Solar Inverter Testing Procedure

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Abstract

The growth and increasing penetration of distributed energy resources (DER) in Australian power grids is creating new challenges for network management and system security, with less regulated and often unobserved DER accounting for a significant proportion of generation during midday hours. To address these challenges, the University of New South Wales (UNSW Sydney) and the University of Wollongong (UoW), in collaboration with the Australian Energy Market Operator (AEMO) and the Commonwealth Scientific and Industrial Research Organisation (CSIRO), under Theme 9 of the Australian Global Power System Transformation (GPST) consortium on DER and stability for power systems with large penetrations of DER, are conducting a comprehensive test of DER and loads connected to distribution networks. These tests include but not limited to, residential solar PV inverters, battery energy storage systems (BESS), hybrid energy storage systems (HESS), loads and Electric Vehicles (EVs) / EV chargers. The outcomes of the tests assess the response of these systems to normal operation as well as grid disturbances, such as frequency and voltage fluctuations, and their ability to ride through network faults and are used to inform the load modelling, provide feedback to AEMO and OEMs on performance and behaviour of the systems and future networks operation and planning.

Index Terms

Grid-connected PV inverters, Battery Energy Storage Systems, Hybrid Energy Storage Systems, Electric Vehicles, Loads, AS4777, Voltage disturbance, frequency disturbance, rate of change of frequency (RoCoF)

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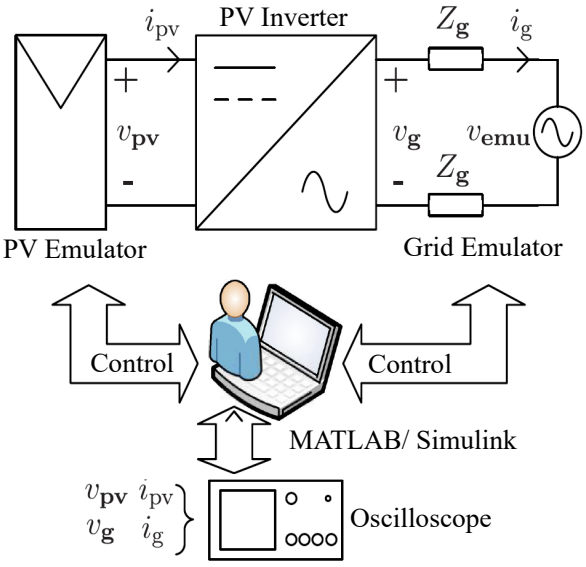
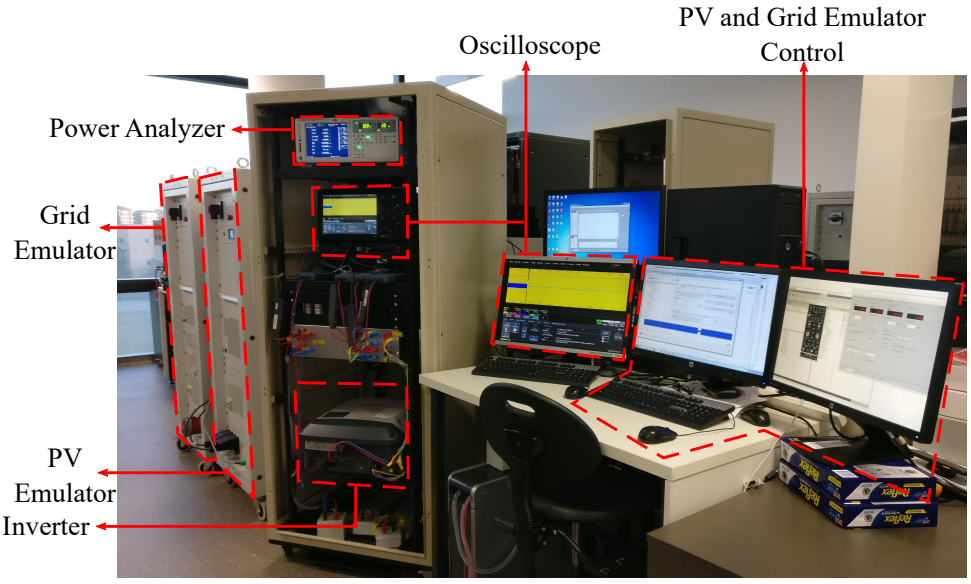
I. Laboratory Setup

The experimental testing of Fig. 1 is currently being performed in the Power Electronics Research Laboratory, Room 334, Tyree Energy Technologies Building (TETB).



(a)



(b)

Fig. 1: (a) Schematics of testing setup, and (c) photo of experimental testing setup.

II. Equipment Used

A. AC Grid Emulator

A Regatron ACS-13038 grid emulators is used [2] operating at 230 V rms phase-to-neutral voltage and 50 Hz of nominal grid frequency. These settings can be adjusted in real-time by using proprietary software for this programmable AC source as is depicted in Fig. 2.

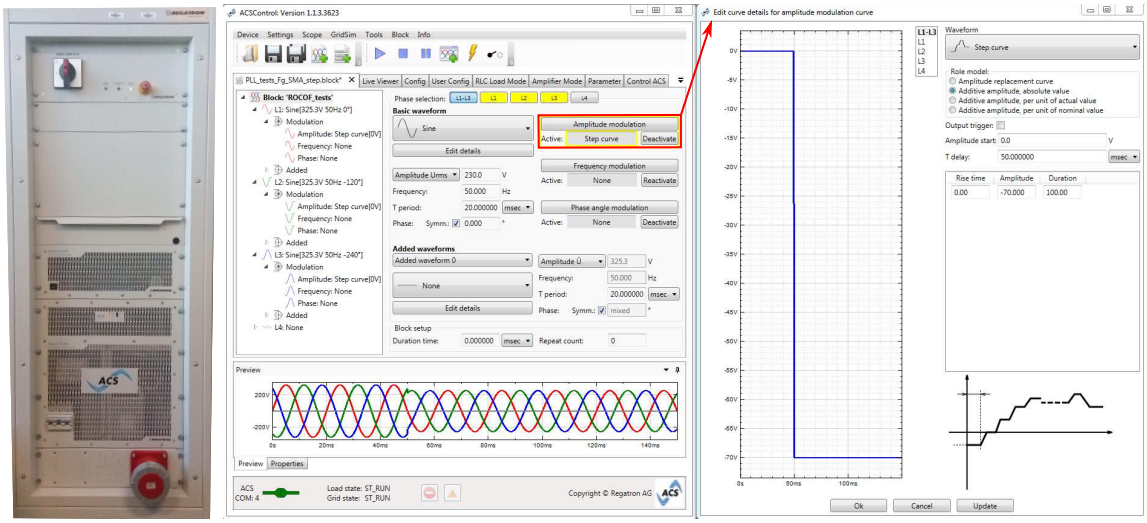


Fig. 2: Regatron ACS-13038 interface.

B. DC PV Emulator

The PV array emulator is a Regatron Q1-LIN-13041 [2] operating at Standard Test Conditions (STC) conditions (1000 W/m^2-25°C). The emulated PV array parameters operating at maximum power point. The interface to this emulated PV array is illustrated in Fig. 3. Note that, the two PV emulators are connected for each array to input of the inverter, if the inverter supports power through two pair of terminals.

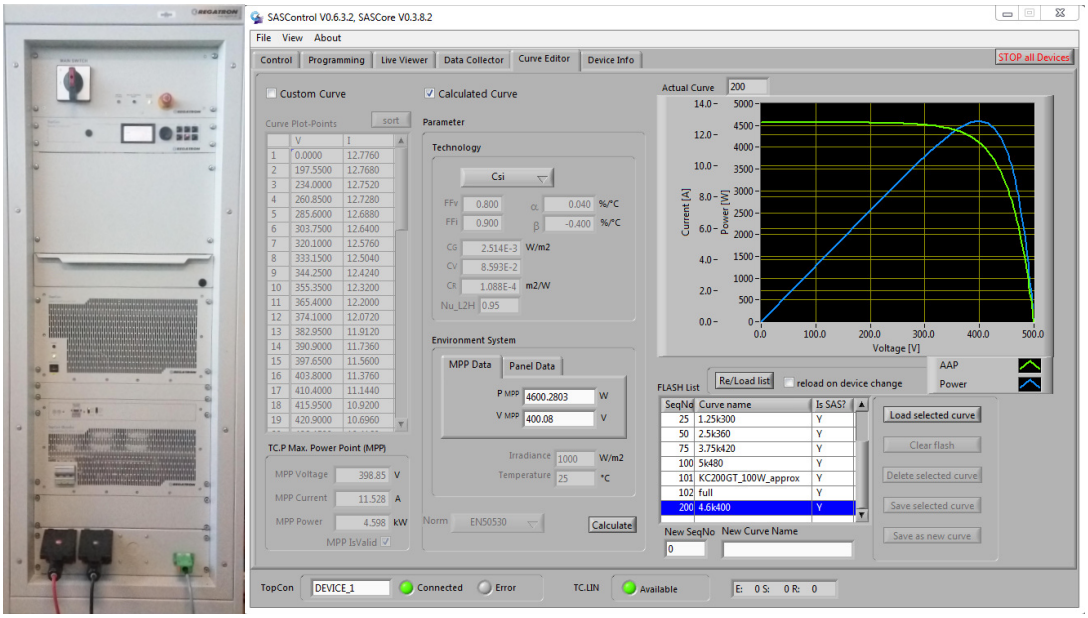


Fig. 3: Regatron Q1-LIN-13041 interface.

C. Power Analyser

The power analyser is a Yokogawa WT3000 [3]. With this instrument it is possible to measure the inverter efficiency. The interface of this power analyser is illustrated in Fig. 4.

Fig. 4: Yokogawa WT3000 interface.

D. Oscilloscope

The oscilloscope is a LeCroy HD4096 [4], which is configured with a sampling frequency of 20 kHz[1]. The interface of these instruments is shown in Fig. 5

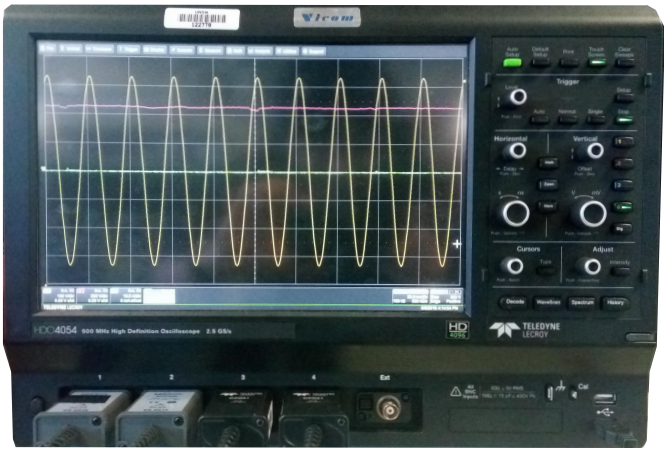


Fig. 5: LeCroy HDO4045 interface.

E. Current Probes

The current probes are LeCroy CP30. The bandwith of this current probe is 100 MHz [4].

F. Voltage Probes

The differential voltage probes are LeCroy ADP300. The bandwith of this voltage probe is 100 MHz [4].

[1]AS4777 defines the sampling frequency for the measurement of electrical quantities as 10 kHz.

III. Testing Procedure - AS4777.2:2020

This section describes the testing of the inverters that comply to the AS4777.2:2020 standard. Emulation of the PV array is performed using default solar PV curves from the Regatron Q1-LIN-13041 according to the Standard EN 50530:2010, defining the maximum voltage and power of the system. All of the experiments below are performed on 50% and 100% of the rated power of the inverter. Emulated *P-V* and *I-V* curves for both cases are shown in Fig. 6. The test numbers indicated on each test corresponds to the tests conducted and waveform uploaded on the website http://pvinverters.ee.unsw.edu.au/.

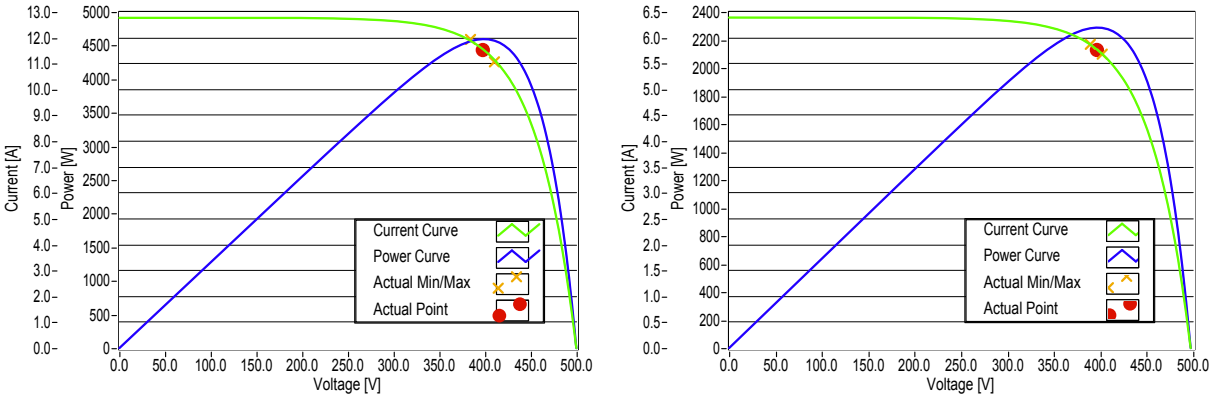


Fig. 6: Emulated P-V and I-V curves at 1000 W/m^2 and 500 W/m^2.

A. Steady-state Performance

Objective: *The objective of this test is to verify the behavior of the PV inverter under steady state conditions.* Steady-state performance for changes in the irradiance is not part of the standard tests related to the AS4777.2:2020. The minimum irradiance that the inverter remains connected to the grid (defined as MIN%) for measurements specifically related to the filtering impedance of each inverter (LCL filter). As these tests do not fall within the scope of the current project, further analysis is not provided. However, current waveform data is being captured and can be used later in the project if relevant.

Test Procedure: On the ac-side of the inverter, rated voltage and frequency is assumed (V_g^{rms} = 230 V and f_g = 50 Hz). On the dc-side of the inverter, standard testing conditions (STC) are assumed for the PV array (Irradiance of 1000 W/m^2 and temperature of 25°C as shown in Fig. 6). The following tests are performed:

(a) **Test 0:** Steady-state inverter performance at MIN% (MIN W/m^2). -See Fig. 7(a) in the test report-. this definition of MIN irradiance is quite ambiguous. Can we perform a low irradiance test instead, say 50 or 100 W/m^2.

(b) **Test 1:** Steady-state inverter performance at 100% (1000 W/m^2). -See Fig. 7(b) in the test report-

B. Frequency Response

Objective: *The objective of this test is to capture the behavior of the inverter for step and ramp variations in the grid frequency and the power ramp of the inverter for excursions of frequency above 50.25 Hz.* AS4777.2:2020 defines different limits for excursions above and below the nominal grid frequency as well as different responses for the inverter in cases of overfrequency or underfrequency.

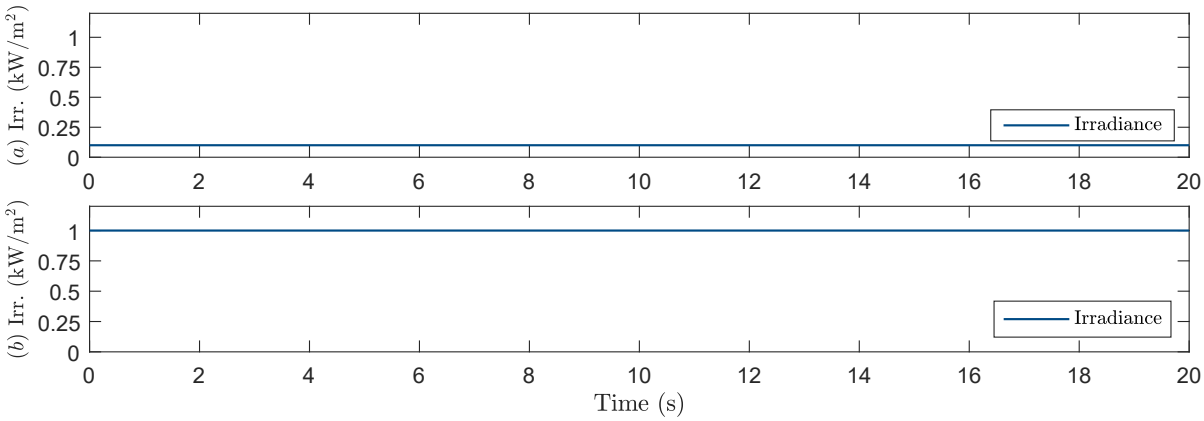


Fig. 7: Minimum and maximum irradiance generated from PV emulator.

Notes in the test and the standard: The standard requires the inverters to include a 1s trip delay time in cases where the frequency excursion is below 47 Hz. However, the behavior of the inverter during the 1s trip delay time is not defined by the standards. If the frequency goes above 51.5 Hz, the 2020 requires the inverters to include a 300s trip delay time and if the frequency goes above 52 Hz standard does not specify any trip delay, while it gives a maximum disconnection time of 0.2s, as seen in Table IV.

Test Procedure: The frequency variations are pre-programmed in the AC Grid Emulator and the response of the inverter is captured[2].

The following tests are performed:

1) Step Frequency Variations: The following step variations in the grid frequency (Δf_g = +1.95 and -2.95 Hz, +2 and -3 Hz, +5 and - 5 Hz) are considered:

(a) **Test 2:** Δf_g = +1.95 Hz (from 50 Hz to 51.95 Hz). -See Fig. 8 (a).

(b) **Test 3:** Δf_g = -2.95 Hz (from 50 Hz to 47.05 Hz). -See Fig. 8 (b).

(c) **Test 4:** Δf_g = +5 Hz (from 50 Hz to 55 Hz). -See Fig. 9 (a).

(d) **Test 5:** Δf_g = -5 Hz (from 50 Hz to 45 Hz). -See Fig. 9 (b).

(e) **Test 6:** Δf_g = +2 Hz (from 50 Hz to 52 Hz). -See Fig. 10 (a).

(f) **Test 7:** Δf_g = -3 Hz (from 50 Hz to 47 Hz). -See Fig. 10 (b).

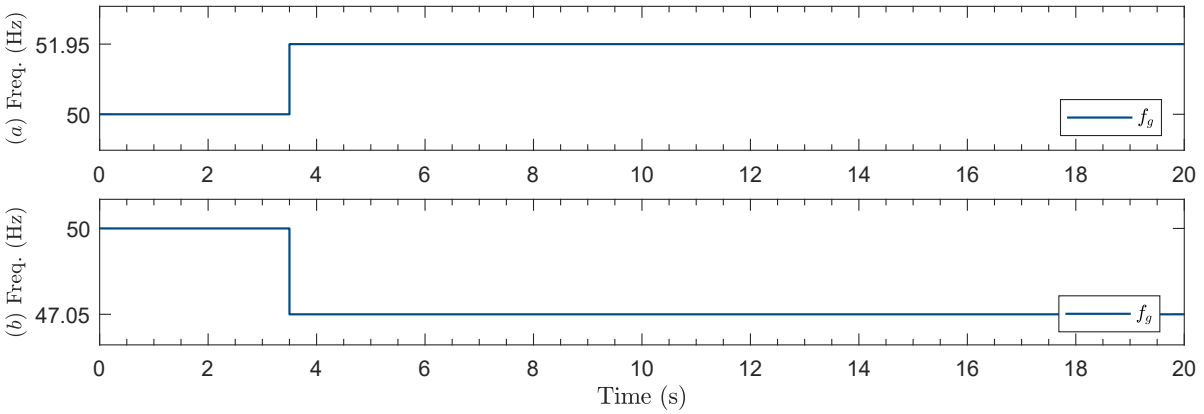


Fig. 8: Step changes of +1.95 Hz and -2.95 Hz in the frequency of the grid voltage.

