The VOLTECH Handbook of Testing to IEC555

John Ford

Product: PM3000A Issue 1.10 November 14th, 1994.

Guide to this Handbook

For an introduction to IEC555 and the measurements required, please read sections 1 to 4.

Details on measurements to IEC555 and a step by step measurement guide are contained in sections 5 to 12.

The measurement limits and test conditions are contained in appendices B and C for reference.

If you are considering the purchase of an IEC555 measuring instrument, please study Appendix H.

Table of Contents

Page

Appendices: Page

Voltech Application Note 104

1. Introduction

Engineers in the electronic and electrical equipment industry are becoming increasingly aware of a standard called 'IEC555'. This standard is concerned with the level of distortion of the current drawn by equipment that is connected to the a.c power line, and with voltage fluctuations that the equipment may cause to the a.c. line.

Whilst the phrase 'IEC555 standard' is becoming familiar with many engineers in this environment, a degree of confusion is becoming evident regarding its real meaning, its relevance to specific products and the best way to test compliance with the standard. This application note aims to clarify some of these requirements.

Since its inception in 1986, Voltech has been dedicated to designing instruments that provide a solution to measurement problems in the power field. In 1988 Voltech released the PM1200 and PM3000. In January 1993, Voltech introduced a new power analyzer called the PM3000A, a second generation product derived from the PM3000 that had become an industry standard instrument within its three year period of production.

In addition to the enhanced performance for established power measurement applications, the PM3000A has the processing power to offer all the required measurements to meet the IEC555 standard. The PM3000A, together with its associated PC software offers a complete measurement solution for testing to IEC555.

A Solution to Meet Your Standard

The International Electrotechnical Commission are an issuing authority who generate documents defining a remit for standards compliance.

IEC 555 is therefore the parent document from which National Standard bodies will derive their standards for adoption by relevant industries or services. For example, the European Standard EN60555-3 has the status of British Standard.

Voltech have developed the PM3000A in accordance with the IEC555 documents in order that the various standards derived from it are fully encompassed.

Acknowledgements

Descriptions contained in this application note include information from the following documents:

EN60-555 Part 2, 1987.
EN 60-555 Part 3, 1987.
IEC1000-4-7, July 1991.
IEC 868-0, April 1991.
IEC Doc 77A (Sec) 82, Sept. 1992.
IEC Doc 77A (Central office) 38, March 1993.
IEC Doc 77A (Sec) 90, April 1993.
IEC Doc 77A (Central Office) 41, December 1993.

IEC documents can be obtained from your local standards authority or from:

IEC - International Electrotechnical Commission **or**
CEI - Commission Electrotechnique International (French):

3, Rue de Varembé,
Genève,
Suisse.

Addendum : April 19th 1994

Since the production of Application Note 104 (Issue 1.01), subsequent amendments and draft international standards relating to IEC555 (or IEC1000-3 as it will ultimately be known) have been produced.

Voltech remains aware of all the latest revisions to ensure our continued compliance to them. Whilst the functionality of our products is enhanced in accordance with prevailing requirements, for logistical reasons there is no intention to reprint this document in response to every revision.

Addendum : Novemember 9th 1994

Voltech continues to monitor the progress of IEC555 and its amendments. The revised IEC555 described in this handbook and implemented on the PM3000A-002 will be published as European standard EN61000-3 parts 2 and 3 during 1995.

2. Why Is the IEC555 Standard Necessary?

Many years ago, all the loads connected to the a.c. supply lines were resistive loads such as filament lamps or heaters, and simple inductive loads such as fixed speed a.c. motors. Such loads draw sinusoidal currents from the a.c. supply and hence do not cause any special problems for the supply.

Today, an increasing proportion of loads that are connected to the a.c. supply draw currents that are distorted (non- sinusoidal) in shape. Examples of such loads are power supplies for computers, T.V. and audio equipment, lamp dimmers, variable speed motor drives, and electronic ballast lights. Figure 1 shows the input circuitry of a typical power supply:

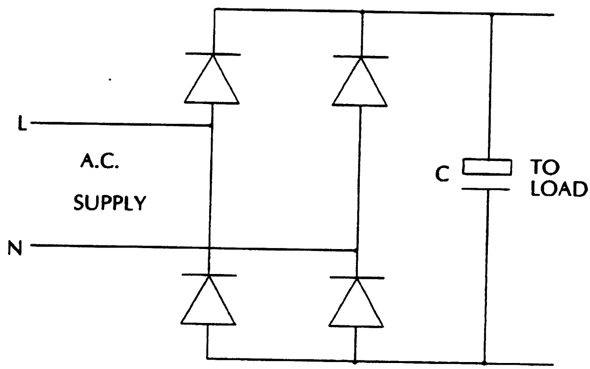


Figure 1 - Power supply input circuit.

When a.c. voltage is applied to the diode bridge, this voltage is rectified by the bridge, and the capacitor (C) charges to near the peak of the rectified a.c. voltage.

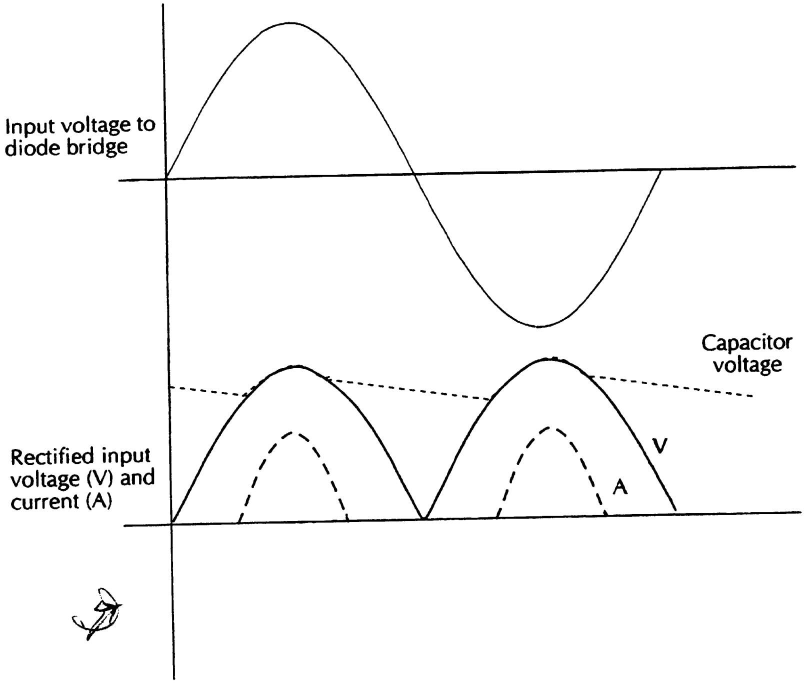


Figure 2 - Bridge rectifier output current.

Current can only flow in the diode bridge when the applied a.c. voltage is greater than the capacitor voltage. When the applied voltage is less than the capacitor voltage, current flow is blocked by the diodes. As a result, current flow into the capacitor is a series of narrow, high current pulses. This creates a current in the a.c. line that is very distorted (non-sinusoidal) in shape.

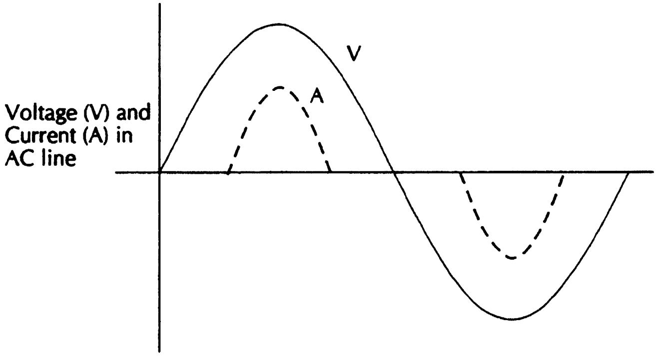


Figure 3 - Input current to diode bridge.

Another source of distorted current waveforms is the use of a.c. phase control to control the power supplied to a load. This principle is used in lamp dimmers and heater controls. A typical phase control circuit is shown below:

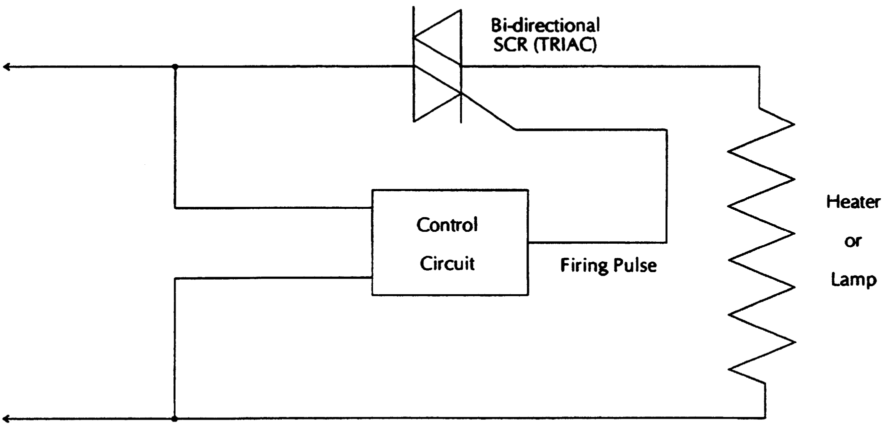


Figure 4 - Phase control circuit.

The power supplied to the load is controlled by delaying the firing pulse relative to the start of each half cycle:

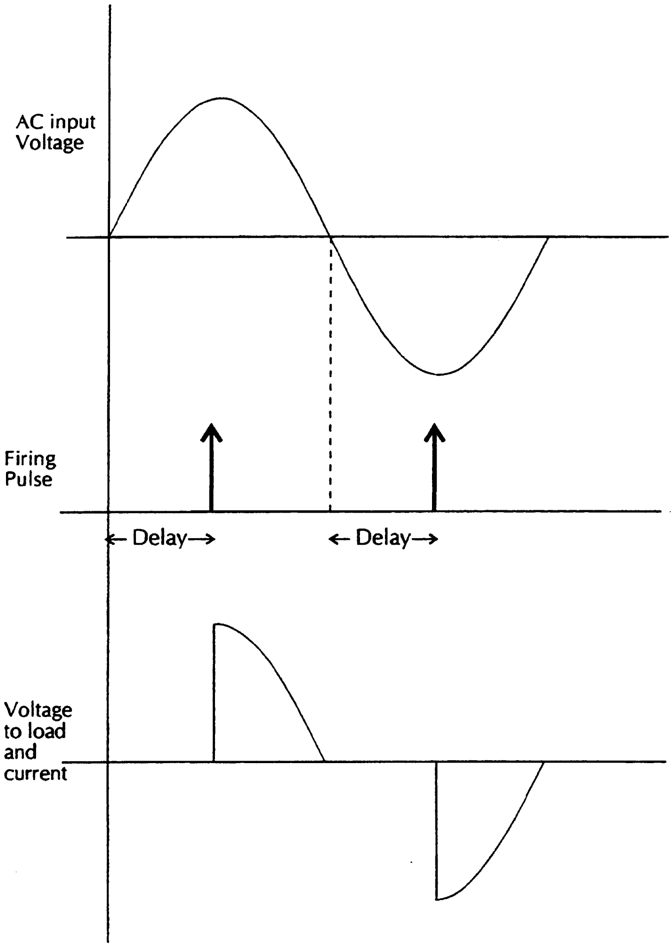


Figure 5 - Waveforms of phase-control circuit.

It can be seen that phase control introduces significant distortion of the a.c. current waveform. Distorted current waveforms can cause many undesirable effects on the a.c. supply. For example:-

1) Distorted currents reduce the effective power factor of a load, (Appendix G), and therefore cause wasteful heating of cables and transmission lines which must be oversized to deal with such loads. Heating due to distorted currents is also a frequent cause of burnout of neutral conductors in three phase systems.

2) The distorted current waveform causes distortion of the a.c. supply voltage. This results in overheating and reduced output from a.c. motors connected to the same a.c. supply system.

3) The distorted currents can interfere with the proper operation of other loads connected to the system, such as power factor correction capacitors. They may also cause electromagnetic interference with communication equipment in the vicinity of the supply.

As well as loads that cause distortion, more and more loads incorporate controls such as thermostats and timers which cause frequent changes of the load to the supply. Examples of such loads are cooking appliances, heaters, air conditioners, photocopiers and welding equipment.

Every a.c. supply has a certain amount of source impedance from the generating source to the distribution point, with a number of loads connected at the distribution point:-

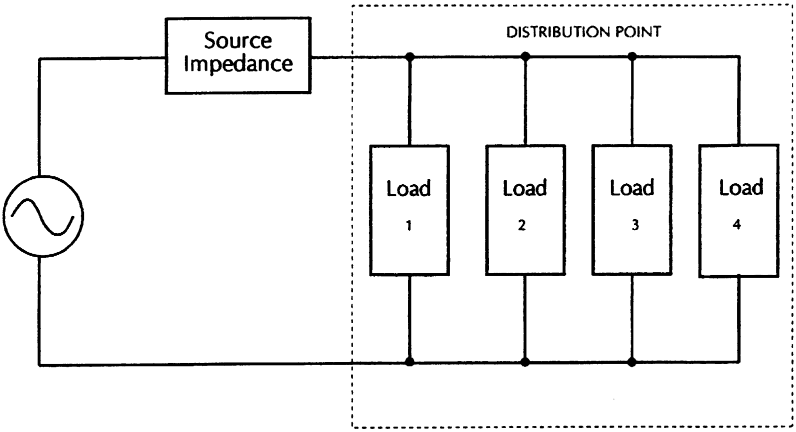


Figure 6 - A.C. supply system.

When a fluctuating load is one of the loads at the distribution point, it causes fluctuations in the voltage drop across the source impedance, and therefore fluctuations in the r.m.s voltage at the distribution point. Variation in the r.m.s voltage will cause fluctuations in the light output of any filament lamps connected as one of the loads.

