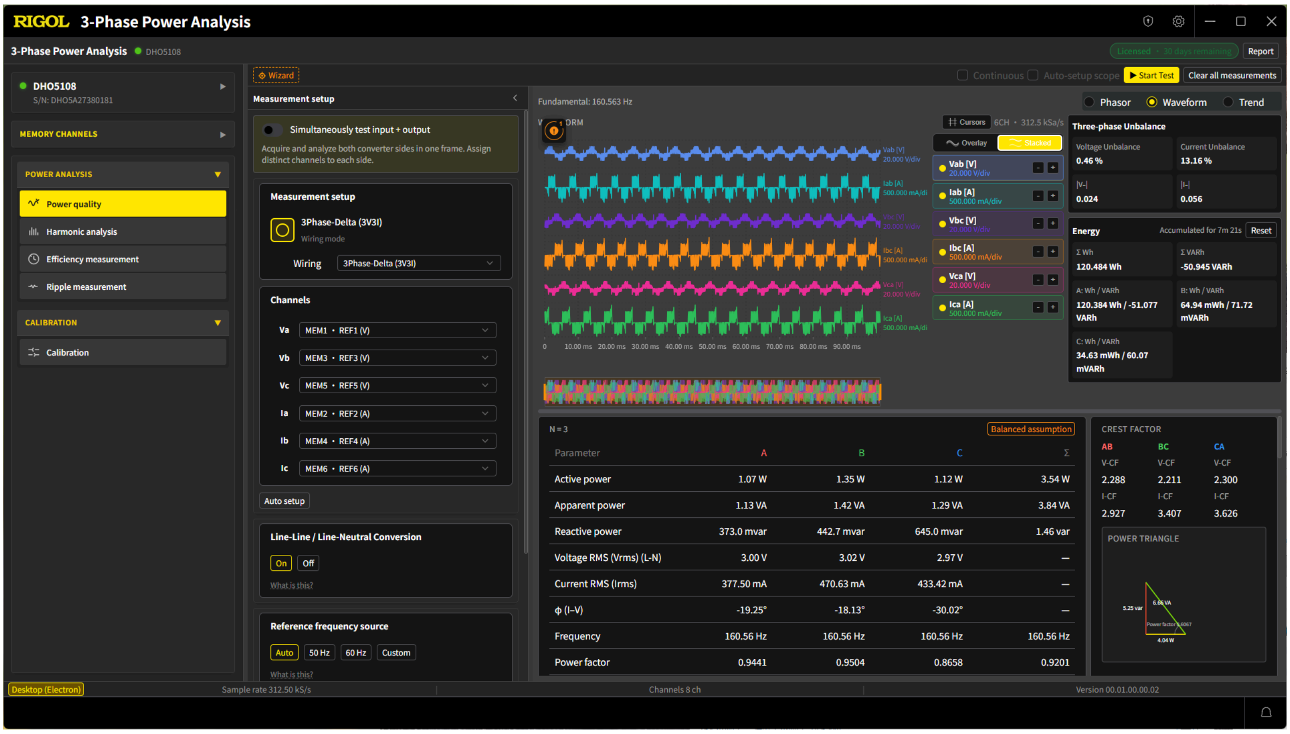


PQ phasor diagram and power results

7.5.3 Waveform View

- Up to 6 channels of V/I waveforms displayed synchronously.
- Helps check for clipping, missing phases, phase sequence and correct channel mapping.
- It is recommended to view the waveform first, confirm signal quality, then read the calculated results.

Interface illustration: PQ six-channel waveform view



PQ multi-channel waveform view

7.5.4 LL-LN Dual-Mode Display

The display can switch between Line-to-Line and Line-to-Neutral. Under 3P3W wiring, L-N values are derived through a software virtual-neutral model and are not directly measured. Use them only when the model assumptions are valid. For materially unbalanced systems or compliance measurements, measure the actual neutral with 3P4W wiring.

7.6 Engineering Practice

- **Phase-sequence confirmation**: first confirm the voltage phase sequence with the phasor diagram, then interpret per-phase power — a reversed phase sequence causes all PF and power values to be abnormal.
- **Current direction**: the current-probe arrow should match the engineering-defined power direction (usually source to load). If P is negative, check the current direction first.
- **Troubleshooting order for abnormal PF**: 1) check current direction; 2) check V/I pairing; 3) run deskew; 4) check whether the waveform has severe harmonic distortion.
- **Unbalance analysis**: when voltage unbalance > 2%, investigate grid supply or wiring issues; when current unbalance > 10%, check load symmetry.
- **Energy accumulation**: Wh and VARh are used for long-term energy evaluation. Note that accumulated values reset when statistics are cleared.
- **In offline mode**, `frequency=AUTO` extracts the fundamental frequency automatically from the waveform.

8 Harmonics (HA)

8.1 Background and Engineering Significance

Nonlinear loads (VFDs, rectifiers, switching supplies, etc.) inject harmonic currents at integer multiples of the fundamental. As these harmonics flow through the equivalent impedance of the distribution system, they cause extra losses, temperature rise, voltage distortion and neutral overcurrent. In industrial three-phase systems, harmonic problems are even more prominent:

- **5th and 7th harmonics** are the characteristic harmonics of three-phase rectifier bridges
- **3rd and triplen harmonics** add up on the neutral in three-phase four-wire systems, possibly overloading the neutral
- **High-frequency harmonics** (related to the switching frequency) come from PWM inverters and are an important source of motor bearing currents and EMI

Every industry has harmonic limit standards. **Pre-compliance testing** lets designers self-test on the bench before sending to a certification lab, solving problems at the board level.

8.2 Supported Compliance Standards

Standard	Scope
IEEE 519	Power-system harmonic control (limit system based on short-circuit ratio and demand current)
IEC 61000-3-2	Harmonic-current limits for equipment with input current ≤16 A per phase intended for connection to public low-voltage supply systems (Class A/B/C/D)
GB/T 14549	China power-quality harmonics on public grids
EN 50160	Voltage characteristics of European public distribution networks
DIN 40160	German grid voltage characteristics
AM14	Railway applications (requires CSV limit-file import)
MIL-STD-1399	Military shipboard power systems (requires CSV limit-file import)
RTCA DO-160	Avionics equipment (requires CSV limit-file import)
CSV custom	User-defined limits (import a two-column, header-less CSV)

8.3 Entering HA

1. Click **Harmonics (HA)** in the left panel.
2. Check the shared wiring configuration and channel mapping.
3. Select the harmonic source: **Voltage**, **Current** or **Both**.
4. Select the measurement-side marker: **Input** or **Output** (for result interpretation and report labeling).
5. Select the compliance standard and harmonic range (start/end harmonic order, up to 400th).
6. Set **Line Frequency**: Auto (follows the PQ fundamental) or manual.
7. Click **Start Analysis**.

8.4 Main Configuration Items

Config item	Description
Compliance Standard	IEEE 519 / IEC 61000-3-2 / GB/T 14549 / EN 50160 / DIN 40160 / AM14 / MIL-STD-1399 / RTCA DO-160 / CSV custom
Harmonic Range	Start and end harmonic order, up to 400th (limited by the Nyquist frequency)
Line Frequency	Auto-follow the PQ fundamental or set manually
Source	Voltage, current, or both
Measurement Side	Input-side or output-side marker

8.5 Interpreting Results

Parameter	Meaning
H1, H2 ... Hn	Amplitude (A or V) and phase (deg) of each harmonic
THD-F	Total harmonic distortion (fundamental-normalized), `THD_F = sqrtsum(n=2..N) H_n^2 / H_1 x 100%`
THD-R	Total harmonic distortion (total-RMS-normalized), `THD_R = sqrtsum(n=2..N) H_n^2 / sqrtsum(n=1..N) H_n^2 x 100%`
TDD	Total Demand Distortion, mainly for IEEE 519 current-harmonic evaluation
Pass/Fail	Per-order compliance verdict against the current standard and limits

