

**Newton4th Ltd**

PPA3500

User Manual



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DANGER OF ELECTRIC SHOCK

Only qualified personnel should install this equipment, after reading and understanding this user manual. If in doubt, consult your supplier.



RISQUE D'ELECTROCUTION

L'installation de cet équipement ne doit être confiée qu'à un personnel qualifié ayant lu et compris le présent manuel d'utilisation. Dans le doute, s'adresser au fournisseur.



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Solo personale qualificato può installare questo strumento, dopo la lettura e la comprensione di questo manuale. Se esistono dubbiconsultate il vostro rivenditore.



PELIGRO DE DESCARGA ELÉCTRICA

Solo personal cualificado debe instalar este instrumento, después de la lectura y comprensión de este manual de usuario. En caso de duda, consultar con su suministrador.

IMPORTANT SAFETY INSTRUCTIONS

This equipment is designed to comply with EN 61010-2-030:2010 (Safety requirements for electrical equipment for measurement, control, and laboratory use) – observe the following precautions:

- This instrument is to be connected and operated only by qualified personnel.
- This appliance **must** be earthed. Ensure that the instrument is powered from a properly grounded supply before connecting to any live inputs.
- Ensure that the supply voltage agrees with the rating of the instrument printed on the back panel **before** connecting the mains cord to the supply.
- The inputs are rated at 1kV rms or dc cat II; 600V rms or dc cat III. **Do not exceed the rated input.**
- Ensure that the voltage and current inputs are connected correctly **before** energising the load to be measured.
- Keep the ventilation slots in the top and sides of the cover free from obstruction.
- Do not operate or store under conditions where condensation may occur or where conducting debris may enter the case. Do not use in a wet environment.
- Ensure that the handle is correctly fitted before using it to lift or to carry the instrument.
- There are no user serviceable parts inside the instrument – do not attempt to open the instrument, refer service to the manufacturer or his appointed agent.

IMPORTANT SAFETY NOTICE

Input Connections:

It is critical that the 4mm inputs and BNC inputs on each PPA input channel are not connected to any external circuit at the same time.

You MUST only use EITHER the 4mm OR the BNC connection – NOT both, this applies to both Voltage and Current inputs.

Note: Newtons4th Ltd. shall not be liable for any consequential damages, losses, costs or expenses arising from the use or misuse of this product however caused.

DECLARATION OF CONFORMITY

Newton4th Ltd.
1 Bede Island Road
Leicester
LE2 7EA

We declare that the product:

Description: Power Analyser

Product name: Precision Power Analyzer

Model: PPA35xx Family

Conforms to the EEC Directives:

2014/30/EU relating to electromagnetic compatibility:
EN 61326-1:2013
EN 55022 class A
EN 61000-3-2:2014
EN 61000-3-3:2013

2014/35/EU relating to Low Voltage Directive:
EN 61010-2-030:2010
EN 61010-1:2010

January 2021

Jigar Patel
(Senior Engineer, Newton4th Ltd.)

WARRANTY

This product is guaranteed to be free from defects in materials and workmanship for a period of 36 months from the date of purchase.

In the unlikely event of any problem within this guarantee period, first contact Newtons4th Ltd. or your local representative, to give a description of the problem. Please have as much relevant information to hand as possible – particularly the serial number and release numbers (press SYSTEM then LEFT).

If the problem cannot be resolved directly then you will be given an RMA number and asked to return the unit. The unit will be repaired or replaced at the sole discretion of Newtons4th Ltd.

This guarantee is limited to the cost of the instrument itself and does not extend to any consequential damage or losses whatsoever including, but not limited to, any loss of earnings arising from a failure of the product or software.

In the event of any problem with the instrument outside of the guarantee period, Newtons4th Ltd. offers a full repair and re-calibration service – contact your local representative. It is recommended that the instrument is re-calibrated annually.

Calibration note:

- Performance test specification available from N4L upon request.

ABOUT THIS MANUAL

This manual describes the general features, usage and specifications of the PPA3500 PPA35xx range of power analysers.

Detailed descriptions of the communications command set for RS232, USB, LAN & GPIB (IEEE448) is given in the separate document: PPA35xx Communications Manual.

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1 Introduction – general principles of operation

The PPA3500 is a sophisticated and versatile power analyser for accurate wide-bandwidth power measurements.

The PPA35xx family of power analysers covers 1 to 6 phase applications in both low current and high current models.

Each phase input has wide-ranging voltage and current channels which are fully isolated from each other and from ground. The voltage input has a built-in high voltage attenuator or may be used with an external attenuator. The current input has a built-in current shunt or may be used with an external shunt.

The phase inputs are associated with two groups which may be independently configured for different wiring modes or maybe synchronised together into a single wiring mode. For example, some combinations available on a 4 phase model are:

Group 1	Group 2
4 phase	n/a
3 phase 3 wattmeter	Single phase
3 phase 2 wattmeter	3 phase 2 wattmeter

For each group, the voltage and current inputs are simultaneously sampled and the data is analysed in real-time by a high-speed DSP (digital signal processor). A separate CPU (central processing unit) takes the results from the two DSPs for display and communications. At the heart of the system is an FPGA (field-programmable gate array) that interfaces the various elements.

This powerful, versatile structure allows the measurement of a wide range of power related parameters including:

- W, VA, VAr, power factor, phase
- true rms, fundamental
- Efficiency
- harmonics, TIF
- integrated values (W hours etc.)
- impedance
- inrush current, voltage surge
- oscilloscope

The PPA3500 is particularly easy to use, with large clear colour displays and single menu levels for all main parameters. Even difficult applications such as lighting ballasts can be easily addressed with the application of the special mode in the firmware of the instrument.

The whole operation of the instrument may be controlled remotely via a serial interface (RS232/USB), a LAN interface, or GPIB.

The voltage and current channels are identical except for the voltage attenuator and current shunt at the very front end.

Each channel consists of a selection switch for external or internal attenuator/shunt followed by a high impedance buffer, then a series of gain stages leading to an A/D converter. Selection of the input gain and the sampling of the A/D converter are under the control of the DSP. There is an autozero switch at the front end for dc accuracy. The analogue circuitry is optimised for high linearity over a wide dynamic range and high-frequency performance.

Both input channels are fully isolated with very good CMRR and noise rejection.

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The current shunt is of a proprietary design which gives very wide bandwidth with a minimum phase shift.

The voltage attenuator is of a proprietary design which has a wide bandwidth response and very high overload withstand capability.

Both the voltage and current channels are calibrated digitally so there are no physical adjustments to be made.

2 Getting started

The PPA3500 is supplied ready to use – it comes complete with an appropriate power lead and a set of test leads. It is supplied calibrated and does not require anything to be done by the user before it can be put into service.

2.1 Temperature Limits

The temperature limits for storage of the instrument and during shipping/transportation are:

-10 °C to +60 °C

The instrument must be within 5°C of the ambient temperature before operation.

2.2 Unpacking and power-up

Remove the instrument and accessories from the packaging and check them against the supplied packing list. Please contact your N4L office or local sales distributor should any items found to be missing or damaged during transportation.

Please retain the original packaging to ensure easy and safe return of the equipment for calibration etc.

If rack mounting brackets have been fitted to the equipment, please remove them before packaging the equipment for return. This reduces the risk of damage to the equipment during transportation.

Before connecting the test leads to an active circuit first connect the mains cord from a properly grounded supply outlet to the inlet on the rear panel of the Unit. The

PPA3500 has a universal mains input and accepts any supply voltage from 90-265Vrms at 50 or 60Hz.

Note: If the power is cycled “off-on” it is advised to wait for 10 seconds before switching the instrument on again. A 10-second power off window allows all microcontrollers to fully reboot and prevents any errors during the power-on sequence.

Switch on the PPA3500. The display should illuminate with the model name and the firmware version for a few seconds while it performs start-up checks. It should then default to the power measurement display. Note that the switch-on message can be personalised – see the User Data section under System Options.

The screen comprises two 4.3” (110mm) LCD colour display. There are no manual adjustments as the display should be clear and visible in all lighting applications.

Allow 30 minutes warm-up time before commencing any tests to ensure accurate readings.

The voltage and current leads may now be connected to a circuit under test. The high common-mode rejection ratio (CMRR) of the instrument allows the current channel to be connected in the live path (high side shunt) or the neutral path (low side).

The test leads supplied meet the safety requirements of BSEN61010-1 to an operating voltage of up to 1000V rms cat II or 600V rms cat III.

The Quick Start guide, Section 3 below, gives an introduction to the operating modes of the PPA3500, and the selection of options and parameters. The Quick Start guide may be followed with no inputs connected to the instrument.

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In the event of any problem with this procedure, please contact customer services at Newtons4th Ltd. or your local authorised representative; contact addresses and telephone numbers are given in the appendix at the back of this manual.

3 Quick Start guide

The instrument is structured as two groups of up to three phases each. When using the menus, options for both groups are displayed if available. If the menu relates to system functions (eg communication options) then the options are displayed only on the left-hand side; if the menu has options which could be different then both sides of the display are used. Menu options shown in red on the right-hand side are common to both groups.

To select group 2 data press and hold NEXT; holding the "next" button for more than 2 seconds changes user control to the right-hand display. Holding "back" for more than 2 seconds changes control back to the left hand display.

control indication line - 2-pixel wide grey control indicator line highlights active display, as shown within the screenshot below



3.1 Input grouping

Before setting other operational parameters, select the appropriate grouping for your application. There are three main configurations:

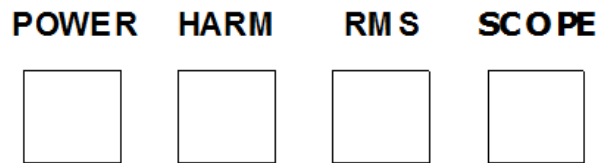
- Two independent groups
- A single group of 4-6 phases
- Two groups using the same data

Press ACQU to set the grouping. A 6 phase instrument would have the following options:

- | | |
|--------------|--|
| 1+2+3: 4+5+6 | (two groups of 3 phases) |
| 1+2+3+4 | (single 4 phase group) |
| 1+2+3+4+5 | (single 5 phase group) |
| 1+2+3+4+5+6 | (single 6 phase group) |
| 1+2+3: 1+2+3 | (two groups, phases 1-3
displayed on both groups) |

Two independent groups is the normal measurement grouping – this allows two independent multi-phase power measurements to be made simultaneously and efficiency computed. The single group mode allows systems up to 6 phases to be analysed. Group2 can use the same data as group 1 so that a waveform display can be shown for the same data as the power measurements.

3.2 Operating Mode Keys



Operating Mode selection

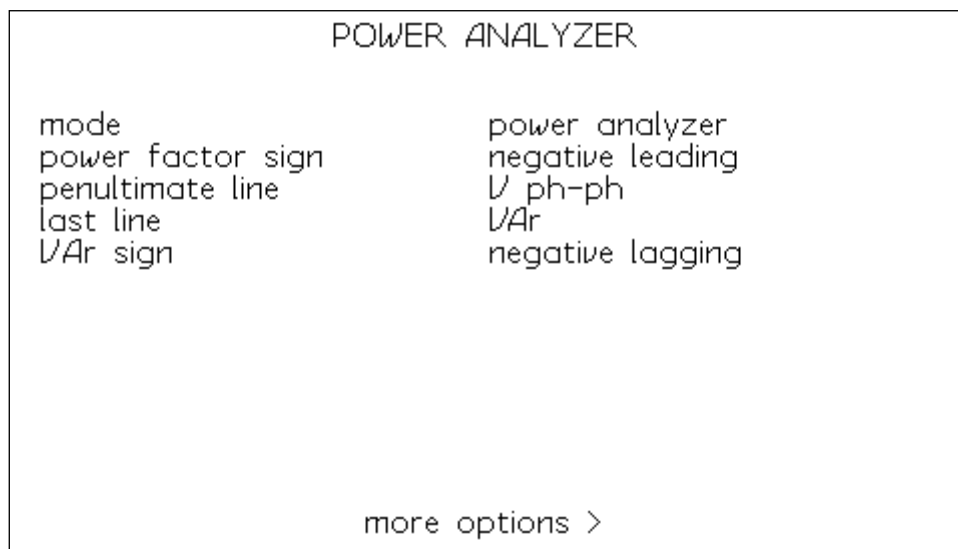
(Power-on default is Power Analyzer – diagram below shows single-phase display. Note that with no inputs connected, the display will be showing noise levels only.)

POWER ANALYZER				15:26:40
Vrange: 1V▼		Arange: 300mA▼		coupling: ac+dc
PH1	total	fundamental		
watts	-443.85nW	-101.01pW		65.741nWdc
V/A	43.295μV/A	121.96pV/A		
pf	0.010	-0.828		
voltage	18.919mV	62.019μV		+000.00°
current	2.2885mA	1.9665μA		-214.08°
frequency	1.0374MHz			
VAr	43.293μVAr	68.347pVAr		

Press the POWER, HARM, RMS, or SCOPE keys to access the operating modes directly, (other modes are available via the MODE menu – see below).

Select Menu Options

Press the Operating Mode key, e.g. POWER, a second time, or press the MODE key, to access mode-specific options (diagram below shows *Power Analyzer* options).



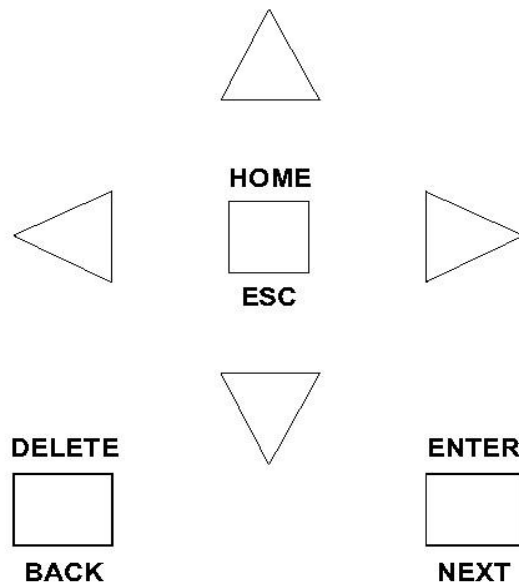
Use UP and DOWN keys to highlight an option, and ENTER to confirm (see para. 3.3 Menu Control Keys). Parameter values within the selected option may be adjusted using the L or R keys or by entering a numeric value directly, as indicated. Press ENTER to confirm.

With **operating mode** highlighted, use the L and R keys to cycle through operating modes and to access *Phase Meter* mode.

Use ENTER or HOME to return to readout display.

For text entry see 3.8 Data Entry Guide.

3.3 Menu Control Keys



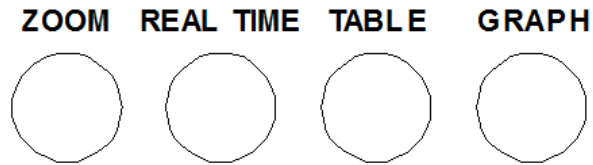
ENTER/NEXT confirms your selection or parameter value/data entry.

HOME/ESC returns to the original entry or to your previous action.

DELETE/BACK removes a previous selection or value or returns to your previous action.

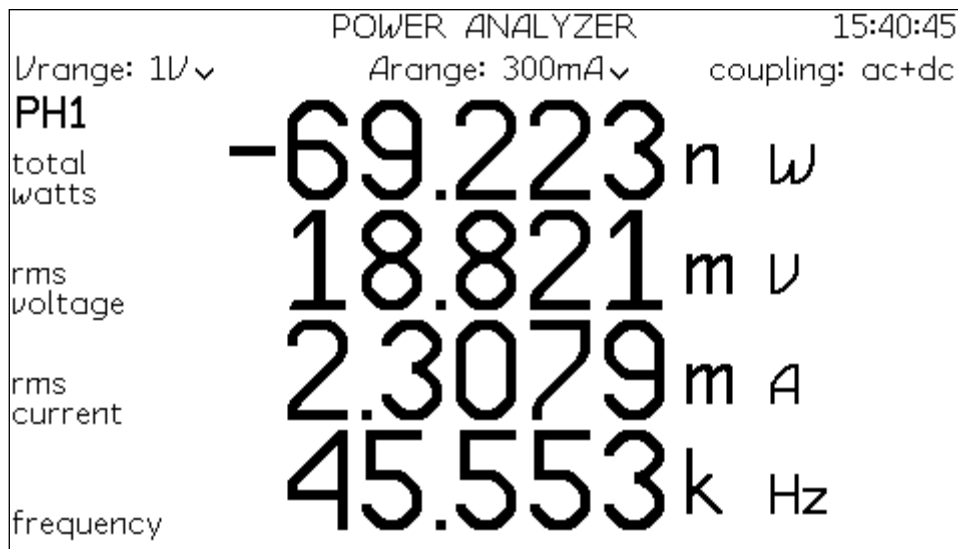
ARROW KEYS (UP, DOWN, L, R) move around menu options; make incremental/decremental changes etc. They are also used to position cursors in *Scope* mode.

3.4 Display Control Keys



ZOOM - up to 4 displayed values may be emphasized.

- a. Press ZOOM to display data in zoom level 2.
- b. Press ZOOM twice more to move through zoom level 3 to no zoom.
- c. Press DELETE to clear the selection.
- d. Position the flashing box over the data to be emphasized using the UP, DOWN, L and R menu control keys.
- e. Press ENTER to confirm (*flashing stops*).
- f. Continue to select up to a total of 4 values.
- g. Press ZOOM to display emphasized values as desired.
(Diagram below shows top zoom level for *Power Analyzer*.)



REAL-TIME toggles between continuous display readings and holding an instantaneous reading on screen. *Note: measurements continue to be taken even when display is in Hold.*

TABLE, GRAPH selects tabular or graphical presentation of data as collected in DATALOG (see 3.5 Setup Keys), or in *Harmonic Analyzer* mode.

3.5 Setup Keys/Keypad

ACQU	COUPLING	RANGE
1	2	3
DATALOG	APP	MATHS
4	5	6
ALARM	REMOTE	AUX
7	8	9
SYS	MODE	PROG
+/-	0	.

SELECT MENUS for non-mode-specific configuration. Also use as numeric keypad when entering parameter values or data.

ACQU – use for configuring inputs appropriate to the source and nature of signals being analyzed. (Diagram below shows *Power Analyzer* default setup.)

ACQUISITION CONTROL	
wiring	3 phase 3 wattmeter
speed	medium
smoothing	normal
smoothing response	auto reset
frequency reference	voltage
phase reference	voltage
frequency filter	off
low frequency	off
advanced options >	

COUPLING – appropriate to input signals.

RANGE – configure according to magnitude (voltage and current) of input signals.

DATALOG – only available for *Power Analyzer* and *True RMS Voltmeter* modes; sampling interval and storage location. Datalog is disabled by default. (See also TABLE, GRAPH in 3.4 Display Control Keys.)

APP – application-specific measurements, e.g. inrush current.

MATHS – a choice of three formulae – functions of up to four measurements.

ALARM – audible/visual indication of thresholds crossed set by ZOOM values (see 3.4 Display Control Keys). Default is Alarm disabled.

REMOTE – configure external comms.