[2]These tests can be repeated with actual network data captured during faults.

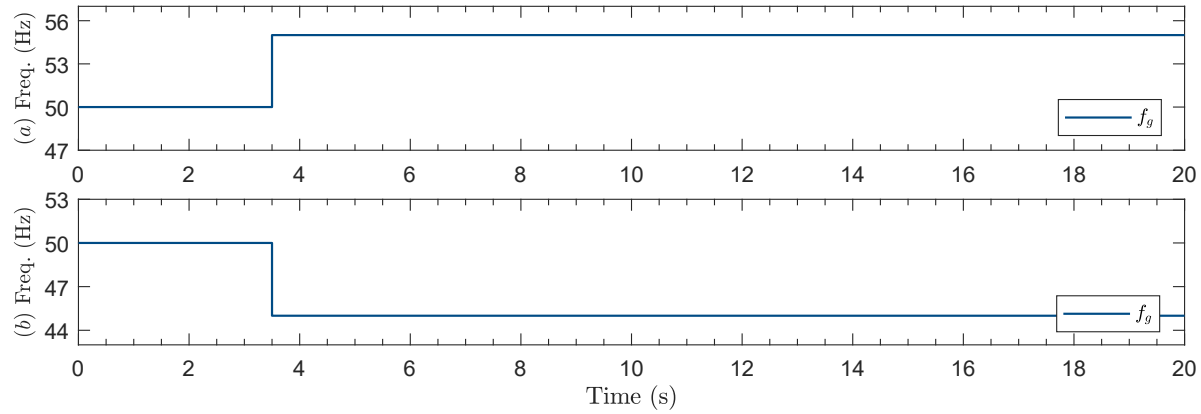


Fig. 9: Step changes of +5 Hz and -5 Hz in the frequency of the grid voltage.

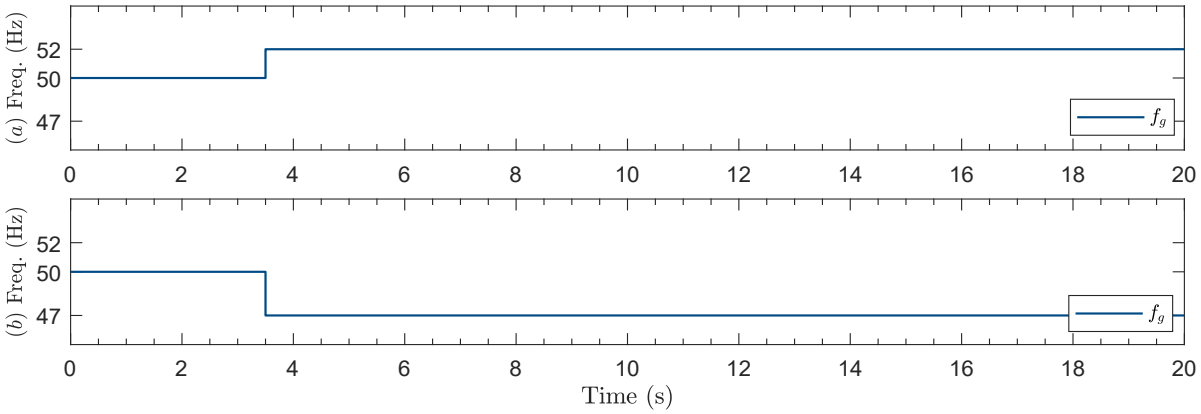


Fig. 10: Step changes of +2 Hz and -3 Hz in the frequency of the grid voltage.

In the cases where the inverter disconnects from the grid, the disconnection and re-synchronisation times are also captured.

2) Ramp Frequency Variations: The following ramps in the frequency (RoCoF) are considered as follows:

(a) **Test 8:** Δf_g = +1 Hz/s (from 50 Hz to 51.95 Hz). -See Fig. 11 (a).

(b) **Test 9:** Δf_g = -1 Hz/s (from 50 Hz to 47.05 Hz). -See Fig. 11 (b).

(c) **Test 10:** Δf_g = +4 Hz/s (from 50 Hz to 51.95 Hz). -See Fig. 11 (c).

(d) **Test 11:** Δf_g = -4 Hz/s (from 50 Hz to 47.05 Hz). -See Fig. 11 (d).

(e) **Test 12:** Δf_g = +0.4 Hz/s (from 50 Hz to 51.95 Hz). -See Fig. 11 (e).

(f) **Test 13:** Δf_g = -0.4 Hz/s (from 50 Hz to 47.05 Hz). -See Fig. 11 (f).

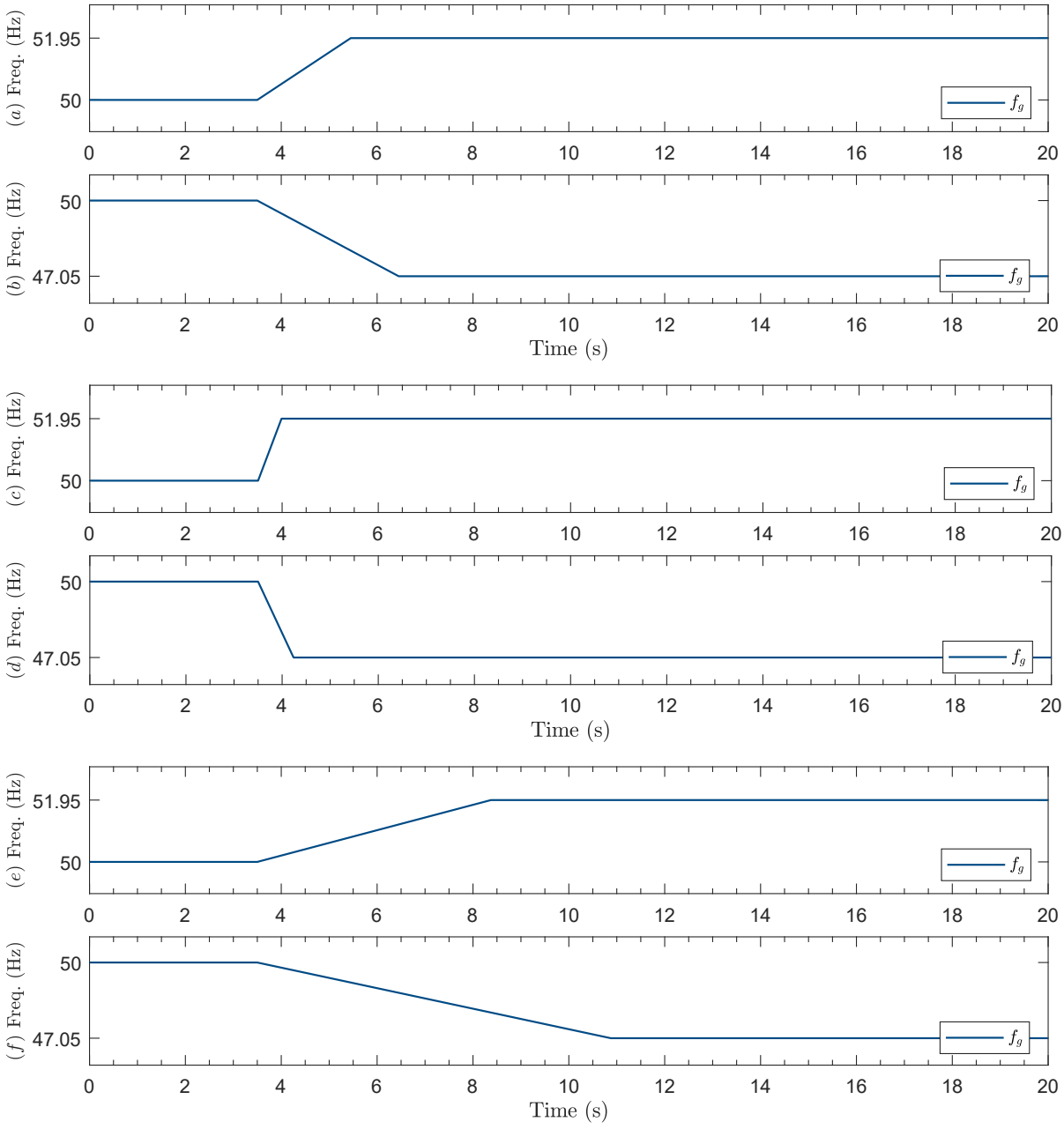


Fig. 11: Frequency ramps with different RoCoF.

C. Voltage Response

Objective: *The objective of this test is to capture the behavior of the inverter for step and ramp variations in the grid voltage*. AS4777.2:2020 defines a Volt-Watt response for the inverters that should be enabled by default. This response requires the inverters to curtail their power output for voltages above a pre-defined limit in linear manner. In-depth bench testing of rooftop PV inverters against voltage sags and swells of duration less than 1s has been performed, verifying inverter behaviours that are otherwise not captured by the current Australian standard AS4777.2:2020 testing procedures. Detailed voltage sag and swell tests highlighted that inverters might be sensitive to the depth and duration of the voltage sags and swells, displaying different behaviours according to these parameters.

Comments on the tests and the standard: AS4777.2:2020 requires a 1s trip delay time for undervoltage less than 70V and 10s trip delay time for undervoltage less than 180V as seen in Table III. During trip delay time the standard mentions that the inverter may continue, reduce of stop its operation. Our current interpretation of the standard is that the behavior of the inverter depends on the implementation by the manufacturer and may differ among different manufacturers.

Testing Procedure: The voltage variations are pre-programmed in the AC Grid Emulator and the response of the inverter is captured[3].

The following tests are performed

1) Step Voltage Variation: The step voltage variation tests are performed[4] as following:

(a) **Test 14:** From 230V to 260V. -See Fig. 12(a).

(b) **Test 15:** From 230V to 50V, then 50V to 230V, during time interval [1,1.9]s. -See Fig. 12(b).

(c) **Test 16:** From 230V to 160V, then 160V to 230V, during time interval [1,10]s. -See Fig. 12(c).

(d) **Test 17:** From 230V to 270V, then 270V to 230V, during time interval [1,1.9]s. -See Fig. 12(d).

2) Ramp Voltage Variation: The inverter voltage is ramped up and down to identify inverter behaviour under slow voltage change. The tests performed are as following:

(a) **Test 18:** From 230V to 185V in 15s. -See Fig. 13(a).

(b) **Test 19:** From 230V to 270V in 15s. -See Fig. 13(b).

3) Comprehensive Voltage Sags and Swells: The following 24 voltages sags and 18 swell tests have been conducted presented in Table I and II. Example are as following:

(a) From 230V to 115V, then 115V to 230V, for duration of 80, 120, and 220ms -See Fig. 14.

(b) From 230V to 270V, then 270V to 230V, for duration of 80, 120, and 220ms -See Fig. 15.

[3]These tests can be repeated with actual network data captured during faults.

[4]AS4777.2:2020 states that during the trip delay time for under-voltage events, the inverter may continue, reduce or stop its operation and if the voltage returns above the limit during the trip delay time, it may resume its operation. This behavior of the inverter should be documented.

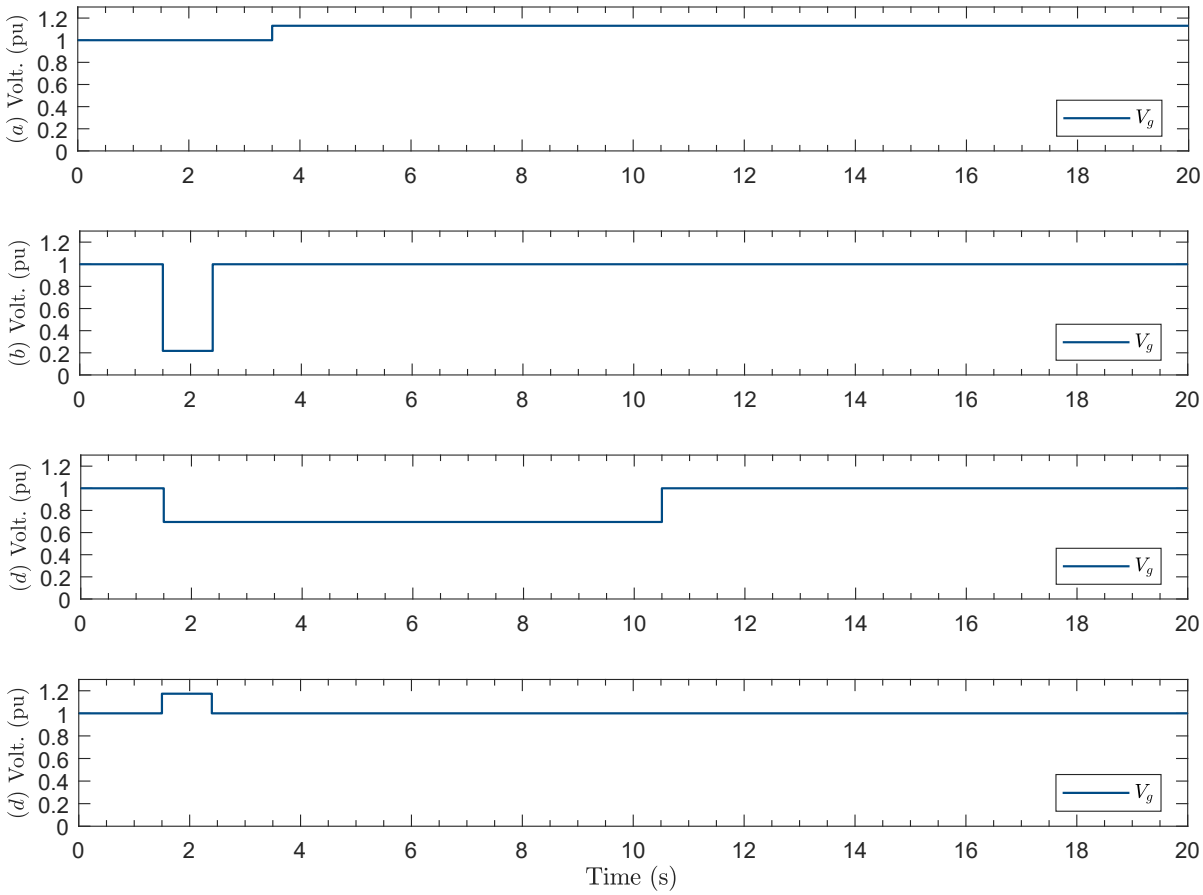


Fig. 12: Performed step voltage variation patterns.

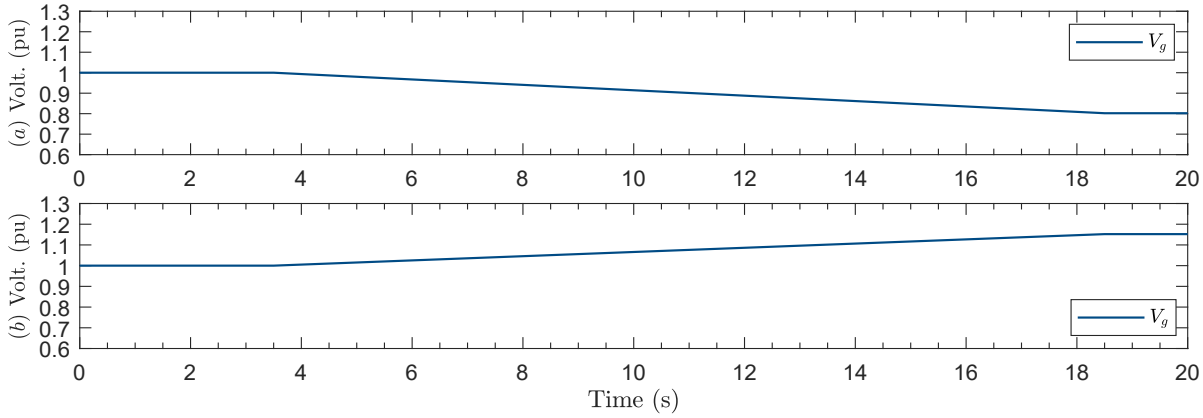


Fig. 13: Ramp changes in the grid voltage

TABLE I: Detailed ac voltage sag testing schedule

sag duration	sag magnitude 10%	20%	30%	40%	50%	60%	70%	80%
80 ms								
120 ms								
220 ms								

Additional tests:

- 800ms, 230 - 50 V sag

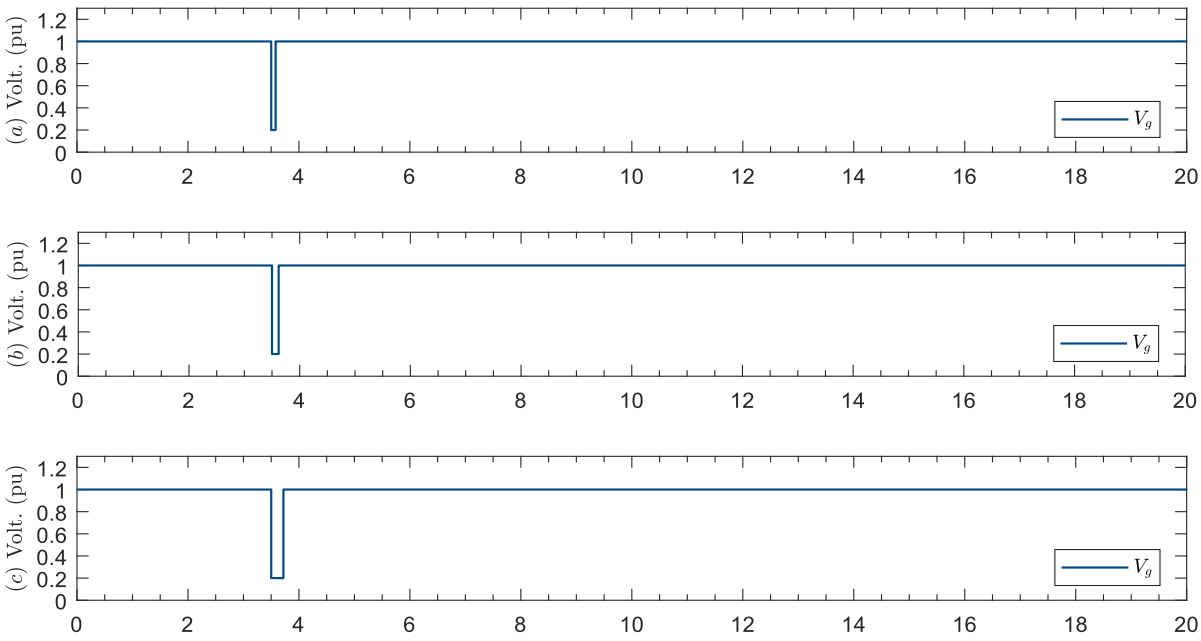


Fig. 14: Voltage sags of 0.8 p.u for duration of 80, 120, and 220ms

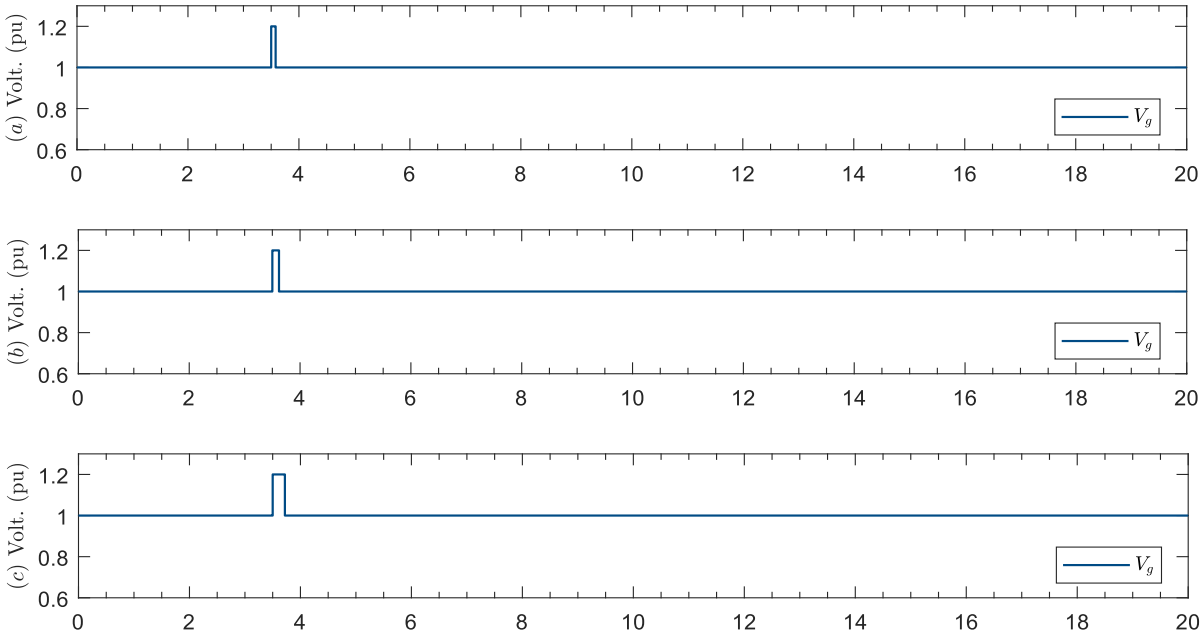


Fig. 15: Voltage swells of 1.2 p.u for duration of 80, 120, and 220ms

TABLE II: Detailed ac voltage swell testing schedule

swell duration	swell magnitude					
	5%	10%	12.5%	15%	17.5%	20%
80 ms						
120 ms						
220 ms						

Additional tests:

- 800ms, 230 - 276 V swell

D. Phase-jumps

Objective: *The objective of this test is to verify the inverter behaviour following phase-jumps in the grid voltage.*

Test Procedure: With the inverter working at rated power and in steady-state, a step variation is given to the phase of the grid voltage. Five tests are performed:

(a) **Test 20:** Phase-jump on grid voltage of -15° and +15°. -See Fig. 16(a).

