

Making Fluorescent Lamp Ballast Measurements with The Tektronix PA1000 Power Analyzer

APPLICATION NOTE

1 Introduction:

An electronic ballast is a power conversion device that is an essential part of today's energy efficient lighting systems. An electronic ballast converts the normal AC line voltage and frequency at its input into a modulated high frequency output suitable for the fluorescent lamp. . During startup of the lamp, the ballast must briefly supply high voltage to establish an arc between the two lamp electrodes. Once the arc is established, the ballast quickly reduces the voltage and regulates the electric current to produce a steady light output. Without a ballast to limit its current, a fluorescent lamp connected directly to an uncontrolled high voltage power source would rapidly and uncontrollably increase its current draw.

The advantages of high-frequency electronic ballast over older line frequency types are that:

- The fluorescent tube converts electrical energy into light much more efficiently at high frequencies than at line frequencies of 50 or 60Hz. Typical ballast frequencies are in the range 40kHz to 150 kHz.
- When regulating the current the excess voltage is dropped across the leakage inductance of the ballast with minimal Watts loss as compared to the copper losses of conventional ballast.

Electronic ballasts are commonplace, reliable and efficient. This application note will focus on measurements of ballasts driving fluorescent tubes. Ballast technology is used in many different lamp types including:

- Electrodeless fluorescent lamps
- LED Lighting
- Fluorescent, high efficiency
- HID lamp with ballast

2 Measurement Challenges

Measuring the efficiency and electrical characteristics of electronic ballasts is not straightforward. Several challenges should be considered and suitable measurement techniques employed.

2.1 Input measurements

As well as measurements of power in Watts at the ballast input, international regulations such as IEC61000-3-2 seek to limit the level of distortion of the current drawn. Current harmonics and power factor are thus required input measurements.

The current drawn by the ballast will not be sinusoidal but is distorted by the input rectifiers and storage capacitors of the ballast. The current may be artificially corrected by power factor correction circuits but even then it is important to confirm the correct and efficient operation of any power factor correction. There may also be high frequency current present at the ballast input which can artificially influence the power factor.

The power analyzer must:

- Measure power and power factor accurately on distorted waveforms
- Measure current harmonics
- Have high bandwidth (several times higher than the ballast switching frequency) to avoid filtering the high frequency current components caused by the output switching frequency which are drawn on the input to the ballast.

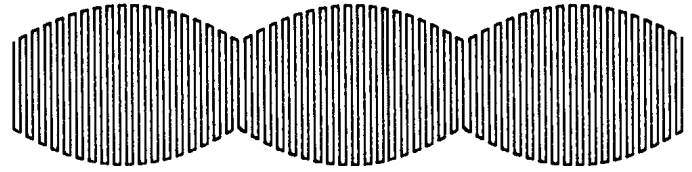


Figure 1. Modulated ballast output waveform.

The ballast output has the following characteristics:

- The frequency is high (40kHz – 150kHz or more) and the measuring instrument must measure accurately at this frequency
- Two frequencies are present and for accurate measurements, the frequency used to calculate power must be the low (or line) frequency so that complete cycles of the waveform are captured.
- Total Harmonic Distortion (THD) of the high-frequency waveform must be controlled to guarantee long life of the lamp. The analyzer must measure high frequency harmonics while simultaneously measuring the power at the line frequency of the ballast input

Only once these measurement challenges have been considered and acknowledged, can accurate power and efficiency measurements be made.

The objective of this application note is to show how to set up fluorescent lamp ballast testing

There are four tutorial sections as follows:

- Section 1: Making Input Measurements on a lamp ballast with the PA1000 power analyzer using either front panel operation or with Tektronix PWRVIEW software
- Section 2: Making Output Measurements on a lamp ballast with the PA1000 power analyzer using either front panel operation or with Tektronix PWRVIEW software
- Section 3: Making simultaneous Measurements of the input and output of a ballast including efficiency using two PA1000s with PWRVIEW software.
- Section 4: Recording measurements using the PA1000 and PWRVIEW

PA1000 Ballast Mode Test Set Up

Equipment Required:

- PA1000
Breakout box (Part numbers: BB1000-NA, BB1000-EU, BB1000-UK)
- NA – North American socket
EU – European Union Shuko Style socket
UK – British style socket
- Ballast Current Transformer (Part number: BALLAST-CT)
- Ballast and lamp to be tested (Abbreviated DUT (Device-under-Test))
- PWRVIEW Software installed on a Windows PC
- Standard Tektronix 4mm Lead Set
- USB Peripheral Cable

Note: This document assumes a USB connection between PA1000 and PWRVIEW. Ethernet or GPIB also can be used for communication between PA1000 and PWRVIEW.

3 Making Input Measurements on a lamp ballast with the PA1000 power analyzer using either front panel operation or with Tektronix PWRVIEW software

Parameters of interest are: Voltage, Current, Watts, Power Factor, Current Harmonics and Current Total Harmonic Distortion.