As the energy output of a filament lamp is proportional to the square of the applied voltage, the change in light intensities can be very significant for even small changes in voltage:

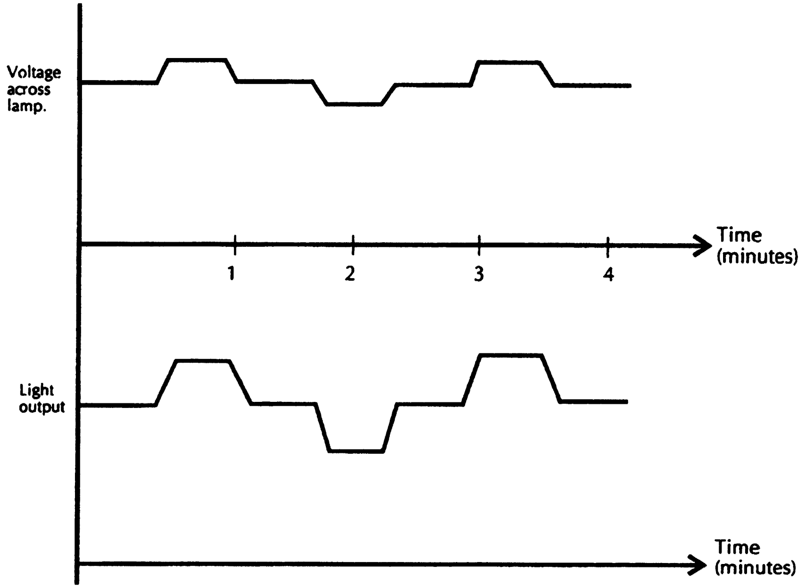


Figure 7 - Variation of lamp intensity with voltage changes.

The effect of this variation in light output of a filament lamp on a human observer is known as flicker.

Many a.c. loads therefore cause disturbances to the a.c. supply due to **distortion** and/or **flicker**. The IEC555 standard is therefore necessary to limit the disturbance that such equipment can cause to the supply.

3 What Is IEC555, and What Are Its Requirements?

The IEC555 standard was created by the International Electrotechnical Commission based in Geneva, Switzerland. The IEC standard consists of three parts:-

Part 1- Glossary of terms.
Part 2- Specification of harmonics.
Part 3- Specification of voltage fluctuations.

The standard was created to provide limits on the disturbing effect that equipment has on the a.c. supply. The standard achieves this in two ways:-

1) By providing limits on the magnitude of harmonic currents created by equipment (IEC555 Part 2- Harmonics).

2) By providing limits on the level of voltage fluctuations produced by equipment (IEC555 Part 3- Voltage fluctuations)

3.1 Harmonics

Using Fourier Analysis, a distorted current waveform, such as that drawn by a power supply, can be shown to consist of a fundamental component (at the supply frequency) plus a series of harmonic components (at multiples of the supply frequency):-

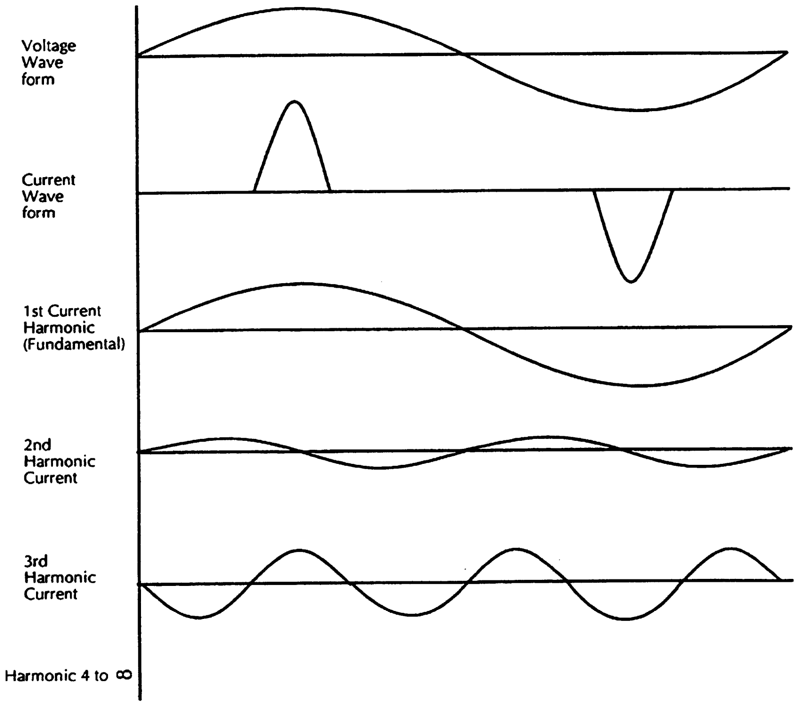


Figure 8 - Analysis of distorted current waveform.

In general, the magnitude of harmonics becomes smaller with increasing harmonic order, so harmonics above the 40th harmonic are usually very small.

An ideal current waveform would consist of only the 1st (fundamental) component. IEC555 Part 2 defines limits on the magnitude of the 2nd to the 40th current harmonic, and thereby controls the level of current distortion that can be produced by equipment.

The limits on the magnitude of each harmonic that IEC555 specifies for equipment depend on which Class (A,B,C or D) the equipment falls in. Appendix A describes the IEC555 classification of equipment, and Appendix B gives the limits for each of the Classes. In addition to the question of class, IEC555 defines harmonics produced by equipment as Steady-State harmonics or as Fluctuating Harmonics.

3.1.1 Steady-State Harmonics.

These are harmonics produced by equipment that generate a distorted current waveform, but present a steady (non-varying) load to the supply. In this case the magnitude of every harmonic will remain constant for the whole time that the equipment is energized from the supply.

For example:

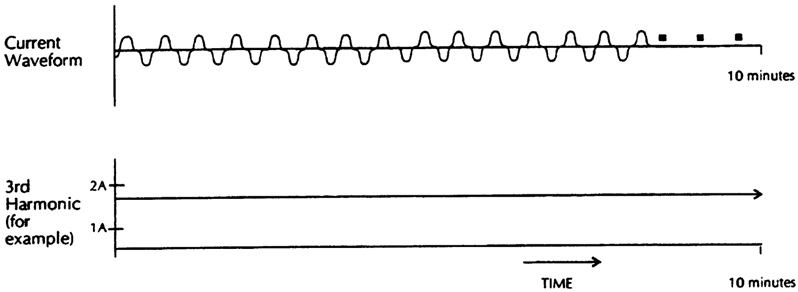


Figure 9 - Steady-state harmonics.

3.1.2 Fluctuating harmonics.

These are harmonics produced by equipment that generates distorted current waveforms, but presents a varying or fluctuating load on the a.c. supply. In this case the magnitude of any particular harmonic will vary during the time the equipment is energized from the supply.

For example:-

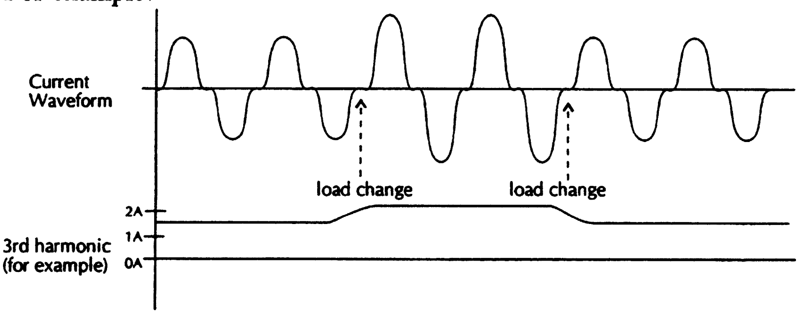


Figure 10 - Fluctuating harmonics.

The method used to measure harmonics for checking conformance to IEC555 Part 2 depends on whether the equipment produces steady-state or fluctuating harmonics.

3.2 Voltage fluctuations.

In section 2 it was shown that a fluctuating load will cause changes in the r.m.s. voltage of the supply, and this will cause flicker in lamps connected to the same supply. The level of voltage changes that equipment can cause to the supply is specified in IEC555 Part 3 by monitoring the voltage changes at the load when the load is supplied through a specified value of source impedance:-

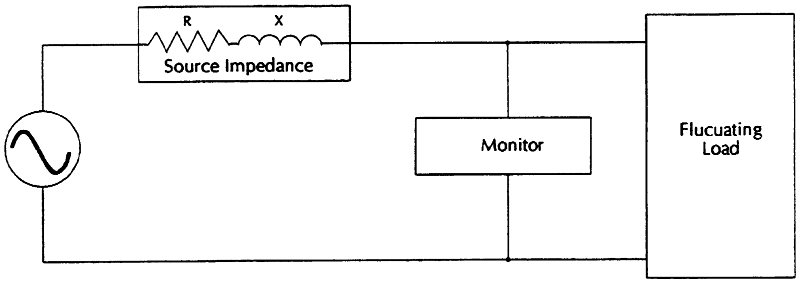


Figure 11 - Determination of voltage changes.

The value of source impedance to be used is defined by the IEC555 standard, and depends on the type of the a.c. supply (Appendix E).

The standard recognizes that the disturbing effect of voltage fluctuations depends not only on the magnitude of the voltage fluctuations, but also on their repetition rate. For example, it has been observed that even quite large voltage changes will have little disturbing effect if these changes occur only occasionally, while quite small voltage changes are quite noticeable if the changes occur at a frequent rate. The following curve, reproduced from IEC555 Part 3, shows the observed relationship between the magnitude of repetitive voltage changes, and the rate of occurrence of these changes, for the same perception of flicker:-

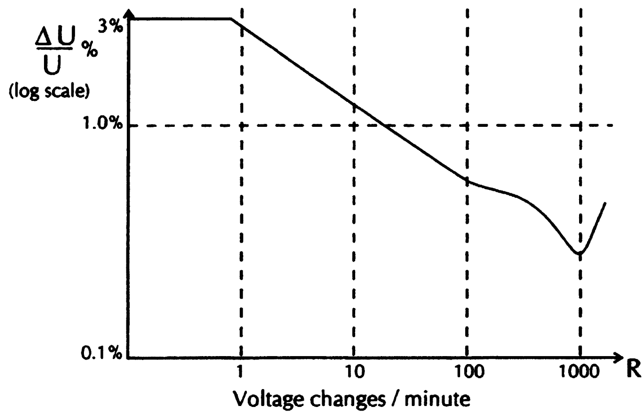


Fig 2

Figure 12 - Magnitude of maximum permissible voltage changes with respect to number of voltage changes per minute (Pst = 1 curve).

IEC555 provides for two techniques for assessing whether the level of voltage fluctuation is acceptable, depending on the nature of the voltage fluctuation. One method is by direct measurement or calculation of the voltage changes themselves and comparing this with the graph of Fig.12. Another method, the preferred one, is by assessment of the disturbing effect of the voltage changes, to provide a direct measurement of flicker, together with a measurement of the maximum level of voltage deviation caused by the equipment.

3.2.1 Voltage changes.

Loads that provide a regular or repeatable load variation can be monitored by installing a source impedance and directly recording the level of voltage changes appearing across the load:-

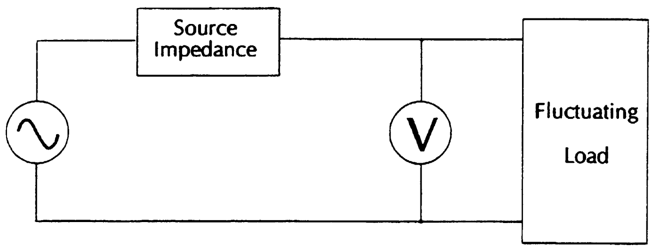


Fig.13 Determining the level of voltage changes by voltage measurements.

These voltage changes can also be determined by measuring the in-phase and quadrature (Ip and Iq) components of the load current, and using vector calculations to determine the voltage drop across the specified value of source impedance.

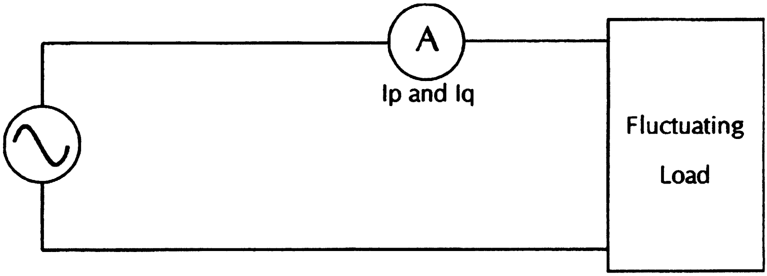


Fig.14 Determining the level of the voltage changes by current measurement.

The magnitude and frequency of the voltage changes can then be directly assessed against the Pst = 1 curve contained in the standard (Fig.12).

3.2.2 Flicker and voltage deviations.

If the load fluctuations are more complex, e.g. if a series of random or continuous voltage changes occurs, then the disturbing effect on human perception cannot be determined from a simple analysis of the magnitude and frequency of these changes. The assessment of these more complex changes requires a simulation of the whole of the lamp-eye-brain chain.

IEC have shown that this can be achieved by processing the voltage changes that occur using a technique (IEC868-Flickermeter -

Figure 15) that uses filters and statistical analysis to produce a flicker value (Pst or Plt) representing the disturbing effect of the voltage fluctuations on the human observer.

Where:-

Pst is the short term flicker severity evaluated over a short period (in minutes).

and

Plt is the long term flicker severity evaluated over a long period, (a few hours, using successive Pst values.)

IEC555 provides limits on the maximum value of Pst or Plt that equipment is allowed to produce.

