BS EN 50065-7:2001

Signalling on low-voltage electrical installations in the frequency range 3 kHz to 148,5 kHz —

Part 7: Equipment impedance

The European Standard EN 50065-7:2001 has the status of a British Standard

ICS 33.040.30

National foreword

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The UK participation in its preparation was entrusted to Technical Committee PEL/205, Mains signalling, which has the responsibility to:

- — aid enquirers to understand the text;
- — present to the responsible European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;
- — monitor related international and European developments and promulgate them in the UK.

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English version

Signalling on low-voltage electrical installations in the frequency range 3 kHz to 148,5 kHz Part 7: Equipment impedance

Transmission de signaux sur les réseaux électriques basse tension dans la bande de fréquences de 3 kHz à 148,5 kHz Partie 7: Impédance des appareils

Signalübertragung auf elektrischen Niederspannungsnetzen im Frequenzbereich 3 kHz bis 148,5 kHz Teil 7: Geräteimpedanzen

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CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Central Secretariat: rue de Stassart 35, B - 1050 Brussels

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Foreword

This European Standard was prepared by SC 205A, Mains communicating systems, of Technical Committee CENELEC TC 205, Home and Building Electronic Systems (HBES).

The text of the draft was submitted to the Unique Acceptance Procedure and was approved by CENELEC as EN 50065-7 on 2000-08-01.

The following dates were fixed :

– latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2002-06-01
– latest date by which the national standards conflicting with the EN have to be withdrawn	(dow)	2003-04-01

Annexes designated "normative" are part of the body of the standard.
Annexes designated "informative" are given for information only.
In this standard, annexes A, B, C and D are informative.

EN 50065 consists of the following parts, under the general title: Signalling on low voltage electrical installations in the frequency range 3 kHz to 148,5 kHz

Part 1	General requirements, frequency bands and electromagnetic disturbances
Part 2-1	Immunity requirements for mains communications equipment and systems operating in the range of frequencies 95 kHz to 148,5 kHz and intended for use in residential, commercial and light industrial environments
Part 2-2	Immunity requirements for mains communications equipment and systems operating in the range of frequencies 95 kHz to 148,5 kHz and intended for use in industrial environments
Part 2-3	Immunity requirements for mains communications equipment and systems operating in the range of frequencies 3 kHz to 95 kHz and intended for use by electricity suppliers and distributors
Part 4-1	Low voltage decoupling filters – Generic specification
Part 4-2	Low voltage decoupling filters – Safety requirements
Part 4-3	Low voltage decoupling filters – Incoming filter
Part 4-4	Low voltage decoupling filters – Impedance filter
Part 4-5	Low voltage decoupling filters – Segmentation filter
Part 4-6	Low voltage decoupling filters – Phase coupler
Part 7	Equipment impedance

Contents

Introduction

Mains communication equipment connected to the low voltage network will load the mains with their inherent impedance.

In general, many types of equipment connected to the same low voltage communication network will present a summative load impedance for transmitters injecting signals onto the mains network.

As a result, the mains impedance, which is time variable, will in general decrease and the attenuation increase, deteriorating the communication over the mains network.

The aim of this standard is to limit the deterioration in communication due to the contribution of the loads formed by other communication equipment connected to the same low voltage network and operating in the same frequency band or adjacent frequency bands.

This standard will therefore specify the suitable minimum impedance (modulus) of the communication equipment impedance in this operating frequency range for both transmitting and receiving mode in order to minimise mutual interference.

An informative annex is included with this part of the standard, identifying characteristics that can influence performance of equipment connected to the same mains network.

1 Scope

This standard applies to electrical equipment, excluding decoupling filters, using signals in the frequency range 3 kHz to 148,5 kHz for data transmission on low voltage electrical networks, either on the public supply network or within installations in consumers' premises.

It specifies requirements for mains communication equipment with respect to the load impedance of the mains.

It does not specify the impedance of external components that are not necessary for the normal functioning of the communication equipment.

2 Normative references

This European Standard incorporates, by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references, the latest edition of the publication referred to applies (including amendments).

EN 50065-1	2001	Signalling on low voltage electrical installations in the frequency range 3 kHz to 148,5 kHz – Part 1: General requirements, frequency bands and electromagnetic disturbances
CISPR 16-1	1993	Specification for radio disturbance and immunity measuring apparatus and methods - Part 1: Radio disturbance and immunity measuring apparatus
IEC 60050-161		International Electrotechnical Vocabulary – Chapter 161: Electromagnetic compatibility

3 Definitions

For the purpose of this standard the following definitions apply. Further, the definitions given in the International Electrical Vocabulary IEC 60050-161 apply.

3.1
Type 1 equipment
the equipment using signals in the frequency range 3 kHz to 95 kHz (see 4.1 of EN 50065-1)

3.2
Type 2 equipment
the equipment using signals in the frequency range 95 kHz to 148,5 kHz (see 4.2 of EN 50065-1)

3.3
bandwidth, BW
see 6.2.1 of EN 50065-1

4 Requirements

The minimum values of the impedance modulus for Type 1 equipment and Type 2 equipment, either in receiving operating mode (RX) and transmitting operating mode (TX), are defined in the following tables.

The abbreviations “Out BW” and “In BW” (for BW, see 3.3) in Table 2 mean “outside the bandwidth” and “inside the bandwidth” respectively.

For example, a system operating in the frequency range from 40 kHz to 60 kHz has an inside bandwidth of 20 kHz and the outside bandwidth range from 3 kHz to 40 kHz and from 60 kHz to 95 kHz.