3.1 Connecting the ballast to the PA1000

- Connect the PA1000 and Breakout Box as shown in Figure 2 .
- Plug the DUT into the Breakout Box as shown in Figure 2.
- Connect the PA1000 to the PC using the USB cable
- Power on the DUT

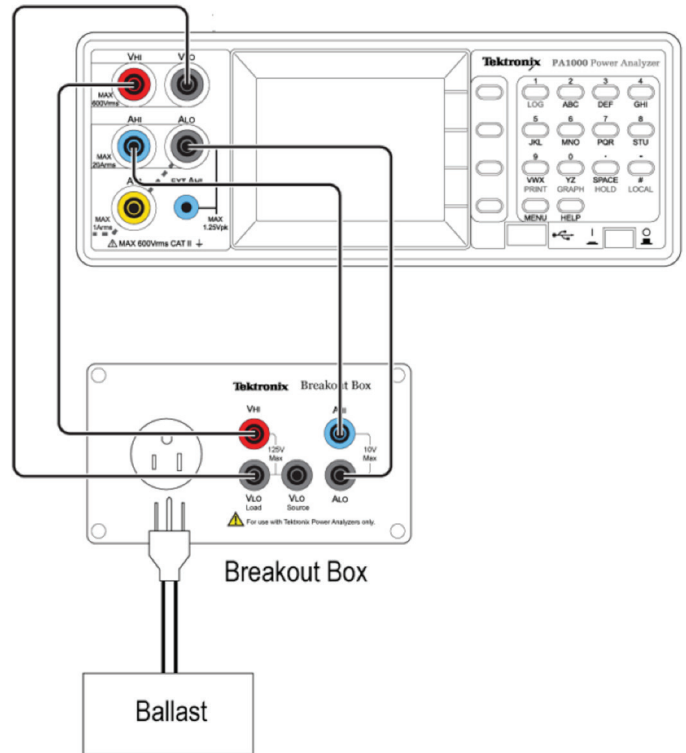


Figure 2. Hardware Setup for Ballast Input Measurement.

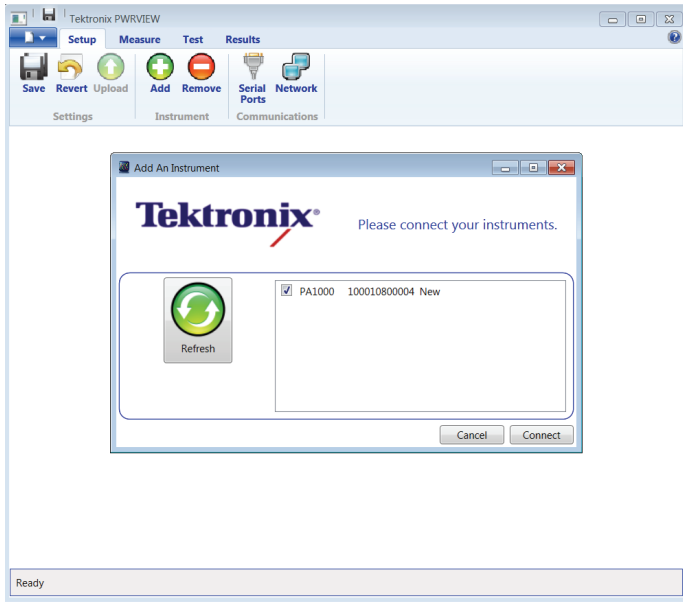


Figure 3. Add an Instrument.

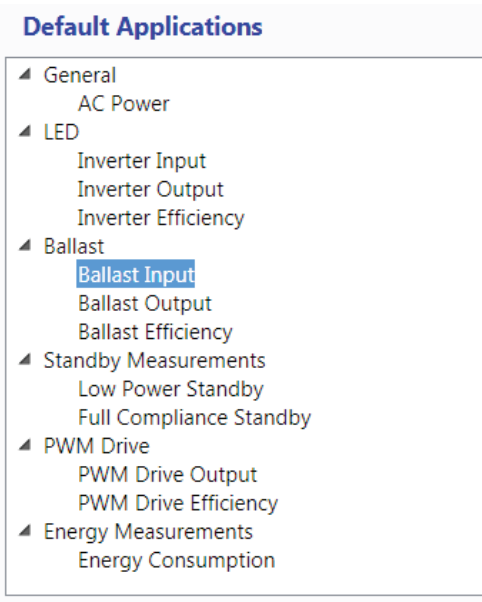


Figure 4. Ballast Setting Window.

3.2 Using PWRVIEW Software for Ballast Input Measurements

- Download the current version of PWRVIEW Software from www.tek.com
- Install PWRVIEW on the PC connected to the PA1000. Open the PWRVIEW software. Select ADD to add an instrument. A list of available instruments will be shown. select the connected PA1000 then click connect. See Figure 3.

- Select Ballast Input in the Default Applications list (see Figure 4), then click on the Wizard button to set up the ballast test.
- Follow the Wizard setup instruction in the main screen window. The Wizard will guide you through ballast parameter setup and how to make connection between PA1000 and ballast under test (see Figure 4).

