50µH Line Impedance Stabilisation Network

1 Introduction

The TBL5016-1 50µH LISN is a device required to setup conducted noise measurements of DC or AC-powered electronic equipment. It is designed according to CISPR 16-1-2 and MIL-STD-461F standard and characterized in the frequency range of 150 kHz to 100 MHz. Jumpering a 5 Ohm resistor enables using the LISN from 9 kHz -30 MHz.
Apart from carrying out conducted noise measurements, LISNs are also used to establish a defined impedance for various other standardized tests.
The LISN is a 50Ω/50µH (+5 Ω) single line design with a high current jumper to short the 5 Ohm resistor and configure it as 50Ω/50µH LISN according to CISPR 16-1-2. The LISN is characterized up to 100 MHz which means that the LISN can be used for the combined range of 9 kHz to 100 MHz.
The LISN is inserted into the supply line of the DUT (Device Under Test). Conducted noise, which is present at the supply terminals of the DUT can be measured at the BNC connector using a spectrum analyzer or a measurement receiver. The source (supply) terminal and the DUT terminal are decoupled by a 50µH inductor.
DC or single phase measurements typically require a pair of TBL5016-1. Combining it with the Tekbox LISN Mate enables separate measurement of common mode and differential mode noise. DUTs with 3 phase supply require three or four pieces of TBL5016-1, depending on whether the product is supplied in delta or star configuration.
The unit comes equipped with a BNC-male to N-male RG232 cable, mating connectors, high current configuration jumpers and ground brackets to attach it to a ground plane.

2 Parameters

LISN type: V-AMN, configurable as 50Ω/50µH+5 Ω or 50Ω/50µH; no 250µH pre-filter

Frequency range: 9/150 kHz – 100 MHz

DC Resistance: < 45 mΩ

Maximum current: 16A continuous

Operating voltage range: 0 – 250V DC; 0 - 250V AC (50/60 Hz), 0 – 90V AC (400 Hz)

Fuse: 2 x 16A slow

High current plug/screw terminals - male: Phoenix Contact 1998933, female: Phoenix Contact 1967375

Dimensions: 250 mm x 225 mm x 140 mm (including ground brackets); weight: 2.7 kg

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2.1 Conformity

The TBL5016-1 is compliant with CISPR 16-1-2.

In line with the CISPR 16-1-1 standard compliant design and setup specification, the TBL5016-1 LISN exhibits high ground leakage currents and non-standard isolation and consequently cannot meet the safety requirements of EN 61010-1.

Furthermore CISPR 16-1-2 specifies high capacitance values for the capacitors from Line / + to Ground. These capacitance values are not commercially available in Y2 rating and are implemented using AC rated capacitors with suitable voltage rating.

In order to prevent the danger of lethal electric shock, the operator is responsible for ensuring protective measures in line with IEC 60364-4-41 and IEC 60364-5-54 and to follow all safety related information of this manual.

2.2 Safety

To ensure safe operations, the user must adhere to all safety-related information in this manual. All metal parts of the housing are connected to the earth pins of the Source and DUT sockets. Before connecting any other conductor to the LISN, connect the Earth brackets to protective Earth.

Protective Earth must not be disconnected from the Earth brackets unless all other wiring has been disconnected first. Special care must be taken to avoid connecting AC - line or VDC+ to the EARTH pin of the SOURCE connector by mistake.

When operating the LISN with alternating current, use an isolation transformer.

While the source connector is under voltage, do not connect or disconnect it.

The TBL5016-1 shall be operated by qualified laboratory staff only.

3 Warning

Spectrum Analyzer / Measurement Receiver protection:

The TBL5016-1 LISN does not contain any protective elements in the RF path. Use an external attenuator and/or limiter, if your DUT may produce harmful transients or high RF noise levels, in order to protect the spectrum analyser / measurement receiver input. If using without transient limiter and testing AC supplied products, it is highly recommended to protect the input of the connected analyzer with TBHPF1-9kHz or TBHPF1-150 kHz highpass filters or to insert the internal highpass jumper.

Safety:

Operating an AC LISN involves dealing with potentially lethal voltages and high ground leakage currents. The LISN shall only be operated by qualified staff.

Read this manual carefully and be sure to understand the operation of the LISN. Make sure that the conducted noise pre – compliance test equipment is set up correctly and that the necessary earth connections are reliably bonded to avoid the risk of lethal electric shocks. The ground brackets must be securely connected to the protective earth conductor available on site, before making any other electrical connection. This connection must not be separated, until the mains supply is disconnected from the LISN setup.

When connecting the LISN to AC mains voltage, always use an isolation transformer.

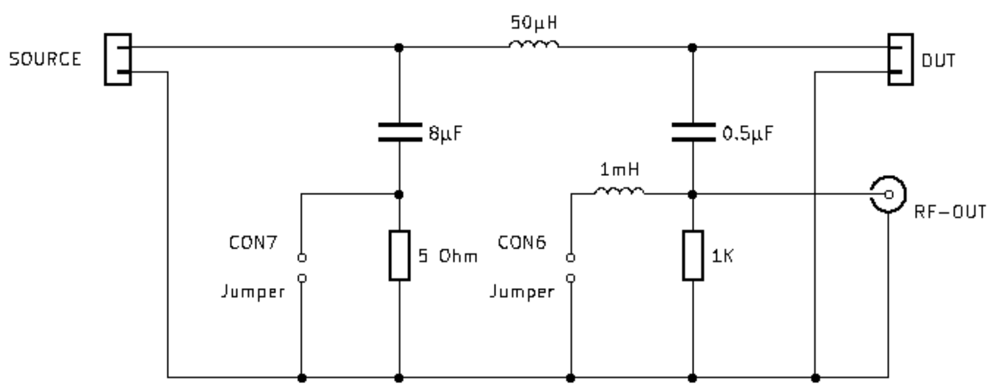
Take precautions, such as validating the signal amplitude at the RF output prior to connecting a spectrum analyzer or using attenuators and/or limiters to prevent damage to your test receiver or spectrum analyzer.

Do not carry out any modifications or manipulations of the TBL5016-1.

Avoid touching the housing, when operating the LISN at maximum current over extended time. The housing temperature may rise up to 50°C. Turn off the DUT after measurements to avoid unnecessary dissipation.

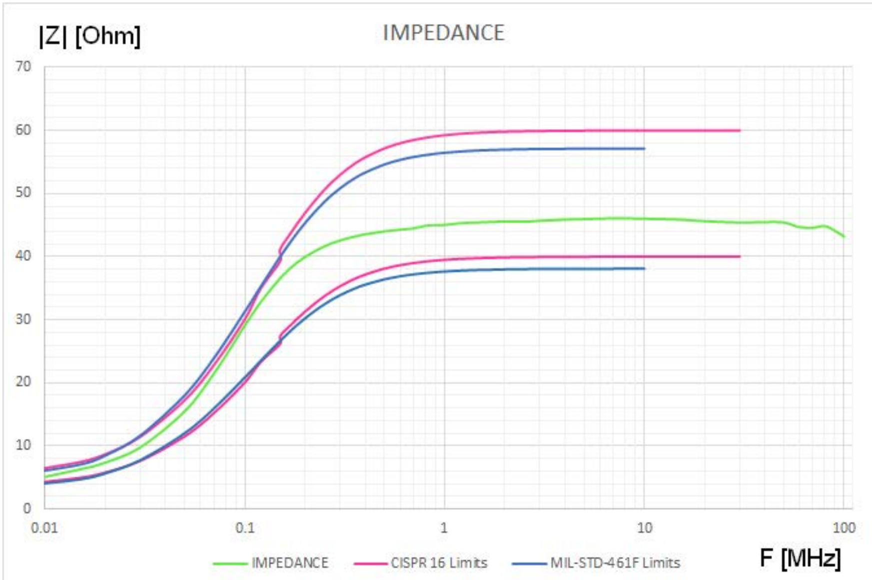
The LISN housing is connected to the negative / ground SOURCE and DUT pin of the terminal block and the ground of the RF connector. Inadvertently connecting the positive voltage to the ground pin will expose you to the risk of electric shock. The maximum source voltage rating with respect to component ratings is 250V.

4 Principle schematic

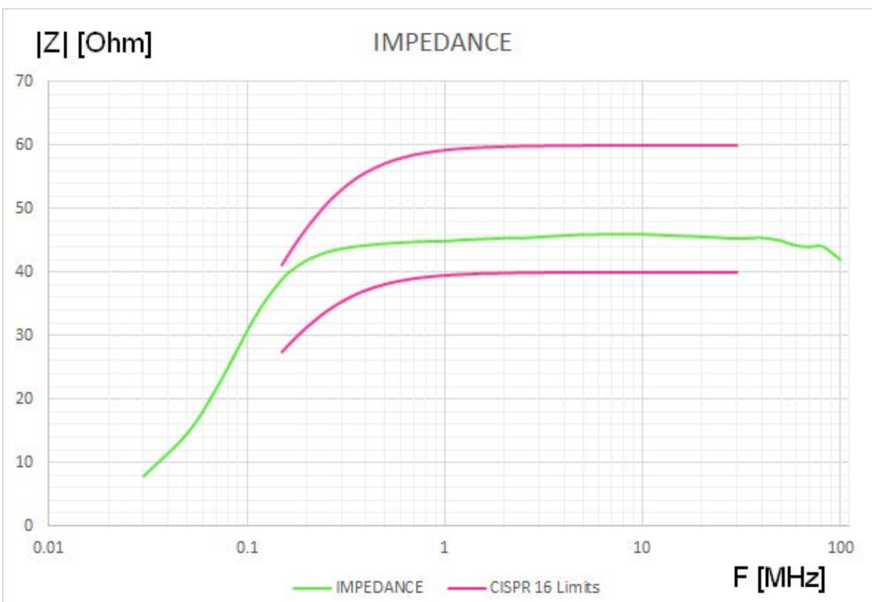


Picture 1: principle schematic

5 Impedance



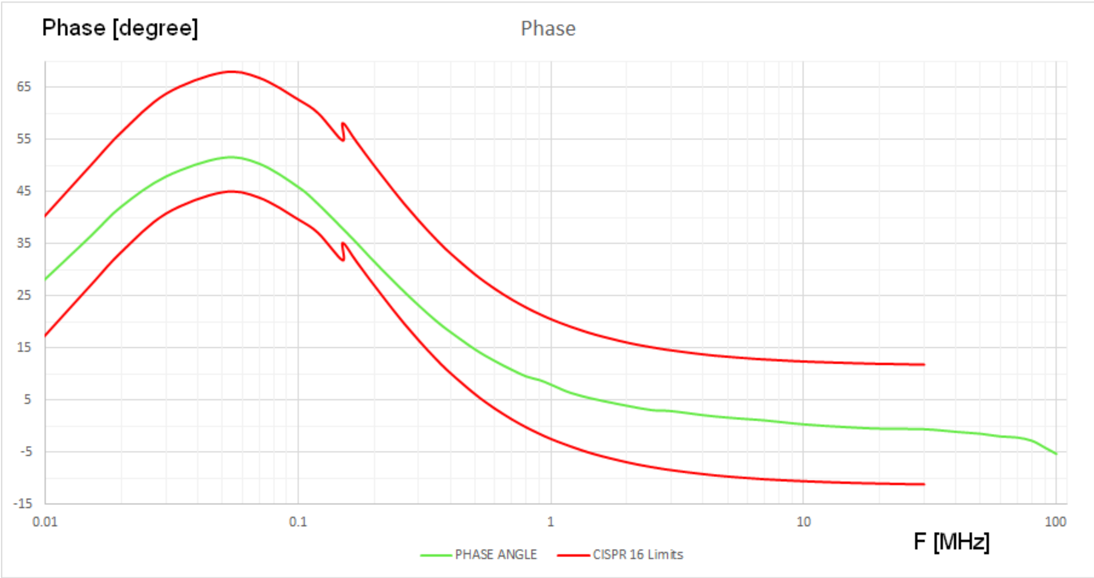
Picture 2: LISN impedance, 50Ω // 50µH + 5Ω



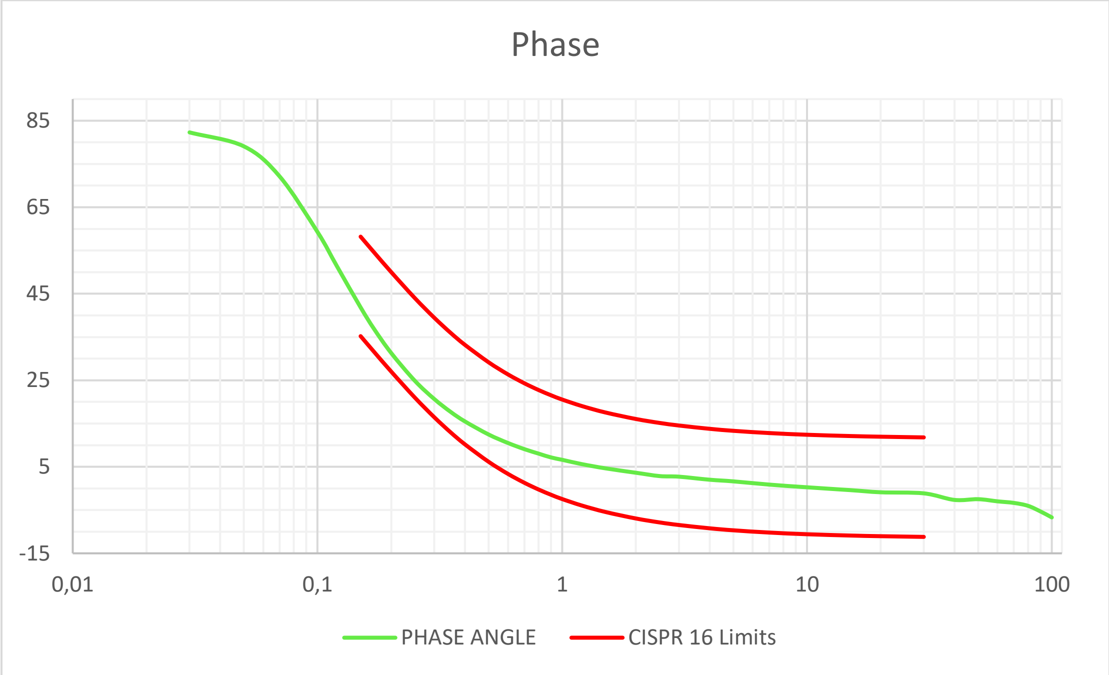
Picture 3: LISN impedance, 50Ω // 50µH

The impedance is referenced to the PCB edge, not including the Phoenix terminal blocks. The male + female terminal block combination can be considered being equivalent to 5cm of additional wiring in the entire set up.

