

**The  
Voltech Handbook  
of  
Power Measurements in  
Lighting Applications**

**Martin Whitley**





## Contents

1. Introduction .....	5
2. Types of Ballast.....	7
2.1 Conventional Ballasts.....	7
2.2 Electronic Ballasts.....	8
2.3 Low Voltage Lighting Ballasts .....	10
3. Power Measurements on Conventional Ballasts .....	13
3.1 Measurements required .....	13
3.1.1 Input Power and Power Factor.....	14
3.1.2 Losses in the Ballast and Starter Components.....	14
3.1.3 Output Power and Efficiency .....	14
3.2 Using the PM6000 with Conventional Ballasts .....	15
4. Electronic Ballasts.....	17
4.1 Measurements Required .....	18
4.1.1 Input Power and Power Factor.....	19
4.1.2 Output Power and Efficiency .....	19
4.2 Using the PM6000 with Electronic Ballasts .....	21
4.2.1 Input Power.....	21
4.2.2 Output Power - Single Tube Applications.....	21
4.2.3 Output Power - Dual Tube Applications .....	21
4.3 Using the PM1000+ Analyzers with Electronic Ballasts .....	23
4.3.1 Input Power.....	23
4.3.2 Output Power .....	23
5. Low Voltage Ballasts.....	25
5.1 Measurements Required .....	25
5.1.1 Input Power and Power Factor.....	25
5.1.2 Output Power and Efficiency .....	26
5.2 Using the PM6000 with Low Voltage Ballasts .....	26
5.3 Using the PM1000+ with Low Voltage Ballasts .....	27

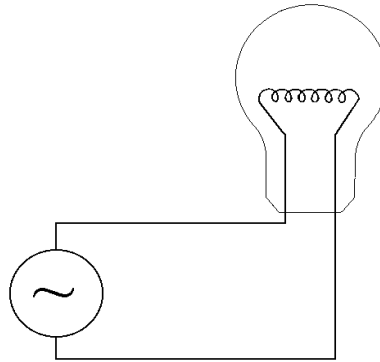
---

Appendix A - Required Number of Watt meters .....	29
Appendix B - Lighting Terminology.....	31

# 1. Introduction

## Filament Lamps

The simplest form of electrical lighting, still widespread in use, is the traditional filament lamp in figure 1. This consists of a fine coil - the filament - which is usually made of tungsten and surrounded by inert gas in a glass bulb.



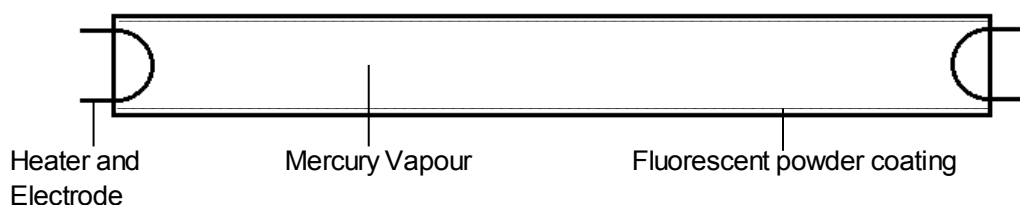
*Figure 1 – Filament Lamp*

The filament is resistive, and can be connected directly to an electrical supply; it then becomes white hot and gives out light.

Although simple and inexpensive to produce, the filament lamp does suffer from a number of disadvantages. It has a relatively short life and must be frequently replaced. It is also inefficient, using a lot of energy for a given amount of light and generating wasted heat.

## Modern lighting

The requirement for modern alternatives which overcome the disadvantages of filament lamps has led to the development of lighting elements such as fluorescent tubes, and sodium and mercury lamps.



*Figure 2 - Fluorescent tube*

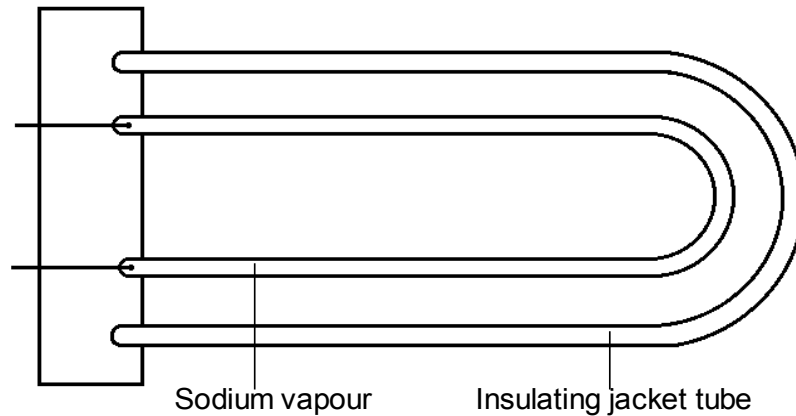


Figure 3 - Sodium lamp

These elements have a much longer life and greater energy efficiency than filament lamps, but they cannot be connected directly to an AC supply. This is because such tubes have very different characteristics when cold and inactive, compared with when illuminated. The energy supply to the lamps must be controlled in order to firstly provide a suitable voltage for the lamp to start, or 'strike', and then to supply the normal running voltage. The control circuit is usually called a 'Ballast'.

Originally the term ballast was used for the energy storing inductor which is part of the starter circuit in a conventional drive for a fluorescent tube. The word is still used in this way for conventional starter circuits, but in more modern electronic lighting, the use of the word 'ballast' has been extended to refer to the complete drive circuit.

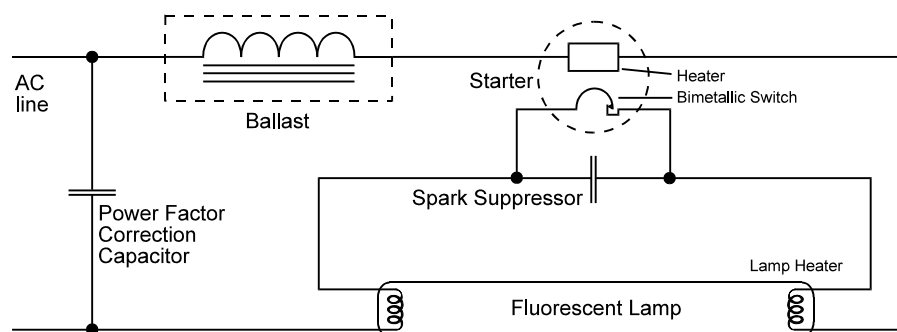
Conventional ballasts are in very widespread use; they are relatively inexpensive to manufacture, and offer a rugged, proven performance. However, for new installation, there is an increased use of electronic ballasts which offer higher efficiency, lower power consumption and cooler operation than the conventional ballasts. They also have a higher input power factor, provide quicker starting, reduced flicker, and greatly enhanced tube life. The savings in maintenance are considerable and can very quickly exceed the small additional initial cost added to the luminaire.