(b) **Test 21:** Phase-jump on grid voltage of -30° and +30°. -See Fig. 16(b).

(c) **Test 22:** Phase-jump on grid voltage of -45° and +45°. -See Fig. 16(c).

(d) **Test 23:** Phase-jump on grid voltage of -60° and +60°. -See Fig. 16(d).

(e) **Test 24:** Phase-jump on grid voltage of -90° and +90°. -See Fig. 16(e).

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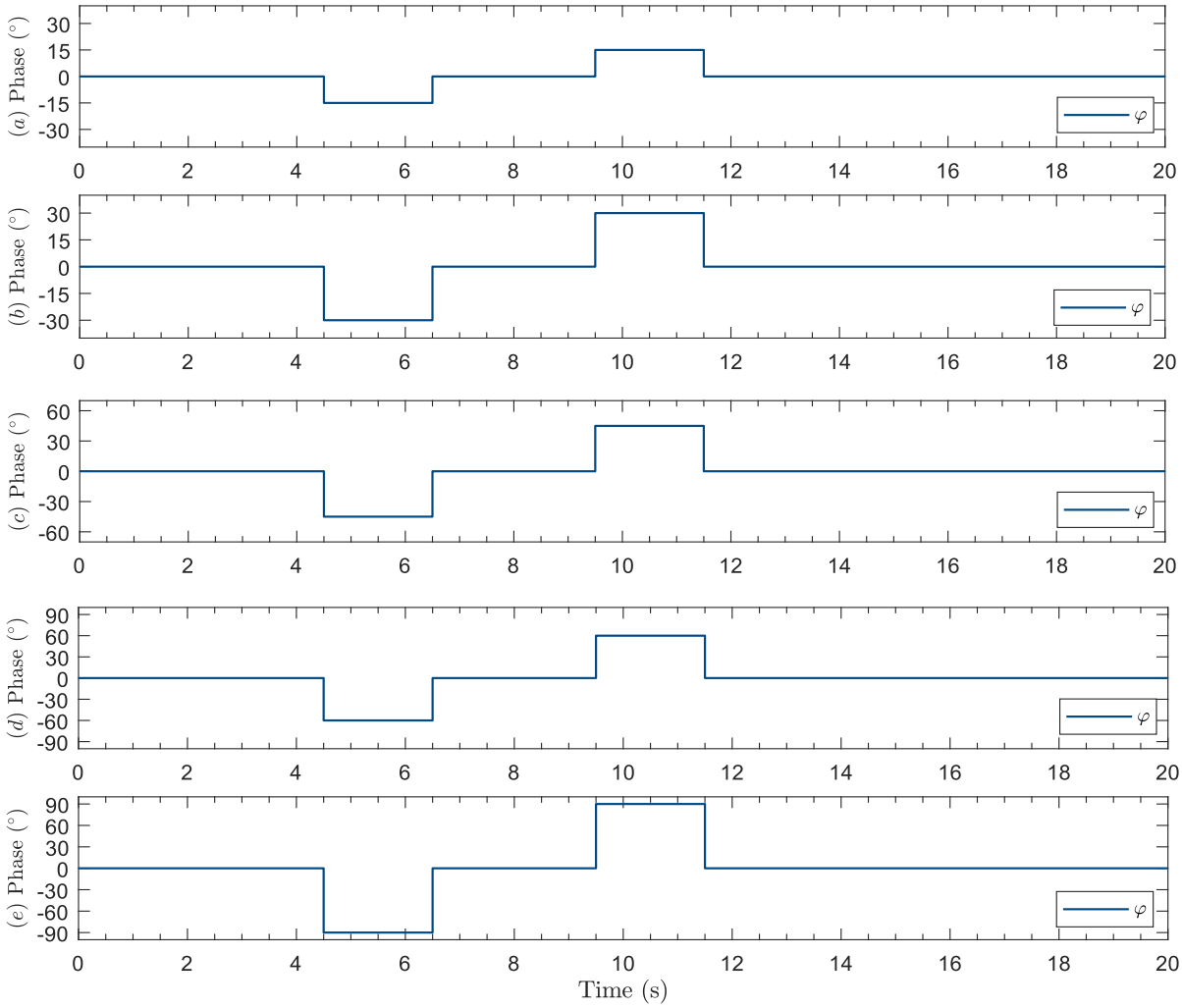


Fig. 16: Voltage phase-angle jumps of different magnitudes

IV. Differences to Testing Procedure described in AS4777.2:2020

The tests reported in this procedure do not intend to prove the compliance to AS 4777.2:2020 , but they rather intend to verify the behaviour of the inverter against disturbances appearing in the gird voltage (mainly voltage and frequency variations). Furthermore, there are some differences in the test setup described in this procedure and the one recommended in the above-mentioned Standards, these are described below.

A. Grid Impedance

The schematic of the test setup being adopted for single phase inverters is the following:

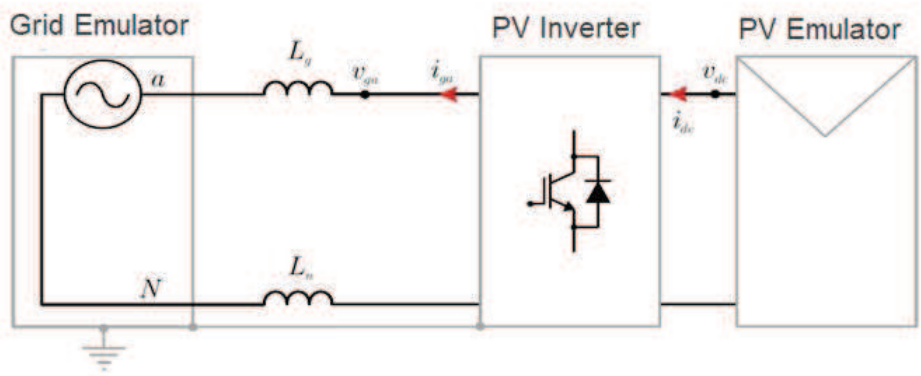


Fig. 17: Single-phase inverter testing setup.

Quoting Appendix A6 of [1, p. 60]:

> For single-phase and three-phase inverters with rated current less than 21.7 A per phase, the impedance of the reference network impedance shall be 0.24 Ω + j0.15 Ω for each phase conductor and 0.16 Ω + j0.10 Ω for the neutral conductor.
>
> For inverters with rated current greater than 21.7 A per phase, the impedance of the reference network impedance shall be 0.15 Ω + j0.15 Ω for each phase conductor and 0.1 Ω + jO.l Ω for the neutral conductor.

The above mentioned impedances, see inductances L_g and L_n in Fig. 17, are connected between the inverter and the grid emulator. In the setup used in the laboratory, differently from what suggested in [1, p. 43], the impedance used was chosen based on availability of components and it is 0.12 Ω + j0.157 Ω, having L_g = L_n = 0.5 mH. The resistive component of such impedance (0.12 Ω) is due to the equivalent series resistance of the inductor and resistivity of the connected cables.

B. Power Level Used For Testing

Passive anti-islanding tests specified in the Appendix I2 and I3 of [1, pp. 81-93] allow to verify the disconnection of the inverter from the AC grid for the voltage and frequency limits specified in [1, Table 4.1 & 4.2] (reported below).

Passive anti-islanding voltage limit values

Protective function	Protective function limit	Trip delay time	Maximum disconnection time
Undervoltage 2 (V <<)	70 V	1 s	2 s
Undervoltage 1 (V <)	180 V	10 s	11 s
Overvoltage 1 (V >)	265 V	1 s	2 s
Overvoltage 2 (V >>)	275 V	—	0.2 s

TABLE III: Table 4.1 from [1].

Passive anti-islanding frequency limit values

	Region	Australia A	Australia B	Australia C	New Zealand
Under-frequency 1 (F <)	Protective function set point	47 Hz	47 Hz	45 Hz	45 Hz
	Trip delay time	1 s	1 s	5 s	1 s
	Maximum disconnection time	2 s	2 s	6 s	2 s
Over-frequency 1 (F >)	Protective function set point	51.5 Hz	51.5 Hz	53 Hz	52.5 Hz
	Trip delay time	300 s	300 s	300 s	300 s
	Maximum disconnection time	310 s	310 s	310 s	310 s
Over-frequency 2 (F >>)	Protective function set point	52 Hz	52 Hz	55 Hz	55 Hz
	Trip delay time	—	—	—	—
	Maximum disconnection time	0.2 s	0.2 s	0.2 s	0.2 s

TABLE IV: Table 4.2 from [1].

In order to verify the voltage trip settings, Appendix I2 of [1] states that ‘The energy source supply shall be varied until the AC output of the device under test equals 50 ±5% of its rated current output’. For the tests concerning the verification of the frequency trip settings, Appendix I4 of [1] states that ‘The input supply shall be varied until the AC output of the device under test equals 50 ±5% of its rated output or 10 A, whichever is the lesser’.

In this test procedure, the input power of the inverter has not been set according to the above-mentioned guidelines. A set of commercial inverters with rated power of about 5 kVA were tested. It was decided to tests these inverters at full input power to produce a comparable set of results. Also the inverters which were not behaving ideally at full power were3 also tested for half power.

The input power at which each inverter is tested is specified in the test report of each individual inverter, but generally this does not follow the rule of being half the rated power of the inverter, as stated in [1].

REFERENCES

[1] AS4777.2-2020, "Grid connection of energy systems via inverters. Part 2: Grid protection requirements," 2020. [Online]. Available: https://www.standards.org.au

[2] R. ACS-13038, "Regatron ACS-13038 Datasheet," 2018. [Online]. Available: https://www.regatron.com

[3] Y. WT3000, "Yokogawa WT3000 Datasheet," 2016. [Online]. Available: https://tmi.yokogawa.com

[4] L. HDO4045, "LeCroy HDO4045 Datasheet," 2018. [Online]. Available: http://teledynelecroy.com

50 kVA / 280 Vrms (L-N) / 72 A
TC.ACS Modular Grid Simulator

Mains Requirements and Specifications

Grid Port

Line voltage ..... 3 x 360 – 440 V_{AC}
Line frequency ..... 48 – 62 Hz
Mains connection type ..... 3L+PE (no neutral)
Input current ..... 3 x 85 Arms
Powerfactor ..... 0 − 1
(At nominal power)

Simulation Port: 3L + active N (4 outputs)

Power range ..... 0 - 50 kVA
Voltage range ..... 0 – 280 Vrms (L-N)
Connection type ..... 3L+N+PE
Current range ..... 3 x 0 – 72 A
Frequency range (fundamental wave) ..... 0 – 1000 Hz
Frequency range (full power) ..... 16 – 1000 Hz
Modulation bandwidth ..... 3 kHz
Resolution frequency ..... 0.001 Hz
Accuracy frequency ..... ± 10 ppm
Stability frequency (-30°… 85°) ..... ± 25 ppm
DC offset ..... ≤1 mV
Bidirectional DC operation ..... allowed
..... with power derating (approx. 25 %)

Operating Modes

- Four quadrant simulator mode
- Four quadrant voltage amplifier mode
- Hardware in the loop mode

Static Accuracy

Load regulation CV ..... < ± 0.3% FS
Line regulation CV ..... < ± 0.1% FS

Overloadability

up to 10 s every 600 s ..... 1.5 p.u
up to 1 s every 60 s ..... 2.0 p.u

General Specifications

Efficiency at nominal power ..... 90 %
Weight ..... approx. 135 kg
Width housing ..... (19") 444 mm
Height housing ..... 11 U
Depth with output terminals ..... 634 mm
Operating orientation ..... upside
Storage, transport orientation ..... upside
Noise level ..... ≤74 dB, at 1 m

Ambient Conditions

Operating temperature ..... 5 – 40 °C
Storage temperature ..... -25 – 70 °C
Relative air humidity (non-condensing) ..... 0 – 95 %

Cooling

External liquid cooling or external air to liquid heat-exchange system using temperature-controlled fans.

Heat exchanger
Material ..... Al
Inlet/outlet on rear side size: ..... G ½''
Liquid temperature ..... 15 – 35 °C
Flow ..... ≥ 5 l/min
Pressure max. ..... ≤ 10 bar

Protection

Built-in Protection

Overvoltage protection ..... programmable
Overcurrent protection ..... programmable
short circuit protection ..... Cont. short circuit allowed
Islandig, grid off, requirements for the connection of micro-generators in public grid according VDE 0126/EN 50438.

Type of Protection (according EN 60529)

Basic construction ..... IP 20
Mounted in cabinet ..... up to IP 53

Conformity CE-Marking

EMC Directive

EMC emission ..... EN 61000-6-4
EMC immunity ..... EN 61000-6-2

Low Voltage Directive

Electronic equipment
for use in power installations ..... EN 50178

Standard Programming Interfaces

Control Port Input Functions

Amplifier mode:
Voltage setting L1: 0 – 100 % ..... -10 – +10 V
Voltage setting L2: 0 – 100 % ..... -10 – +10 V
Voltage setting L3: 0 – 100 % ..... -10 – +10 V

Trigger port

Input 1 (Start) ..... TTL
Input 2 (Stop) ..... TTL
Output (programmable) ..... TTL

Control Port Output Functions

Analogue output ..... configurable

RS232

9 pin D-sub connector, female
Isolation to electronics and earth ..... 125 Vrms

Ethernet

Integrated interface ..... planned

TopCon Quadro Power Supply

Programmable High-Power DC Supply

16 kW / 600 VDC / 32 A

TC.P.16.600.400.S

TopCon Quadro Power Supply unit with optional front panel control unit HMI

- Constant voltage (0 – 100 %), constant current (0 – 100 %) and constant power operation (5 – 100%) with automatic and fast crossover and mode indication. Internal resistance simulation.
- Finely graduated product line: 52, 65, 100,130, 200, 400, 500, 600, 800, 1000, 1200 VDC. Power categories of 10, 16, 20 and 32 kW are available for each nominal output voltage.
- Optional extras and accessories complete the product line of power supply units.
- Modular concept for easy power increase: Parallel, series or multiload master-slave-operation for up to eight power supply units.
- High efficiency at a low cost, resulting from the application of innovative IGBT and transformer technology. Primary switched. Galvanic isolated. Full digital control and regulation.
- A user-friendly PC program, the operating and service software TopControl, enables the user to communicate with the power supply.
- TopControl installation file, LabVIEW® and C/C++ API (DLL file) are included in the scope of delivery.
- CE conformity
- Swiss made: Further developed, manufactured and tested in Switzerland by Regatron AG.

Regatron AG
Kirchstrasse 11
CH-9400 Rorschach
Switzerland
Tel +41 71 846 67 67
Fax +41 71 846 67 77
www.regatron.com
topcon@regatron.ch

Mains requirements and output specifications

AC line input

Line voltage	3 x 360 – 440 VAC
Line frequency	48 – 62 Hz
Mains connection type	3L+PE (no neutral)
Input current	3 x 32 Arms [1]
Leakage current L to PE	< 10 mA

Output ratings

Output power range	0 – 16 kW
Output voltage range	0 – 600 VDC
Output current range	0 – 32 A [2]
Internal resistance range	0 – 18750 mΩ [3]

Operating modes

Voltage regulation (CV)	0 – 100 % Umax
Current regulation (CC)	0 – 100 % Imax
Power regulation (CP)	5 – 100 % Pmax

Static accuracy

Load regulation CV, CC	< ± 0,1 % FS [4]
Line regulation CV, CC	< ± 0.1 % FS [5]

Transient response time

Load regulation CV, CC	< 2 ms [6]
Set value tracking CV, CC	< 2 ms [7]

Stability

CV, CC	< ± 0.05 % FS [8]

Temperature coefficient

CV	< 0.02 % FS / °C [9]
CC	< 0.03 % FS / °C [9]

Output ripple

300 Hz Vpp	< 1.1 % FS [10]
300 Hz Vrms	< 0.4 % FS [10]

Output noise

40 kHz – 1 MHz Vpp	< 1.5 V [10]
40 kHz – 1 MHz Vrms	< 0.1 V [10]

Remote sensing

Terminals on rear side	Line voltage drop compensation

General specifications

Efficiency at nominal power	92 %
Weight	44 kg
Width front panel	483 mm
Width housing	(19“) 444 mm
Height front panel	265 mm
Height housing	(6 U) 262 mm
Depth with output terminals	495 mm
Depth housing	450 mm
Line input connections:	terminal block 4 x 10 mm^2
Output terminals:	nickel–plated copper bars, length: 40 mm, 1 hole 9 mm ∅ in each bar

1) At nominal output power and line input voltage 3 x 390 VAC / 50 Hz. Soft-start to limit turn-on surge currents.
2) Current according to the given power limit of the corresponding units.(P=Uout * Iout ≤ 16 kW; for Iout > 27 A --> Uout < 600 V).
3) The maximum value of the internal resistance is automatically calculated via the DC nominal values (Ri [mΩ] = V_{Load} / I_{Load} = 600 VDC / 32 A) or limited by the maximum Ri-value: 32000 [mΩ].
4) Typical value for 0 – 100 % load variation, at constant line input and temperature conditions.
5) Typical value for input voltage variation within 360 – 440 VAC, at constant load and temperature conditions.
6) Typical recovery time to within < ± 5 % band of set value for a load step 10 – 90 %, ohmic load, at constant line input and temperature conditions. Transient response time can be slightly affected by multi-unit operation.
7) Typical recovery time to within < ± 5 % band of set value for a set value step 10 – 90 %, ohmic load, at constant line input and temperature conditions. Transient response time can be slightly affected by multi-unit operation.
8) Maximum drift over 8 hours after 30 minute warm-up time, at constant line input, load and temperature conditions.
9) Typical change of output values versus ambient temperature, at constant line input and load conditions.
10) Typical value at nominal ohmic load, line asymmetry < 1 Vrms.

Non-ohmic loads can lead to deviations in the technical data. All product specifications are subject to change without notification.