6 Phase



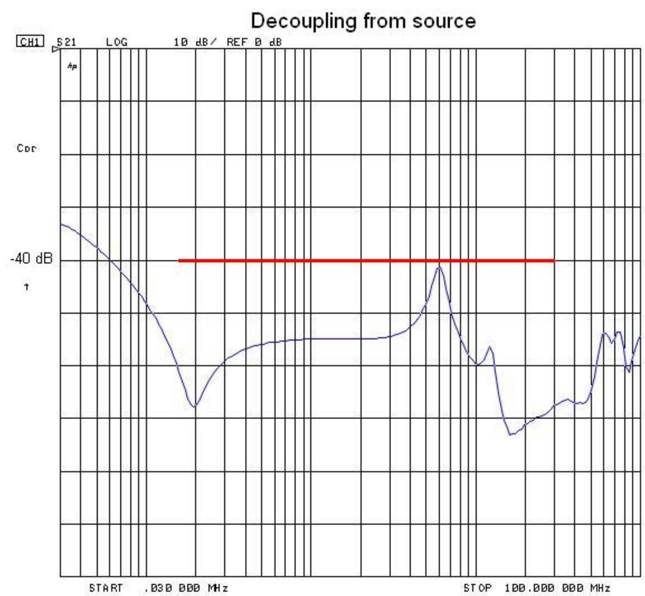
Picture 3: LISN phase, 50Ω // 50µH + 5Ω



Picture 4: LISN phase, 50Ω // 50µH

The phase is referenced to the PCB edge, not including the Phoenix terminal blocks. The male + female terminal block combination can be considered being equivalent to 5cm of additional wiring in the entire set up.

7 Isolation

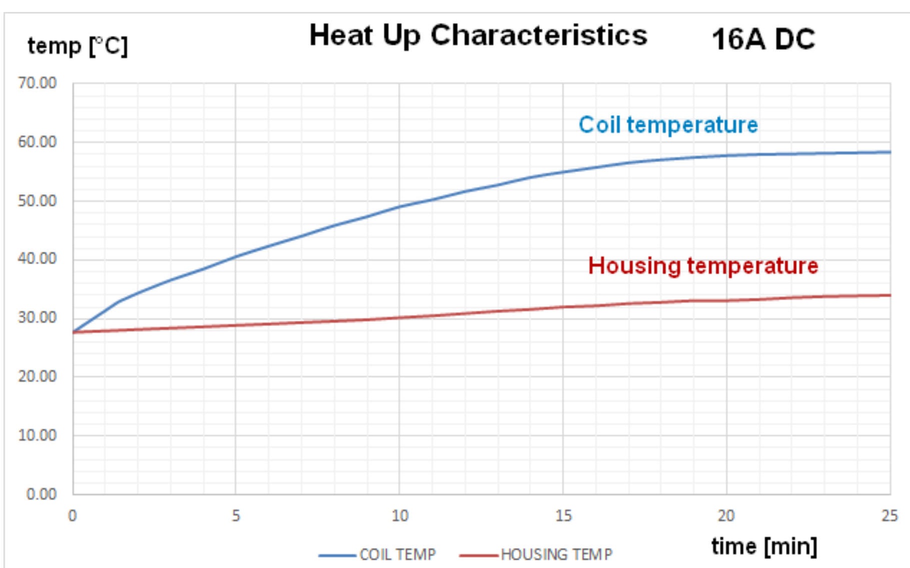


Picture 5: LISN Isolation, Source to RF out, 50Ω // 50µH

The isolation is measured between SOURCE terminal and RF port, with the DUT port terminated with 50 Ohm.

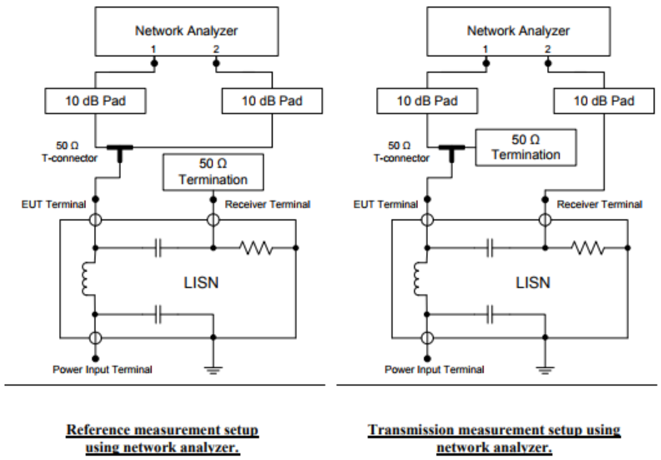
Note that the isolation is not within CISPR 16 limits below 3 MHz, when enabling the 5 Ohm resistor (50Ω // 50µH+5 Ω configuration), as the TBL5016-1 is not equipped with a 250µH pre-filter.

8 Thermal characteristics

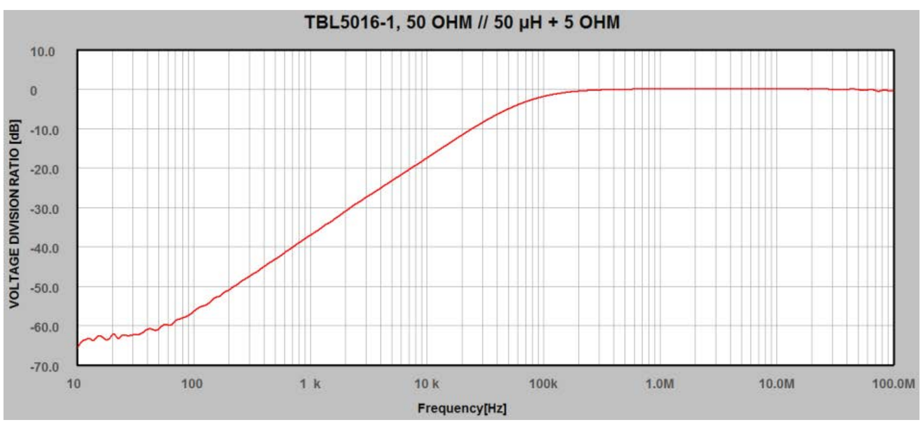


Picture 6: Coil and housing temperature at 16 A DC current

9 Calibration data according to CISPR 16 -1-2 Annex A8



Picture 7: Calibration set up according to CISPR 16-1-2 Annex A.8.

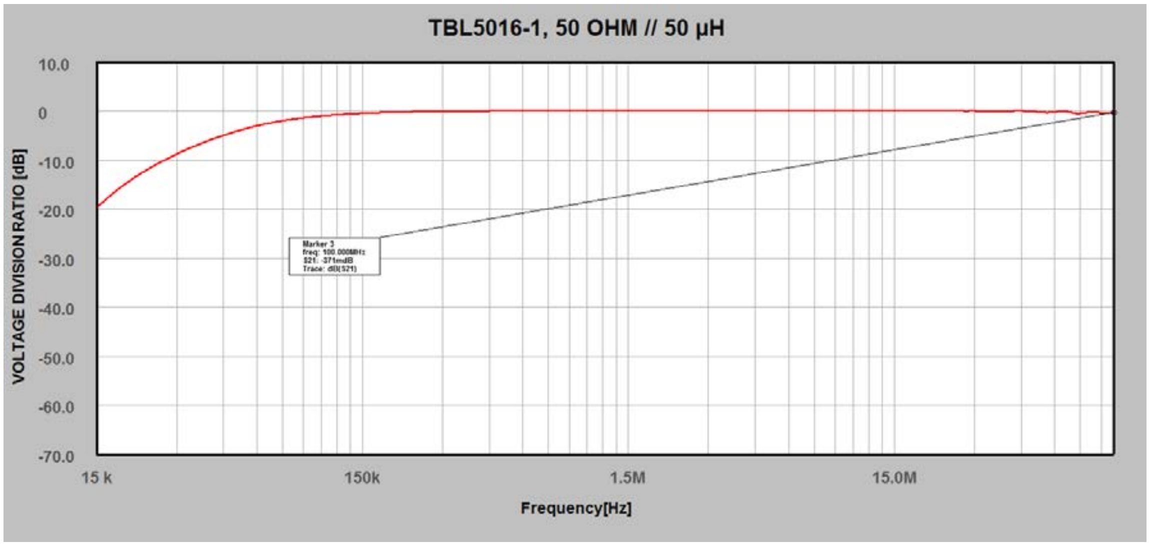


Picture 8: Voltage division ratio DUT terminals to RF connector, 50Ω // 50µH + 5Ω

Frequency [MHz]	Voltage Division Ratio DUT port to RF port [dB]	Frequency [MHz]	Voltage Division Ratio DUT port to RF port[dB]
0.0001	-55.66	2	-0.04
0.0005	-43.21	5	-0.04
0.001	-37.09	7	-0.04
0.005	-23.2	10	-0.03
0.01	-17.48	20	-0.05
0.015	-14.06	30	-0.03
0.03	-8.46	40	-0.03
0.05	-5.01	50	-0.09
0.1	-1.88	60	-0.03
0.15	-0.95	70	-0.11
0.3	-0.27	80	-0.05
0.5	-0.11	90	-0.04
0.75	-0.05	100	-0.03
1	-0.04		

Table 1 - LISN calibration data, voltage division ratio, 50Ω // 50µH + 5Ω

50µH Line Impedance Stabilisation Network



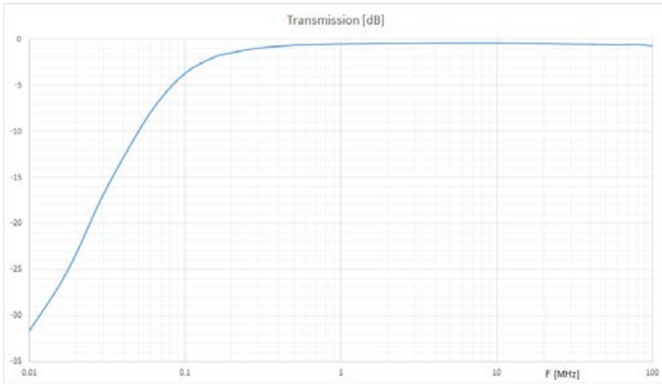
Picture 9: Voltage division ratio DUT terminals to RF connector, 50Ω // 50µH

Frequency [MHz]	Voltage Division Ratio DUT port to RF port [dB]	Frequency [MHz]	Voltage Division Ratio DUT port to RF port[dB]
0.015	-19.86	7	-0.03
0.03	-8.85	10	-0.04
0.05	-4.25	20	-0.06
0.1	-1.19	30	-0.08
0.15	-0.56	40	-0.13
0.3	-0.16	50	-0.21
0.5	-0.07	60	-0.31
0.75	-0.03	70	-0.45
1	-0.03	80	-0.39
2	-0.02	90	-0.48
5	-0.02	100	-0.37

Table 2 - LISN calibration data, voltage division ratio, 50Ω // 50µH

The voltage division ratio is referenced to the PCB edge, not including the Phoenix terminal blocks. The male + female terminal block combination can be considered being equivalent to 5cm of additional wiring in the entire set up.

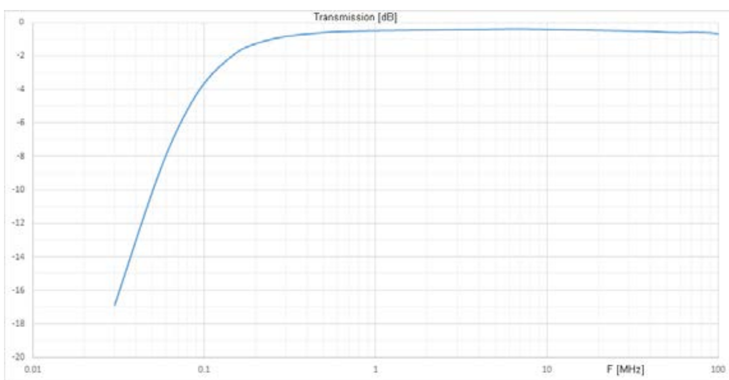
10 Transmission loss



Picture 10: Transmission , DUT terminals to RF connector, 50Ω // 50µH + 5Ω

Frequency [MHz]	Transmission DUT port to RF port [dB]	Frequency [MHz]	Transmission DUT port to RF port[dB]
0.009	-32.76 (-34.89 with High Pass jumpered)	2	-0.45
0.015	-27.13 (-27.53 with High Pass jumpered)	5	-0.39
0.02	-23.22	7	-0.39
0.03	-16.75	10	-0.39
0.05	-10.02	20	-0.46
0.07	-6.39	30	-0.51
0.1	-3.66	40	-0.53
0.15	-1.99	50	-0.57
0.2	-1.43	60	-0.61
0.3	-0.93	70	-0.59
0.5	-0.64	80	-0.56
0.7	-0.56	90	-0.64
1	-0.5	100	-0.71
1.5	-0.47		

Table 3 - LISN calibration data, transmission, 50Ω // 50µH + 5Ω



Picture 11: Transmission , DUT terminals to RF connector, 50Ω // 50µH

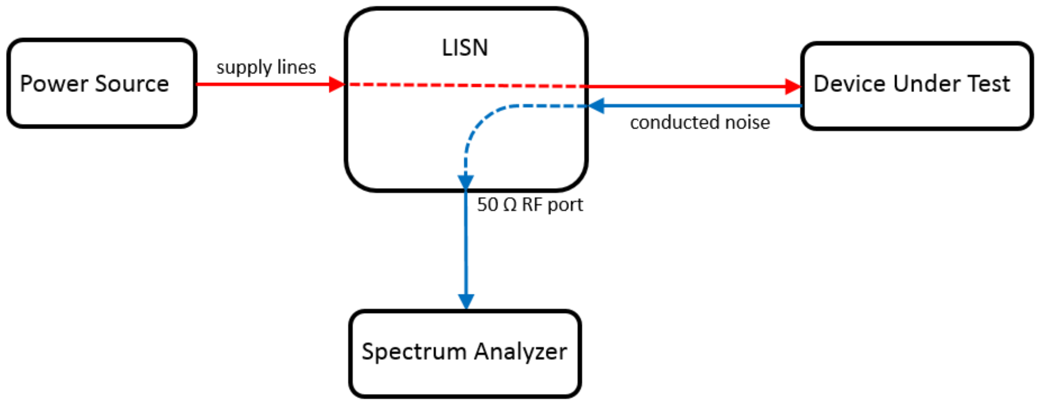
Frequency [MHz]	Transmission DUT port to RF port [dB]	Frequency [MHz]	Transmission DUT port to RF port[dB]
0.03	-16.86	7	-0.39
0.05	-10.03	10	-0.41
0.07	-6.33	20	-0.47
0.1	-3.61	30	-0.51
0.15	-1.89	40	-0.53
0.2	-1.26	50	-0.59
0.3	-0.83	60	-0.61
0.5	-0.6	70	-0.59
0.7	-0.53	80	-0.6
1	-0.49	90	-0.62
2	-0.47	100	-0.67
5	-0.45		

Table 4 - LISN calibration data, transmission, 50Ω // 50µH

11 Application

The abbreviation LISN stands for Line Impedance Stabilisation Network.