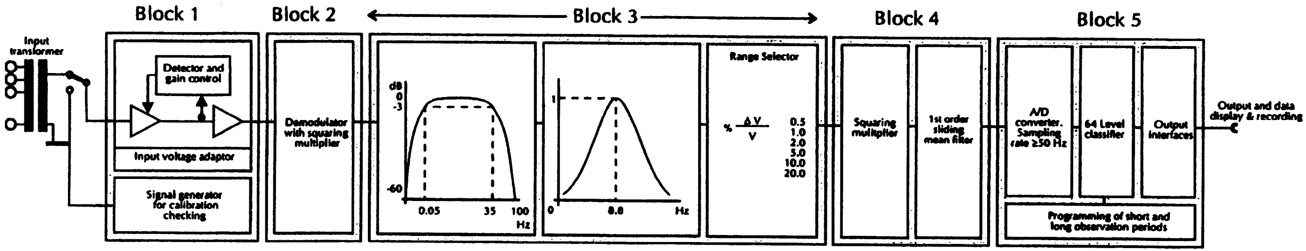


Figure 15 Functional diagram of IEC flickermeter

In addition to measurements of flicker value Pst and Plt using the flickermeter technique, IEC 77A (Central Office) 38 requires that measurements of voltage deviation (dc and dmax) are also made. This is because whilst the flickermeter technique provides an excellent assessment of continuous voltage changes, a load that causes a single or very occasional large voltage change will have only a small effect on the Pst/Plt measurement, yet this large voltage change will be very disturbing.

For example, an appliance may draw a very large inrush current from the supply when it is first switched on, particularly if the input has no inrush current limiting circuitry. This inrush current may cause a substantial deviation in the supply voltage, causing disturbance to other loads on the same supply:-

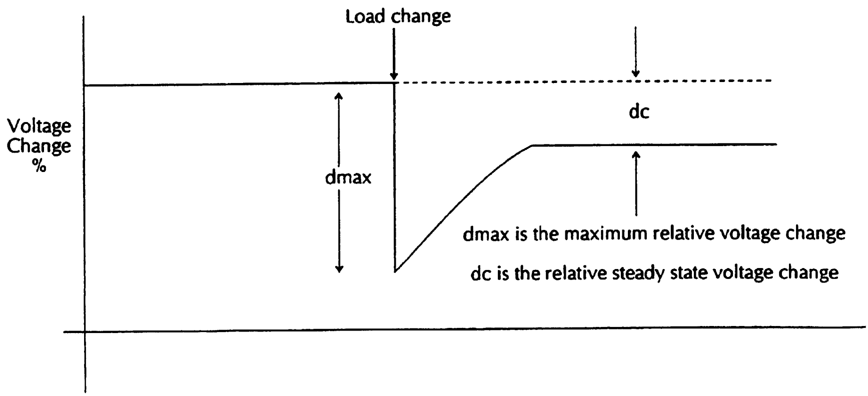


Figure 16

Setting of limits for the voltage deviations, as well as for flicker, controls the level of disturbance due to load changes that equipment can cause to the supply.

4 To what equipment is the IEC555 standard applicable and what measurements should be made?

IEC555 is currently applicable to electrical and electronic equipment for household and similar use. From 1st January 1995 it is planned to extend the scope to make the IEC555 standard applicable to all electrical equipment having an input current up to and including 16A per phase, intended to be connected to public low voltage distribution systems.

In due course, the IEC555 standard will be extended to cover equipment rated at more than 16A, and IEC555 Part 4 and Part 5 (Guides) are recommendations for harmonics and voltage fluctuations for equipment exceeding 16A.

At the moment the standard considers only a.c. distribution systems of the following types:-

nominal voltages up to 240V, single-phase, two or three wire.
nominal voltages up to 415V, three-phase, three of four wire.
nominal frequency 50Hz or 60Hz.

For systems with nominal voltages less than 220V line to neutral e.g. 100V,120V a.c. , limits have not yet been established by the standard. However, as other organisations such as Underwriters Laboratory are also considering disturbance standards, designers must expect that equipment for use on lower voltage networks will in due course have to meet disturbance standards similar to IEC555. At the moment the standard is therefore applicable to equipment such as cooking and heating appliances, motor operated and magnetically driven appliances, portable tools, light dimmers, radio and television receivers, video recorders and audio equipment. Currently the standard is not applicable to equipment intended exclusively for professional purposes, but from January 1995 it can be expected that the standard will apply to equipment such as ballast lighting, computers, printers and photocopiers and other similar equipment, and eventually to all equipment that is connected to single and three phase supplies.

To meet the standard, equipment must conform to the requirements of the standard for both harmonics and for voltage fluctuations. In some cases, it will be clear that equipment will meet the requirements of the standard and will not need to be tested. For example, a simple filament lamp that does not incorporate an electronic transformer or dimming device will clearly not produce harmonics or voltage fluctuations, so will not need to be tested - in fact IEC555 considers such a lamp as meeting the requirements.

In some cases it will be evident that the equipment will meet, for example, the standard for harmonics, but there may be some doubt as to whether it meets the standard for voltage fluctuations. An electric heater with bi-metal thermostat would be one example. In this case it would be necessary to test only for voltage fluctuations as the heater draws sinusoidal currents so no harmonics are produced.

In most cases, however, it will be necessary to test equipment for both harmonics and for voltage fluctuations, not only to confirm that the requirements of both Part 2 and Part 3 of IEC555 are being met, but to provide evidence to customers and to the electrical supply authority that this is the case.

To meet requirements of IEC555 the following measurements should be made:

IEC555 Part 2:-

Steady state harmonics.

If the equipment produces a steady load to the supply, harmonics can be measured as steady-state harmonics. For example, a light dimmer set up as described in the standard can be expected to provide a steady load to the supply, and will produce steady state harmonics.

OR

Fluctuating harmonics.

If the equipment produces a fluctuating load to the supply, or if there is any doubt as to whether the equipment produces steady state harmonics, then the equipment should be measured for fluctuating harmonics. A photocopier is an example of such a piece of equipment.

AND

IEC555 Part 3.

Voltage changes.

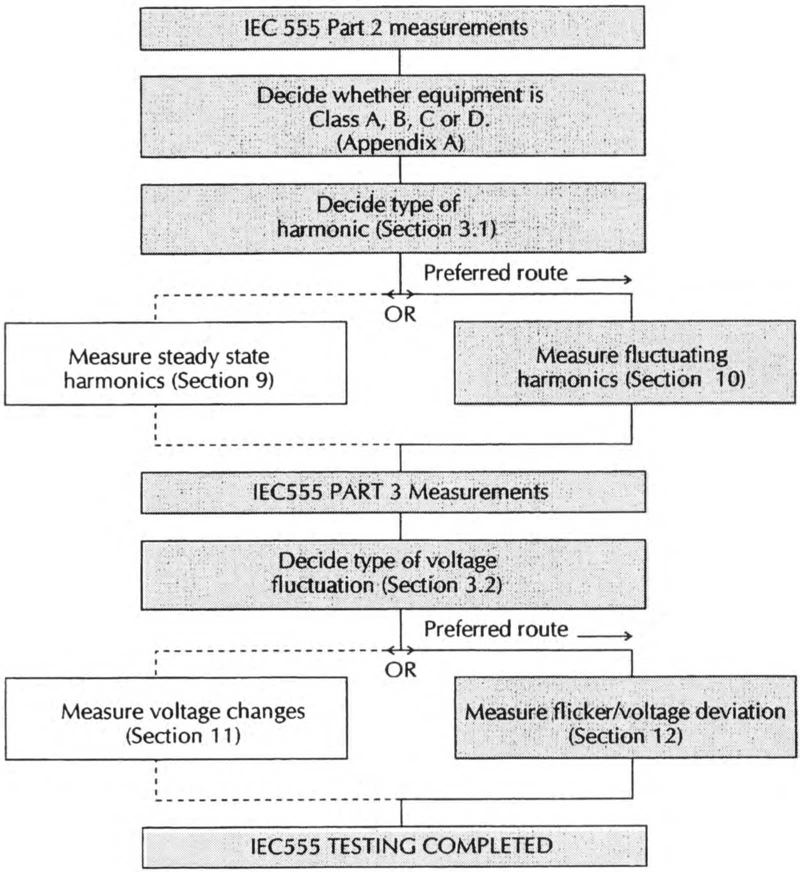
If the equipment incorporates a control device that causes the load presented to the supply to change in a regular and repeatable manner, then the equipment can be measured for voltage changes.

OR

Flicker and voltage deviations.

This is the preferred method of verifying conformance to Part 3 of the standard. If there is any possibility that the equipment produces an irregularly-varying load, then the equipment should be measured for flicker and voltage deviations. Examples of such equipment are hot-plates, ovens, washing machines, hairdryers, copiers, laser printers and many others.

5. Flow Chart Summarizing Actions for IEC555 Measurements



6. Making IEC555 measurements.

6.1 Full Compliance and Pre-Compliance testing.

Full compliance testing is required by test laboratories that need to offer customers traceable certification that equipment meets the required standard. In this case it is necessary to set up a test environment (power source, source impedance, measuring equipment) that meets all the requirements of the IEC555 specification.

Pre-compliance testing requires setting up a test environment that will provide a very high degree of confidence that the equipment meets the required specification, but without the traceability inherent in full-compliance testing. Such an environment is much less expensive to create. If equipment is shown to meet the standard with a reasonable margin during pre-compliance testing then it can be submitted for full-compliance testing to an outside authority with the confidence that it will meet the required specification. In addition pre-compliance testing provides valuable feedback to engineering departments during product development.

6.2 Test equipment required

6.2.1 Power source.

Full compliance testing.

For full compliance testing the a.c. power source must meet the stability and distortion specifications contained in the standard. Details of these requirements are given in Appendix D.

Pre-compliance testing.

Many users choose to utilise the regular single-phase or three-phase a.c. line for pre-compliance testing. The user should choose an a.c. line that is as clean and as stable as possible. In general, if the equipment meets the standard with a good margin when tested with the regular a.c. line, the equipment should meet the standard easily when submitted for full compliance testing.

6.2.2. Source Impedance.

A source impedance is not required when testing for harmonics or for measurement of voltage changes, as currents are measured.

Full compliance testing.

Full-compliance testing for flicker is by voltage measurement and a source impedance is required. Details of this source impedance as defined in the standard are given in Appendix E. An impedance network is available from Voltech which fully meets the standard.

Pre-compliance testing.

A source impedance is not required for pre-compliance testing for flicker, as the PM3000A offers the means to measure flicker by measurement of the changing load current. This method is not described in the standard, but Voltech have found that results using this method give good agreement with results made using voltage measurement. Current derived measurements having a good margin below the limits should meet the standard easily.

Alternatively, flicker can be measured with the PM3000A by voltage measurement using the specified source impedance, which can be made in house or purchased.

6.2.3 Current Transducers.

Full-compliance testing.

IEC555 Part 2 stipulates that the maximum voltage drop caused by the measuring equipment shall not be more than 0.15V peak. The standard model PM3000A has an input impedance of less than 12.5mΩ on all ranges, so direct connection can be used for currents less than about 12A peak.

Alternatively, the PM3000A-002 version is available with a low impedance shunt (3.5mΩ) for full compliance testing to IEC555 part 2 up to 16 Arms. This includes peak compliant current, as described in Appendix F.

Pre-compliance testing.

For pre-compliance testing, the error caused by voltage drop in the input impedance of the PM3000A series is small enough at currents up to the rated current of the analyzer (30Arms) to not cause significant errors.

6.2.4. Measuring equipment.

Full compliance and pre-compliance testing.

The PM3000A is suitable for both full-compliance and pre-compliance testing to IEC555, as it fully meets all the requirements of the standard as outlined in Appendix H.

6.3 Equipment set-up for tests requiring current measurements.

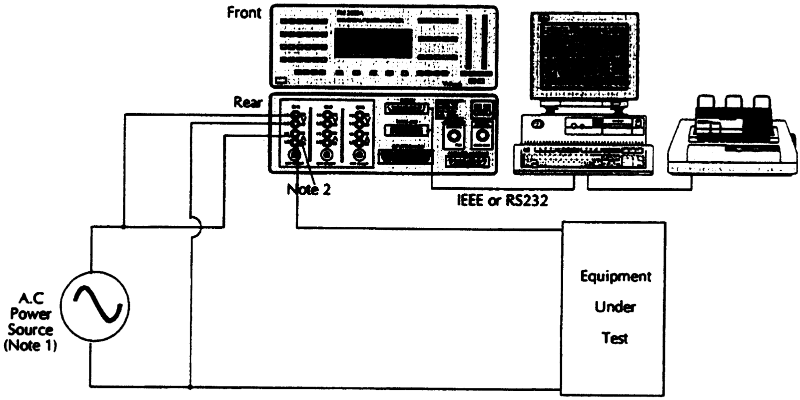


Figure 17

Note 1: For power source requirements see section 6.2.1.

Note 2: For current measurement requirements see section 6.2.3.

6.4. Equipment set up for tests requiring voltage measurements.

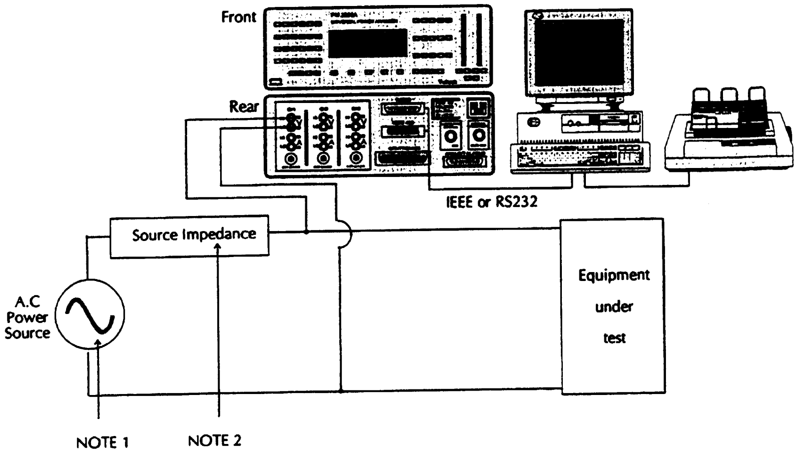


Figure 18

Note 1: For power source requirements see section 6.2.1.