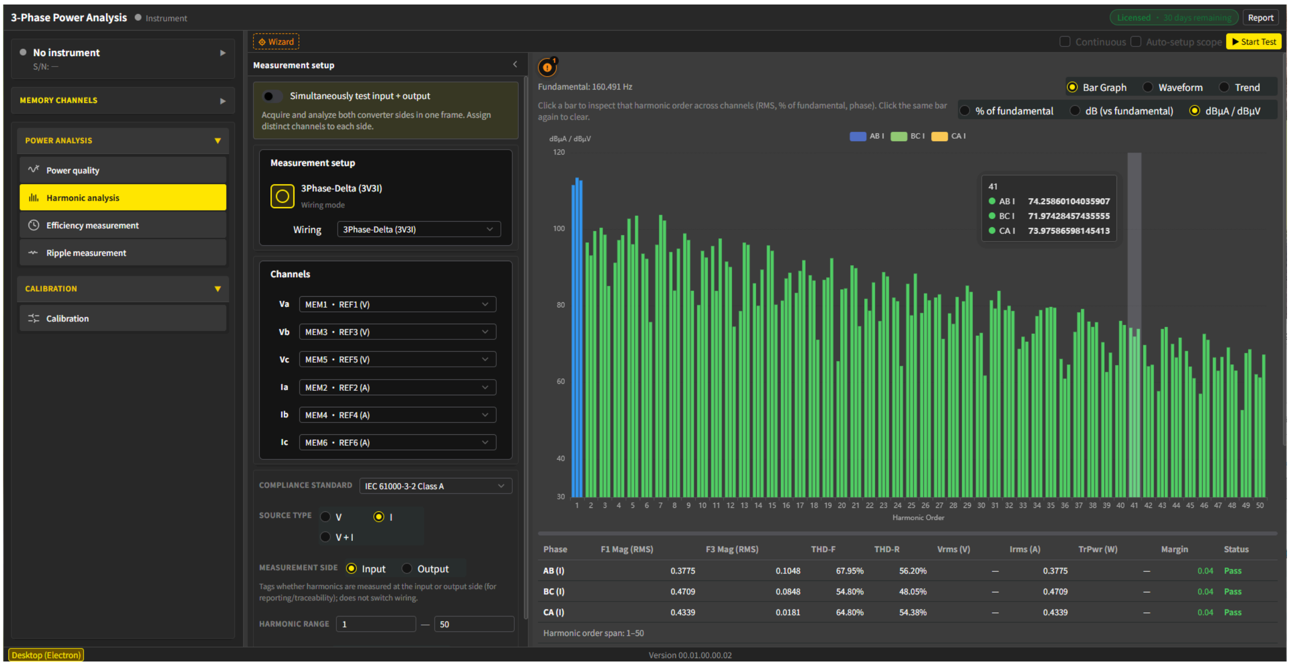
EN

Margin	Margin between the measured value and the limit (positive = pass, negative = exceed)

8.5.1 Bar Chart

- Blue bar = fundamental
- Green bar = Pass
- Red bar = Fail
- Red dashed line = limit line
- The currently selected harmonic order is highlighted, linked with the result table

Interface illustration: HA harmonic bar chart + measurement result table



HA harmonic bar chart and results

8.5.2 Harmonic Spectrum Detail Table

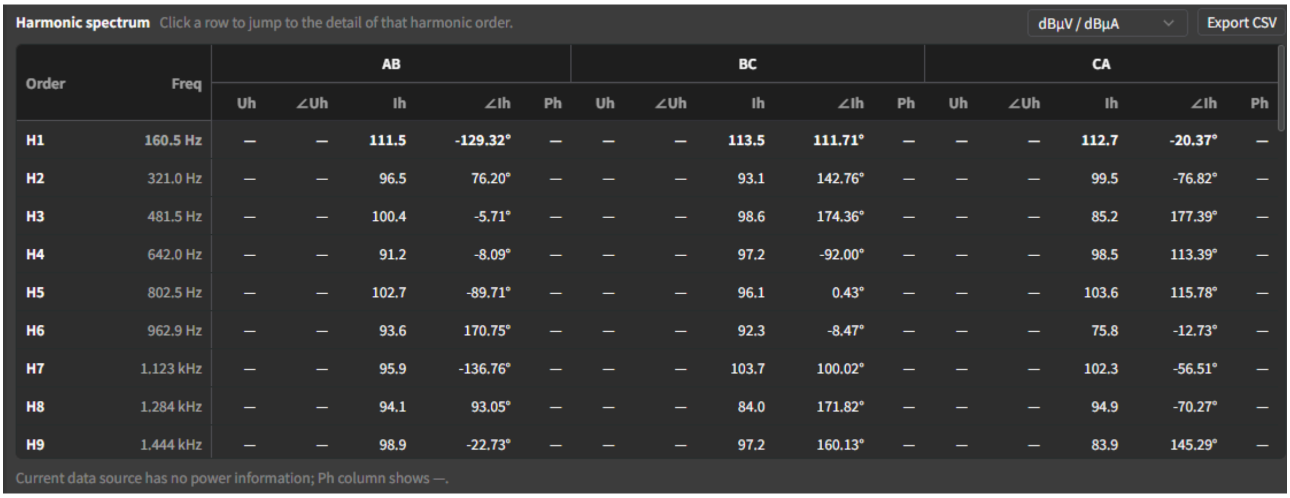
Below the bar chart is a **Harmonic Spectrum Detail Table** that lists detailed per-phase data row by row in harmonic order:

Column	Meaning	Note
Order	Harmonic order H1, H2 ... Hn	Fundamental row (H1) highlighted, over-limit rows in red
Uh	Voltage harmonic amplitude at this order	—
∠Uh	Voltage harmonic phase at this order	deg

Ih	Current harmonic amplitude at this order	—
∠Ih	Current harmonic phase at this order	deg
Ph	Active power of this harmonic `P_h = U_h * I_h * cos(angle U_h - angle I_h)`	Filled only when Source = **Both** (voltage+current), otherwise shows —

- Clicking a table row locates and highlights the corresponding harmonic order in the bar chart; clicking a bar conversely highlights the table row (bidirectional linking).
- The header provides an **Export CSV** button to export the spectrum detail table separately for further analysis.

Interface illustration: Harmonic Spectrum Detail Table (listing Uh / ∠Uh / Ih / ∠Ih / Ph order by order)



Order	Freq	AB Uh	AB ∠Uh	AB Ih	AB ∠Ih	AB Ph	BC Uh	BC ∠Uh	BC Ih	BC ∠Ih	BC Ph	CA Uh	CA ∠Uh	CA Ih	CA ∠Ih	CA Ph
H1	160.5 Hz	—	—	111.5	-129.32°	—	—	—	113.5	111.71°	—	—	—	112.7	-20.37°	—
H2	321.0 Hz	—	—	96.5	76.20°	—	—	—	93.1	142.76°	—	—	—	99.5	-76.82°	—
H3	481.5 Hz	—	—	100.4	-5.71°	—	—	—	98.6	174.36°	—	—	—	85.2	177.39°	—
H4	642.0 Hz	—	—	91.2	-8.09°	—	—	—	97.2	-92.00°	—	—	—	98.5	113.39°	—
H5	802.5 Hz	—	—	102.7	-89.71°	—	—	—	96.1	0.43°	—	—	—	103.6	115.78°	—
H6	962.9 Hz	—	—	93.6	170.75°	—	—	—	92.3	-8.47°	—	—	—	75.8	-12.73°	—
H7	1.123 kHz	—	—	95.9	-136.76°	—	—	—	103.7	100.02°	—	—	—	102.3	-56.51°	—
H8	1.284 kHz	—	—	94.1	93.05°	—	—	—	84.0	171.82°	—	—	—	94.9	-70.27°	—
H9	1.444 kHz	—	—	98.9	-22.73°	—	—	—	97.2	160.13°	—	—	—	83.9	145.29°	—

Harmonic spectrum detail table

8.5.3 Trend View

In Continuous mode, use **Acq Trend** to observe how THD, TDD or a specified harmonic amplitude changes over acquisition counts, useful for assessing measurement stability and the impact of load dynamics.

8.6 CSV Custom Standard

When the built-in standards do not cover your test specification, import a CSV limit file.
CSV file format (two columns, no header):

```
# order,limit
2,1.0
3,5.0
5,4.0
7,3.0
11,2.0
```

- Column 1: harmonic order (integer)
- Column 2: limit (number)
- Lines starting with `#` are comments
- Choose the unit in the import dialog as **A** (absolute) or **%** (relative to the fundamental)

After import, the standard name uses the file name, and the bar chart and Pass/Fail are recalculated against the new limits.

