Insights and best practice

EMC COMPLIANCE KNOW-HOW

TECHNICAL NOTE 0112

CHANGES TO IEC 61000-3-2 AMD1 ED5

HARMONICS CURRENT EMISSIONS

This Technical Note summarises the changes detailed in the recently published IEC Amendment 1 to the IEC 61000-3-2 standard. It provides an overview for product design teams and test engineers, of the most relevant changes to the standard, and discusses the differences to the previous version of the standard and the impact on compliance testing.

The most relevant changes are discussed, these include:

Fixed lambda factors for Class C devices
A new method for POHC calculations
Clarification of the conditions for multi-function devices
More precise definitions for repeatability

The document is designed to accompany a video recording of a live webinar presented by Thomas Handschin. You will find a timestamp on each page of this document which corresponds to the relevant part of the video presentation.

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You can view the **recording here**

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TIMELINE

1995-03
Edition 1 | - IEC 61000-3-2:1995

2014-05
Edition 4 | IEC 61000-3-2:2014

2018-01
Edition 5 | IEC 61000-3-2:2018

2020-07
Edition 5.1 | IEC 61000-3-2:2018/AMD1:2020

The amendment 1 is the newest addition to the IEC 61000-3-2 standard.

The story began in 1995 with the edition one. In 2014 with edition 4 a number of important changes were introduced, namely to the measurement methods.

Edition 5 from 2018 is the so called "lighting edition" which added changes that reflected the technical advance for this industry, namely the widely used LED technology.

Edition 5.1 then was published in July 2020 with corrections and clarifications to edition 5. The stability date is until 2023, where the next major rework for this standard is planned.

OVERVIEW OF CHANGES

- Rework and detailing of definitions, test conditions and limits for lighting equipment (removal lambda factor)
- Introduction of "multifunction equipment" with definitions and clarifications
- Revision of "control methods"
- Added test conditions for external power supplies (EPS)
- Clarifications for the allowed POHC calculation methods
- Editorial changes, i.e. spelling and numbering

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CLASS C CHANGE – THE LAMBDA FACTOR

- Modern lighting equipment (based on LEDs) use active PFC
- Typical Power Factor is > 0.9
- 3rd harmonic: 0.9 x 30 = 27 %
- Simplifies the measurement

Table 2 – Limits for Class C equipment [a]

Harmonic order *h*	Maximum permissible harmonic current expressed as a percentage of the input current at the fundamental frequency %
2	2
3	~~30 · λ~~ 27 [b]
5	10
7	7
9	5
11 ≤ *h* ≤ 39 (odd harmonics only)	3

[a] For some Class C products, other emission limits apply (see 7.4).

[b] ~~λ is the circuit power factor.~~ The limit is determined based on the assumption of modern lighting technologies having power factors of 0,90 or higher.

Class C, which applies for lighting equipment, has several sub-classes with different requirements and limits. For devices with more than 25W the limits are given in Table 2. This table defines values for the individual harmonic currents. For the 3rd harmonic, the limit depended on the power factor of the device. A higher power factor would have higher limits and a lower power factor lower limits. This was introduced when mainly incandescent or fluorescent lamps existed.

Today most of the lighting equipment is based on LED technology. These lamps include electronic circuits to drive the LEDs. To be efficient, most of them have active power factor control functions implemented. Because of this, the power factor of modern and efficient lighting equipment has a power factor that is bigger than 0.9.

Therefore the IEC working group has agreed on fixing the limit for the 3rd harmonic to 27% of the fundamental current. This corresponds to a power factor of 0.9 according the old rule. With this change, all the limits have a fixed value. Therefore it is not required to measure the power factor during a test for IEC 61000-3-2. Nevertheless, most of the harmonic analyzers measure the power factor anyway since it is an essential value to be determined for a lighting equipment.

The IEC working group has added a note b) that says, that the assumption was that all lighting equipment has a power factor above 0.9. This leaves the door open to change this in the future again, in case there is another technology or method in lighting equipment that has again lower power factors.

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SATURATED AND P1DB POWER PERFORMANCE

P	600W
U	230V
I_{fund}	200mA
PF	0.95

	EDITION 5		EDITION 5.1	
h	%	mA	%	mA
2	2%	4	2%	4
3	29%	57	27%	54
4				
5	10%	20	10%	20
6				
7	7%	14	7%	14
8				
9	5%	10	5%	10
10				
11	3%	6	3%	6

Here is an example that shows the differences between the two limits. It is based on the assumption of a 600W lighting equipment with a fundamental current of 200mA and a power factor of 0.95.