Note 2: For source impedance requirements see section 6.2.2.

A reference impedance that fully meets the requirements of the standard is available from Voltech. The impedance simplifies the interconnection of the AC source, the PM3000A and the equipment under test.

7 Setting up the PC and the PM3000A for IEC555 testing

The IEC555 software supplied by Voltech is used with the PM3000A to perform testing to IEC555.

The following description relates to the software (Version 1.15) available at the time of writing this application note. Later versions may have additional features.

PC requirements.

The software runs on any PC that has a hard disk. To display graphics, a VGA display is required. MS DOS Version 5 or higher is required for printing graphics.

PC to PM3000A communications.

The software can either use IEEE-488 or RS232 communications from the P.C. to the PM3000A.

IEEE-488

Ensure the P.C. has an IEEE card installed. Suitable cards are IOTECH 488B or NATIONAL PCII/IIA. Connect between PC and PM3000A using IEEE488 cable.

Setting up the PM3000A for IEEE-488.

1. Press INTERFACE.

2. Press SELECT until the display shows >IEEE488<

3. Press ENTER.

4. Press SELECT until the display shows >enabled<

5. Press ENTER.

6. Type in an IEEE address. The default address for the IEC555 software is 9.

7. Press ENTER.

8. Press SELECT until the display shows >enabled<

9. Press ENTER.

RS232

Install an RS232 cable between a communication port on the PC and the PM3000A.

Setting up the PM3000A for RS232.

The IEC555 software works at 19200 baud.

1. Press the INTERFACE button.

2. Press SELECT until the display shows >RS232<

3. Press ENTER

4. Press SELECT until the display shows >enabled<

5. Press ENTER.

6. Press SELECT until the display shows >19200<

7. Press ENTER.

8. Press SELECT until the display shows >computer control<

9. Press ENTER.

Suitable leads for RS232:

25 way PC Connector

PM3000A				Computer
screen	1	————	1	screen
Rx	2	————	2	Tx
Tx	3	————	3	Rx
CTS	4	————	4	RTS
RTS	5	————	5	CTS
	20	————	20	DTR
	6	————	6	DSR
ground	7	————	7	ground

Note: On some PC's it may be necessary to link pins 20 and 6 at the PC connector

9 Way PC Connector

PM3000A				Computer
Rx	2	————	3	Tx
Tx	3	————	2	Rx
CTS	4	————	7	RTS
RTS	5	————	8	CTS
		—	1	DCD
		—	4	DTR
		—	6	DSR
ground	7	————	5	ground

Note: On some PC's it may be necessary to link pins 1, 4 and 6 at the PC connector

Initial Installation of Software

Before the IEC555 software can be used it must be installed on the hard disk. To do this:

1) Place the disk in a floppy drive.

2) Change to the drive into which the disk has been installed (e.g. Type A:)

3. Type INSTALL C: to install on hard disk drive C: or INSTALL D: to install hard disc drive D:

4. If you intend to print graphs you will need to activate graphics.com

Graphics.com is a program that is provided with DOS. To print the graphics in IEC555 you need the version of GRAPHICS.COM from DOS 5 (or later).

To run this:

4.1) Change to the directory containing the program Graphics.com. (This is not necessary if you have a path to DOS).

To change directory, type: CD\DOS or CD\"name of directory containing DOS"

4.2) To install Graphics.Com type: GRAPHICS

This will install Graphics.Com in memory and it will use the printer specified in graphics.pro.

4.3) Change to the IEC555 directory by typing: CD\IEC555

5) Run the IEC555 software by typing "RUN".

* It may be necessary to use the command "RUN -b" with software version 1.36.

Help menus guide the user through operating the software and carrying out the IEC555 tests.

Graphics should be capable of being printed. If it does not work then you will need to change Step 4.2 to specify the printer.

GRAPHICS.COM uses a setup program called GRAPHICS.PRO. When GRAPHICS.COM is run it loads in information about the type of printer being used from the file GRAPHICS.PRO.

E.g If you are using a laserjet printer at the C: prompt type:

GRAPHICS LASERJETII

This will install GRAPHICS.COM so that it will work with a laserjet printer.

The version of GRAPHICS.PRO supplied with this software has been modified so that the default printer prints at a resolution of 240 dots per inch (the DOS 5 default is 120dpi) and the graph is not rotated. This will print smaller graphs. This will only work if your printer supports the ESC 'Z' escape sequence for setting dpi.

8 Automatic Class D selection with PM3000A.

Before making measurements to IEC555 Part 2, it is first necessary to decide which class the equipment falls into; A, B, C or D.

The classification of equipment is described in Appendix A, and it can be seen that the decision for classifying the equipment into Class D depends on whether it has the special wave shape shown in the appendix, and has an input power of ≤600W.

It is very difficult to determine from an oscilloscope trace whether the input current waveshape falls within the Class D waveshape. For this reason the PM3000A and its associated IEC555 software provide a means of automatic Class D determination. This is achieved by capturing one complete cycle of the input current waveforms, which are then displayed on the PC:-

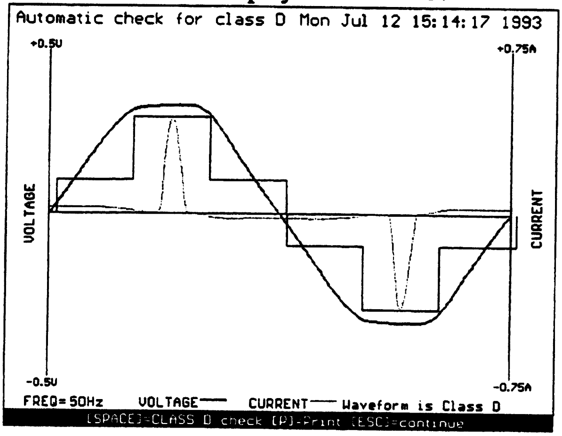


Figure 19

If the input power as measured by the PM3000A is ≤600W, the system will draw limit lines around the current waveshape representing the Class D criteria, and automatically determine if 95% of the current waveshape is contained within these limit lines, as required for the wave shape to be Class D.

To test for Class D:-

1. Set up for current measurements as described by Section 6.3.

2. Install the PC software and set up the PC and PM3000A as described in Section 7.

3. Select 'Automatic Class D' from the menu and follow the procedure described in the software.

9. Measuring steady state harmonics with PM3000A.

The PM3000A tests for steady-state harmonics by capturing precisely 16 cycles of the input current waveform and using Discrete Fourier Analysis to determine the magnitude of each current harmonic.

The value of each harmonic is then transmitted to the PC and compared with limit values stored in the PC program. These limit values are as defined in the IEC555 Part 2 standard for the particular class (A, B, C or D) of equipment being tested.

The system will present these results in the form of a bargraph or intable form, and show whether the equipment is PASS or FAIL.

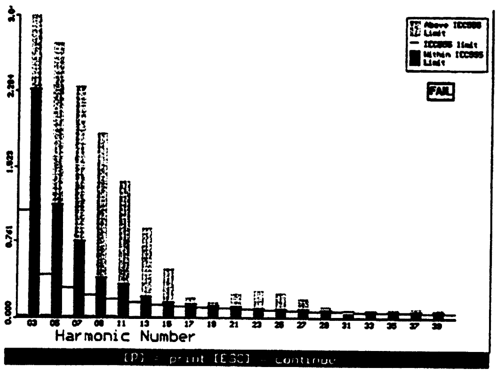


Figure 20 - Example of bargraph for steady state harmonics.

The PM3000A also monitors the purity and stability of the AC source during this test. The voltage harmonics and voltage changes of the AC source are measured and compared against the limits set by the standard. A table of the voltage harmonics and voltage deviations is printed.

To test for steady-state harmonics:-

1. Set up for current measurements as described in Section 6.3
2. Install the PC software and set up the PC and PM3000A as described in Section 7.
3. Decide which Class (A, B, C or D) the test will be made to.
4. Select 'Steady State harmonics' from the menus and follow the procedure described in the software.

10. Measuring Fluctuating Harmonics with PM3000A.

The PM3000A tests for fluctuating harmonics by continuously capturing successive blocks, with no gap between the blocks, and each block equal to precisely 16 cycles of the input current wave form:-

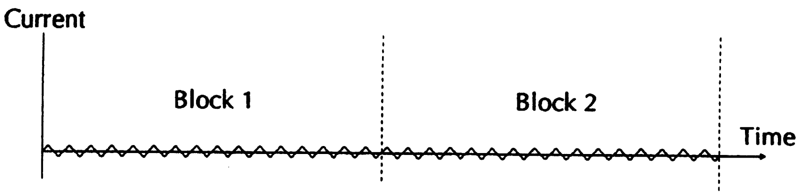


Figure 21

Each block is analyzed using Discrete Fourier analysis to determine the magnitude of each of the 40 current harmonics.

Results representing the magnitude of each harmonic are then passed through 1.5 second time constant low pass filters to provide smoothing of the amplitudes as defined by the standard. The output from these filters is continuously read by the PC that will log the results.

The PC examines the results as they are read from the PM3000A to determine if the magnitude of any harmonic exceeds the limit values defined in the standard for the particular class (A, B, C or D) for which the equipment is being tested.

Limit values for fluctuating harmonics are more complex than for steady state harmonics. The standard for fluctuating even harmonics 2 to 10, and for fluctuating odd harmonics 3 to 19, allows values up to 1.5 times the limits for steady-state harmonics during a maximum of 10% of any observation period of 2.5 minutes.

For example:

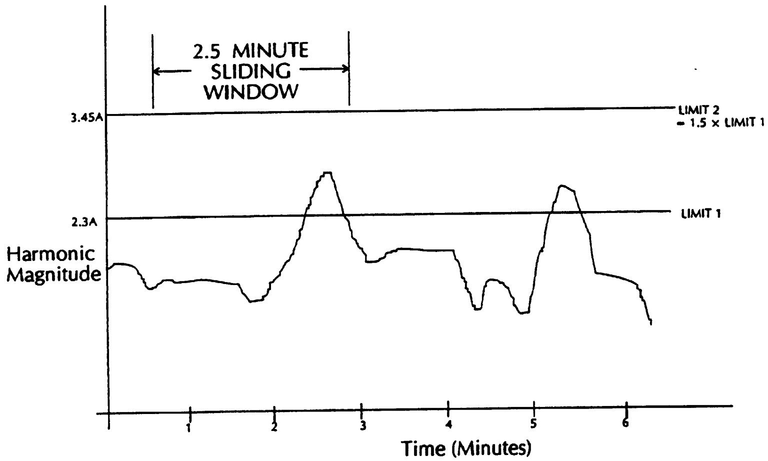


Figure 22

This is checked for by creating a 2.5 minute sliding window, and checking that values for each harmonic do not persist between Limit 1 and Limit 2 for more than 0.25 minutes in any 2.5 minute period. If this is exceeded, or a result exceeds Limit 2, then that particular harmonic has failed the test.

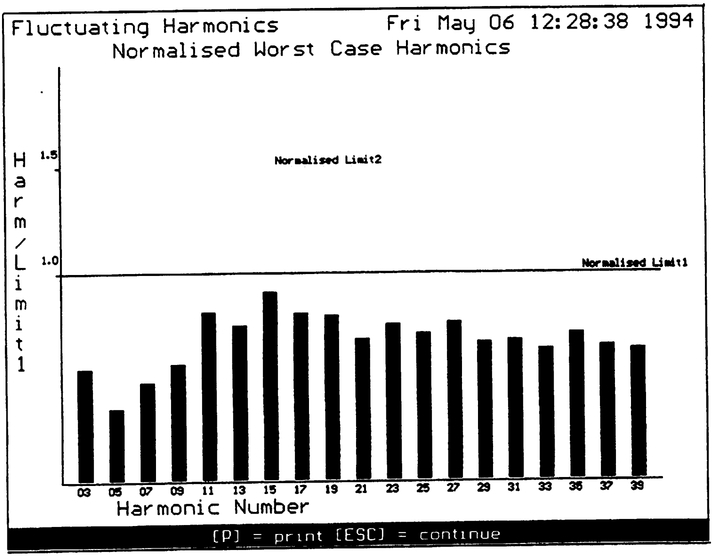
For a fluctuating load, the real power watts will vary during the course of the measurement. Class D limits are a function of the instantaneous watts, and will vary accordingly. The PM3000A and PC software account for this by adjusting the limits in real time according to the watts for class D measurements.

Results are presented in the form of a bargraph (showing harmonic amplitudes in real time), charts (showing harmonic amplitude vs. time) and in table form summarising results. Results can be printed together with pass/fail indication.

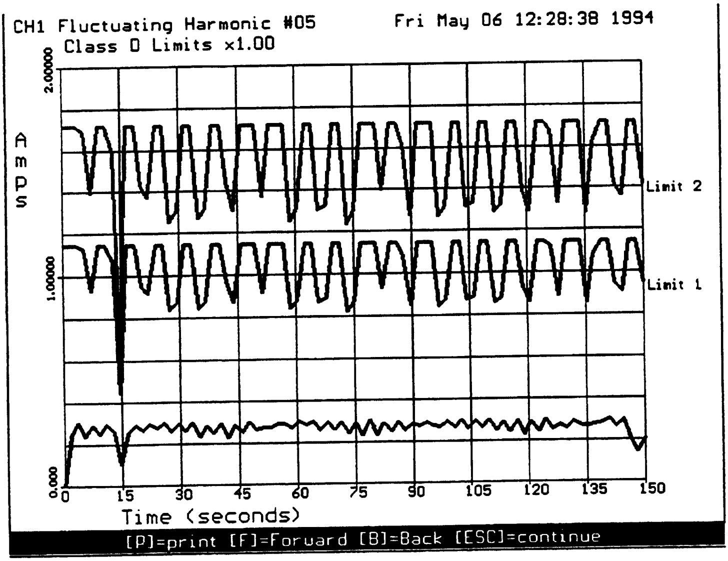
To test for fluctuating harmonics:-

1. Set up for current measurements as described in Section 6.3
2. Install the PC software and set up the PC and PM3000A as described in Section 7.
3. Decide which Class (A, B, C or D) the test will be made to.
4. Select 'Fluctuating harmonics' from the menus and follow the procedure described in the software.