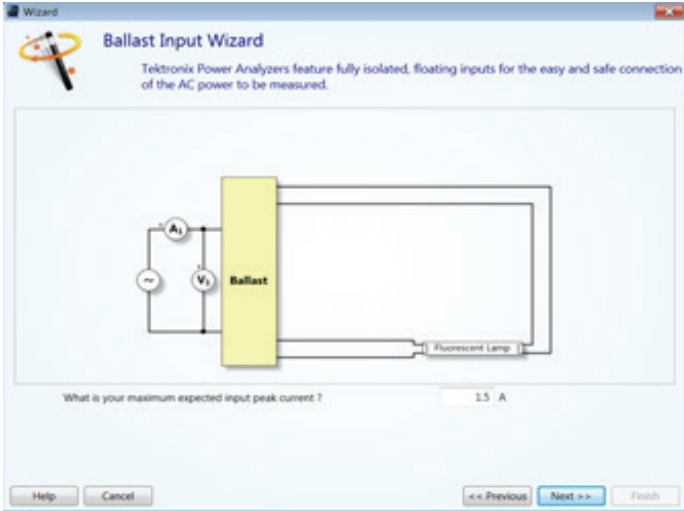


Figure 5. Ballast Setting Wizard Window.

- Enter the anticipated peak input current and click on Next as shown in Figure 5. The following screen will show you how to make connections between the ballast input and the power analyzer. These connections are simplified by the use of the Breakout Box,
- Clicking on Finish will return you to the set up window and ready to do the measurement. There is no need to click Apply since the wizard will have already made the changes to the configuration.
- The wizard will have chosen a default set of measurements that are typically required when measuring the input power of ballast. Changes to the measurements returned can be made on the Settings tab.
- When you are ready to start making measurements click on the Measure Tab. PWRVIEW will display the measurement grid.
- Click on the start button to begin the measurement. The requested unit configuration will be sent to the PA1000. Once the PA1000 has been configured, the measurement grid will start to update at approximately twice per second, as shown in Figure 5.

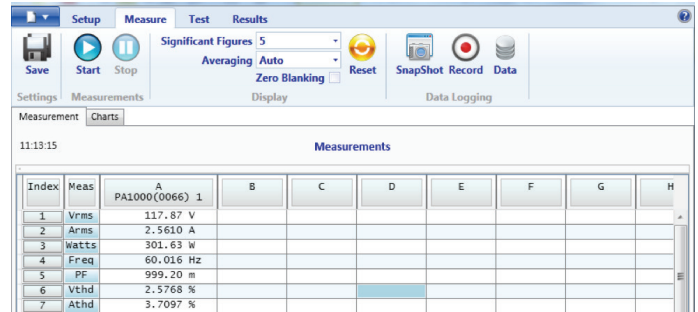


Figure 6. Measurement Grid.

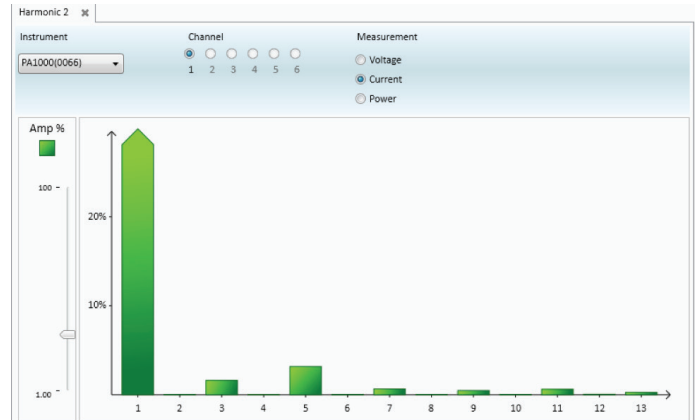


Figure 7. Harmonic bar chart.

- The results can also be viewed in a graphical form. To display charts and graphs, click on the Graphs tab. From there, select either Harmonic or Waveforms to view data in a graphical format. An example of a bar chart is shown in Figure 7.

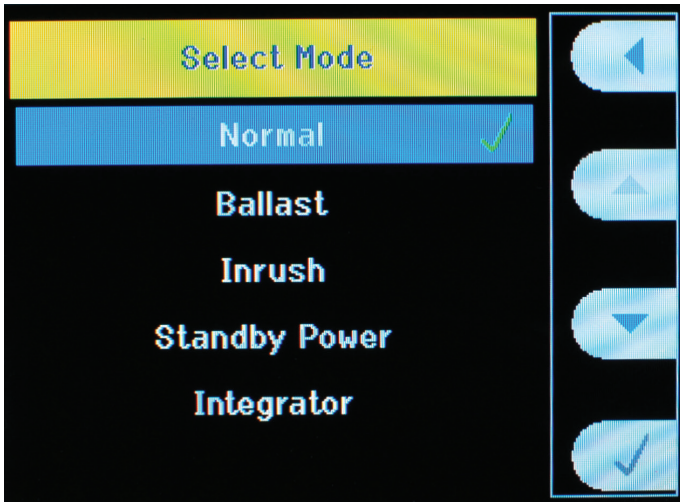


Figure 8. Select Mode Window.