> The AM14, MIL-STD-1399 and RTCA DO-160 standards require you to find the limit tables in the corresponding standard documents and manually create the CSV limit files for import.

8.7 Engineering Practice

- Harmonic analysis has strict requirements on the sampling window: you must acquire an **integer number of fundamental cycles** to avoid spectral leakage. If fundamental detection fails, set the line frequency manually.
- The sample rate and record length must satisfy the target highest harmonic order and the Nyquist condition: `f_s > 2 x H_max x f_fund`.
- After switching standards, click **Start Analysis** again.
- In three-phase four-wire systems, watch for the 3rd-harmonic addition on the neutral.
- IEEE 519 is assessed at the PCC. Until the PCC, maximum demand load current IL, short-circuit current ISC, and ISC/IL category are established, treat the software result as a pre-check—not a compliance pass/fail verdict.
- When using a CSV standard, archive the limit file together with the HTML/CSV report.

9 Efficiency (EF)

9.1 Background and Engineering Significance

Efficiency `eta = P_out / P_in` is one of the most important performance metrics of power-electronics equipment, directly affecting:

- **Thermal design**: each 1% efficiency improvement significantly reduces heatsink volume and system temperature rise
- **Energy-efficiency regulations**: mandatory certification metrics such as PV inverter efficiency, charging-module efficiency and UPS efficiency
- **Operating cost**: the efficiency difference of industrial motor drives and large UPS is a considerable cost item in annual cumulative electricity bills

The core difficulty of three-phase efficiency measurement is that the input and output sides may have different wiring topologies (e.g. three-phase AC input → DC output, DC input → three-phase AC output, three-phase input → three-phase output), so the voltage/current channel roles on the two sides must be defined independently.

9.2 Measurement Principles

The EF module of the 3-Phase Power Analyzer supports **independent configuration of wiring and channel mapping** for the input and output sides:

- Input-side label system: a / b / c (Va, Vb, Vc, Ia, Ib, Ic)
- Output-side label system: x / y / z (Vx, Vy, Vz, Ix, Iy, Iz)

This allows typical rectifier scenarios (three-phase four-wire input, DC output) and typical inverter scenarios (DC input, three-phase output) to be completed in a single configuration.

9.3 Entering EF

1. Click **Efficiency (EF)** in the left panel.
2. Set **Input Wiring** and **Output Wiring** separately in the center panel.
3. Complete the channel mapping for the input and output sides respectively.
4. Check **Continuous** or **Auto Setup** as needed.
5. Click **Start Analysis**.

9.4 Main Configuration Items

Config item	Description
Input Wiring	Input-side wiring method (independent of the output side)
Input Channel Assignment	Input-side voltage/current channel mapping (labels a/b/c)
Output Wiring	Output-side wiring method (independent of the input side)

Output Channel Assignment	Output-side voltage/current channel mapping (labels x/y/z)
Continuous	Continuous acquisition with statistics update
Auto Setup	Invoke the scope auto-setup before starting analysis

9.4.1 Input/Output Label System

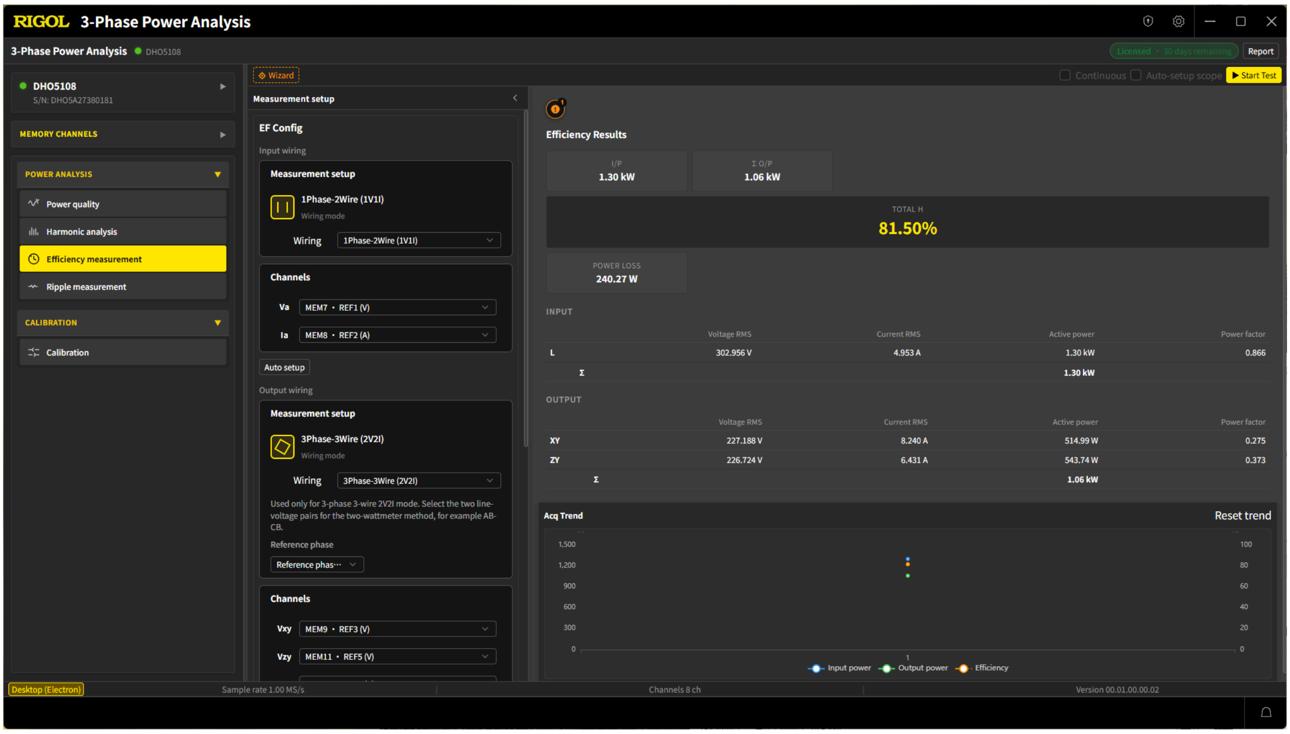
Side	Labels	Example
Input side	a / b / c	Va, Vb, Vc, Ia, Ib, Ic
Output side	x / y / z	Vx, Vy, Vz, Ix, Iy, Iz

Using independent label systems avoids confusion between input and output sides in reports, charts and channel mappings.

9.5 Interpreting Results

Parameter	Meaning
Input Power (Σ Pin)	Sum of input-side active power (W)
Σ Output Power	Sum of output-side per-phase/per-channel active power (W)
Total η	Total efficiency, η = ΣPout / ΣPin × 100%
Ploss	Power loss, Ploss = ΣPin − ΣPout (W)

Interface illustration: EF efficiency results (ΣPin / ΣPout / η / Ploss + input/output per-phase power)



EF efficiency results

9.5.1 Efficiency Trend Chart

In Continuous mode, the EF Trend simultaneously tracks Pin, Pout, η and Ploss over acquisition counts, making it easy to assess load changes and the thermal-stabilization process.

9.6 Troubleshooting

Symptom	Possible cause	Investigation
Efficiency > 100%	Input/output channel mapping error	Check whether V/I channels are cross-assigned to the input/output sides
Efficiency > 100%	Probe-ratio or unit configuration error	Check probe attenuation ratio and current-probe mV/A setting
Efficiency > 100%	Current direction opposite to the power-flow definition	Check current-probe arrow direction and input/output side definitions
Efficiency > 100%	Deskew not calibrated	Run deskew then re-measure

Efficiency > 100%	Input/output or power-direction definitions are inconsistent during regeneration	Apply one passive sign convention to Pin and Pout; regeneration alone does not make efficiency greater than 100%
Efficiency clearly too low	Wrong probe ratio, range or coupling	Check probe settings channel by channel
Efficiency drift	Device thermal-stabilization process or load change	Wait for steady state or enable Continuous to observe the trend

> For one defined energy-conversion direction, steady-state efficiency above 100% is not a normal result. The app retains the raw value for diagnosis; check wiring, ratio, skew, input/output definitions, sign convention and sampling window.