These requirements apply for the design of equipment satisfying the impedance requirements for both Type 1 and Type 2. If the impedance requirements (see Tables 1, 2, 3 and 4) are not satisfied, an appropriate decoupling filter shall be used.

Table 1 – Minimum impedance modulus value $|Ze|$ of Type 1 equipment working in the frequency range 3 kHz to 9 kHz

Frequency range	3 kHz to 9 kHz		9 kHz to 95 kHz		95 kHz to 148,5 kHz	
Operating mode	RX	TX	RX	TX	RX	TX
$|Ze|$	10 Ω	Free	10 Ω	Free	10 Ω	10 Ω

Table 2 - Minimum impedance modulus value $|Ze|$ of Type 1 equipment working in the frequency range 9 kHz to 95 kHz

Frequency range	3 kHz to 9 kHz		9 kHz to 95 kHz			95 kHz to 148,5 kHz	
Operating mode	RX	TX	RX		TX	RX	TX
$|Ze|$	10 Ω	Free	Out BW Free 1)	In BW 50 Ω	Free	5 Ω	3 Ω

1) The free value is indicated for single system. For multiple systems, that is when more than one system operates in the same frequency range on the same network, a finite minimum impedance modulus value of 10 Ω is recommended.

Table 3 - Minimum impedance modulus value |Ze| of Type 2 equipment working in the frequency range 95 kHz to 148,5 kHz

Frequency range	3 kHz to 9 kHz		9 kHz to 95 kHz		95 kHz to 148,5 kHz	
Operating mode	RX	TX	RX	TX	RX	TX
|Ze|	10 Ω	10 Ω	5 Ω	5 Ω	5 Ω	Free

Table 4 - Minimum impedance modulus value |Ze| of Type 2 equipment working in the frequency range 3 kHz to 9 kHz using the common mode signalling [1)]

Frequency range	3 kHz to 9 kHz		9 kHz to 95 kHz		95 kHz to 148,5 kHz	
Operating mode	RX	TX	RX	TX	RX	TX
|Ze|	5 Ω	Free	5 Ω	5 Ω	10 Ω	10 Ω

1) Common-mode injection devices may disturb the normal operation of residual current protection devices and cause serious safety hazards to the user. Therefore, common-mode injection shall not be used unless otherwise explicitly allowed in local regulations (see EN 50065-1).

These impedance values have to be measured in accordance with clause 5.

5 Test method

5.1 General

Two test methods are proposed the "impedance analyser method" and the "voltage ratio method".

The "impedance analyser method" allows the measurement of real and imaginary parts of the impedance of the device under test (DUT). This method is the reference method.

The "voltage ratio method" only indicates if the modulus of the impedance of the DUT is above or below the limit.

5.2 Test conditions

The mains communication equipment (DUT) shall be connected with all external components that are necessary for operation.

For mains communication equipment incorporated in appliances, the test must be carried out only on the communication equipment.

The test must be carried out with respect to in band and out of band frequency range which the communication equipment operates.

The DUT impedance shall be measured in receiving operating mode (RX) and transmitting operating mode (TX).

5.3 Impedance analyser measuring method

The value of the impedance of the Device Under Test (DUT) shall be measured using an indirect method based on the use of the artificial mains, CISPR 16-1 V-network, defined in EN 50065-1.

This method applies to devices working in differential mode.

The measuring equipment is shown in Figure 1. The transformer is necessary to provide the galvanic isolation between the LV mains neutral (N) and the ground (GND) of the CISPR 16-1 V-network.

The earth termination of the device under test, when this termination is present, shall not be connected to the ground termination (GND) of the artificial mains network.

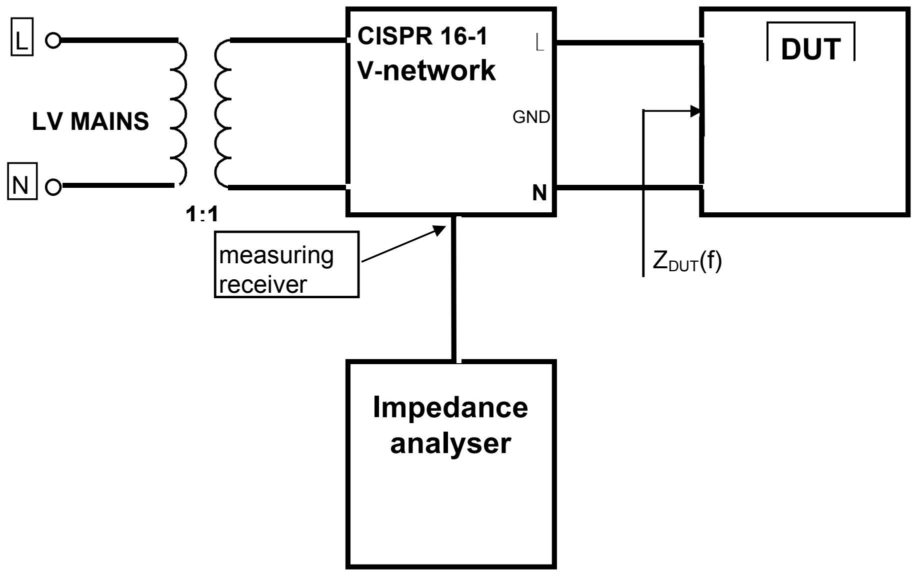


Figure 1 - Block diagram of the measuring set-up

The impedance of the DUT is calculated as follows :

- step 1: evaluation of the Z-parameters (Z_{11}, Z_{22}, Z_{12}, Z_{21}) of the CISPR 16-1 V-network as a two port network (see annex C);
- step 2: measurement of the input impedance ($Z_m(f)$) when the DUT is connected to the V-network output port;
- step 3: calculation of $Z_{DUT}(f)$ using the Z-parameters and $Z_m(f)$.