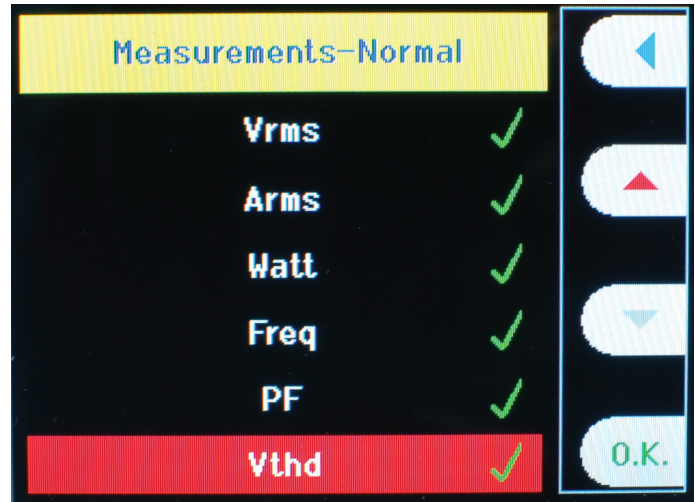


Figure 9. Select Athd parameter Window.

3.3 Ballast Input Measurements Using the Front Panel

3.3.1 Setting the PA1000 Mode

- Press menu → Modes → Select Mode → check mark Normal as shown in Figure 8.
Note that normal is selected because input power from AC source to Ballast is measured.

3.3.2 Adding Additional Measurements:

- Selecting a mode will apply a default set of measurements. To add additional measurements, such as Amps THD, do the following:
Press Menu, select MEASUREMENTS.
- Scroll down the measurement menu using the down scroll key and select the required measurement (Athd in this example), as shown in Figure 9.



Figure 10. An example of additional results.

- Press OK.
- Athd will now appear in the measurement result screen
- Press MENU to return to the measurement display screen as shown in shown in Figure 10.
- Repeat the process for any of the other measurements you wish to view.

To view harmonic results, you will need to add the Volts and Amps harmonics measurements using the method detailed above. Once the results have been added, you can view the numerical values in the normal results window, or you can view the amplitudes on a barchart. To view the barchart, Graph key on the keyboard. An example of a harmonic barchart is shown in Figure 11.

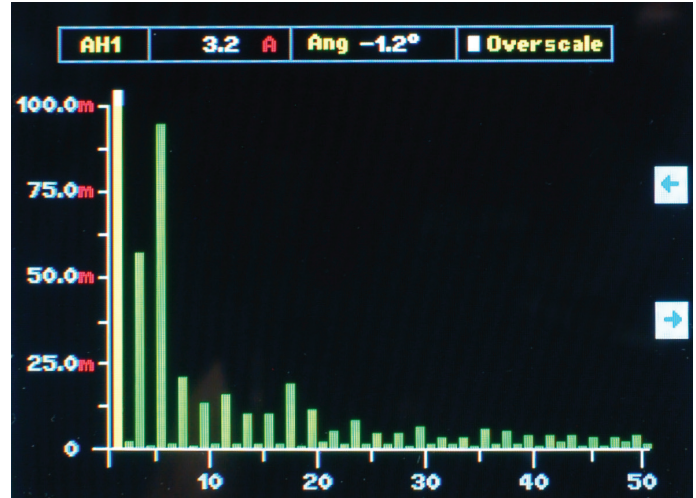


Figure 11. Harmonic bar chart.

The PA1000 ZOOM function allows user to display either 4 or 14 measurements. To change the number of result displayed:

- Press Menu, scroll down the main menu and select VIEW, select ZOOM, select either 4 or 14 results,
- Press MENU to return to the measurement display.

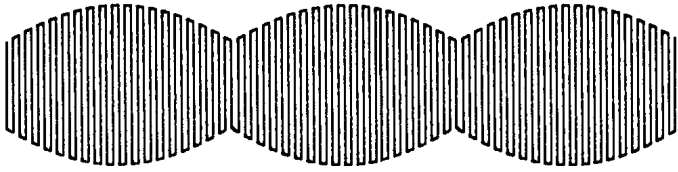


Figure 12. Typically 50k Hz to 150k Hz partially modulated at the power frequency.

4 Ballast

Making Output Measurements on a lamp ballast with the PA1000 power analyzer using either front panel operation or with Tektronix PWRVIEW software

The output voltage waveform of electronic ballast consists of a carrier with a frequency of typically 50kHz to 150kHz or higher, partially modulated at the power frequency. (typically 50, 60 or 400Hz) Figure 12 shows a typical ballast waveform. The PA1000 is equipped with a special operating mode specifically for ballasts or modulated ultrasonic applications, both of which have similar waveforms. This mode locks the measurement to the 50, 60 or 400Hz line frequency, whilst performing analysis at the actual carrier frequency of 25kHz to 1MHz. Interested measured parameters are: Voltage, Amps, Watts, Frequency and Power Factor.

4.1 The Tektronix Ballast CT Box

The Ballast CT is a precision in high-bandwidth current transformer, which is to use the current in high-frequency lighting ballasts the Ballast CT provides:

- Isolation of the current signal from common-mode voltages, improving the overall accuracy.
- For tubes with heaters, the two inputs act to provide the difference between the two currents at the output to the power analyzer. The Ballast CT is closely coupled, high-frequency differential transformer. The resultant output is the current in the tube. In this way, the Ballast CT simplifies the connection to tubes with heaters.