AUX – Phase-Controlled Inrush Switch control.
– ADI40 Analogue-Digital Interface unit.

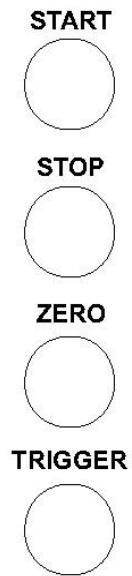
SYS – configure general system features.

MODE – see 3.2 Operating Mode Keys.

PROG – save, recall or delete Mode, Display and Setup configurations for user-defined applications. Recall data saved in DATALOG (see DATALOG key above).

For numeric entry see 3.8 Data Entry Guide.

3.6 Control Keys



START & **STOP** datalog function (when enabled) or integration (*Integ* mode). Either key also triggers single-shot in *Scope* mode.

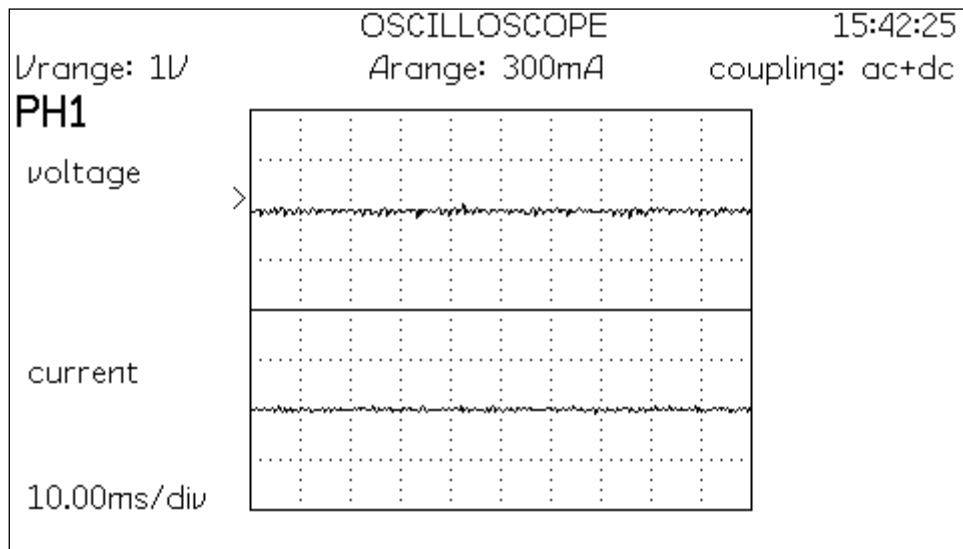
Use **ZERO** key for:

- a. Zero compensation of input amplifier chain.
- b. Reset integrator to zero (*Integ* mode).

TRIGGER (or **START**) returns **the** display to Real-Time from Hold. It also arms single-shot triggering in *Scope* mode.

3.7 Scope Mode

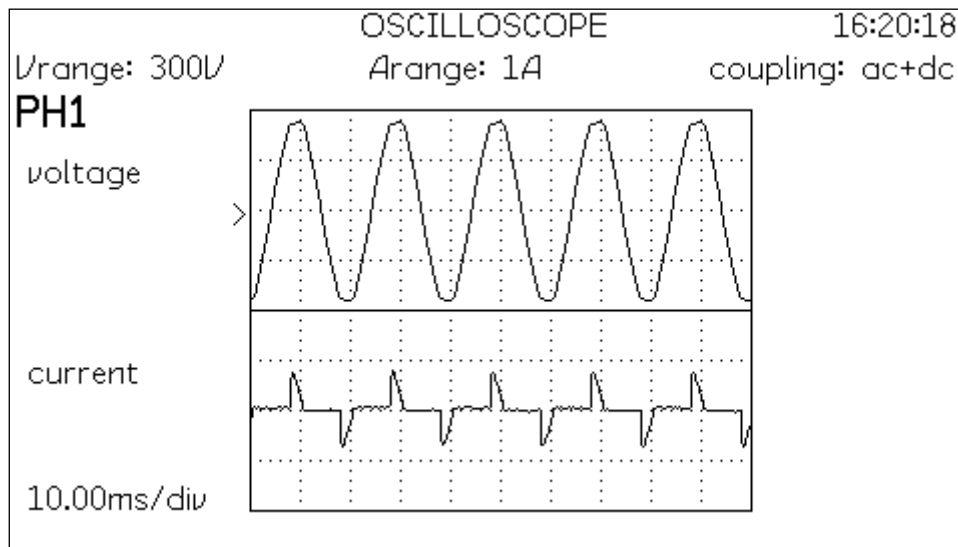
Selecting *Scope* mode from the operating mode keys, or by cycling through the operating modes in any of the operating mode select options, displays voltage and current waveforms as a conventional oscilloscope – diagram below shows the default display with no inputs connected.



The following diagram shows the options available in *Scope* mode:

MEASUREMENT SETTINGS	
mode	oscilloscope
timebase	10.00ms/div
trigger reference	voltage
trigger level	+200.0mV
trigger mode	auto
trigger polarity	rising edge
trigger HF reject	off
pretrigger	25%
cursors	off
trace	dual

A typical display of voltage and current waveforms for a switched-mode power supply is shown below:



When operating in *Scope* mode, the L and R control keys operate in one of two ways:

- A. With the cursor option 'off' (default), the L and R control keys change the timebase.
- B. With the cursor option 'on' the L and R control keys change the cursor position and the UP and DOWN keys toggle between cursor 1 control and cursor 2 control.

When cursors are enabled, the scope screen will display the following parameters; Vrms, Vpk, Watts, pf, Arms, Apk

3.8 Data Entry Guide

Text Entry

Use MODE key to select text entry. Enter text via the 4 function keys in the upper right of the panel. Each function key jumps to a different letter of the alphabet:

(POWER) **A**, (HARM) **I**,
(RMS) **O**, (SCOPE) **space**

Choose other characters by stepping forward or backwards using the UP and DOWN keys. Select upper/lower case with the ZOOM key.

(Values may be overwritten or edited by use of the L, R and DELETE keys)

Alternatively, text entry can be made via the numerical keypad resembling a telephone keypad, where key 1 is symbols, key 2 ABC, key 3 DEF etc.

Numeric Entry

Use MODE/numeric keys for number, decimal point, or +/- to enter parameter value. The 4 function keys in the upper right of the panel may be used as quick multipliers, where POWER is 10^6 (M), HARM is 10^3 (k), RMS is 10^{-3} (m), and SCOPE is 10^{-6} (μ).

Press ENTER (menu control keys) to set value.

Press HOME (menu control keys) to abort data entry, restore original.

(Values may be overwritten, or edited by use of the R, L and DELETE keys)

4 Using the menus

The PPA3500 is a very versatile instrument with many configurable parameters. These parameters are accessed from the front panel via a number of menus.

Many of the menu options can be set independently for the two groups. To select group 2 data press and hold NEXT; to return to group 1 data press and hold BACK. The menu title is shown on the active side of the display.

Each of the main menus may be accessed directly from a specific key.

ACQU	data acquisition parameters such as speed and filtering
COUPLING	select ac/dc coupling
RANGE	select input ranges, and scaling
DATALOG	specify datalog parameters
APP	Application-specific functions
MATHS	User-defined computations
ALARM	control of audible alarm
REMOTE	communications options (RS232 etc)
AUX	control of auxiliary devices connected to the rear EXTENSION and AUX ports
SYSTEM	general system options such as phase convention, keyboard beep etc.
MODE	function control
PROG	recall/store/ delete of programs and datalog

Each menu starts with the currently set parameters visible but no cursor. In this condition, pressing the menu key again or the HOME key aborts the menu operation and reverts to normal operation.

To select any parameter, press the UP or DOWN key and a flashing box will move around the menu selecting each

parameter. In this condition, the keys take on their secondary function such as numbers 0-9 etc.

Pressing the HOME key reverts to the opening state where the parameters are displayed but the cursor is hidden. Pressing the HOME key again exits the menu sequence and reverts to normal operation.

To abort the menu sequence, press the HOME key twice.

There are three types of data entry:

- selection from a list
- numeric
- text

4.1 Selection from a list

This data type is used where there are only specific options available such as the smoothing may be 'normal', 'slow', or 'none', the graph drawing algorithm may use 'dots' or 'lines'.

When the flashing cursor is highlighting the parameter, the R key steps forward through the list, and the L key steps backwards through the list. The number keys 0-9 step directly to that point in the list, which provides a quick way to jump through long lists. There is no need to press the ENTER key with this data type

For example, if the smoothing selection list comprises the options:

normal	(item 0)
slow	(item 1)
none	(item 2)

and the presently selected option is normal, there are 3 ways to select none:

- press R twice
- press L once
- press number 2

4.2 Numeric data entry

Parameters such as external shunt impedance and scale factor are entered as real numbers; shunt impedance is an example of an unsigned parameter, the scale factor is an example of a signed parameter.

Real numbers are entered using the number keys, multiplier keys, decimal point key, or +/- key (if signed value is permitted). When the character string has been entered, pressing the ENTER key sets the parameter to the new value. Until the ENTER key is pressed, pressing the HOME key aborts the data entry and restores the original number.

If a data value is entered that is beyond the valid limits for that parameter then a warning is issued and the parameter set as close to the requested value as possible. For example, the minimum user-defined measurement window 10ms; if a value of 5ms is entered, a warning will be given and the amplitude set to the maximum of 10ms.

When the parameter is first selected there is no character cursor visible – in this condition, a new number may be entered directly and will overwrite the existing number.

To edit a data value rather than overwrite it, press the R key and a cursor will appear. New characters are inserted at the cursor position as the keys are pressed, or the character before the cursor position can be deleted with the DELETE key.

Data values are always shown in engineering notation to at least 5 digits (1.0000-999.99 and a multiplier).

4.3 Text entry

There are occasions where it is useful to enter a text string; for example, a stored program may have some text as a title.

Numbers and text can be inserted using the number keys which function similarly to a phone keypad.

The UP and DOWN keys step forward and backwards using the ASCII character definitions – other printable characters such as # or ! can be obtained by stepping on from the space. The available character set is given in the Appendix.

When entering alphabetic characters, the PROG key toggles between the upper and lower case for the character preceding the cursor and the next characters to be entered.

The editing keys, R, L, DELETE and ENTER operate in the same way as for numeric entry.

5 Special functions

5.1 Display zoom

The PPA3500 normally displays many results on the screen in a combination of small font size (no zoom) and up to 4 values in larger font size (first zoom level). There are two further zoom levels which can display up to four and up to three selected values respectively at larger font sizes (second and third zoom levels).

To set the data values for the larger font size, first, return to no zoom by pressing ZOOM as many times as necessary. Press the ZOOM key to view the presently selected data, and press DELETE to clear the selection.

A flashing box surrounds the first available result. The flashing box is moved around the available results using the cursor keys, UP, DOWN, L and R. Pressing the ENTER key selects the result for zoom and the box ceases to flash. Further results (up to four in total) can then be selected using the cursor keys in the same way – a solid box remains around the already selected item, and a new flashing box appears.

Having selected the desired results, pressing the ZOOM key steps through the zoom levels until the highest is reached, at which point a further press returns to no zoom.

Note that any of the parameters selected for the zoom function can be used as the input for the alarm monitoring, and datalog.

5.2 PROG – store and recall

There are 3 types of data which can be saved:

- Programs
- Datalog
- Measurement results

There are 999 program locations where the settings for the entire instrument can be saved for recall at a later date. Each of the 999 locations has an associated name of up to 20 characters that can be entered by the user to aid identification.

Program numbers 1-4 may be recalled with a single press of the function keys if the direct load option is selected in the system menu (see system options).

The instrument can be restored to the factory default settings at any time by recalling program number 0. Any program saved to location 1 will automatically be loaded every time the instrument is restarted. The program menu is accessed using the PROG key. The program location can be selected either by stepping through the program locations in turn to see the name or by entering the program number directly.

When storing a configuration in a program, there will be a short pause of about 1 second if the program location had previously been written or deleted. The process will be very quick if the location has not been used.

When supervisor mode is disabled (see system options), programs can only be recalled, not stored nor deleted, to avoid accidental modification.

When recalling a program it may be desirable for the program to recall the selected communications interface

that was in use when the program was stored (RS232 or USB etc). Alternatively, it is more common for the communications interface to be associated with the instrument rather than a stored program. There is a selectable option in the REMOTE menu to enable the 'recall with program'. If this is 'off' then recalling the program will not change the communications interface.

All file directory information can be displayed by pressing the PROG key and then the TABLE button. This will allow all the information to be displayed as a table and show what the internal file directory contains. (pressing the TABLE button again exits the directory).

Datalog can be stored directly onto a USB memory stick (Note USB Memory stick maximum capacity 2GB) or logged to RAM and stored subsequently. The data then can be recalled for viewing or to download to a PC for further analysis.

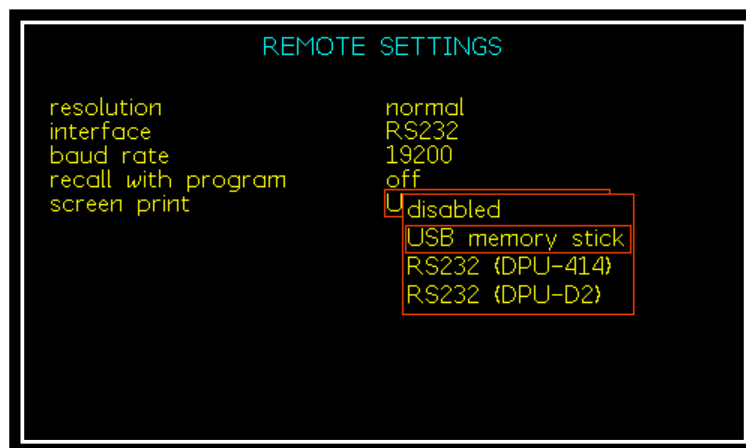
Measurement results can be stored in one of 999 locations. Press REAL-TIME to hold the results, press PROG and select memory = results. Each location holds the entire set of computed results for all the phases no matter what phase is on the display. In each case the full instrument set up is stored with the data and recalled so that measurements may easily be repeated and verified.

When using a large capacity (Note USB Memory stick maximum capacity 2GB) or slow USB memory device, all the data may not be transferred within the transfer time window. If this happens it will be recognised, and a display caption appears to prompt the user to 'press any key' to terminate the transfer when completed.

5.3 Screenprint

The screen display can be printed to an RS232 printer or saved to a USB memory stick as a bitmap. Press REMOTE to access the remote settings menu and select "screen print" to be USB memory stick, DPU-414 or DPU-D2 printers.

To capture the screen data, press HOLD to freeze the display then press START and hold for 2s. When the START button is released the capture starts. If writing to USB the front panel USB led will flash for several seconds then the usual "USB device ready" message will be displayed.



The "active" side of the display will be printed; for both sides press NEXT or BACK to switch to the other side and hold START again.

5.4 Zero compensation

There are 2 levels of zero compensation:

- 1) Trim out the dc offset in the input amplifier chain.
- 2) Measure any remaining offset and compensate.

The trim of the dc offset in the input amplifier chain can be manually invoked with the ZERO key, or over the RS232 with the REZERO command. This dc offset trim measures the dc present while the autozero switch is active and applies an equal and opposite offset via a D/A converter so that the input range to the A/D is optimised.

The measurement of the remaining offset also happens when the offset is trimmed but is also repeated at regular intervals. This is to compensate for any thermal drift in the amplifier chain. The remaining DC offset is precisely measured and stored so that the measurements can be compensated by an appropriate algorithm in the instrument firmware.

Real-time measurement is not possible while the autozero measurement is in progress so this repeated autozero function can be disabled via the SYSTEM OPTIONS menu.

5.5 ALARM - alarm function

The PPA3500 has 2 independent alarms that can be used to generate an audible warning:

- sound the alarm if the value exceeds a threshold
- sound the alarm if the value is below a threshold
- sound the alarm if the value is outside a window
- sound the alarm if the value is inside a window

The values to which the alarms are applied can be any of the measurements selected for zoom. The alarm status is also available as a logic output via the communications.

The first alarm also has the option to generate a variable sound changing linearly as the value changes between two thresholds.

To program an alarm, first select the functions for the zoom; up to four measurements can be selected for the display, the alarm is applied to any of them; then press ALARM to invoke the alarm menu:

- select which of the zoom functions is to be used
- select the type of alarm
- set the upper limit (if appropriate)
- set the lower limit (if appropriate)
- select whether the alarm is to be latched
- select whether the alarm sounder is enabled

If the alarm latch is selected then both alarms will continue to sound even if the value returns to within the normal boundaries. To clear the alarm, press HOME.

The alarm latch can also be set to HOLD the data so that an event can be captured. The data on the screen will be the measurement that first triggered the alarm condition.

The linear alarm option allows tests to be carried out even if it is not possible to see the display. Pressing ZERO in the alarm menu sets the upper and lower threshold to $4/3$ and $1/3$ of the measured value respectively. The repetition rate of the sounder then varies linearly as the value changes between these thresholds.

5.6 Data hold

When in real-time display mode, the data on the display can be held at any time by pressing the REAL TIME key. When HOLD is activated the word HOLD flashes in the top right-hand corner of the display.

Press the REAL TIME key again or the HOME key or START key to release HOLD; in this case, HOME and START do not have their normal functions. Changing the mode also releases hold.

When HOLD has been activated, the DSP continues to sample, compute and filter the results but the data is ignored by the CPU. When HOLD is released the display is updated with the next available value from the DSP.

HOLD can also be triggered by an alarm condition (see section 5.5 alarm function)

6 Using remote control

The PPA3500 is fitted with RS232 serial communications port, a USB port, a LAN interface and GPIB as standard. All the interfaces use the same ASCII protocol with the following end of line terminators:

	Rx expects	Tx sends
RS232 USB LAN	carriage return (line feed ignored)	carriage return and line feed
GPIB	line feed	line feed + EOI

All the functions of the PPA3500 can be programmed via any of the interfaces, and results read back.

The commands are not case sensitive and white space characters are ignored (e.g. tabs and spaces). Replies from the PPA3500 are always upper case, delimited by commas, without spaces.

Only the first six characters of any command are important – any further characters will be ignored. For example, the command to set the bandwidth is BANDWI but BANDWIDTH may be sent as the redundant DTH at the end will be ignored.

Fields within a command are delimited by comma, multiple commands can be sent on one line delimited with a semi-colon, e.g.

BANDWI,LOW;SPEED,SLOW

Mandatory commands specified in the IEEE488.2 protocol have been implemented, (e.g. *IDN?, *RST) and all commands that expect a reply are terminated with a question mark.

Data values returned by the PPA3500inetiQ are in scientific notation, with a 5 digit mantissa by default. There is also an option for higher speed data transfer by selecting resolution = 'binary' where each value is returned in 4 bytes, each of which has the MSB set so that it will not be interpreted as an ASCII character.

byte 1	2's complement signed exponent
byte 2	bit 6 = mantissa sign bit 5:0 = mantissa bits 19:14
byte 3	mantissa bits 13:7
byte 4	mantissa bits 6:0

When the MSB's are stripped off and the bytes put together, there is 6-bit signed exponent, a mantissa sign bit and a 20-bit mantissa magnitude. The value then is given by:

$$\text{Value} = +/- 2^{\text{exponent}} \times \text{mantissa} / 2^{20}$$

The PPA3500 maintains an error status byte consistent with the requirements of the IEEE488.2 protocol (called the standard event status register) that can be read by the mandatory command *ESR? (see section 5.1).