- It is a low pass filter typically placed between a power source and the supply terminals of a device under test (DUT).
- It has a feed-through path to supply the DUT with power
- It provides a well-defined RF-impedance to the DUT
- It couples electrical noise generated by the DUT to a 50 Ω RF port, which can be connected to a spectrum analyser or measurement receiver
- It suppresses electrical noise from the supply side towards the DUT
- It suppresses electrical noise from DUT side towards the supply



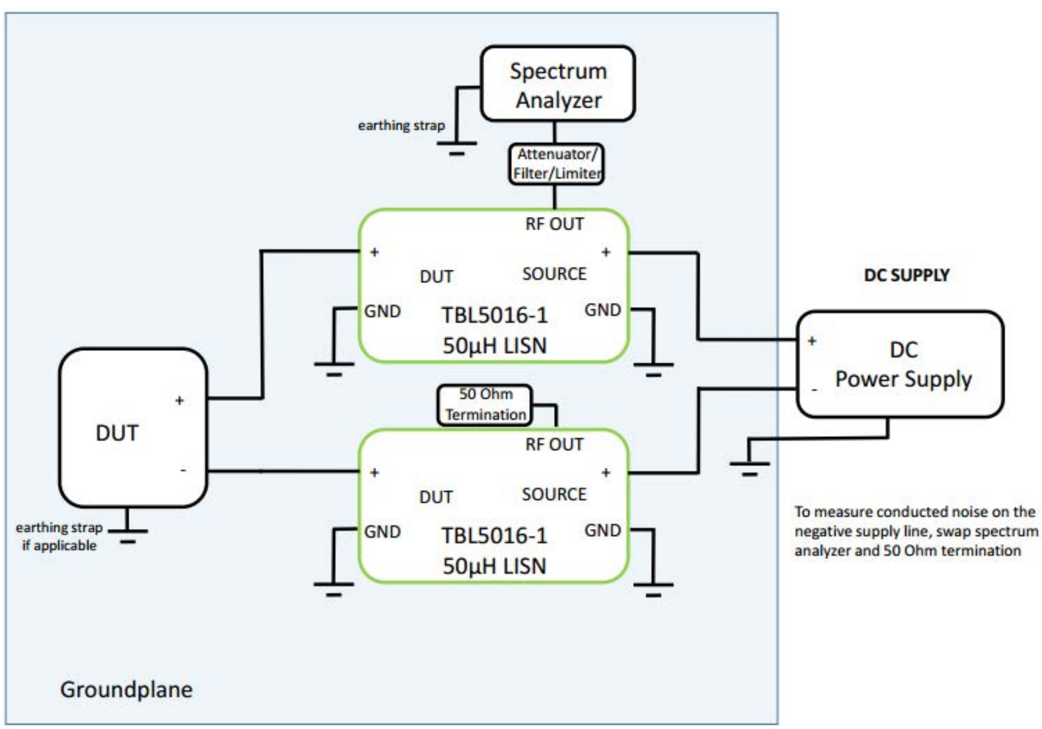
Picture 12: Basic diagram of a conducted emission measurement setup with a LISN

Note that the above basic diagram is simplified. Typically, a standard conformant setup needs two TBL5016-1. One LISN is inserted in the positive supply line and the other LISN is inserted in the negative supply line. Conducted noise measurements have to be carried out on both supply lines. While measuring the noise on one of the supply lines, the RF output of the other LISN must be terminated with 50 Ohm. Similarly, when testing an AC supplied product, one LISN must be inserted in the phase line and the other LISN in the neutral line. Products with 3 phase AC supply can be tested using three (delta configuration) or four (star configuration) TBL5016-1.

11.1 Operation

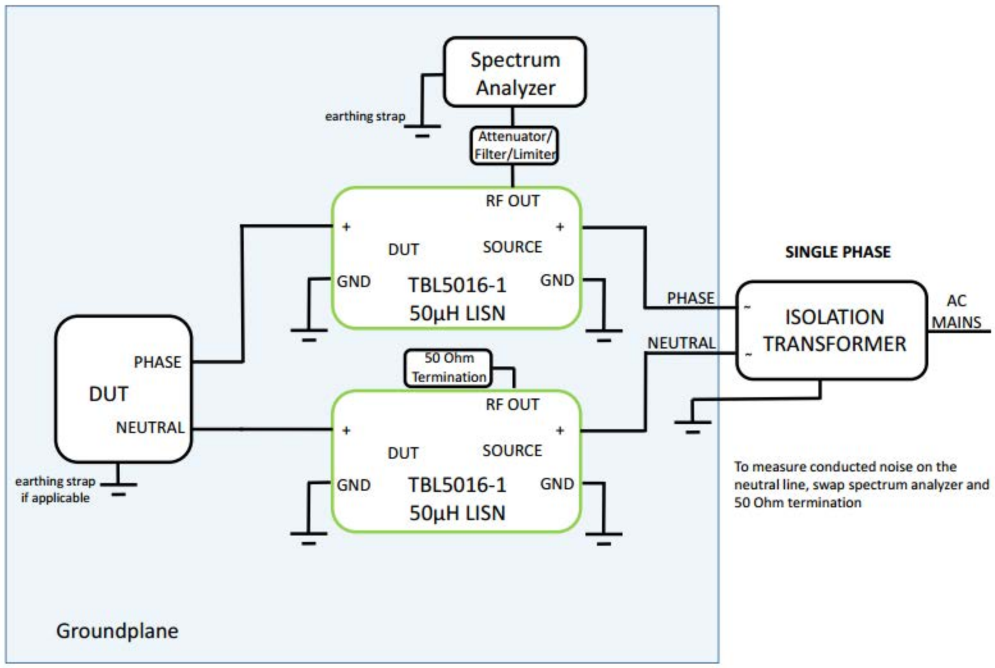
The TBL5016-1 LISN does not contain a 250µH pre-filter. It contains a high pass at the BNC output, but no transient limiter. Consequently 50 Hz harmonics with high amplitude may appear at the RF output and overdrive or even damage the measurement receiver / spectrum analyser. It is highly recommended to use an external filter/attenuator/transient limiter such as the TBFL1 or similar. External attenuators may also be necessary, depending on the behaviour of the DUT.
50 Hz suppression without high pass jumpered: 57 dB
50 Hz suppression with high pass jumpered: 78 dB
Furthermore, the TBL5016-1 LISN has an 8µF capacitor to ground. In AC applications, the capacitor draws a significant amount of blind current, which would trip the mains ground fault switch. Hence, the TBL0550-1 must be supplied through an isolation transformer.
Though the TBL5016-1 LISN is designed for both AC and DC supplied DUTs, a 50µH LISN with 250µH pre-filter is the better choice when testing AC supplied DUTs in most cases. The TBL5016-1 is primarily targeting conducted noise measurements of DC supplied ISM, Telecom or IT products in the range 150 kHz – 30 MHz. Separate measurement of differential and common mode noise can be carried out using two TBL5016-1 in combination with the Tekbox LISN Mate TBLM1.

11.2 Wiring Variants

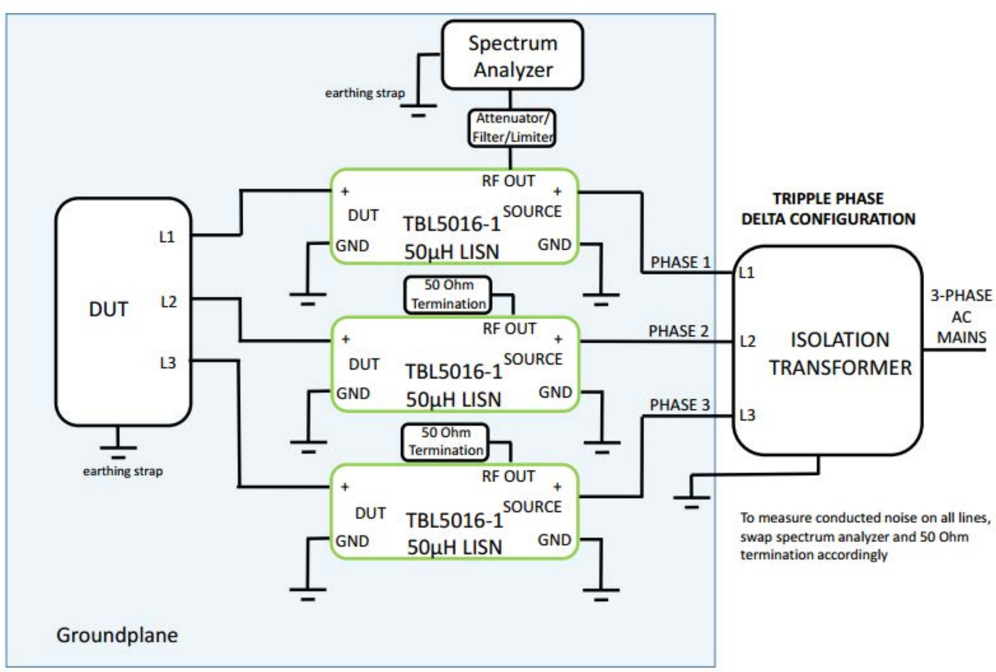


Picture 13: Measurement set up for DC supplied equipment

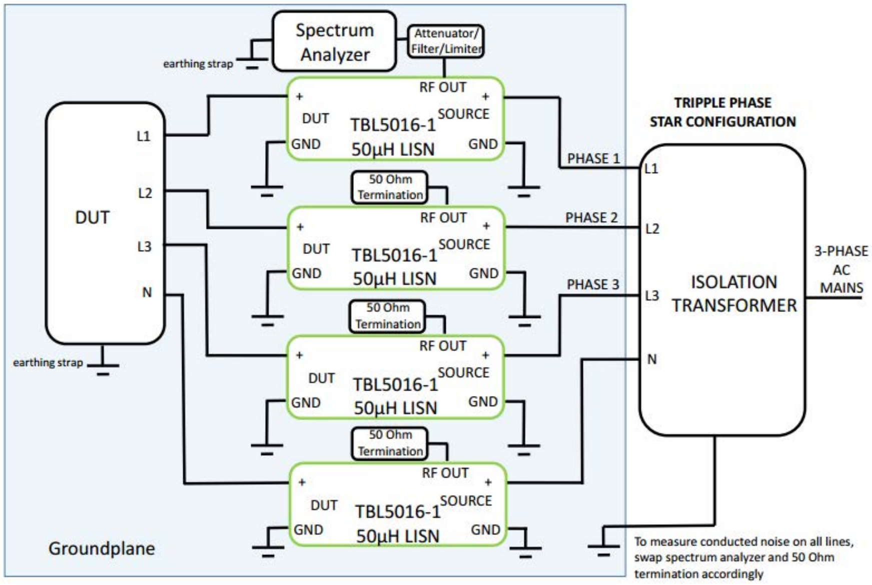
50µH Line Impedance Stabilisation Network



Picture 14: Measurement set up for single phase AC supplied equipment



Picture 15: Measurement set up for triple phase AC supplied equipment in Delta configuration



Picture 16: Measurement set up for triple phase AC supplied equipment in Star configuration

12 Ordering Information

Part Number	Description
TBL5016-1	50µH LISN, 2 pcs. ground brackets, 2pcs. female terminal blocks Phoenix Contact 1967375, 1 pc. 75 cm BNC-male to N-male RG223 cable, 1 pc jumper Harwin D3087-98

By default, the LISN is jumpered to 50Ω // 50µH. In order to configure the LISN to 50Ω // 50µH + 5 Ω, remove the two plastic frames of the housing and then remove the top cover. Remove the supplied jumper from PCB position, marked CON7 in silk screen. In order to jumper the high pass filter, insert the supplied jumper into PCB position CON6.

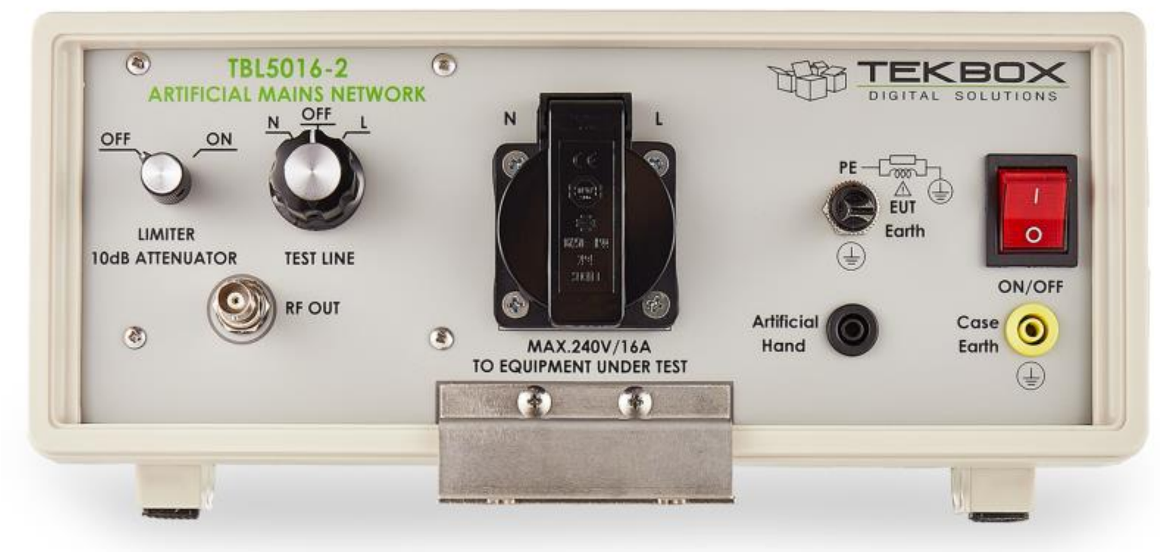
13 History

Version	Date	Author	Changes
V1.0	5.11.2019	Mayerhofer	Creation of the document
V1.1	4.02.2020	Mayerhofer	Graphs updated
V1.2	4.02.2020	Mayerhofer	Chapter 11.2 added
V1.3	27.11.2021	Mayerhofer	Chapter 9 updated
V1.4	28.02.2022	Mayerhofer	Safety information updated
V1.5	7.12.2022	Mayerhofer	Ordering information corrected
V1.6	4.01.2023	Mayerhofer	Chapter 7 and 12 updated
V1.7	11.04.2023	Mayerhofer	Chapters 1, 2, 11 updated

Table 5 – History

TBL5016-2 50µH AC-LISN

The TBL5016-2 is a Line Impedance Stabilization Network for the measurement of line-conducted interference within the range of 9kHz to 30MHz, according to the CISPR 16-1-2 standard. The device is designed for testing single phase, AC-powered equipment with supply voltages up to maximum 240V and 16A. Conducted noise can be measured on the phase and on the neutral conductor. The TBL5016-2 is equipped with a switchable limiter/attenuator and an artificial hand connection.
The device is available with country-specific DUT connectors.



TBL5016-2 , variant with Schuko connector (CEE 7/3)

Features

- Frequency range: 9 kHz to 30 MHz
- Impedance: 50 Ω ‖ (50 µH + 5 Ω)
- Artificial hand: 220 pF + 511 Ω
- Switchable PE: 50 Ω ‖ 50 µH
- Limiter / attenuator: 150 kHz to 30 MHz; 10 dB
- Air core inductors
- Line voltage: max. 240V / 50 – 60 Hz, CAT Ⅱ
- Max. current: 16A @ 23°C
- DUT socket: country specific
- Measurement connector: 50 Ω BNC
- Power connector: IEC 60320 C19
- Operating Temperature Range: +5°C … + 40°C; 5% to 80% RH

Application

- EMC conducted noise measurements

TBL5016-2 50µH AC-LISN

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SAFETY

Operating an AC LISN involves dealing with potentially lethal voltages and high ground leakage currents. The LISN shall only be operated by qualified staff.

Read this manual carefully and be sure to understand the operation of an AC LISN. Make sure that the conducted noise pre – compliance test equipment is set up correctly and that the necessary earth connections are reliably bonded to avoid the risk of lethal electric shocks. The ground brackets must be securely connected to the protective earth conductor available on site, before making any other electrical connection. This connection must not be separated, until the mains supply is disconnected from the LISN setup.