9.7 Engineering Practice

- **Always run Deskew before efficiency measurement**: the V/I channels on both input and output sides need skew correction.
- **Multi-load-point sweep**: record efficiency at 10%, 25%, 50%, 75% and 100% load points to plot an efficiency-load curve.
- **Synchronous sampling on both sides**: efficiency calculation relies on synchronized input/output data within the same sampling window.
- **Three-phase three-wire input efficiency**: when using Input Wiring = 3P3W (2V2I), confirm the pairing of Vab/Vbc and Ia/Ib and the phase-sequence selection are correct.
- **Steady-state recording**: let each load point stabilize for more than 30 seconds before recording efficiency and exporting the report, to avoid transient interference.
- **An 8-channel oscilloscope** can synchronously support 3V3I input + DC output (6+2 channels). Full 3V3I input + 3V3I output requires 12 synchronized analog channels. If fewer channels are available, use a lower-channel-count wiring method, a system with enough synchronized channels, or sequential measurements and state that they do not share one acquisition window.

10 Ripple (RP)

10.1 Background and Engineering Significance

Ripple on DC buses and outputs directly affects the performance of power-electronics systems:

- **Line ripple**: comes from the rectification stage, frequency = 2× or 6× the input frequency (100/120 Hz for single-phase full-wave rectification, 300/360 Hz for three-phase full-bridge rectification). Excessive line ripple suggests insufficient DC-bus capacitance or excessive ESR.
- **Switching ripple**: comes from PWM switching, frequency = switching frequency and its multiples (kHz to tens of kHz). Excessive switching ripple points to insufficient output filter (L, C) design or excessive layout parasitics.

The two ripple components correspond to different physical roots and filtering strategies, so they require **separate measurement** rather than being lumped together as "ripple."

10.2 Entering RP

1. Click **Ripple (RP)** in the left panel.
2. Check the channel mapping (supports single-channel voltage or multi-channel voltage+current).
3. Choose the ripple type (Line Ripple or Switching Ripple) and the FFT window function in **Ripple Config**.
4. Check **Continuous** or **Auto Setup** as needed.
5. Click **Start Analysis**.

10.3 Ripple Types

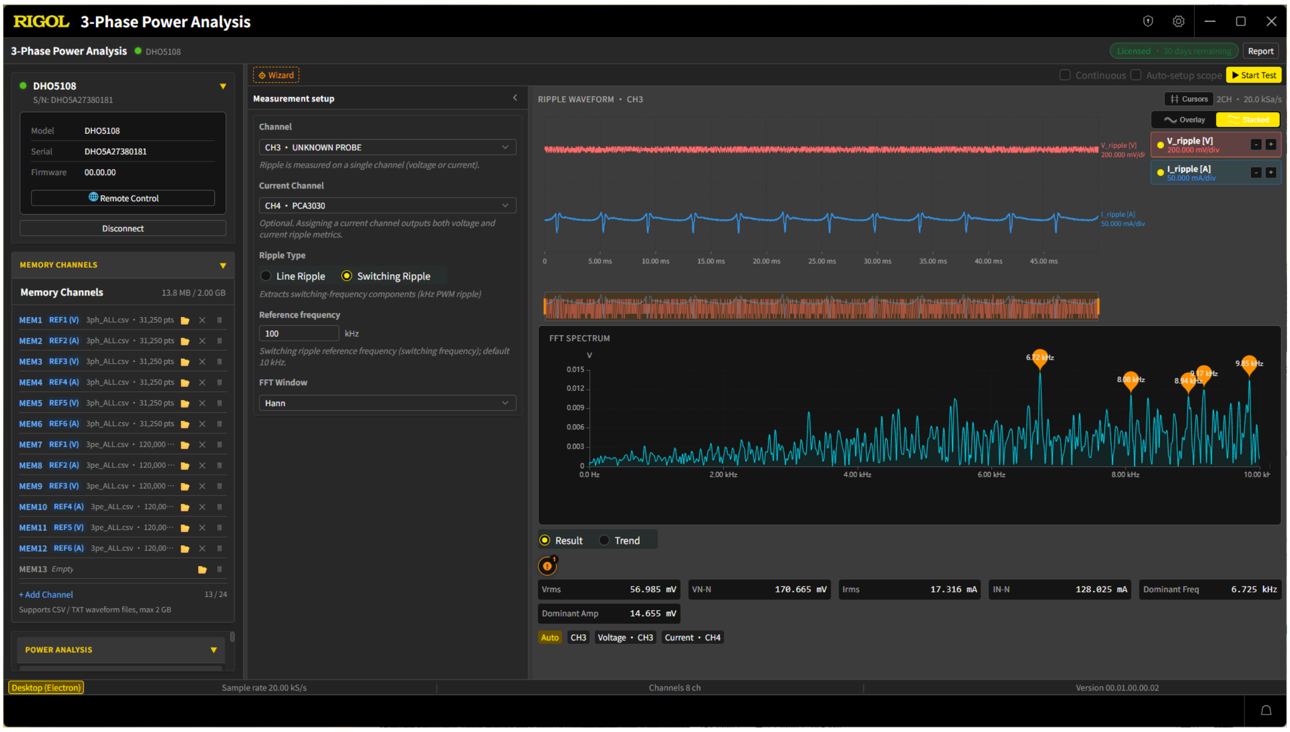
Type	Description	Typical band	Filtering strategy
Line Ripple	Low-frequency ripple related to mains rectification or grid frequency	Mains frequency and low-order harmonics (50/60 Hz and multiples)	Low-pass filtering to extract the line-frequency component
Switching Ripple	High-frequency ripple caused by PWM switching	kHz to tens of kHz or higher	High-pass/band-pass filtering to extract the switching-frequency component

10.4 Interpreting Results

Parameter	Meaning
Vrms / Irms	RMS of the ripple component (after AC coupling and band-pass filtering)
VN-N / IN-N	Ripple voltage/current peak-to-peak

Dominant Frequency	The dominant frequency in the FFT spectrum (Hz)
Dominant Amplitude	The amplitude at the dominant frequency (V or A)
FFT Spectrum	Ripple spectrum curve with automatic peak annotation

Interface illustration: RP ripple measurement results and FFT spectrum



RP ripple measurement results

10.4.1 Spectrum Analysis Order

1. Check the time-domain VN-N to confirm whether the peak-to-peak meets the spec.
2. Check Vrms to judge whether ripple energy changes with operating conditions.
3. Check the Dominant Frequency to determine whether the ripple is line-related or switching-related.
4. Check the spectrum peaks to confirm whether there are multiples, sidebands or abnormal ringing.

10.5 Engineering Practice

- **Line ripple**: increase the record length appropriately to improve low-frequency resolution; confirm the sampling window contains enough mains cycles.
- **Switching ripple**: increase the sample rate and check whether the Nyquist frequency covers the target band; high-frequency measurement is extremely sensitive to probe grounding.
- **FFT window selection**: Hanning window suits general scenarios; Flat-top window suits accurate amplitude measurement; Rectangular window suits transient signals.
- **Small ripple amplitude**: ripple voltage may be far smaller than the DC component; use a probe with an appropriate range to avoid quantization noise contaminating the ripple signal.

- **Dominant-peak drift**: when the dominant spectral peak drifts with operating conditions, enable **Continuous** and **RP Trend** to observe the change path.
- **Measurement loop**: long ground leads and improper grounding introduce extra high-frequency noise; keep the ground path as short as possible.

11 Trend, Statistics and Advisor

11.1 Statistics

Each analysis module supports statistical analysis over multiple acquisitions. Statistics fields include:

Statistic	Description
Mean / Avg	Average over multiple acquisitions
Min	Minimum over multiple acquisitions
Max	Maximum over multiple acquisitions
Std / StdDev	Standard deviation over multiple acquisitions (reflects data stability)
Cnt / N	Number of statistics samples

> The statistics limit is 1000 historical entries; beyond that they roll over FIFO (first-in first-out). In PQ results, statistics rows such as Mean and Std dev are separate from the slash-separated Fundamental/Wideband pair; `–` means that no valid statistics result is currently available.