In annex C, a possible calculation method is shown using the Z-parameters.

5.4 Voltage ratio method

The measuring method is based on the use of the artificial mains, CISPR 16-1 V-network defined in EN 50065-1 for measuring the output voltage of the mains communication devices.

This method does not apply to devices working in common mode.

The measuring equipment for measuring the signal output voltage, as defined in EN 50065-1, is replaced by a signal generator having an output impedance of 50 Ω, working at the measuring frequency and having an output voltage not exceeding 100 dB(μV)rms. Using the relevant switch on the V-network, the generator shall be connected to Line.

A differential voltmeter tuned at the measuring frequency with a bandwidth ≤ 200 Hz is connected by a high-pass filter blocking the 50 Hz signal and having a high input impedance

1) in parallel with the DUT,

2) between ground (GND) and neutral (N) of the CISPR 16-1 V-network.

The input impedance value of this set (differential voltmeter plus high-pass filter) has to be greater than 20 x $|Z_{ART}|$, where Z_{ART} is the impedance of the artificial mains network as defined in EN 50065-1.

The earth termination of the device under test, when this termination is present, shall not be connected to the ground termination (GND) of the artificial mains networks.

The block diagram of the measuring set-up is shown in Figure 2.

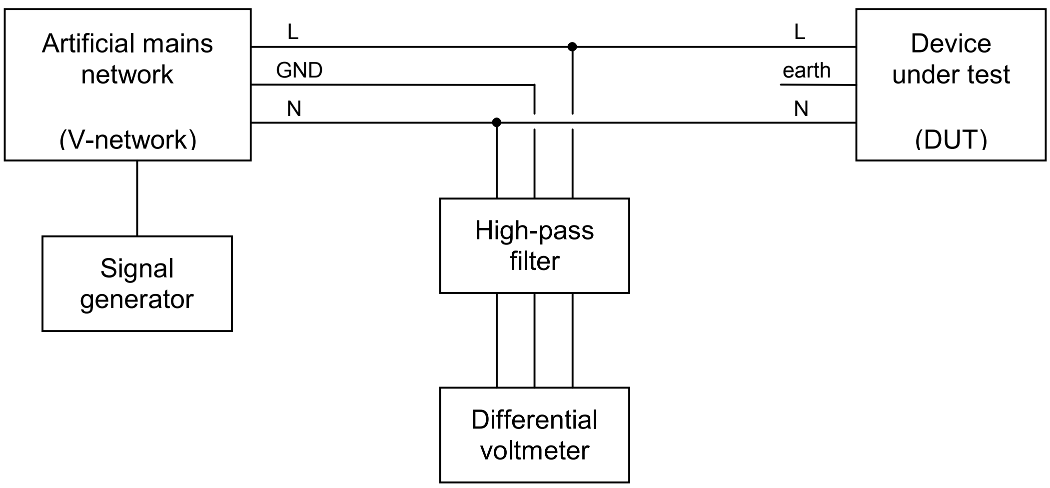


Figure 2 – Block diagram for measuring set-up

The measurement is made as follows with the DUT connected to the artificial network:

- step 1: a first reading is done by measuring the voltage over the DUT (V_{DUT});
- step 2: a second reading is done by measuring the voltage between ground and neutral (V_N);
- step 3 : calculate the weighted voltage ratio $D = \frac{V_N}{V_{DUT}} \cdot |Z_e|$, where $|Z_e|$ is the minimum input impedance of the DUT in accordance with Table 1, 2 and 3;
- step 4 : check that the voltage ratio D is below the curves in Figure 3 and Figure 4 according to the frequency.

It is important to check that the artificial mains network has a V-structure and its impedance meets the requirements given in EN 50065-1, i.e.:

$$Z_{ART} = \begin{cases} 50\,\Omega \parallel (50\,\mu\text{H} + 1.6\,\Omega) & \text{for 3 kHz to 9 kHz} \\ 50\,\Omega \parallel (50\,\mu\text{H} + 5\,\Omega) & \text{for 9 kHz to 150 kHz} \end{cases}$$

NOTE The curves in Figures 3 and 4 are based on calculations which include 20% worst case tolerance for $|Z_{ART}|$ in accordance with EN 50065-1