The voltage source is simultaneuosly monitored for harmonic content and voltage deviations. Results are tabulated at the end of a test.



Example bargraph of normalised fluctuating harmonics and limits.



Example graph of the 5th harmonic variation with time.

11. Measuring Voltage Changes with PM3000A.

If the load presented by equipment changes in a regular and repetitive manner, the equipment may be tested for conformance to IEC555 Part 3 by measuring voltage changes.

Voltage changes are actually determined by measuring the current drawn by the equipment, and calculating the voltage drop across a value of source impedance as specified by the standard.

The magnitude of the current during every half-cycle is measured, together with its phase relative to the a.c. voltage waveform. The current can then be represented in terms of its in-phase (Ip) and quadrature (Iq) components.

The percentage voltage change (ΔU/U) is calculated as specified in the standard as:

$$\frac{\Delta U}{|U|} = \frac{(I_p \times R) + (I_q \times X)}{|U|} \times 100\%$$

Where the source impedance is defined R + jX. The PM3000A determines the magnitude of all the voltage changes, and the number of changes per minute for that magnitude.

These results are sent to the PC, which then plots these results on a graph showing the IEC555 Part 3 limits for voltage changes:-

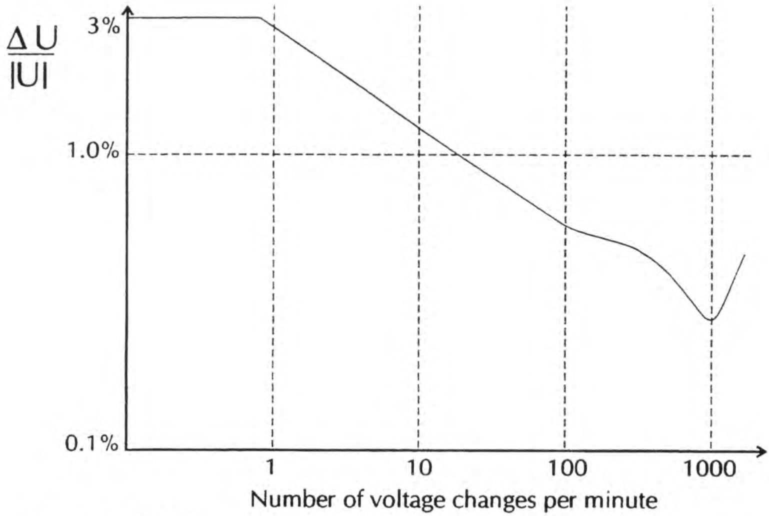


Figure 23 - Magnitude of maximum permissible voltage changes with respect to number of voltage changes per minute (Pst = 1 curve)

All results must be below the limit curve - if any result is above the curve the PC will indicate failure of the voltage change test.

To test for fluctuating voltage:

1. Set up for current measurements as described in Section 6.3
2. Install the PC software and set up the PC and PM3000A as described in Section 7.
3. Select 'Voltage Changes' from the menus and follow the procedure outlined in the software.

12. Measuring flicker and voltage deviation with PM3000A.

* The PM3000A measures flicker by performing the functions required by IEC specification 868 (Flickermeter - functional and design specification.) These functions are represented in figure 15 on page 23.

* Block 1 is a voltage adapter that scales the input mains frequency voltage (carrier) to a reference level so that flicker measurements will be made independently of the actual carrier level. This function is implemented digitally so calibration checking is not required as would be the case if implementation was analogue.

* Block 2 is a demodulator that recovers the voltage fluctuation by squaring the output of Block 1, thus simulating the behaviour of the lamp.

* Block 3 is composed of cascade filters which eliminate the dc and double frequency components in the demodulator output, and simulate the frequency response to voltage fluctuations of a filament lamp combined with the human visual system. No ranging is required as the digital implementation employed by the PM3000A operates over the whole range required for a flickermeter.

* Block 4 consists of a squaring multiplier and 300ms low pass filter, which combines with Blocks 2 and 3 to provide an overall response that simulates the lamp, eye and brain.

* Block 5 is implemented partly by the PM3000A and partly by the PC software that is used with the instrument. The output of Block 4 is the instantaneous flicker sensation. During the whole of the observation period the value of instantaneous flicker severity is classified 100 times per second into 1024 logarithmically scaled bins, providing a 1024 level classifier. (The class levels 0.01 to 6400 as defined by IEC 868 are required to be divided into a minimum of 64 divisions. The PM3000A uses 1024).

Flicker Class 6400	BIN # 1024	0
"	BIN # 1023	0
" "		
"	BIN # 4	3
"	BIN # 3	66
"	BIN # 2	72
Flicker Class 0.01	BIN # 1	120

* At the end of the observation period no more values are stored in this set of bins, and the values in the bins are available to be read by the PC.

(If a second observation period immediately follows the first, for measurement of Plt for example, the PM3000A continues measurements and stores results in an alternate set of bins).

* The PC reads the values in the bins, and from these results creates a cumulative probability function, representing the proportion of the observation period for which a particular flicker level has been exceeded (or, the probability that a particular flicker level would be exceeded at any point of time during the observation period).

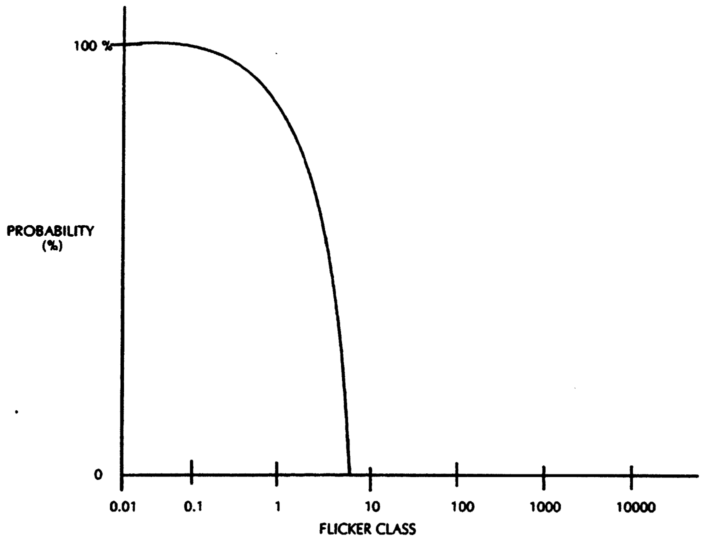


Figure 24

* Using the cumulative probability function, the PC can then calculate values for Pst and Plt. Where:

$$Pst = \sqrt{(0.0314P_{0.1}+0.0525P_{1s}+0.0657P_{3s}+ 0.28P_{10s}+ 0.08P_{50s})}.$$

Where Px represents the flicker level exceeded x% of the time. The suffix s in the formula indicates that smoothed values are used derived from the following equations:-

* $P50_s = (P_{30} + P_{50} + P_{80}) / 3$
* $P10_s = (P_6 + P_8 + P_{10} + P_{13} + P_{17}) / 5$
* $P3_s = (P_{2.2} + P_3 + P_4) / 3$
* $P1_s = (P_{0.7} + P_1 + P_{1.5}) / 3$

* Plt is calculated using the expression:-

$$Plt = \sqrt[3]{\frac{\sum_{i=1}^{N}(Pst_i)^3}{N}}$$ for successive Pst values

* The values for Pst and Plt are then compared with the limits.

The PM3000A measures voltage deviations at the same time as it is performing the flicker measurements.

* The rms voltage is calculated in real time during each half-cycle interval.

* The PM3000A determines the maximum deviation in the value of rms voltage, (dmax), at each voltage change.

* The PM3000A determines the value of steady-state voltage change (dc) due to a change in load.

The PM3000A measures the time interval (dt) during which any rms voltage deviation exceeds a prescribed limit.

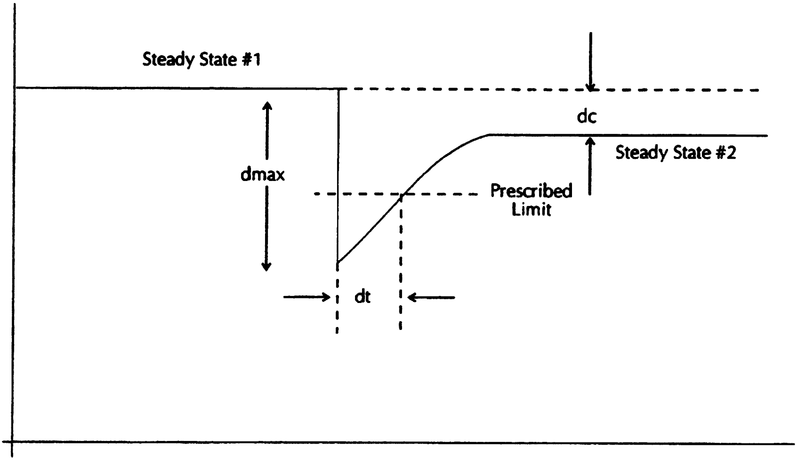


Figure 25

These values are read by the PC at the end of the observation period , and the PC compares these values with the limits.

The PM3000A can make the above measurements using either:

Voltage measurement - full-compliance testing. This requires a physical source impedance and the voltages appearing at the load are analyzed directly.

Current measurement - pre-compliance testing. This method does not require a physical source impedance. The current drawn by the appliance is analyzed, and the PM3000A uses a proprietary technique to compute in real time the voltage drop in the value of source impedance (R,X) entered at the PC by the user.

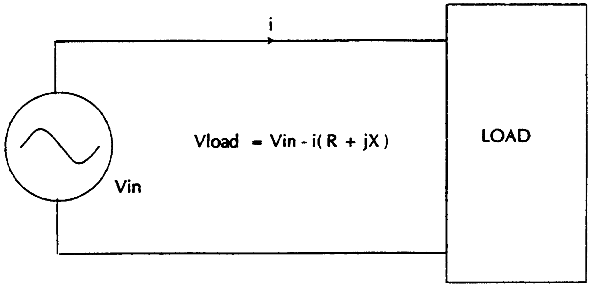


Figure 26

Values for flicker and voltage deviations are calculated from the real time values of load voltage as determined above.

This technique, as well as having the advantage of not requiring a physical source impedance, has been designed to provide the additional benefit of significantly reducing the effect of input voltage variations on the measured results. It can therefore provide excellent results with the regular line supply.

12.1. To test for flicker and voltage deviations by voltage measurements:-

1) Set up for voltage measurements as described in Section 6.4.

2) Install the PC software and set up the PC and PM3000A a described in Section 7.

3) Select 'Flicker' from the menus.

4) Select 'Voltage method' and follow the procedure outlined in th software.

12.2 To test for flicker and voltage deviation by current measurement.

1) Set up for current measurement as described in Section 6.3.

2) Install the PC software and set up the PC and PM3000A a: described in Section 7.

3) Select 'Flicker' from the menus.

4) Select 'Current method' and follow the procedure outlined in the software.

APPENDIX A

Classification of Equipment into Classes A,B,C,D for Harmonic Measurement.

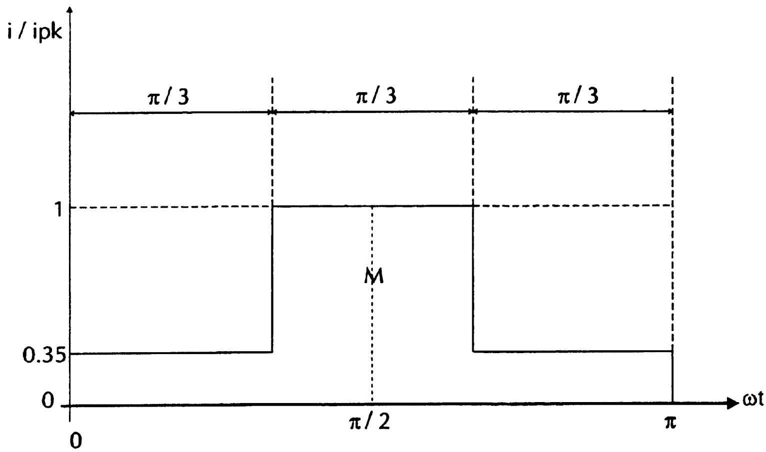
Class A: Balanced three-phase equipment and all other equipment except that stated in one of the following classes.

Class B: Portable tools.

Class C: Lighting equipment including dimming devices.

Class D: Equipment having an input current with a "special waveshape" as defined below and an active power P£600W. Whatever the waveshape of their input current, Class B, Class C, and provisionally motor-driven equipment (with phase angle control) are not considered as Class D equipment.

Note: The exception of motor driven equipment with phase angle control should in future be reconsidered in relation to the effective coincidence factor of motor-driven appliances.



Envelope of the input current to define the "special wave shape" and to classify an equipment into class D.

Figure 27

Equipment shall be deemed to be Class D equipment if the input current wave shape of each half-period referred to its peak value Ipk- is within the envelope as given in the figure above for at least 95% of the duration of each half-period. The centre line, M, coincides with the peak value of the input current. The 95% factor implies those waveforms having small peaks outside the envelope are considered to fall within the envelope.