The middle column shows the limits according edition 5. There the limit for the 3rd harmonic is calculated with 0.95 x 30 = 28.5mA.

The third column shows the now fixed limits according edition 5.1. *Note: the limits are give in % of the fundamental current.* As it can be seen, the differences are very small for this example. The limit of 27% is a compromise. This means that not for all of the equipment it is a benefit. If, for example, the device has a power factor of 1, the limit would have been 30mA whereas now it is reduced to 27mA.

On the other hand, equipment with older technology with lower power factors would benefit from this new limit. But it is assumed, that the dominant technology is based on modern power electronics with higher power factors.

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PARTIAL ODD HARMONIC CURRENT – WHAT IS IT?

$$POHC = \sqrt{\sum_{h=21,23}^{39} I_h^2}$$

Another change in edition 5.1 is related to the POHC – partial odd harmonic current. The POHC essentially summarizes the higher odd harmonic currents into one measurement value. It is similar to the THC – total harmonic current – which summarized all of the harmonics into one value. The POHC considers all odd harmonic currents from the 21st up to the 39th harmonic.

The mathematical expression can be seen on the right hand side of the graph above. It is the square root of the sum of the squared individual harmonics – so the RMS value of it.

The concept of the POHC was introduced to give more flexibility to the equipment manufacturers. It allows to have some higher odd harmonic currents and compensate them by others that have lower values. It attempts to define the total energy that the odd harmonic currents can have.

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PARTIAL ODD HARMONIC – WHERE IS IT USED?

- **Values per time window**
  - < 150% of limits, or
  - < 200% of limits if
    - Class A device
    - Average is < 90%
    - Excursion beyond 150% lasts less than 10% of the observation time
- **Average values**
  - < 100% of limits, or
  - POHC < 100% of limits and individual harmonics < 150% and other harmonics <100

Where is the POHC used?

As a reminder, there are two values that matter for harmonic current emissions. These are the values per time window and the average values.

The IEC 61000-3-2 measurement method (defined in IEC 61000-4-7) chunks the waveform into 200ms time windows. The value for each time window needs to be within certain limits. IEC 61000-3-2 defines two cases:

All of the values have to be within 150% of the limits defined

All of the values have to be within 200% of the limits if certain conditions are met. This condition was mainly introduced for washing machines. These have very long cycles with very different behaviour. At the beginning there is the pumping of the water, then turning, then heating, then waiting, then spinning etc. This exception allows the washing machines to generate higher current harmonics during the spinning phase but this has to be "compensated" by having less harmonic currents in the rest of the time.

The average values are calculated over the complete testing time. Here each individual harmonic has to be within 100% of the limits. The POHC comes with the second option into play. The standard allows some higher individual odd harmonic currents above 21st when the POHC is within the 100% limits. For the other harmonics not considered in the POHC, the 100% rule applies.

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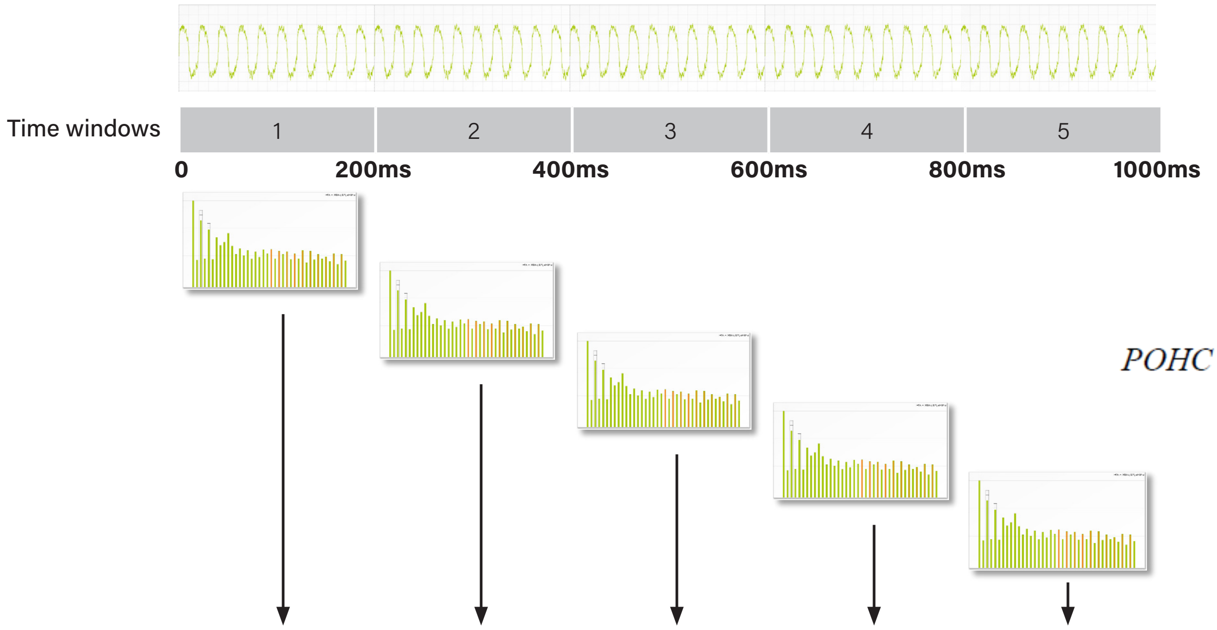
POHC CALCULATION – WITH AVERAGE VALUES (CLAUSE C2)