Always supply the LISN only through an isolation transformer.

Take precautions, such as validating the signal amplitude at the RF output prior to connecting a spectrum analyzer or using attenuators and/or limiters to prevent damage to your test receiver or spectrum analyzer.

Do not carry out any modifications or manipulations of the TBL5016-2.

Avoid touching the housing, when operating the LISN at maximum current over extended time. The housing temperature may rise up to 50°C. Turn off the DUT after measurements to avoid unnecessary dissipation.

TBL5016-2 50µH AC-LISN

1 Introduction

1.1 Pre-compliance testing of conducted emissions

Full compliance measurement of AC mains supplied products requires a high end set up consisting of an anechoic or screened chamber, a measurement receiver that complies with the requirements of CISPR 16, a 50µH LISN and a suitable table for the measurement setup. Great effort and cost ensures optimum accuracy and repeatability.

Pre-compliance measurements target to give an approximation of the EMC performance of the Device Under Test at a fraction of the cost of full compliance testing. The measurement receiver can be replaced by a spectrum analyzer with suitable sensitivity, bandwidth and detectors. The advent of affordable spectrum analyzers with EMI IF filters and Quasi-Peak detectors made EMC pre-compliance testing affordable for any company which develops electronic products. Together with test accessories from Tekbox, EMC pre-compliance set-ups cost hardly more than a standard oscilloscope a few years ago.

Eliminate uncertainty before going to the test house for compliance testing. There is hardly anything that can give you a return on invest as quickly as EMC pre compliance test equipment.

1.2 Line Impedance Stabilization Networks

Any LISN (line impedance stabilization network) is basically a kind of filter. A LISN is always inserted between the supply input terminals of the DUT (Device Under Test) and the supply which is used to power the DUT. It presents a defined impedance for the noise which is produced by the DUT and emitted via the supply cables of the Device Under Test. The impedance seen by the RF emissions is 50 Ohms ‖ 50µH which results in 50 Ohms for the most part of the specified frequency range. Only at the lower edge of its bandwidth, the impedance decreases. This impedance curve is specified in the corresponding test standards such as CISPR 16-1-2. Having a defined impedance for the emissions at the DUT terminals eliminates any influence of the power source impedance. Consequently, the measured amplitudes of the noise spectrum become independent of the power source characteristics:

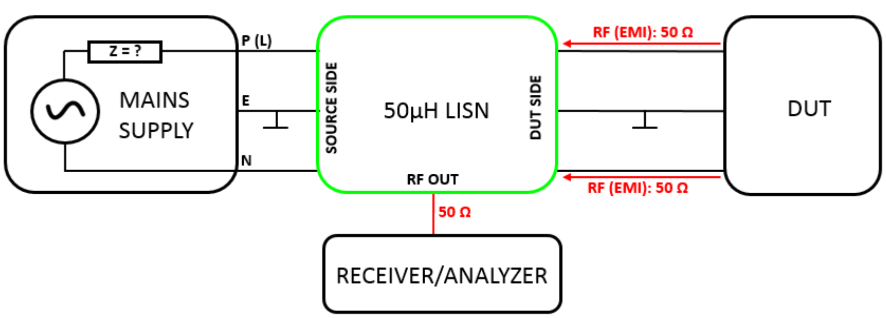

Figure 1 – Basic AC LISN set up: impedance levels

Furthermore, the AC LISN attenuates noise originating from the incoming mains supply towards the Receiver/Analyzer and DUT.

TBL5016-2 50µH AC-LISN

1.3 RF output

The RF output section is AC coupled to either the phase or neutral line. The path can be selected by a rotary switch at the front panel. The RF section also contains an attenuator/limiter and a high pass filter.

Purpose of the high pass filter is the attenuation of harmonics originating from the mains supply. The attenuator/limiter protects the measurement receiver / spectrum analyzer input from high amplitude pulse transients. The phase and neutral line can be the source of such transients, in particular those produced on turning off the DUT. Consequently it is highly advised to disconnect the spectrum analyzer via cable or line selector switch in OFF position while turning on/off the DUT. Use external attenuators and the built in attenuator/limiter to check the lower frequency range for spurious with high power until you are sure, that the spurious levels are not exceeding the maximum input level range of the spectrum analyzer. For pre-compliance measurements the Attenuator/Limiter should be turned off then, as the limiter is a non-linear component which can create intermodulation and falsify the measurement result. Use external attenuators instead, if ncessary

WARNING: Ensure that the spectrum analyzer RF input is disconnected when powering on or powering off the DUT. Leave the attenuator always turned on, if the DUT switches inductive loads during operation or in case of any uncertainty concerning the DUT characteristics. After ensuring that the spectrum analyzer is not over loaded, turn the Attenuator/Limiter Off or use external attenuators to avoid potential intermodulation products creating a measurement error.

1.4 Informative schematic

The picture below shows the basic topology and the values of the main components of the TBL5016-2 AC LISN. A rotary line selector switch connects the RF output to either Line, Ground or Neutral. A combined 10dB attenuator / 150 kHz highpass filter / limiter can be inserted into the RF path with another rotary switch.

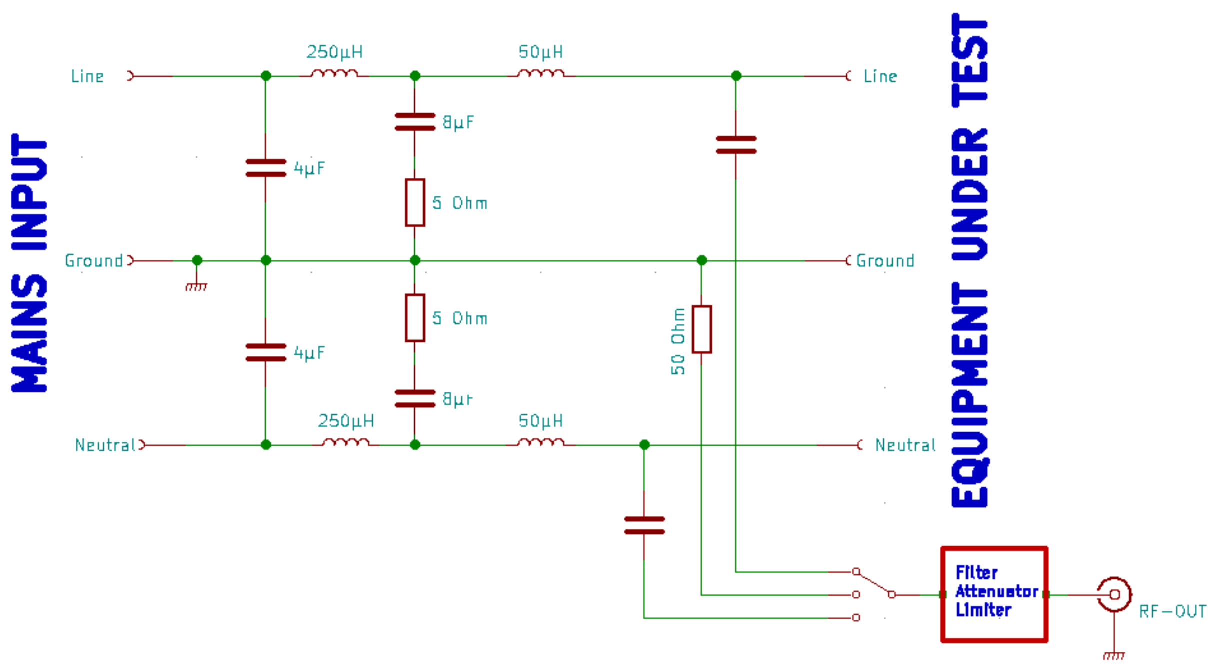

Figure 2 – AC LISN, informative schematic

TBL5016-2 50µH AC-LISN

NOTE the high capacitor values, which cause considerable blind current at 50Hz/60Hz line voltages. Direct connection to the mains outlet would cause tripping of the ground fault switch. Refer to the next chapter on how to set up the AC LISN in a standard laboratory environment.

1.5 Laboratory set up

The DUT shall be isolated and elevated from the ground plane. The spectrum analyzer shall measure the conducted emissions on both line and neutral.

The value of the parallel combination of the capacitors is 12µF from line and neutral to ground. This causes around 0.75A flowing into the earth connection and would trip the ground fault switch. Hence, an insulation transformer is required for any mains supply which is protected by a residual current device or ground fault (earth leakage) circuit breaker and good grounding is essential for safety.

For the exact details of the set up and for the limits of conducted emissions refer to the CISPR 16 and other relevant applicable standards.

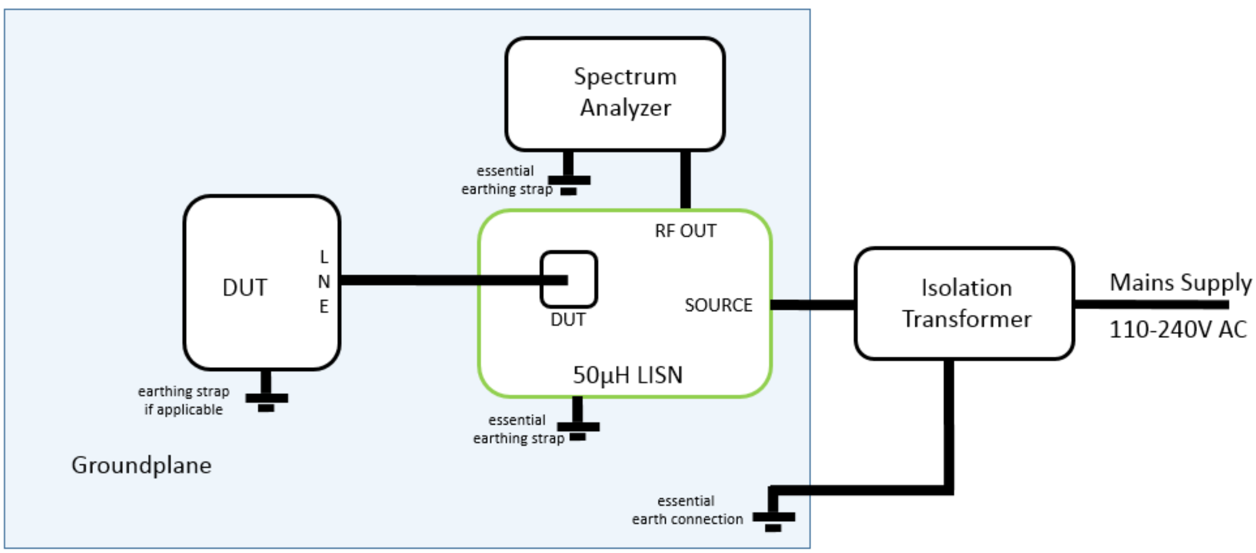

Figure 3 – Conducted noise pre-compliance measurement setup

SAFETY: Ensure that all required earth connections are reliably bonded and that the isolation transformer can supply the required load current.

1.6 Ground plane

Any voltage measurement must be made against a common circuit node which can be referred to as the “zero volt” reference. In order to provide a low impedance zero volt reference for RF measurements, a metal sheet must be provided as ground plane. All ground straps between equipment and ground plane shall be as short as possible and fastened with screws. Exact details on the size of the ground plane and the arrangement of the equipment and interconnecting cables are described in the applicable standards.

In a pre-compliance test set up, as a rule of thumb, the size of the ground plane shall be large enough to accommodate all involved equipment and exceed at least 10cm each side.

TBL5016-2 50µH AC-LISN

2 TBL5016-2 specifications

2.1 Conformity

The TBL5016-2 is compliant with CISPR 16-1-2.

In line with the CISPR 16-1-2 standard compliant design and setup specification, the TBL5016-2 V-LISN exhibits high ground leakage currents and non-standard isolation and consequently cannot meet the safety requirements of EN 61010-1.

Furthermore CISPR 16-1-2 specifies high capacitance values for the capacitors from Line and from Neutral to Ground (PE). These capacitance values are not commercially available in Y2 rating and are implemented using AC rated capacitors with suitable voltage rating.

In order to prevent the danger of lethal electric shock, the operator is responsible for ensuring protective measures in line with IEC 60364-4-41 and IEC 60364-5-54 and to follow all safety related information of this manual.

2.2 Safety

In order to ensure safe operations, the user must follow all safety relevant information of this manual. All housing parts are connected with the earth conductor of the power cable, DUT socket, yellow banana receptacle and with the ground strap of the housing. It is not allowed to carry out any modifications or manipulations of the TBL5016-2. The TBL5016-2 shall be operated by qualified laboratory staff only.

2.3 Specifications

- Frequency range: 9 kHz to 30 MHz
- Impedance: 50 Ω ‖ (50 µH + 5 Ω)
- Artificial hand: 220 pF + 511 Ω
- Switchable PE: 50 Ω ‖ 50 µH
- Limiter / attenuator: 150 kHz to 30 MHz; 10 dB
- Line voltage: max. 240V / 50 – 60 Hz
- Max. current: 16A @ 23°C; Fuses: 16A, slow
- DUT socket: country specific, note country specific DUT socket limits (see chapter 4)
- Measurement connector: 50 Ω BNC
- Power connector: IEC 60320 C19
- Operating Temperature Range:
- +5°C … + 40°C; 5% to 80% RH

2.4 Supply voltage

The TBL5016-2 does not require any particular voltage settings. It can be operated with any supply voltage which does not exceed 240V, 50Hz/60Hz.