Ambient conditions
Operating temperature ..... 5 – 40°C
Storage temperature..... -25 – 70°C
Relative air humidity (non-condensing) ..... 0 – 95 %
Cooling
Standard: internal temperature-controlled fans
Optional: integrated liquid cooling of the power stage, heat exchanger material: AC100 (Al-Ti-alloy), inlet / outlet on rear side, size: G 1/2"

Protection

Built-in protection
Overvoltage protection (programmable).....0 – 110 % Umax
Overcurrent protection (programmable).....0 – 110 % Imax
Max. reactive load voltage.....≤ 110 % Umax
Short circuit protection..... Cont. short circuit allowed
Internal diagnostics: line input conditions, transformer primary current, temperature conditions, processor idle time, system configuration, system communication, sensor signals, power semiconductors

Type of protection (IEC 60529)
Basic construction .....IP 20 (current bars on rear side excluded)
Mounted in cabinet ..... Up to IP 53

Conformity CE-Marking

EMC Directive
EMC emission .....EN 61000-6-4
EMC immunity .....EN 61000-6-2
Low Voltage Directive
Electronic equipment for use in power installations ..... EN 50178

Isolation
Line to case/ logic.....1670 VDC 1s
Output to case/ logic.....2540 VDC 1s
Output to case ..... > 10 MΩ
per DC bar ..... 13.6 nF
- bar [16] .....+ 1000 VDC / - 1000 VDC
+ bar [16] .....+ 1500 VDC / - 1000 VDC

Standard programming interfaces

Control port
Isolation to electronics and earth: 125 Vrms
25 pin D-sub connector, female, on rear panel

Control port input functions
Output voltage on / off .....0 / 24 VAC / DC
2 digital application inputs ..... 0 / 24 VAC / DC [12]
Interlock circuit.....0 / 24 VDC
Voltage setting 0 – 100 %..... 0 – 10 V
Current setting 0 – 100 % ..... 0 – 0 V
Power setting 0 – 100 %..... 10 – 0 V
Int. resistance setting 0 – 1000 mΩ [3] ..... 0 – 10 V

Control port output functions
Unit ready / error..... Relay contact
Output voltage on ..... Relay contact
Temperature warning ..... Relay contact
Actual voltage readback 0 – 100 %..... 0 – 10 V
Actual current readback 0 – 100 %..... 0 – 10 V
Resolution (programming and readback): U, I, P, Ri ..... 0.2 % FS

Standard programming interfaces (continued)

RS232
9 pin D-sub connector, female, on front panel
Isolation to electronics and earth ..... 125 Vrms
Baud rate .....38400 baud
Resolution (programming and readback):
U, I .....0.025 % FS
P, Ri .....0.1 % FS

Ordering Information

Ordering code
TC.P.16.600.400.S(.Option)

Standard Scope of delivery
TopCon power supply unit ready to install, including:
..... Operating manual (English or German)
..... RS232 cable 1.8 m
.....Installation disc TopControl,
.....LabVIEW® and C/C++ API (DLL file)

Options

Front panel control unit HMI
Integrated control, programming and display unit with graphic LC-Display, select wheel, push buttons and interactive text menus
Languages (switchable) .....English, German
Display resolution:
U ..... 4 digits
I..... 3 digits
P ..... Kilowatt + 1 decimal digit
Ri .....1 mΩ

Remote control unit RCU
Specifications same as HMI, available in 2 versions:
..... desk top and 19“ rackmount
max. cable length.....40 m
Desk top W x H x D..... 355 x 100 x 290 mm
19“ rackmount W x H x D .. 483 x 133 (3 U) x 290 mm

Further options
TFEAAP ..... Function Generating Engine Time-based and parametric programming
SASControl [12] ..... SAS application program including TFEAAP
BatControl [12] ..... Battery application program
BatSim [12] ..... Battery simulation program
CapSim [12] ..... Capacitor simulation program
RS232REAR [13] ..... RS-232 on front and rear panel
USB [14] ..... USB on rear panel
RS422 [13] ..... RS-422 on rear panel
ETHERNET [14] ..... Ethernet on rear panel
IEEE [14] ..... GPIB/ IEEE488.2/ SCPI on rear panel
....cannot be combined with CANOPEN nor with USB
CANOPEN [14] ..... CAN/ CANOPEN on rear panel
CANmp ..... CANmp on rear panel
OptoLink [14] ..... OptoLink on rear panel
CANCABLE..... Connecting cable
..... for Multi-Unit Operation or RCU: 2, 5, 10 m
PACOB ..... Protection against accidental contact
LCAL..... Integrated liquid cooling of the power stage, inlet / outlet on rear side, size G 1/2"
AIRFILTER ..... Front panel airfilter 6 U
ISR.....2 channel Integrated Safety Relay
NSOV.....Non-Standard output voltage

11) Ambient temperature or CDF restrictions: refer to output ratings.
12) Customer-specificly programmable.
13) This option and RS232: time-shared mode required, if used together.
14) RS232 only on Rear Panel.
15) Please order option RS232REAR separately.
16) Peak Voltage including DC-Output Voltage.

Linear Post-Processor Unit

for Regatron Power Supplies

45 A/22 A/1000 VDC

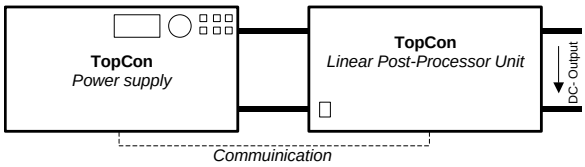
TC.LIN.SER.45.1000.45

Linear Post-Processor Unit

Features

- The *Linear Post-Processor Unit* combines the advantages of a primary switched power supply like high efficiency, small outline, leight weight, cost efficiency, with the fast, smoth linear controlled output capability of a linear power supply.
- To be used in combination with TopCon power supplies.
- Modular concept for easy power increase: Parallel, master-slave-operation of power supplies and *Linear Post-Processor Units*.
- Very fast digital controller features quick response time, enhanced dynamics and programmable control characteristics.
- User-friendly PC program available. This enables the user to communicate over the power supply to the *Linear Post-Processor Unit*.[1)]
- Seamless integration into the well established TopControl software.
- Swiss made: developed, manufactured and tested in Switzerland by Regatron AG.

System Configuration (single Modules)



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Input requirements and output specifications

Mains input data (Auxiliary Supply)

Voltage	85 – 264 V_{AC}
Frequency	48 – 62 Hz
Input power	120 W

DC Input ratings

Input voltage	0 – 1000 V_{DC}
Input current	45 A_{DCmax}
Leakage current DC to PE	< 10 mA

Output ratings

Output voltage range	0 – 1000 V_{DC} [2)]
Drop Voltage (typical)	35 V [3)]
Output current full range	0 – 45 A [4)]
Output current half range	0 – 22 A
Output Capacitor	< 10 nF

Dissipation Power

Continous power diss.	1500 W [5)]
Power diss. < 3 Min	2000 W [6)]
Transient power diss.	Full SOA protection

Operating modes

AAP[7)] current regulation	0 – 100 % I_{max} @0 – (V_{max}-V_{Drop})

Resolution

Voltage, current resolution	14.5 Bit [8)]

Static accuracy

Load regulation	< ± 0.05 % FS typ.[9)]
Line regulation	< ± 0.05% FS typ.[10)]

Transient response time

Load regulation	< 10 µs [11)]
Set value tracking	< 50 µs [12)]

Stability

	< ± 0.02 % FS [13)]

Temperature coefficient

Current, voltage	< 0.01 % FS/°C [14)]

Remote sensing

Terminals on rear side	cable voltage drop compensation

General specifications

Weight	23 kg
Width front panel	483 mm
Width housing	444 mm (19“)
Height front panel	265 mm
Height housing	262 mm (6 U)
Depth with output terminals	485 mm
Depth housing	450 mm
DC input terminals max (DC+, DC-, PE)	3 x 25 mm^2
DC Output terminals max (DC+, DC-, PE)	3 x 25 mm^2
Remote Sensing terminals max (DC+,DC-)	2 x 10 mm^2

1) Most commonly used parameter are accessible via PC Program TopControl connected to TopCon power supply.
2) Maximum Output Voltage = Input Voltage – Drop Voltage.
3) Adjustable Value, the Drop Voltage influences directly the power dissipation.
4) Full Range / Half Range are selectable by PC program TopControl.
5) At ambient temperature 25 °C, for *current half range* 60 % of specified value.
6) For Drop Voltage < 250 V_{DC}, for *current half range* 50 % of specified value.
7) Application Area Programming, e.g. I(U) curves of solar panel / solar array.
8) Improved by using oversampling technics.
9) Typical value for 60 % to 70 % load variation, at voltage drop and temperature conditions.
10) Typical value for variation within 20 V to 60 V drop voltage, at constant load and temperature conditions.
11) Typical recovery time to within < ± 2 % band of set value for a load step 60 % to 70 %, ohmic load, voltage drop > 30 V and constant temperature conditions.
12) Typical recovery time to within < ± 2 % band of set value for a set value step 60 % to 70 %, ohmic load, voltage drop > 30 V and constant temperature conditions. line input and temperature conditions. Transient response time can be slightly affected by multi-unit operation.
13) Maximum drift over 6 hours after 30 minute warm-up time, at constant line input, load and temperature conditions.
14) Typical change of output values versus ambient temperature, at constant line input and load conditions.

Ambient conditions
Operating temperature ..... 5 – 40 °C
Storage temperature..... -25 – 70 °C
Relative air humidity ..... 0 – 95 %
(non-condensing)

Cooling
Fans ..... internal temperature-controlled

Safety

Type of protection (IEC 60529)
Basic construction .....IP 20
Mounted in cabinet .....up to IP 53

Isolation
Line to output (auxiliary supply).....4000 V_{rms}
Line to case (auxiliary supply) .....2500 V_{rms}
DC-Input, Output to case:.....± 1000 V_{DC}, > 10 MΩ

Conformity CE-Marking

EMC Directive
EMC emission .....EN 61000-6-4
EMC immunity .....EN 61000-6-2
Low Voltage Directive
Electronic equipment
for use in power installations ..... EN 50178

Standard programming interfaces

Control port
Isolation to electronics and earth: ..... 125 V_{rms}
Connector .....15 pin D-sub, female
.....on rear panel

Control port
Input functions .....Future use
Output functions .....Future use

Standard programming interfaces (continued)

RS232
Isolation to electronics and earth: ..... 125 V_{rms}
Connector .....9 pin D-sub, female
.....on rear panel
Baud rate .....38400 baud
Resolution (programming and readback):
U, I .....0.005 % FS

Ordering code
TC.LIN.SER.45.1000.45

Scope of delivery
TopCon Linear Post-Processor Unit ready to install, including:
Operating manual language..... english
RS232 cable length..... 1.8 m
CAN bus .....CAN cable
..... CANTerm Connector

Software
TopControl ..... on Installation disc
API (DLL file)..... for LabVIEW® and C/C++
..... (and other programming languages,
.....to be used incombination
..... with TopCon Power Supplies.)

TELEDYNE LECROY
Everywhereyoulook™

DEBUG IN HIGH DEFINITION

HDO4000A

200 MHz – 1 GHz
Oscilloscopes

HD 4096

Lowest Noise and Powerful Toolbox

- HD4096 Technology
- Superior User Experience
- Powerful, Deep Toolbox
- Exceptional Serial Data Tools

The HDO4000A with HD4096 Technology provides exceptional signal fidelity with 12-bit resolution and a superior oscilloscope experience to deliver faster time to insight.

teledynelecroy.com/hdo

DEBUG IN HIGH DEFINITION

High Definition Oscilloscopes with HD Technology have a variety of benefits that allow the user to debug in high definition. Waveforms displayed by High Definition Oscilloscopes are cleaner and crisper. More signal details can be seen and measured; these measurements are made with unmatched precision resulting in better test results and shorter debug time.

Experience HD4096 accuracy, detail, and precision and never use an 8-bit oscilloscope again. Whether the application is general-purpose design and debug, high-precision analog, power electronics, automotive electronics, mechatronics, or other specialized applications, the HD4096 technology provides unsurpassed confidence and measurement capabilities.

Clean, Crisp Waveforms

When compared to waveforms acquired and displayed using conventional 8-bit oscilloscopes, waveforms captured with HD4096 12-bit technology are dramatically crisper and cleaner, and are displayed more accurately.

More Signal Details

16x more resolution provides more signal detail. This is especially helpful for wide dynamic range signals in which a full-scale signal must be acquired while at the same time very small amplitude signal details must be analyzed.

Unmatched Measurement Precision

HD4096 technology delivers measurement precision several times better than conventional 8-bit oscilloscopes. Higher oscilloscope measurement precision provides better ability to assess corner cases and design margins, perform root cause analysis, and create the best possible solution for any discovered design issue.

	HDO4000A	HDO6000A	HDO8000A	HDO9000
HD Technology	**HD4096** **12 bits**	HD4096 12 bits	HD4096 12 bits	HD1024 10 bits
Bandwidth	**200 MHz - 1 GHz**	350 MHz - 1 GHz	350 MHz - 1 GHz	1 GHz - 4 GHz
Input Channels	**4**	4	8	4
Sample Rate	**10 GS/s**	10 GS/s	10 GS/s	40 GS/s
Standard Toolbox	**Basic**	Advanced	Advanced	Advanced
Serial Data Tools	**TD**	TDME	TDME	TDME, SDAII, QPHY
User Experience	**MAUI with OneTouch**	MAUI with OneTouch	MAUI with OneTouch	MAUI with OneTouch

HD1024

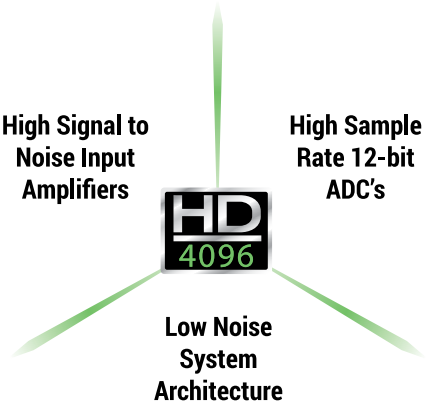
HD1024 technology provides 10 bits of vertical resolution with 4 GHz bandwidth. As with all members of Teledyne LeCroy's HDO family, the HDO9000 utilizes an exceptionally low-noise system architecture that delivers outstanding effective number of bits (ENOB). Dynamic ADC Configuration permits the ADC to be set to 8, 9, or 10 bits. Optimized filtering provides additional resolution beyond 10 bits (extending up to 13.8 bits).

DEBUG IN HIGH DEFINITION

Lowest Noise and Powerful Toolbox

HDO4000A

HD4096
High Definition Technology



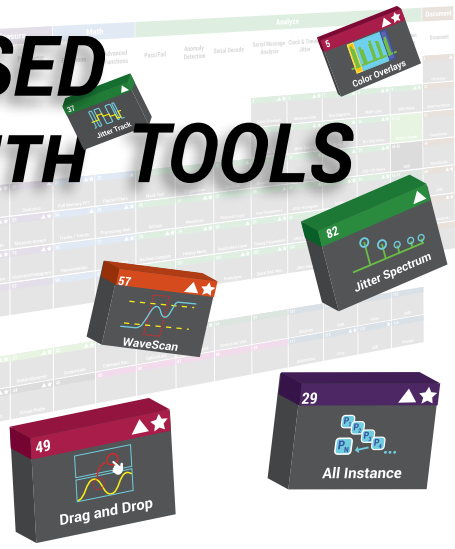
HD4096 technology enables 12 bits of vertical resolution with 1 GHz bandwidth

- Clean, Crisp Waveforms
- More Signal Details
- Unmatched Measurement Precision

Deep Toolbox

OBSESSED WITH TOOLS

HDO4000A has the greatest breadth and depth of tools, ensuring quick resolution of the most complicated debug tasks.



The HDO4000A with **HD4096 Technology** provides **exceptional signal fidelity** with 12-bit resolution and a **superior oscilloscope experience** to deliver **faster time to insight.**

1. HD4096 Technology
2. Superior User Experience
3. Powerful, Deep Toolbox
4. Exceptional Serial Data Tools

Faster Time to Insight

Insight alone is not enough. Markets and **technologies** change too rapidly. The **timing** of **critical design decisions** is significant.

Faster Time to Insight is what matters.

TIME TO **INSIGHT**™

MAUI® – SUPERIOR USER EXPERIENCE

MAUI – Most Advanced User Interface was developed to put all the power and capabilities of the modern oscilloscope right at your fingertips. Designed for touch; all important oscilloscope controls are accessed through the intuitive touch screen. Built for simplicity; time saving shortcuts and intuitive dialogs simplify setup. Made to solve; a deep set of debug and analysis tools helps identify problems and find solutions quickly.

Designed for Touch

MAUI is designed for touch. Operate the oscilloscope just like a phone or tablet with the most unique touch screen features on any oscilloscope. All important controls are always one touch away. Touch the waveform to position or zoom in for more details using intuitive actions.

Built for Simplicity

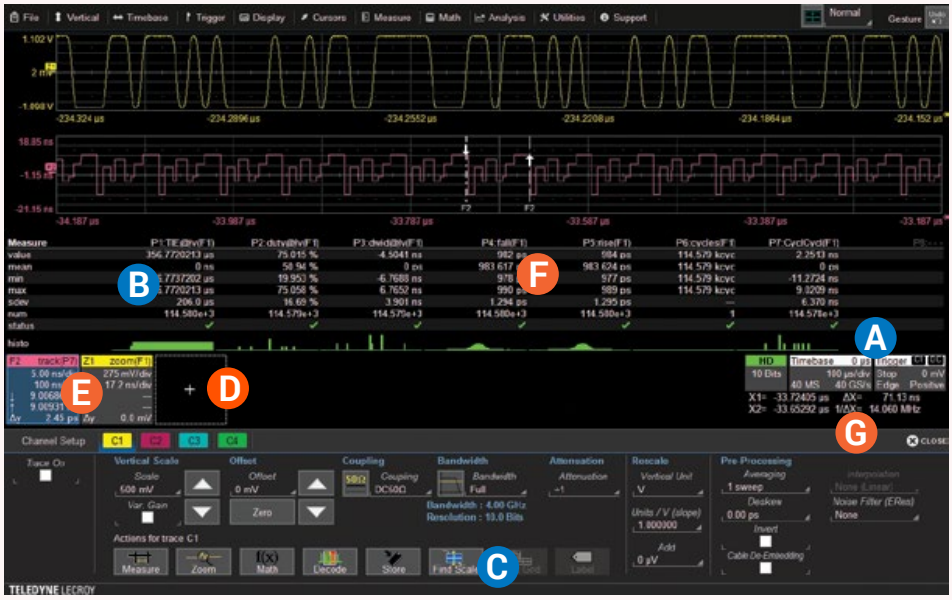
MAUI is built for simplicity. Basic waveform viewing and measurement tools as well as advanced math and analysis capabilities are seamlessly integrated in a single user interface. Time saving shortcuts and intuitive dialogs simplify setup and shorten debug time.

Made to Solve

MAUI is made to solve. A deep set of integrated debug and analysis tools help identify problems and find solutions quickly. Unsurpassed integration provides critical flexibility when debugging. Solve problems fast with powerful analysis tools.