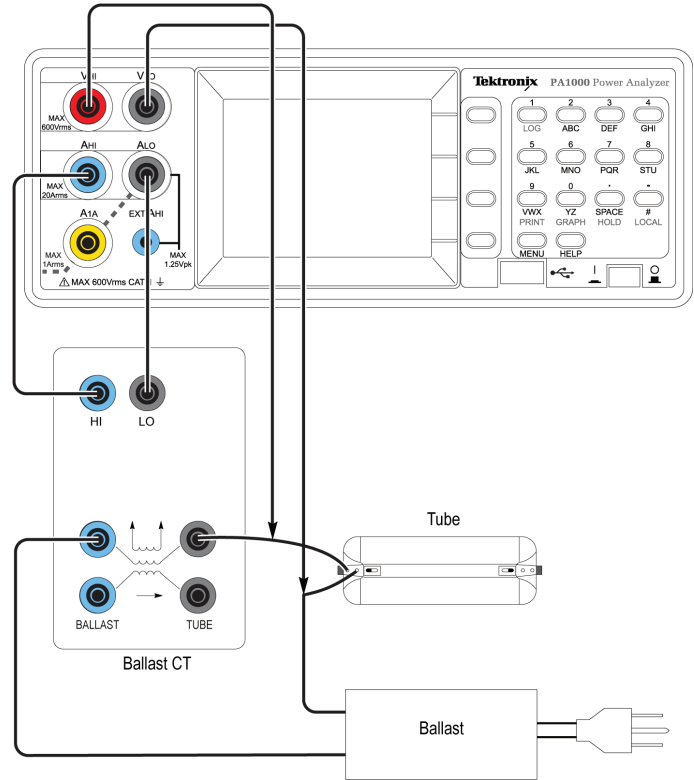


Figure 13. An example of Hardware Set up for Ballast Output Measurement.

4.2 Ballast Output Measurement:

4.2.1 Connecting the Ballast Output to the PA1000

- Connect the DUT, Ballast-CT and PA1000 as shown in Figure 13.
- Connect the PA1000 USB port to a PC running PWRVIEW.

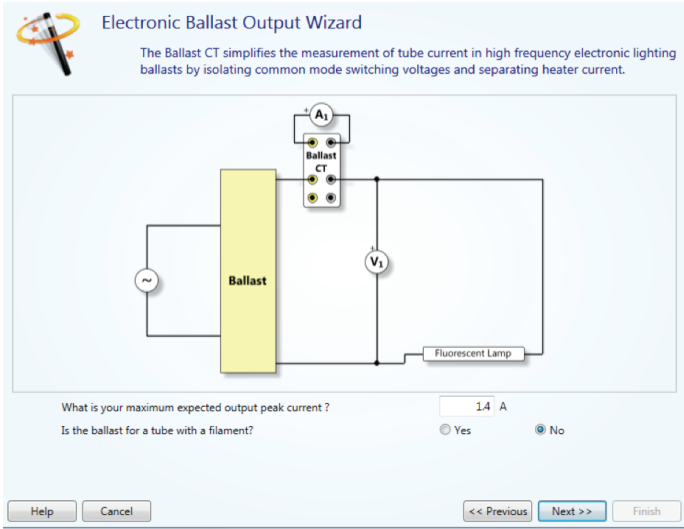
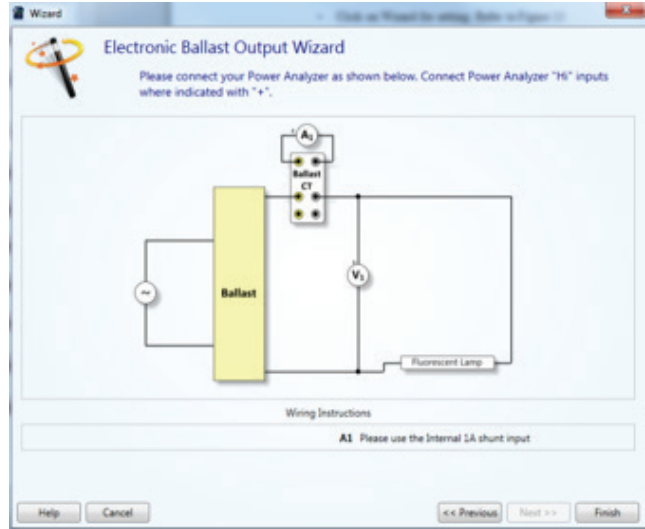


Figure 14. Ballast Wizard setting Window.



4.3 PWRVIEW Software Set up for Ballast Output Measurement:

- Start PWRVIEW and connect to the PA1000 as described in Section 2.1
- Select Ballast output in the Default Applications, then click on the Wizard button to set up the Ballast test.
- Follow the Wizard set up instructions as shown in Figure 14.
- Click on Measure and Start to capture all the measured parameters' values, as shown in Figure 15.