This document describes electrical measurements on both conventional and electronic single and multi-tube luminaire.

## 2. Types of Ballast

### 2.1 Conventional Ballasts

Originally the term ballast was applied to an inductor which formed part of the starter circuit for a fluorescent lamp. A typical starter circuit is shown in Figure 4.



*Figure 4 - Conventional Fluorescent Lamp Drive*

When power is first applied, the bi-metallic starter switch is in the closed position as shown. A current flows through the starter switch heater, and through the lamp heaters (via the bi-metallic switch) causing the lamp heaters to emit ions into the tube.

Eventually the bi-metallic switch heats up and opens. The inductor tries to maintain the current flow, and generates a high voltage across the tube, which, due to the presence of the ions, causes the tube to strike.

Once the discharge is established, the tube voltage falls to a value lower than the line voltage. The difference between this voltage and the line supply voltage is dropped across the inductor. The inductor therefore limits the flow of current, ideally with little power loss.

Unfortunately, the load presented to the supply is inductive, so the resulting power factor is unacceptably low, and the circuit requires a power factor correction capacitor as shown.

Once the lamp is running, the waveform presented to the tube, and the current drawn by the tube, are relatively undistorted waveforms at the line frequency.

## 2.2 Electronic Ballasts

In modern electronic lamp drivers, the term 'ballast' refers to the complete circuit which provides both the starting conditions and the continuous operating conditions for the lamp. These 'electronic ballasts' are available in versions for driving 1, 2 or 4 fluorescent tubes. A typical electronic ballast driving two fluorescent tubes is shown in Figure 5.

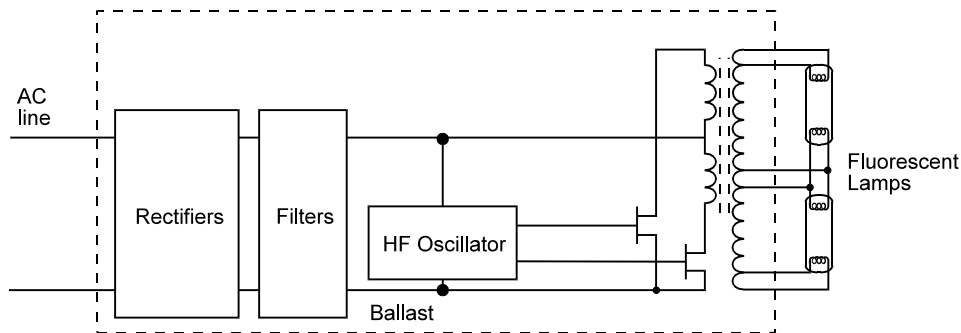


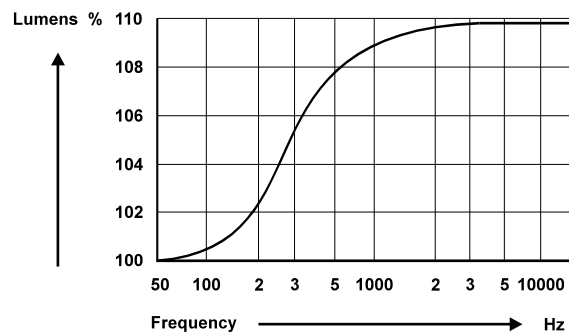
Figure 5 - Typical 2 Tube Electronic Ballast

The line frequency signal is rectified and filtered to produce a dc supply for the electronic switching circuit. The oscillator in the circuit produces a high frequency signal (typically at 25kHz to 1MHz) which drives the switching transistors, which in turn drive the primary side of the output transformer. The different secondary windings on the transformer provide the correct voltages for both heaters and main discharge in the fluorescent tube. At switch-on, a large voltage is required across the tube to start the discharge. However, once the lamp has lit, the voltage needed to sustain the discharge is smaller, being typically 100 Volts. The output transformer is designed with a relatively large leakage inductance, which will drop the difference between these two voltages without significant power loss once current starts to flow.

The example above is just one of many possible designs. Some make use of a combination of capacitors and inductors, rather

than an output transformer, to couple the switching transistors to the fluorescent tube. Others are designed to drive one tube, three tubes or four tubes.

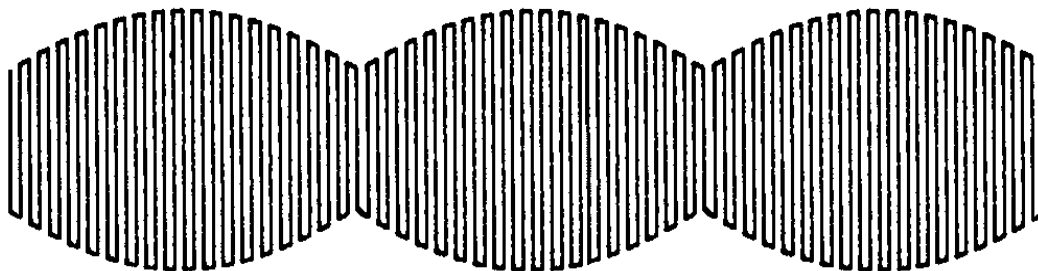
All electronic ballasts use a switching frequency of greater than 25kHz to drive the lamp. This is because the efficiency of a fluorescent tube increases by typically more than 10% when driven at higher frequencies compared with operation at 50 or 60Hz (see Figure 6).



*Figure 6 - Optical Efficiency vs. Operating Frequency*

In addition, the electronic circuit components for operation at high frequency (particularly inductors and transformers) are physically smaller and lighter, and have smaller power losses than the 50Hz or 60Hz equivalents. All this can provide a total power saving of more than 20%, compared with a conventional ballast, for the same light output.

The output voltage waveform of an electronic ballast is a carrier with a frequency of typically 25kHz to 1MHz modulated at the power frequency, 50 or 60Hz (see Figure 7).