MAUI with OneTouch

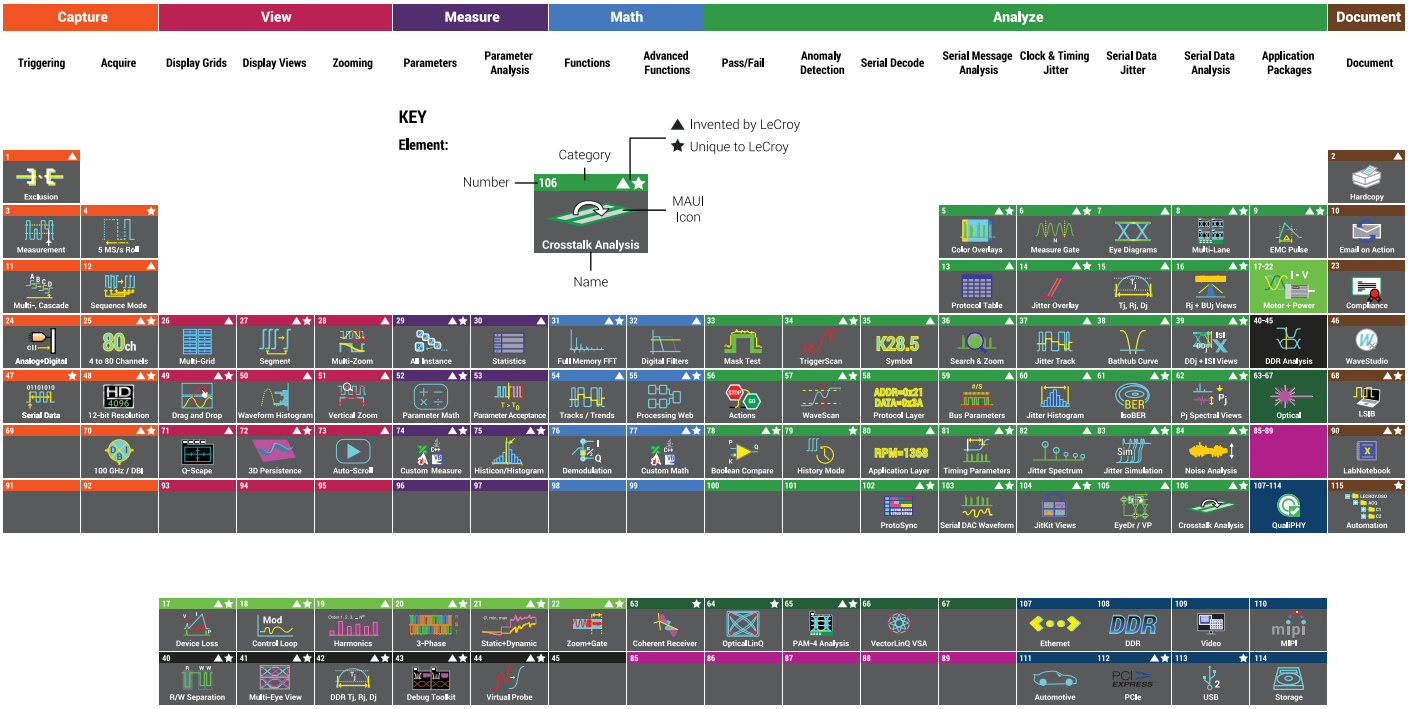
MAUI with OneTouch introduces a new paradigm for oscilloscope user experience. Dramatically reduce setup time with revolutionary drag and drop actions to copy and setup channels, math functions, and measurement parameters without lifting a finger. Use common gestures like drag, drop, and flick to instinctively interact with the oscilloscope. Quickly enable a new channel, math or measurement using the "Add New" button and simply turn off any trace with a flick of the finger. These OneTouch innovations provide unsurpassed efficiency in oscilloscope operation.



- **A** Channel, timebase, and trigger descriptors provide easy access to controls without navigating menus.
- **B** Configure parameters by touching measurement results.
- **C** Shortcuts to commonly used functions are displayed at the bottom of the channel, math and memory menus.
- **D** Use the "Add New" button for one-touch trace creation.
- **E** Drag to change source, copy setup, turn on new trace, or move waveform location.
- **F** Drag to copy measurement parameters to streamline setup process.
- **G** Drag to quickly position cursors on a trace.

MAUI *Unique to OneTouch*

POWERFUL, DEEP TOOLBOX



Our Heritage

Teledyne LeCroy's 50+ year heritage has its origins in the high-speed collection of data in the field of high-energy physics, and the processing of long records to extract meaningful insight. We didn't invent the oscilloscope, but we did invent the digital oscilloscope, which can take full advantage of advanced digital signal processing and waveshape analysis tools to provide unparalleled insight.

Our Obsession

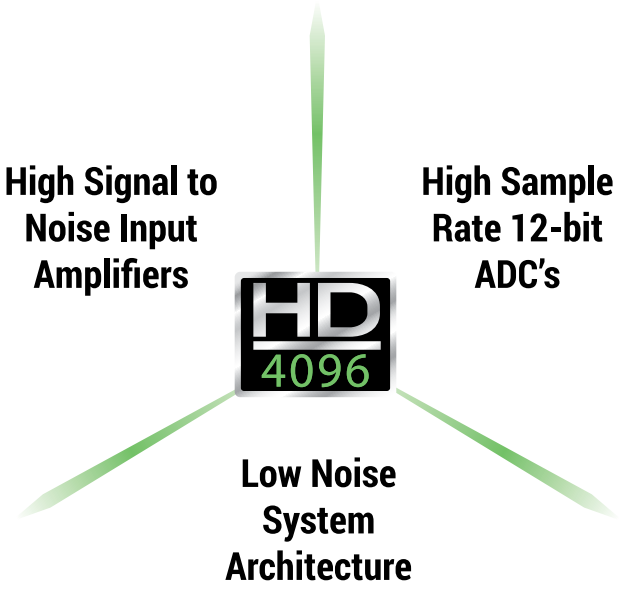
Our developers are true to our heritage – they are more obsessed with making better and smarter tools than anybody else. Our tools and operating philosophy are standardized across much of our product line for a consistent user experience. Our mission is to help you use these tools to understand problems, including the ones you don't even know you have. Our deep toolbox inspires insight; and your moment of insight is our reward.

Our Invitation

Our Periodic Table of Oscilloscope Tools provides a framework to understand the toolsets that Teledyne LeCroy has created and deployed in our oscilloscopes. Visit our interactive website to learn more about what we offer and how we can help you develop and debug more efficiently.

teledynelecroy.com/tools

HD4096 TECHNOLOGY – 16X CLOSER TO PERFECT

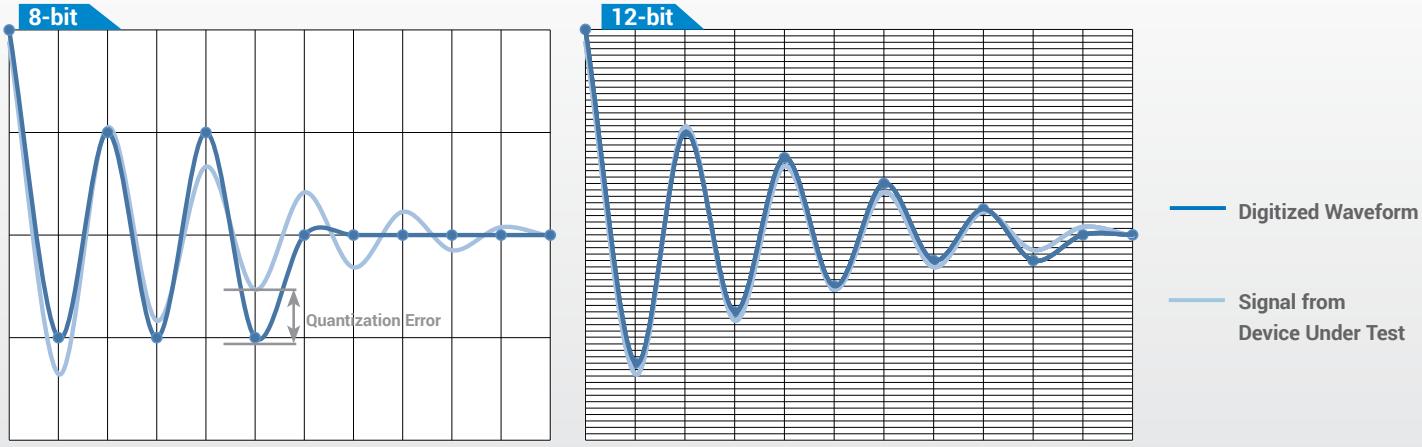


Teledyne LeCroy HDO high definition oscilloscopes use unique HD4096 technology to provide superior and uncompromised measurement performance:

- **12-bit ADCs with high sample rates**
- **High signal-to-noise amplifiers (55 dB)**
- **Low noise system architecture (to 1 GHz)**

Oscilloscopes with HD4096 technology have higher resolution than conventional 8-bit oscilloscopes (4096 vs. 256 vertical levels) and low noise for uncompromised measurement performance. The 12-bit ADCs support capture of fast signals and oscilloscope bandwidth ratings up to 1 GHz, and Enhanced Sample Rate to 10 GS/s ensures the highest measurement accuracy and precision. The high performance input amplifiers deliver pristine signal fidelity with a 55 dB signal-to-noise ratio. The low-noise system architecture provides an ideal signal path to ensure that signal details are delivered accurately to the oscilloscope display – 16x closer to perfect.

16x Closer to Perfect



16x More Resolution

HD4096 technology provides 12-bits of vertical resolution with 16x more resolution compared to conventional 8-bit oscilloscopes. The 4096 discrete vertical levels reduce the quantization error compared to 256 vertical levels. This improves the accuracy and precision of the signal capture and increases measurement confidence.

EXPERIENCE THE DIFFERENCE

Experience HD4096 accuracy, detail, and precision and never use an 8-bit oscilloscope again. Whether the application is general-purpose design and debug, high-precision analog, power electronics, automotive electronics, mechatronics, or other specialized applications, the HD4096 technology provides unsurpassed confidence and measurement capabilities.

Clean, Crisp Waveforms

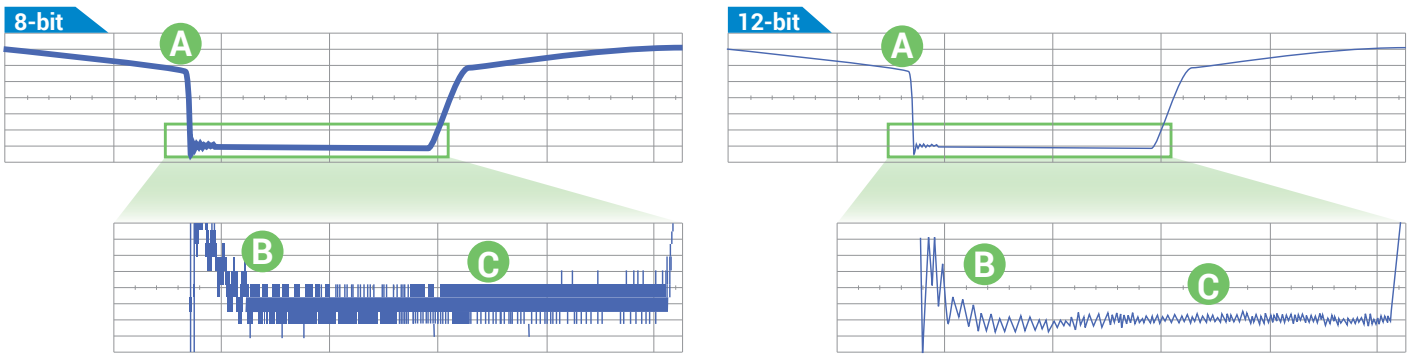
When compared to waveforms acquired and displayed using conventional 8-bit oscilloscopes, waveforms captured with HD4096 12-bit technology are dramatically crisper and cleaner, and are displayed more accurately. Once you see a waveform acquired with HD4096 technology, you will not want to go back to using a conventional 8-bit oscilloscope.

More Signal Details

16x more resolution provides more signal detail. This is especially helpful for wide dynamic range signals in which a full-scale signal must be acquired while at the same time very small amplitude signal details must be analyzed. 12-bit acquisitions combined with the oscilloscope's vertical and horizontal zoom can be used to obtain unparalleled insight to system behaviors and problems.

Unmatched Measurement Precision

HD4096 technology delivers measurement precision several times better than conventional 8-bit oscilloscopes. Higher oscilloscope measurement precision provides better ability to assess corner cases and design margins, perform root cause analysis, and create the best possible solution for any discovered design issue.



A **Clean, Crisp Waveforms** | Thin traces show the actual waveform with minimal noise interference

B **More Signal Details** | Waveform details lost on an 8-bit oscilloscope can now be clearly seen

C **Unmatched Measurement Precision** | Measurements are more precise and not affected by quantization noise

HDO4000A AT A GLANCE

HDO4000A oscilloscopes have 4 analog input channels, 12-bit resolution using Teledyne LeCroy's HD4096 high definition technology, up to 1 GHz of bandwidth and a compact form factor with a large 12.1" multi-touch display. They are ideal for debug and troubleshooting of power electronics designs, digital power management or power integrity analysis, automotive electronics systems, and deeply embedded or mechatronic designs.

Key Features

4 analog channels

12-bit ADC resolution, up to 15-bit with enhanced resolution

200 MHz, 350 MHz, 500 MHz and 1 GHz bandwidths

Long Memory – up to 50 Mpts

Multi-language User Interface

WaveScan - Search and Find

LabNotebook Documentation and Report Generation

History Mode

Spectrum Analyzer Mode

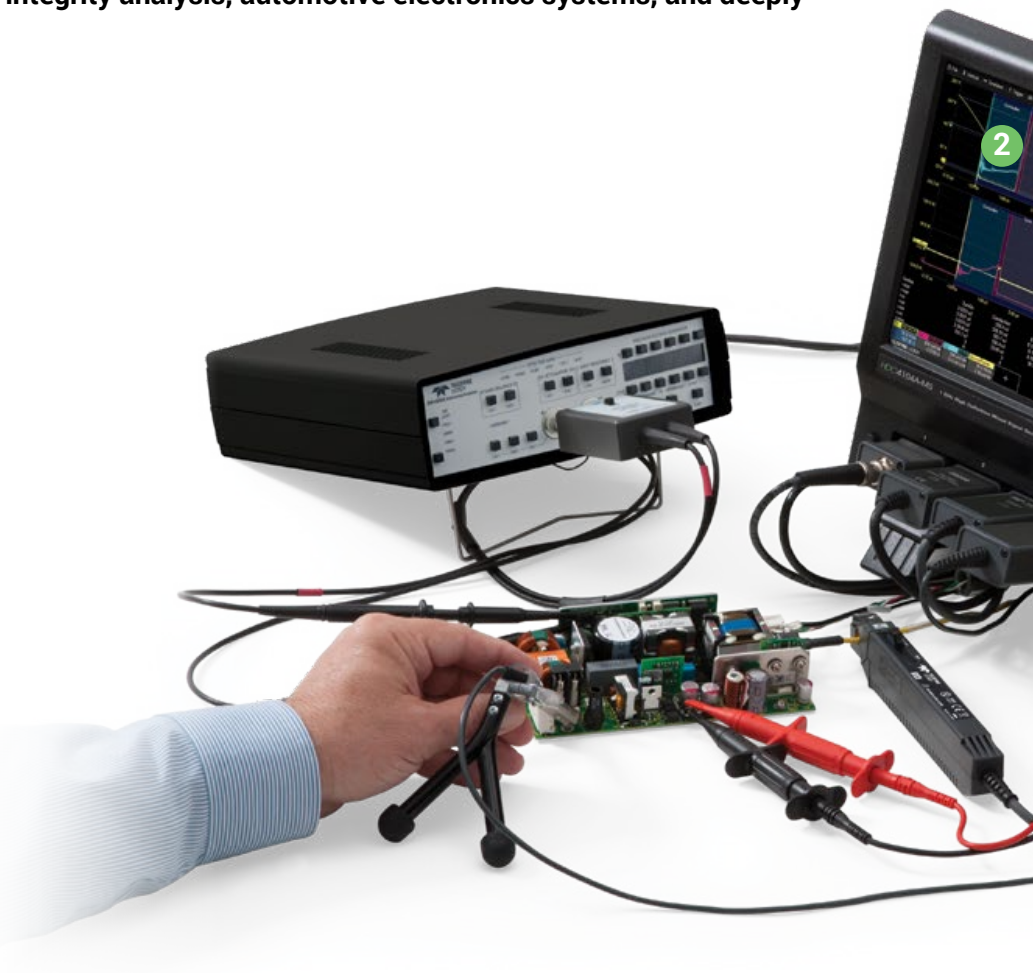
Power Analysis Software

16 Digital Channel MSO option

Serial Trigger and Decode options

12.1" WXGA multi-touch screen display

Wide probe selection for power electronics, embedded electronics, and mechatronics applications



Power Electronics

Measure single-device(s), half, or Full/H-bridge outputs, including gate-drive voltages. Measure device loss or switch-mode power supply power or control loop performance, including line harmonics. The best performing HV probes support full characterization of all aspects of the power conversion system.

Automotive Electronics

Automotive electronic control units (ECUs) are tested to stringent standards. 12-bits and 250 Mpts provides the amplitude and time resolution needed for better and more intuitive cause-effect analog signal analysis. Deep digital logic capture and extensive serial data toolsets provides an all-in-one characterization tool for the complex, dynamic behavior of the vehicle ECUs.

1. Only 13 cm (5”) Deep – The most space-efficient oscilloscope for your bench from 200 MHz to 1 GHz
2. 12.1” Widescreen (16 x 9) high resolution WXGA color multi-touch screen display.
3. Built-in stylus for touch screen
4. Local language user interface front panel overlay
5. “Push” Knobs – All knobs have push functionality that provides shortcuts to common actions such as Set to Variable, Find Trigger Level, Zero Offset, and Zero Delay
6. Waveform Control Knobs for channel, zoom, math and memory traces
7. Dedicated buttons to quickly access popular debug tools
8. Easy connectivity with two convenient USB ports on the front, two on the side
9. Mixed Signal Capability - Debug complex embedded designs with integrated 16 channel mixed signal capability
10. Rotating and Tilting Feet provide 4 different viewing positions
11. Auxiliary Output and Reference Clock Input/Output connectors for connecting to other equipment
12. USBTMC (Test and Measurement Class) port simplifies programming

Digital Power Management, Power Integrity

12-bit accuracy and precision and 1 GHz of bandwidth is perfect for transient rail response, rail voltage power integrity, crosstalk and harmonics evaluation. Specialized probes, analysis software, and serial decoders make fast work of complex embedded system power management and integrity validation.

Deeply Embedded and Mechatronic Systems

Today’s consumer appliances and industrial systems combine complex embedded controls, power electronics, and sensors to achieve the highest efficiency and provide important control and other benefits. Time-to-market, cost and quality pressures place exceptional demands on new product test, debug and troubleshooting.

POWERFUL MIXED SIGNAL CAPABILITIES

The HDO4000A High Definition Oscilloscopes offer powerful mixed signal solutions that combine high definition analog channels with the flexibility of digital inputs. The HDO4000A-MS options provide an integrated 16 digital channels and a 1.25 GS/s sampling rate to create an all-in-one debug machine.

Integrated 16-Channel Mixed Signal Capability

With embedded systems growing more complex, powerful mixed signal debug capabilities are an essential part of modern oscilloscopes. The 16 integrated digital channels and set of tools designed to view, measure and analyze analog and digital signals enable fast debugging of mixed signal designs.

Extensive Triggering

Flexible analog and digital cross-pattern triggering across all 20 channels provides the ability to quickly identify and isolate problems in an embedded system. Event triggering can be configured to arm on an analog signal and trigger on a digital pattern.

Advanced Digital Debug Tools

Using the powerful parallel pattern search capability of WaveScan, patterns across many digital lines can be isolated and analyzed. Identified patterns are presented in a table with timestamp information and enables quick searching for each pattern occurrence.

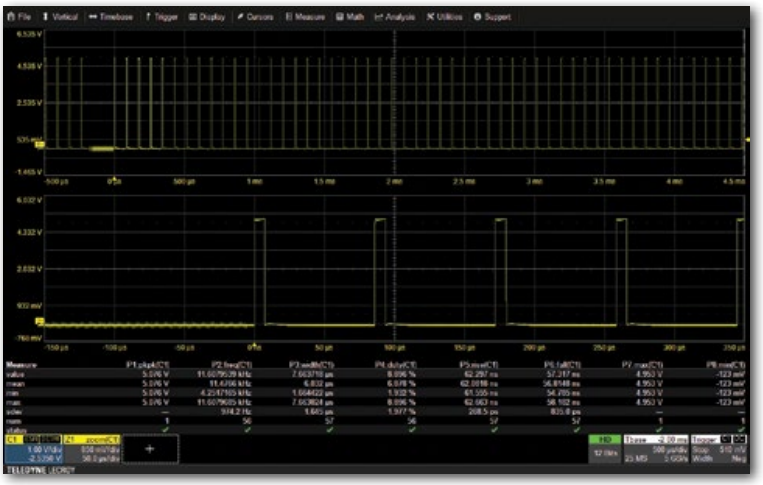
Use a variety of the many timing parameters to measure and analyze the characteristics of digital busses. Powerful tools like tracks, trends, statistics and histicons provide additional insight and help find anomalies.