The PPA3500 also maintains a status byte consistent with the requirements of the IEEE488.2 protocol, that can be read by the mandatory command *STB? over RS232, USB or LAN (see section 5.2).

The LAN IP address defaults to auto-assigned (DHCP) but can be set manually by the REMOTE menu.

The RS232 data format is:- start bit, 8 data bits (no parity), 1 stop bit. Flow control is RTS/CTS (see section 5.2), baud rate is selectable via the REMOTE menu.

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A summary of the available commands is given in the Appendix. Details of each command are given in the communications manual.

Commands are executed in sequence except for two special characters that are immediately obeyed:

- Control T (20) – reset interface (device clear)

- Control U (21) – warm restart

6.1 Standard event status register

PON		CME	EXE	DDE	QYE		OPC
-----	--	-----	-----	-----	-----	--	-----

- bit 0 OPC (operation complete)
cleared by most commands
set when data available
- bit 2 QYE (unterminated query error)
set if no message ready when data read
- bit 3 DDE (device-dependent error)
set when the instrument has an error
- bit 4 EXE (execution error)
set when the command cannot be executed
- bit 5 CME (command interpretation error)
set when a command has not been recognised
- bit 7 PON (power-on event)
set when power first applied or unit has reset

The bits in the standard event status register except for OPC are set by the relevant event and cleared by a specific command (*ESR?, *CLS, *RST). OPC is also cleared by most commands that change any part of the configuration of the instrument (such as MODE or START).

6.2 Serial Poll status byte

		ESB	MAV	ALA			RDV
--	--	-----	-----	-----	--	--	-----

bit 0 RDV (result data available)
set when results are available to be read as enabled by DAVER

bit 1,2 not used

bit 3 ALA (alarm active)
set when an alarm becomes active as enabled by ALARMER

bit 4 MAV (message available)
set when a message reply is waiting to be read

bit 5 ESB (standard event summary bit)
set if any bit in the standard event status register is set as well as the corresponding bit in the standard event status enable register (set by *ESE).

6.3 RS232 connections

The RS232 port on PPA3500 uses the same pinout as a standard 9 pin serial port on a PC or laptop (9-pin male 'D' type).

Pin	Function	Direction
1	DCD	in (+ weak pull up)
2	RX data	in
3	TX data	out
4	DTR	out
5	GND	
6	DSR	not used
7	RTS	out
8	CTS	in
9	RI	not used

The PPA3500 will only transmit when CTS (pin 8) is asserted, and can only receive if DCD (pin 1) is asserted. PPA3500 constantly asserts (+12V) DTR (pin 4) so this pin can be connected to any unwanted modem control inputs to force operation without handshaking. The PPA3500 has a weak pull up on pin 1 as many null modem cables leave it open circuit. In electrically noisy environments this pin should be driven or connected to pin 4.

To connect PPA3500 to a PC, use a 9 pin female to 9 pin female null modem cable:

1 & 6	-	4
2	-	3
3	-	2
4	-	1 & 6
5	-	5
7	-	8
8	-	7

6.4 RS232 printer

The RS232 port can also be connected to a serial printer for making a hard copy of any screen. When printing is enabled in the REMOTE menu then pressing START will commence a screen dump to the printer. The graphic protocol used is the ESC/P so any printer which supports this protocol should work, e.g. the Seiko DPU-414.

The other communication options, USB or LAN, can still be used while the RS232 printer is enabled.

7 System options

Press SYS to access the system options.

The PPA3500's real-time clock can be set to the current date and time.

The display brightness may be set to "low" or "high" depending on viewing conditions.

Measurements of phase can be expressed in one of three conventional formats:

-180° to +180° (commonly used in circuit analysis)

0° to -360° (commonly used in power applications)

0° to +360°

The measurement is exactly the same it is only the way that it is expressed that changes.

There are two ways of computing the DFT, cosine or sine. The only difference arises in the computed phase angle of the harmonics.

Each keypress is normally accompanied by an audible 'beep' as well as the tactile 'click'. The 'beep' can be disabled for quiet environments if the feel of the key is sufficient feedback

Regular autozero measurements can be suppressed.

The 4 main function keys, POWER, HARM, RMS, SCOPE, can be used to load stored configurations as a "one-touch" way of configuring the instrument for specific applications. This is particularly useful in a production environment where an operator has a small number of specific tests to perform.

Data is normally displayed to 5 digits but it is possible to display 6 digits of resolution in zoom 2. This is particularly useful when looking at low-frequency phase angles which would then be displayed to 0.001° .

With no input connected the display normally shows measurements of random noise but this can be replaced with all zeroes if low-value blanking is selected.

Pressing RIGHT from the SYSTEM OPTIONS menu selects the USER SETTINGS screen where up to three lines of user-specified text may be entered. These are displayed on power-up and maybe read remotely by the command USER? to identify the instrument.

Note: Supervisor access mode is also displayed on the USER SETTING screen but this option is not currently supported in the firmware.

Pressing LEFT from first SYSTEM OPTIONS menu displays the serial numbers, manufacture code, release versions, and calibration dates. These cannot be changed by the user.

7.1 User data

The PPA3500 can be personalised by entering up to 3 lines of user data as text (see section on text entry).

User data is displayed every time that the instrument is switched on to identify the instrument. The entered text may also be read over the communications to identify the instrument (see USER?).

Typical arrangement of the user data might be:

- line 1 company name
- line 2 department or individual name
- line 3 unique identifying number (eg. asset number)

Any user data may be entered as required, as the lines are treated purely as text and are not interpreted by the PPA3500 at all.

After changing the user data, execute 'store' to save the data in non-volatile memory.

For use in a production environment, PPA3500 supports two modes of operation, supervisor and user. When supervisor mode is disabled, the stored programs can only be recalled, not changed. The PPA3500 saves the mode of operation with the user data so that it may be configured to power up in either mode as required.

8 Measurement options

8.1 Grouping configuration

Grouping selects the arrangement of the phases into one or two groups. If a single group, then all selected phases are synchronised and their results combined to compute the sum channel. If two groups then each group can be independently configured in various wiring modes.

For a single group, the grouping selects the number of phases to be used. For a six-phase instrument (PPA3560) the options are:

1+2+3+4
1+2+3+4+5
1+2+3+4+5+6

For a four-phase instrument (PPA3540) the only single group option is:

1+2+3+4.

For two groups, a six-phase instrument has two options:

1+2+3: 4+5+6
1+2+3: 1+2+3

A four-phase instrument has four options for two groups:

1: 2+3+4
1+2: 3+4
1+2+3: 4
1+2+3: 1+2+3

8.2 Wiring configuration

The available wiring options depend on the number of phases allocated to that group.

configuration	3 phase	2 phase	Single phase
single phase 1 (4)	✓	✓	✓
2 phase	✓	✓	
3 phase 2 wattmeter	✓	✓	
3 phase 3 wattmeter	✓		
single phase 2 (5)	✓	✓	
single phase 3 (6)	✓		
3 phase 2 wattmeter + single phase 3 (6)	✓		

In the single-phase modes (phase 1-6) the other phase inputs in the group are completely ignored and the selected phase acts as a completely independent single-phase power analyser.

In the 3 phase 2 wattmeter configuration, the voltages are measured relative to the third unmeasured phase. The phase 1 voltage input is connected across phase 1 and phase 3, and phase 2 voltage input is connected across phase 2 and phase 3, thus measuring phase to phase voltage directly. Phase 1 and 2 current inputs are connected normally. There is no need to measure the current in phase 3 as phase 3 has no voltage relative to itself so the power contribution is zero. In this mode, the neutral channel displays the synthesised phase 3 current.

The advantage of this connection method is that 3 phase power can be measured with only 2 wattmeters. This frees up phase 3 of a 3 phase group to simultaneously measure

the power of a single-phase input (3 phase 2 wattmeter + phase 3 configuration). This allows direct measurement of efficiency in a 3 phase motor drive or 3 phase inverter application. The frequency reference for the independent phase 3 may be selected to be voltage or current. In this mode, frequencies up to 1kHz can be measured with phase 3.

The 3 phase 2 wattmeter + phase 3 configuration can be used as an additional Torque & Speed application to supplement the existing "EXT" BNC connections on the rear panel.

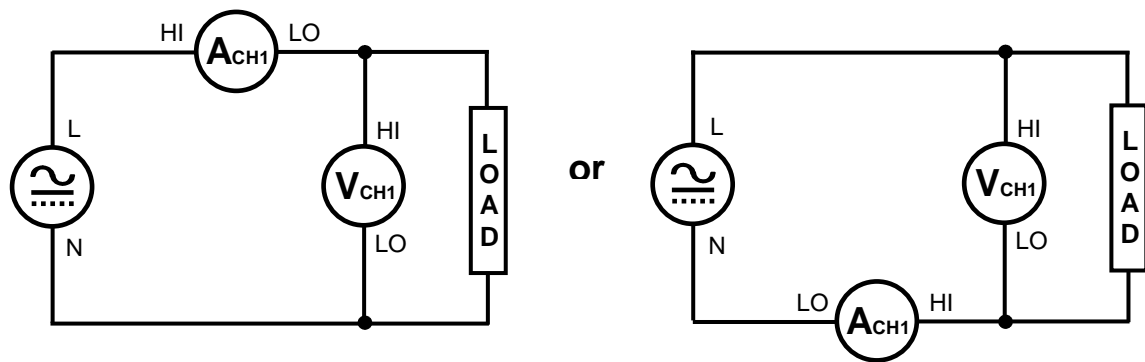
With the 3 phase 3 wattmeter configuration, each measurement phase is connected to a phase of the load with the voltage inputs measuring to neutral. In this mode, phase to neutral voltages are measured directly and phase to phase voltages are also computed.

For a three-phase inverter system, with a six-phase instrument (PPA3560) one group can measure the three-phase input using 3 phase 2 wattmeter while phase three measures the dc bus and simultaneously the output can be measured by group 2 in a 3 phase 3 wattmeter configuration.

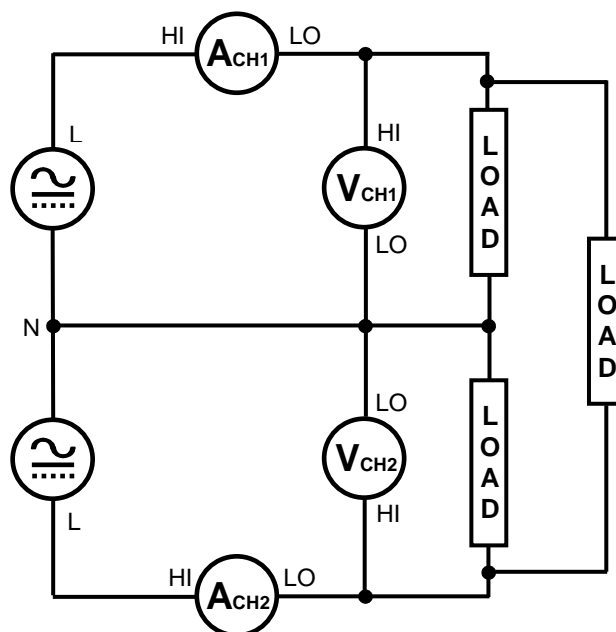
The wiring configuration is the first item to be selected after grouping under the ACQU menu.

8.2.1 Wiring diagrams

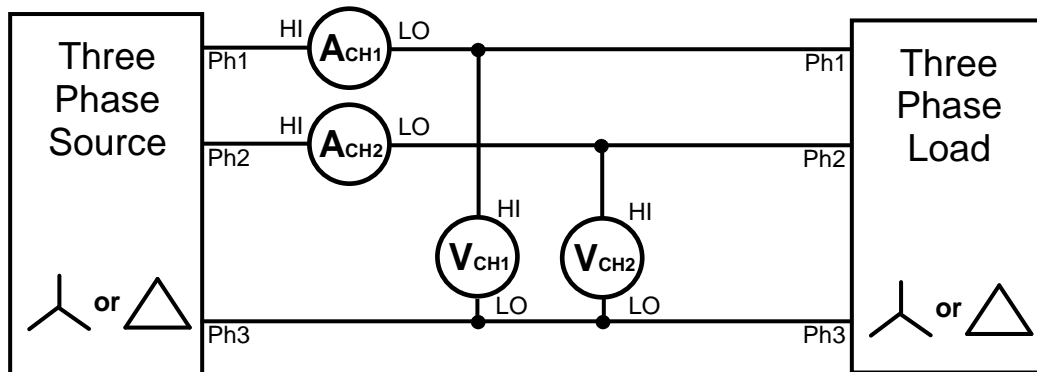
Single Phase



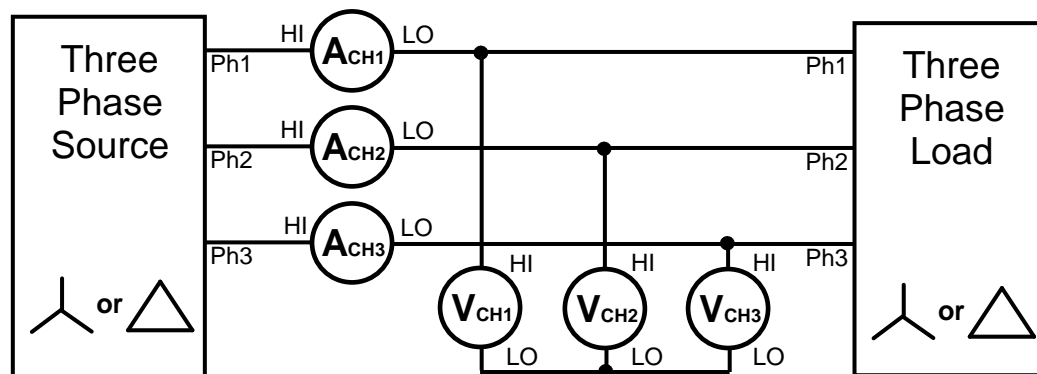
Two-Phase Two Wattmeter



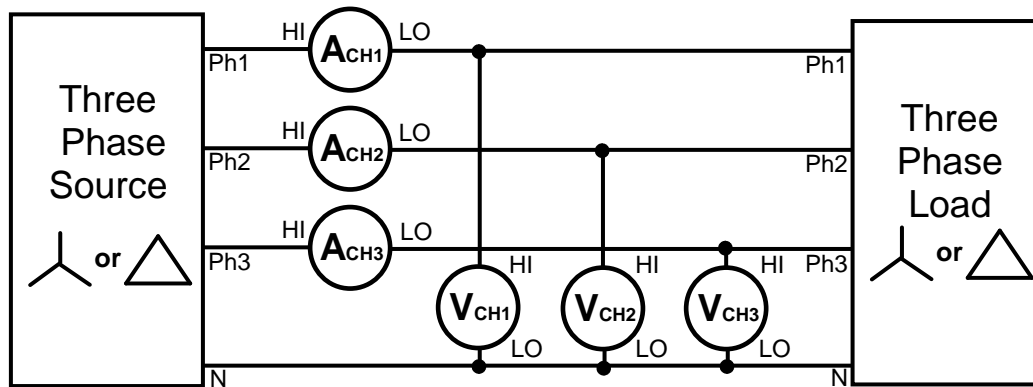
Three-Phase Two Wattmeter



Three Phase-Three Wattmeter - simulated neutral

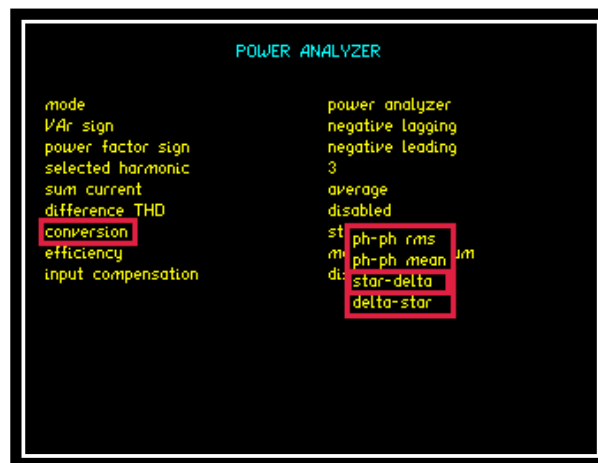


Three Phase Three Wattmeter – Star Connections



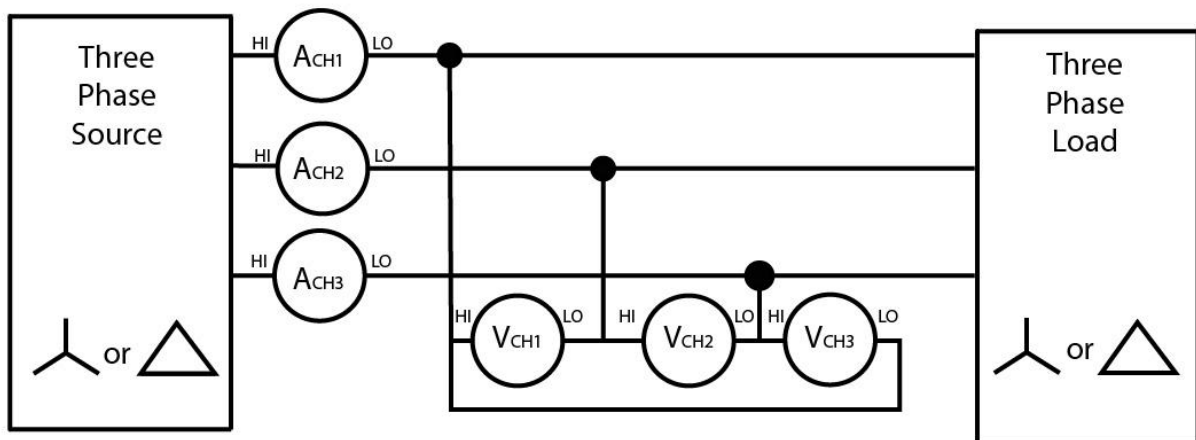
To configure PPA35xx to calculate the correct phase power when the Load topology is in a Star Configuration:

Access "Power Analyzer" mode either through the "Mode" or the "POWER" button as per the screenshot below



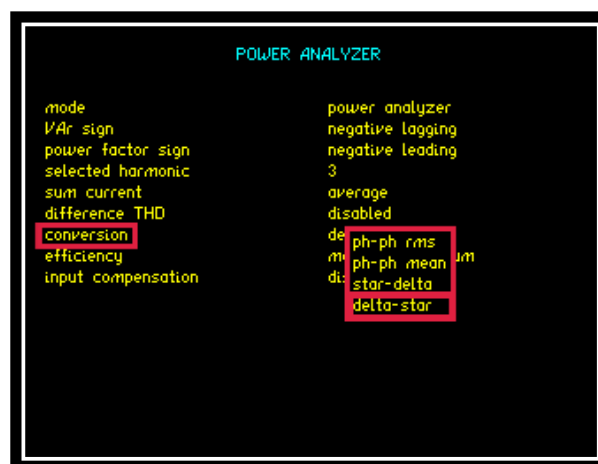
Press ▼ 7 times until red box surrounds "conversion"
 Press ► to open up dropdown menu selections
 Press ▼ until red box surrounds "star-delta"
 Press "ENTER" to confirm the selection

Three Phase Three Wattmeter– Delta Connections



To configure PPA35xx to calculate the correct phase power when the Load topology is in a Delta Configuration:

Access “Power Analyzer” mode either through the “Mode” or the “POWER” button as per the screenshot below



Press ▼ 7 times until red box surrounds “conversion”

Press ► to open up dropdown menu selections

Press ▼ until red box surrounds “delta – star”

Press “ENTER” to confirm the selection

Conversion Settings:

It is not possible for the instrument to detect the wiring configuration used to connect the instrument to the motor / DUT. All “conversion” options have to be available with the User ensuring the correct option is selected from the menu.