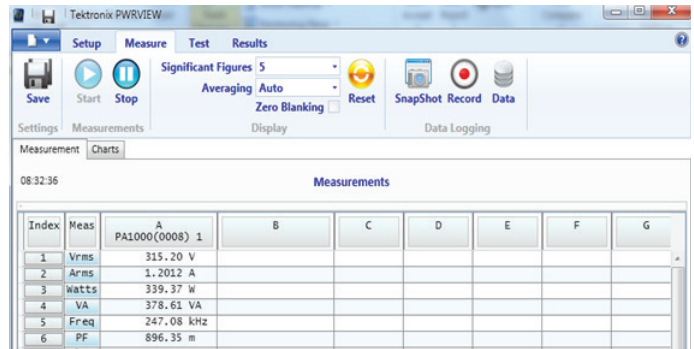


Figure 15. Example of Ballast result display Window.

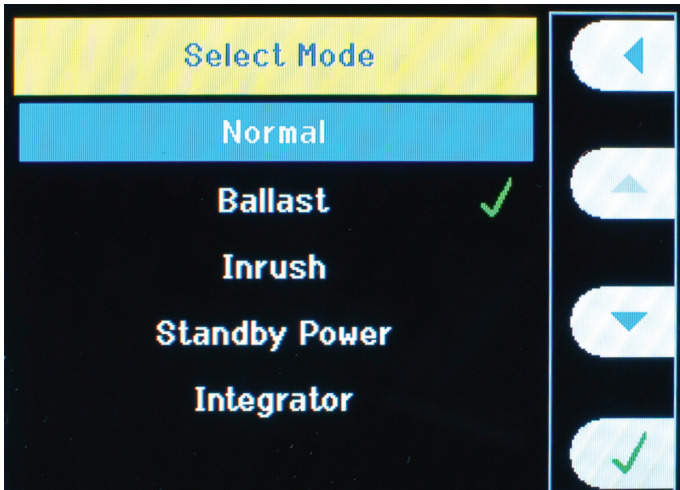


Figure 16. Ballast Select Mode Window.



Figure 17. Example of Ballast output result display Window.

4.4 Ballast Output Measurements Using the Front Panel

4.4.1 Return the Instrument to the Default configuration.

- Press Menu, select USER CONFIGURATION and then select Load Default.
- Press Menu to return to the measurement display. The PA1000 will now display the Input Watts, Vrms , Arms, PF, Freq

4.4.2 Set the PA1000 into BALLAST MODE

To make accurate measurements on the ballast waveform, the ballast mode should be selected. This is done as follows

- Press menu → Modes → Select Mode → check mark Ballast as shown in Figure 16
- Press Menu to return to the measurement display.

The measurement window should now display “Ballast” in the bottom right hand corner of the display. The PA1000 is now configured to measure the Watts, Arms, Vrms, power factor and frequency of the output of the lighting ballast (see Figure 17). Apply power to the Ballast and view the measurements required.

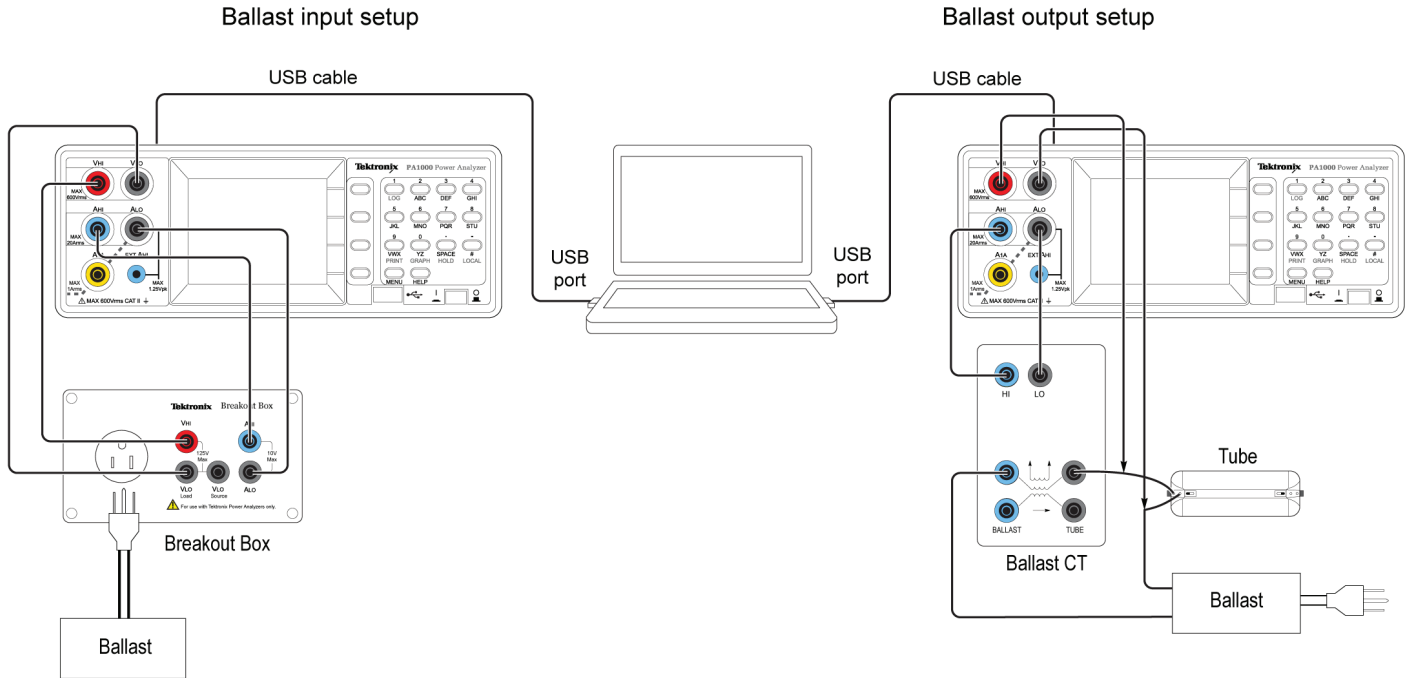


Figure 18. An example of two PA100 set up via PWRVIEW.