*Figure 7 - Electronic Ballast Waveform*

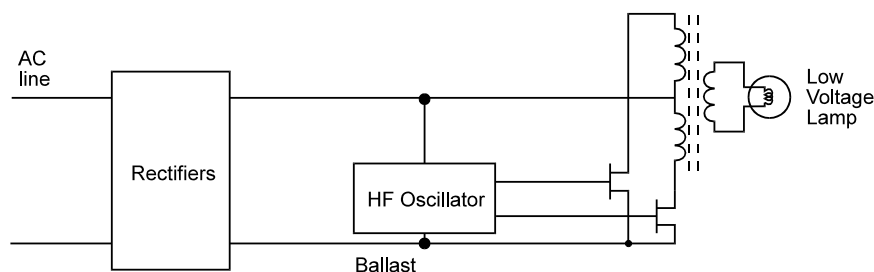
In practice, both the high frequency carrier and the modulation waveform may be non-sinusoidal, resulting in a complex waveform rich in harmonics.

As the frequency of ballasts reach 500kHz and beyond, there is a need for higher bandwidth power analyzers to be able to accurately measure the output of the ballast. Also, as the efficiency of the ballasts increase, there is a need to be able to make all measurements on both the input and outputs simultaneously to ensure accurate efficiency measurements. Depending on the ballast configuration, the need for up to 6 watt meters is not uncommon.

## 2.3 Low Voltage Lighting Ballasts

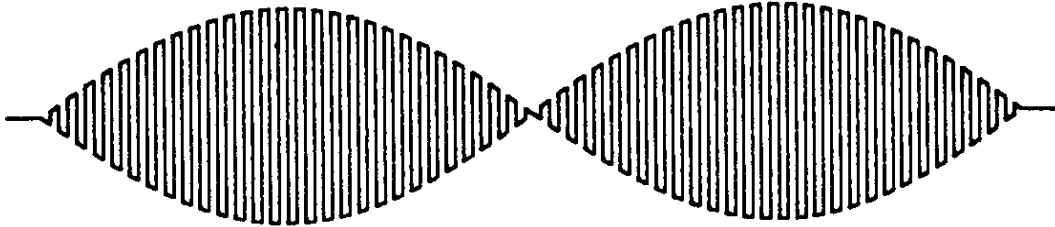
Although ballasts are mainly associated with fluorescent lights, similar electronic circuits are now being used to drive other types of lamps. This particularly applies to low voltage lighting, for example 12V Tungsten Halogen lamps (typically 100W), used both in room spot-lighting, and in equipment such as photographic slide projectors. Only by using low voltages is it possible to create a reliable lamp in the small size required.

Figure 8 shows an example of such a circuit. Its operation is similar to that of the electronic fluorescent lamp ballast except that, in this case, the design is simpler as there is no need to 'start' the lamp.



*Figure 8 - Low Voltage Lighting Ballast*

Normally, low voltage lighting ballasts have no smoothing filter between the rectifiers and the HF oscillator. This allows the low voltage ballast to appear as almost unity power factor to the ac supply, but results in the waveform applied to the low voltage lamp being 100% modulated, as shown in Figure 9. 100% modulation is possible as the thermal inertia of the lamp filament prevents this modulation appearing as flicker to the human eye.

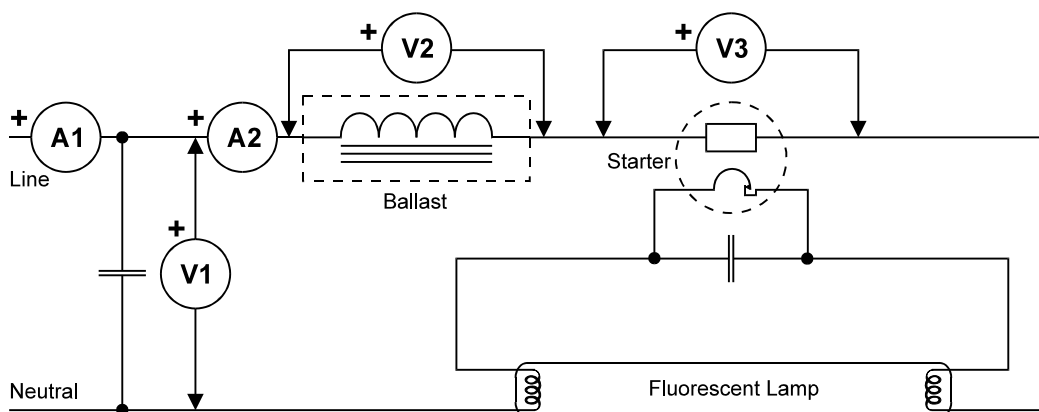


*Figure 9 - Electronic Ballast Waveform with 100% Modulation*

This page is intentionally left blank.

### 3. Power Measurements on Conventional Ballasts

Measurements on the conventional ballast are relatively straightforward as all the components operate at the line supply frequency. There are, however, some configurations of ballast(s), starter(s) and tube(s) where the measurements can be complicated, as there is no direct access to the tube power. A typical example with a 4 terminal starter is given in Figure 10, which also shows possible positions for the voltage and current channels of a Power Analyzer.



*Figure 10 - Power Measurements on Conventional Ballasts*

#### 3.1 Measurements required

Usually, the parameters of interest are:

- Total input power and power factor
- Losses in the ballast and starter components
- Power delivered to the lamp (including heaters)
- Efficiency
- Tube Currents (not including heaters)

In addition, although the conventional ballast does not significantly distort the waveform, it may still be necessary to verify the harmonic currents to the limits specified by IEC61000-3. Voltech Application Note 104 VPN: 86-626 explains how to test to this specification.

### 3.1.1 Input Power and Power Factor

The total input power and power factor are both measured with the power factor correction capacitor in place, and with the Power Analyzer current and voltage channels in the positions marked A1 and V1. The Power Analyzer indicates the input power and power factor directly.

### 3.1.2 Losses in the Ballast and Starter Components

To measure the losses in the ballast and starter components, either remove the power factor correction capacitor and leave the current channel at A1, or connect the Power Analyzer current channel in the position marked A2. Then connect the Power Analyzer voltage channel across each of the components in turn (the positions marked V2 and V3) to measure the power lost, and calculate the total losses as the sum of the losses in each component.

In a configuration with more than one ballast or starter, repeat the same procedure for every component in the system.