11.2 Trend View

The trend view observes how measured values change over time or acquisition count:

Module	Trend type	Observable metrics
PQ	AcqTrend / TimeTrend	Per-phase P/Q/S/PF (Fundamental/Wideband), Freq, unbalance ratio, etc.
HA	AcqTrend	THD-F, THD-R, TDD, specified harmonic amplitude
EF	AcqTrend	Pin, Pout, η, Ploss
RP	AcqTrend	Vrms, VN-N, Irms, IN-N, dominant frequency, dominant amplitude

The trend chart supports hovering to view the instantaneous value and timestamp of a data point.

11.3 Advisor

The app has a built-in **Advisor** rule engine that gives tiered hints (info / warning / critical) as an Advisor Banner above the result area, along with troubleshooting suggestions. Hints are at two levels:
Result-level advice (based on PQ/HA/EF/RP analysis results):

Trigger condition	Default threshold	Suggested direction
High three-phase unbalance	unbalance ratio > 2%	Check load distribution, wiring method and probe ratios
Low power factor on a phase	PF < 0.8	Investigate inductive/capacitive load mismatch, consider PF compensation
High harmonic distortion	THD > 5%	Check nonlinear loads, add harmonic filtering if needed
Harmonics exceed compliance limits	per the selected standard	Check the over-limit individual harmonics in the Pass/Fail report
Ripple RMS over threshold	project-dependent	Check filter capacitors and regulator status
Low efficiency	η < 70%	Check load condition and probe calibration
Efficiency > 100%	η > 100%	Re-run probe identification and verify channel assignment

Signal-level advice (based on raw channel waveform quality):

Trigger condition	Suggested direction
No voltage/current signal detected on a channel	Check probe connection and channel assignment
Channel near saturation (peak/range too high)	Increase probe attenuation or widen the channel range
Fundamental frequency out of the mains range	Confirm the supply mains frequency or update the expected range
Abnormal three-phase phase sequence	Check wiring; voltage/current channel order may be wrong
Channel amplitude does not match the assigned probe range (suspected V/I swap)	Re-run probe identification or swap the V/I channel assignment

> Thresholds are defaults; some can be adjusted in Settings. The Advisor helps locate anomalies; the final verdict still requires the waveform and engineering context.

12 Calibration

12.1 Why Calibration Is Needed

In three-phase power measurement, the propagation-delay difference between voltage and current probes is one of the largest sources of systematic error. For power factor, active power, reactive power, efficiency and harmonic-phase measurement:

- Uncalibrated V/I skew causes systematic bias in PF and P
- In low-PF scenarios (unloaded transformers, lightly loaded motors), phase error has a particularly pronounced effect on P
- In high-frequency PWM scenarios, even a few ns of skew significantly affects transient-power calculations

Deskew calibration measures the relative delay between channels and writes the calibration value into the oscilloscope hardware (or applies software compensation), eliminating this systematic error.

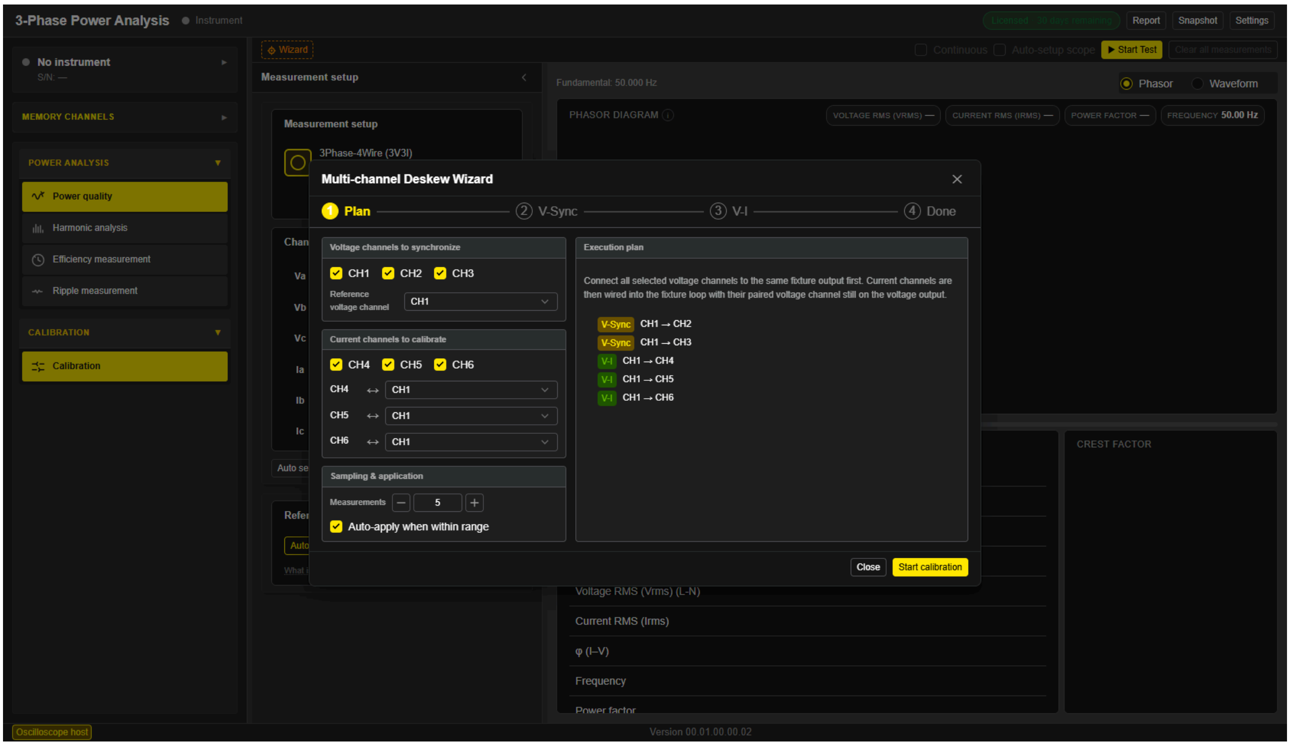
12.2 Opening Calibration

Open the Deskew calibration dialog from **Utility** → **Calibration** in the left panel. The entry is available from any module.

12.3 Deskew Workflow

1. Connect the voltage and current probes to be calibrated to the same reference signal or a dedicated calibration fixture.
2. Open the calibration wizard from **Utility** → **Calibration** in the left panel.
3. Select the voltage channels, voltage reference channels and current channels to participate in calibration.
4. Choose a paired voltage reference channel for each current channel (should match the V/I pairing in subsequent measurements).
5. Set the number of measurements (10–20 averages recommended to reduce random error) and whether to apply automatically.
6. Run the following sub-steps via the wizard:
   - **V-V Deskew**: correct the relative delay between voltage channels
   - **V-I Deskew**: correct each current channel's delay relative to its paired voltage channel
7. When finished, review each sub-step's skew value (ns), calibration status (within range / out of range) and apply result (applied / not applied).

Interface illustration: multi-channel Deskew calibration wizard



Multi-channel Deskew wizard

12.4 Interpreting Calibration Status

Status	Meaning
skew_ns	Delay value (positive = current lags voltage, negative = current leads voltage)
within range	Delay within the hardware's calibratable range, applicable
out of range	Delay beyond the hardware's calibratable range; change probe or calibration fixture
applied	The calibration value has been written to hardware or software compensation applied

12.5 Engineering Practice

- Re-run Deskew after every probe, channel or cable change.
- In low-PF scenarios (PF < 0.5), deskew has a particularly significant effect on active power.
- In high switching-frequency scenarios (> 100 kHz), deskew is more important for transient power and efficiency stability.
- For multi-probe systems, do V-V Deskew first (unify delay between voltage channels), then V-I Deskew.
- Checking "Include Deskew summary" in the report attaches this calibration's skew values and directions for traceability.

13 Utility Tools

The left-panel **Utility** group provides Deskew calibration and waveform preview:

Entry	Function
Utility → Calibration	Open the Deskew calibration wizard (see Chapter 12)
Utility → Waveform Preview	Select oscilloscope or Memory channels for waveform preview, basic measurements, and CSV/BIN export

13.1 Waveform Preview and Basic Measurements

1. Select **Utility → Waveform Preview** in the left panel.
2. Select channels from the connected oscilloscope and/or Memory channels that contain data, up to 10 mixed sources.
3. Click **Refresh Preview**. If the oscilloscope is acquiring, the application stops acquisition before reading the complete acquisition memory. The oscilloscope remains stopped after the read so you can zoom and export; explicitly resume acquisition when required.
4. The waveform chart first displays an overview of the long record. Zooming or panning loads more detailed data for the visible interval.
5. **Basic Measurements** shows RMS, peak-to-peak, frequency, maximum, minimum and mean for each channel. This operation does not start a full PQ / HA / EF / RP analysis.