TBL5016-2 50µH AC-LISN

2.5 Front Panel

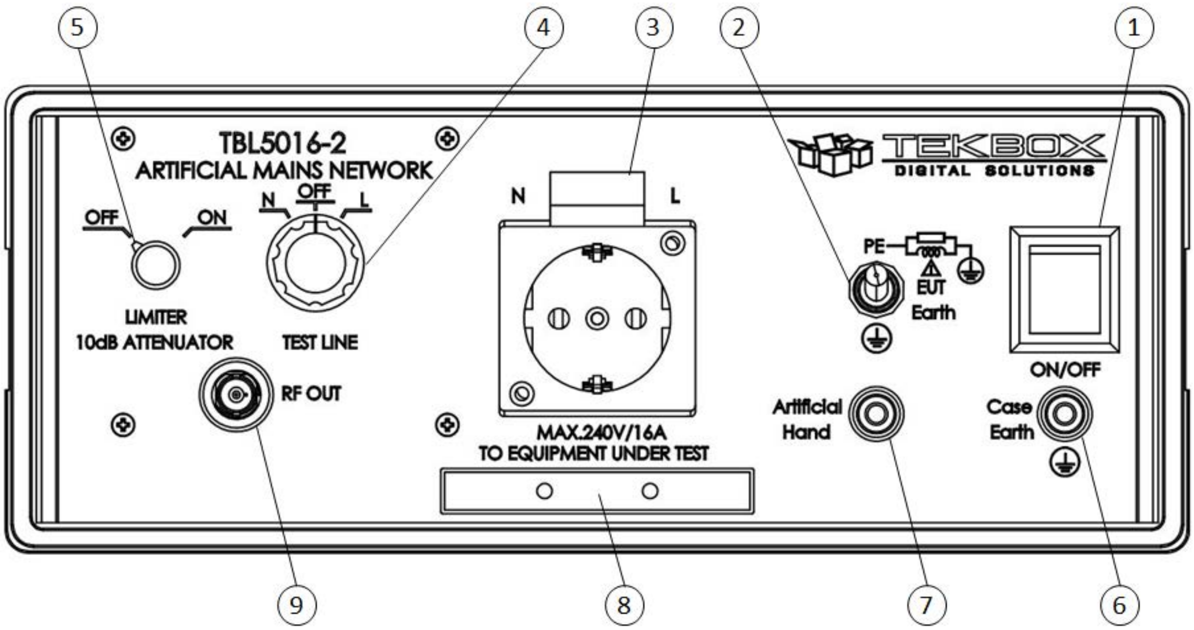

Figure 4 – Front panel layout

1) Mains switch
2) Protective Earth switch to connect DUT earth either directly to case earth, or via 50µH ‖ 50 Ohm
3) DUT socket, country specific
4) RF path selection, N (neutral), OFF, L (phase)
5) Limiter + 10 dB attenuator + 150kHz high pass filter switch
6) Auxiliary case earth connector, safety banana jack
7) Artificial hand connector, safety banana jack
8) Ground plane bracket
9) 50 Ω RF output, BNC jack

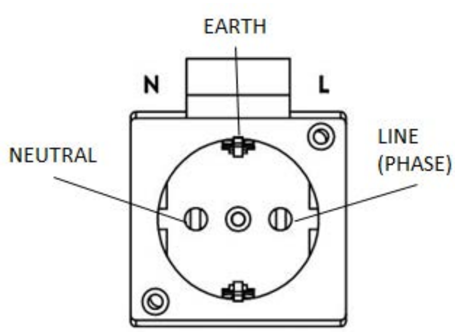

*Figure 5 – DUT connector, pin assignment with reference to the rear power connector *)*

*) Provided that the TBL5016-2 is correctly connected to the mains power outlet

TBL5016-2 50µH AC-LISN

2.6 Rear Panel

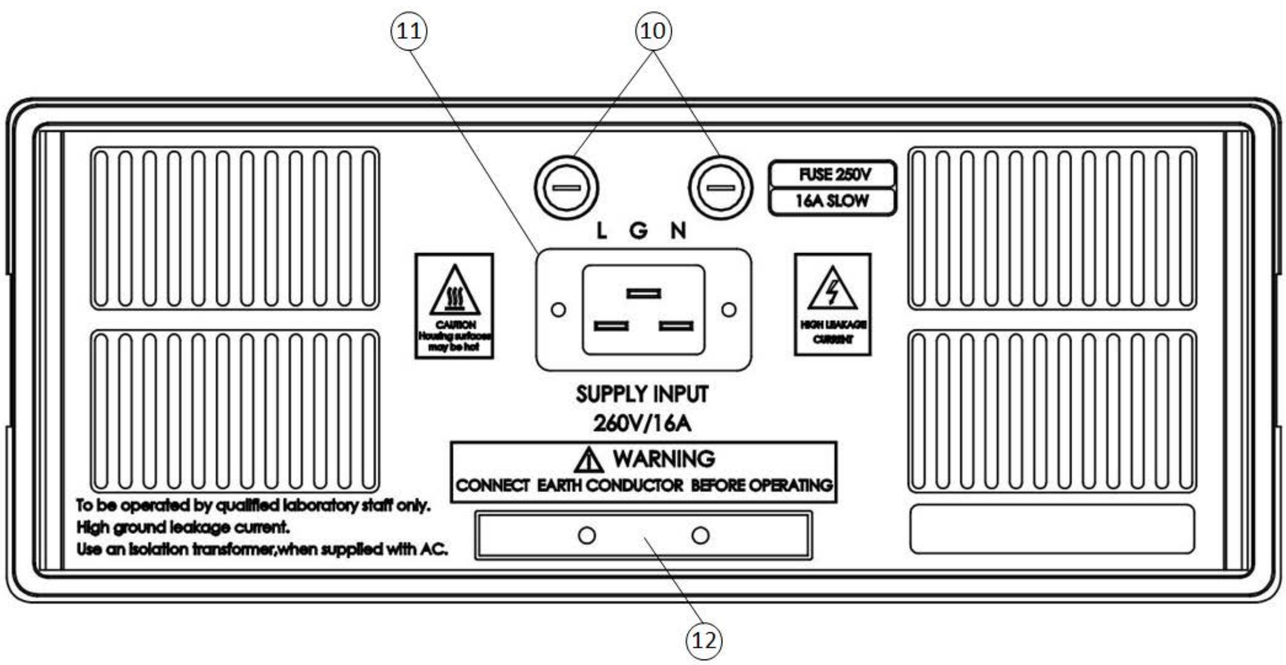

Figure 6 – Rear panel layout

10) Power socket: IEC 60320 C19
11) Fuses, 16A, slow
12) Ground plane bracket

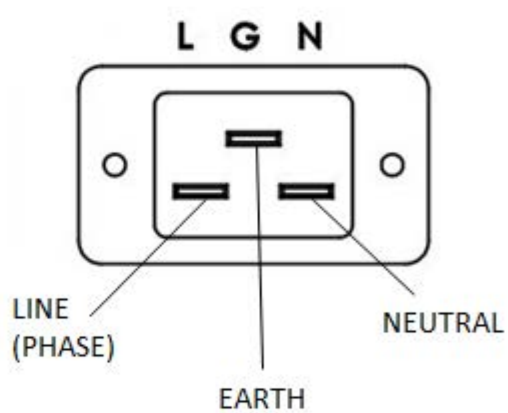

*Figure 7 – Mains connector, pin assignment *)*

*) Requires correct connection of the TBL5016-2 to the mains power outlet (-> Schuko orientation)

TBL5016-2 50µH AC-LISN

2.7 Impedance

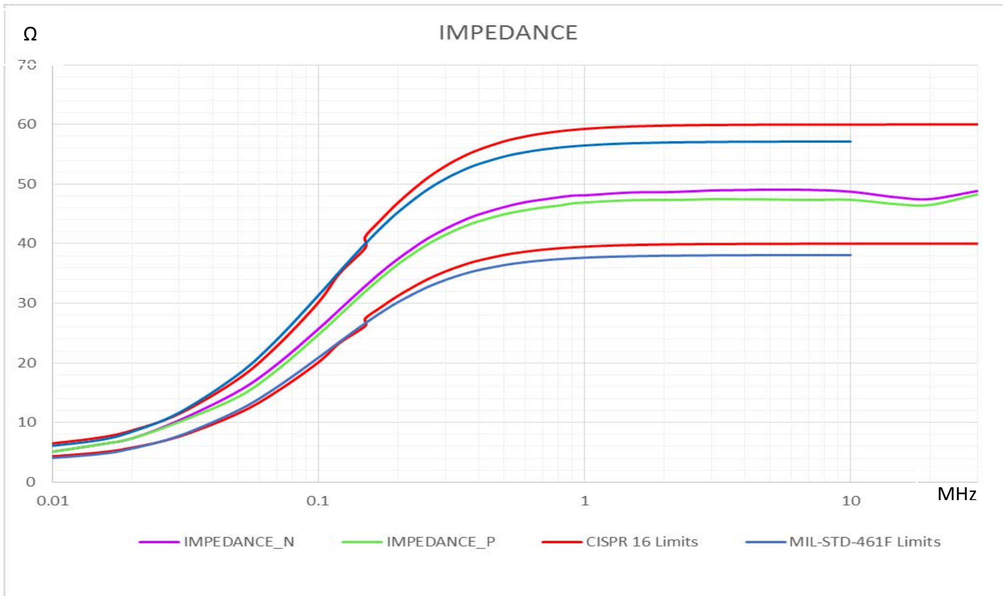

*Figure 8 – Impedance vs. frequency at DUT terminals**

*) Impedance measured at PCB edge. The wiring from DUT connector to the PCB can be considered as an additional 11 cm of DUT supply cable length.

2.8 Phase

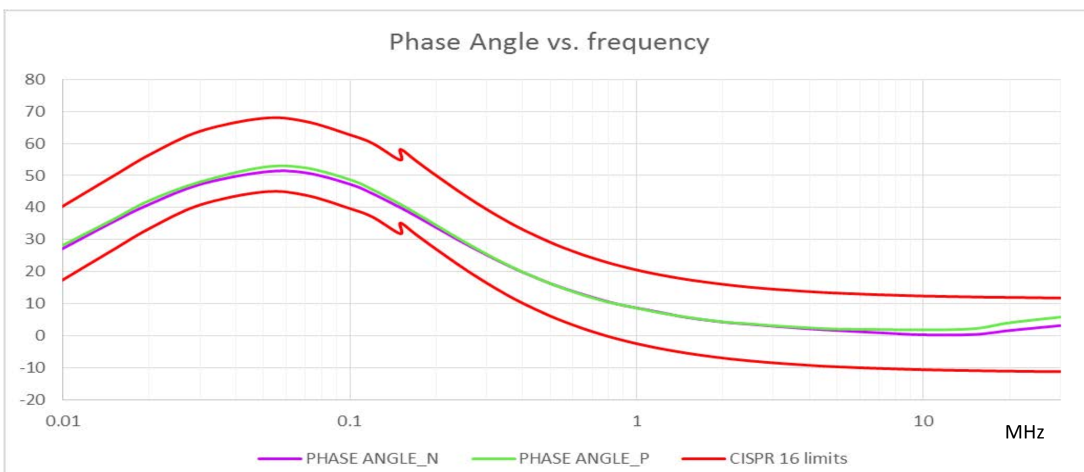

*Figure 9– Phase angle vs. frequency at DUT terminals**

*) Phase angle measured at PCB edge. The wiring from DUT connector to the PCB can be considered as an additional 11 cm of DUT supply cable length

TBL5016-2 50µH AC-LISN

2.9 Frequency response, S21 from DUT port to RF port

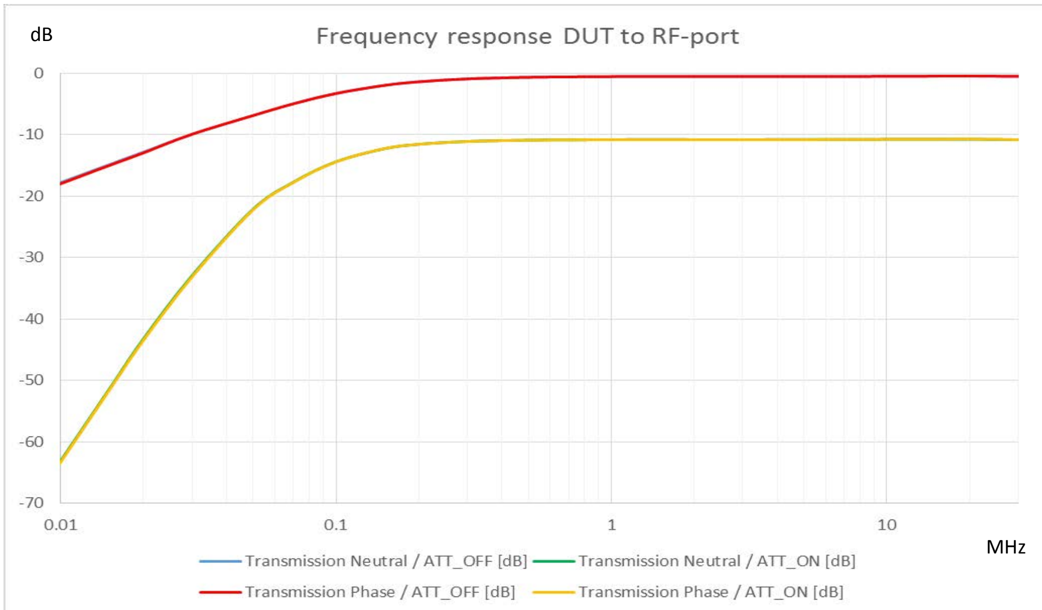

Figure 10– Frequency response 9kHz to 300MHz, DUT connector Phase/Neutral to RF connector

Frequency [MHz]	Transmission Neutral / ATT_OFF [dB]	Transmission Neutral / ATT_ON [dB]	Transmission Phase / ATT_OFF [dB]	Transmission Phase / ATT_ON [dB]
0.009	-18.53	-66.12	-18.74	-66.31
0.015	-14.87	-51.43	-15.01	-51.59
0.02	-12.81	-43.21	-12.95	-43.42
0.03	-9.93	-32.95	-9.91	-33.14
0.05	-6.87	-22.12	-6.87	-22.21
0.07	-4.95	-17.72	-4.97	-17.76
0.1	-3.28	-14.39	-3.28	-14.41
0.15	-1.96	-12.27	-1.96	-12.26
0.2	-1.37	-11.55	-1.38	-11.55
0.3	-0.91	-11.09	-0.91	-11.1
0.5	-0.65	-10.88	-0.65	-10.89
0.75	-0.57	-10.83	-0.57	-10.82
1	-0.54	-10.81	-0.53	-10.8
1.25	-0.52	-10.78	-0.52	-10.79
2.5	-0.52	-10.79	-0.52	-10.81
5	-0.51	-10.78	-0.51	-10.79
7.5	-0.51	-10.77	-0.51	-10.78
10	-0.49	-10.75	-0.49	-10.75
20	-0.46	-10.73	-0.44	-10.71
30	-0.52	-10.82	-0.49	-10.79

*Table 1 – Frequency response 9kHz to 30MHz, DUT connector Phase/Neutral to RF connector**

*) measured from PCB edge (RF board terminals) to BNC

TBL5016-2 50µH AC-LISN

2.10 Calibration data according to CISPR 16 -1-2 Annex A8

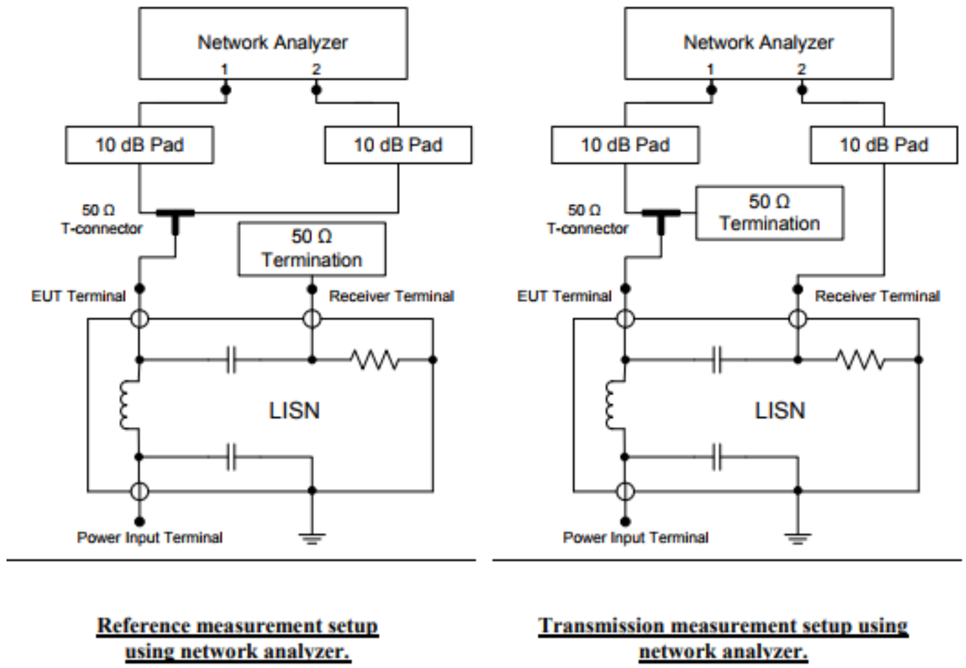

Figure 11 – Calibration set up according to CISPR 16-1-2 Annex A.8.