### 3.1.3 Output Power and Efficiency

The power consumed by the lamp may then be calculated by subtracting the power lost in the ballast and starter components from the input power:

$$\begin{aligned} \textit{Total losses} &= \textit{Ballast losses} + \textit{Starter losses} \\ \textit{Lamp power} &= \textit{Input power} - \textit{Total losses} \end{aligned}$$

Efficiency may then be calculated as:

$$\textit{Efficiency} = \frac{\textit{Lamp power}}{\textit{Input power}} \times 100\%$$

where the 'input power' is the value measured with the power factor correction capacitor in place (see 3.1.1).

### 3.2 Using the PM6000 with Conventional Ballasts

As the conventional ballast operates at standard line frequency, the PM6000 may be used in its default operating mode for reading input power. Although the circuit parameters could be measured one at a time by connecting the PM6000 channel 1 in the various positions described in the previous section, a better approach is to use channels simultaneously, to measure the input power, the loss in the ballast, and the loss in the starter and the tube power, as shown in figure 11.

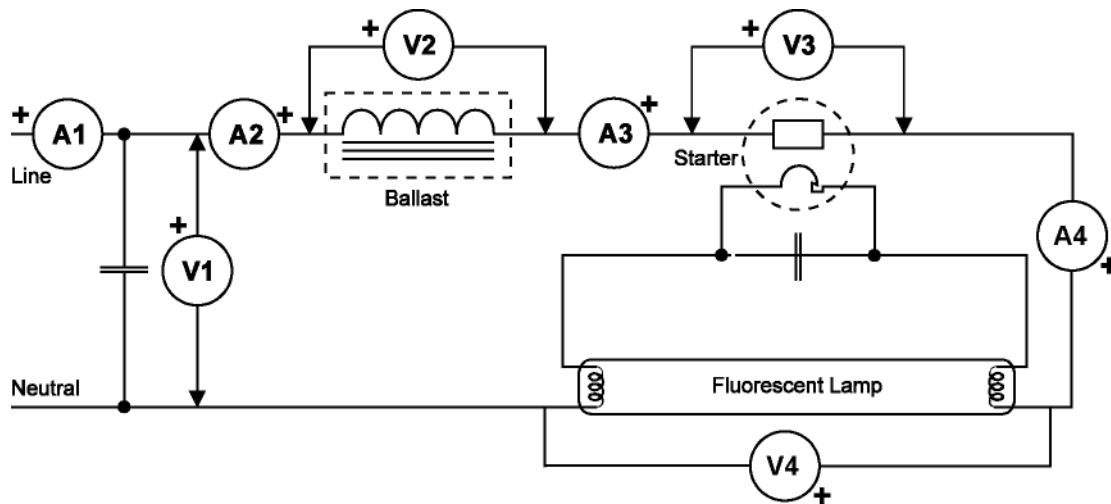


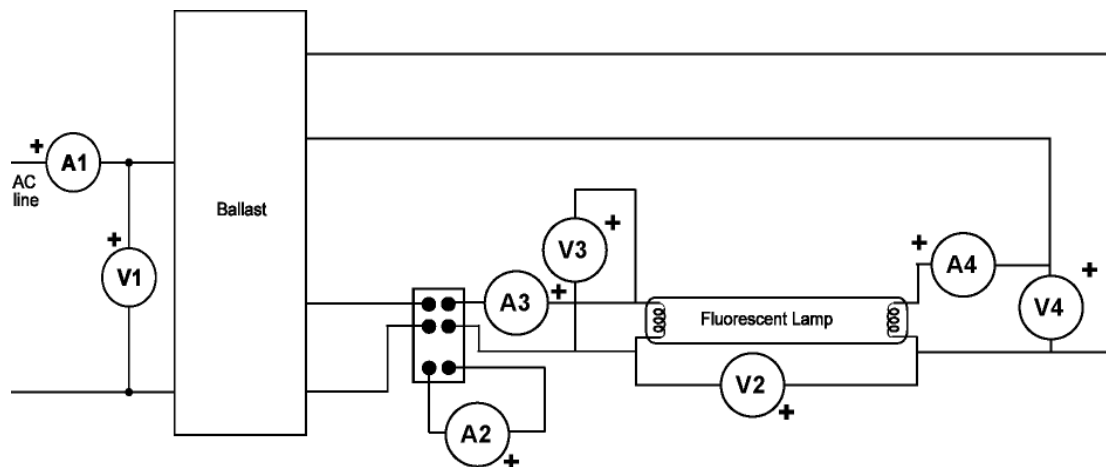
Figure 9 Simultaneous Measurements Using the PM6000

This page is intentionally left blank.

## 4. Electronic Ballasts

The presence of the high frequency, modulated waveforms make the measurements on electronic ballasts more complicated than those for a conventional ballast. To accurately measure the power of such a waveform, high frequency measurements must be made that are locked to the line frequency.

Typical wiring configurations for a single tube electronic ballast, and for a dual tube application are shown in Figures 12 and 13.



*Figure 12 - Single Tube Electronic Ballast Measurements*

One parameter which is difficult to measure with electronic ballasts is the current that flows through the tube. The difficulty arises because the current is combined with the heater current in the external leads to the tube. The Voltech Ballast Current Transformer (part number Ballast-CT) is designed to overcome this difficulty and provided a convenient solution to the problem of measuring the tube current. The Ballast CT is shown in figure 12 with connections to A2.

Filament current and power can also be measured by placing a current channel in one of the two connections to the filament. Choose the connection which reads the lowest current of the two connections, as this wire will contain the filament current only. The other wire will contain the filament current and the tube current.

Ensure that each channel reads positive Watts, reversing the voltage connection if necessary. Connect V2 across the pair of terminals that read the largest tube voltage as shown in figure 12.