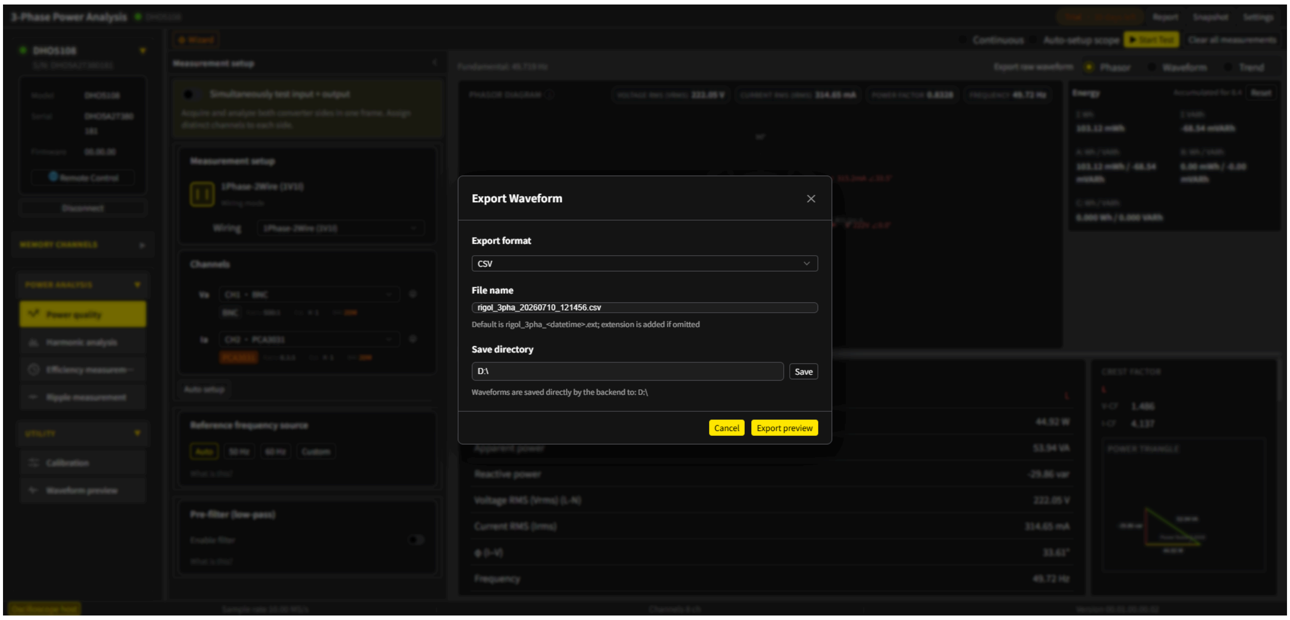
Waveform preview and basic measurements

13.2 Waveform Export (CSV / BIN)

When preview data is available, click **Export**:

Option	Description
Format	CSV or BIN; BIN can be imported back into Memory
Save directory	Defaults to the report-export directory and can be changed in the dialog
File name	Includes the generation date and time by default and can be edited

The export button is unavailable when there is no preview data.



Waveform export dialog

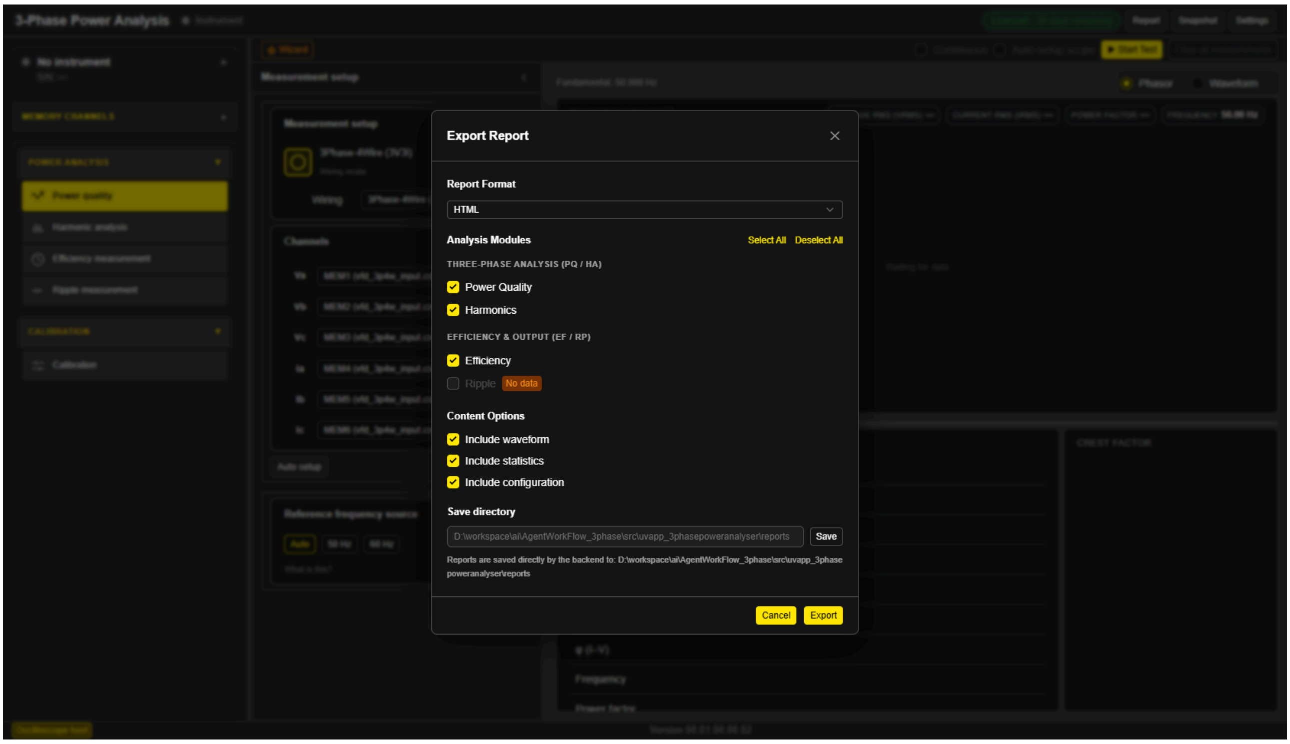
13.3 Exporting Raw Waveforms from Measurement Modules

After PQ / HA / EF / RP completes at least one valid analysis, select **Export Raw Waveform** in that module's result area to save the latest complete time-domain waveforms as CSV or BIN. The button is unavailable until a valid analysis completes. The save dialog and directory rules match §13.2.

14 Report Export

14.1 Opening Report Export

Click **Report** in the header to open the report-export dialog.
Interface illustration: report-export dialog (format / modules / content options / save directory)



Report export dialog

14.2 Supported Formats

Format	Use
HTML	Self-contained single file with embedded screenshots and result data, suited to email distribution, offline browser viewing, review and archiving
CSV	Structured data export, suited to further analysis and processing in Excel, Python, MATLAB, etc.

> **Note**: PDF report generation is deferred to v1.1; the current version supports HTML and CSV only.

14.3 Exportable Content

Content	Description
Module Data	Data of PQ, HA, EF, RP modules that have valid results
Measurement Config	Configuration summary: wiring method, channel mapping, sample rate, test mode, etc.
Waveform	PQ waveform preview data
Statistics	Statistics such as Mean, Min, Max, Std, Cnt
Metadata	Report metadata: timestamp, device model (IDN), app version, etc.
Compliance Summary	HA module compliance verdict and limit comparison (optional)

14.4 Export Recommendations

- **Review and archiving**: export HTML with the config summary, statistics and waveform screenshots checked.
- **Data review**: export CSV, keeping the metadata and config-summary fields.
- **Certification submission**: HTML report + CSV data in duplicate, with the raw waveform files and limit files attached.
- Before exporting, confirm the current results are not in pending or invalid state — if a module has not run or has no valid data, the corresponding item shows N/A in the report.