Quickly see the state of all the digital lines at the same time using convenient activity indicators.

STANDARD TOOLS FOR ADVANCED ANALYSIS

WaveScan Advanced Search

WaveScan provides powerful isolation capabilities that hardware triggers can't provide. WaveScan allows searching analog, digital or parallel bus signal in a single acquisition using more than 20 different criteria. Or, set up a scan condition and scan for an event over hours or even days.



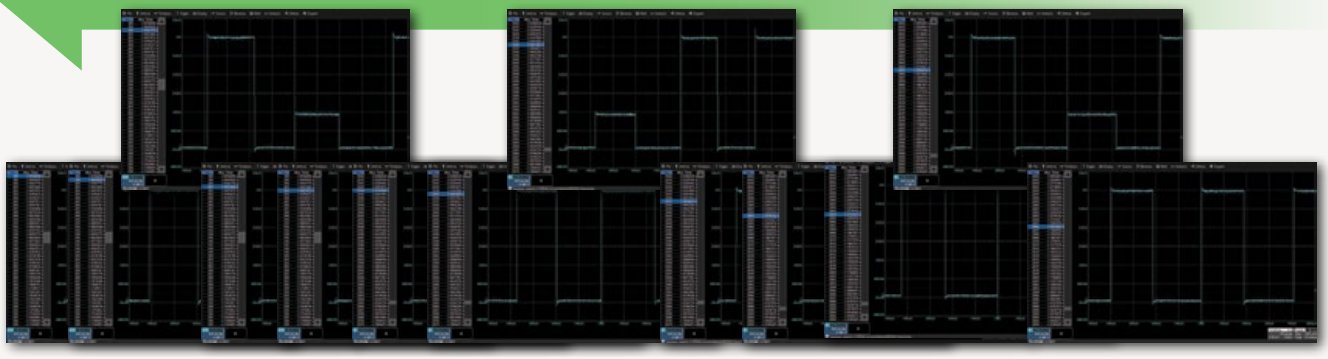
Advanced Math and Measure

With many math functions and measurement parameters available, the HDO4000A can measure and analyze every aspect of analog and digital waveforms. By utilizing HD4096 technology, the HDO4000A measures 16 times more precisely than traditional 8-bit architectures. Additionally, the HDO4000A provides statistics, histicons and trends to show how waveforms change over time.

History Mode Waveform Playback

Scroll back in time using History Mode to view previous waveforms and isolate anomalies. Use cursors and measurement parameters to quickly find the source of problems. History mode is always available with a single button press, no need to enable this mode and never miss a waveform.

Go Back in Time to Identify the Source of a Problem

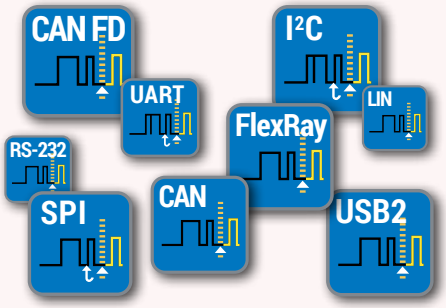


EXCEPTIONAL SERIAL DATA TOOLS

The HDO4000A features the widest range and most complete serial data debug toolsets.

- Triggering
- Decoding

	HDO4000A Serial Data Protocol Support	Trigger	Decode
Embedded Computing	I²C	•	•
	SPI	•	•
	UART-RS232	•	•
	USB2-HSIC		•
Automotive + Industrial	CAN	•	•
	CAN FD	•	•
	FlexRay	•	•
	LIN	•	•
	SENT		•
Avionics	ARINC429		•
	MIL-STD-1553	•	•
	SPACEWIRE		•
Computing + Peripherals	Ethernet (10/100Base-T)		•
	MDIO		•
	USB 1.1/2.0	•	•
	8b/10b	•	•
MIPI	D-PHY/CSI-2/DSI		•
	DigRF3G		•
	DigRFv4		•
	SPMI		•
Other	Audio (I²S, LJ, RJ, TDM)	•	•
	Manchester		•
	NRZ	•	•



Trigger

Powerful, flexible triggers designed by people who know the standards, with the unique capabilities you want to isolate unusual events. Conditional data triggering permits maximum flexibility and highly adaptable error frame triggering is available to isolate error conditions. Efficiently acquire bursted data using Sequence Mode to maximize the oscilloscope's memory usage. Sequence Mode enables the oscilloscope to ignore idle time and acquire only data of interest.

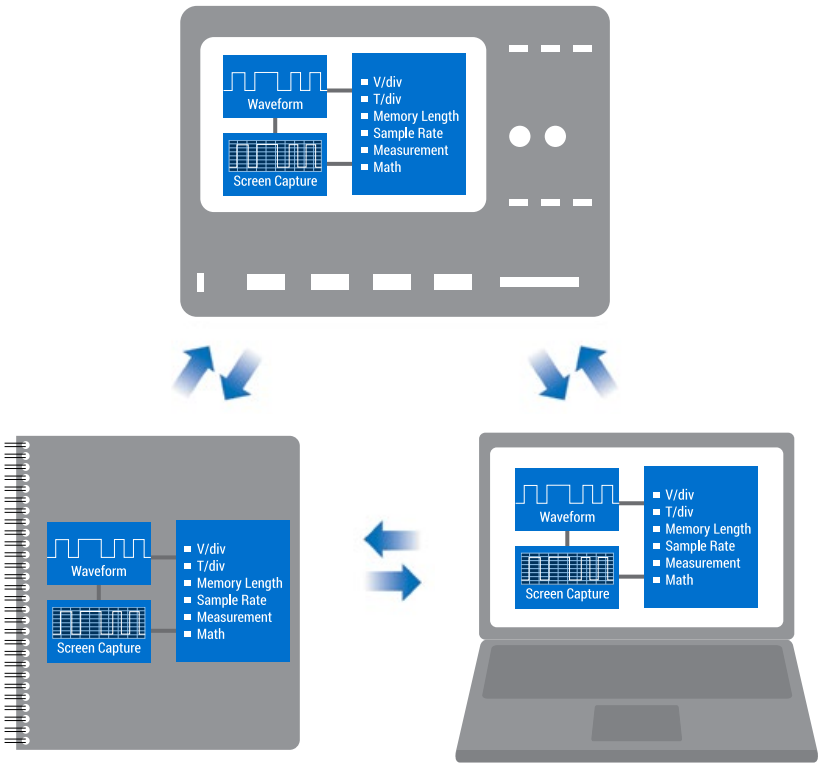
Decode

Decoded protocol information is color-coded to specific portions of the serial data waveform and transparently overlaid for an intuitive, easy-to-understand visual record. All decoded protocols are displayed in a single time-interleaved table. Touch a row in the interactive table to quickly zoom to a packet of interest and select a column header to create filter criteria, as is commonly done in spreadsheets. Easily search through long records for specific protocol events using the built-in search feature.

DOCUMENTATION AND SEQUENCE MODE

LabNotebook Documentation Tool

LabNotebook is a standard feature of HDO4000A and is the ideal documentation tool. LabNotebook automatically saves all displayed waveforms, oscilloscope setup file, and a screen image with a single button press, eliminating the need to navigate multiple menus to save all these files independently. Report files can be annotated and shared with colleagues to fully document all results. Easily recreate experiments and compare tests results amongst colleagues across the world by recalling LabNotebook files back onto the oscilloscope or view on a PC using WaveStudio.



Advanced Waveform Capture with Sequence Mode

Use Sequence mode to store up to 10,000 triggered events as segments. This is ideal when capturing fast pulses in quick succession or when capturing events separated by long time periods. Each segment has a timestamp and dead-time between triggers is less than 1 µs. Isolate rate events over time by combining with advanced triggers.

SPECTRUM ANALYZER OPTION

Key Features

Spectrum analyzer style controls for the oscilloscope

Dual Spectrum Capability

Select from six vertical scales (in dB, V, or A)

Automatic frequency peak identifications

Display up to 20 markers, with interactive table readout of frequencies and levels

Easily make measurements with reference and delta markers

Automatically identify and mark fundamental frequency and harmonics

Spectrogram shows how spectra changes over time in 2D or 3D views

Use two independent input settings and frequency ranges for advanced spectrum analysis.

Simplify Analysis of FFT Power Spectrum

Get faster and better insight to the frequency content of any signal with use of the Spectrum Analyzer mode on the HDO4000A. This mode provides a spectrum analyzer style user interface with controls for start/stop frequency or center frequency and span. The resolution bandwidth is automatically set for best analysis or can be manually selected. Peak search automatically labels spectral components and presents frequency and level in an interactive table. Utilize up to 20 markers to automatically identify harmonics and quickly analyze frequency content by making measurements between reference and delta markers. Spectrograms display a 2D or 3D history of the frequency content to provided insight into how the spectrum changes over time.

Spectrum analyzer style controls simplify waveform analysis in the frequency domain.

POWER ANALYSIS OPTION

Key Features

Automated measurement zone identification with color-coded overlays

Control loop and time domain response analysis

Line power and harmonics tests to IEC 61000-3-2

Total harmonic distortion table shows frequency contribution

B-H Curve shows magnetic device saturation

Power Analyzer Automates Switching Device Loss Measurements

Quickly measure and analyze the operating characteristics of power conversion devices and circuits with the Power Analyzer option. Critical power switching device measurements, control loop modulation analysis, and line power harmonic testing are all simplified with a dedicated user interface and automatic measurements. Areas of turn-on, turn-off, and conduction loss are all identified with color-coded waveform overlays for faster analysis.

Power Analyzer provides quick and easy setup of voltage and current inputs and makes measurements as simple as the push of a button. Tools are provided to help reduce sources of measurement errors and the measurement parameters provide details of single cycle or average device power losses.

Beyond the advanced power loss measurement capabilities, the Power Analyzer modulation analysis capabilities provide insight to understand control loop response to critical events such as a power supply's soft start performance or step response to line and load changes. The Line Power Analysis tool allows simple and quick pre-compliance testing to EN 61000-3-2.

PROBES

Teledyne LeCroy offers an extensive range of probes to meet virtually every probing need.

ZS Series High Impedance Active Probes ZS1000, ZS1000-QUADPAK ZS1500, ZS1500-QUADPAK		High input impedance (1 MΩ), low 0.9 pF input capacitance and an extensive set of probe tips and ground accessories make these low-cost single-ended probes ideal for a wide range of applications. The ZS Series is available up to 4 GHz bandwidth.
Differential Probes (200 MHz – 1.5 GHz) ZD1500, ZD1000, ZD500, ZD200 AP033		High bandwidth, excellent common-mode rejection ratio (CMRR) and low noise make these active differential probes ideal for applications such as automotive electronics and data communications. AP033 provides 10x gain for high-sensitivity measurement of series/shunt resistor voltages.
Active Voltage/Power Rail Probe RP4030		Specifically designed to probe a low impedance power/voltage rail. The RP4030 has 30V built-in offset adjust, low attenuation (noise), and high DC input impedance with 4 GHz of bandwidth and a wide assortment of tips and leads, including solder-in and U.FL receptacle connections.
High Voltage Fiber Optically-isolated Probe HVFO103		The HVFO103 is a compact, simple, affordable probe for measurement of small signals (gate-drives, sensors, etc.) floating on an HV bus in power electronics designs, or for EMC, EFT, ESD, and RF immunity testing sensor monitoring. Suitable for up to 35kV common-mode. 140 dB CMRR.
HVD Series High Voltage Differential Probes HVD3102, HVD3106 (1 kV) HVD3206 (2 kV) HVD3605 (6 kV)		Available with 1, 2 or 6kV common-mode ratings. Excellent CMRR (65 dB @ 1 MHz) at high frequencies is combined with low inherent noise, wide differential voltage range, high offset voltage capabilities, and 1% gain accuracy. The ideal probe for power conversion system test.
High Voltage Passive Probes HVP120, PPE4KV, PPE5KV, PPE6KV		The HVP and PPE Series includes four fixed-attenuation probes covering a range from 1 kV to 6 kV. These probes are ideal for lightning/surge or EFT testing, or for probing in-circuit beyond the range of a LV-rate passive probe.
Differential Amplifier DA1855A DXC100A, DXC200 DXC-5100, DA101		The DA1855A is a stand-alone high performance 100 MHz differential amplifier with 100 dB CMRR and HV common-mode when combined with a suitable probe pair (sold separately). It is ideal for semiconductor device conduction/switching loss or high sensitivity voltage measurements.
Current Probes CP030, CP030-3M, CP030A CP031, CP031A CP150, CP150-6M CP500, DCS015		Available in bandwidths up to 100 MHz with peak currents of 700 A and sensitivities to 1 mA/div. Extra-long cables (3 or 6 meters) available on some models. Ideal for component or power conversion system input/output measurements. DCS015 deskew calibration source also available.
Probe and Current Sensor Adapters TPA10, TPA10-QUADPAK CA10, CA10-QUADPAK		TPA10 adapts supported Tektronix TekProbe-compatible probes to Teledyne LeCroy ProBus interface. CA10 is a programmable adapter for third-party current sensors that have voltage or current outputs proportional to measured current. QUADPAKs of four pieces each are available.

SPECIFICATIONS

Vertical - Analog Channels	HDO4024A HDO4024A-MS	HDO4034A HDO4034A-MS	HDO4054A HDO4054A-MS	HDO4104A HDO4104A-MS
Bandwidth @ 50 Ω (-3 dB)	200 MHz	350 MHz	500 MHz	1 GHz
Rise Time (10–90%, 50 Ω)	1.75 ns	1 ns	700 ps	450 ps
Input Channels	4			
Vertical Resolution	12-bits; up to 15-bits with enhanced resolution (ERES)			
Effective Number of Bits (ENOB)	8.8 bits	8.7 bits	8.6 bits	8.4 bits
Vertical Noise Floor				
1 mV/div	70 µVrms	85 µVrms	100 µVrms	145 µVrms
2 mV/div	70 µVrms	85 µVrms	100 µVrms	145 µVrms
5 mV/div	75 µVrms	90 µVrms	105 µVrms	150 µVrms
10 mV/div	80 µVrms	95 µVrms	110 µVrms	155 µVrms
20 mV/div	100 µVrms	110 µVrms	130 µVrms	185 µVrms
50 mV/div	195 µVrms	210 µVrms	265 µVrms	275 µVrms
100 mVdiv	340 µVrms	360 µVrms	450 µVrms	500 µVrms
200 mV/div	1.00 mVrms	1.10 mVrms	1.25 mVrms	1.75 mVrms
500 mV/div	1.90 mVrms	2.10 mVrms	2.60 mVrms	2.75 mVrms
1 V/div	3.40 mVrms	3.70 mVrms	4.50 mVrms	4.90 mVrms
Sensitivity	50 Ω: 1 mV/div–1 V/div, fully variable; 1 MΩ: 1 mV/div–10 V/div, fully variable			
DC Vertical Gain Accuracy (Gain Component of DC Accuracy)	±(0.5%) F.S, offset at 0 V			
Channel-Channel Isolation	DC-200 MHz: 60 dB (>1000:1), (For any two input channels, same V/div settings, typical)	DC-200 MHz: 60 dB (>1000:1), 200 MHz up to rated BW: 50 dB (>300:1), (For any two input channels, same V/div settings, typical)	DC-200 MHz: 60 dB (>1000:1), 200 MHz up to rated BW: 50 dB (>300:1), (For any two input channels, same V/div settings, typical)	DC-200 MHz: 60 dB (>1000:1), 200-500 MHz: 50 dB (>300:1), 500 MHz up to rated bandwidth: 40 dB (>100:1) (For any two input channels, same V/div settings, typical)
Offset Range	50 Ω: 1 mV - 4.95 mV: ±1.6 V, 5 mV - 9.9 mV: ±4 V, 10 mV - 19.8 mV: ±8 V, 20 mV - 1 V: ±10 V 1 MΩ: 1 mV - 4.95 mV: ±1.6 V, 5 mV - 9.9 mV: ±4 V, 10 mV - 19.8 mV: ±8 V, 20 mV - 100 mV: ±16 V, 102 mV - 198 mV: ±80V, 200 mV - 1 V: ±160 V, 1.02 V -10 V: ±400 V			
DC Vertical Offset Accuracy	±(1.0% of offset setting + 0.5%FS + 0.02% of max offset + 1mV)			
Maximum Input Voltage	50 Ω: 5 Vrms, 1 MΩ: 400 V max (DC + Peak AC ≤ 10 KHz)			
Input Coupling	50 Ω: DC, GND; 1 MΩ: AC, DC, GND;			
Input Impedance	50 Ω ± 2.0%;1 MΩ ± 2.0% || 16 pF,			
Bandwidth Limiters	20 MHz, 200 MHz			

Horizontal - Analog Channels

Acquisition Modes	Real-time, Roll, Random Interleaved Sampling (RIS), Sequence
Time/DIvision Range	200 ps/div - 1.25 ks/div with standard memory (up to 2.5 ks/div with -L memory); RIS available at ≤ 10 ns/div; Roll Mode available at ≥ 100 ms/div and ≤ 5 MS/s
Clock Accuracy	±2.5 ppm + 1.0ppm/year from calibration
Sample Clock Jitter	Up to 10 ms acquired time range: 280 fsrms (internal timebase reference)
Delta Time Measurement Accuracy	$\sqrt{2} * \sqrt{\left(\frac{Noise}{SlewRate}\right)^2 + (Sample\ Clock\ Jitter)^2}$ (RMS) + (clock accuracy * reading) (seconds)
Jitter Measurement Floor	$\sqrt{\left(\frac{Noise}{SlewRate}\right)^2 + (Sample\ Clock\ Jitter)^2}$ (RMS, seconds, TIE)
Jitter Between Channels	Analog Channels: 2 psrms (TIE, typical); Digital Channels: 350 ps (maximum) between any two channels Analog-Digital Channels: <5ns (maximum) between any analog and any digital channel
Channel-Channel Deskew Range	±9 x time/div. setting, 100 ms max., each channel
External Timebase Reference (Input)	10 MHz ±25 ppm at 0 to 10 dBm into 50 Ω
External Timebase Reference (Output)	10 MHz, 2.0 dBm ±1.5 dBm, sinewave synchronized to reference being used (internal or external reference)

Acquisition - Analog Channels

Sample Rate (Single-shot)	10 GS/s on all 4 Channels with Enhanced Sample Rate
Sample Rate (Repetitive)	125 GS/s, user selectable for repetitive signals (20 ps/div to 10 ns/div)
Memory Length (# of Segments in Sequence Mode)	Standard: 12.5 Mpts/ch for all channels, 25 Mpts (interleaved) (10,000 segments) Option - L: 25 Mpts/ch for all channels, 50 Mpts (interleaved) (10,000 segments)
Intersegment Time	1 µS
Averaging	Summed averaging to 1 million sweeps; continuous averaging to 1 million sweeps
Enhanced Resolution (ERES)	From 12.5- to 15-bits vertical resolution
Envelope (Extrema)	Envelope, floor, or roof for up to 1 million sweeps
Interpolation	Linear or Sin x/x (2 pt and 4 pt); 5 or 10 GS/s Enhanced Sample Rate defaults to 2 pt or 4 pt Sin x/x respectively