Equipment can be tested to determine whether it can be classified as class D by testing the equipment according to the procedure in Section 8 of this application note. A flow chart summarising the classification of equipment is shown in figure 28.

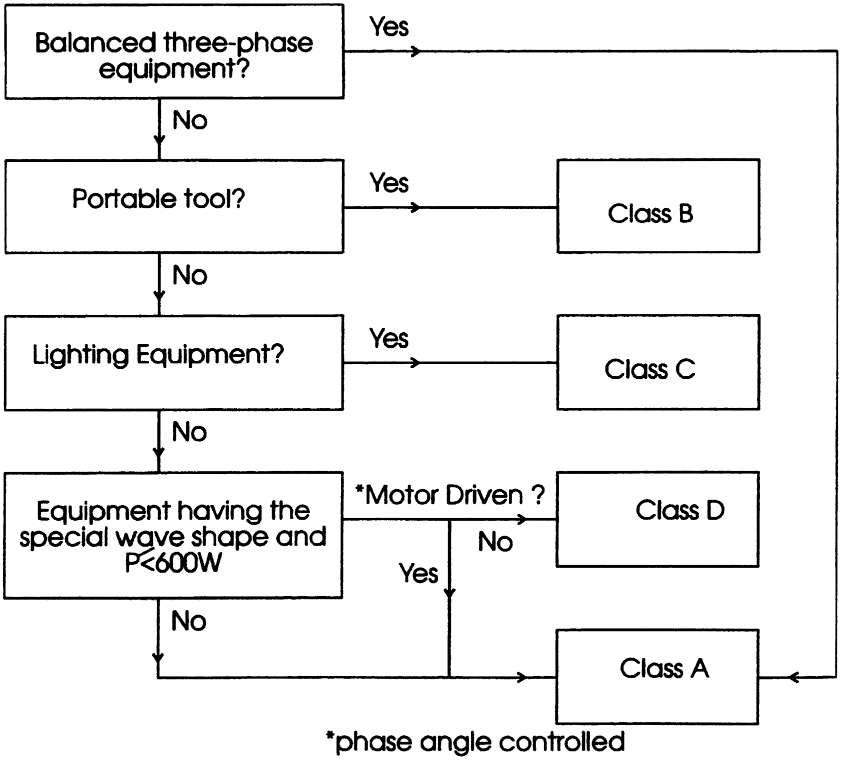


Figure 28 - Flow chart summarizing the Classification of equipment for IEC555 Part 2 (Harmonics).

APPENDIX B

Harmonic Limits for Classes A, B, C, D and Test Conditions.

Limits for class A equipment.

Harmonic order (n)	Maximum permissible harmonic current (A)
Odd harmonics.	
3	2.30
5	1.14
7	0.77
9	0.40
11	0.33
13	0.21
$15 \leq n \leq 39$	$0.15 \times 15/n$
Even harmonics.	
2	1.08
4	0.43
6	0.30
$8 \leq n \leq 40$	$0.23 \times 8/n$

e.g. Harmonic #23

$$Limit = 0.15 \times \frac{15}{23} = 0.098A$$

Limits for Class B equipment.

Class B limits are set at 1.5 × Class A limits:-

Harmonic order (n)	Maximum permissible harmonic current (A)
Odd harmonics.	
3	3.45
5	1.71
7	1.155
9	0.60
11	0.495
13	0.315
$15 \leq n \leq 39$	$0.225 \times 15/n$
Even harmonics	
2	1.62
4	0.645
6	0.45
$8 \leq n \leq 40$	$0.345 \times 8/n$

e.g. Harmonic #34

$$Limit = 0.345 \times \frac{8}{34} = 0.081A.$$

Limits for Class C equipment.

Harmonic order (n)	Maximum value expressed as a percentage of the fundamental input current of luminaires
2	2
3	$30 \times \lambda$
5	10
7	7
9	5
$11 \leq n \leq 39$	3

Where λ = Power Factor (W/VA)

$$e.g.\ PF = 0.63$$
$$H(1) = 0.305A$$

$$Harmonic\ \#3 = 0.305A \times \frac{(30 \times 0.63)}{100} = 57.6mA$$

$$Harmonic\ \#29 = 0.305A \times \frac{3}{100} = 9.15mA$$

Limits for class D equipment.

Harmonic order.	mA / W	Maximum permissible harmonic current A
3	3.4	2.30
5	1.9	1.14
7	1.0	0.77
9	0.5	0.40
11	0.35	0.33
13 and on	Linear extrapolation 3.85/n	See limits for class A equipment.

For example:-

Active input power of a 5V 40A d.c. power supply = 253 watts.
3rd harmonic limit = 253 x 3.4mA = 860.2mA.
15th harmonic limit = 253 x 3.85/15mA = 64.9mA.

Authors notes:-

1) Current IEC documentation suggests that the above Class D limits will be applicable from 1st January 1995 to all equipment having an input power from 75W to 600W. At a later date the limits will apply to equipment having an input

power from 50W to 600W. Until these dates, no limits are applicable, but the author believes that equipment should meet the requirements of Class A at least.

2) In the above table for class D, the harmonic limit is the smaller of the values calculated as 'mA/W', and the value in 'maximum permissible harmonic current'. For example, if

P_{IN} = 600W

15th harmonic from 'mA/W' = 154mA
15th harmonic from 'max permissible' = 150mA

Use 150mA value as limit.

The PC software supplied with the PM3000A takes care of this automatically

3) The Class D limits provide no values for even harmonics. Equipment that draws currents that are symmetrical in positive and negative half cycles will create negligible even harmonics. It is believed that the standard intends for Class D equipment to have this symmetry.

The following is reproduced from IEC document 77A(sec)82.

1 General test conditions

The test conditions for the measurements of harmonic currents are given in the following Clauses. For equipment not mentioned there, user's operation controls or automatic programs shall be set to produce the maximum harmonic components under the normal operating conditions, for each successive harmonic component in turn.

The equipment is tested as presented by the manufacturer. Preliminary operation of motor drives by the manufacturer as long as necessary may be needed before the tests to ensure that results corresponding to those of normal use are obtained.

2 Test conditions for television receivers

2.1 General conditions

Measurement shall include the loading of any auxiliary circuits included in the receiver but exclude the loading of any peripheral equipment powered from the receiver.

2.2 Conditions for measurement

A radio frequency signal modulated in accordance with Sub-clause 2.2.1 shall be supplied by a test generator and the receiver shall be adjusted to display a picture with appropriate settings for brightness, contrast and sound level in accordance with Sub-clause 2.2.2.

2.2.1 The TV receiver is fed by an r.f. TV signal with a level of 65 dB/μV on 75Ω and with the following test modulations:

a) Colour Television

Radio frequency signal: a full TV signal with modulated picture chrominance and sound carrier.

The sound modulation factor is 100% at 1000Hz.
The picture modulation content is a colour bar test pattern with:

100%	reference white level bar,
0%	reference black level bar,
75%	Amplitude (reference made to the white level) and,
100%	saturation

b) Monochrome television

Radio frequency signal: a full TV signal with modulated picture and sound carrier.

Sound modulation: see Item a) above.

The picture modulation is a monochrome test pattern with a black and white level according to Item a) and an average overall picture content of 50% of the reference white level.

2.2.2. The receiver shall be tuned and adjusted according to Clause 37 of IEC publication 107-1: Recommended methods of Measurement on Receivers for Television Broadcast Transmissions, Part 1: General Considerations - Electrical Measurements other than those at audio frequencies.

The white reference level corresponds to 80 cd/m^2 and the black level to less than 2 cd/m^2.

The sound level is set in such a manner that one-eighth of rated output power is obtained, measured at the loudspeaker terminals, at a frequency of 1000Hz.

Note

For devices that operate on base-band signals, a suitable video input signal should be used, and the same setting made for brightness, contrast and sound level.

3 Test Conditions for audio amplifiers

Measurement shall be made under the normal operating condition described in Sub-Clause 4.2.6 of IEC publication 65, 5th edition (1985) and Amendment No.1 May 1987.

4. Test conditions for video cassette recorders

Measurement shall be made on the playback mode with the standard tape speed.

5. Test conditions for lighting equipment.

5.1 General Conditions

Measurements shall be made in a draft-free atmosphere and at an ambient temperature within the range from 20°C to 27°C. During measurement the temperature shall not vary by more than 1K.

5.2 Lamps

Lamps shall be aged for at least 100h at rated voltage. They shall be operated for at least 15 minutes before a series of measurements is made. During ageing and measurement lamps shall be installed as in normal use.

Note - Some lamp types may require a stabilising period exceeding 15 minutes. Corresponding information given in the relevant lamp specification must be observed.

5.3. Luminaires

The luminaire is measured as manufactured. It shall be tested with reference lamps, or with lamps having electrical characteristics close to their nominal values. In case of doubt measurements are made with reference lamps. When the luminaire incorporates more than one lamp, all lamps are connected and operated during the test. When the luminaire is assigned for use with more than one type of lamp, measurements shall be made with all the types and the luminaire shall comply each time. In each case where the luminaire is equipped with a glow starter, a starter in accordance with IEC Publication 155 : "Starters for Tubular Fluorescent Lamps", shall be used.

Incandescent lamp luminaires which do not incorporate an electronic transformer or a dimming device are deemed to fulfil the harmonic current requirements and need not be tested.

If separate tests with reference lamps have proved that ballasts for fluorescent or other discharge lamps or step-down converters for tungsten halogen or other filament lamps comply with the requirements the luminaire is deemed to comply with these requirements and need not be checked. Where these components have not been approved separately or do not comply, the luminaire shall be tested and shall comply.

If a luminaire has a built-in dimming device, the harmonic currents shall be measured with the maximum load of the lamps according to the manufacturer. The setting of the dimming device is varied in 5 equidistant steps between the minimum and the maximum power.

5.4. Ballasts and step-down converters.

Ballast for fluorescent or other discharge lamps or step-down converters for tungsten halogen or other filament lamps shall be tested with reference lamps or with lamps having electrical characteristics close to their nominal values. In case of doubt measurements are made with reference to lamps.

In the case where a ballast can be used with or without a series capacitor or where a ballast or step-down converter is designed for several types of lamps, the manufacturer shall indicate in his catalogue for which type of circuit and lamps the ballast fulfils the harmonic requirements and the ballast shall be tested accordingly.

6. Test conditions for independent dimmers

The independent dimmer is tested with incandescent lamps having the maximum power allowed for the dimmer. The control is set to a firing angle of 90° ± 5°. Dimmers with a maximum power up to and including 600W need not to be tested.

7. Test conditions for vacuum cleaners

The vacuum cleaner is tested in continuous operation with empty dustbag or paper filter, with tube if existing, but without extending pipe or nozzle. The control is set to a firing angle of 90° ± 5° or if controlled by steps to that step closest to 90°.

8. Test conditions for washing machines

The washing machine is tested in the normal 60°C laundry program. It is filled with nominal quantity of cotton clothes, size 70cm × 70cm, dry weight from 140 to 175 g/m^2.

Normally it is sufficient to measure the harmonics during the last rinsing; in case of doubt a full program is tested. Transitory harmonics are measured during a few reversing speed-up operations during the spinning speed-up operation.

9. Test conditions for microwave ovens

The micro-wave oven is tested with 100% nominal power. It is operated with a potable water load of initially (1000 $\pm$ 50) g in a cylindrical borosilicate glass vessel having a material thickness of 3mm and an outside diameter of approximately 190mm. The load is placed at the centre of the shelf.

10 Test conditions for Information Technology Equipment (ITE)

ITE is tested with the equipment configured to its rated current. In this case the equipment, if necessary, may be configured with its power supplies loaded with additional load (resistive) boards to simulate rated current conditions.

For ITE systems designed for use with a manufacturer-supplied power distribution system, i.e. transformers, UPS, power conditioner etc., compliance with the limits of this Standard shall be met at the input to the power distribution system.

11 Test conditions for further equipment

Test conditions for further equipment will be given according to the necessity.

APPENDIX C

Limits for Voltage Changes & Flicker and Test Conditions.

Reference - IEC Document 77A (Central Office) 38 - Revision of IEC Publication 555-3.

Limits.

Tests made to prove the compliance with the limits are considered to be type tests.

The following limits apply:

- The value of Pst shall not be greater than 1.0.
- The value of Plt shall not be greater than 0.65.

  The relative steady state voltage change, dc, shall not exceed 3%.

  The maximum relative voltage change, d_{max}, shall not exceed 4%.
- The value of d(t) during a voltage change shall not exceed 3% for more than 200 ms.

If voltage changes are caused by manual switching or occur less frequently than once per hour, the Pst and Plt requirements shall not be applicable. The three requirements related to voltage changes shall be applicable with the previously mentioned values multiplied by a factor of 1.33.

The limits do not apply to emergency switching or emergency interruptions.

General test conditions.

The test conditions for the measurement of voltage fluctuations and flicker are given in the following clauses. For equipment not mentioned in Annex A, controls or automatic programmes shall be set to produce the most unfavourable sequence of voltage changes using only those combinations of controls and programmes that are mentioned by the manufacturer in the instruction manual, or are otherwise likely to be used. Particular test conditions for equipment not included in Annex A are under consideration.

The equipment shall be tested in the condition in which it is supplied by the manufacturer. Preliminary operation of motor drives may be needed before the tests to ensure that results corresponding to those of the normal use are obtained.

For motors, locked-rotor measurements may be used to determine the largest rms voltage change, dmax, occurring during motor starting.

For equipment having several separately controlled circuits, the following conditions apply:

- Each circuit shall be considered as a single item of equipment if it is intended to be used independently, provided that the controls are not designed to switch at the same instant.

- If the controls of separate circuits shall be designed to switch simultaneously, the group of circuits so controlled are considered as a single item of equipment.

For control systems regulating part of a total load only the voltage fluctuations produced by each variable part of the load alone shall be considered.