Selecting an incorrect conversion option with respect to the actual wiring configuration used will result in incorrect computations being performed. Negative values can be expected in 3 phase 2 Wattmeter mode (section 11.2) but can be displayed in other wiring modes should an incorrect conversion option be selected.

Note:

Select Delta-Star for Delta wiring configurations.
Select Star-Delta for Star wiring configurations.

On a multi-phase wiring configuration, all the phases usually use the same input control data – internal/external, scaling factor etc. It is possible to enable ‘independent ranging’ so that the phases can be set up differently – press RANGE. This is useful if different scaling factors are required for external shunts or if one phase is using internal shunt when others are external. When independent ranging is enabled use the RIGHT and LEFT ARROW keys to navigate between the settings for the individual phases.

8.3 ACQU - Acquisition options

In normal acquisition mode, the window over which the measurements are computed is adjusted to give an integral number of cycles of the input waveform. The results from each window are passed through a digital filter equivalent to a first-order RC low pass filter.

There are five pre-set speed options – very fast, fast, medium, slow, and very slow – that adjust the nominal size of the window, and therefore the update rate and the time constant of the filter. Greater stability is obtained at the slower speed at the expense of a slower update rate.

There is also an option to set a specific size of the window to a value other than the preset options. In order to synchronise to an integral number of cycles, the window size is either reduced by up to 25% or increased as necessary.

Note that at low frequencies, the window is extended to cover a complete cycle of the input waveform even if this is a longer period than the nominal update rate.

There are two-time constants for the smoothing filter, normal or slow, or the filter can be deselected. The nominal values are:

speed	update rate	normal time constant	slow time constant
Very Fast	1/80s	0.05s	0.2s
fast	1/20s	0.2s	0.8s
medium	1/3s	1.5s	6s
slow	2.5s	12s	48s
very slow	10s	48s	192s

When Speed: Window is set, the smoothing time constant is nominally 4.5 times (normal) and 18 times (slow) the window size (synchronised to the frequency).

The smoothing response is usually set to 'auto-reset' where the filtering is reset in response to a significant change in data. This speeds up the response of the instrument to changing conditions. This function can be disabled so that the filtering has a fixed time constant, which would have an exponential response to a step change.

The frequency may be measured from the voltage or current. On a multi-phase instrument, any channel may be selected for the frequency measurement.

Phase angle measurements have to be made with reference to a specific input – normally phase 1 voltage. The phase angle reference can be set to current which is useful if operating the instrument with only current inputs, or with low-level voltage inputs. In multi-wattmeter wiring modes, phase 1 is always used for the phase angle reference; phase 2 or phase 3 is used when in single-phase 2 wiring or single phase 3 wiring.

A frequency filter, 4kHz low-pass, may be selected to filter out the hf carrier component of a PWM waveform ensuring measurements are carried out on the fundamental frequency.

Normal frequency measurement is from 5Hz upwards so that there is not a very long delay if measuring dc. There is a low-frequency option that extends the frequency measurement down to 20mHz. This low-frequency option also applies a digital filter, which can be useful when measuring in a low frequency, noisy environment.

8.3.1 Advanced options

Pressing ACQU to access the acquisition control menu then the RIGHT arrow key gives access to some advanced options which would not be needed for most normal measurement applications.

The displayed name of the groups default to SUM1 and SUM2 but these can be changed for clarity, for example, to "input" and "output"

The analysis for the fundamental component uses a DFT (discrete Fourier transform) algorithm. The selectivity of the DFT analysis is a compromise between noise rejection of frequencies close to the frequency of the fundamental component and the required stability of the frequency measurement. Selecting "narrow" increases the selectivity of the DFT analysis (reducing the effective bandwidth) which has the effect of improving the noise rejection. It does, however, require that the frequency of the fundamental component is more stable.

In a noisy application, any spikes present on the signal may push the instrument onto a higher range than is necessary for the signal being measured. If the nature of the spurious spikes are such that they do not contribute to the measurement and can safely be ignored then the range can be manually set as appropriate for the signal to be measured and the instrument can be told to ignore any overload. If using this mode it is wise to check the signal on the oscilloscope to be sure that the signal being measured is not genuinely over range.

In a very noisy application, where the frequency of the signal is known but PPA3500 is unable to measure the frequency even with low-frequency mode filters applied, it is possible to enter the frequency to be used for analysis. When 'frequency lock' is selected to be 'on' the present

measured frequency is displayed but this can be overwritten with the known frequency. This entered frequency is then used for all the analysis and the frequency of the input signal is not measured.

There is also the option for “dynamic” frequency control where the measurement frequency is taken as that measured on the previous window even if the measured frequency has changed significantly. This is particularly useful to avoid missing data on a motor start-up test.

Power (Watts) is usually a signed measurement but in applications where power can flow in both directions, the measurement can be fixed to be unsigned (absolute) so that integration gives the total power flow in either direction.

Selecting the Normalise Reference function adjusts the scale factors on each current channel so that they read the same as phase 1. The reference can be either the current measured on phase 1 or if there is a reference CT it can be connected to the external input of phase 1 voltage and used as a reference.

8.4 COUPLING - coupling options

There are three coupling options - AC only, AC+DC, or DC only. AC+DC coupling is the normal option and should be used where possible. AC coupling should be used for measuring signals that are biased on a DC level (such as an amplifier operating on a single supply or the output of a DC PSU). DC coupling should be selected when making DC measurements as it prevents noise from resetting the frequency measurement algorithm.

In multi-phase applications, if independent CH3 input control has been set in the acquisition menu then the coupling options are independently set for PH1 + PH2 together and PH3 separately.

Coupling and bandwidth options are applied in hardware before the A/D conversion.

Coupling option	Bandwidth option	Measurement bandwidth	Notes
ac+dc	wide	dc – 1MHz	default
	low	dc – 200kHz	
ac	wide	5Hz – 1MHz	
	low	5Hz – 200kHz	
dc	wide	dc – 1MHz	* dc coupling disables auto frequency search
	low	dc – 200kHz	

For noisy signals, a second-order digital filter can be applied at a cut off frequency from 1kHz to 250kHz

All these options are applied to both voltage and current channels to maintain phase accuracy.

8.5 RANGE - input channel options

All the input channels are fully isolated from each other and from earth with very high CMRR (common-mode rejection ratio). They are controlled independently but sampled synchronously.

Each input channel has an external input as well as an internal shunt or high voltage attenuator. The external input gives versatility in the input ranging by using external shunts or attenuators. If the external shunt or external attenuator option is selected, the data is scaled by the appropriate value (entered under the relevant channel menu).

Precision low inductance current shunts or current transformers may be used with the current channels; high voltage attenuators or oscilloscope probe may be used with the voltage channels. **Note that when using external shunts or attenuators on high voltage signals, the inputs must not exceed 1000V rms cat II, or 600V cat III, to ground.**

There are 10 (8 for the external input) input ranges with nominal full-scale values set with a 1:3:1 ratio. For convenience, the peak range system has been converted to the equivalent rms ranges on the next page of this manual, this gives the following range system:

20Arms Model

Peak Ranges				RMS Ranges – Sinusoid	
Range	internal current	internal voltage	external input	internal current	Internal voltage
1	10mA	100mV	1mV	8.48mArms	84.8mVrms
2	30mA	300mV	3mV	25.4mArms	254mVrms
3	100mA	1V	10mV	84.8mArms	848mVrms
4	300mA	3V	30mV	254mArms	2.54Vrms
5	1A	10V	100mV	848mArms	8.48Vrms
6	3A	30V	300mV	2.54Arms	25.4Vrms
7	10A	100V	1V	8.48Arms	84.8Vrms
8	30A	300V	3V	20Arms	254Vrms
9	100A	1kV	N/A	20Arms	848Vrms
10	300A	3kV	N/A	20Arms	1000Vrms

30Arms Model

Peak Ranges				RMS Ranges – Sinusoid	
Range	internal current	internal voltage	external input	internal current	Internal voltage
1	30mA	100mV	1mV	25.4mArms	84.8mVrms
2	100mA	300mV	3mV	84.8mArms	254mVrms
3	300mA	1V	10mV	254mArms	848mVrms
4	1A	3V	30mV	848mArms	2.54Vrms
5	3A	10V	100mV	2.54Arms	8.48Vrms
6	10A	30V	300mV	8.48Arms	25.4Vrms
7	30A	100V	1V	25.4Arms	84.8Vrms
8	100A	300V	3V	30Arms	254Vrms
9	300A	1kV	N/A	30Arms	848Vrms
10	1000A	3kV	N/A	30Arms	1000Vrms

The actual ranges have approximately 20% overload (subject to noise) headroom so, for example, the 300Vpk range has an actual peak input value of 360Vpk allowing for the 20% headroom.

All N4L analyzers auto-range to the waveform peak, this is vitally important as it ensures that the waveform is not clipped unlike within traditional rms ranging power analyzers.

The ranges may be selected manually, or by autoranging (default). To speed up the autoranging, the start range for

autoranging may be selected if it is known that the signal will not be below a certain level.

There is also an option to autorange 'up only' so that a test may be carried out to find the highest range. Once the highest range has been determined, the range can be set to manual and the test carried out without losing any data due to range changing. Pressing the TRIGGER key (or sending *TRG) restarts the autoranging from the selected minimum range.

In multi-phase applications, it is usual to allow the phases to independently range but there is an option to lock the ranges across the phases. When enabled, this means that all the voltage channels will be on the same range, and all the current channels will be on the same range.

When in an input channel menu, the ZERO key provides a quick way to lock and unlock the range. When no flashing box is visible in the input channel menu and autoranging is selected, pressing the ZERO key selects the range that the instrument is currently using and sets the autoranging to manual, thus locking the range and preventing further autoranging. Pressing the ZERO key again returns to full autoranging from the bottom range.

For most measurement functions full autoranging is the most suitable option but some applications, such as where transient events are occurring, are more reliable with manual ranging. Manual ranging (or up-only autoranging) is essential for low-frequency measurements.

Separately from the current shunt and attenuator value, a scaling factor can be entered for each channel.

In multi-phase applications, if independent ranging has been set (see system options) then the ranging options may be independently set on each phase. Press the R and L keys to step between the phases.

8.6 DATALOG – datalog options

PPA3500 can store and display measurements recorded at regular intervals over a time period. Each data record consists of the elapsed time and up to four data values selected by ZOOM. The instrument can graph and display all four sets of measurements simultaneously.

The actual interval between data points is governed by the measurement speed and the datalog interval. PPA3500 stores the next available measurement after the datalog interval has elapsed: the actual elapsed time is attached to each datalog record, displayed with the data on the table or each graph, and returned with each record over the communications (RS232, USB, LAN, or GPIB).

The data values may be stored to an external memory device (memory stick) as each value becomes available. In this mode, the data may be viewed in real-time, as it is being acquired.

For high-speed data acquisition, the datalog interval may be set to zero so that each measurement is stored. The measurement interval is controlled with the 'speed' option in the ACQU menu. Using the 'window' option for speed allows greater control of the measurement interval. In this mode, the display flashes 'DATALOG RUNNING' and only shows the acquisition time. The minimum datalog interval depends on the function but is typically 10ms.

Note that in all cases the measurement interval is necessarily adjusted to be an integral number of cycles of the measured waveform.

Press DATALOG to set up the datalog options. The datalog is started with the START key and stopped with the STOP key unless the store becomes full first. The zero reference

for the elapsed time is taken as the first data measurement after START.

The data can be viewed as a table or as individual graphs. Pressing GRAPH steps the graph through the stored parameters. If more than 250 records have been stored, the graph can show the data for the whole period or pressing ZOOM redraws the graph to show 250 records about the cursor. The cursor can be moved in single steps (L or R) or large steps (UP or DOWN). Movements of the cursor are synchronised in both the TABLE and GRAPH views.

8.7 MATHS – custom result computation

Non-standard results may be computed from a combination of voltage and current parameters, signals on the torque and speed inputs, and constants.

There are 4 formulae, each combining up to 4 terms:

- 1: $(\text{term1} + \text{term2}) / (\text{term3} + \text{term4})$
- 2: $(\text{term1} + \text{term2}) \times \text{term3} / \text{term4}$
- 3: $\text{term1} \times \text{term2} / (\text{term3} + \text{term4})$
- 4: $(\text{term1} + \text{term2} + \text{term3}) / \text{term4}$

Each term comprises a result, scaled by a signed factor, or a signed constant.

For example, consider the formula:

$$\text{maths} = V_{pk}.A_{pk} / \sqrt{2}$$

Select formula 2 with:

term1 = voltage peak x 1.0
term2 = disabled
term3 = current peak x 1.0
term4 = constant x 1.414

or

term1 = voltage peak x 1.0
term2 = disabled
term3 = current peak x 0.7071
term4 = disabled

The selected formula is applied to the data from each phase.

The result is displayed with a user-definable label of up to 12 characters and units up to 8 characters.

9 Application specific modes

Select the application-specific options from the APP menu. Selecting the application sets the application mode and shows some key parameters in the menu. To set the default settings for the application move the cursor to highlight the box "Press ENTER here to load" and press ENTER. The values shown in the menu will be changed to their default values.

Application modes can be independently set for each group.

9.1 PWM motor drive

The nature of the waveforms in a PWM motor drive application makes the measurement of the fundamental frequency difficult. Within the application mode for PWM motor drive, it is possible to select one of seven predetermined frequency filter ranges, 64Hz, 250Hz, 1KHz, 4KHz, 16KHz, 64KHz or 250KHz. As a general guide, it is advisable to select the range closest to the highest fundamental frequency, for example, if a PWM motor is running at 500Hz the best filter to select would be the 1KHz. However, experimentation is sometimes the best way to select the optimum filter.

Note: The filter does **NOT** change the measured data at all - it is only applied to the data for the frequency measurement

PWM application mode also allows torque and speed to be simultaneously measured so that mechanical efficiency can be computed. Torque and speed inputs may be set for an analogue level or a pulsed input.

When low-frequency mode is enabled this allows frequency measurements down to 10mHz and is good to 30Hz for 100 harmonics and 60Hz for 50 harmonics.

The calculation for efficiency may be selected as the ratio of:

- Phase and next phase
- Group1 and 2
- Mechanical and sum
- Phase 3 and sum

9.2 Lighting ballast

Electronic lighting ballast waveforms consist of a high-frequency carrier signal modulated by the line frequency. PPA3500 measures the line frequency independently of the input waveform frequency and synchronises the measurement period to the line frequency.

The carrier frequency measurement ignores any 'dead-band' around the zero crossing of the ac line to compute the actual switching frequency of the ballast.

Both the frequency measured on the input waveform and the frequency of the line input are displayed.

As the switching frequency can vary over the cycle, the analysis frequency of the DFT measurement is continually adjusted to give an optimum measurement of the fundamental and harmonics. The response of the tracking algorithm can be adjusted to suit the ballast being measured:

- Fixed time (no adjustment)
- Fast
- Medium
- Slow

To select lighting ballast mode, press the APP key, select the mode with the cursor keys, move down to the 'default settings' option and press ENTER. The defaults are loaded and the particularly important parameters can then be changed.

9.3 Inrush current

Measurement of inrush current (surge) requires very fast sampling to catch the highest instantaneous value. Measurements must be made under conditions of manual ranging and with the voltage applied to the instrument. Then when the load is switched on the highest peak value can be detected. In inrush mode, PPA3500 samples and analyses every sample at the full sample rate of 1Msamples/s to catch even very fast peaks.

When performing analysis of inrush current of a product such as a transformer or the input stage of a switched-mode power supply, "range up only" (found in the RANGE menu) can provide a useful method for determining an appropriate range for the inrush tests if the current consumption of the product during an inrush event is unknown.

However, precautions should be taken regarding the range-up only function as this functionality is generally intended for use when monitoring gradual load current changes, such as when a motor load is gradually increased over time.

Ideally, before performing an inrush test the range setting in the PPA would be manually selected and fixed using the "manual" setting in the range menu. This setting will reflect the maximum peak current you expect the device under test to draw from the voltage supply.

*It is important that the voltage supply signal is always present at the voltage input terminals of the PPA, do not turn the source on and off to perform inrush current tests. The voltage source should be disconnected and reconnected to the device under test using safe working practices.

To utilise “range up only” to determine an appropriate range, it is advisable to make the following settings;

1. Speed, medium
2. Smoothing, fixed time
3. Low-frequency mode, ON
4. RANGE, current, range up only

After these settings are made, the device under test should be connected to the voltage source repeatedly until the range up only function no longer “ranges up”.

If at any time you observe the range briefly ranging up and then ranging back down, you should revert to manual ranging and perform the tests manually until a suitable range is found.

After these tests are made, the appropriate range should be set to manual and smoothing and low-frequency mode disabled.

The user can then select an appropriate update speed for their tests, if the single-cycle “peak RMS current” is of interest, then setting the window size to that of the fundamental time period will provide an RMS current measurement after each cycle is completed.

If you wish to analyse the peak current (this is the highest single sample point detected) within any cycle, then a slower speed can be selected and the surge parameter in RMS mode will provide this value.

For the worst-case inrush current the input to the device under test must be switched on at the worst point in the cycle (90° or 270° for a capacitive load, 0° or 180° for an inductive load). The Phase Controlled Inrush Switch, or PCIS, available as an accessory for PPA3500, controls the

switch on of the power to the DUT from 0° to 315° in steps of 45° from the PPA3500 front panel.

ENTERing the default settings in inrush mode in the application menu selects the PCIS and sets PPA3500 to manual ranging. If PCIS is not being used then it can be deselected in the AUX menu. Having selected the default settings, the current range should be set to an appropriate range for the DUT.

The oscilloscope mode is also useful for qualitatively evaluating the inrush current.

Note:

- Short term inrush current specification available from N4L upon request.

9.4 Transformer mode

Large power transformers operate at very low power factor (<0.01) and the phase accuracy is critical to measure the losses. Power transformer application mode sets the configuration options to the optimum for phase accuracy eg. AC+DC coupling, range lock across phases.