15 Application Settings

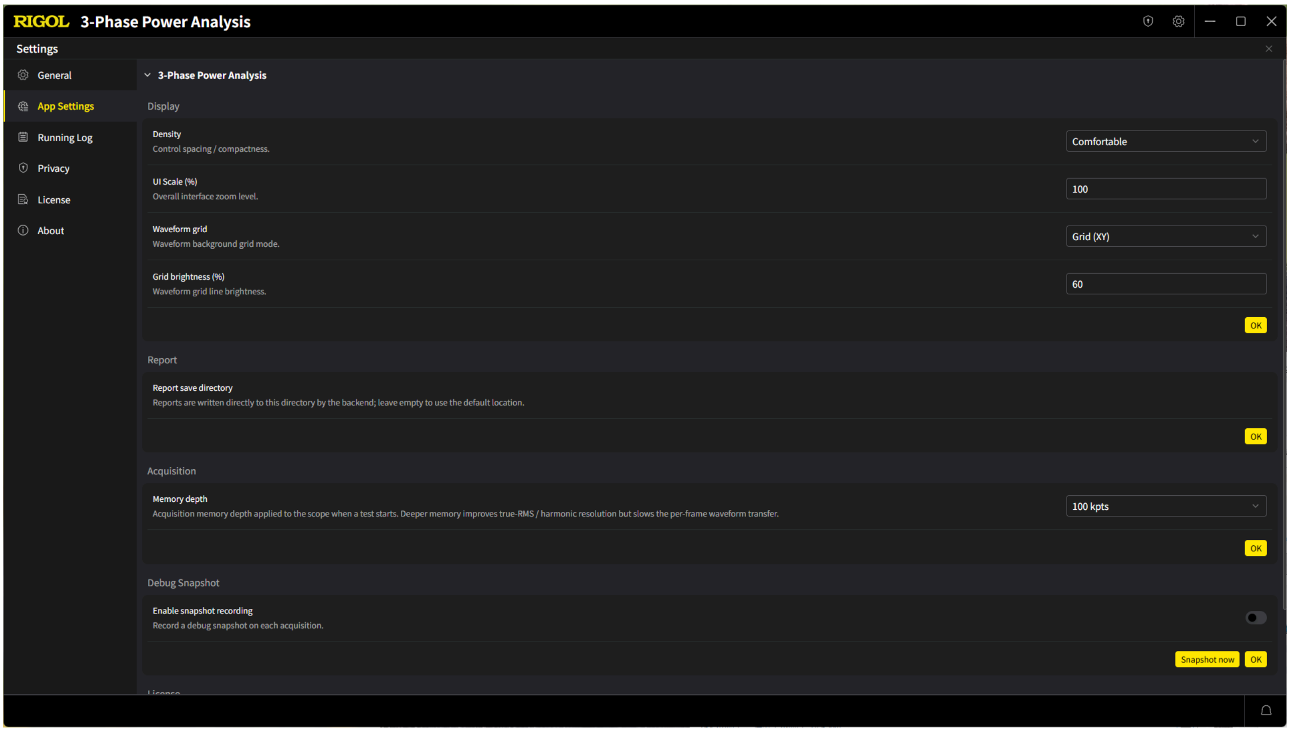
15.1 Settings

Click **Settings** in the header to open the display-settings dialog. Current settings include:

Setting	Description
Display density	Compact / Comfortable / Spacious, controls card spacing and font size
UI scaling	85% – 150%, adapts to different resolutions and vision needs
Chart grid mode	XY (full grid) / X only (vertical grid) / Y only (horizontal grid) / no grid
Chart grid brightness	Adjust grid-line brightness, dim the grid to reduce visual clutter

> **Language / Theme / About** are not configured in this app's Settings.

Interface illustration: display-settings dialog



Display settings dialog

15.2 License and Trial

The four analysis modules PQ, HA, EF, RP are license-controlled. The app determines authorization status from the following sources (taking the union):

Authorization source	Description
Oscilloscope online option	When the scope has the **3PHA** option activated, online measurement for all analysis modules is unlocked
Offline license file	An offline license (`.lic`) imported through the platform unlocks modules item by item, unlocking both online and offline measurement modes
Trial mode	If the current release provides a valid trial, the corresponding analysis modules are available without the other authorization sources

Trial rules:
- Trial duration and available modules depend on the software release and licensing policy. Use the remaining term and authorization status displayed by the application.
- When the trial ends, activate the oscilloscope 3PHA option or import a valid offline license file to continue using controlled modules.

Authorization is shown as **Licensed / Trial / Expired**. This manual does not document internal license storage or anti-tamper implementation.

16 Frequently Asked Questions (FAQ)

Q1: The Start Analysis button is unavailable? A: Another module may be analyzing, acquisition may be busy, or the current module may be temporarily unavailable for switching. Stop the running analysis first, then switch modules.
Q2: PF or power is negative? A: Negative power usually means the current direction, probe direction or input/output energy direction is opposite to expectation. Check the current-probe arrow direction, V/I pairing and phase-sequence settings. Note: in energy-regeneration scenarios (e.g. an inverter feeding the grid), negative power may be a normal result.
Q3: The three-phase phasor angles are not close to 120°? A: Possible causes: channel mapping error (V phase labels do not match the actual wiring), reversed phase sequence (e.g. A and B swapped), inherent system unbalance, the device under test in a non-sinusoidal/PWM state, or deskew not calibrated. First confirm the per-phase voltage fundamental relationships with the PQ waveform.
Q4: How many harmonic orders can be analyzed at most? A: Up to 400th, but the actual analyzable count is limited by the fundamental, sample rate, record length and Nyquist frequency. If the sample rate is insufficient or the acquisition is too short, the app automatically lowers the highest analyzable order and gives a hint.
Q5: Efficiency exceeds 100%? A: Possible causes are: 1) input/output channel mapping error; 2) probe ratio or unit error; 3) inconsistent current direction, input/output definition, or sign convention; 4) deskew not calibrated; 5) input/output sampling-window mismatch. Even during regeneration, steady-state efficiency for one defined energy direction should not exceed 100%.
Q6: The ripple spectrum does not show the expected dominant peak? A: Confirm the sample rate covers the target band (sample rate > 2 × target frequency), the FFT window is appropriate, the ripple type is correct (Line vs Switching), and check whether the signal has been attenuated by a filter or coupling method.
Q7: An item in the exported report shows N/A or Invalid? A: It means the module had no valid result when the report was generated, or the data could not be judged due to a missing channel, clipping, unconfigured standard, calculation failure, etc. Re-run the corresponding analysis module and export again.
Q8: CSV standard import fails? A: Confirm the CSV contains at least two columns "harmonic order, limit", with integer orders and numeric limits. Comment lines must start with `#`. Use a header-less two-column CSV format.
Q9: How do I read the phasor diagram under 3P3W wiring? A: 3P3W (2V2I) directly measures Vab, Vbc, Ia and Ib. Vca and Ic are derived from three-wire constraints. Any displayed L-N values use a virtual-neutral model and are not direct measurements; use caution when the system is materially unbalanced.
Q10: After connecting the oscilloscope, the footer does not show the channel count and sample rate? A: Confirm the connection succeeded (header connection status green). If it still does not show, the device-capability read command may have failed — try disconnecting and reconnecting, or check whether VISA communication is normal.
Q11: The three-phase unbalance ratio is high but the load is symmetric? A: 1) Check whether the three voltage probes' attenuation ratios are consistent; 2) confirm the vertical scale settings of each channel match; 3) check for a poor contact on a phase or a faulty probe.
Q12: There are not enough channels on the input/output side during efficiency measurement? A: The channel requirements of the EF module's input and output sides are determined by their respective wiring methods. For example: 3V3I input (6 channels) + DC output (2 channels) = 8

channels. If the oscilloscope has insufficient channels, choose a wiring method with fewer channels (e.g. use 2V2I instead of 3V3I), or measure sequentially.
Q13: An analysis module reports unauthorized or locked? A: PQ/HA/EF/RP are license-controlled. Confirm the scope has the 3PHA option activated, a valid offline license file imported, or the application shows an active trial. See §15.2.