SPECIFICATIONS

	HDO4024A HDO4024A-MS	HDO4034A HDO4034A-MS	HDO4054A HDO4054A-MS	HDO4104A HDO4104A-MS
Vertical, Horizontal, Acquisition - Digital Channels (with HDO4000A-MS only)				
Input Channels	16 Digital Channels			
Threshold Groupings	Pod 2: D15 - D8, Pod 1: D7 - D0			
Threshold Selections	TTL, ECL, CMOS (2.5 V, 3.3 V, 5 V), PECL, LVDS or User Defined			
Maximum Input Voltage	±30V Peak			
Threshold Accuracy	±(3% of threshold setting + 100mV)			
Input Dynamic Range	± 20V			
Minimum Input Voltage Swing	400mV			
Input Impedance (Flying Leads)	100 kΩ || 5 pF			
Maximum Input Frequency	250 MHz			
Sample Rate	1.25 GS/s			
Record Length	Standard: 12.5 MS (25 MS interleaved) - 16 Channels Optional -L: 25 MS (50 MS interleaved) - 16 Channels			
Minimum Detectable Pulse Width	2 ns			
Channel-to-Channel Skew	350 ps			
User Defined Threshold Range	±10 V in 20 mV steps			
User Defined Hysteresis Range	100 mV to 1.4 V in 100 mV steps			
Triggering System				
Modes	Normal, Auto, Single, and Stop			
Sources	Any input channel, External, Ext/10, or line; slope and level unique to each source (except for line trigger)			
Coupling	DC, AC, HFRej, LFRej			
Pre-trigger Delay	0-100% of memory size (adjustable in 1% increments of 100 ns)			
Post-trigger Delay	0-10,000 Divisions in real time mode, limited at slower time/div settings or in roll mode			
Hold-off	From 2 ns up to 20 s or from 1 to 99,999,999 events			
Trigger and Interpolator Jitter	≤ 4 ps rms (typical)	≤ 4 ps rms (typical)	≤ 3.5 ps rms (typical)	≤ 3.5 ps rms (typical)
Internal Trigger Level Range	±4.1 div from center (typical)			
External Trigger Input Range	Ext: ±400 mV, Ext/10: ±4 V			
Maximum Trigger Rate	1,000,000 waveforms/sec (in Sequence Mode, up to 4 channels)			
Trigger Sensitivity with Edge Trigger (Ch 1–4)	0.9 division: 10 MHz 1.0 divisions: 200 MHz	0.9 division: 10 MHz 1.0 divisions: 200 MHz 2.0 divisions: 350 MHz	0.9 division: 10 MHz 1.0 divisions: 200 MHz 1.5 divisions: 250 MHz 2.0 divisions: 500 MHz	0.9 division: 10 MHz 1.0 divisions: 200 MHz 1.5 divisions: 500 MHz 2.0 divisions: 1 GHz
Trigger Sensitivity with Edge Trigger (External Input)	0.9 division: 10 MHz 1.0 divisions: 200 MHz 2	0.9 division: 10 MHz 1.0 divisions: 200 MHz 2.0 divisions: 350 MHz	0.9 division: 10 MHz 1.0 divisions: 200 MHz 1.5 divisions: 250 MHz 2.0 divisions: 500 MHz	0.9 division: 10 MHz 1.0 divisions: 200 MHz 1.5 divisions: 500 MHz 2.0 divisions: 1 GHz
Max. Trigger Frequency, Smart Trigger	200 MHz	350 MHz	500 MHz	1 GHz
Trigger Types				
Edge	Triggers when signal meets slope (positive, negative, or either) and level condition			
Width	Triggers on positive or negative glitches with selectable widths. Minimum width 1.5ns, Maximum width: 20 s			
Glitch	Triggers on positive or negative glitches with selectable widths. Minimum width 1.5ns, Maximum width: 20 s			
Window	Triggers when signal exits a window defined by adjustable thresholds			
Pattern	Logic combination (AND, NAND, OR, NOR) of up to 5 inputs (4 channels and external trigger input). Each source can be high, low, or don't care. The High and Low level can be selected independently. Triggers at start or end of the pattern.			
TV-Composite Video	Triggers NTSC or PAL with selectable line and field; HDTV (720p, 1080i, 1080p) with selectable frame rate (50 or 60 Hz) and Line; or CUSTOM with selectable Fields (1–8), Lines (up to 2000), Frame Rates (25, 30, 50, or 60 Hz), Interlacing (1:1, 2:1, 4:1, 8:1), or Synch Pulse Slope (Positive or Negative)			
Runt	Trigger on positive or negative runts defined by two voltage limits and two time limits. Select between 1 ns and 20 ns			
Slew Rate	Trigger on edge rates. Select limits for dV, dt, and slope. Select edge limits between 1 ns and 20 ns			
Interval	Triggers on intervals selectable between 1 ns and 20 s			
Dropout	Triggers if signal drops out for longer than selected time between 1 ns and 20 s			
Triggers with Exclusion Technology	Glitch, Width, Interval, Runt, Slew Rate - Trigger on intermittent faults by specifying the expected behavior and triggering when that condition is not met			
Qualified (Timeout or State/Edge Qualified)	Triggers on any input source only if a defined state or edge occurred on another input source. Delay between sources is selectable by time or events. (Note: event B pattern trigger cannot include analog channels).			
Low Speed Serial Protocol Trigger (Optional)	I2C, SPI (SPI, SSPI, SIOP), UART-RS232, CAN1.1, CAN2.0, CAN FD, LIN, FlexRay, MIL-STD-1553, AudioBus (I2S, LJ, RJ, TDM), USB1.x/2.0			

SPECIFICATIONS

	HDO4024A HDO4024A-MS	HDO4034A HDO4034A-MS	HDO4054A HDO4054A-MS	HDO4104A HDO4104A-MS
Measurement Tools				
Measurement Functionality	Display up to 8 measurement parameters together with statistics, including mean, minimum, maximum, standard deviation, and total number. Each occurrence of each parameter is measured and added to the statistics table. . Histicons provide a fast, dynamic view of parameters and wave shape characteristics. Parameter gates define the location for measurement on the source waveform.			
Measurement Parameters - Horizontal + Jitter	Delay (from trigger, 50%), Duty Cycle (50%, @level), Edges (@level),Fall Time (90-10, 20-80), Frequency (50%, @level), Period (50%, @level), Δ Period (@level), Phase (@level), Rise Time (10-90, 20-80), Skew, Time (@level), Δ Time (@level), Width+, Width-			
Measurement Parameters - Vertical	Amplitude, Base, Maximum, Mean, Minimum, Peak-to-Peak, RMS, Std. Deviation, Top.			
Measurement Parameters - Pulse	Area, Base, Fall Time (90-10, 80-20), Overshoot (positive, negative), Rise Time (10-90, 80-20), Top, Width+, Width-			
Math Tools				
Math Functionality	Display up to 2 math functions traces (F1-F2). The easy-to-use graphical interface simplifies setup of up to two operations on each function trace, and function traces can be chained together to perform math-on-math.			
Math Operators - Basic Math	Average (summed), Average (continuous), Difference (–), Envelope, Floor, Invert (negate), Product (x), Ratio (/), Reciprocal, Rescale (with units), Roof, Sum (+).			
Math Operators - Filters	Enhanced resolution (to 15 bits vertical)			
Math Operators - Frequency Analysis	FFT (power spectrum, magnitude), up to full record length. Select from Rectangular, VonHann, Hamming, FlatTop and Blackman Harris windows.			
Math Operators - Functions	Absolute value, Derivative, Integral, Invert (negate), Reciprocal, Rescale (with units), Square, Square root, Zoom (identity).			
Measurement and Math Integration				
	Trend (datalog) of up to 1 million measurement parameters.			
Pass/Fail Testing				
Pass/Fail Testing	Mask Test (pre-defined or user-defined mask, waveform All In, All Out, Any In, or Any Out conditions) with following THEN Save (waveforms), Stop, Alarm, (send) Pulse, Hardcopy (send email, save screen image, save to clipboard, send to printer), or (save) LabNotebook.			
Display System				
Display Size	Color 12.1" widescreen flat panel TFT-Active Matrix with high resolution touch screen			
Display Resolution	WXGA; 1280 x 800 pixels			
Number of Traces	Display a maximum of 8 traces. Simultaneously display channel, zoom, memory, math, and X-Y traces			
Grid Styles	Auto, Single, Dual, Quad, Octal, Tandem, Quattro, X-Y, Single+X-Y, Dual+X-Y			
Waveform Representation	Sample dots joined, or sample dots only			

SPECIFICATIONS

	HDO4024A HDO4024A-MS	HDO4034A HDO4034A-MS	HDO4054A HDO4054A-MS	HDO4104A HDO4104A-MS
Processor/CPU				
Type	Intel® Core™ i3-2330E Dual, 2.2 GHz (or better)			
Processor Memory	8 GB standard standard			
Operating System	Microsoft Windows® 7 Pro 64-Bit Embedded			
Oscilloscope Operating Software	Teledyne LeCroy MAUI™ with OneTouch			
Connectivity				
Ethernet Port	Supports 2 10/100/1000BaseT Ethernet interface (RJ45 ports)			
USB Host Ports	Minimum 6 total (incl. 2 front panel) USB 2.0 ports support Windows compatible devices			
USB Device Port	1 USBTMC port			
GPIB Port (Optional)	Supports IEEE – 488.2 (External)			
External Monitor Port	DVI connector, HDMI connector and 15 pin D-Type WXGA compatible DB-15 to support customer-supplied external monitor. Includes support for extended desktop operation with WXGA resolution on second monitor. Supports touch screen integration of external monitor (Note: external display can not use a Fujitsu touch-screen driver).			
Remote Control	Via Windows Automation, or via Teledyne LeCroy Remote Command Set			
Probes				
Standard Probes	Qty. (4) ÷10 Passive Probes			
Probing System	ProBus. Automatically detects and supports a variety of compatible probes			
Power Requirements				
Voltage	100–240 VAC ±10% at 45-66 Hz; 110-120 VAC ±10% at 380-420 Hz; Automatic AC Voltage Selection; Installation Category 300 V CAT II			
Power Consumption (Nominal)	200 W / 200 VA			
Max Power Consumption	320 W / 320 VA (with all PC peripherals and active probes connected to 4 channels)			
Environmental				
Temperature	Operating: 5 °C to 40 °C; Non-Operating: -20 °C to 60 °C			
Humidity	Operating: 5% to 90% relative humidity (non-condensing) up to +31 °C, Upper limit derates to 50% relative humidity (non-condensing) at +40 °C; Non-Operating: 5% to 95% relative humidity (non-condensing) as tested per MIL-PRF-28800F			
Altitude	Operating: 3,048 m (10,000 ft) max at +30 °C; Non-Operating: Up to 12,192 meters (40,000 ft)			
Random Vibration	Operating : 0.31 g_{rms} 5 Hz to 500 Hz, 15 minutes in each of three orthogonal axes; Non-Operating: 2.4 g_{rms} 5 Hz to 500 Hz, 15 minutes in each of three orthogonal axes			
Functional Shock	30 g_{peak}, half sine, 11 ms pulse, 3 shocks (positive and negative) in each of three orthogonal axes, 18 shocks total			
Physical				
Dimensions (HWD)	11.48"H x 15.72"W x 5.17"D (291.7 mm x 399.4 mm x 131.31 mm)			
Weight	12.9 lbs. (5.86 kg.)			
Certifications				
CE Certification UL and cUL Listing	CE Compliant, UL and cUL listed, confirms to: UL 61010-1 (3rd Edition), UL 61010-2-030 (1st Edition) CAN/CSA C22.2 No.61010-1-12			
	CE Compliant, UL and cUL listed, confirms to: UL 61010-1 (3rd Edition), UL 61010-2-030 (1st Edition) CAN/CSA C22.2 No.61010-1-12			
Warranty and Service				
	3-year warranty; calibration recommended annually. Optional service programs include extended warranty, upgrades, and calibration services			

ORDERING INFORMATION

Product Description	Product Code
HDO4000A Oscilloscopes	
200 MHz, 10 GS/s, 4 Ch, 12.5 Mpts/Ch 12-bit HD Oscilloscope with 12.1" WXGA Touch Display	HDO4024A
350 MHz, 10 GS/s, 4 Ch, 12.5 Mpts/Ch 12-bit HD Oscilloscope with 12.1" WXGA Touch Display	HDO4034A
500 MHz, 10 GS/s, 4 Ch, 12.5 Mpts/Ch 12-bit HD Oscilloscope with 12.1" WXGA Touch Display	HDO4054A
1 GHz, 10 GS/s, 4 Ch, 12.5 Mpts/Ch 12-bit HD Oscilloscope with 12.1" WXGA Touch Display	HDO4104A
HDO4000A-MS Mixed Signal Oscilloscopes	
200 MHz, 10 GS/s, 4+16ch, 12.5 Mpts/Ch 12-bit HD Mixed Signal Oscilloscope w/ 12.1" WXGA Color Display	HDO4024A-MS
350 MHz, 10 GS/s, 4+16ch, 12.5 Mpts/Ch 12-bit HD Mixed Signal Oscilloscope w/ 12.1" WXGA Color Display	HDO4034A-MS
500 MHz, 10 GS/s, 4+16ch, 12.5 Mpts/Ch 12-bit HD Mixed Signal Oscilloscope w/ 12.1" WXGA Color Display	HDO4054A-MS
1 GHz, 10 GS/s, 4+16ch, 12.5 Mpts/Ch 12-bit HD Mixed Signal Oscilloscope w/ 12.1" WXGA Color Display	HDO4104A-MS
Included with Standard Configurations (HDO4000A and HDO4000A-MS)	
÷10 Passive Probe (Total of 1 Per Channel), Getting Started Guide, Anti-virus Software (Trial Version), Microsoft Windows Embedded Standard 7 P 64-Bit License, Commercial NIST Traceable Calibration with Certificate, Power Cable for the Destination Country, Protective Front Cover, 3-year Warranty	
Included with HDO4000A-MS	
16 Channel Digital Leadset, Extra Large Gripper Probe Set (Qty. 22), Ground Extenders (Qty. 20), Flexible Ground Leads (Qty. 5)	
Memory Option	
25 Mpts/ch (50 Mpts interleaved) memory	HDO4KA-L
Hardware Options	
Removable Solid State Drive Package (includes removable solid state drive kit and two solid state drives)	HDO4KA-RSSD
Additional Removable Solid State Drive	HDO4KA-RSSD-02
General Accessories	
External GPIB Accessory	USB2-GPIB
Soft Carrying Case	HDO4K-SOFTCASE
Rack Mount Accessory	HDO4K-RACK
Accessory Pouch	HDO4K-POUCH
Local Language Overlays	
German Front Panel Overlay	HDO4K-FP-GERMAN
French Front Panel Overlay	HDO4K-FP-FRENCH
Italian Front Panel Overlay	HDO4K-FP-ITALIAN
Spanish Front Panel Overlay	HDO4K-FP-SPANISH
Japanese Front Panel Overlay	HDO4K-FP-JAPANESE
Korean Front Panel Overlay	HDO4K-FP-KOREAN
Chinese (Tr) Front Panel Overlay	HDO4K-FP-CHNES-TR
Chinese (Simp) Front Panel Overlay	HDO4K-FP-CHNES-SI
Russian Front Panel Overlay	HDO4K-FP-RUSSIAN

Product Description	Product Code
Software Options	
Electrical Telecom Mask Test Package	HDO4K-ET-PMT
Spectrum Analysis Option	HDO4K-SPECTRUM
Power Analysis Option	HDO4K-PWR
Serial Data Options	
ARINC 429 Symbolic Decode Option	HDO4K-ARINC429bus DSymbolic
Audiobus Trigger and Decode Option for I^2S, LJ, RJ, and TDM	HDO4K-Audiobus TD
CAN, LIN and FlexRay Trigger and Decode Option	HDO4K-AUTO
CAN FD Trigger and Decode Option	HDO4K-CAN FDbus TD
CAN Trigger and Decode Option	HDO4K-CANbus TD
D-PHY Decode Option	HDO4K-DPHYbus D
DigRF 3G Decode Option	HDO4K-DigRF3Gbus D
DigRF v4 Decode Option	HDO4K-DigRFv4bus D
ENET Decode Option	HDO4K-ENETbus D
FlexRay Trigger and Decode Option	HDO4K-FlexRaybus TD
I^2C, SPI and UART Trigger and Decode Option	HDO4K-EMB
I^2C Bus Trigger and Decode Option	HDO4K-I2Cbus TD
LIN Trigger and Decode Option	HDO4K-LINbus TD
MDIO Decode	HDO4K-MDIObus D
Manchester Decode Option	HDO4K-Manchesterbus D
MIL-STD-1553 Trigger and Decode Option	HDO4K-1553 TD
NRZ Decode Option	HDO4K-NRZbus D
SENT Decode Option	HDO4K-SENTbus D
SPI Bus Trigger and Decode Option	HDO4K-SPIbus TD
SPMI Decode	HDO4k-SPMIbus D
SpaceWire Decode Option	HDO4K-SpaceWirebus D
UART and RS-232 Trigger and Decode Option	HDO4K-UART-RS232bus TD
USB 2.0 Trigger and Decode Option	HDO4K-USB2bus TD
USB2-HSIC Decode Option	HDO4K-USB2-HSICbus D

ORDERING INFORMATION

Product Description	Product Code
Probes and Amplifiers	
250 MHz Passive Probe for HDO4000A, 10:1, 10 MΩ	PP017
500 MHz Passive Probe 10:1, 10 MΩ	PP018
500 MHz Passive Probe, 5mm, 10:1, 10 MΩ	PP026
Power/Voltage Rail Probe. 4 GHz bandwidth, 1.2x attenuation, ±30V offset, ±800mV	RP4030
Browser for use with RP4030	RP4000-BROWSER
1,500 V, 120 MHz High-Voltage Differential Probe	HVD3106
1kV, 80 MHz High Voltage Differential Probe with 6m cable	HVD3106-6M
1kV, 120 MHz High Voltage Differential Probe with-out tip Accessories	HVD3106-NOACC
1,500 V, 25 MHz High-Voltage Differential Probe	HVD3102
1kV, 25 MHz High Voltage Differential Probe without tip Accessories	HVD3102-NOACC
2kV, 120 MHz High Voltage Differential Probe	HVD3206
2kV, 80 MHz High Voltage Differential Probe with 6m cable	HVD3206-6M
6kV, 100 MHz High Voltage Differential Probe	HVD3605
High Voltage Fiber Optic Probe, 60 MHz (requires accessory tip)	HVFO103
±1V (1x) Tip Accessory for HVFO103	HVFO100-1X-TIP
±5V (5x) Tip Accessory for HVFO103	HVFO100-5X-TIP
±20V (20x) Tip Accessory for HVFO103	HVFO100-20X-TIP
30 A; 100 MHz Current Probe – AC/DC; 30 A_{rms}; 50 A_{peak} Pulse	CP031
30 A; 100 MHz High Sensitivity Current Probe – AC/DC; 30 A_{rms}; 50 A_{peak} Pulse	CP031A
30 A; 50 MHz Current Probe – AC/DC; 30 A_{rms}; 50 A_{peak} Pulse	CP030
30 A; 50 MHz High Sensitivity Current Probe – AC/DC; 30 A_{rms}; 50 A_{peak} Pulse	CP030A
150 A; 10 MHz Current Probe – AC/DC; 150 A_{rms}; 500 A_{peak} Pulse	CP150
500 A; 2 MHz Current Probe – AC/DC; 500 A_{rms}; 700 A_{peak} Pulse	CP500
Deskew Calibration Source for CP031, CP030 and AP015	DCS015

Product Description	Product Code
Probes and Amplifiers (cont'd)	
500 MHz Differential Probe	AP033
200 MHz, 3.5 pF, 1 MΩ Active Differential Probe, ±20 V, 60V common-mode	ZD200
1 GHz, 1.0 pF, 1 MΩ Active Differential Probe, ±8 V, 10V common-mode	ZD1000
1.5 GHz, 1.0 pF, 1 MΩ Active Differential Probe, ±8 V, 10V common-mode	ZD1500
1 GHz, 0.9 pF, 1 MΩ High Impedance Active Probe	ZS1000
Set of 4 ZS1000	ZS1000-QUADPAK
1.5 GHz, 0.9 pF, 1 MΩ High Impedance Active Probe	ZS1500
Set of 4 ZS1500	ZS1500-QUADPAK
1 Ch, 100 MHz Differential Amplifier with Precision Voltage Source	DA1855A
100:1 or 10:1 Selectable, 250 MHz Passive Diff. Probe Pair	DXC100A
1:1, 50 MHz Passive Differential Probe Pair	DXC200
100:1, 250 MHz, 2.5kV High Voltage Probe Pair	DXC5100
10x, 1 MΩ Passive Attenuator for DXC Series Probes	DA101
100:1 400 MHz 50 MΩ 1 kV High-voltage Probe	HVP120
100:1 400 MHz 50 MΩ 4 kV High-voltage Probe	PPE4KV
1000:1 400 MHz 50 MΩ 5 kV High-voltage Probe	PPE5KV
1000:1 400 MHz 50 MΩ 6 kV High-voltage Probe	PPE6KV
TekProbe to ProBus Probe Adapter	TPA10
Set of 4 TPA10 TekProbe to ProBus Probe Adapters.	TPA10-QUADPAK
Programmable Current Sensor to ProBus Adapter for use with third party current sensors	CA10
Set of 4 CA10 Programmable Current Sensor to ProBus Adapters for use with third party current sensors	CA10-QUADPAK

Customer Service

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Current Probes

Key Features

- **ProBus active probe interface with automatic scaling in A/div**
- **Autozero and degauss capabilities built into instrument's user interface**
- **CP030**
  - 30 A_{rms} continuous current
  - 50 A_{peak} current
  - 50 MHz bandwidth
- **CP030A**
  - 30 A_{rms} continuous current
  - 50 A_{peak} current
  - 50 MHz bandwidth
  - 1 mA/div sensitivity
- **CP031**
  - 30 A_{rms} continuous current
  - 50 A_{peak} current
  - 100 MHz bandwidth
- **CP031A**
  - 30 A_{rms} continuous current
  - 50 A_{peak} current
  - 100 MHz bandwidth
  - 1 mA/div sensitivity
- **CP150**
  - 150 A_{rms} continuous current
  - 500 A_{peak} current
  - 10 MHz bandwidth
- **CP500**
  - 500 A_{rms} continuous current
  - 700 A_{peak} current
  - 2 MHz bandwidth

Teledyne LeCroy current probes do not require the breaking of a circuit or the insertion of a shunt to make accurate and reliable current measurements. Based on a combination of Hall effect and transformer technology, Teledyne LeCroy current probes are ideal for making accurate AC, DC, and impulse current measurements.