The multiple phase display is also changed to show imbalance across the phases. Phase 1 appears with the normal measurements but the voltage and current measurements for phase 2 and phase 3 are expressed as a percentage of the corresponding values from phase 1. The phase angle measurements are expressed as a deviation from the expected values of -120° and -240° .

The temperature can be monitored at the same time by connecting a suitable temperature sensor to the "torque" BNC input. The input accepts an analogue voltage from -10V to $+10\text{V}$ which can be scaled by an offset and a factor in degrees per Volt. The offset is entered as the zero degree voltage so for a sensor with an output range of $5^\circ / \text{Volt}$ and $0\text{V} = 10$ degrees, the offset to be entered would be -2V .

9.5 Standby power measurement

In order to minimise standby power, some devices operate in a 'dormant' mode whereby power is only drawn from the supply when needed. These devices draw very little current for most of the time and then draw a larger current for a single cycle to charge a reservoir capacitor. This pattern is repeated on an irregular basis.

Most of the power consumed by devices in this mode is taken in the periodic higher current cycles so to accurately measure the power drawn by these devices, so the instrument synchronises to the power frequency for the analysis but extends the measurement window to the irregular period of higher energy pulses. Because the instrument samples in true real-time without any gaps, no data is missed and every power cycle is captured.

It is important that ranging is set to manual or up only autoranging so that the power cycles are not missed while ranging.

10 Auxiliary Devices

Auxiliary devices are connected to the 15 way D type "extension" port on the rear of the instrument. They are selected via the AUX menu.

10.1 PCIS Inrush Switch

Phase Controlled Inrush Switch – an accessory for the PPA range to provide the precise measurement of Inrush Current on a single-phase AC load.

Application: When measuring the maximum inrush current taken by a load, it is necessary to switch on the supply at a specific point in the voltage cycle. The point at which maximum inrush current will be drawn is dependent upon the type of load being tested, but usually, this is 90° or 270° for capacitive loads and 0° or 180° for an inductive load. It can also be useful to measure the inrush current at intermediate points between the maximum and minimum levels; therefore an ideal phase switching device allows the selection of phase angle at increments of 45° .

10.2 ADI40 - Multi-Channel DC Analogue<> Digital Data Logger with Multiple Analogue Output

The ADI40 extends the versatility of the PPA3500, collecting a multitude of DC measurements and streaming the data digitally to the Power Analyzer. Featuring 4x, 8x, 12x or 16x direct thermocouple inputs (type J or type k), 4x, 8x, 12x or 16x analogue DC inputs and 20x analogue DC outputs. Analogue outputs can be mapped to any PPA measured parameter, as well as the analogue/thermocouple inputs.

Typical applications include system integration where multiple power/sensor parameters must be analysed within one central measurement system, bringing together external sensors and primary power measurements from the PPA3500. This data is available via the command line (through the intuitive "MUTILOG" command, see PPA3500 comms manual for more details) or sent out as a DC voltage level to one of the 20x outputs on the ADI40 to chart recorders or similar devices.

0.1% FS Basic accuracy	4~16 Analogue DC Inputs +/-10V
20 Analogue Outputs +/-10V	4~16 Thermocouple Inputs (Type J or Type K)
Up to 10ms update rate	Measured Parameters within PPA are able to be mapped to the Analogue Outputs
High speed sampling on all channels	Connects to Power Analyzer via Extension Port
Compatible with many Pressure, Torque & Flow Rate Sensors	Ideal for Systems Integrators
Temperature Range	Type J: +200 to -180, Type k: +200 to -200

11 Power measurements

In the POWER mode, PPA3500 measures the following values for each phase:

Parameter	Type	Units
Frequency	elementary	Hz
True power	elementary	W
Apparent power	secondary	VA
Reactive power	secondary	VAR
Power factor	secondary	
RMS voltage	elementary	V
RMS current	elementary	A
Fundamental power	secondary	W
Fundamental VA	secondary	VA
Fundamental VAR	secondary	VAR
Fundamental power factor	secondary	
Voltage fundamental	elementary	V
Current fundamental	elementary	A
Voltage magnitude	secondary	V
Current magnitude	secondary	A
phase	secondary	degrees
Voltage harmonic	elementary	V
Current harmonic	elementary	A
Voltage harmonic magnitude	secondary	V
Current harmonic magnitude	secondary	A
DC voltage	elementary	V
DC current	elementary	A
dc power	secondary	W
Peak voltage	elementary	V
Peak current	elementary	A
Rectified mean voltage	elementary	V
Rectified mean current	elementary	A

All elementary parameters (e.g. Watts) are computed from their true definitions in real time so the measurements are

valid for all waveshapes. Secondary parameters are computed from one or more of the elementary parameters (eg. $VA = V_{rms} \times A_{rms}$).

Not all of the parameters listed are displayed in POWER mode but they are all computed.

A multi-phase instrument also computes the equivalent values for total power (SUM channel) and the values for the NEUTRAL current. Step through the phase values with NEXT and BACK.

The measurements are computed over rectangular windows with no gaps. The processing power of the DSPs allows the measurements to be made in true real-time without missing any samples. In this way, the measured power is a true value even if the signal is fluctuating. The only occasion when data is missed is when an autozero measurement is requested – this can be disabled in the SYSTEM OPTIONS menu.

The elementary values are individually filtered before being used for secondary computations.

11.1 Individual phase computations

The power dissipated in a load subjected to a periodic voltage, $v(\phi)$, with a current flowing $a(\phi)$, is given by:

$$w = 1/2\pi \int_0^{2\pi} v(\phi).a(\phi) d\phi$$

For a sampled signal, the formula becomes:

$$w = 1/n \sum_{i=0}^{i=n-1} v[i].a[i]$$

Where n is the number of samples for an integral number of complete cycles of the input waveform.

The rms value of a periodic waveform, $v(\phi)$, is given by:

$$\text{rms} = \sqrt{\left[1/2\pi \int_0^{2\pi} v^2(\phi) d\phi \right]}$$

For a sampled signal, the formula becomes:

$$\text{rms} = \sqrt{\left[1/n \sum_{i=0}^{i=n-1} v^2[i] \right]}$$

Where n is the number of samples for an integral number of complete cycles of the input waveform.

The dc present is given by:

$$dc = 1/2\pi \int_0^{2\pi} v(\phi) d\phi$$

For a sampled signal, the formula becomes:

$$dc = 1/n \sum_{i=0}^{i=n-1} v[i]$$

Where n is the number of samples for an integral number of complete cycles of the input waveform.

From these elementary values of W, rms and dc, the following secondary values can be derived:

VA	= $V_{rms} \times A_{rms}$
VA _r	= $\sqrt{VA^2 - W^2}$
power factor	= W/VA
W _{dc}	= $V_{dc} \times A_{dc}$

The fundamental in-phase and quadrature values of a periodic waveform, $v(\phi)$, are given by:

$$a_1 = 1/\pi \int_0^{2\pi} v(\phi) \cdot \cos(\phi) d\phi$$

$$b_1 = 1/\pi \int_0^{2\pi} v(\phi) \cdot \sin(\phi) d\phi$$

For a sampled signal, the formulae become:

$$a_1 = 1/n \sum_{i=0}^{i=n-1} v[i] \cdot \cos(2\pi ci/n)$$

$$b_1 = 1/n \sum_{i=0}^{i=n-1} v[i] \cdot \sin(2\pi ci/n)$$

Where n is the number of samples for an integral number of complete cycles of the input waveform, and c is the number of cycles.

These 'a' and 'b' values yield the further elementary parameters:

$$\text{magnitude} = \sqrt{a^2 + b^2}$$

$$\text{phase angle} = \tan^{-1}(b/a)$$

From these elementary 'a' and 'b' values of voltage and current, the following secondary values can be derived:

$$\begin{aligned}
 \text{fundamental Watts} &= V_a \times A_a + V_b \times A_b \\
 \text{fundamental VA} &= V_{\text{mag}} \times A_{\text{mag}} \\
 \text{fund power factor} &= W_{\text{fund}} / VA_{\text{fund}} \\
 \text{fundamental VAr} &= V_a \times A_b - V_b \times A_a
 \end{aligned}$$

The signs of Watts and VAr are a direct result of the computation (watts has the sign of $\cos(\text{phase angle})$, VAr has the sign of $\sin(\text{phase angle})$). The sign of fundamental power factor is determined by convention such that a lagging current (inductive load) is shown as a positive power factor and a leading current (capacitive load) is shown as a negative power factor; this is effectively the sign of $\sin(-\text{phase angle})$. Optionally the signs of fundamental VAr and power factor can be independently inverted.

11.2 Sum computations

When in 3 phase wiring modes (2 Wattmeter or 3 Wattmeter), the values for the total load are computed from the data for each individual channel.

W, VAr, W.f, VAr.f, W.dc, and W.h are computed as the sum of the individual phase data.

V.rms, V.mag, V.pprms and V.ppmag are computed as the average of the individual phase data.

A.rms and A.mag are computed from $\text{sum VA} / \text{sum V}$ and $\text{sum VA.f} / \text{sum V.f}$ respectively then may optionally be divided by the number of phases to give the average.

Sum VA and sum VAr are computed depending on wiring mode. When calculating 3 phase 3 wattmeter sum, sum Var is the individual phase data and the sum VAr is computed as:

$$\text{sum.VA} = \sqrt{(\text{sum.W}^2 + \text{sum.VAr}^2)}$$

There are two options when calculating 3 phase 2 wattmeter sum VA and VAr. For low distortion signals they are computed in the same way as for 3 phase 3 wattmeter, for high distortion there is an option:

$$\begin{aligned} \text{sum.VA} &= \sqrt{3/2 (\text{ph1.VA} + \text{ph2.VA})} \\ \text{sum.VA} &= \sqrt{(\text{sum.VA}^2 - \text{sum.W}^2)} \end{aligned}$$

Sum power factor is computed as $\text{sum W} / \text{sum VA}$ and the fundamental power factor is computed as $\text{fundamental sum W} / \text{fundamental sum VA}$ with the sign derived from the sign of sum VAr.

Negative Reading?

In 3ph 2w mode, Phase 3 is used as the reference point.

In certain conditions, the combination of power factor values below 0.5 and Phase Angle can result in leading and lagging Power vectors. These can cause negative watts values to be displayed particularly for Phase 2.

Application Note **APP014** describes 3 Phase 2 Wattmeter Power Measurements in more detail. Vector diagrams and example calculations are used to explain how the measurements are computed.

11.3 Neutral synthesis

In 3 phase 3 wattmeter configuration, the values for the neutral current are synthesised from the measured values of the three phases. By Kirchoff's law, the sum of the instantaneous currents flowing into a node must be zero. By convention neutral current is regarded as flowing out of the load so the neutral current can be derived from the sum of the three-phase currents.

In 3 phase 2 wattmeter configuration, the "neutral current" values are synthesised from the 2 phase currents and represent the third phase current.

Values available are rms, fundamental magnitude and phase. Additional values for dc, ac, peak and crest factor are displayed in RMS mode.

11.4 Phase to phase computations

In 3 phase 3 wattmeter configuration, the voltmeters are connected across each individual phase and neutral. The phase to phase voltages are synthesised from the individual phase data:

display phase	computation
phase 1	phase 1 – phase 2
phase 2	phase 2 – phase 3
phase 3	phase 3 – phase 1

Phase to phase values are computed for rms, fundamental magnitude and phase.

Consider the fundamental component:

$$\begin{aligned}
 V_{12}(t) &= V_1(t) - V_2(t) \\
 &= V_1 \sin(\omega t) - V_2 \sin(\omega t + \phi_{12}) \\
 &= V_1 \sin(\omega t) - V_2 [\sin(\omega t) \cos(\phi_{12}) + \cos(\omega t) \sin(\phi_{12})] \\
 &= \sin(\omega t) [V_1 - V_2 \cos(\phi_{12})] - V_2 \cos(\omega t) \sin(\phi_{12})
 \end{aligned}$$

In a balanced system:

$$V_1 = V, V_2 = V \text{ and } \phi_{12} = 120^\circ$$

$$\begin{aligned}
 V_{12} &= \sin(\omega t) [V - V \cos(120^\circ)] + V \cos(\omega t) \sin(120^\circ) \\
 &= 1.5 V \sin(\omega t) - \sqrt{3}/2 V \cos(\omega t) \\
 &= \sqrt{3} V \sin(\omega t - 30^\circ)
 \end{aligned}$$

So the phase to phase voltage would have a magnitude $\sqrt{3}$ times larger than the phase to neutral voltage at a phase displacement of -30° .

PPA3500 applies the computations in a general way without any assumptions about the system. It, therefore, computes the correct values whatever the waveform.

The phase to phase values may also be displayed as a rectified mean measurement.

11.5 Efficiency

Within a single group, efficiency may be computed as a ratio of:

phase 1 and phase 2 power
phase 3 and sum power
mechanical power and sum power

In both cases, either term may be input power or output power.

Using two groups, efficiency may additionally be computed as the ratio of the sum powers.

Total efficiency is computed from the total power, fundamental efficiency is computed from the fundamental power.

Efficiency computation is one of the measurement options available for the last line, or the penultimate line of the display. Press MODE to select efficiency. Once selected for display it can be set to the ratio required.

11.6 Torque & Speed

Dedicated BNC inputs are provided for torque and speed measurement. Each input can either be for an analogue sensor (+/-10V) or a logic level pulsed input (+/-10V). The analogue inputs can be scaled in Nm/V or rpm/V and the pulsed input is scaled in Nm/Hz or pulses/revolution.

The mechanical power is computed as

$$\text{Power (W)} = \text{torque (Nm)} \times \text{speed (rad/s)}$$

The torque and speed inputs are differential to prevent any earth loops.

11.7 Input compensation

This compensation option subtracts the power absorbed by the voltage input.

When measuring low power with the voltage input wired after the current input the Power measurement would include the power absorbed by the voltage attenuator.

For example, at 230V a 1M Ω voltage attenuator would absorb power of 0.0529W ($230^2/1\text{M}$). Enabling Input compensation subtracts this power and the corresponding currents from the measured values.

12 Integrated power measurements

In the INTEG mode, PPA3500 computes the following additional values:

Parameter	Units
Watt hours	Wh
VA hours	VAh
VAr hours	VArh
Average power factor	
Average rms voltage	V
Ampere hours	Ah
Fundamental watt hours	Wh
Fundamental VA hours	VAh
Fundamental VAr hours	VArh
Average fundamental power factor	
Average fundamental voltage	V
Fundamental ampere hours	Ah

The integrator is started by pressing the START key; the elapsed time is displayed in the upper left corner of the display. The integration can be stopped by pressing the STOP key then restarted by pressing the START key again. To reset the accumulated values and time press the ZERO key. While the integration is running, pressing the REAL TIME key holds the displayed values but accumulation continues in the background.

Once started, the integration continues to accumulate in the background even if the MODE is changed to POWER or RMS. This allows the real-time values to be displayed without disturbing the integration.

To make an integrated measurement over a specific interval, an integration run time can be entered in hours and minutes. The integration will automatically stop when the integration timer reaches the value entered as if the

STOP button had been pressed. Setting the integration time to zero, disables the timer.

The Watt hour integration and the Ampere hour integration can be selected to be signed or magnitude. To integrate the total power in terms of heating effect, choose magnitude. If signed integration is selected then the rms current is given the sign of the power before integration. The Ampere hours and Watt hours then reflect the power taken by the load, less any power generated by the load, such as during regenerative braking in battery systems.

The integrated results may be displayed as the total accumulated values or as the average over the integration period.

13 True RMS Voltmeter

The RMS voltmeter displays the additional secondary parameters of ac, crest factor, surge, mean and form factor:

Having computed the true rms and the dc component, the ac component can be derived from:

$$\text{rms}^2 = \text{ac}^2 + \text{dc}^2 \quad \Rightarrow \quad \text{ac}^2 = \text{rms}^2 - \text{dc}^2$$

Crest factor is derived from the peak and rms:

$$\text{cf} = \text{peak} / \text{rms}$$

In order to measure surge conditions, the maximum instantaneous peak value (unfiltered) is also recorded. It is important that PPA3500 does not autorange while measuring surge – either set the range to manual or repeat the test several times with ranging set to up only. To reset the maximum, press TRIGGER.

The mean value, also known as rectified mean, is computed by the arithmetic mean of the absolute value of the samples:

$$\text{mean} = 1/2\pi \int_0^{2\pi} |v(\phi)| d\phi$$

For a sampled signal, the formula becomes:

$$\text{mean} = 1/n \sum_{i=0}^{i=n-1} |v[i]|$$

where n is the number of samples for an integral number of complete cycles of the input waveform.

Note that the mean value will not give the same measurement as rms. The form factor indicates the ratio of mean to rms:

$$\text{form factor} = \text{rms} / \text{mean}$$

For an undistorted sinewave, the form factor is given by:

$$\begin{aligned}\text{Sine wave form factor} &= \pi / 2\sqrt{2} \\ &= 1.11072\end{aligned}$$

There is also an option to normalise the rectified mean measurement (factor = $\pi / 2\sqrt{2} = 1.11072$) as the form factor is always computed from the absolute value (before normalisation).

Both Voltage and Current positive and negative peak are available, filtered and unfiltered.

14 Harmonic analyser

The HARM mode of PPA3500 computes multiple DFTs on the input waveforms in real-time.

There are two modes of operation: difference THD, and series harmonics. Series harmonic mode includes options for THD, TIF, THF, TRD, TDD and phase. There is also an option of a series harmonic bar graph display which shows both the voltage and current harmonics simultaneously.

In difference THD mode, the THD (Total Harmonic Distortion) is computed from the rms and fundamental:

$$\text{THD} = 1/h_1 \sqrt{(\text{rms}^2 - h_1^2)}$$

In series THD mode, the THD is computed from a series of up to 50 harmonics.

$$\text{THD} = 1/h_1 \sqrt{\sum_{i=2}^{i=n} h_i^2} \quad \text{where } h_i \text{ is the } i^{\text{th}} \text{ harmonic}$$

TIF (Telephone Influence Factor) is similar to THD but each harmonic has a weighting factor applied to reflect the severity of the potential interference of that harmonic on telephone communication.

$$\text{TIF} = 1/\text{rms} \sqrt{\sum_{i=1}^{i=n} (h_i \times t_i)^2}$$

where h_i is the i^{th} harmonic
and t_i is the i^{th} weighting factor

TIF is defined by IEEE standard 115 and the weighting factors are given in ANSI standard C50-13. The harmonic factors for TIF are specified for harmonics of 60Hz.

THF (Telephone Harmonic Factor) is a similar computation to TIF but uses different weighting factors and is expressed as a percentage.

$$\text{THF} = 1/\text{rms} \sqrt{\sum_{i=1}^{i=n} (h_i \times t_i)^2}$$

where h_i is the i^{th} harmonic
and t_i is the i^{th} weighting factor

The THF computation and weighting factors have been implemented according to IEC standard 60034 part 1 (1996) with amendments A1 (1997) and A2 (1999). The harmonic factors are specified for harmonics of 50Hz.