$$POHC = \sqrt{\sum_{h=21,23}^{39} I_h^2}$$

H	1	2	3	4	5		Average
21	9	10	9	8	11		9.4
23	7	8	6	5	6	→	5.4
...	...	...	...	...	...		...
39	2	3	1	2	3		2.2

POHC

IEC 61000-3-2 edition 5 had the POHC formula already included. But it had not specified the exact method for the calculation. This led to discussion in the IEC working group about the correct method: if the POHC had to be calculated for each individual time window, only for the average values or even some other – not yet considered – method.

Annex C now defines two methods for the calculation. One is based on the average values and the other on each time window.

We'll first a look at the method based on the average value. Here an example of a 1s current measurement. It is divided into 200ms time window. For the first time window, the individual harmonic current are calculated (using a fast fourier transformation). This gives individual values for each of the odd harmonic currents between the 21st and 39th harmonic.

It is the same for the second time window. And so on for all five windows. At the end of the 1s measurement time, the average value for each harmonic order is calculated. This follows the IEC 61000-4-7 method, here only a simplified example is shown. What we get is the average values of all odd harmonic currents. With these, the POHC is calculated with the formula shown before.

The advantage of this method is, that it can be easily calculated based on the average value – for example from an existing test report. The disadvantage is, that the POHC can only be calculated when all the measurement is done. In case of the washing machine example, this would mean that one had to wait for 2h until the complete washing cycle has finished only to find out that the POHC is out of limits.