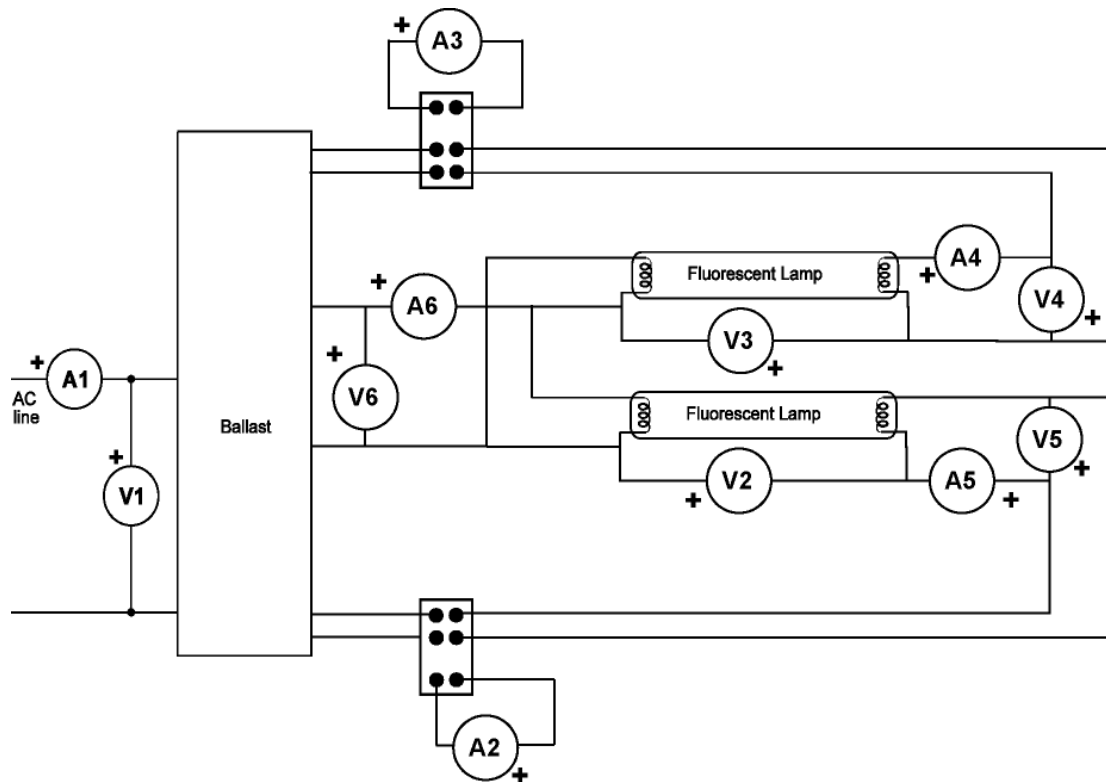


Figure 13 – Dual Tube Electronic Ballast Measurements

## 4.1 Measurements Required

Typically, the parameters of interest are:

- Total input power and power factor
- Power delivered to the lamp (including the heaters)
- Efficiency
- Tube power (not including the heaters)

As electronic ballasts can derive a dc supply for the control electronics by directly rectifying the line input voltage, they could generate significant harmonics in the supply current. It is therefore usually necessary to verify that these harmonic currents are within

the limits specified by IEC61000. Voltech Application Note 104 VPN: 86-626 explains how to test to this specification.

#### 4.1.1 Input Power and Power Factor

The input power to the ballast is at the 50 or 60Hz line supply frequency, and is therefore relatively straightforward to measure. Simply connect the Power Analyzer voltage and current channels in the positions marked V1 and A1 in Figures 12 and 13, and the analyzer will indicate the input power and power factor.

#### 4.1.2 Output Power and Efficiency

With the single tube configuration shown in Figure 10, which has 4 connections, three watt meters are required to read the total power. The positions for the voltage and current channels for each reading are shown in Figure 12 as V2 and A2, to V4 and A4 respectively.

The dual tube configuration shown in Figure 13 has six connections, which requires five watt meters to be connected to read the total power. The positions for the voltage and current channels for each reading are shown in Figure 13 as V2 and A2, to V6 and A6. Each of these readings will then contain elements of heater currents and discharge currents which when added together will yield the total power delivered to the lamp.

Note that, in both the single tube and dual tube examples, the correct polarity must be observed when connecting the watt meters, and that all of the watt meters must read positive watts.

The output power delivered to the lamp is:

$$\text{Lamp power} = \sum \text{Watts readings}$$

The efficiency of the ballast can then be calculated as:

$$\text{Efficiency} = \frac{\text{Lamp power}}{\text{Input power}} \times 100\%$$

As the lamp voltage and current waveforms contain a switching frequency of 25kHz or more, modulated at the 50 or 60Hz line

frequency, the most stable readings are obtained if the Power Analyzer is set to a 'ballast mode' which will make high frequency measurements that are locked to the 50 or 60 Hz line frequency. For some measurements it also may be better to disable the auto-averaging reset.

To give repeatable results, the line frequency source must be stable while measurements are being made. If a single channel has to be used for each of the measurements in turn, ensure conditions have stabilized before a taken for each measurement.

## 4.2 Using the PM6000 with Electronic Ballasts

### 4.2.1 Input Power

The input power to an electronic ballast may be measured with the PM6000 using its default 'Normal' mode configuration. Connect channel 1 to the input terminals marked V1 and A1 in Figure 10.

### 4.2.2 Output Power - Single Tube Applications

The PM6000 is equipped with 2 frequency source options, fixed frequency and channel frequency. Fixed frequency is a manual frequency entry and channel frequency locks it onto the selected channels measured frequency. The operation of these modes with the PM6000 is the same as with the 50/60Hz option, locking the measurements to the fixed frequency or channel frequency, whilst performing high frequency analysis at the carrier frequency (25kHz to 1MHz). One of these options should always be used when making measurements on electronic ballast outputs.

The output power of a 4 wire single tube electronic ballast may be measured directly by a single PM6000. Connect three channels to the output wires as shown for V2 and A2, V3 and A3, V4 and A4 on Figure 12.

- a. Press 'Wiring'
- b. Select 'Wiring Setup' (tunnel down).
- c. Select '3 Phase 4 Wire'.
- d. Press 'Menu' to escape.
- e. Press 'Mode'.
- f. Select 'HF Ballast' (tunnel down).
- g. Select 'Frequency Source' (tunnel down).
- h. Select '50/60Hz'
- i. Press 'Menu' to escape.
- j. Press 'Measure'
- k. Select 'SUM' to read the total output power.

The three individual powers may now be read from channels 1, 2 and 3; and the total power may be read from the SUM channel.

### 4.2.3 Output Power - Dual Tube Applications

If your PM6000 has at least 5 channels, it is possible to simultaneously read the 5 output powers by connecting the outputs as shown in figure 13. If you only have 5 channels, not 6, then channel 1 will become watt meter 2, channel 2 will be watt meter 3 etc.