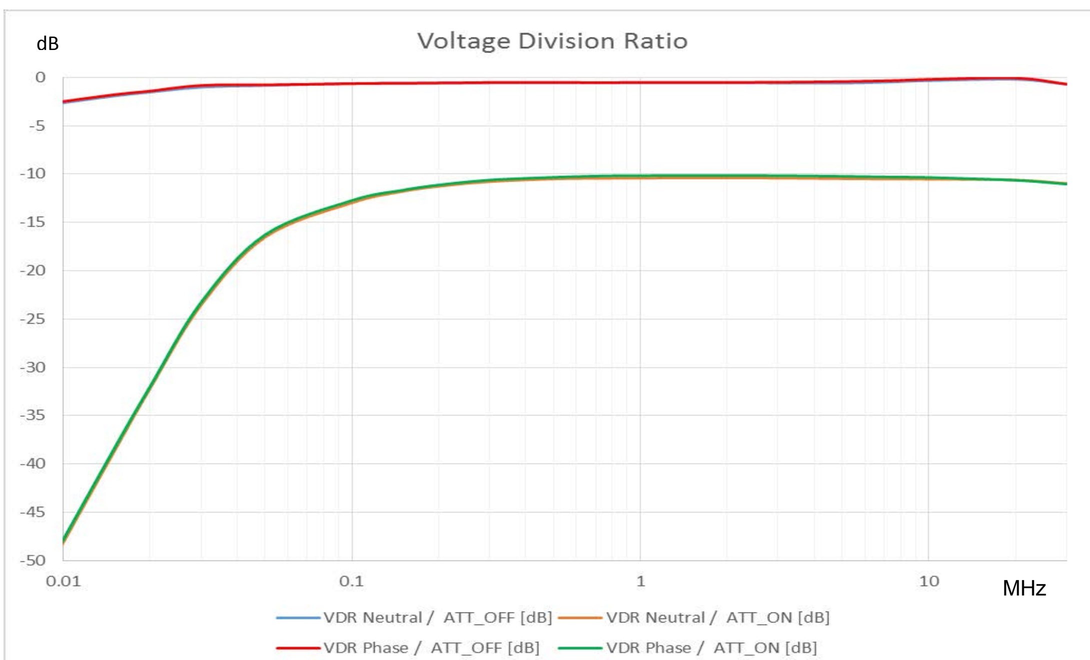

Figure 12 – Voltage Division Ratio versus frequency

TBL5016-2 50µH AC-LISN

Frequency[MHz]	VDR Neutral / ATT_OFF [dB]	VDR Neutral / ATT_ON [dB]	VDR Phase / ATT_OFF [dB]	VDR Phase / ATT_ON [dB]
0.009	-2.81	-50.54	-2.67	-50.25
0.015	-1.93	-38.69	-1.79	-38.42
0.02	-1.53	-32.15	-1.41	-31.97
0.03	-1.02	-23.55	-0.83	-23.29
0.05	-0.84	-16.53	-0.77	-16.29
0.1	-0.63	-12.98	-0.65	-12.74
0.15	-0.59	-11.8	-0.61	-11.67
0.2	-0.59	-11.27	-0.58	-11.13
0.3	-0.58	-10.79	-0.53	-10.62
0.5	-0.57	-10.51	-0.53	-10.34
0.75	-0.57	-10.44	-0.54	-10.2
1	-0.56	-10.42	-0.53	-10.17
2.5	-0.58	-10.41	-0.51	-10.16
5	-0.59	-10.48	-0.43	-10.24
7.5	-0.47	-10.52	-0.33	-10.31
10	-0.34	-10.53	-0.21	-10.36
20	-0.21	-10.62	-0.07	-10.65
30	-0.71	-10.97	-0.69	-11.04

*Table 2, TBL5016-2 LISN voltage division ratio, calibration data**

*) measured from PCB edge (RF board terminals) to BNC

2.11 Isolation

Limit according
CISPR 16-1-2

Neutral
Phase

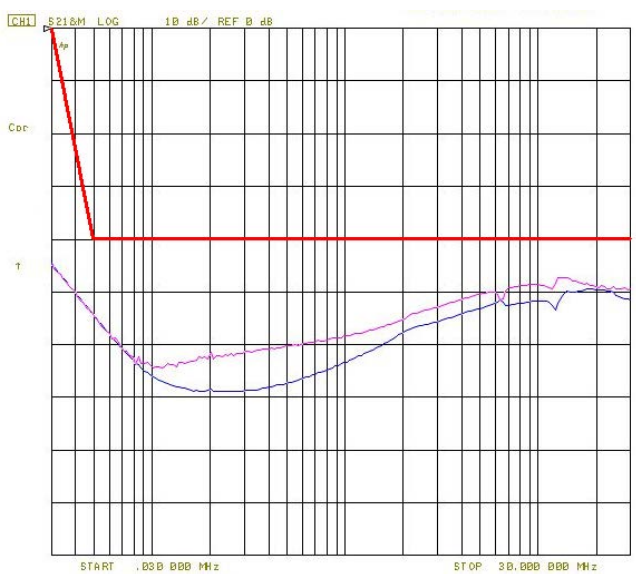

Figure 13: LISN Isolation, Source to RF out

The isolation is measured between the mains (source) connector and RF port, with the DUT port terminated with 50 Ohm.

TBL5016-2 50µH AC-LISN

2.12 Thermal characteristics

Avoid touching the housing, when operating the LISN at maximum current over extended time. Typical conducted noise measurements take less than 10 minutes per line. Turn off the DUT after measurements to avoid unnecessary dissipation.

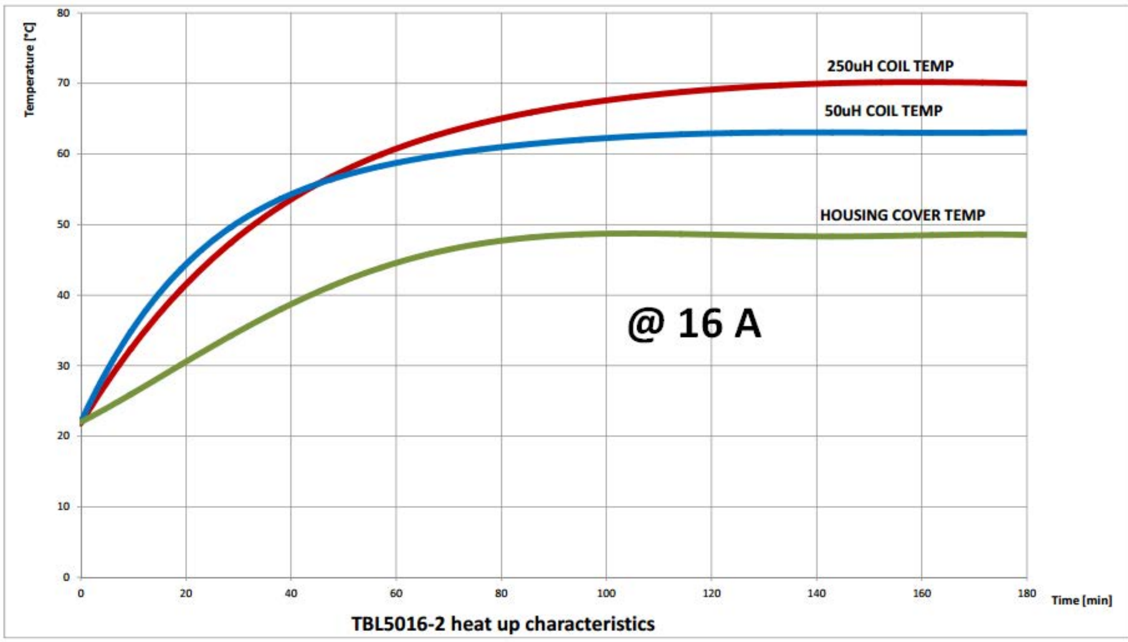

Figure 14: Coil and housing temperature at 16 A DUT current @ 22 °C ambient temperature

2.13 Protection

The TBL5016-2 offers several levels of protection to prevent surges appearing at the input of the measurement receiver or analyzer.

Both the neutral line and phase line are equipped with a 275V varistor to ground. The RF path is always protected by a 50V gas discharge tube.

When the attenuator/limiter switch is in "ON" position, a 10dB attenuator and a Schottky diode limiter offer additional protection. Furthermore, the attenuator/limiter path contains a 150kHz high pass filter.

TBL5016-2 50µH AC-LISN

2.14 Artificial hand

When performing conducted noise measurements with devices which are held in hand, the artificial hand network mimics the influence of the human hand. Examples for such devices are power tools, hair driers, kitchen tools and similar equipment.

Insulated housing sections that are touched by the hand when operating the equipment are covered with metal foil and connected to the artificial hand jack.

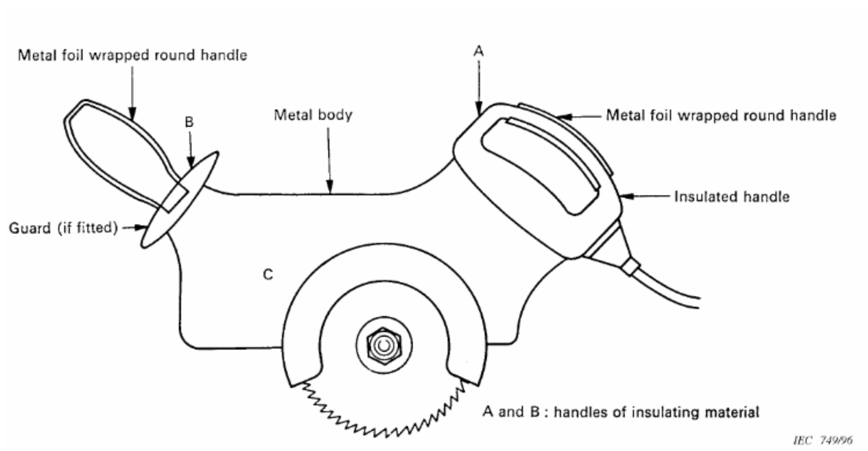

Figure 15 – Example from CISPR 16, portable electric saw with artificial hand

3 Operation checklist

- Setup the isolation transformer, TBL5016-2 , DUT and spectrum analyzer according to Figure 3.
- Before powering the isolation transformer, measure the connectivity between each equipment chassis and ground plane.
- Ensure that the supply cable of the isolation transformer, the supply cable of the LISN, the supply cable of the spectrum analyzer and if applicable the supply cable of the DUT contain a ground conductor.
- Ensure that the line selection switch of the TBL5016-2 is set to “OFF”.
- Ensure that the Protective Earth switch is set to direct ground position
- Ensure that the Limiter/Attenuator switch of the TBL5016-2 is in “ON” position.
- Ensure that the power switch of the TBL5016-2 is in “OFF” position.
- Ensure that the DUT power switch is in “OFF” position.
- Power on the isolation transformer
- Power on the spectrum analyzer, set frequency, bandwidth, amplitude etc.
- Power on the TBL5016-2
- Power on the DUT
- Set the line selection switch to “L” or “N” to carry out the conducted noise measurements. Disengage the Limiter/Attenuator for better sensitivity and in order to avoid potential intermodulation.
- After finishing the measurement, proceed in reverse order. Take special care to set the limiter/attenuator to “ON” and the line selection switch to “OFF” before powering off the DUT.

TBL5016-2 50µH AC-LISN

4 Ordering Information

Part Number	**Description**
TBL5016-2 -EU	50µH LISN with Schuko socket (CE7/3, 16A), 16A cold appliance cable, 75 cm coaxial cable BNC-male / N-male/RG223
TBL5016-2 -US	50µH LISN with US socket (NEMA 5-15, grounded, type B, 15A), 15A cold appliance cable, 75 cm coaxial cable BNC-male / N-male/RG223
TBL5016-2 -AU	50µH LISN with Australian socket (AS/NZS 3112:201, 15A), 15A cold appliance cable, 75 cm coaxial cable BNC-male / N-male/RG223
TBL5016-2 -UK	50µH LISN with English socket (BS1363, 13A), 16A cold appliance cable, 75 cm coaxial cable BNC-male / N-male/RG223
TBL5016-2 -xx	Any other socket requirements upon customer request will have 2-3 weeks lead time
TBSP-16-Schuko	Rewirable 16A Schuko (CEE 7/4) plug for extension cables
TBLCAC-16-Schuko	Additional cold appliance cable, 16A, 1.8m, CE7/4 to C20

Table 3– Ordering Information

Note the maximum current limitations of country specific DUT sockets and cold appliance cables. If you want to make full use of the 16A maximum current rating, order a TBL5016-2-EU plus a rewirable Schuko plug which can be used to make a 16A extension cable for the DUT.

5 History

Version	Date	Author	Changes
V1.0	18.6.2020	Mayerhofer	Creation of the document
V1.1	7.9.2020	Mayerhofer	Information on country specific DUT connectors added, version number corrected
V1.2	24.6.2021	Mayerhofer	Table4 updated (RG223 added)
V1.3	16.2.2022	Mayerhofer	Chapter 4 corrected
V1.4	28.2.2022	Mayerhofer	Updated safety information

Table 4– History

TEKBOX DIGITAL SOLUTIONS

TBL5016-3 50µH AC-LISN

The TBL5016-3 is a Line Impedance Stabilization Network for the measurement of line-conducted interference within the range of 9 kHz to 30MHz, according to the CISPR 16-1-2 standard. The device is designed for testing 3-phase and single phase, AC-powered equipment with supply voltages up to maximum 450V/260V and 16A. Conducted noise can be measured on each phase and on the neutral conductor. The TBL5016-3 has separate RF outputs for each phase and neutral and consequently can be coupled with the TBLM1 to split the emissions in its common mode and differential mode components. The TBL5016-3 has no integrated high pass filter at the RF outputs, but comes with an external 9 kHz coaxial high pass instead.
The single phase DUT socket is available in country-specific variants.

TBL5016-3, variant with Schuko connector (CEE 7/3) socket

Features

- Frequency range: 9 kHz to 30 MHz
- Impedance: 50 Ω ‖ (50 µH + 5 Ω)
- Artificial hand: 220 pF + 511 Ω
- Switchable PE: 50 Ω ‖ 50 µH
- 250µH pre-filter
- Separate RF outputs for each line and neutral
- Air core inductors
- Line voltage: max 540V/260V / 50 – 60 Hz
- Max. current per line and neutral: 16A @ 23°C each
- 3-phase DUT socket: CEE / IEC60309, 3L+N+PE, 16A, female
- Single phase DUT socket: country specific
- Power connector: CEE / IEC60309, 3L+N+PE, 16A, male
- Measurement connectors: 50 Ω BNC
- External 9 kHz high pass filter, N-male / N-female
- Operating Temperature Range: +5°C … + 40°C; 5% to 80% RH

Application

- EMC conducted noise measurements

Factory 4, F4, Lot I-3B-1 | Saigon Hi-Tech Park | Tan Phu Ward, District 9 | Ho Chi Minh City

TBL5016-3 50µH AC-LISN

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TBL5016-3 50µH AC-LISN

SAFETY

Operating an AC LISN involves dealing with potentially lethal voltages and high ground leakage currents. The LISN shall only be operated by qualified staff.