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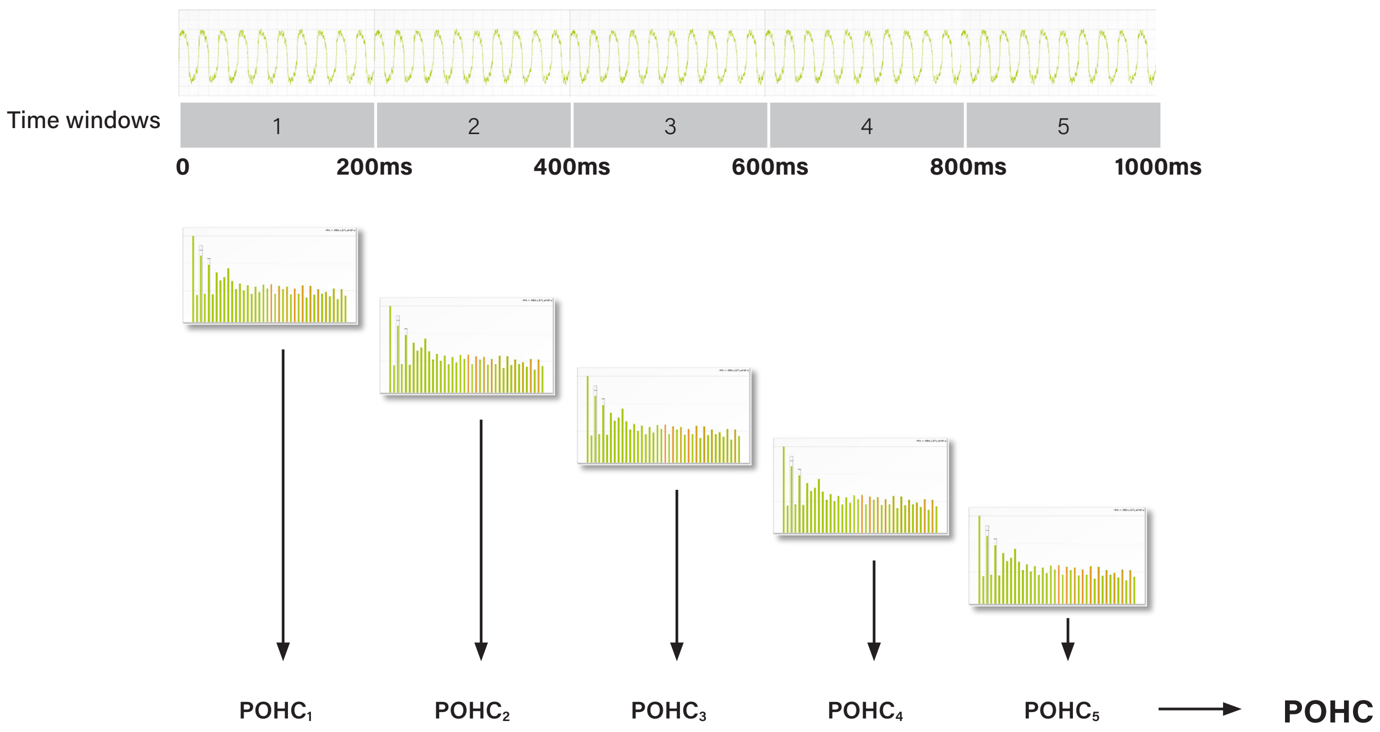
POHC CALCULATION – PER TIME WINDOW (CLAUSE C3)



The second method is based on a POHC calculation by time window. Again we have the same measurement of a 1s length. For the first time window of 200ms, the FFT is performed and gives each individual harmonic current including the odd harmonic currents above the 21st harmonic. Now the POHC is calculated for this time window one.

This is done for all the time window, so we get one POHC value per time window.

Now the average POHC is calculated with the time window POHC values. This again follows the method defined in IEC 61000-4-7 for the average method which includes some smoothing and averaging.

The advantage of this method is that at any time during the measurement, the average POHC can be calculated. This allows visibility of the POHC during the measurement time and provides the possibility to react if necessary.

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COMPARISON POHC METHODS

	POHC [A]		
	Average	**Per time window**	**Difference**
Test Case 1	0.019291	0.019353	-0.32%
Test Case 2	0.019896	0.020012	-0.58%
Test Case 3	0.012590	0.012604	-0.11%
Test Case 4	0.004255	0.004277	-0.51%
Test Case 5	0.256361	0.256730	-0.14%

Conclusion

- Both methods give very similar results
- Both methods are allowed in edition 5.1
- Method “per time window” will remain in future editions

One of the discussion points within the working group was, if the two methods would give different results. If so, which method would have been the correct method. Therefore a series of measurements was performed to verify this.

There were five test cases measured that had different characteristics, i.e. stable vs. fluctuating harmonics, pass vs. fail, etc.

The results of the two methods are shown in the table. For all of the cases, the differences were very small – most even down in the measurement error of the harmonic analyzer.

The conclusion therefore is:

> Both methods give very similar results. The differences are well below the measurement accuracy of typical devices and play no role in the pass/fail decision.
> Therefore the IEC WG allowed in edition 5.1 both methods.
>
> > The method C3 based on the time windows is the preferred method.
> > The method C2 based on average values will be removed in one of the next editions.
> > It is allowed during the transition time because it can be used for measurements performed earlier and where only the test report with the final values is available.

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REPEATABILITY & OBSERVATION PERIOD

6.3.3.1 Repeatability

The repeatability (see 3.15) of the average value for the individual harmonic currents over the entire test observation period ~~shall~~ should be better than ±5 % of the applicable limit, when the following conditions are met:

– the same equipment under test (EUT) (not another of the same type, ~~however similar~~ but the exact same specimen);
– the same test system;
– the same location;
– identical test conditions;
– identical climatic conditions, if relevant.

This repeatability ~~requirement~~ recommendation serves the purpose of defining the necessary observation period~~,~~ (see 6.3.4)~~. It is~~, but not ~~intended to serve~~ as a pass/fail criterion for the assessment of compliance with the requirements of this document.