TRD (Total Rated Distortion) uses a different reference to scale the harmonic percentages instead of the fundamental. The voltage harmonics are scaled by the rms voltage, and the current harmonics are scaled by the larger of the rms current or the rated current entered by the HARM menu. The rms is computed from the series of harmonics.

$$\text{TRD} = 1/\text{ref} \sqrt{\sum_{i=2}^{i=n} h_i^2}$$

where h_i is the i^{th} harmonic
and ref is rms or rated current

Similarly, TDD (Total Demand Distortion) scales the computed harmonic distortion by the measured rms. For voltage, TDD is the same as TRD; for current, TRD is less

than TDD unless the measured rms current is greater than the entered rated current.

The value for TRD and TDD will always be lower than the computed THD as rms is always greater than the fundamental.

$$TDD = 1/\text{rms} \sqrt{\sum_{i=2}^{i=n} h_i^2}$$

where h_i is the i^{th} harmonic

Harmonic phase can be selected instead of a thd computation and each harmonic in the series is computed as a magnitude and phase angle.

The number of harmonics used for THF, TIF, TRD, TDD and series harmonic phase computation is selectable in the same way as for THD.

In all cases, the harmonics are phase referred to Phase 1 voltage fundamental so that their in-phase and quadrature components may be separately filtered to minimise noise.

Accurate frequency synchronisation is essential for reliable harmonic measurement. Good results can be obtained in a reasonable time using the medium speed setting (which runs a little slower than other modes) but for the best results, use the slow speed setting.

Harmonic phase angle reference

As phase angle is a measurement of the relative difference between the computed harmonic and the zero phase angle reference, it is important to understand what the harmonic is being referred to.

Single-phase

The default phase angle reference is voltage fundamental but can be set by menu option to current fundamental.

As all harmonics are referred to the same measurement, the harmonics can be combined to recreate the original waveform by adding the components:

$$V(t) \approx \sum_{i=1}^{i=n} A_i \cos(i \omega t + \phi_i)$$

where:

ω = angular frequency

i = harmonic number

n = maximum harmonic

A_i = amplitude of harmonic i

ϕ_i = phase angle of harmonic i

Note that computed phase angles are quoted according to the cosine formula above not a sine formula.

Multi-phase

In a multi-phase measurement, the fundamental phase angle of each phase is expressed relative to a common reference, normally phase 1 voltage; while the harmonic phase angles of each phase are expressed relative to their own phase, normally voltage as with single phase. So on a three-phase system with the same waveform on each phase displaced by 120 degrees at the fundamental, the harmonic measurements would show the same phase angle on each phase (because they are referred to their own phase) while the fundamentals would show the 120-degree phase displacement.

So to recreate the original waveform, apply the same formula as for single phase but first refer the phase angle of the fundamentals to the same reference as that of the harmonics. If the reference is voltage, subtract the voltage phase angle from the current angle and set the voltage to zero; if the reference is current, subtract the current phase angle from the voltage phase angle and set the current phase angle to zero.

Phase to phase harmonics

When the instrument is wired phase to neutral but the option is selected to display phase to phase harmonics, the phase angle reference for all the harmonics, including the fundamentals, is the same. The common phase angle reference is the original phase to neutral signal on phase 1 so the formula for single-phase can be applied without changing the phase reference for the fundamentals.

Harmonic Factor

The Harmonic Voltage Factor and Harmonic Current Factor are defined in section 7.2.1.1 of EN60034-1:2010.

Harmonic Voltage Factor.

HVF is the square root of the sum of the squared voltage harmonics divided by their harmonic number, for harmonics 2 to 13 excluding those divisible by 3.

Note: we do not limit the upper harmonic to 13 to allow the user to enter the upper harmonic of their choice. However, this should be set to 13 for the test to be compliant to the standard.

The HVF is computed using the following formula:

$$HVF = \sqrt{\sum_{n=2}^k \frac{u_n^2}{n}}$$

Where:

$k = 13$

n = the order of harmonic (not divisible by three)

u_n = is the ratio of the harmonic voltage U_n to the rated voltage UN .

Harmonic Current Factor.

The HCF is the square root of the sum of the squared current harmonics for Harmonics 2 to 13.

Note: the harmonics are not divided by the harmonic number, nor are those divisible by 3 excluded. It is effectively the same as THD with the maximum harmonic set to 13.

The HCF is computed using the following formula:

$$HCF = \sqrt{\sum_{n=2}^k i_n^2}$$

Where:

$k = 13$

n = the order of harmonic

i_n = is the ratio of harmonic current I_n to the rated current IN .

15 Impedance meter

The IMP mode on PPA3500 uses the real and imaginary components at the fundamental frequency using DFT analysis as described previously to compute the impedance of the load and associated parameters.

From the fundamental components of voltage, $(a + jb)$, and those of the current, $(c + jd)$, PPA3500 computes the complex impedance given by:

$$\begin{aligned}\mathbf{z} &= \mathbf{v} / \mathbf{i} \\ &= (a + jb) / (c + jd)\end{aligned}$$

The components of the complex impedance are filtered independently to minimise the effects of noise, which would have a random phase and would, therefore, be filtered out.

The magnitude of the voltage and current are also computed.

From the complex impedance the following parameters can be derived:

- resistance
- inductance,
- capacitance
- impedance
- phase
- $\tan\delta$ (= real/imaginary)
- Q factor (= imaginary/real)

Values can be displayed for either series or parallel models.

If the parameter option in the LCR menu is set to 'auto', PPA3500 will display capacitance or inductance according to the phase of the measurement. Alternatively, the display can be forced to capacitance, inductance or impedance.

Capacitance is displayed with $\tan\delta$, inductance is displayed with Q factor, and impedance is displayed in its resistive + reactive form and as magnitude. The phase of the impedance is displayed with all options.

For phase critical impedance measurements, is it possible to offset the phase measurement to allow for phase shift within the connection leads.

Note that the phase of the impedance is the opposite of the phase of the current in POWER mode. This is because the impedance is defined as voltage/current which, considering the magnitude and phase of Z (impedance), V (voltage) and A (current), gives:

$$\begin{aligned} Z_{\text{magnitude}} &= V_{\text{magnitude}} / A_{\text{magnitude}} \\ Z_{\text{phase}} &= V_{\text{phase}} - A_{\text{phase}} \end{aligned}$$

As the phase is referred to the voltage:

$$Z_{\text{phase}} = - A_{\text{phase}}$$

Therefore, using the phase convention from -180° to $+180^\circ$, an inductive load which has an impedance with a positive phase would cause a current with a negative phase.

16 Oscilloscope mode

PPA3500 provides a storage oscilloscope function in order to view the waveforms being measured.

The display for the oscilloscope is divided into 10 divisions along the time axis with the selected timebase displayed in units of time/division. The timebase may be set to any real value between $15\mu\text{s}/\text{div}$ to $5\text{s}/\text{div}$ using the SCOPE menu. Pressing L and R adjust the timebase by a factor of 2. For slow timebase operation, ($> 0.8\text{s}/\text{div}$) the display operates in 'roll' mode where the waveform scrolls across from left to right until triggered.

Two cursors can be enabled on the display. If cursors are "on" in the menu (press SCOPE or MODE) then the L and R key move the selected cursor, UP and DOWN toggle which cursor is selected. The time difference between the 2 cursors, ' Δt ', is displayed on the lower left of the display. When the cursors are enabled, L and R no longer adjust the timebase.

The vertical scaling is shown as a full-scale value, rather than as a V/cm. This indicates the range that the instrument is using for each channel.

Triggering is very important to obtain a stable trace and there are various options to control the trigger:

- source
- level
- type
- polarity
- HF reject
- pretrigger

The data source for the trigger can be selected to be either voltage or current. On a multiphase instrument, any of the phases may be selected for the trigger source.

The trigger level is set directly in Volts or Amps and does not change if the range is changed, i.e. it is an absolute trigger level and not relative to the range full scale. Pressing NEXT and ENTER adjust the trigger level by a factor of 2.

The trigger level is shown as a small horizontal bar on the extreme left-hand edge of the display against the appropriate channel. If the trigger is set to a value above or below the range of the input channel then a small carat ^ is shown at the top or inverted at the bottom of the display as appropriate.

The trigger type may be set to:

auto	(trigger if possible but do not wait)
normal	(wait indefinitely for trigger)
single shot	(wait for trigger then hold)

The single-shot option is reset using the TRIGGER key. The trigger polarity may be set to a rising edge or falling edge.

When 'trigger HF reject' is on, a low pass filter is applied to the trigger data to stabilise the trace with noisy signals. The filter only influences trigger detection and does not change the data displayed.

Pretrigger may be set to:

none
25%
50%
75%

Autoranging can be used with the oscilloscope functions but it is more customary to fix the range manually particularly when looking for a single event in 'single shot' mode. Manual ranging is essential for rare events with a low mark space ratio.

17 Phase meter

The phase meter mode is a secondary function which does not have a separate button. It is selected by stepping through the operating mode via the MODE menu.

The phase meter uses the terminology of channel 1 for voltage and channel 2 for current as it is normal to use a phase meter to compare voltages directly. In this case, the current input is set to external attenuator in the RANGE menu, and a voltage probe (oscilloscope probe) can be used. For optimum phase accuracy the same type of voltage probe should be used for the voltage input which can also be set to external attenuator in the RANGE menu. Remember to trim the oscilloscope probes if necessary by connecting them to a 1kHz square wave and adjusting them for 33.3% 3rd harmonic in the harmonic analyser mode.

The phase meter measures the phase and gain of channel 2 relative to channel 1 using a discrete Fourier transform (DFT) algorithm at the fundamental frequency. Relative gain is given as an absolute value and in dB. The ratio can be inverted to give the gain of channel 1 relative to channel 2.

To look at differences in gain from a nominal value, an offset gain can be applied either manually or by pressing ZERO.

$$\text{offset gain} = \text{measured dB} - \text{offset dB}$$

18 Specifications & Comparisons

Frequency Range

Normal: DC and 10mHz to 1MHz

Range 1+ 2: DC and 10mHz to 100kHz

Voltage Input

Ranges: 100mVpk to 2500Vpk (1000Vrms) in 10 ranges

Accuracy:

1V -2500Vpk Range: $0.04\% \text{Rdg} + 0.1\% \text{Rng} + (0.005\% \times \text{kHz Rdg}) + 5\text{mV}^*$

Range 1+2: $0.04\% \text{Rdg} + 0.1\% \text{Rng} + (0.01\% \times \text{kHz Rdg}) + 1\text{mV}^*$

External sensor input: 1mVpk to 3Vpk in 8 ranges – BNC connector

Accuracy: $0.04\% \text{Rdg} + 0.1\% \text{Rng} + (0.005\% \times \text{kHz Rdg}) + 3\mu\text{V}^*$

Current Input

20Arms

Ranges: 10mA_{pk} to 300A_{pk} (20Arms) in 10 ranges

Accuracy:

Normal - $0.04\% \text{Rdg} + 0.1\% \text{Rng} + (0.005\% \times \text{kHz Rdg}) + 300\mu\text{A}^*$

Range 1+ 2: $0.04\% \text{Rdg} + 0.1\% \text{Rng} + (0.01\% \times \text{kHz Rdg}) + 100\mu\text{A}^*$

30Arms

Ranges: 30mA_{pk} to 1000A_{pk} (30Arms) in 10 ranges

Accuracy:

Normal - $0.04\% \text{Rdg} + 0.1\% \text{Rng} + (0.005\% \times \text{kHz Rdg}) + 900\mu\text{A}^*$

Range 1+ 2: $0.04\% \text{Rdg} + 0.1\% \text{Rng} + (0.01\% \times \text{kHz Rdg}) + 300\mu\text{A}^*$

External sensor input:

1mVpk to 3Vpk in 8 ranges – BNC connector

Accuracy $0.04\% \text{Rdg} + 0.1\% \text{Rng} + (0.005\% \times \text{kHz Rdg}) + 3\mu\text{V}^*$

* measured fundamental value

Phase Accuracy

Normal: 5 millidegrees + (10 millidegrees x kHz)

Range 1 + 2: 5 millidegrees + (20 millidegrees x kHz)

Watts Accuracy

Normal: $[0.1\% + 0.1\%/\text{pf} + (0.01\% \times \text{kHz})/\text{pf}] \text{Rdg} + 0.05\% \text{VA Rng}$

Range 1+2 $[0.1\% + 0.1\%/\text{pf} + (0.02\% \times \text{kHz})/\text{pf}] \text{Rdg} + 0.05\% \text{VA Rng}$

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40Hz-850Hz Accuracy – V, A and Watts

$[0.06\% + 0.1\%/pf + (0.01\% \times kHz)/pf]$ Rdg + 0.03%VA Rng

DC Accuracy

Voltage:

Normal: $0.1\% \text{ Rdg} + 0.1\% \text{ Rng} + 10\text{mV}$

Range 1+2: $0.1\% \text{ Rdg} + 0.1\% \text{ Rng} + 2\text{mV}$

Current:

(20Arms)

Normal: $0.1\% \text{ Rdg} + 0.1\% \text{ Rng} + 1\text{mA}$

Range 1+2: $0.1\% \text{ Rdg} + 0.1\% \text{ Rng} + 200\mu\text{A}$

(30Arms)

Normal: $0.1\% \text{ Rdg} + 0.1\% \text{ Rng} + 3\text{mA}$

Range 1+2: $0.1\% \text{ Rdg} + 0.1\% \text{ Rng} + 600\mu\text{A}$

External sensor input: $0.1\% \text{ Rdg} + 0.1\% \text{ Rng} + 10\mu\text{V}$

Watts

(20Arms)

$0.20\% \text{ Rdg} + 0.20\% \text{ VA Rng} + 10\mu\text{W}$

$0.20\% \text{ Rdg} + 0.20\% \text{ VA Rng} + 2\mu\text{W}$ (Voltage set to Range 1 or 2)

$0.20\% \text{ Rdg} + 0.20\% \text{ VA Rng} + 2\mu\text{W}$ (Current set to Range 1 or 2)

$0.20\% \text{ Rdg} + 0.20\% \text{ VA Rng} + 0.4\mu\text{W}$ (Both set to Range 1 or 2)

(30Arms)

$0.20\% \text{ Rdg} + 0.20\% \text{ VA Rng} + 30\mu\text{W}$

$0.20\% \text{ Rdg} + 0.20\% \text{ VA Rng} + 6\mu\text{W}$ (Voltage set to Range 1 or 2)

$0.20\% \text{ Rdg} + 0.20\% \text{ VA Rng} + 6\mu\text{W}$ (Current set to Range 1 or 2)

$0.20\% \text{ Rdg} + 0.20\% \text{ VA Rng} + 1.2\mu\text{W}$ (Both set to Range 1 or 2)

Notes:

Normal: excludes Current and Voltage Range 1 and 2

Voltage Range 1=100mV and Range 2=300mV

Current Ranges:

PPA3500-20A: Range 1=10mA and Range 2=30mA

PPA3500-30A: Range 1=30mA and Range 2=100mA

Total Harmonic Distortion (THD) Accuracy

$$THD + THD Error = \left(\frac{1}{h_1 + h_1 error} \right) \sqrt{\sum_{i=2}^{i=n} (hi + hi error)^2}$$

Voltage:

hi error (Voltage) = 0.05% hi rdg + 0.1% rng + 0.005% * KHz + 5mV

Range 1+2:

hi error (Voltage) = 0.05% hi rdg + 0.1% rng + 0.01% * KHz + 1mV

Current:

20A:

hi error (Current) = 0.05% hi rdg + 0.1% rng + 0.005% * KHz + 500uA

Range 1+2:

hi error (Current) = 0.05% hi rdg + 0.1% rng + 0.01% * KHz + 100uA

30A:

hi error (Current) = 0.05% hi rdg + 0.1% rng + 0.005% * KHz + 1mA

Range 1+2:

hi error (Current) = 0.05% hi rdg + 0.1% rng + 0.01% * KHz + 300uA

External Sensor Input:

hi error (Voltage) = 0.05% hi rdg + 0.1% rng + 0.005% * KHz + 5uV

Common Mode Rejection

Total Common Mode and Noise effect on current channels

Applied 250V @ 50Hz – typical 1mA (150dB)

Applied 100V @ 100kHz – typical 3mA (130dB)

Datalog

Functions	Up to 4 measured functions user-selectable (60 with optional PC software)
Datalog window	From 10ms with no gap between each log
Memory	RAM up to 16,000 records

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General

Crest factor	Voltage and Current – 20
Sample rate	Real-time no gap - 1Ms/s on all channels
IEC Modes	Compliant with IEC62301/EN50564 using Internal shunt
Low power	Refer to low power measurement application note
Accuracy	
Remote Operation	Full capability, control and data
Application modes	PWM, Ballast, Inrush and Standby power

Ports

RS232	Baud rate to 38400 – RTS/CTS flow control
LAN	10/100 Base-T Ethernet auto-sensing RJ45
USB	USB device – 2.0 and 1.1 compatible (Note USB Memory stick maximum capacity 2GB)
GPIOB	IEEE 488.2 compatible
Extension	N4L accessory port
Aux	N4L auxiliary port

Physical

Display	960 x 272 pixel 8.3" colour TFT
Size	92H x 405W x 312D mm – excluding feet
Weight	4kg – 1 phase; 5kg – 3 phase
Safety isolation	1000V rms or dc – category II
Power supply	90-265 rms 50-60Hz 45VA max

Environmental

Storage temperature range.	0°C to +50°C
Storage temperature range.	-10°C to +60°C
Relative Humidity Range.	20 to 95% Non-Condensing
Maximum Altitude.	2,000 Metres

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PPA SERIES COMPARISON TABLE			
	PPA1500/500	PPA3500	PPA5500
Phases			
Maximum V & A phases	3	6	3
Accuracy			
Basic V & A reading + range	0.05% + 0.1%	0.04% + 0.1%	0.01% + 0.038%
Power reading + VA range	0.1% + 0.1%	0.1% + 0.05%	0.03% + 0.03%
Voltage Input			
Direct Voltage	2500Vpk	2500Vpk	3000Vpk
Ranges	8 (10♦)	10	9
Direct current input options			
10Arms			3mA-30Apk
20Arms	10mA - 30Apk♦ 100mA - 300Apk	10mA-30Apk• 100mA-300Apk	
30Arms	30mA-100Apk♦ 300mA-1000Apk	30mA-100Apk• 300mA-1000Apk	30mA-300Apk
50Arms			100mA-1000Apk
Ranges	8	10	9
Bandwidth			
ac+dc coupled	DC to 1MHz	DC to 1MHz	DC to 2MHz
Selectable Low BW		✓	✓
General features			
Display	High contrast Colour Graphic	High contrast colour Graphic	High contrast Colour Graphic
Processing power - Harmonic computations per second	300	600	1,800
Non volatile internal Memory	192kB	1GB	1GB
USB port for memory drive	✓	✓	✓
Plug in USB memory drive		2GB	2GB
Non-volatile real-time clock	✓	✓	✓
Torque and speed inputs		Analog & pulsed	Analog & pulsed
Analogue output			✓
Internal datalog functions	4	32 (2 x 4 x 4)	16 (4 x 4)
Datalog record storage capacity	16,000	10,000,000	10,000,000
Frequency measurement accuracy	0.02%	0.02%	0.001%
Application modes			
PWM		✓	✓
Lighting	✓	✓	✓
Inrush	✓	✓	✓
Transformer		✓	✓
Standby Power	✓	✓	✓
Mechanical			
Handle	Adjustable	Adjustable	Adjustable
Tilt	Multiple position	Multiple position	Multiple position
19" Rack mounting option		✓	✓

X10 range mode = ♦ Range 1+2 = •

19 General Maintenance and Functional Checks

General maintenance:

1. Ensure unit ventilation is clear of obstructions
2. Check ventilation fans are working ok
3. Ensure 4mm connectors are clear of dirt
4. Ensure BNC inputs are clear of dirt
5. Check the display for defects
6. Check chassis and front panel for visual damage

General operation check:

1. Does the unit power on?
2. If no: Check Fuse, If Yes, move on to step 4
3. If the fuse is OK and the unit does not power on, contact a local representative.
4. Apply voltage signal to all HV attenuators (4mm red/black connections) and external current signal to all internal current shunts (4mm yellow/black connections), does the PPA measure correctly?
5. If no: contact N4L, If yes, move on to step 6
6. Apply external voltage ($<3\text{Vpk}$) to all external inputs (BNC), set inputs to "external attenuator and external shunt" in RANGE menu, does the PPA measure correctly?