Wide Range of Applications

Teledyne LeCroy current probes are available in a variety of models for a wide range of applications. The full range of Teledyne LeCroy current probes includes models with bandwidths up to 100 MHz, peak currents up to 700 A and sensitivities to 1 mA/div. Teledyne LeCroy current probes are often used in applications such as the design and test of switching power supplies, motor drives, electric vehicles, and uninterruptible power supplies.

High Sensitivity

The CP030A and CP031A provide a high sensitivity of 1 mA/div. This allows for more precise low current measurements on Teledyne LeCroy oscilloscopes. When used with HDO high definition oscilloscopes with HD4096 technology, users will obtain highly accurate, low current waveforms with unmatched 12-bit resolution for improved debug and analysis.

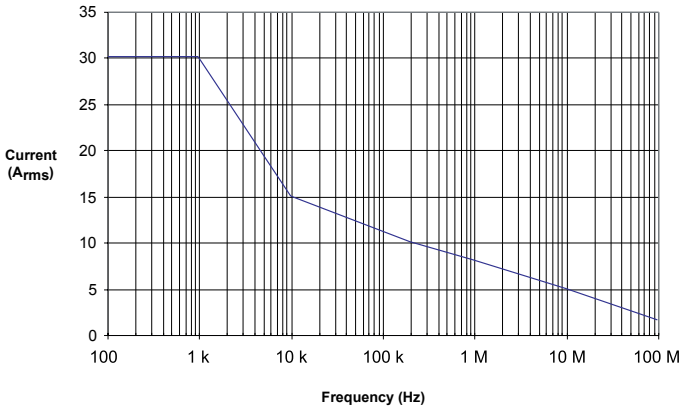
Fully Integrated

All Teledyne LeCroy current probes are powered through the Teledyne LeCroy ProBus® connection and require no additional hardware. Along with providing power, the ProBus connection allows the current probe and oscilloscope to communicate, resulting in current waveforms automatically displayed on screen in Amps, and calculated power traces scaled correctly in Watts. This full integration also allows for Degauss and Autozero functions to be done directly from the oscilloscope's user interface.

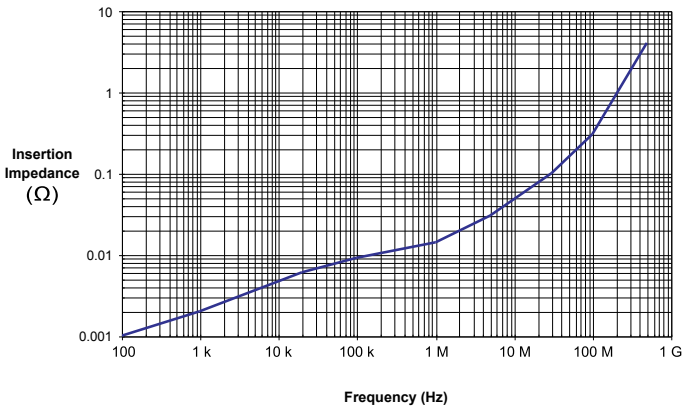
Deskew Calibration Source

The DCS025 deskew calibration source has both voltage and current time-aligned signals, which enables the precise deskew of voltage and current probes. Most voltage probes along with 30, 150 and 500A current probes are compatible with the DSC025.

CP031/ CP031A

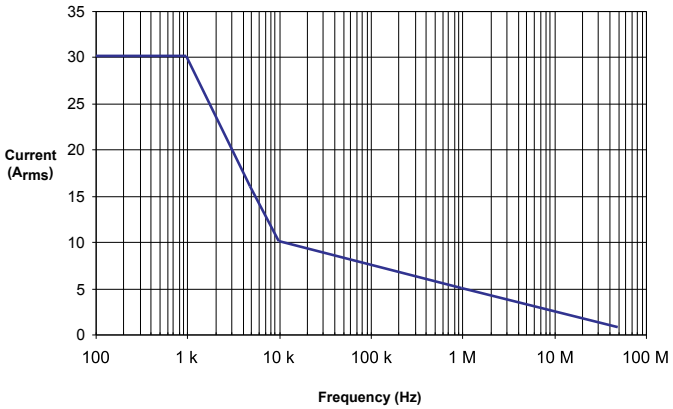


Maximum Input Current vs. Frequency

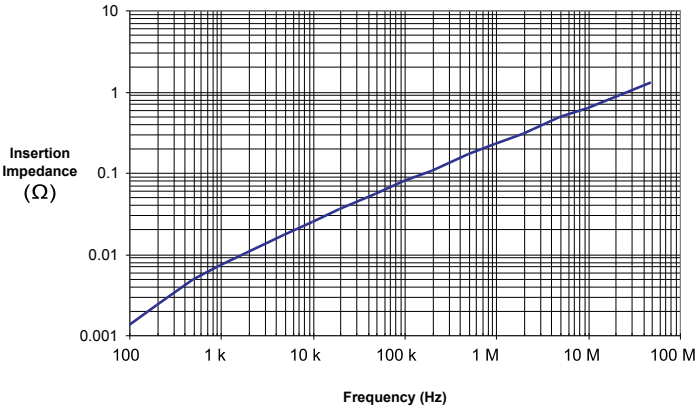


Insertion Impedance vs. Frequency (typical)

CP030 / CP030A



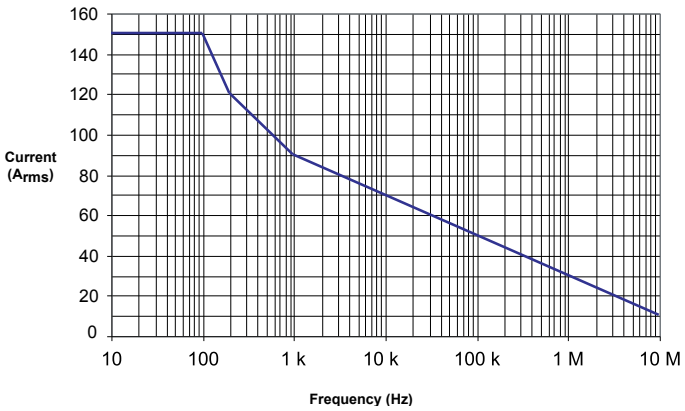
Maximum Input Current vs. Frequency*



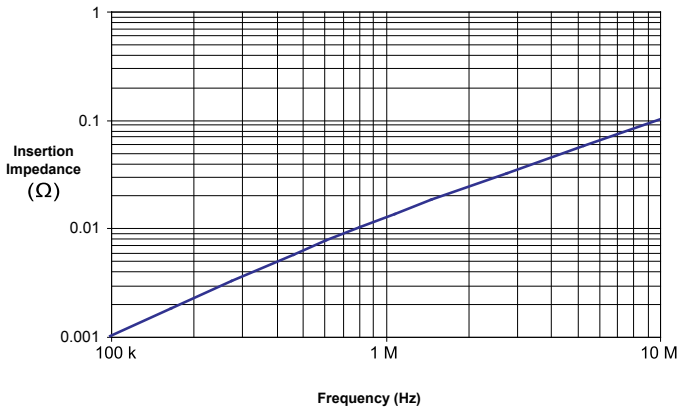
Insertion Impedance vs. Frequency* (typical)

**This performance does not apply to CP030-3M model.*

CP150

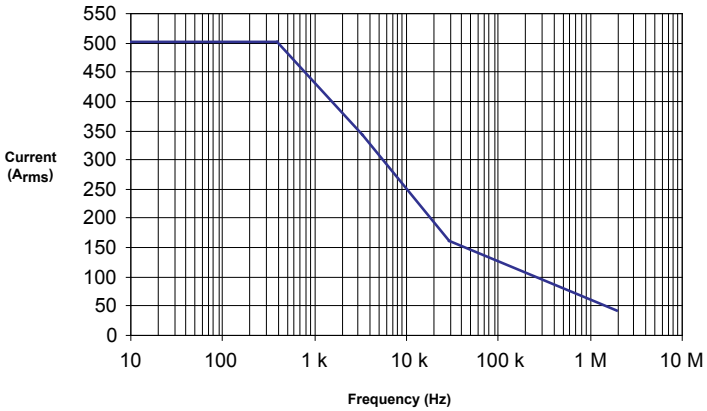


Maximum Input Current vs. Frequency*

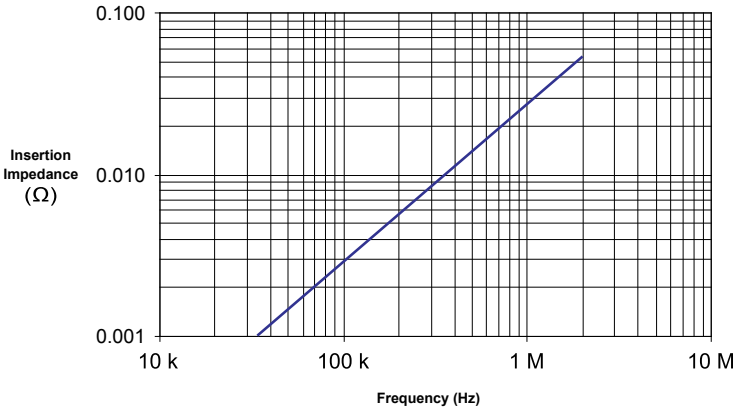


Insertion Impedance vs. Frequency* (typical)

CP500



Maximum Input Current vs. Frequency



Insertion Impedance vs. Frequency (typical)

*****This performance does not apply to CP150-6M model.*

SPECIFICATIONS & ORDERING INFORMATION

Specifications

Electrical Characteristics*

	CP030 (CP030-3M)	CP030A	CP031	CP031A	CP150 (CP150-6M)	CP500
Max. Continuous Input Current	30 A_{rms}				150 A_{rms}	500 A_{rms}
Bandwidth	50 MHz (10 MHz)		100 MHz		10 MHz (5 MHz)	2 MHz
Rise Time (typical)	≤ 7 ns (≤ 35 ns)		≤ 3.5 ns		≤ 35 ns (≤ 70 ns)	≤ 175 ns
Max. Peak Current	50 A_{peak} (non-continuous)				300 A_{peak} (non-continuous); 500 Apeak ≤ 30 µs	700 A_{peak} (non-continuous)
Output Voltage	0.1 V/A	0.1 V/A & 1 V/A	0.1 V/A	0.1 V/A & 1 V/A	0.01 V/A	
Max Continuous Input Current at 1 V/A (100mA/div or less)	–	5 A	–	5 A	–	
Offset Range at 1V/A (100mA/div or less)	–	±5 A	–	±5 A	–	
Minimum Sensitivity	10 mA/div	1 mA/div	10 mA/div	1 mA/div	100 mA/div	
Low-Frequency Accuracy	1%					
AC Noise at 20 MHz BWL	≤ 2.5 mA	≤ 150 µA	≤ 2.5 mA	≤ 150 µA	≤ 6.0 mA	≤ 8.0 mA
Coupling	AC, DC, GND					

General Characteristics

Cable Length	1.5 m (3 m)	1.5 m			2 m (6 m)	6 m
Weight	240 g (290 g)	260 g	240 g	260 g	500 g (600 g)	630 g
Max. Conductor Size (Diameter)	5 mm				20 mm	
Interface	ProBus, 1 MΩ only					
Usage Environment	Indoor					
Operating Temperature	0˚ C to 40˚ C					
Max. Relative Humidity	80%					
Max. Altitude	2000 m					
Maximum Insulated Wire Voltage	300 V CAT I				600 V CAT II, 300 V CAT III	

* Electrical Characteristics Guaranteed at 23 °C ±3 °C

CP03x, CP150, and CP500 probes (and long cable versions of these) are compatible with any Teledyne LeCroy oscilloscope with a ProBus interface running firmware version 4.3.1.1 or great.

CP03xA probes are compatible with most Teledyne LeCroy oscilloscopes with a ProBus interface running X-Stream™ firmware version 7.8.x.x or later, including WaveSurfer Xs-A, MXs/MXs-A/MXs-B, and 10; HDO4000, 6000, 8000, and 9000; MDA800, HRO/WaveRunner 6 Zi, WaveRunner 8000, Xi/Xi-A/MXi/MXi-A, WavePro/SDA/DDA 7 Zi/Zi-A; WaveMaster/SDA/DDA 8 Zi/Zi-A/Zi-B, and LabMaster 9 Zi-A series. WavePro 7000/7000A series are compatible if they are running Windows XP Professional and X-Stream™ firmware version 7.8.x.x or later. WaveSurfer Xs series must be upgraded to Windows XP Professional. Contact your local service center regarding upgrades.

Ordering Information

Product Description	Product Code
30 A; 50 MHz Current Probe – AC/DC; 30 A_{rms}; 50 A Peak Pulse, 1.5 meter cable	CP030
30A; 10 MHz Current Probe - AC/DC, 30 Arms; 50 A Peak Pulse, 3 meter cable (not EMC compliant)	CP030-3M
30 A; 50 MHz High Sensitivity Current Probe – AC/DC; 30 A_{rms}; 50 A Peak Pulse, 1.5 meter cable	CP030A
30 A; 100 MHz Current Probe – AC/DC; 30 A_{rms}; 50 A Peak Pulse, 1.5 meter cable	CP031
30 A; 100 MHz High Sensitivity Current Probe – AC/DC; 30 A_{rms}; 50 A Peak Pulse, 1.5 meter cable	CP031A
150 A; 10 MHz Current Probe – AC/DC; 150 A_{rms}; 500 A Peak Pulse, 2 meter cable	CP150
150 A; 5 MHz Current Probe – AC/DC; 150 Arms; 500 A Peak Pulse, 6 meter cable (not EMC compliant)	CP150-6M
500 A; 2 MHz Current Probe – AC/DC; 500 A_{rms}; 700 A Peak Pulse, 6 meter cable	CP500
Deskew Calibration Source	DCS025

Customer Service

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ADP300
ADP305
High Voltage Differential Probes

Key Features

- 20 MHz and 100 MHz bandwidths
- 1,000 VRMS common mode voltage
- 1,400 Vpeak differential voltage
- EN61010 Cat III
- 80 dB CMRR at 50/60 Hz
- ProBus® system
- Full remote control

ADP30X high-voltage active differential probes are safe, easy-to-use probes ideally suited for measuring power electronics. The ADP300 is good for troubleshooting low-frequency power devices and other circuits where the reference potential is elevated from ground or the location of ground is unknown. The ADP305 is designed for measuring the high-speed floating voltages found in today's power electronics.

Easy-to-use

With the ProBus interface, the ADP30X becomes an integral part of the oscilloscope. The attenuation, offset, and bandwidth limit are all controlled from the oscilloscope front panel or by using the remote control commands. This means the complete measurement setup can be saved and recalled by the oscilloscope, and all measurement values will be correct. The scope provides power to the probe, so there is no need to worry about a separate power supply or changing batteries.

Autozero

The ADP30X offset can be easily set to zero by pushing a button in the oscilloscope's coupling menu, even when connected to live circuits. This makes it easy to get accurate measurements.

Meets EN61010 Category III requirements

Safety is the top priority when you work around high-voltage signals. The ADP300 and ADP305 are both designed to the standards required for Installation Category III. This means in addition to being used on appliances and portable equipment (Cat II), they can be used in fixed-installation environments.

SPECIFICATIONS & ORDERING INFORMATION

Specifications

Electrical Characteristics

	ADP300	ADP305
Bandwidth	20 MHz	100 MHz
Differential Voltage	1400 v peak	
Common Mode Voltage	1000 vrms Cat III	
Best Low-Frequency Accuracy (probe only)	1% of reading	
CMRR	50/60 Hz 80 dB (10,000:1)	100kHz 50 dB (300:1)
Max. Slew Rate (referenced to input)	60,000 V/us	300,000 V/us
AC Noise (referenced to input)	50 mVRMS	
Attenuation	÷100/÷1000 (automatically selected by scope)	
Input Impedance	Between inputs 8 MΩ, 6 pF	Each input to ground 4 MΩ, 1 pF
Sensitivity	1 V/div to 350 V/div	200 mV/div to 350 V/div

General Characteristics

Overall Length	2 meters
Input Connectors	4mm shrouded banana plug
Operating Temperature	0° C to 50° C
Max Altitude	2000 meters
Max Relative Humidity	80% (max 31° C)
Warranty	One year

Standard Accessories

Instruction Manual Certification of Calibration Plunger Hook Clip (1-Red, 1-Blue) Straps for Holding Probe	ADP300
All ADP300 Accessories Safety Spade (1-Red, 1-Blue) Plunger Clamp Clip (1-Red, 1-Blue) Plunger Jaw Clip (1-Red, 1-Blue) Safe Alligator Clip (1-Red, 1-Blue) Soft Accessory Case	ADP305

Ordering Information

Product Description	Product Code
1,400 V, 20 MHz High-Voltage Differential Probe	AP300
1,400 V, 100 MHz High-Voltage Differential Probe	AP305
Plunger Hook Clips (Quantity 2 - 1 Red, 1 Blue)	PK30X-1
Safety Alligator Clips (Quantity 2 - 1 Red, 1 Blue)	PK30X-2
Plunger Jaw Clips (Quantity 2 - 1 Red, 1 Blue)	PK30X-3
Plunger Clamp Clips (Quantity 2 - 1 Red, 1 Blue)	PK30X-4
Safety Spade Terminals (Quantity 2 - 1 Red, 1 Blue)	PK30X-5

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