Table 4 – Test observation period

Type of equipment behaviour	Observation period
Quasi-stationary	T_{obs} of sufficient duration, so that it can be expected to meet the ~~requirements~~ recommendations for repeatability in 6.3.3.1
Short cyclic (T_{cycle} ≤ 2,5 min)	T_{obs} ≥ 10 cycles (reference method) or T_{obs} of sufficient duration or synchronization, so that it can be expected to meet the ~~requirements~~ recommendations for repeatability in 6.3.3.1 [a]
Random	T_{obs} of sufficient duration, so that it can be expected to meet the ~~requirements~~ recommendations for repeatability in 6.3.3.1
Long cyclic (T_{cycle} > 2,5 min)	Full equipment program cycle (reference method) or a representative 2,5 min period ~~considered by the manufacturer as~~ expected to be the operating period with the highest *THC*

[a] 'Synchronization' means that the total observation period is sufficiently close to including an exact integral number of equipment cycles such that the ~~requirements~~ recommendations for repeatability in 6.3.3.1 are met.

- Recommendation, not a requirement
- Chose the appropriate observation period based on EUT behaviour

Edition 5.1 also clarifies again the repeatability and test observation period. In the recent years, this has led to continuous discussion with users of harmonic emission test equipment which wanted to determine the repeatability of the measurement. In this edition it is now made clear, that repeatability and observation time is not a requirement but a recommendation. It is not considered in the pass or fail decision for a device. Therefore there is not need to measure it.

The observation period defines the time of the measurement depending on the behavior of the device. Some examples:

A device that is constantly running, i.e. a lamp or a PC, is a quasi-stationary type. The harmonic currents remain more or less stable over time. Here a very short measurement time of i.e. 30s can be used.

Devices with long cycles, i.e. a washing machine, are considered to be long cyclic and therefore the harmonic measurement must be performed over the full length of the cycle.

No proof needs to be delivered about the repeatability. Therefore there is no need to perform several tests of the same device.

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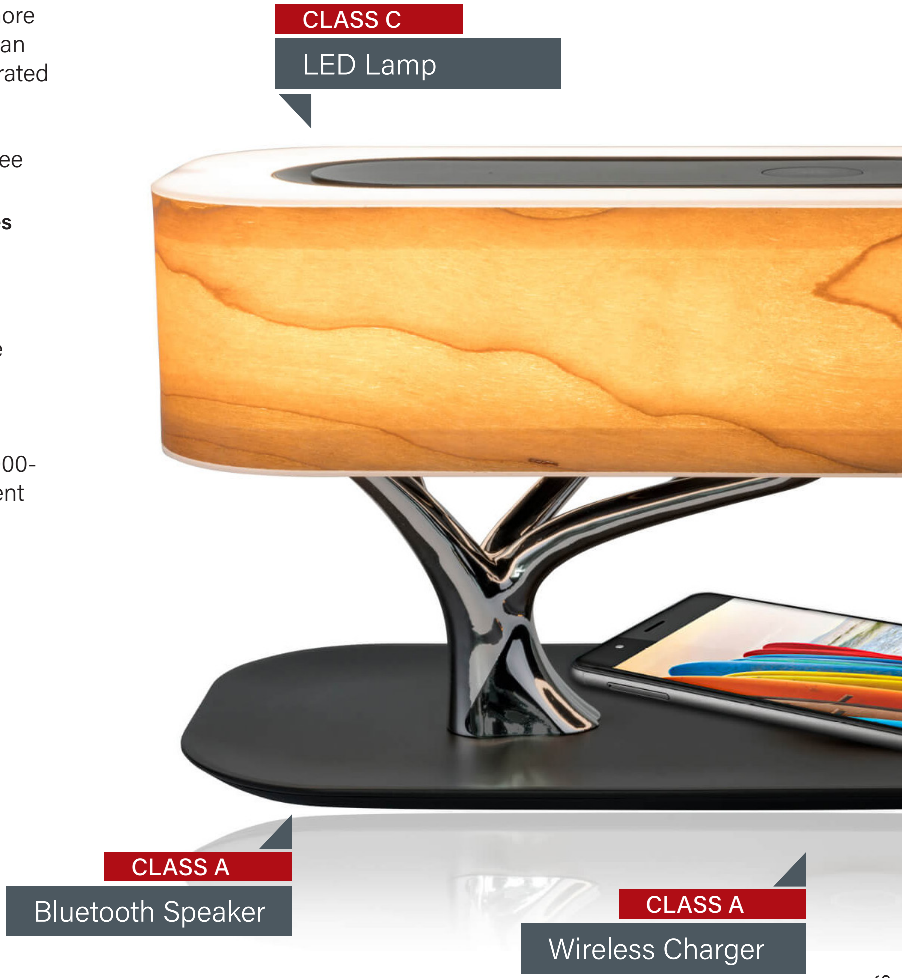
MULTIFUNCTION EQUIPMENT