5 Making Ballast Measurement of Lamp Ballast with two PA1000 and PWRVIEW

PWRVIEW Software also allows user to synchronize two PA1000 for making simultaneous input and output of Lamp Ballast measurement. One PA1000 is connected to the ballast input using a Breakout Box and the other is connected to the ballast output using a Ballast-CT. the connections are shown in Figure 18.

- Open PWRVIEW and click on “ADD” button and then click on connect as shown in Figure 19. This time, select two instruments.
- To setup the instrument connected to the ballast input, first select the tab of PA1000 connected to the ballast input. The tab contains the last 5 digits of the serial number of the instrument it is associated with to help link it to the instrument. Next, follow the PWRVIEW Wizard as described in Section 1.2.

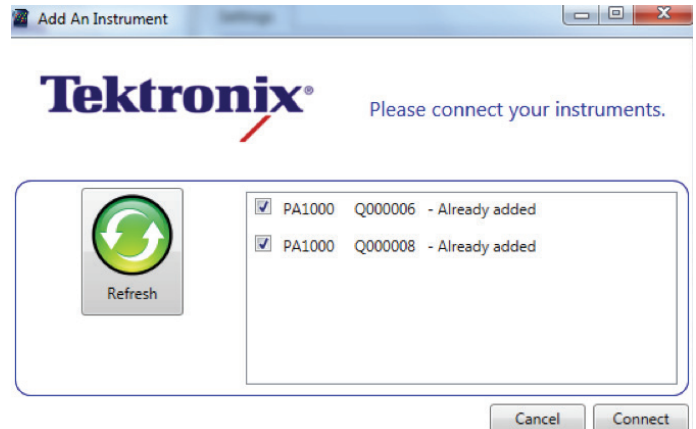


Figure 19. Example of two PA1000s Connected via PWRVIEW.

- To setup the instrument connected to the ballast output, first select the tab of the PA1000 connected to the ballast output and then follow the Wizard as described in Section 2.3.

Note: There are a number advantages of using two PA1000s with PWRVIEW for ballast testing

Measurement Charts

13:53:23

Measurements

Index	Meas	A PA1000(0006) 1	B PA1000(0008) 1	C	D	E	F	G
1	Vrms	116.59 V	305.44 V					
2	Arms	3.3682 A	1.1896 A	efficiency	$=B/A*100$			
3	Watts	392.13 W	335.88 W					
4	Freq	60.000 Hz	247.00 kHz					
5	PF	998.56 m	924.37 m					
6	Vthd	2.4009 %	1.2964 %					
7	Athd	3.2155 %						
8	Vh1m	116.55 V	317.40 V					

Index	Meas	A PA1000(0006) 1	B PA1000(0008) 1	C	D	E	F	G
1	Vrms	116.21 V	339.55 V					
2	Arms	3.7649 A	1.1814 A	efficiency	85.918e+00			
3	Watts	436.84 W	375.32 W					
4	Freq	60.009 Hz	246.74 kHz					
5	PF	998.42 m	935.65 m					
6	Vthd	2.4029 %	1.3127 %					
7	Athd	3.2279 %						

Figure 20A/B. An example of making ballast with two PA1000s via PWRVIEW.

- PWRVIEW enables user to display both the ballast input and output measurements on a PC simultaneously
- PWRVIEW allows the user to enter equations for calculation as required. Figures 20A and B show how to enter an equation to calculate the efficiency of the ballast based on the input and output power.

6 Recording data with the PA1000 and PWRVIEW

Both PWRVIEW and the PA1000 offer convenient methods for recording results for further analysis.

6.1 Recording data to a USB memory device

- To log data to a USB memory device, plug it in to the front panel USB port. The “Normal” Label on the right corner of the display screen will momentarily change to “USB RDY” to indicate that the PA1000 is ready to start recording data. Refer to Figure 21.

Press the LOG button to enable datalog
Press the LOG button again to stop datalog

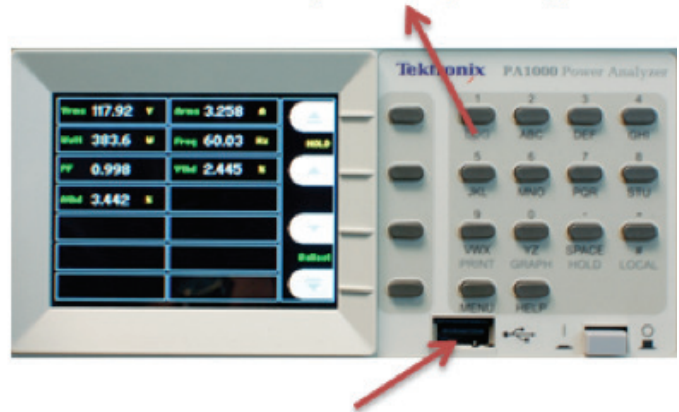


Figure 21. Datalog from PA10006.