Ensure that all watt meter channels read positive watts. The sum of watt meters 2 through 5 gives the total power.

## 4.3 Using the PM1000+ Analyzers with Electronic Ballasts

### 4.3.1 Input Power

As stated before in section 4.1.1, measuring the input power and power factor for an electronic ballast is fairly straightforward using a single phase analyzer such as the PM1000+.

With a PM1000+ for example, connect the voltage and current channels in the V1 - A1 positions of Figure 12 or 13. Using the default 'Normal' mode (power on) settings, read the watts and power factor from the display listing.

### 4.3.2 Output Power

As there are several connections between the electronic ballast and the tube, the output power must be measured separately when using a single phase analyzer such as the PM1000+ and using Voltech Ballast Current Transformers, which isolate the current channel from the high frequency common mode signals, as shown in figures 12 and 13.

The PM1000+ is equipped with a special operating mode specifically for ballast 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.

To perform the output power measurement using the PM1000+ in 'Ballast Mode', with the analyzer in the default 'Normal' mode (power on) settings:

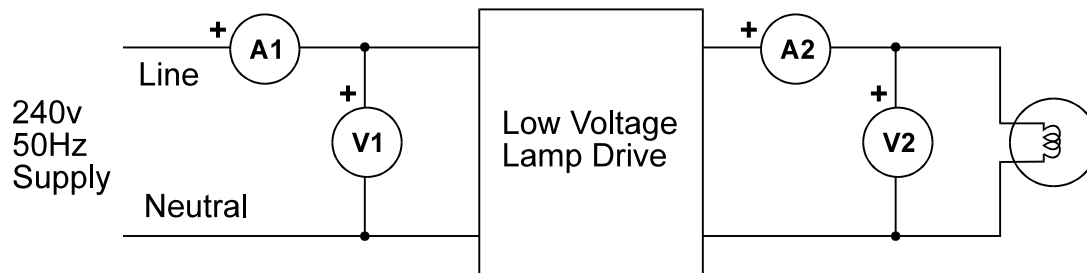
- a). Press 'Menu'.
- b). Select 'Modes' (tunnel down).
- c). Select 'Select Mode' (tunnel down).
- d). Select 'Ballast'.
- e). Press 'Menu' to escape.

Measure each of the power components one at a time. Ensure that a stable a.c. source is used and that conditions have stabilized before each measurement is made.

This page is intentionally left blank.

## 5. Low Voltage Ballasts

Low voltage electronic ballasts generate waveforms similar to those used with fluorescent tube electronic ballasts requiring the measurements to be locked to the 50Hz or 60Hz line frequency. The bulbs, however, are rather simpler than fluorescent tubes as they do not need a heater current. Figure 14 shows a typical wiring configuration for making measurements on a low voltage lighting ballast application.



*Figure 14 - Low Voltage Lighting Ballast Application*

### 5.1 Measurements Required

Interesting parameters are:

- Total input power and power factor
- Power delivered to the lamp
- Efficiency

In addition, as the low voltage lamp ballast derives a dc supply for the control electronics by directly rectifying the line input voltage, input current harmonics may be generated which may contravene the limits set by IEC61000-3. Voltech Application Note 104 VPN: 86-626 explains how to test to this specification.

#### 5.1.1 Input Power and Power Factor

The input power to the ballast is at the line supply frequency and may be measured without any special considerations. With the Power Analyzer current channel in the position marked A1, and

the voltage channel in the position marked V1, the analyzer will indicate the input power and input power factor.

### 5.1.2 Output Power and Efficiency

As there are no heater currents, the output power may be measured with the Power Analyzer current channel in the position marked A2, and the voltage channel in the position marked V2.

Efficiency may then be calculated as:

$$\text{Efficiency} = \frac{\text{Lamp power}}{\text{Input power}} \times 100\%$$

As the lamp voltage and current waveforms contain a switching frequency of 25kHz or more, modulated at the 50 or 60Hz line frequency, the most stable readings are obtained if the Power Analyzer is set up to lock to the 50 or 60 Hz line frequency.

## 5.2 Using the PM6000 with Low Voltage Ballasts

As stated in section 4.2, the PM6000 is equipped with a special operating mode specifically for ballast or modulated ultrasonic applications, both of which have similar waveforms. This mode performs high frequency measurements that are locked to the line frequency of 50Hz or 60Hz, and will also measure the actual carrier frequency (25kHz to 1MHz). This mode should always be used when making measurements on the output of low voltage lighting ballast outputs. The input power may be measured with the standard configuration.

As the PM6000 has 1 - 6 channels which may operate independently, it is possible to simultaneously measure input and output power.

Connect channel 2 of the PM6000 to the output connection, A2 and V2; and connect channel 1 to the input connections, A1 and V1, (see Figure 14). Select standard configuration for channel 1 (Group A) and then select ballast mode on channel 2 (group B):

- a. Press 'Wiring'
- b. Select 'Wiring Setup' (tunnel down).
- c. Ensure the group selected is group B
- d. Select '1 Phase 2 Wire'.
- e. Press 'Menu' to escape.
- f. Press 'Mode'.
- g. Select 'HF Ballast' (tunnel down).
- h. Select 'Frequency Source' (tunnel down).
- i. Select '50/60Hz'.
- j. Press 'Menu' to escape.

If the readings are too noisy, select fixed averaging:

- a. Press 'Format'.
- b. Select 'Averaging' (tunnel down).
- c. Select 'Fixed' (press the tick key).
- d. Select 'Depth' and enter averaging of 16 – 64.
- e. Press 'Menu' to escape.

Allow the readings to stabilize before noting down the power measurement.

Read the output power from channel 1 (verify the switching frequency is 20kHz-1MHz), and the input power from channel 3 (verify that the measured frequency is 50Hz or 60Hz as appropriate).

### **5.3 Using the PM1000+ with Low Voltage Ballasts**

As stated previously, both the PM1000+ and PM6000 have an operating mode specifically for use in ballast applications, where high frequency measurements are locked to the 50Hz or 60Hz line frequency. This mode should always be used for measuring the output power of low voltage ballasts. In contrast, the input power may be measured with the default configuration which is selected on power up.

With the PM1000+, connect the analyzer I turn to the input and output as shown in Figure 15.