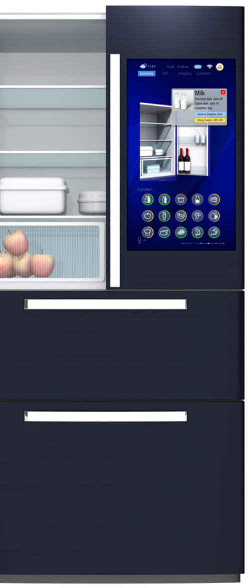
The next change that comes with edition 5.1 is related to multifunction equipment. Today more and more electronic equipment has more than one function. Washing machines have integrated Bluetooth, fridges integrated TVs, etc.

Here is an example of a lamp. It includes three main functions:

- **It has a wireless charger for mobile phones**
- **It has integrated Bluetooth speakers**
- **And eventually it is also a lamp**

What is nice from a personal use experience is more difficult from a compliance test perspective. To which class such a device belongs to? Wireless charger and Bluetooth speakers are Class A devices as per IEC 61000-3-2. And the LED lamp is a lighting equipment and therefore considered Class C.





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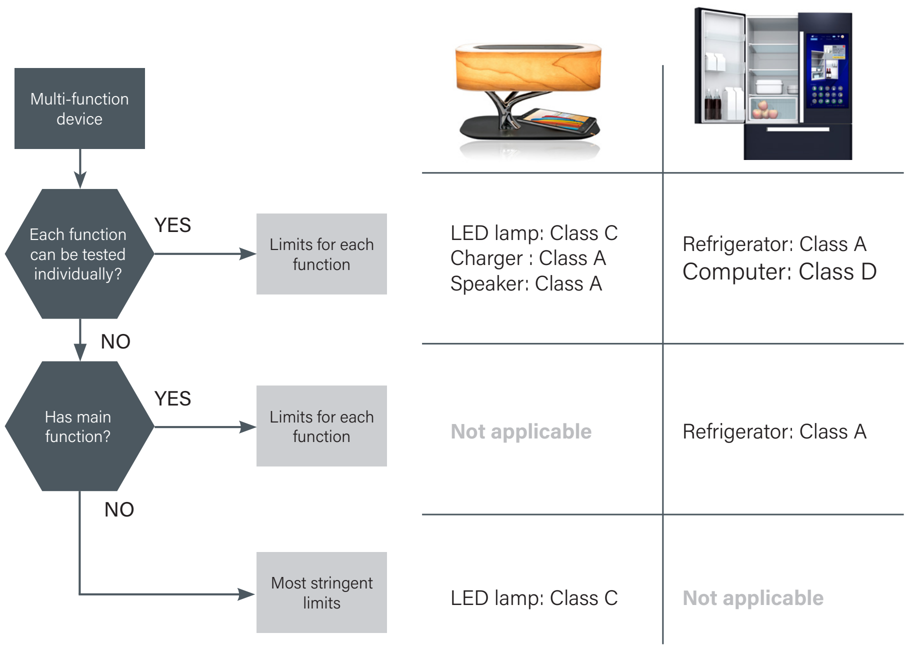
MULTIFUNCTION EQUIPMENT – TESTING OPTIONS



The working group has defined the following rules that apply to multifunction equipment.

a) Test each individual function stand-alone > needs to comply to the requirements for the Class
b) Operating all the functions at the same time > need to comply with the most stringent limits
c) If one of the functions I the main functions compared to the others > limits for the main function apply

Here are two examples that should clarify these rules.

The multifunction lamp can be tested in two way. Either each of the function is tested individually in case each can be enabled individually. So the lamp is tested according Class C and the charger and speaker according Class A. The lamp must fulfil all of the requirements for all functions. Or, second possibility, all of the functions are used at the same time. Then the most stringent limits are applied, in this case this would be Class C for lighting.