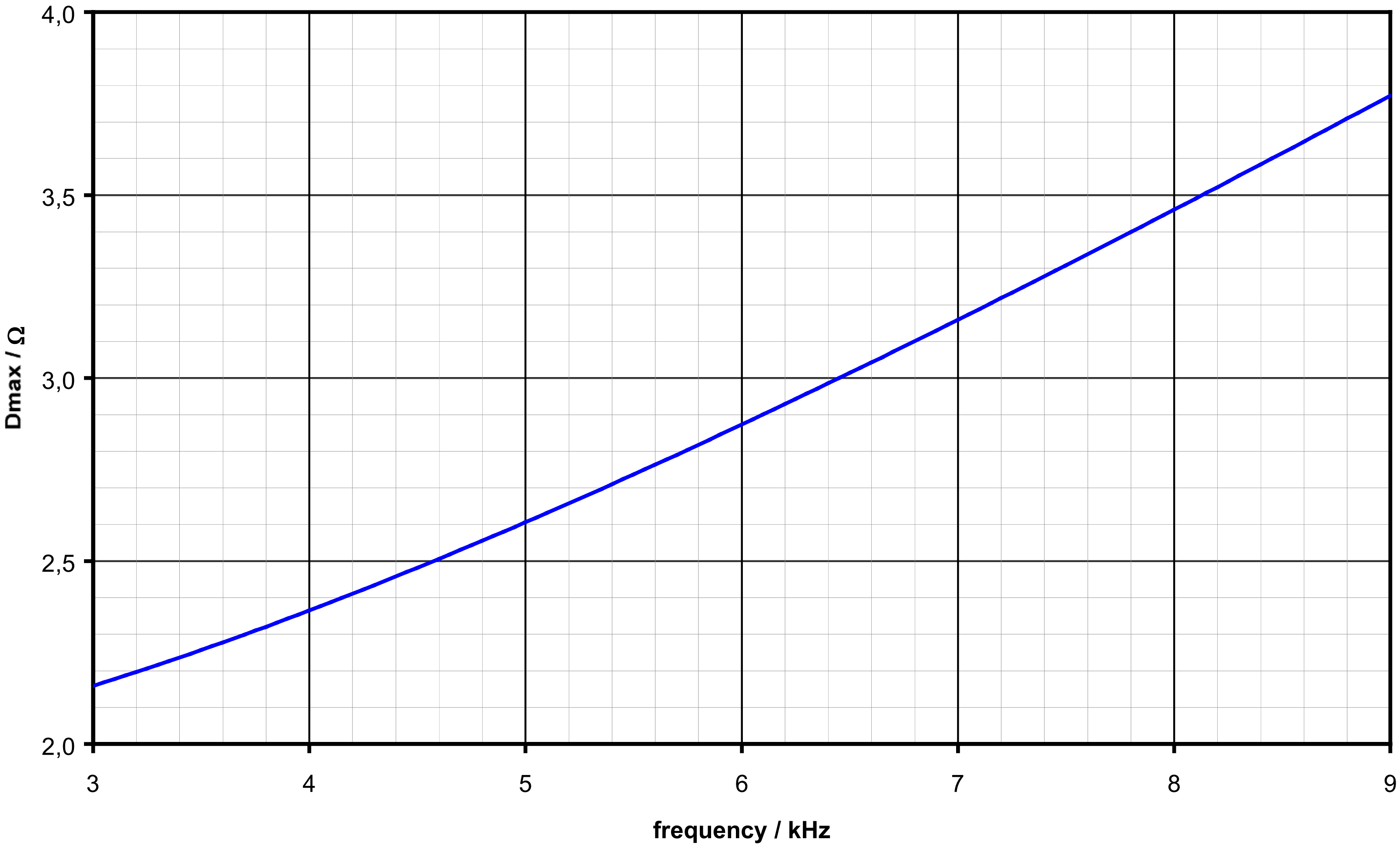


Figure 3 - Maximum weighted voltage ratio D_{MAX} in the frequency range 3 kHz to 9 kHz