Read this manual carefully and be sure to understand the operation of an AC LISN. Make sure that the conducted noise pre – compliance test equipment is set up correctly and that the necessary earth connections are reliably bonded to avoid the risk of lethal electric shocks. The ground strap must be securely connected to the protective earth conductor available on site, before making any other electrical connection. This connection must not be separated, until the mains supply is disconnected from the LISN setup.

Always supply the LISN only through an isolation transformer.

Always use the LISN together with the supplied 9 kHz high pass attached to the input of the spectrum analyzer / EMI receiver.

Take precautions, such as validating the signal amplitude at the RF output prior to connecting a spectrum analyzer or using attenuators and/or limiters to prevent damage to your test receiver or spectrum analyzer.

Do not carry out any modifications or manipulations of the TBL5016-3.

Avoid touching the housing, when operating the LISN at maximum current over extended time. The housing temperature may rise up to 50°C. Turn off the DUT after measurements to avoid unnecessary dissipation.

TBL5016-3 50µH AC-LISN

1 Introduction

1.1 Pre-compliance testing of conducted emissions

Full compliance measurement of AC mains supplied products requires a high end set up consisting of an anechoic or screened chamber, a measurement receiver that complies with the requirements of CISPR 16, a 50µH LISN and a suitable table for the measurement setup. Great effort and cost ensures optimum accuracy and repeatability.

Pre-compliance measurements target to give a very close approximation of the EMC performance of the Device Under Test at a fraction of the cost of full compliance testing. The measurement receiver can be replaced by a spectrum analyzer with suitable sensitivity, bandwidth and detectors. The advent of affordable spectrum analyzers with EMI IF filters and Quasi-Peak detectors made EMC pre-compliance testing affordable for any company which develops electronic products. Together with test accessories from Tekbox, EMC pre-compliance set-ups cost hardly more than a standard oscilloscope a few years ago.

Eliminate uncertainty before going to the test house for compliance testing. There is hardly anything that can give you a return on invest as quickly as EMC pre compliance test equipment.

1.2 Line Impedance Stabilization Networks

A LISN is a device inserted between a power source and the supply terminals of a DUT (Device Under Test). It presents a defined impedance for the emissions produced by the DUT and emitted via the supply cables of the Device Under Test. The impedance seen by the RF emissions is 50 Ohm ‖ 50µH + 5 Ohm which results in 50 Ohms for the most part of the specified frequency range. Only at the lower edge of its bandwidth, the impedance decreases. This impedance curve is specified in the corresponding test standards such as CISPR 16-1-2. Having a defined impedance for the emissions at the DUT terminals eliminates any influence of the power source impedance. Consequently, the measured amplitudes of the noise spectrum become independent of the power source characteristics:

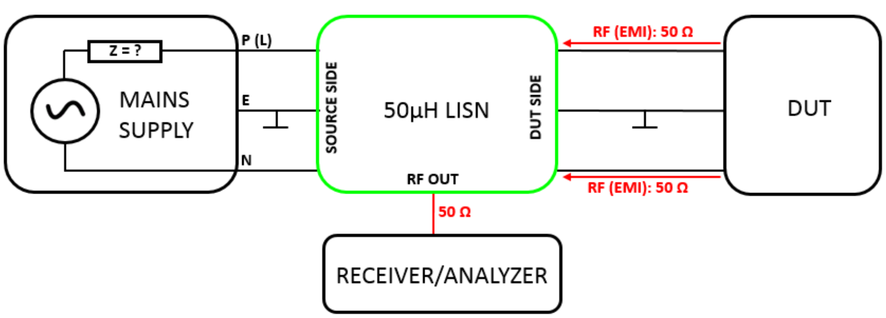


Figure 1 – Basic AC LISN set up: impedance levels

Furthermore, the AC LISN attenuates noise originating from the incoming mains supply towards the Receiver/Analyzer and DUT. For detailed information, refer to the LISN overview document, which can be downloaded from the Tekbox website.

TBL5016-3 50µH AC-LISN

1.3 RF output

The TBL5016-3 provides separate RF outputs for L1, L2, L3 and Neutral. Consequently, a complete conducted emission measurement consists of four separate measurements in case of a DUT supplied in Y-configuration, three separate measurements in case of DUTs supplied in Delta-configuration, or two separate measurements in case of single phase supplied DUTs. L1 is connected both to the 3-phase DUT socket, as well as to a country specific single phase socket to simplify connectivity of single phase supplied products. When measuring conducted emissions on any of the four paths, the three unused RF outputs have to be terminated with 50 Ohm.

As the TBL5016-3 provides separate outputs for each path, it can be connected to a TBLM1 LISN mate in order to split the output signal into its common mode and differential mode components.

The TBL5016-3 RF paths do not provide any built in attenuators / filters / limiters.

Always connect the supplied TBHPF1-9kHz low pass filter to the RF input of your spectrum analyzer / measurement receiver, unless you don´t use external attenuators which provide a 50 Ohm impedance down to DC or an external attenuator / limiter/filter such as the Tekbox TBFL1.

Take precautions, such as validating the signal amplitude at the RF output prior to connecting a spectrum analyzer or using attenuators and/or limiters such as the Tekbox TBFL1 to prevent damage to your test receiver or spectrum analyzer.

WARNING: Ensure that the spectrum analyzer RF input is disconnected when powering on or powering off the DUT. Use an attenuator/limiter, if the DUT switches inductive loads during operation or in case of any uncertainty concerning the DUT characteristics. After ensuring that the spectrum analyzer is not over-driven, you may remove or reduce external attenuation.

1.4 Informative schematic

The simplified schematic below shows the basic topology and the values of the main components of the TBL5016-3 AC LISN. It consists of four identical LISN paths.

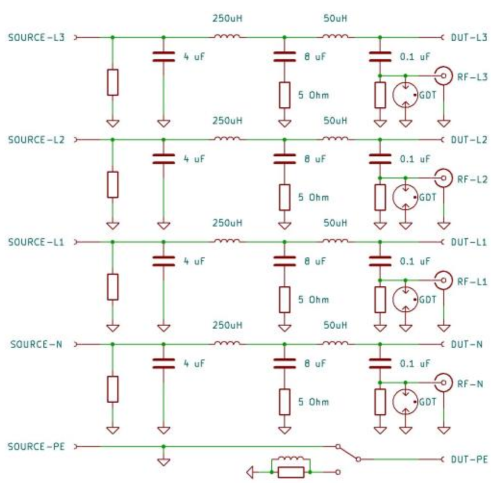


Figure 2 – 3-phase LISN, simplified schematic

NOTE the high capacitor values, which cause considerable blind current at 50Hz/60Hz line voltages. Direct connection to the mains outlet would cause tripping of the ground fault switch. Refer to the next chapter on how to set up the AC LISN in a standard laboratory environment.

TBL5016-3 50µH AC-LISN

1.5 Laboratory set up

Always refer to the set-up specified in the applicable standard for your product. If it cannot be implemented in your available laboratory environment, refer to the set up below.

The DUT shall be isolated and elevated from the ground plane. The spectrum analyzer shall measure the conducted emissions on both line and neutral.

The value of the parallel combination of the capacitors is 12µF from each line and neutral to ground. This causes around 0.75A flowing into the earth connection and would trip the ground fault switch. Hence, an insulation transformer is required for any mains supply which is protected by a residual current device or ground fault (earth leakage) circuit breaker and good grounding is essential for safety.

The set up below is just informative. For the exact details of the set up and for the limits of conducted emissions refer to the relevant applicable standard or the examples in the LISN overview document, which can be downloaded from our website.

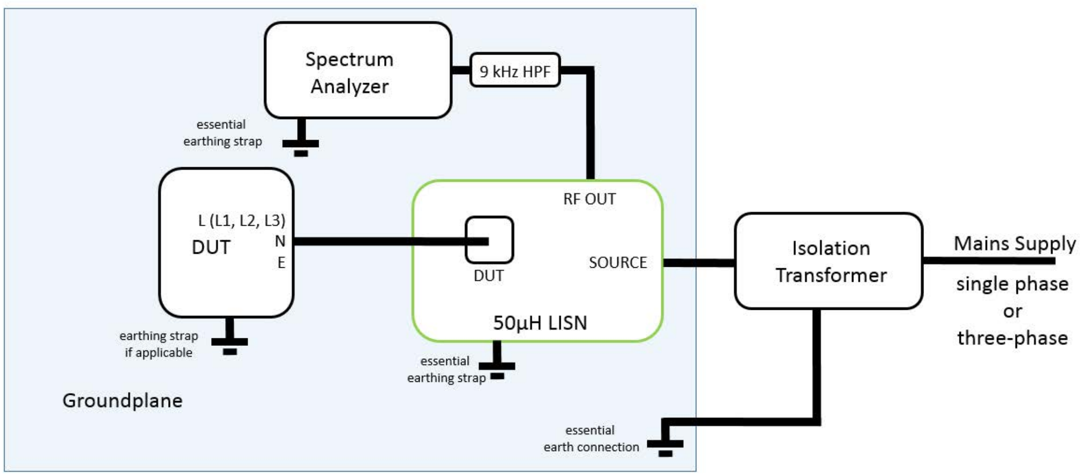


Figure 3 – Conducted noise pre-compliance measurement setup

SAFETY: Ensure that all required earth connections are reliably bonded and that the isolation transformer can supply the required load current.

1.6 Ground plane

Any voltage measurement must be made against a common circuit node which can be referred to as the "zero volt" reference. In order to provide a low impedance zero volt reference for RF measurements, a metal sheet must be provided as ground plane. All ground straps between equipment and ground plane shall be as short as possible and fastened with screws. Exact details on the size of the ground plane and the arrangement of the equipment and interconnecting cables are described in the applicable standards.

In a pre-compliance test set up, as a rule of thumb, the size of the ground plane shall be large enough to accommodate all involved equipment and exceed at least 10cm each side.

TBL5016-3 50µH AC-LISN

2 TBL5016-3 specifications

2.1 Conformity

The TBL5016-3 is compliant with CISPR 16-1-2.

In line with the CISPR 16-1-2 standard compliant design and setup specification, the TBL5016-3 V-LISN exhibits high ground leakage currents and non-standard isolation and consequently cannot meet the safety requirements of EN 61010-1.

Furthermore CISPR 16-1-2 specifies high capacitance values for the capacitors from Line1/2/3 and from Neutral to Ground (PE). These capacitance values are not commercially available in Y2 rating and are implemented using AC rated capacitors with suitable voltage rating.

In order to prevent the danger of lethal electric shock, the operator is responsible for ensuring protective measures in line with IEC 60364-4-41 and IEC 60364-5-54 and to follow all safety related information of this manual.

2.2 Safety

In order to ensure safe operations, the user must follow all safety relevant information of this manual. All housing parts are connected with the earth conductor of the power cable, DUT socket, yellow banana receptacle and with the ground strap of the housing. It is not allowed to carry out any modifications or manipulations of the TBL5016-3. The TBL5016-3 shall be operated by qualified laboratory staff only.

2.3 Specifications

- Frequency range: 9 kHz to 30 MHz
- Impedance: 50 Ω ‖ (50 µH + 5 Ω)
- Artificial hand: 220 pF + 511 Ω
- Switchable PE: 50 Ω ‖ 50 µH
- 250µH pre-filter
- Air core inductors
- Line voltage: max. 540V/260V, 50 – 60 Hz
- Max. current: 16A @ 23°C for each phase and neutral
- 3-phase DUT socket: CEE / IEC60309, 3L+N+PE, 16A, female
- Single phase DUT socket: country specific, note country specific DUT socket limits (see chapter 4)
- Power connector: CEE / IEC60309, 3L+N+PE, 16A, male
- Measurement connector: 50 Ω BNC, separate outputs for each line and phase; external 9 kHz HPF
- Operating Temperature Range: +5°C … + 40°C; 5% to 80% RH
- Weight: 21 kg, length: 520mm, width: 470 mm, height: 180 mm

2.4 Supply voltage

The TBL5016-3 does not require any particular voltage settings. It can be operated with any supply voltage which does not exceed 540V/260V, 50Hz/60Hz. It is also suitable for DC operation.

TBL5016-3 50µH AC-LISN

2.5 Front Panel

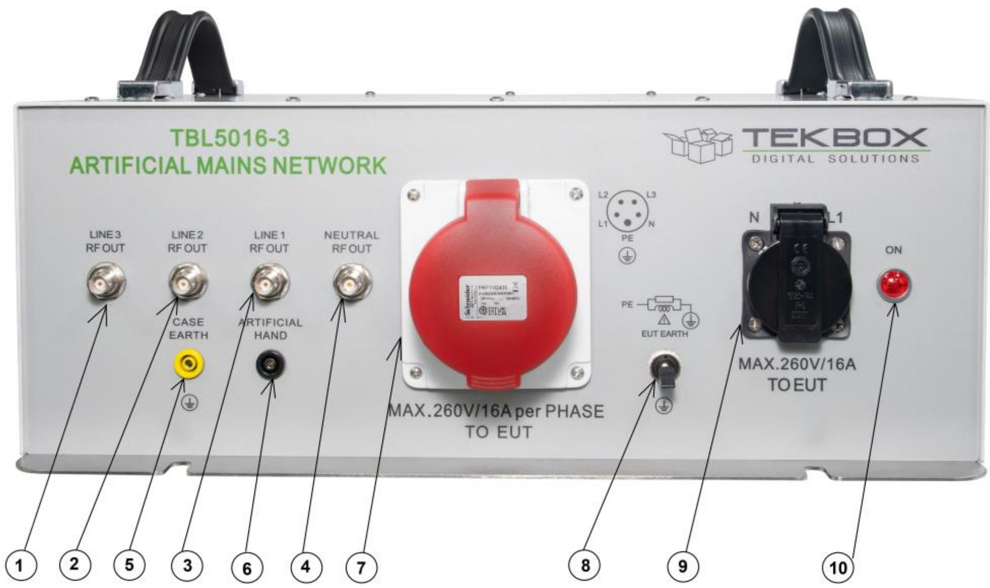


Figure 4 – Front panel layout

1) Line 3 BNC RF output
2) Line 2 BNC RF output
3) Line 1 BNC RF output
4) Neutral BNC RF output
5) Auxiliary case earth connector, safety banana jack
6) Artificial hand connector, safety banana jack
7) Three phase DUT socket, IEC60309, 3L+N+PE, 16A, female
8) Protective Earth switch to connect DUT earth either directly to case earth, or via 50µH ‖ 50 Ohm
9) Single phase DUT socket, country specific
10) Power On indicator

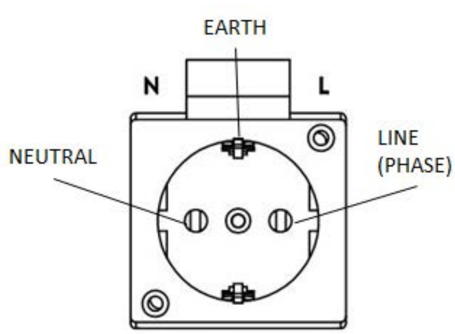


Figure 5 – DUT socket, pin assignment with reference to the rear power connector

For the pin-assignment of the three phase socket, refer to the graphics on the front panel

TBL5016-3 50µH AC-LISN

2.6 Rear Panel

Figure 6 – Rear panel layout

11) Three phase power (source) socket, IEC60309, 3L+N+PE, 16A, male
12) Power switch

For the pin assignment of the power socket, refer to the graphics on the rear panel.