In case of the fridge with the integrated computer, each of the functions can be tested individually. So Class A for the fridge and Class D for the computer. Or it is determined that the main function of this device is cooling (and it uses most of the energy), then the complete device can be tested according class A with both of the functions running (cooling and computer on).

You may ask now: how do I determine if it has a main function and which one it is? Good question that cannot be clearly answered. In the case of the fridge it is more obvious since the cooling uses much more energy and is constantly used, whereas the computer uses less energy and is not always used (I don't think that the family will spend their evenings watching movies in front of the fridge).

But in case of the lamp it is less clear. Probably the charging function and the lamp are equally often used whereas the speaker has a higher power consumption (depending on the size). If it is not clear, there are still two options. Since Class C for the complete device with all functions on will be hard to fulfil, the manufacturer will opt for testing each function individually. And make sure that it can be switched on and off individually.

I expect that there will be some clarification required in one of the next revisions to make more clear when each of the options can or shall be used.

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EXTERNAL POWER SUPPLIES (EPS)

Definition

3.29
external power supply
EPS
equipment which converts power supplied by the mains into power at a different voltage, which has its own physical enclosure, and which is intended for use with separate equipment that constitutes the load

EPS **designated** for specific models of equipment

- Shall be tested together with the specific models of equipment
- Meet the limits of the specified equipment

EPS **not designated** for specific models of equipment

- Shall be tested together with (artificial) loads
- Need to specify with types of equipment it can power
- Meet all Limits of the different specified equipment

Example: generic EPS (lamp, kitchen mixer, etc.) need to comply to -
Class A (kitchen mixer) and **Class C** (lamp)

The last main change in the amendment 1 is related to external power supplies. There has been a discussion about the different possibilities of external power supplies, if it is sold together with the device, sold as a generic power supply or even as a spare part.

So the working group has come up with this definition. It defines two types:

Designated (EPS delivered with the main equipment or available as a spare part)
Not designated (generic, i.e. a USB power supply)

For the designated nothing has change much to edition 5. The EPS has to be tested together with the equipment. For the not designated it limits the use case on what is specified by the manufacturer.

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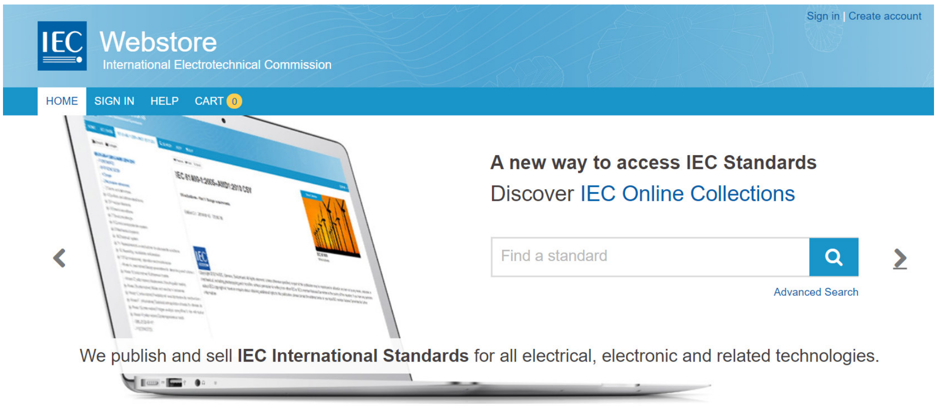
WHAT REMAINS THE SAME

There are no changes to

- Class A, B and D limits
- Calculation methods (other than POHC)
- Application of limits
- Measurement set-ups or methods
- Most of the test conditions

WHERE TO GET MORE INFORMATION



IEC official Webstore
https://webstore.iec.ch/?ref=menu

Available versions
IEC 61000-3-2:2018/AMD1:2020 is the amendment only which includes only the changes

IEC 61000-3-2:2018+AMD1:2020 CSV is the consolidated version including the full text with highlighted changes

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About Thomas Handschin

Thomas is the Product Manager for EMC conducted products at AMETEK CTS. His product portfolio includes testing solutions for harmonics, flicker, and HV electrical vehicle testing.

Thomas has an engineering degree in microtechnology and business management engineering, and 15 years of test and measurement experience. He is also a member of IEC technical committee 77A working group 1(harmonics) and 2 (flicker).

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