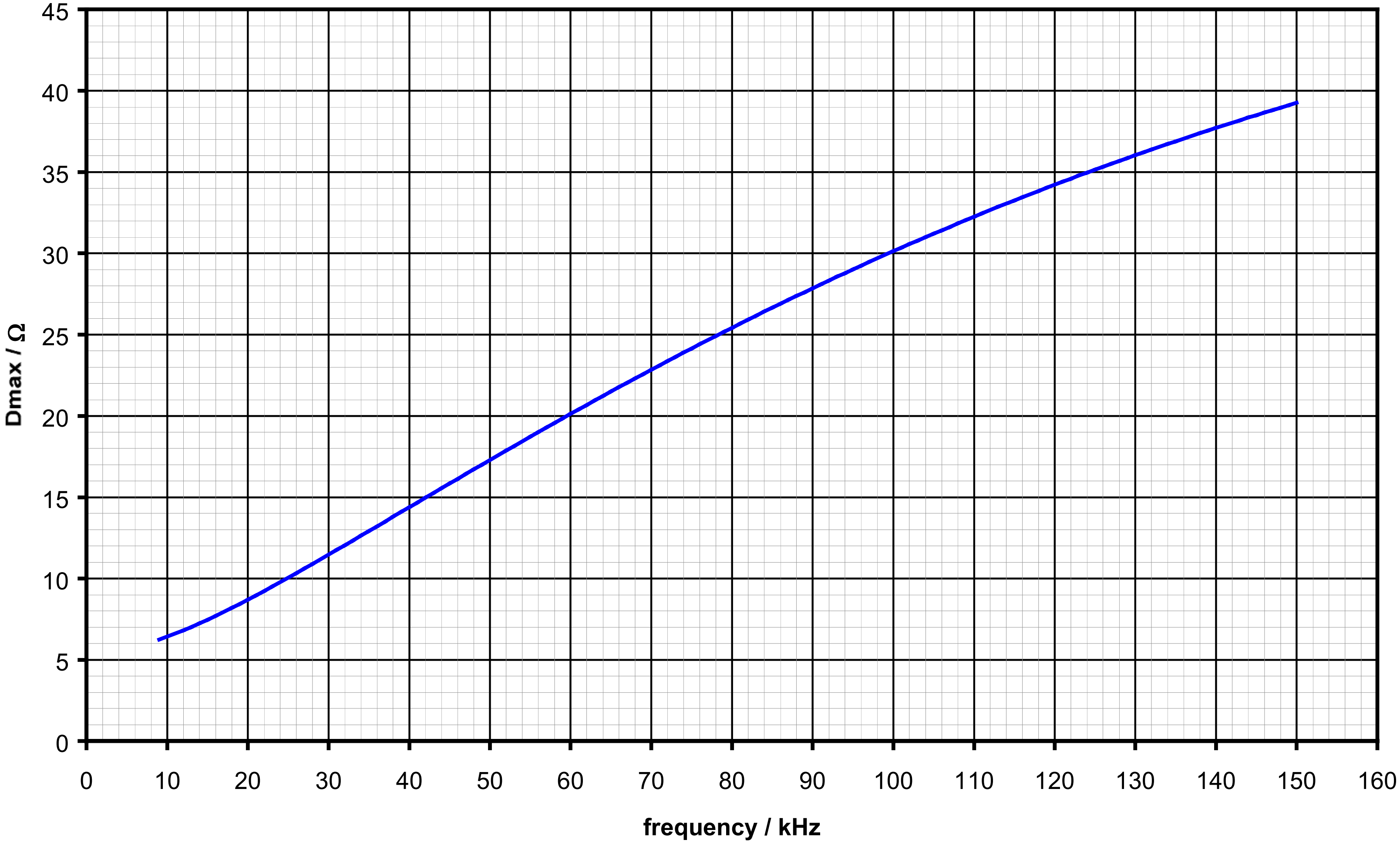


Figure 4 - Maximum weighted voltage ratio D_{MAX} in the frequency range 9 to 148,5 kHz

Annex A
(informative)

Signalling on low voltage electrical installations in the frequency range 3 kHz to 148,5 kHz, potential problems

The low voltage power lines are designed to carry and deliver electrical power at 230 V, 50 Hz. Recent developments have shown that it is very interesting and possible to transmit data communication signals over the low voltage power line. The inherent difficulties of transmitting data over the low voltage network include

- electrical equipment is designed to consume electrical power at 50 Hz and not transmit and receive data at mains signalling frequencies (3 kHz to 148,5 kHz),
- the low voltage mains power line does not have a characteristic impedance that other communication media are characterised by,
- the attenuation and the impedance of the low voltage mains network vary considerably over the frequency range 3 kHz to 148,5 kHz,
- the attenuation and the impedance characteristics depend on the equipment connected to the low voltage mains network,
- electrical equipment generates several types of electrical noise which can disturb Mains Communication Equipment and Systems (MCES),
- the frequency range available to PLC is very wide (from 3 kHz to 148,5 kHz), which means it is difficult to have an equipment impedance covering the whole frequency range.

This European Standard on equipment impedance is presented in the light of the current developments of low voltage mains signalling. It represents the best practical compromise on impedance values for the frequency range covered.

Any future development will be taken into account in the next revision of this standard.

The following points identify the most significant characteristics effecting the definition of impedance values:

- the range of impedance values established in the tables is the best compromise to achieve interoperability of different PLC systems operating over the same low voltage mains network;
- resonance phenomena;
- discontinuities of impedance values at frequency boundaries;
- time dependency of impedance due to periodic effects of power supplies.

Consideration of measurements in each working frequency range

- difficulty in measuring impedance values with mains voltage present (230 V),
- problems with measuring low impedance values across the whole frequency range,
- the relatively high impedance of coupling and CISPR 16-1 V-network dominating compared with the low impedance of the equipment under test,
- the operating conditions of the DUT are difficult to define due to the wide range of operating parameters.

Annex B
(informative)

Minimum value of the equipment impedance

B.1 Consumer's network impedance

A limited program of network impedance measurements was carried out in three European countries (France, Germany, Italy). These results are considered representative of similar networks.

In particular, the statistic distribution of the impedance values measured on consumer's networks in the frequency range 3 kHz to 148,5 kHz, shows that the impedance has the following characteristics:

- it is very rarely greater than 20 Ω;
- ≈90% of the values lie in the range 0,5 Ω to 10 Ω;
- the most frequent values are around 5 Ω;
- the impedance depends on the measuring point.

The reasons for this behaviour are as follows :

- the consumer's power network has, in general, a complex "tree" structure having lines or cables with three conductors (phase, neutral and earth), with the power supply point situated on the "root" and the loads distributed on the "branch ends";
- the layout of the network and the loads differs between consumers;
- some consumer's loads (that is, households and professional equipment) have a very low impedance (in the range 0,1 Ω to 10 Ω) mainly due principally to the radio-interference suppression filters installed in them (upstream of the apparatus switch);
- the impedance of the lines or cables is not negligible in relation to that of the loads.

B.2 Type 1 & 2 equipment impedance versus environment

As a consequence of the above considerations and taking into account that

- each Type 1 equipment may be installed either in a distributed way, at each consumer's premise, or in a concentrated way on a centralised board,
- each Type 2 equipment may be associated with an household or professional equipment, generally distributed on the consumer's network,

it is possible to prescribe a minimum value of the impedance modulus of each Type 2 equipment, without limiting the number of equipment installations and it is mandatory to choose a suitable constant minimum value of the equipment impedance modulus ($|Z_e|$) for both Type 1 and Type 2.

These choices, either for TX or RX mode in the signalling band and adjacent bands, allow

- avoidance of, as much as possible, unsuitable **mutual interference** between equipment of different types in order to allow simultaneous operation of systems in adjacent frequency bands,
- the **coexistence** of equipment of the same type either for a stand alone system and for installations where more than one system operates (multiple systems).