Notes: no customer serviceable parts

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Appendix A – Accessories

Supplied Standard Accessories

Leads	Power, RS232, USB
Connection	20Arms rated 1.5 meter long leads with 4mm –
cables	stackable terminals
	1x Yellow, 1 x Red and 2x Black per phase
Connection	4mm terminated alligator clips –
clips	1x Yellow, 1 x Red and 2x Black per phase
Documentation	Calibration Certificate,
	User manual with quick start guide,
	Communications manual

External shunts

A range of high bandwidth external shunts is available to extend the operating range of the current measurements.

The external shunts are built using an N4L proprietary shunt design to give high accuracy from DC to 1MHz. They are designed to comply with the safety standards of BS EN61010-1 to 1000V rms cat II. The sense output is via safety BNC connection to connect to the instrument, the current connections depend on the device.

Part numbers

HF003	470m Ω 3A rms	4mm safety
HF006	100m Ω 6A rms	4mm safety
HF020	10m Ω 20A rms	4mm safety
HF100	1m Ω 100A rms	safety terminals
HF200	500u Ω 200A rms	M10 stud
HF500	200u Ω 500A rms	M16 stud

PCIS - Phase controlled inrush switch

To measure the maximum inrush current of a load it is important to switch on the supply to it at the worst point in the cycle – usually 90° or 270° for a capacitive load, 0° or 180° for an inductive load.

The PCIS is an active device which is controlled by PPA3500 over the extension port. It accurately synchronises to the line input, measures the frequency, and switches on the output at a precise phase angle selectable from the PPA3500 front panel in steps of 45° .

Note: The PCIS is designed for use at Frequencies of 50Hz–60Hz only. Do not use at other frequencies to avoid damage to the device.

Part numbers

PCIS	Phase Controlled Inrush Switch
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Ultra low capacitance high voltage probes

The PPA3500 voltage inputs have a capacitance to ground of around 50pF but even this low value can cause problems with high frequency high voltage waveforms. The ultra-low capacitance high voltage probes use a differential input arrangement optimised for minimum capacitance to achieve an input capacitance to ground less than 1pF with an input range up to $\pm 3\text{kV}$ pk and a bandwidth from dc to 2MHz $\pm 1\text{dB}$.

The probes connect to the external voltage input using the touch-proof BNC cable supplied. They are powered either by an ac/ac mains adaptor or a dedicated $\pm 12\text{V}$ dc supply.

Part numbers

ULCP	Ultra-Low Capacitance Probe
------	-----------------------------

External input attenuator

The PPA3500 voltage inputs have a $\pm 3\text{V}$ peak external input for use with probes or attenuators.

A divide by 10 or divide by 20 passive attenuator with a bandwidth of dc-30MHz ($\pm 1\text{dB}$) is available to extend the $\pm 3\text{V}$ peak input to $\pm 30\text{V}$ and $\pm 60\text{V}$ respectively.

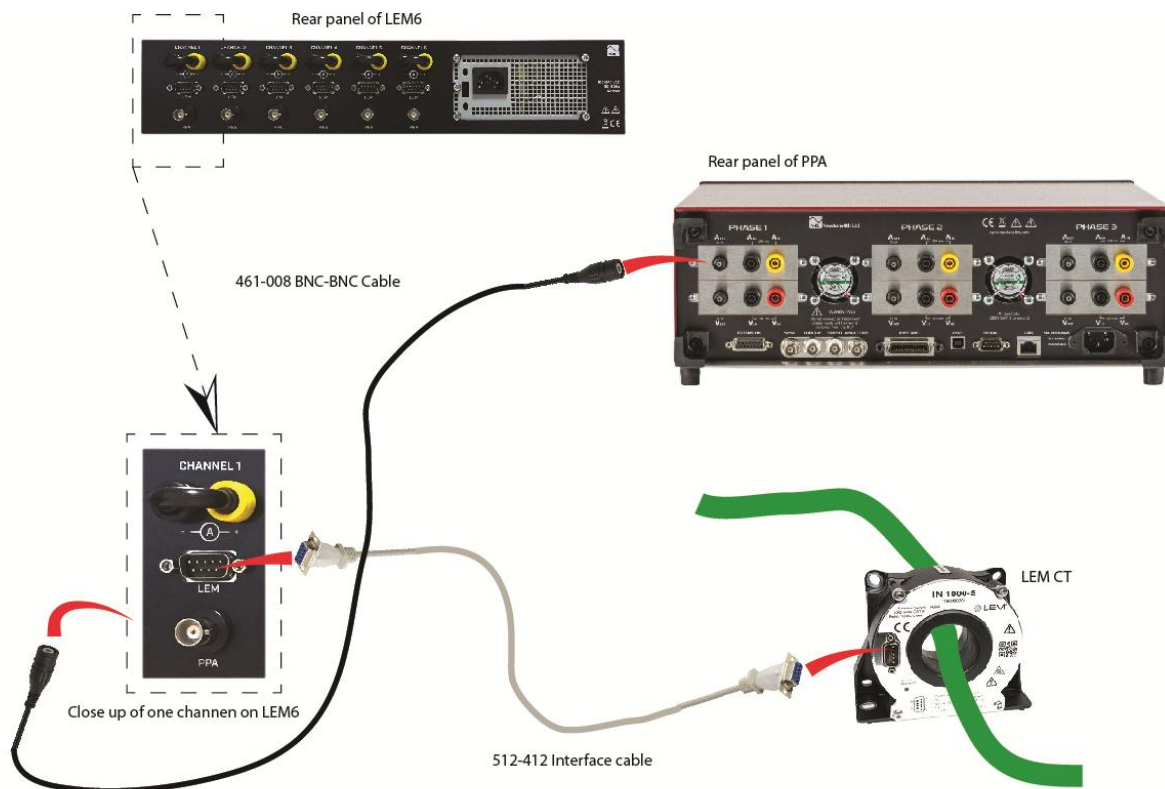
The low-frequency accuracy is $\pm 0.3\%$ max

The attenuators have a short flying lead to connect to the external BNC of the instrument.

Part numbers

ATT10	divide by 10 attenuator
ATT20	divide by 20 attenuator

LEM6: 3-6 Channel Interface



Connection Diagram

The N4L LEM-6 Interface serves as a high accuracy, highly stable interfacing unit allowing simple "plug and play" connection of any N4L PPA to the LEM current transducers listed in table 1.

The LEM-6 supplies the LEM transducer with a highly stable isolated supply voltage; each channel is isolated from the next providing excellent cross channel coupling immunity. There are 4x current shunts per channel, 1Ω, 2.5Ω, 5Ω & 10Ω; this ensures the transducer can be utilized accurately throughout its dynamic range without the introduction of noise into the measurement.

The LEM-6 is 19 inch rack mountable and available in 3 - 6 phase configurations.

Table 1

Model Number	Current Rating		Conversion Factor
IT60-S	60Apk	42Arms	600
IT65-S	85Apk	60Arms	600
IT200-S	200Apk	141Arms	1000
IT205-S	283Apk	200Arms	1000
IT400-S	400Apk	282Arms	2000
IT405-S	566Apk	400Arms	1500
IT700-S	700Apk	495Arms	1750
ITN600-S	600Apk	424Arms	1500
IT605-S	849Apk	600Arms	1500
ITN900-S	900Apk	639Arms	1500
ITN1000-S	1000Apk	707Arms	1500
LF510-S	800Apk	500Arms	5000
LF1010-S	2700Apk	1000Arms	5000
LF2010-S	4250Apk	2000Arms	5000

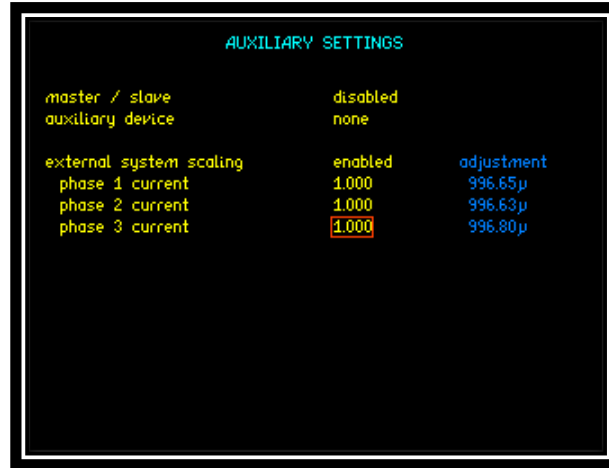
System Calibration

If the LEM-6 is purchased with an N4L power analyzer and LEM transducers, the LEM-6 Interface can be "system calibrated" within N4L's ISO17025 UKAS laboratory. This provides the engineer with a single uncertainty figure and improved accuracy performance.

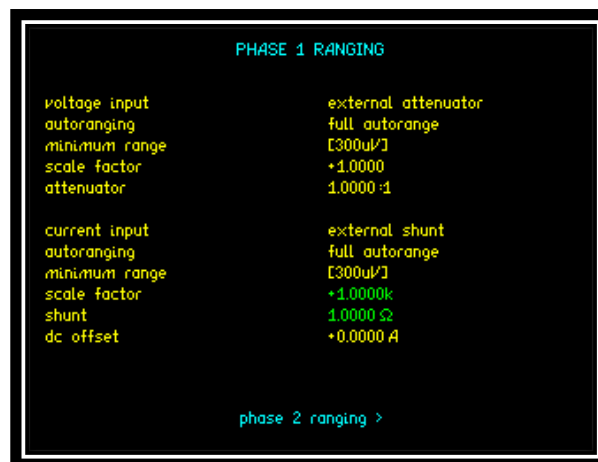
Following System Calibration the Calibration Adjustment figures for the 4 current shunts on the LEM6 are stored in program location 1 on the instrument. They are then automatically recalled each the instrument is switched on.

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These values can be viewed by pressing the AUX button and referring to the External system Scaling option. The screenshot below shows the adjustment figures for the 1Ω current shunt:

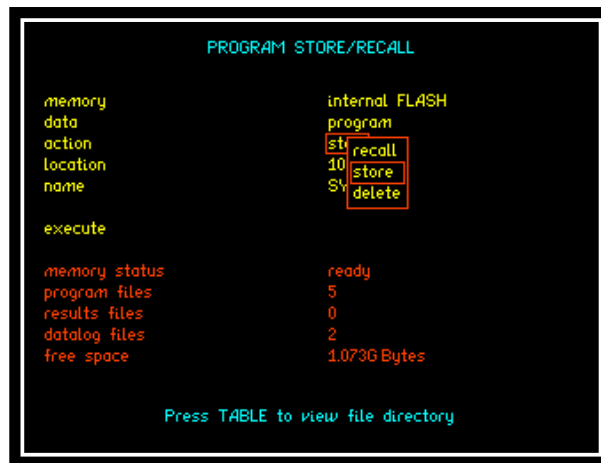


Pressing the RANGE key to display the RANGING menu will confirm that the external system scaling has been selected in the AUX menu. The Scale factor and the nominal shunt value will be displayed in green text. The screenshot below shows the settings for Phase 1.



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Only the settings stored in program location 1 are automatically recalled each time the instrument is switched on. Should it be preferred to not have them automatically recalled they can instead be saved to an alternative memory location and then deleted from location 1. The User can then recall the System Calibration data when required. The Program Store/Recall/Delete menu should be used to make the changes:



The LEM6 can also be used with non-system calibrated CT's.

Full details of the LEM6 features, Specification and setup procedure for use with System Calibrated and Non-System Calibrated CT's can be found in the LEM6 User Manual.

CommView2 PC software

CommView2 is a self-contained software program for a PC, which facilitates communication with PPA3500 over RS232, USB or LAN.

CommView2 allows strings to be sent and received between a PC and PPA3500. The strings can be viewed in a window and optionally stored in a file. Data received from PPA3500 may be displayed in normal scientific notation with an identifying label.

Strings to be sent to PPA3500 can be stored in a "script file" and executed automatically. The script file is created with any text editor and includes three types of lines (interpreted by the first character on each line):

- lines beginning with " are sent to PPA3500
- lines beginning with # are commands for CommView2
- any other line is a comment.

The # commands that are recognised:

#beep	<i>sound the beeper on the PC</i>
#label,i,string	<i>apply a label to data value[i]</i>
#pause,t	<i>wait for time t</i>
#reply,t	<i>wait time t for a reply</i>

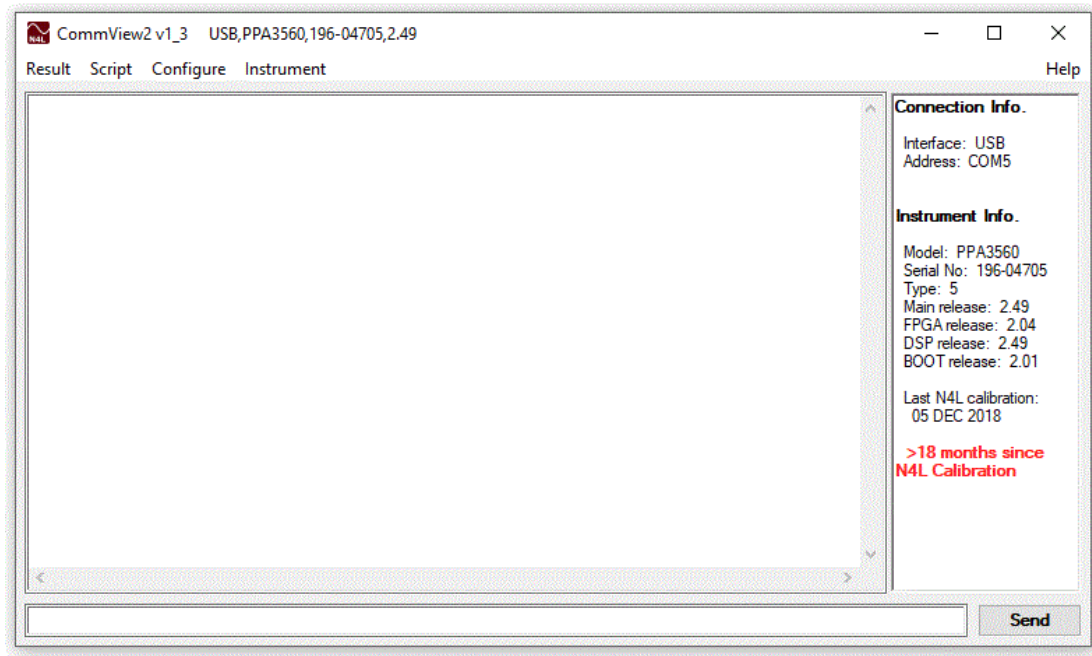
For an example script file, look at example.scr on the CommView2 release disc.

Other functions in CommView2:

save results	<i>results menu</i>
set COM port parameters	<i>configure menu</i>
firmware upgrade	<i>instrument menu</i>
read/store user programs	<i>instrument menu</i>

All N4L software applications are available to download free of charge from our website. To find out more please visit us at www.newtons4th.com

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When connecting to the instrument the panel to the right hand side of the software window will display details about the instrument.

This includes:

Connection Information: Details of the interface used to connect the instrument to the PC.

Instrument Information: Instrument Model, Serial number along with firmware details.

Calibration information: Details of when the instrument was last calibrated*

*From firmware version v2.49 onwards details of the last N4L Calibration procedure are displayed along with details of any later calibration performed by a locally based Calibration Laboratory.

An advisory message is displayed if the N4L Calibration & Adjustment was last performed more than 18 months ago.

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PPA Datalogger PC software

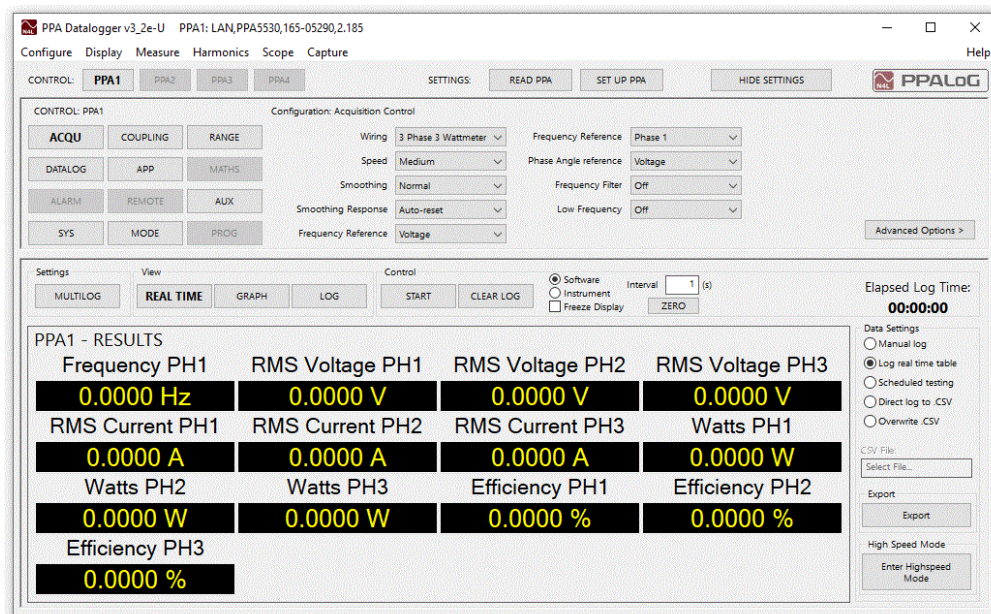
PPA Datalogger is a self contained executable software program written in C++ using the Microsoft win32 graphics set.

PPA Datalogger has the ability to connect to the PPA series of instruments via RS232, USB and LAN. The software includes all measurement modes to reflect instrument operation.

PPA Datalogger has the capability to communicate with up to 4 different PPA Instruments at the same time.