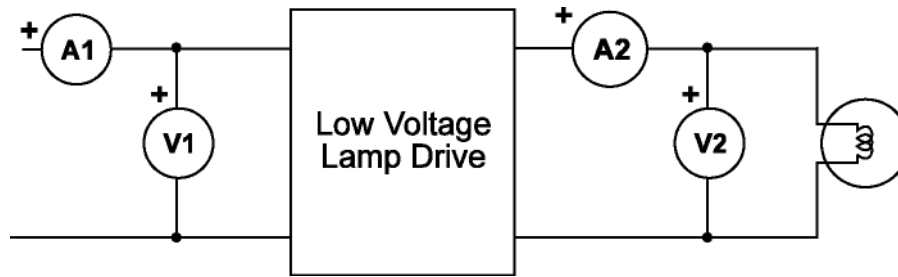


Figure 15 – PM1000+ connection for a low voltage ballast

To read the output power, connect the PM1000+ voltage and current inputs in the positions V2 and A2 of figure 15, and switch on the ballast.

Select the ballast mode on the PM1000+:

- a). Press 'Menu'.
- b). Select 'Modes' (tunnel down).
- c). Select 'Select Mode' (tunnel down).
- d). Select 'Ballast'.
- e). Press 'Menu' to escape.

The PM1000+ will now measure in Ballast Mode and the output power will be displayed.

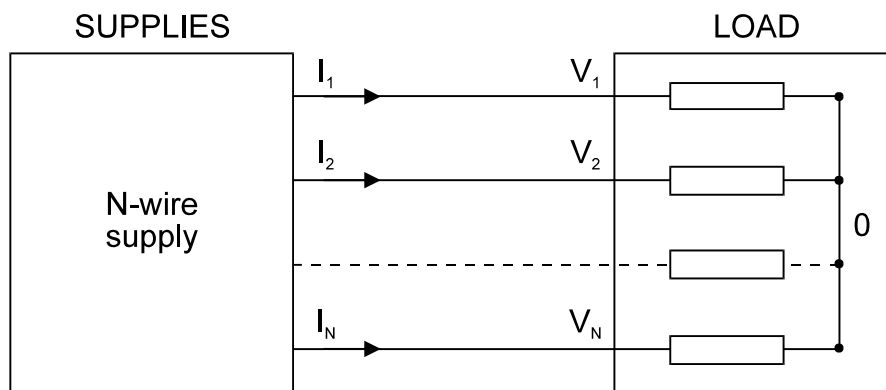
To read the input power, switch off the ballast power supply and remove the connections to the PM1000+. Replace them in the positions marked as V1 and A1 in figure 16., and re-connect the supply.

On the PM1000+, switch off Ballast Mode by repeating the button press sequence above and selecting 'Normal' instead of 'Ballast' the PM1000+ will return to its default settings providing no other settings were made.

The input power will now be displayed.

## Appendix A - Required Number of Watt meters

Consider the circuit shown in Figure A1, where the circuit is powered by N wires. Each wire has an associated voltage ( $V_1$  to  $V_N$ ) with respect to a separate reference (e.g. point 0), and an associated current ( $I_1$  to  $I_N$ ).



*Figure A1. Circuit Powered by N Wires*

The total instantaneous power ( $P$ ) in the circuit is given by:

$$P = V_1 I_1 + V_2 I_2 + \dots + V_{N-1} I_{N-1} + V_N I_N$$

Applying Kirchhoff's first law, that the total current flowing into a circuit must equal the current flowing out, allows us to write the Nth current in terms of all the others:

$$I_N = -(I_1 + I_2 + \dots + I_{N-1})$$

We can therefore rewrite the expression for the power in the circuit as:

$$P = V_1 I_1 + V_2 I_2 + \dots + V_{N-1} I_{N-1} + V_N (I_1 + I_2 + \dots + I_{N-1})$$

$$P = (V_1 - V_N) I_1 + (V_2 - V_N) I_2 + \dots + (V_{N-1} - V_N) I_{N-1}$$

This equation shows that the total power can be measured with  $n-1$  watt meters (i.e. voltmeter-ammeter pairs) connected as shown in Figure A2, where the Nth wire has now taken on the function of a 'Common' or 'Lo' terminal.

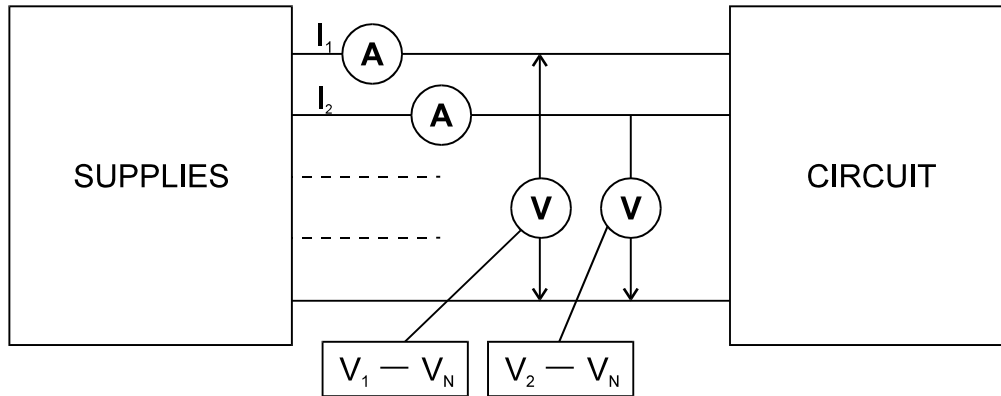


Figure A2. Power Measurement in a Circuit Powered by N Wires

In theory, it does not matter which of the wires is assumed to be the reference terminal, as the expression for power is symmetrical for all nodes. In practice, however, if one of the voltages is near to ground potential, this would probably be a good choice.

Clearly, the general result from the final equation for the power measured is as follows:

*In a circuit powered by several leads, the total associated power can be measured using a number of watt meters equal to the number of leads minus 1.*

This is the principle used when measuring the power delivered to a group of fluorescent tubes driven from one ballast.

## **Appendix B - Lighting Terminology**

### **Candela (cd)**

The SI unit of luminous intensity, equal to one lumen per steradian.

### **Chroma**

In the Munsell system, an index of saturation of color ranging from 0 for natural grey to 16 for strong colors. A low chroma implies a pastel shade.