B.3 Minimum value of the equipment impedance

The following information is a supplement to the tables described in clause 3.

B.3.1 Table 1

Frequency range 3 kHz to 95 kHz

- RX mode: the proposed value allows the coexistence,
- TX mode: the impedance in transmitting mode should be adapted to the impedance of the network.

Frequency range 95 kHz to 148,5 kHz

- RX and TX modes: the proposed value is justified in order to avoid mutual interference.

B.3.2 Table 2

Frequency range 3 kHz to 9 kHz

- RX mode: the proposed value allows the coexistence,
- TX mode: the impedance in transmitting mode should be adapted to the impedance of the network.

Frequency range 9 kHz to 95 kHz

- RX mode: the proposed values allow the coexistence, particularly in the centralised installations of stand alone system equipment. For multiple system installations, the coexistence is guaranteed with 10 Ω in “Out BW”,
- TX mode: the impedance in transmitting mode should be adapted to the impedance of the network.

Frequency range 95 kHz to 148,5 kHz

- RX and TX modes: the proposed values are justified in order to avoid mutual interference.

B.3.3 Table 3

Frequency range 3 kHz to 95 kHz

- RX and TX modes: the proposed values are justified in order to avoid mutual interference.

Frequency range 95 kHz to 148,5 kHz

- RX mode: the proposed value allows the coexistence,
- TX mode: the impedance in transmitting mode should be adapted to the impedance of the network.

B.3.4 Table 4

Frequency range 3 kHz to 9 kHz

- RX mode: the proposed value allows the coexistence,
- TX mode: the impedance in transmitting mode should be adapted to the impedance of the network.

Frequency range 9 kHz to 148,5 kHz

- RX and TX modes: the proposed values are justified in order to avoid mutual interference.

Annex C
(informative)

Impedance measurement method with impedance analyser

C.1 Theory

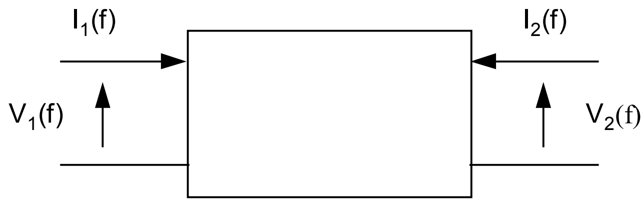


Figure C.1 - Two-port network

For a two-port network shown in Figure C.1, the voltages can be expressed as linear functions of $I_1(f)$ and $I_2(f)$:

$$V_1 = Z_{11}(f)I_1(f) + Z_{12}(f)I_2(f) \quad (1)$$

$$V_2 = Z_{21}(f)I_1(f) + Z_{22}(f)I_2(f) \quad (2)$$

Re-arranging (1):

$$I_2(f) = \frac{1}{Z_{12}(f)}V_1(f) - \frac{Z_{11}(f)}{Z_{12}(f)}I_1(f) \quad (3)$$

Using (3) to substitute for $I_2(f)$ in (2) :

$$V_2(f) = \frac{Z_{22}(f)}{Z_{12}(f)}V_1(f) + \left(Z_{21}(f) - \frac{Z_{11}(f)Z_{22}(f)}{Z_{12}(f)}\right)I_1(f) \quad (4)$$

Dividing (3) by (4):

$$\frac{V_2(f)}{I_2(f)} = \frac{\frac{Z_{22}(f)V_1(f)}{Z_{12}(f)I_1(f)} + \left(Z_{21}(f) - \frac{Z_{11}(f)Z_{22}(f)}{Z_{12}(f)}\right)}{\frac{V_1(f)}{Z_{12}(f)I_1(f)} - \frac{Z_{11}(f)}{Z_{12}(f)}} \quad (5)$$

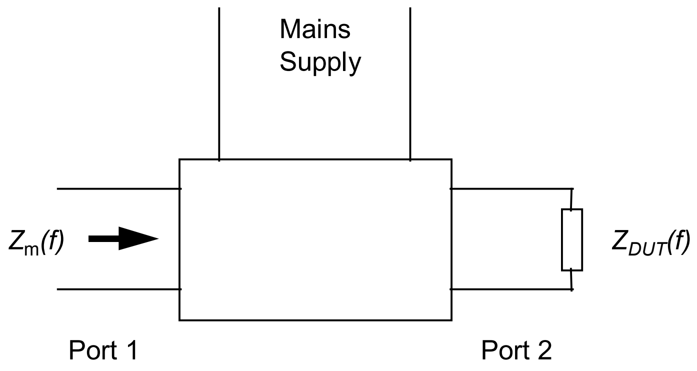


Figure C.2 - Two-port network with DUT as load

From Figures C.1 and C.2 we define:

$$Z_m(f) = \frac{V_1(f)}{I_1(f)}, \quad Z_{DUT}(f) = \frac{-V_2(f)}{I_2(f)}$$

Using these definitions in equation (5) we obtain:

$$Z_{DUT}(f) = \frac{Z_{11}(f)Z_{22}(f) - Z_{22}(f)Z_m(f) - Z_{12}(f)Z_{21}(f)}{Z_m(f) - Z_{11}(f)} \quad \text{.. (6)}$$

C.2 Practice

Step 1: Measuring the Z-parameters:

Only $Z_{11}(f)$, $Z_{22}(f)$ and ($Z_{12}(f).Z_{21}(f)$) need to be measured.