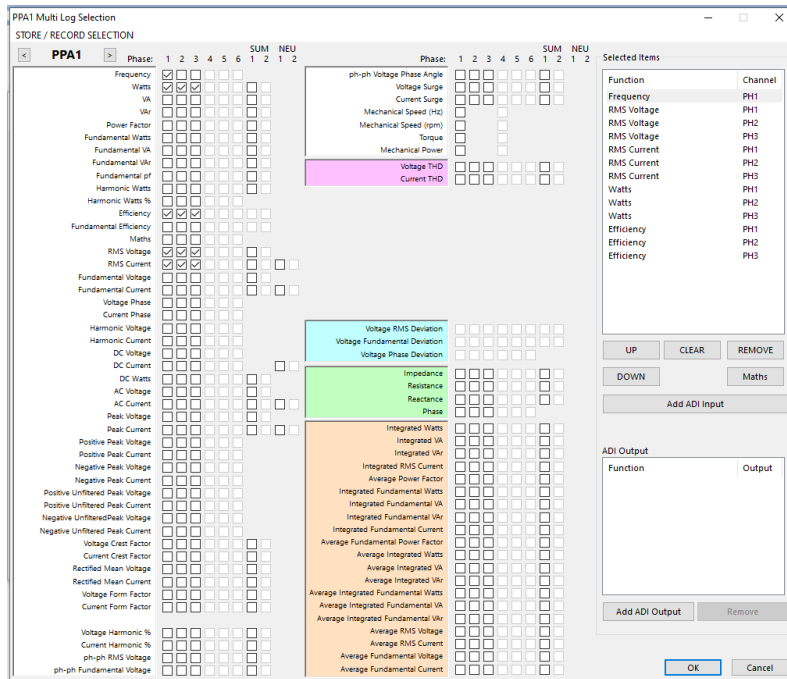
PPA Datalogger supports the ability to export text files in CSV format as well as export directly to Microsoft Excel.

Measure Mode is PPA Datalogger's all purpose measurement mode. Measure mode is an intuitive way to log a wide range of parameters using Real Time, Graph and Log datalogging methods. A few simple steps will see PPA Datalogger ready to record up to 60 of the PPAs wide range of multilog parameters, on up to 4 PPAs synchronised by PPA Datalogger, with speeds up to 200 results a second.



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Measure mode is a truly flexible measuring system which will fulfil most needs. The Parameters to be datalogged are selected using the Multilog selection window:



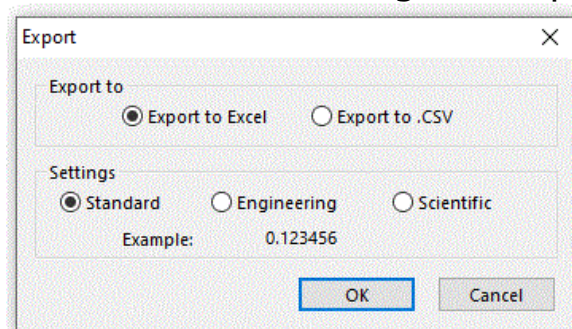
There are several measuring modes including:

Real Time: the default mode which records each result read from the connected Instrument to the Data Log.

Scheduled Testing Mode: The Start Time and Date and End Time and Date for the test are pre-selected.

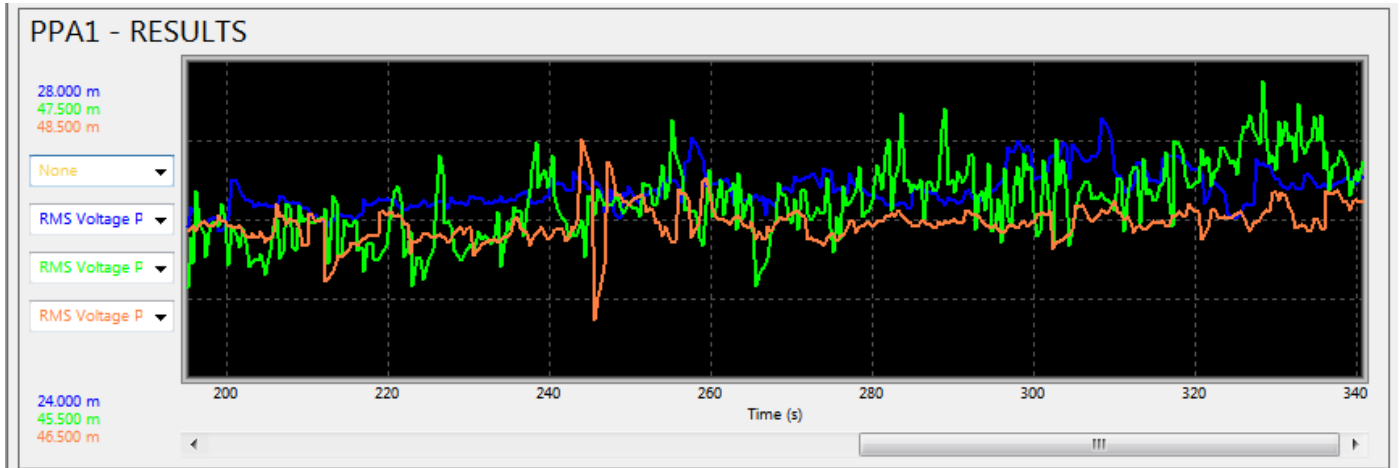
Direct Log to CSV Mode: The data is recorded from the instruments straight to a CSV file.

On completion of the test the results can be exported to Excel or CSV in several formats using the Export function:



Other PPA Datalogger Features:

Customisable Graph mode allowing up to 4 parameters to be selected:



Harmonics Mode: Harmonic data can be displayed in graph or table format.

Scope Mode: Allows up to 4 parameters to be displayed in Scope format, either in single step or continuous mode.

Capture Mode: Allows screenshots to be taken of the PPA display.

Display mode: Allows the displayed software screen to be saved to the clipboard, a Bitmap file or a Word document.

Equations Mode: Measure Mode's Multilog Parameters can be used to create custom equations. The equations can be added to Multilog Setups and logged alongside other Multilog Parameters, as well as exported.

The PPA Datalogger User Manual provides a full description of the various datalogging modes and functionality. There are full setup instructions for the software and connecting to the instruments

Appendix B – Serial command summary

command format	reply format
*CLS	
*ESE,value	
*ESR?	single integer data value
*IDN?	company,product,serial no,version
*OPC?	0 or 1
*RST	
*SRE,value	single integer data value
*SRE?	
*STB?	single integer data value
*TRG	
*TST?	single integer data value
*WAI	
ABORT	
ADIMAP,output,multilog, offset,scale	
ALARM,latch,sounder	
ALARM?	single integer data value
ALARM1,type,data,hi,lo	
ALARM2,type,data,hi,lo	
ALARME,value	
ALARME?	single integer data value
ANALOG,channel,value	
ANALOG?channel?	
APPLIC,type,setting	
BEEP	
BLANKI,on/off	
CALSNO?	alpha-numeric string
CALSTR,string	
CALSTR?	string
CONFIG,parameter,data	
CONFIG,parameter?	single integer or real data value
COUPLI,phase,coupling	
COUPLI?	numerical value
CYCLES,value	
DATALO,func,interval,speed	
DATALO,LINES?	single integer data value
DATALO,0?	index,time,data... one record per line
DATALO,start,records?	index,time,data... one record per line
DAV?	single integer data value
DAVER,value	

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DAVER?	single integer data value
DISPLAY,page	
DISPLAY?	multiple real data values
EFFICI,value	
EFFICI?	total efficiency, fundamental efficiency
FAST on/off	
FQLOCK,type, value	
FQREF,phase,channel	
FREQUE,frequency	
FSD?	calibrated range
GROUP,value	
GROUP1,value	
HARMON,para,h,max	
HARMON,phase?	freq,mag1,mag2,hmag1,hmag2,h1,h2, thd1,thd2,hphase1,hphase2
or	
HARMON,SERIES?	mag,%, X n harmonics
or	
HARMON,phase,SERIES?	mag,phase, X n harmonics
HOLD,on/off	
INPUT,channel,type	
INTEGR,type,display	
INTEGR,RUNTIM,hours,mins	
INTEGR,phase?	time,Wh,Wh.f, VARh,VARh.f,VAh,VAh.f, pf,pf.f,Vav,Vav.fAh,Ah.f
KEYBOA,value	
LCR,parameter	
LCR,phase?	freq, Vmag, Amag, impedance, phase, R, L, C, tan δ , Qf, reactance
LOWFRE,on/off	
MODE,type	
MULTIL,index,phase,func	
MULTIL?	up to 30 data values
NEWLOC	
NORMALISE,current	
NORMALISE,voltage	
NOISEF,on/off,value	
NOOVER,value	
PFCONV,type	
PHANGREF,type	
PHASEM,ratio	
PHASEM,phase?	freq,mag1,mag2,dB,phase
PHCONV,convention	
POWER,sum,type	

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POWER,phase,WATTS?	freq,W,W.f, VA,VA.f,Var,Var.f,pf,pf.f, Wdc,W.h
POWER,phase,VOLTAGE?	freq,rms,mag,dc, ϕ ,peak,cf,mean,ff, harmonic
POWER,phase,CURRENT?	freq,rms,mag,dc, ϕ ,peak,cf,mean,ff, harmonic
POWER,PH-PH?	freq,rms1,mag1, ϕ 1,rms2,mag2, ϕ 2, rms3,mag3, ϕ 3
POWER,RMS?	freq,vrms1,vdc1,arms1,adc1,vrms2, vdc2,arms2,adc2,vrms3,vdc3, arms3, adc3
POWER,VECTORS?	freq,mag1, ϕ 1,mag2, ϕ 2,mag3, ϕ 3, mag4, ϕ 4,mag5, ϕ 5,mag6, ϕ 6,mag7, ϕ 7, mag8, ϕ 8,mag9, ϕ 9,mag10, ϕ 10,mag11, ϕ 11,mag12, ϕ 12
POWER,WVA?	freq,w1,vrms1,arms1,w2,vrms2, arms2,w3,vrms3,arms3,w4,vrms4,arms4, w5,vrms5,arms5,w6,vrms6,arms6
PRIMARY on/off	
PROGRA,function,number	
PROGRAM,files?	Lists all program files
PROGRAM,name?	Name of the selected program
RANGE,ch,ranging,range	
RESOLU.format	
RESULT,function,number	
RESULT?	multiple integers
REZERO	
SCALE,channel,factor	
SCOPE,phase,channel?	range, trigger, 250 signed integer data values
SCREEN?	multiple data values
SETUP,index,data	
SETUP?	16 lines of ASCII data
SHUNT,channel, resistance	
SMOOTH,type,dynamics	
SPEED,value>window	
START	
STATUS,channel?	range number,range text,over/under/ok
STOP	
SUSPEN,on/off	
TAGREP.on/off	
TORQSP,type,scale,scale	
TORQSP,OFFSET,offs,offs	

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TORQSP?	power,torque,speed
USBLOCK,on/off	
USER?	3 CR terminated text strings
VARCON,type	
VERSIO?	datecode,cpu,dsp,fpga,boot
VRMS	
VRMS,PHASE,RMS?	Vrms,Arms,Vdc,Adc,Vac,Aac
VRMS,PHASE,MEAN?	Vrms,Arms,Vmean,Amean,Vff,Aff
VRMS,PHASE,SURGE?	Vrms,Arms,Vpk,Apk,Vcf,Acf,Vsurge,Asurge
WIRING,type	
ZERO	
ZERO,DELETE	
ZOOM,level,d1,d2,d3,d4	
ZOOM?	level,d1,d2,d3,d4

Appendix C – Available character set

The following characters can be selected in text entry mode.

The table is to be read across then down (eg, starting at space and repeatedly pressing NEXT gives ! " # \$ % & ' () * etc.)

	!	"	#	\$	%	&	'
()	*	+	,	-	.	/
0	1	2	3	4	5	6	7
8	9	:	;	<	=	>	?
@	A	B	C	D	E	F	G
H	I	J	K	L	M	N	O
P	Q	R	S	T	U	V	W
X	Y	Z	[\]	^	_
`	a	b	c	d	e	f	g
h	i	j	k	l	m	n	o
p	q	r	s	t	u	v	w
x	y	z	{		}		

Appendix D – Configurable parameters

All parameters can be accessed using the CONFIG command:

```
CONFIG,parameter?
CONFIG,parameter,data
```

Where the config can be different between the two groups the command applies to the current “active” group

Number	Function	Dual
System parameters		
1	operating mode	/
2	digital resolution	
4	autozero manual or auto	
6	phase convention	
7	Frequency lock on/off	/
8	graph	
9	keyboard beep on/off	
10	ignore overload	/
11	low frequency mode	/
12	window size	/
13	speed	/
14	smoothing	/
15	smoothing response	/
16	baud rate	
18	LAN IP address nibble 3	
19	LAN IP address nibble 2	
20	LAN IP address nibble 1	
21	LAN IP address nibble 0	
22	Independent ranging	/
23	grouping	
Input parameters (phase 1 or 4)		
24	enable channel 1	/
25	enable channel 2	/
26	input range channel 1	/

27	input range channel 2	/
28	input ranging channel 1	/
29	input ranging channel 2	/
30	coupling	/
31	bandwidth	/
32	scale factor channel 1 voltage	/
33	scale factor channel 2 current	/
34	external attenuator channel 1	/
35	external shunt channel 2	/
36	enable noise filter	/
37	noise filter frequency	/
38	Voltage or current frequency reference	/
40	frequency reference phase	/

Display parameters

41	display page	/
42	zoom level	/
43	function zoomed on 1	/
44	function zoomed on 2	/
45	function zoomed on 3	/
46	function zoomed on 4	/
47	datalog display type	

Advance parameters

48	manual frequency	/
49	DFT selectivity	/
50	program 1-4 direct load	
51	language (if installed)	
52	frequency filter	/
53	voltage or current phase reference	/

Datalog parameters

54	datalog zoom 1	
55	datalog zoom 2	
56	datalog zoom 3	
57	datalog zoom 4	
58	datalog memory type	
59	datalog interval	
60	datalog graph	

	Maths parameters	
61	formula	
62	argument 1	
63	sub-argument 1	
64	coefficient 1	
65	argument 2	
66	sub-argument 2	
67	coefficient 2	
	Miscellaneous parameters	
68	user window frequency	/
69	minimum frequency	/
	Application mode parameters	
70	application mode	/
71	filter strength	/
72	ballast frequency tracking speed	/
73	PWM low-frequency mode	/
	More maths parameters	
74	argument 3	
75	sub-argument 3	
76	coefficient 3	
77	argument 4	
78	sub-argument 4	
79	coefficient 4	
	Power meter parameters	
82	wiring configuration	/
83	integration type	
84	torque and speed enable	
85	torque scale	
86	speed scale	
87	speed pulses per rev	
88	integration display	
89	sum current average	/
91	power factor sign convention	
92	VAr sign convention	
93	efficiency computation	/

94 torque offset
95 speed offset

Harmonic analyser parameters

99 computation mode
100 selected harmonic
101 maximum harmonic
102 harmonic bargraph voltage
103 rated current for TRD
104 harmonic bargraph current

Oscilloscope parameters

106 timebase /
107 trigger level /
108 pretrigger /
109 trigger polarity /
110 trigger mode /
111 trigger reference /
112 trigger phase /
113 cursors enable /
114 trigger HF reject /
115 traces /

System parameters

117 DFT type cosine/sine
119 zoom 2 high resolution
120 brightness

Auxiliary parameters

122 Auxiliary drive
128 PICS phase offset
129 PICS cycles

Other power parameters

131 2 wattmeter sum computation /
132 integrator run time
134 phase to phase mean /
135 Difference THD /

LCR meter parameters

- 137 parameter
- 138 measurement
- 139 Offset

Phase meter parameters

- 140 voltage peak
- 144 rectified mean
- 148 dB offset
- 150 computation

System parameters

- 152 RS232 printer enable
- 153 IEEE address
- 154 interface
- 155 recall with program

Alarm functions

- 156 alarm 1 data
- 157 alarm 1 type
- 158 alarm 1 high threshold
- 159 alarm 1 low threshold
- 160 alarm latch
- 161 alarm sounder
- 167 alarm 2 data
- 168 alarm 2 type
- 169 alarm 2 high threshold
- 170 alarm 2 low threshold

Input parameters (phase 2 or 5)

- 176 enable channel 3 /
- 177 enable channel 4 /
- 178 input range channel 3 /
- 179 input range channel 4 /
- 180 input ranging channel 3 /
- 181 input ranging channel 4 /
- 182 coupling phase 2 /
- 184 scale factor channel 3 voltage /
- 185 scale factor channel 4 current /

186	external attenuator channel 3	/
187	external shunt channel 4	/
188	enable noise filter	/
189	noise filter frequency	/
190	Voltage or current frequency reference	/
191	frequency reference phase	/

Miscellaneous parameters

196	tag reply	
197	high speed mode	/
196	enable system calibration	/

Input parameters (phase 3 or 6)

200	enable channel 5	/
201	enable channel 6	/
202	input range channel 5	/
203	input range channel 6	/
204	input ranging channel 5	/
205	input ranging channel 6	/
206	coupling phase 3	/
208	scale factor channel 5 voltage	/
209	scale factor channel 6 current	/
210	external attenuator channel 5	/
211	external shunt channel 6	/
212	enable noise filter	/
213	noise filter frequency	/
214	voltage or current frequency reference	/
215	frequency reference phase	/

Program storage

231	memory
232	data
233	action
234	location

System clock

240	set clock (hrs)
241	set clock (mins)
242	set clock (secs)

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243	set date (day)
244	set date (month)
245	set clock (year)

Appendix E – Useful Application Guides

App Note 009

[Power accuracy at specified frequency and phase angle](#)

App Note 013

[Efficiency Measurements of AC – DC Power supplies using the PPA1500 series Power Analyzers](#)

App Note 014

[Phase 2 Wattmeter Explained – Power Analysis](#)

App Note 015

[Standby Power Testing – IEC62301](#)

App Note 017

[PWM Motor Drives – Pulse Width Modulation Theory](#)

App Note 019

[RMS and Peak range consideration in Precision Power Analyzers](#)

App Note 021

[Master Slave Efficiency Testing](#)

App Note 023

[Harmonic Analysis in Power Applications](#)

App Note 032

[Efficiency Measurement of Traction Motors](#)

App Note 035

[Low Power Factor Watts Measurement & Calibration](#)

App Note 036

[6 & 7 Phase Motor Drive Analysis](#)

App Note 038

[Understanding Power Calibration](#)

Appendix F – Contact details

Please direct all queries or comments regarding the PPA3500 instrument or manual to:

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At Newtonson4th Ltd. we have a policy of continuous product improvement and are always keen to hear comments, whether favourable or unfavourable, from users of our products.

An example comment form can be found at the end of this manual – if you have any comments or observations on the product please fill a copy of this form with as much detail as possible then fax or post it to us.

Alternatively, send an email with your comments.



PPA35xx PPA3500 comments

serial
number:

main release:
dsp release:
fpga release:
boot release:
(press SYS then LEFT)

date:

Your contact details:

Comments:

A detailed description of application or circumstances:

Please post or fax to Newtons4th Ltd.