Detailed type test conditions for some equipment is given in Annex A:

Annex A

(Normative) Application of limits and type test conditions for specific equipment.

A.1 Test conditions for cookers

For cookers designed for use in domestic premises the evaluation of Plt shall not be required.

The tests of Pst shall be performed at steady state temperature conditions unless otherwise stated.

Each heater shall be tested separately as follows:

A.1.1 Hot plates

Hot plates shall be tested using standard saucepans with diameter, height and water quantity as follows:

Diameter of the hotplate (mm)	Height of the pot (mm)	Quantity of water (g)
145	about 140	1000+/-50
180	about 140	1500+/-50
220	about 120	2000+/-50

Possible losses by evaporation have to be compensated for during the time of measurement.

In all the following tests the hot plate shall comply with the specified limits.

a) Boiling temperature range: Set the control to the position where the water just boils. The test is made 5 times and the mean value of the test results calculated.

b) Frying temperature range: Fill the pot, without a lid, with silicone oil to 1.5 times the quantity of water shown in the table. Set the control to a temperature of 180°C measured by a thermocouple in the geometric centre of the oil.

c) Total range of power settings: The total power range shall be checked continuously during a 10 minute observation period. If control switches have discrete stages, test all stages up to a maximum of 20 stages. If there are no discrete stages divide the total range into 10 equally spaced steps. The measurements shall then be made starting at the highest power stage.

A.1.2 Baking ovens.

The oven shall be tested empty with the door closed. Adjust the control so that a thermocouple fixed in the geometric centre measures a mean temperature of 220°C for conventional ovens and 200°C for hot air ovens.

A.1.3 Grills.

The grill shall be tested empty with the door closed if not otherwise stated by the manufacturer. If a control is available it shall be set to the lowest, medium and highest setting for grilling operation and the worst result recorded.

A.1.4 Baking oven/grill combinations

The oven/grill combination shall be tested empty with the door closed. Adjust the control so that a thermocouple fixed in the geometric centre measures a mean temperature of 250°C or that available temperature closest to this value.

A.1.5 Microwave ovens.

The microwave oven or the microwave function of a combination oven shall be tested at the lowest, medium and a third stage that is the highest adjustable power less than or equal to 90% of the maximum power. Load the oven with a glass bowl containing 1000 ± 50g of water.

A.2 Test conditions for lighting equipment.

Lighting equipment shall be tested with a lamp of that power for which the equipment is rated. If lighting equipment includes more than one lamp, all lamps have to be in use.

Pst and Plt are only evaluated for lighting equipment that is likely to produce flicker, for example, disco lighting.

A.3 Test conditions for washing machines.

The washing machine shall be tested in a complete laundry programme at 60°C filled with the nominal quantity of cotton cloths, size 70cm × 70cm, dry weight from 140 to 175g/m^2.
Neglect simultaneous switching of heater and motor in the evaluation of dc, dmax and d(t).
Pst and Plt shall be evaluated.

A.4 Test conditions for clothes dryers.

The dryer shall be tested with 50% of the nominal quantity of cotton cloths, size 70cm x 70cm, dry weight from 140 to 175 g/m^2 and 100% residual humidity.

If a control of the drying degree is available the test shall be performed at the maximum and minimum settings,
Pst and Plt shall be evaluated.

A.5 Test conditions for refrigerators.

Refrigerators shall be operated continuously with the door closed. Adjust the thermostat to the mid-value of the adjusting range. The cabinet shall be empty and not heated. The measurement shall be made after a steady state has been reached.
Pst and Plt shall not be evaluated.

A.6 Test conditions for copying machines, laser printers and similar appliances.

The appliance is tested for Pst at the maximum rate of copying. The original to be copied/printed is white blank paper and the copy paper should have a weight of $80g/m^2$ if not otherwise stated by the manufacturer.
Obtain the Plt value in the stand-by mode.

A.7 Test conditions for vacuum cleaners.

For vacuum cleaners Pst and Plt shall not be evaluated.

A.8 Test conditions for food mixers.

For food mixers Pst and Plt shall not be evaluated.

A.9 Test conditions for portable tools.

For portable tools Plt shall not be evaluated. For portable tools without heating elements Pst shall not be evaluated. For portable tools with heating elements Pst shall be evaluated as follows:

Switch on the tool and allow to operate continuously for 10 minutes or until it switches off automatically, in which case 6.5 applies.

A.10 Test conditions for hairdryers.

For hand held hairdryers Plt shall not be evaluated. To evaluate Pst switch on the hairdryer and allow to operate continuously for 10 minutes or until it switches off automatically, in which case 6.5 applies.

For hairdryers incorporating a power range, check the total power range continuously during a 10 minute observation period. If control switches have discrete stages all stages shall be tested up to a maximum of 20 stages. If there are no discrete stages divide the total range into 10 equally spaced steps. The measurements shall then be made starting with the highest power stage.

A.11 Test conditions for consumer electronics products (brown goods).

For brown goods, only the dmax test is made.

(Authors note: dmax limit = 4% × 1.33 = 5.32% as manual switching)

A.12 Test conditions for direct water heaters.

For direct water heaters without electronic controls evaluate dc only by switching the heater on and off (sequence 0 - Pmax - 0).

For direct water heaters with electronic controls the output temperature of the water has to be chosen so that by means of the variation of water flow-rate all electric power consumption rates between Pmin and Pmax may be produced. Pmax is defined as the minimum power which can be chosen.

NOTE - For some appliances the maximum power Pmax which can be chosen may be less than the rated power.

The set temperature value shall be kept unchanged during the total test. Starting from the water-flow rate demand for maximum power consumption, Pmax, reduce the rate of flow in 20 approximately equal steps to minimum power consumption, Pmin.

Then, in another 20 approximately equal steps, increase the water flow-rate to power consumption Pmax. For each of these 40 stages the Pst, i value shall be evaluated; the measurements start when the steady state is reached, i.e. about 30 seconds after changing the water flow-rate.

Additionally, the flicker Pst, z caused by switching the heater on and off has to be measured within a ten minute interval. In this interval the power consumption has to be changed twice in the quickest possible way between the stages P = 0 and P = Pmax.
(sequence: 0 - Pmax - 0 - Pmax - 0)

The duty cycle of the heater shall be 50% i.e. Pmax during 5 minutes.

Evaluate the resultant Pst value by:

$$Pst = \left(\mathrm{Pst}_z^{\,3} + \frac{1}{40}\sum_{i=1}^{i=40} Pst_i^{\,3} \right)^{\frac{1}{3}}$$

and compare against the limit value.
Plt shall not be evaluated.

Author's notes:

1. Where the test conditions specify a value shall not be evaluated, it is still necessary to test for all other values specified as limits. For example, if test conditions specify that Pst and Plt shall not be evaluated, then test for dc, dmax and d(t) only).

2. Section 6.5, Extract from IEC555-3 reads as follows:

6.5 Observation period

The observation period, T_p, for the assessment of flicker values by flicker measurement, flicker simulation or analytical method shall be:

for P_{st}, T_p = 10 min
for P_{lt}, T_p = 2 hours (eg 12 consecutive 10 minute intervals)

The observation period shall include that part of the whole operation cycle in which the equipment under test produces the most unfavourable sequence of voltage changes.

For the assessment of P_{st} the cycle of operation shall be repeated continuously unless stated otherwise in Annex A. The minimum time to restart the equipment shall be included in this observation period when testing equipment that stops automatically at the end of a cycle of operation which lasts for less than the observation period.

For P_{lt} assessment the cycle of operation shall not be repeated, unless stated otherwise in Annex A, when testing equipment with a cycle of operation of less than two hours and which is not normally used continuously.

NOTE - For example, in the case of equipment with a cycle of operation lasting 45 minutes, five consecutive P_{st} values will be measured during a total period of 50 minutes, and the remaining seven P_{st} values in the 2 hour observation period will be deemed as zero.

APPENDIX D

IEC555 Specification of A.C. Voltage Sources for Full-Compliance Testing.

The source shall meet the following requirements:

For both Part 2 and Part 3:-

While the measurements are being made, the voltage shall be maintained within +/- 2% of the selected value and the frequency within +/- 0.5% of nominal value.

For Part 2 (Harmonics):-

The internal impedance of the supply source, including that of the measuring equipment, at each frequency at which measurement has to be made, shall be sufficiently low so that the measured harmonic components of the input current do not deviate from the ideal values (obtained with an ideal zero impedance supply source) by more than 5% of the permissible limits.

NOTE:- In some special case, particular care may be necessary to avoid a resonance between the internal inductance of the source and capacitances of the equipment under test.

The harmonic ratios of the voltage(s) supplied by the source (at no load and when supplying a resistive load corresponding to the rated power of the equipment under test) shall remain small in order to avoid influencing the measurements.

The following maximum values are given as a guideline:
0.9% for harmonic of order 3;
0.4% for harmonic of order 5;
0.3% for harmonic of order 7;
0.2% for harmonic of order 9;
0.2% for even harmonics of order from 2 to 10;
0.1% for harmonics of order from 11 to 40.

For Part 3 (Voltage fluctuations)
The percentage total harmonic distortion of the supply shall be less than 3% (Authors note - this will be met if supply source meets the Part 2 specification given above).

Fluctuations of the supply voltage during a test may be neglected if the Pst value (of the supply voltage) is less than 0.4. This condition shall be verified before and after each test.

APPENDIX E

Source Impedance for Measurement of Voltage Changes and for Flicker Measurements.

Three Phase, four wire, 230/400V supplies, 50Hz.

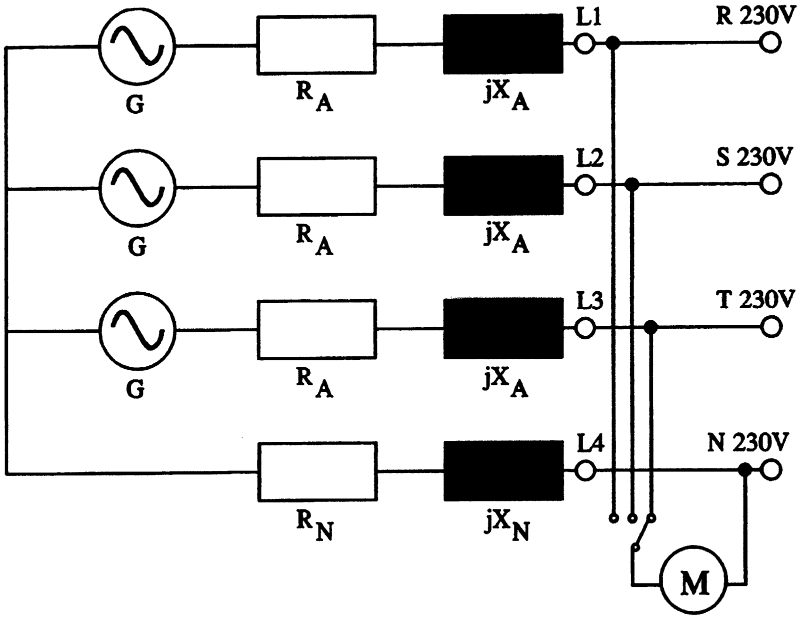


Figure 29

$R_A = 0.24\ \Omega$

$jX_A = j\omega L_A = j0.15\ \Omega$ ($L = 477.5\mu H$ @ 50Hz).

$R_N = 0.16\ \Omega$

$jX_N = j\omega L_N = j0.10\ \Omega$ ($L = 318.3\mu H$ @ 50Hz).

Note - In general, three-phase loads are balanced and Rn and Xn can be neglected as there is no current in the neutral wire. Measurements on a balanced three - phase load can therefore be made as shown with R_N and jX_N equal to zero (eg no impedance)

Single phase, two wire, 230V supplies, 50Hz.

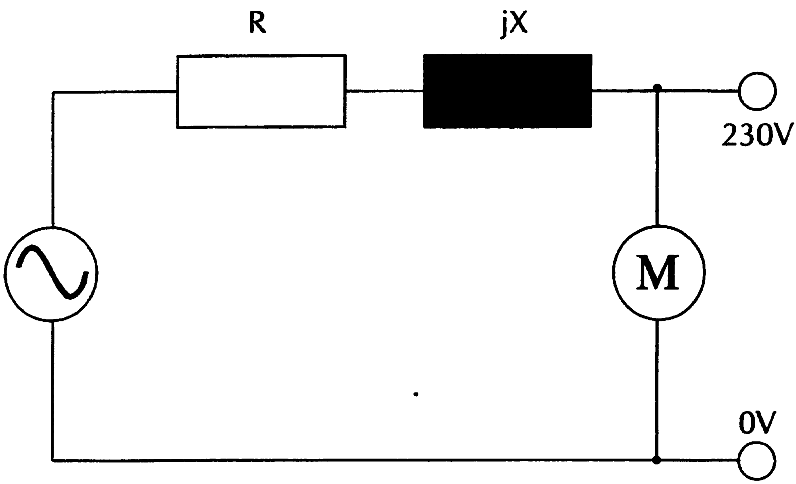


Figure 30

R = Ra + Rn = 0.24 Ω + 0.16 Ω = 0.4 Ω.

jX = jω(La + Ln) = j(0.15 Ω + 0.10 Ω) = j0.25 Ω

(L = 795.8μH @50Hz).

APPENDIX F

Compliant Current Shunts

The PM3000A can make current measurements up to 30A rms with direct connection to its internal shunt (12.5mΩ). The measuring system must not introduce more than 0.15V pk drop in the measuring circuit, entailing that that the 12.5mΩ shunt remains compliant up to approximately 12 Amps peak.

The PM3000A-002 version is available with lower shunt resistance for full compliance measurements to IEC555 Part 2, at all values up to 16 Arms.