Measuring $Z_{11}(f)$

$$Z_{11}(f) = \left. \frac{V_1(f)}{I_1(f)} \right|_{I_2(f)=0} \quad \text{.. (7)}$$

$Z_{11}(f)$ can be measured by connecting the measuring probe of the impedance analyser to the measuring receiver plug (input port) of the CISPR 16-1 V-network without the mains connected and with the points L and N (output port) open circuit (see Figure 1).

The impedance $Z_m(f) = Z_{11}(f)$ is measured for the appropriate frequency ranges specified in the body of this standard.

Measuring $Z_{22}(f)$

$$Z_{22}(f) = \left.\frac{V_2(f)}{I_2(f)}\right|_{I_1(f)=0} \quad \text{(8)}$$

$Z_{22}(f)$ can be measured by connecting the measuring probe of the impedance analyser to the points L and N (output port) of the CISPR 16-1 V-network without mains and with the measuring receiver plug (input port) open circuit (see Figure 1).

Measuring $Z_{12}(f)Z_{21}(f)$

$$Z_{12}(f)Z_{21}(f) = Z_{DUT}(f)[Z_{11}(f) - Z_m(f)] + Z_{11}(f)Z_{22}(f) - Z_{22}(f)Z_m(f) \text{corrected} \quad (9)$$

($Z_{12}(f).Z_{21}(f)$) can be measured by inserting a known impedance (between 5 Ω and 50 Ω) instead of $Z_{DUT}(f)$ as a dummy load connected to points L and N (Figure 1) and measuring $Z_m(f)$ from the measuring receiver plug (input port) of the CISPR 16-1 V-network at appropriate frequencies. ($Z_{12}(f)Z_{21}(f)$) can then be calculated for the appropriate frequency ranges from equation (9). Equation (9) is obtained from (6).

Step 2: Measuring $Z_m(f)$:

$Z_m(f)$ is then measured for the appropriate frequency ranges with the measuring probe of the impedance analyser connected on the measuring receiver plug (input port) of the CISPR 16-1 V-network and with the DUT as the load connected to points L and N (Figure 1).

Step 3: Calculating $Z_{DUT}(f)$:

$Z_{DUT}(f)$ is then calculated for the appropriate frequency ranges from equation (6).

Annex D
(informative)

Analysis of voltage ratio method for impedance measurement

D.1 Introduction

This annex provides an analysis of the determination of the impedance of a device under test (DUT) using the voltage ratio method. This is one of two methods, for determining the impedance of a device under test, the other method used is the impedance analyser method.

The aim of the analysis below is to show where the voltage-ratio-formalism in this European Standard is derived from. Furthermore, it is explained how the curves in the D_{MAX} diagrams can be calculated.

D.2 Principle of the voltage ratio method

The voltage ratio method is based on the ratio between the impedance of the device under test Z_{DUT} and the impedance of the artificial mains network Z_{ART}. Therefore, Z_{ART} has to meet the requirements given in CISPR 16-1 (9 kHz to 150 kHz) and EN 50065-1 (3 kHz to 9 kHz). The artificial mains network shall have a V-structure as shown in Figure D.1.

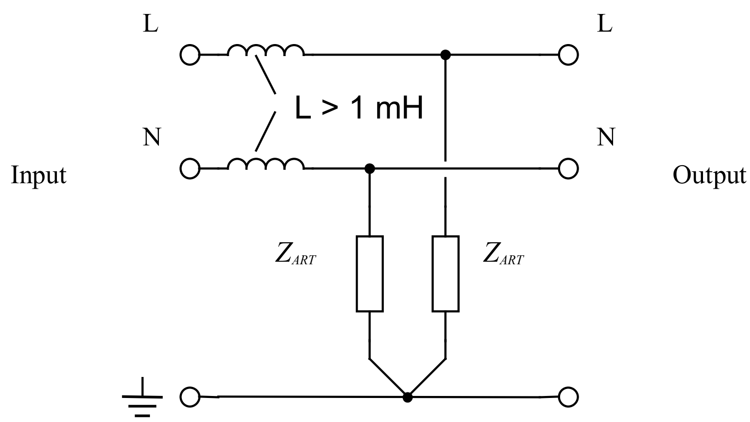
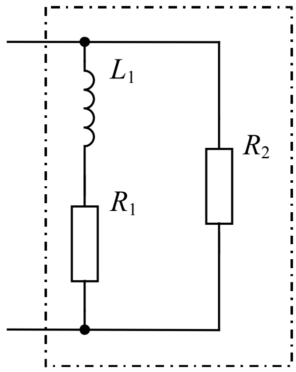


Figure D.1 - Simplified structure of the artificial mains network

For signal frequencies, Z_{ART} can be described by the circuit in Figure D.2.



<u>3 kHz to 9 kHz</u>

L_1 = 50 µH, R_1 = 1.6Ω, R_2 = 50 Ω

<u>9 kHz to 150 kHz</u>

L_1 = 50 µH, R_1 = 5 Ω, R_2 = 50 Ω

Figure D.2 - Equivalent circuit for Z_{ART}

If a signal generator (V_{IN}) is connected between Line and Earth through the measuring output of the artificial mains network, the signal current in both branches of the artificial mains network is identical to the signal current I_{DUT} in the DUT as shown in Figure D.3. (The output impedance of the signal generator is part of Z_{ART}).