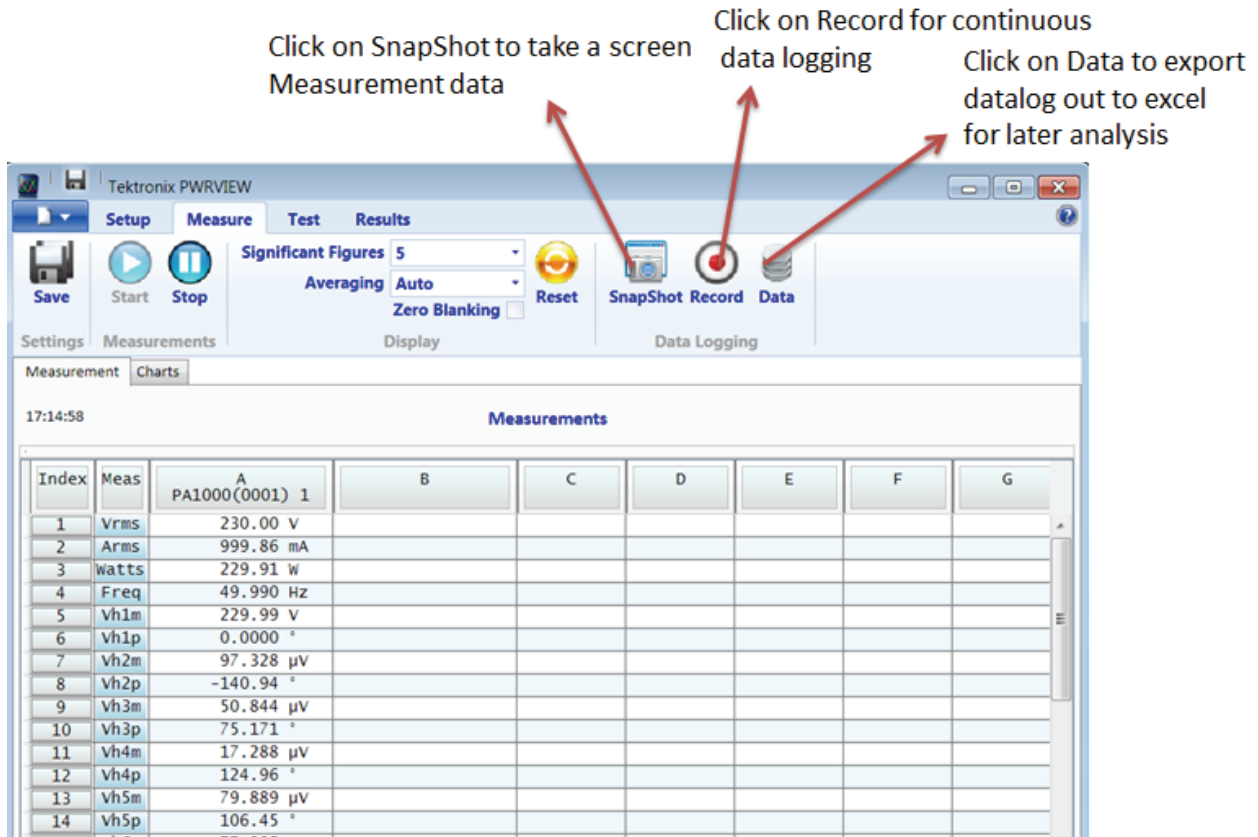


Figure 22. PWRVIEW Datalog options.

6.2 Recording Data in PWRVIEW

PWRVIEW provides 2 different methods for recording data for later analysis.

1. The Record button in PWRVIEW enables the user to record each sample set of measured data continuously over a period of time onto a PC for later analysis. The data is recorded directly to an SQL database. The data can be recalled and exported to an Excel file by clicking on the Data button.
2. The Snapshot button in PWRVIEW allows the user to instantly capture the data shown in the measurement screen.

7 Conclusion

In today's modern ballasts, the need for more accurate answers is greater than ever due to the need to improve efficiency. Higher efficiency ballasts require higher accuracy measurements and detailed consideration of the measurement challenges that can affect results.

A power analyzer must have:

- Power measurement accuracy sufficient to determine the required efficiency
- High bandwidth for both input and output measurements
- Ability to accept high input current crest factors without user intervention nor degradation of measurement accuracy. Ability to measure harmonics and THD at the input and output of ballasts
- Built in ballast mode to enable accurate and stable measurements at the ballast output

When combined with the PWRVIEW software, two PA1000s offer a cost effective method for determining ballast efficiency while maintaining the flexibility of two single phase analyzers.

For further support, please contact Tektronix technical support or at www.tek.com

8 References

1. PA1000 User Manual, www.tek.com
2. PA1000 Accessory Brochure, www.tek.com
3. PWRVIEW SW, www.tek.com

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