### **Chromaticity**

The color quality of stimulus, usually defined by co-ordinates on a plane diagram in the CIE colorimetric system (CIE Publication 15) or by the combination of dominant wavelength and purity.

### **Color rendering**

A general expression for the appearance of surface colours when illuminated by light from a given source compared, consciously or unconsciously, with their appearance under light from some reference source. 'Good colour rendering' implies similarity of appearance to that under an acceptable light source, such as daylight.

### **Color temperature**

The temperature of a full radiator which emits radiation of the same chromaticity as the radiator being considered.

### **Daylight factor**

The illuminance received at a point indoors, from a sky of known or assumed luminance distribution, expressed as a percentage of the horizontal illuminance outdoors from an unobstructed hemisphere of the same sky. Direct sunlight is excluded from both values of illuminance.

Diffused lighting

Lighting in which the luminous flux come from many directions, none or which predominates.

### **Direct lighting**

Lighting in which the greater part of the luminous flux from the luminaries reaches the surface (usually the working plane) directly, i.e. without reflection from surrounding surfaces. Luminaries with a flux fraction ratio less than 0.1 are usually regarded as direct.

### **Discharge lamp**

A lamp in which the light is produced either directly or indirectly by the excitation of phosphors by an electric discharge through a gas, a metal vapour or a mixture of several gases and vapours.

### **Discomfort glare**

Glare which causes visual discomfort.

### **Emergency lighting**

Lighting provided for use when the main lighting installation fails.

*Maintained* - Here the lamp is on all the time. Under normal conditions it is powered by the mains. Under emergency conditions it uses its own battery supply.

*Non-maintained* - Here the lamp is off when mains power is available to charge the batteries. Upon supply failure the lamp is supplied from a battery supply.

*Sustained* - This is a hybrid of the previous two. A lamp is provided which operates from the mains supply under normal conditions. Under emergency conditions a second lamp, powered from the battery pack takes over. Exit signs commonly use sustained luminaries.

## **Escape lighting**

Emergency lighting provided to ensure that the means of escape can be safely and effectively used at all material times.

## **Flicker**

A visible oscillation in luminous flux.

## **Flux fraction**

The proportion of luminous flux emitted from a luminaire in the upper or lower hemisphere (upper and lower flux fractions)

## **General lighting**

Lighting designed to illuminate the whole of an area uniformly, without provision for special local requirements.

## **General surround lighting**

Lighting designed to illuminate the non-working parts of a working interior.

## **Glare**

The impairment or discomfort of vision experienced when parts of the visual field are excessively bright in relation to the general surroundings.

## **Hazardous environment**

An environment in which a risk of fire or explosion exists.

## **Hostile environment**

An environment in which the lighting equipment may be subjected to chemical, thermal or mechanical attack.

Illuminance (E) (unit:  $\text{lm/m}^2$ , lux)

The illuminous flux density at a surface i.e. the luminous flux incident per unit area. (This quantity was formally known as the illumination value or illumination level).

### **Initial light output (unit: lm)**

The luminous flux from a lamp after 100 hours of operation.

### **Installed efficacy (unit: lm/w)**

A factor which quantifies the efficiency of a lighting installation in converting electrical power to light. Specifically it is the product of the lamp circuit luminous efficacy and the utilization factor.

### **Isolux diagram**

A diagram showing contours of equal illuminance.

### **Load factor**

The ratio of the energy actually consumed by a lighting installation over a specified period of time to the energy that would have been consumed had the lighting installation always been operating during that period of time.

### **Local lighting**

Lighting designed to illuminate a particular small area which usually does not extend far beyond the visual task, e.g. a desk light.

### **Lumen (lm)**

The SI of luminous flux, used in describing a quantity of light emitted by a source or received by a surface. A small source which has a uniform luminous intensity of one candela emits a total of 4 lumens in all directions and emits one lumen within one solid angle.

## **Luminaire**

An apparatus which controls the distribution of light given by a lamp or lamps and which includes all components necessary for fixing and protecting the lamps and for connecting them to the supply circuit. Luminaire has superseded the term lighting fitting.

## **Luminance (L) (unit:cd/m)**

The physical measure of the stimulus which produces the sensation of brightness measured by the luminous intensity of the light emitted or reflected in a given direction from a surface element, divided by the area of the element in the same direction. The SI unit of luminance is the candela per square metre.

## **Luminance efficacy (unit:lm/W)**

The ratio of the luminous flux emitted by a lamp to the power consumed by the lamp. When the power consumed by control gear is taken into account this term is often known as lamp circuit luminous efficacy and is expressed in lumens/circuit watt.

## **Luminous flux (unit:lm)**

The light emitted by a source or received by a surface

## **Luminous intensity (unit:cd)**

A quantity which describes the power of a source or illuminated surface to emit light in a given direction. It is the luminous flux emitted in a narrow cone containing the given direction divided by the solid angle of the cone: the result is expressed in candelas.

## **Luminous intensity distribution**

The distribution of the luminous intensity of a lamp or luminaire in all spatial directions. Luminous intensity distributions are often shown in the form of a polar diagram or as a table for a single vertical plane, in terms of candelas per 1000 lumens of lamp flux.  
Mounting height

Usually the vertical distance between a luminaire and the working plane, but sometimes the distance between the luminaire and the floor.

### **Power factor**

In an electric circuit the power factor is equal to the ratio:

$$\frac{\text{Watts}}{\text{Volt Amperes}}$$

For sinusoidal waveforms this equals the cosine of the phase angle between the volts and amperes.

### **Room index (RI)**

An index related to the dimensions of a room and used when calculating the utilization factor and other characteristics of the lighting installation;

$$\text{Room index} = \frac{LW}{H(L + W)}$$

where L is the length of the room, W the width and H the height of the luminaries above the working plane.

### **Standby lighting**

Emergency lighting provided to enable normal activities to continue.

### **Steradian (sr)**

A unit of solid angle. A complete sphere subtends 4 steradians from the centre.

## **Stroboscopic effect**

An illusion caused by oscillation in illuminous flux that makes a moving object appear as stationary or as moving in a manner different from that in which it is truly moving.

## **Utilization factor**

The proportion of the luminous flux emitted by the lamps which reaches the working plane.

## **Working plane**

The horizontal, vertical, or inclined plane on which the visual task lies. The working plane can be considered to be horizontal and at 0.7m above the floor for offices and 0.85m above the floor for industrial applications.

This page is intentionally left blank.