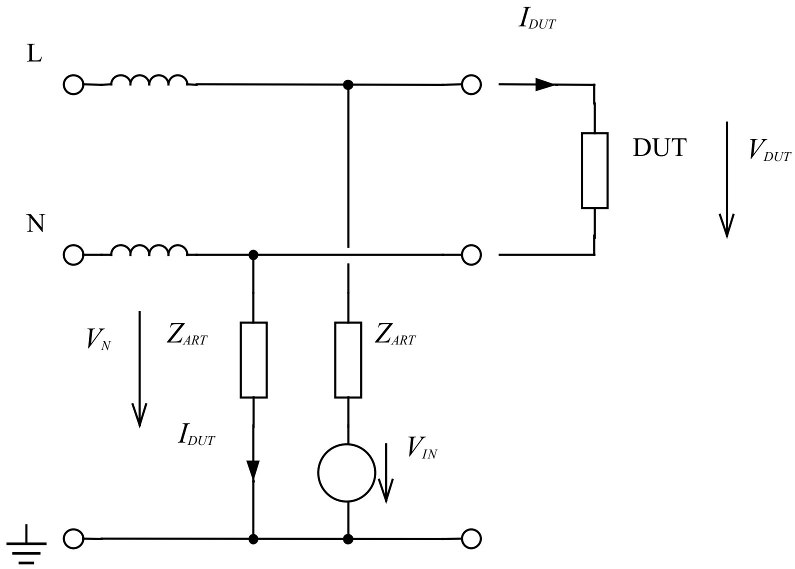


Figure D.3 - Device under test (DUT) connected to the artificial mains network

This means for the complex values:

$$I_{DUT} = \frac{V_N}{Z_{ART}} = \frac{V_{DUT}}{Z_{DUT}}$$

This equation can be rewritten for the ratio of modulus values as follows:

$$\frac{|V_N|}{|V_{DUT}|} = \frac{|Z_{ART}|}{|Z_{DUT}|}$$

So the voltage ratio is independent from the phase of Z_{ART} and Z_{DUT}. For a given minimum impedance $|Z_{MIN}| \leq |Z_{DUT}|$, this equation leads to:

$$\frac{|V_N|}{|V_{DUT}|} \cdot |Z_{MIN}| \leq |Z_{ART}|$$

So, the upper limit of the weighted voltage ratio D defined as:

$$D := \frac{|V_N|}{|V_{DUT}|} \cdot |Z_{MIN}|$$

is given by $|Z_{ART}|$ including additional 20 % tolerance in accordance with CISPR 16-1 and EN 50065-1.

$$D_{MAX} = 1.2 \cdot |Z_{ART}|$$

D.3 Measuring notes

For the measurement a high frequency voltmeter (BW ≤ 200 Hz) must be connected to the artificial mains network by a high-pass filter. This filter shall have an input impedance greater than 20 x $|Z_{ART}|$. If the voltmeter has no differential input the filter has to provide such an input allowing the measurement of $|V_{DUT}| = |V_L - V_N|$. An implementation of this filter can be based on the principle shown in Figure D.4.

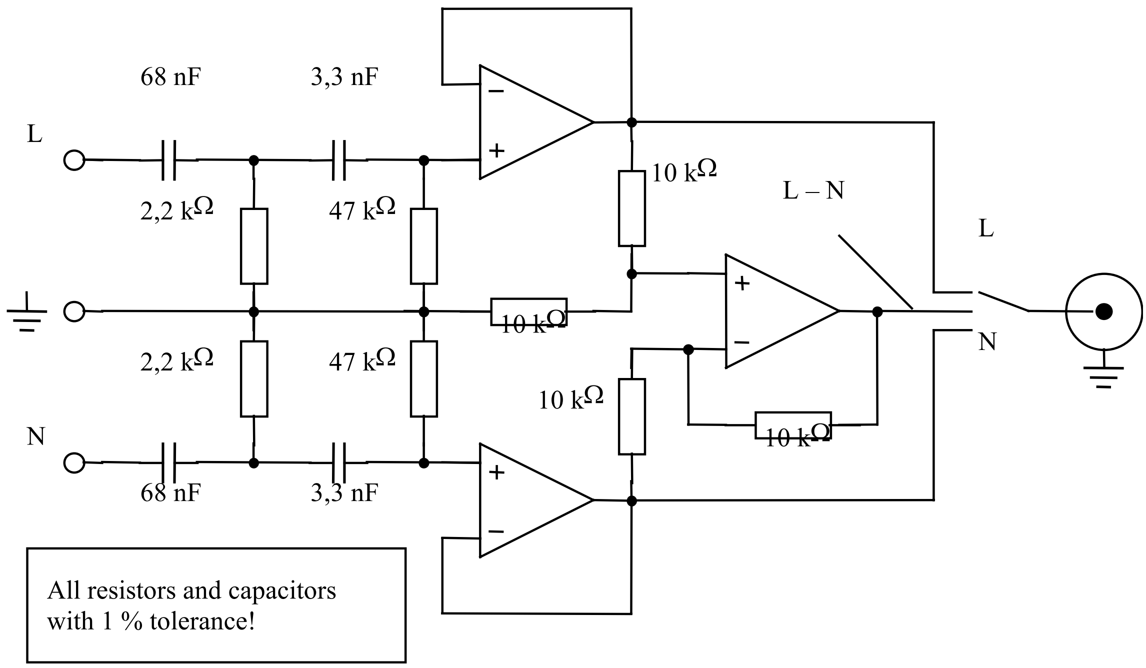


Figure D.4 - Principle of a high-pass filter with a differential input

The output of this filter can directly be connected to a spectrum analyser. For accurate measurements, overload must be avoided.

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