The IEC555 Part 2 standard defines a maximum voltage drop across a shunt as 150mVpeak. Maximum compliant peak current, using worst case harmonics within 16Arms, can be calculated as 42.4Apeak. The maximum impedance allowed for full compliance with worst case harmonics, is therefore specified as 3.54mΩ. This is derived as follows:

$$\text{Impedance} = \frac{\text{Vpk}}{\text{Apk}} = \frac{0.15\text{Vpk}}{42.4\text{Apk}} = 3.54\text{m}\Omega$$

The maximum input impedance of the PM3000A (Option 002) is 3.50mΩ.

APPENDIX G

Why Harmonics Cause Poor Input Power Factor.

The power factor of an a.c. system is defined as the ratio W/VA, where W is the real power drawn by the system, and VA is the apparent power (Vrms × Arms).

In Section 3.1, it was shown that a distorted current waveform consists of a fundamental component of current plus a series of harmonic currents. Using Fourier analysis, a distorted current waveform f(t) can be expressed as:

$$A1 \sin \omega t + B1 \cos \omega t \quad \text{(Fundamental component)}$$
$$A2 \sin 2\omega t + B2 \cos 2\omega t \quad \text{(2nd harmonic)}$$
$$A3 \sin 3\omega t + B3 \cos 3\omega t \quad \text{(3rd harmonic).}$$

etc..

Where An and Bn represent the magnitude of the in-phase and the quadrature components of current harmonic n.

Note - The magnitude of harmonic n is given by:

$$Mn = (An^2 + Bn^2)^{1/2}$$

The rms current of the distorted waveform is due to ALL the frequency components in the waveform:-

$$e.g.\ Arms = (A1^2 + B1^2 + A2^2 + B2^2 + A3^2 + B3^2 \ldots\ldots)^{1/2}$$

The harmonic currents therefore increase the rms current of the system, and as VA = Vrms × Arms, the harmonic currents increase the apparent power in the system.

The real power (W) supplied by a system is the average of the product of the supply voltage and the current. e.g.

$$W = \frac{1}{2\pi}\int_0^{2\pi} V \times I$$

As the supply voltage is essentially sinusoidal, the power due to each component of current in the distorted wave form can be expressed as:

$$\begin{aligned}
\textit{Real power} &= \frac{1}{2\pi}\int_0^{2\pi} V\sin\omega t \times A1\sin\omega t = \frac{VA1}{2} \\
&+ \frac{1}{2\pi}\int_0^{2\pi} V\sin\omega t \times B1\sin\omega t = 0
\end{aligned} \Bigg]\ \textit{Fundamental power}$$

$$\begin{aligned}
&+ \frac{1}{2\pi}\int_0^{2\pi} V\sin\omega t \times A2\sin 2\omega t = 0 \\
&+ \frac{1}{2\pi}\int_0^{2\pi} V\sin\omega t \times B2\sin 2\omega t = 0
\end{aligned} \Bigg]\ \textit{2nd}\text{ harmonic } \textit{power}$$

$$+ \ldots \text{etc} \qquad]\ \textit{etc}\ldots$$

When these expressions are evaluated, it is seen that only the fundamental component of current that is in phase with the supply voltage is capable of transmitting real power. The quadrature component of fundamental current cannot transmit any power, and neither can the in phase or the quadrature components of any harmonic currents.

As the rms current is due to all the components in the current wave form, it can be seen that the VA of the system is increased, (but the power is not) if the current contains any of those components that do not transmit useful power. It follows therefore that the power factor (W/VA) is decreased if:

1) The fundamental component of current is not in-phase with the fundamental voltage.

and/or

2) The current contains any harmonic components.

The 'ideal' current drawn by equipment is therefore a sinusoidal current in-phase with the supply voltage.

APPENDIX H

Why The PM3000A Is Ideal For Testing To IEC555.

1) The instruments have been designed with the requirement to measure to IEC555 in mind - they are not general purpose instruments that have been adapted at some later stage to meet this requirement.

2) Harmonics are measured using a DFT (Discrete Fourier Transform) with a rectangular window of 16 cycles of the fundamental frequency, and an integral number of cycles. This is the technique being considered by IEC for a 'reference' instrument for harmonic measurement. The sample rate is synchronised to the fundamental frequency, as specified by the standard, and anti-alias filters provide the required degree of attenuation.

   Some measuring systems use an FFT (Fast Fourier Transform) for measuring harmonics. This technique generally requires using a binary number of samples (e.g. 256, 1024) within the measuring interval and this can make it very difficult to ensure that the sample rate is exactly synchronised to the required number of fundamental cycles. If strict synchronisation is not achieved then higher order harmonics will give misleading results. The rectangular window, DFT technique and synchronisation employed by the PM3000A avoids this problem.

3) The standard specifies that for harmonic measurement, the total error of measuring equipment shall not exceed 5% of the permissible limits or 0.2% of the rated current of the tested equipment, whichever is greater (77A (Sec) 82). In fact, the accuracy of the PM3000A is much better than the 0.2% limit, and the accuracy requirements are therefore met for all classes of harmonics (Class A,B,C and D).

4) Most power analyzers cannot analyze for fluctuating harmonics at all. The PM3000A can analyze for fluctuating harmonics, and can analyze for 40 harmonics at once, in real time, with no gap between windows, as required by the standard. By simultaneously measuring Watts, class D limits are automatically adjusted in real time during the course of measurement according to the real power. This provides accurate results for all harmonics in the shortest possible measurement time. Instruments such as selective receivers can only analyze for one harmonic at a time, so measurement with such instruments is very time consuming.

5) The PM3000A is unique in that, besides being a general purpose power analyzer for steady state and fluctuating harmonics, it can also perform measurements of voltage changes and flicker. Voltage changes are measured using the power measurement technique (Ip and Iq) as specified in IEC555. This technique is applicable to loads with both high and low harmonic distortion of the current, as described in the standard. Flicker is measured using the filters and statistical

analysis techniques prescribed in the standard. In addition the PM3000A does not require the user to estimate and set the level of flickermeter range, as this is often difficult to do, and can measure voltage deviations which a flickermeter cannot.

6) The PM3000A can be used as a stand-alone instrument for pre-compliance checking of the equipment to IEC555. It does not require a stabilised a.c. source, or a source impedance. If full-compliance testing is required then the PM3000A can be used with the accessories available. The PM3000A also has the capability to measure and present the voltage harmonics of the a.c. source applied during conformance measurement to IEC555 Part 2, thus allowing source conformance checking to Annex A of the standard.

7) The PM3000A-002, with special low impedance current shunts (See Appendix F), provides a full compliance measurement solution for all conditions specified in the standard. It is a requirement of the standard that a measuring instrument be capable of continuous analysis while maintaining harmonic accuracy. This is achieved in the PM3000A-002 by using a single shunt for each channel and using fixed ranging. In this way, there is no shunt or range switching and full accuracy is maintained even though the current may vary considerably during a test. There are no gaps in the analysis.

8) The PM3000A is supplied complete with PC software that takes the user through all the steps required so that the IEC555

testing can be carried out quickly and automatically. As well as presenting simple pass/fail results, the software provides detailed numerical and graphical information. Results can be studied at any time after a test, and clearly printed to maintain a technical file. Diagnostic tools (for example reviewing fluctuating harmonics against time) are provided to assist equipment designers determine the causes of test failures.

9) Voltech pursue a policy of software update to all our customers. This ensures that customers are kept up to date with all further revisions for the IEC and other standards and with all additional features that may be required by future versions of standards, that can be incorporated in the product.

10) When making any measurement it is important to have confidence that the results are reliable and accurate. The Voltech PM3000A-002 is the only power analyzer available with independent certification that it meets the accuracy requirements of IEC555. The National Physical Laboratory (the UK standards authority) certified that the harmonic and flicker accuracy of a PM3000A-002 is as specified by IEC555. Flicker accuracy was confirmed by using both sine and square wave amplitude modulated waveforms as defined by IEC868. Testing with both types of modulation is required to prove that all the filters and analysis of a flickermeter have been correctly implemented.

* For further information on any of the above areas, please contact your local Voltech distributor.

APPENDIX J

PM3000A Accuracy and IEC 555

IEC555 Appendix B "Requirements for Measurement Equipment" specifies that "**the total error of the measurement equipment ... shall not exceed 5% of the permissible limits or 0.2% of the rated current of the tested equipment whichever is greater.**"

It will be shown that the harmonic measurement accuracy of the PM3000A will always be equal to or better than the 0.2% rated current requirement.

Take, for example, some Class A equipment being operated at a rated 16A, 50Hz. The maximum permissible 3rd harmonic current is 2.30 Amps (see Appendix B) The maximum allowed measurement error is thus the greater of

5.0% of 2.3A = 115mA and 0.2 % of 16A = 32mA
or **maximum allowed error = 115 mA.**

Harmonic accuracy of the PM3000A is specified as

$\pm$ (0.1 $\pm$0.05%/kHz)% **of fundamental,** where the accuracy of the fundamental is

$$\pm 0.1\%\text{reading} \pm 0.1\%\text{range} \pm 0.05\%/\text{khz} \pm 1\text{mA}$$

For a 16A RMS input the PM3000A will be on its 50A (peak) range. The accuracy of the PM3000A fundamental measurement will be:

$$16\text{A} \pm(0.001 \times 16) \pm(0.001 \times 50) \pm(0.0005 \times 0.05) \pm(1\text{mA})$$

or Fundamental Measurement = **16A ±67mA**

Note that 16A has been used as a magnitude for the fundamental in the above calculation. This is a worst case figure which would be considerably smaller for a waveform with high harmonic content.

The accuracy of the 3rd harmonic measurement will be

$$\pm\ (0.1 \pm (0.05 \times 0.15\text{kHz}))\%\ \text{of}\ (16\text{A} \pm 67\text{mA})$$

or ± 0.1075% of (16A ±67mA).

i.e. the **3rd harmonic measurement accuracy is better than**

± **17.27 mA**, well within the 115mA allowed error.

Notice how the harmonic accuracy term dominates. Even though the fundamental current is possibly inaccurate by 67mA the 3rd harmonic current is measured to an accuracy of ± 17.30mA. Some further results are tabulated below, and it can be seen that even at the 40th harmonic of 50Hz the PM3000A harmonic error of

$\pm$ (0.1 $\pm$0.05 $\times$ 2.0kHz)% or $\pm$ **0.20% of fundamental**

will always be equal to or better than the 0.2% rated current IEC555 measurement accuracy limit.

IEC555 required measurement accuracy vs PM3000A (in mA)

1) 16A Direct Measurement

Harmonic	Class A limit (A)	5% of limit	0.2% rated current	Allowed Err.	PM3000A Max Err.
3	2.3	115.0	32	115.0	17
5	1.1	57.0	32	57.0	18
7	0.8	38.5	32	38.5	19
13	0.2	10.5	32	32.0	21
40	0.05	2.3	32	32.0	32

2) Class D for 253W (input)
2.10 Arms Power Factor = 0.502

Harmonic	Class D limit (mA)	5% of limit	0.2% rated current	Allowed Err.	PM3000A Max Err.
3	860.2	43.0	4.2	43.0	2
5	480.7	24.0	4.2	24.0	2
7	253.0	12.7	4.2	12.7	2
13	74.9	3.7	4.2	4.2	3
39	25.0	1.2	4.2	4.2	4

Maximum allowed error is whichever is the greater of these 2 columns. vs Maximum PM3000A error.

Sales and Support Offices

POWER ANALYZER SALES AND SUPPORT OFFICES

AUSTRALIA

Westinghouse Industrial Products
Tel: (61)-3391-1300
Fax: (61)-3391-6607

AUSTRIA

Kiepe Electric GmbH
Tel: (43)-1-33127
Fax: (43)-1-33127-270

BELGIUM

Air-Parts Electronics
Tel: (32)-2-241-6460
Fax: (32)-2-241-8130

CANADA

Tektronix Canada Inc
Tel: (1)-416-747-5000
Fax: (1)-416-747-9799

SCANDINAVIA

Powerlab
Tel: (45)-4248-4344
Fax: (45)-4248-0038

FRANCE

Kontron
Tel: (33)-1-3070-2727
Fax: (33)-1-3070-2700

GERMANY

Nucletron GmbH
Tel: (49)-89-1490-0274
Fax: (49)-89-1490-0211

HOLLAND

Air-Parts BV
Tel: (31)-1720-43221
Fax: (31)-1720-20651

HONG KONG & CHINA

Asian Automation Associates
Tel: (852)-788-5311
Fax: (852)-788-5314

INDIA

Four-C-Tron
Tel: (91)-812-572506
Fax: (91)-812-568392

ISRAEL

Emdo Representatives Ltd
Tel: (972)-3-497571
Fax: (972)-3-497572

ITALY

Insitec Elettronica
Tel: (39)-2-665-03003
Fax: (39)-2-665-01096

JAPAN

Monte Systems Corp.
Tel: (813)-3827-0956
Fax: (813)-3827-0957

KOREA

Newtronix Company Ltd
Tel: (82)-2652-4663
Fax: (82)-2652-4662

NEW ZEALAND

Wheeler Instruments Ltd
Tel: (64)-4-528-8658
Fax: (64)-4-527-8925

POLAND

Poray
Tel: (48)-71-442923
Fax: (48)-71-444739

SINGAPORE & MALAYSIA

Evox Singapore Pte Ltd
Tel: (65)-2739900
Fax: (65)-2739049

SOUTH AFRICA

BSW Channels PTY Ltd
Tel: (27)-11-315-0610
Fax: (27)-11-805-2148

SWITZERLAND

Mesomatic Ag
Tel: (41)-1-492-8880
Fax: (41)-1-492-7706

TAIWAN

Chinatech Corporation
Tel: (886)-2-9121510
Fax: (886)-2-9126641

UK

Voltech Ltd
Tel: (44)-1235-861173
Fax: (44)-1235-861174

USA

Voltech Inc
Tel: (1)-508-881-7329
Fax: (1)-508-879-8669