17 Appendix A: Wiring Quick Reference

Wiring method	Voltage channels	Current channels	Power-calc method	Typical use
3Phase-4Wire (3V3I)	Va, Vb, Vc	Ia, Ib, Ic	Three-wattmeter	Three-phase four-wire systems (with neutral)
3Phase-3Wire (2V2I)	Vab, Vbc	Ia, Ib	Two-wattmeter (Vca is derived)	Three-phase three-wire systems (no neutral)
3Phase-Delta (3V3I)	Vab, Vbc, Vca	Ia, Ib, Ic	Three line-voltage/line-current synthesis	Delta-connected loads
1Phase-2Wire (1V1I)	V	I	Single-phase power	Single-phase input or single-channel output
1Phase-3Wire (2V2I)	Va, Vb	Ia, Ib	Split-phase power synthesis	Single-phase three-wire systems
DC (1V1I)	Vdc	Idc	P = V × I	DC bus or DC output
Single-channel ripple (V)	V	—	Ripple analysis	Single-channel voltage ripple measurement

18 Appendix B: Measurement Parameter Reference

Abbr.	Name	Unit	Description
VRMS	Voltage RMS	V	True RMS voltage per phase
IRMS	Current RMS	A	True RMS current per phase
Vmag	Fundamental voltage amplitude	V	Voltage amplitude at the FFT fundamental
Imag	Fundamental current amplitude	A	Current amplitude at the FFT fundamental
P1 / Pwb	Fundamental/Wideband active power	W	Displayed as `P1/Pwb`; `Pwb = mean(v × i)`
Q1 / Qwb	Fundamental/Wideband reactive power	var	Displayed as `Q1/Qwb`; both values are signed
S1 / Swb	Fundamental/Wideband apparent power	VA	Displayed as `S1/Swb`; `Swb = Vrms × Irms`
PF1 / PFwb	Fundamental/Wideband power factor	—	Displayed as `PF1/PFwb`; `PF1=P1/S1`, `PFwb=Pwb/Swb`
φ (I–V)	Current-to-voltage phase angle	deg	`ϕI1 - ϕV1`; `Q1 = -V1rms × I1rms × sin[ϕ(I-V)]`
Freq	Fundamental frequency	Hz	System fundamental frequency
VCF	Voltage crest factor	—	Vpeak / VRMS
ICF	Current crest factor	—	Ipeak / IRMS

Wh	Active energy	Wh	Accumulated active energy
VARh	Reactive energy	VARh	Accumulated reactive energy
THD-F	Fundamental-referenced THD	%	Harmonic RMS / fundamental RMS
THD-R	RMS-referenced THD	%	Harmonic RMS / total RMS
TDD	Total demand distortion	%	Current-harmonic metric defined by IEEE 519
Uh / Ih	Per-order harmonic amplitude	V / A	Per-order voltage/current amplitude in the spectrum detail table
∠Uh / ∠Ih	Per-order harmonic phase	deg	Per-order voltage/current phase in the spectrum detail table
Ph	Per-order harmonic active power	W	`P_h = U_h * I_h * cos(angle U_h - angle I_h)`, filled only when Source=Both
VN-N / IN-N	Ripple peak-to-peak	V / A	Peak-to-peak of the ripple component
η	Efficiency	%	ΣPout / ΣPin × 100%
Ploss	Power loss	W	ΣPin − ΣPout
Unbalance	Unbalance ratio	%	Three-phase voltage/current unbalance

19 Appendix C: Chart Interaction

Action	Effect
Chart zoom control (DataZoom slider)	Zoom the X-axis range to inspect a specific interval in detail
Mouse hover	Show the instantaneous value, harmonic order, frequency or statistics summary at a data point
Scroll wheel	Pan or zoom the chart view
Click a result-table row	Cross-highlight the corresponding component in the bar chart, waveform or phasor
Drag a splitter	Adjust the width of the left, center and right panels
Double-click a splitter	Restore default panel sizes
Phasor hover	Show that vector's amplitude and angle
Spectrum hover	Show the frequency and amplitude of peaks

20 Appendix D: RIGOL Probe Selection Quick Reference

The 3-Phase Power Analyzer recommends pairing with genuine RIGOL probes for the best compatibility and measurement accuracy. **PHA high-voltage differential probes do not support auto-identification; before use you must manually configure the probe type, attenuation ratio, unit and range on the scope or in the app. The identification capability of PCA current probes depends on the specific model and scope support.** The specific specifications listed below are for reference only; for the final bandwidth, range, attenuation ratio and CAT rating of all probes and oscilloscopes, refer to the official RIGOL datasheets.

20.1 High-Voltage Differential Voltage Probes (PHA2150B / PHA1150B preferred)

Model	Reference specs	Recommended scenario
PHA2150B	200 MHz, 20×/200×; max. differential input ±150 V / ±1500 V; CAT II 1000 V / CAT III 600 V	★ First choice — three-phase high-frequency switching analysis, inverter D-S voltage, dv/dt measurement
PHA1150B	100 MHz, 20×/200×; max. differential input ±150 V / ±1500 V; CAT II 1000 V / CAT III 600 V	★ First choice — three-phase input voltage, PFC bus, power-quality analysis
PHA0150	70 MHz, 1500 V, 50×/500× dual range	Mains three-phase analysis, mains-frequency harmonics, low-frequency high-voltage measurement

20.2 Current Probes (PCA3000 series preferred)

Model	Reference specs	Recommended scenario
PCA3031	120 MHz, 3 A / 30 A self-powered	★ First choice — highest bandwidth, high-frequency three-phase inverters, SiC/GaN high dI/dt
PCA3030	50 MHz, 3 A / 30 A self-powered	High-frequency low-current, high dI/dt

PCA2030	100 MHz, 30 A	High-frequency mid-current, three-phase power quality, efficiency testing
PCA1030	50 MHz, 30 A	General three-phase efficiency testing, power quality
PCA1150	10 MHz, 150 A	High-current three-phase input, industrial motor drives
PCA1500	2 MHz, 500 A	Ultra-high-current scenarios, large inverter outputs

> **Measurement-category limitation**: the PCA3000 Series user guide specifies CAT I. Use these probes only on circuits isolated from mains; do not use them for CAT II, CAT III or CAT IV measurements.

20.3 Oscilloscope Channel Capability and Wiring Suitability

Oscilloscope series	Analog-channel capability	Typical suitability in this application
MHO5000 / DHO5000	4, 6 or 8 analog channels, depending on model	4 channels suit 2V2I; 6 support one 3V3I side; 8 support 3V3I + DC. Confirm the exact model before ordering.

20.4 Probe Combination Recommendations for Three-Phase Measurement

Measurement scenario	Voltage probe	Current probe	Channel need
Three-phase four-wire input (3V3I)	**PHA1150B** ×3 (200×)	**PCA2030 / PCA1030** ×3	6 channels
Three-phase three-wire (2V2I two-wattmeter)	**PHA1150B** ×2	**PCA2030** ×2	4 channels
Three-phase inverter output high-frequency analysis	**PHA2150B** ×3	**PCA3031 / PCA3030** ×3	6 channels

DC-bus ripple	Use a rated differential probe for floating or high-voltage buses; use a 1× passive probe + ground spring only on low-voltage, earth-referenced nodes within all ratings	—	1 channel
Industrial motor-drive high current	**PHA1150B** ×3	**PCA1150** ×3	6 channels
AC input + DC output efficiency	Input **PHA1150B** ×2/×3 + an output probe rated for the node potential	Input **PCA2030** ×2/×3 + output **PCA1030**	6 channels for 2V2I+DC; 8 for 3V3I+DC

20.5 General Selection Principles

1. **Bandwidth**: probe bandwidth should be ≥ 5× the highest signal frequency.
2. **Range**: reserve current-probe range ≥ 1.5 × the peak current to avoid clipping and saturation.
3. **Delay matching**: always run Deskew calibration after combining multiple probes.
4. **Measurement category**: select probes for the measurement point's overvoltage category, working voltage and transients. Never apply a CAT I current probe directly to a CAT II/III/IV circuit.
5. **Ripple-measurement safety**: use a 1× passive probe + ground spring only on low-voltage, earth-referenced nodes within every probe and oscilloscope rating. Floating or high-voltage DC buses require a differential probe with adequate differential, common-mode and CAT ratings. Balance safety ratings, bandwidth and noise floor.

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