TBL5016-3 50µH AC-LISN

2.7 Impedance

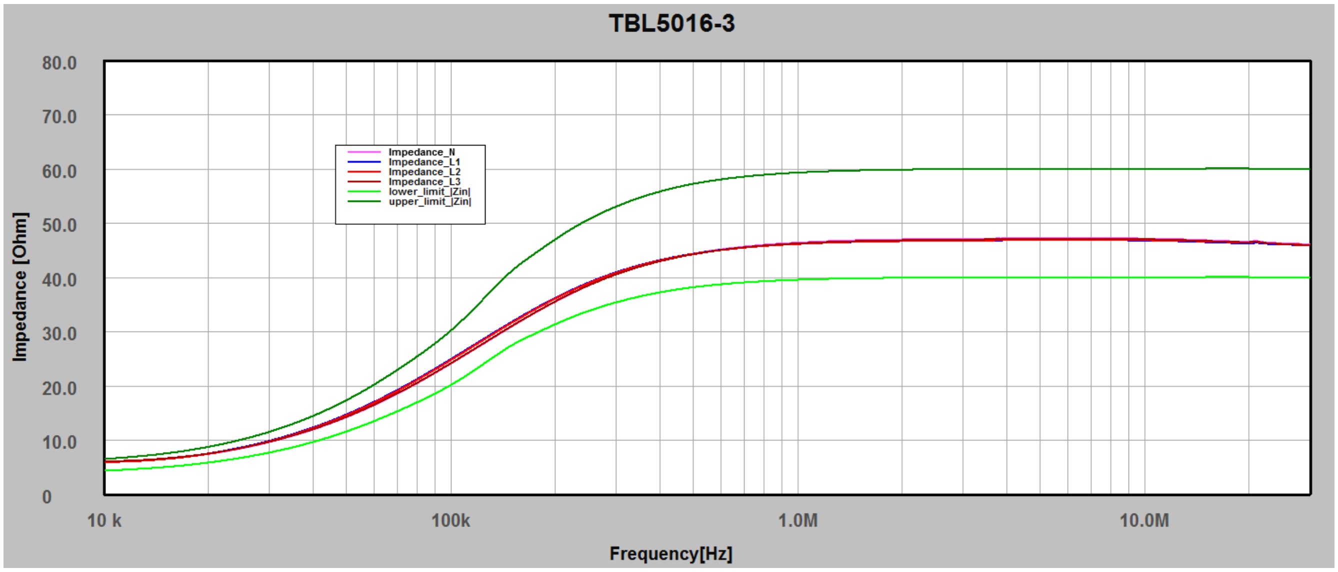


*Figure 7 – Impedance vs. frequency at DUT terminals, limit lines according CISPR 16-1-2**

*) BNC connectors terminated with 50 Ohm. Impedance measured at the DUT terminals on the PCB. The wiring from DUT connector to the PCB can be considered as an additional 20 cm of DUT supply cable length.

2.8 Phase

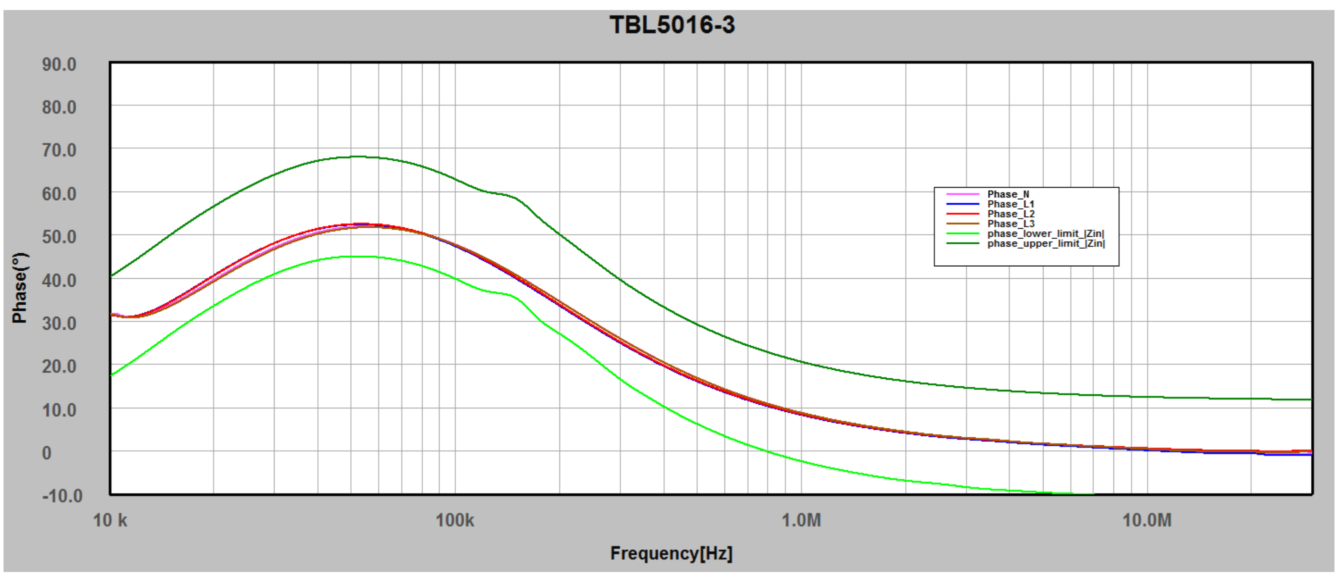


*Figure 8 – Phase angle vs. frequency at DUT terminals, limit lines according CISPR 16-1-2**

*) BNC connectors terminated with 50 Ohm. Phase angle measured at the DUT terminals on the PCB. The wiring from DUT connector to the PCB can be considered as an additional 20 cm of DUT supply cable length

TBL5016-3 50µH AC-LISN

2.9 Frequency response, S21 from DUT port to RF port

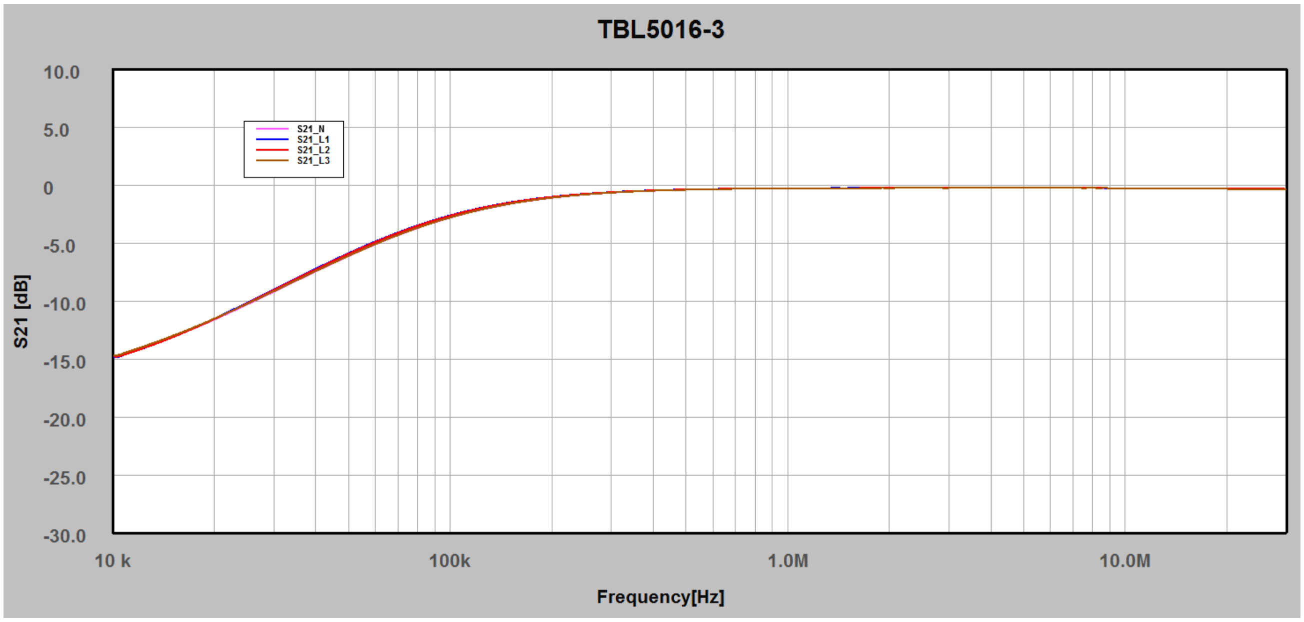


Figure 9 – Frequency response, S21, DUT terminals to BNC connector

Frequency [MHz]	Transmission Neutral / ATT_OFF [dB]
0.009	-15,76
0.015	-13.17
0.02	-11.57
0.03	-9.07
0.05	-5.93
0.07	-4.14
0.1	-2.67
0.15	-1.55
0.2	-1.11
0.3	-0.66
0.5	-0.42
0.75	-0.35
1	-0.32
1.25	-0.31
2.5	-0.30
5	-0.29
7.5	-0.30
10	-0.31
20	-0.36
30	-0.38

Table 1 – Frequency response, PCB DUT terminals to BNC, typical data

2.10 Calibration data according to CISPR 16 -1-2 Annex A8

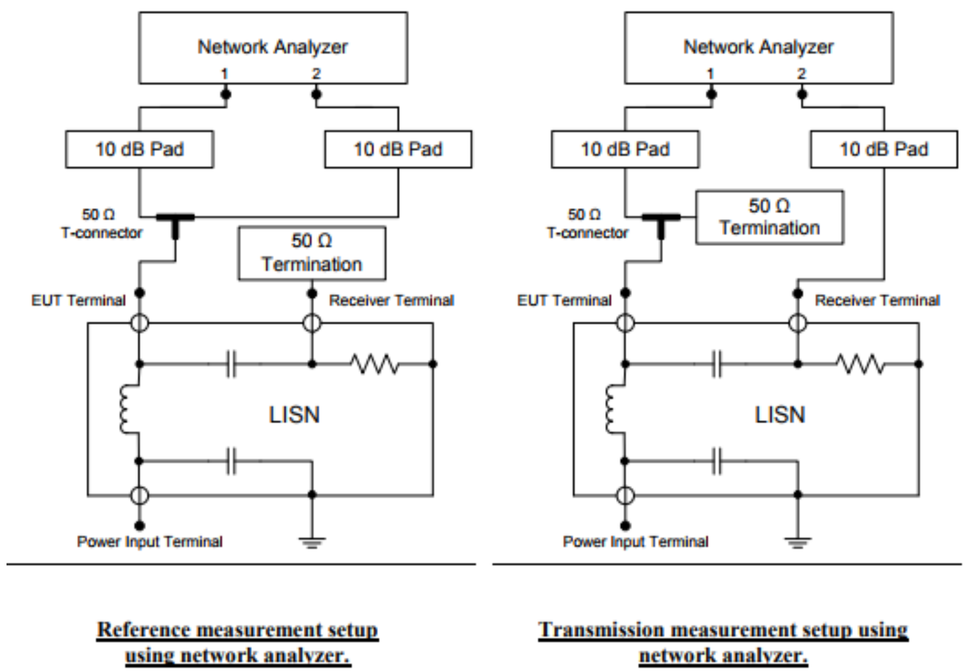


Figure 70 – Calibration set up according to CISPR 16-1-2 Annex A.8.

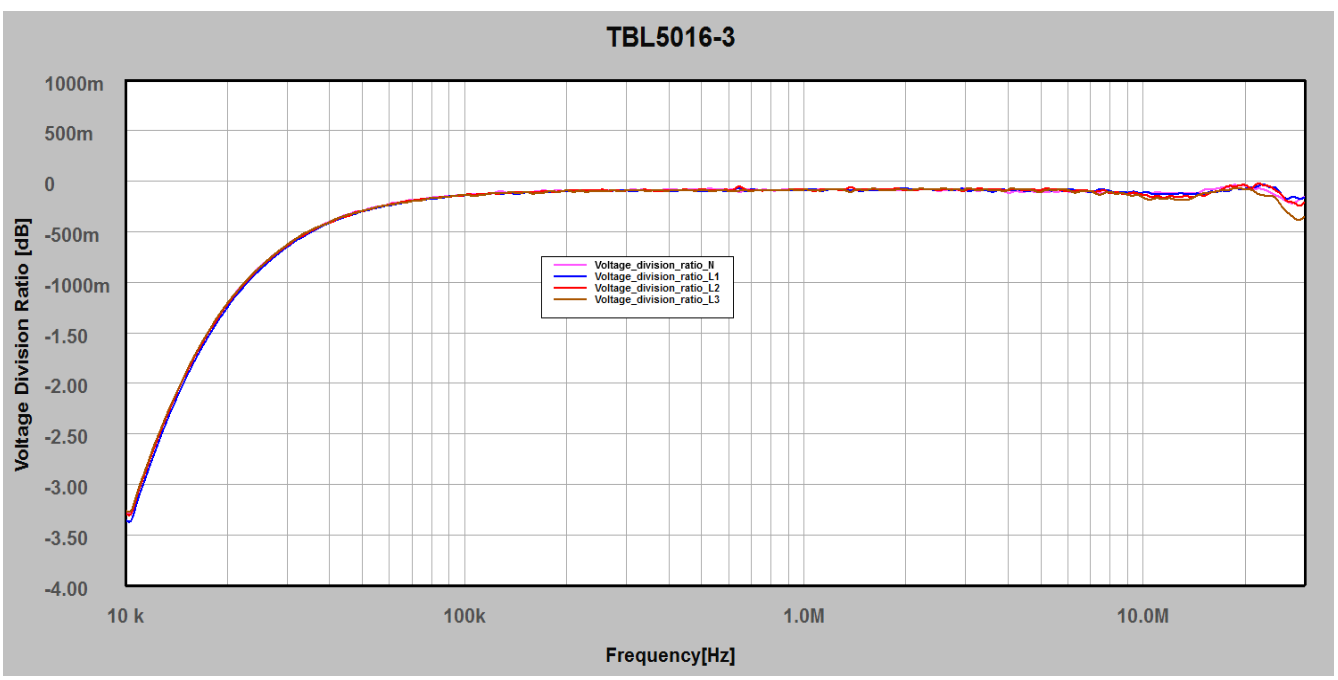


Figure 81 – Voltage Division Ratio versus frequency

TBL5016-3 50µH AC-LISN

Frequency[MHz]	Typical Voltage Division Ratio [dB], L1, L2, L3, N
0.009	-3.48
0.015	-1.92
0.02	-1.21
0.03	-0.64
0.05	-0.31
0.1	-0.14
0.15	-0.11
0.2	-0.097
0.3	-0.096
0.5	-0.085
0.75	-0.091
1	-0.083
2.5	-0.095
5	-0.091
7.5	-0.11
10	-0.13
20	-0.22
30	-0.21

*Table 2, TBL5016-3 LISN voltage division ratio, typical calibration data**

*) measured from DUT terminals on the PCB to BNC

2.11 Isolation

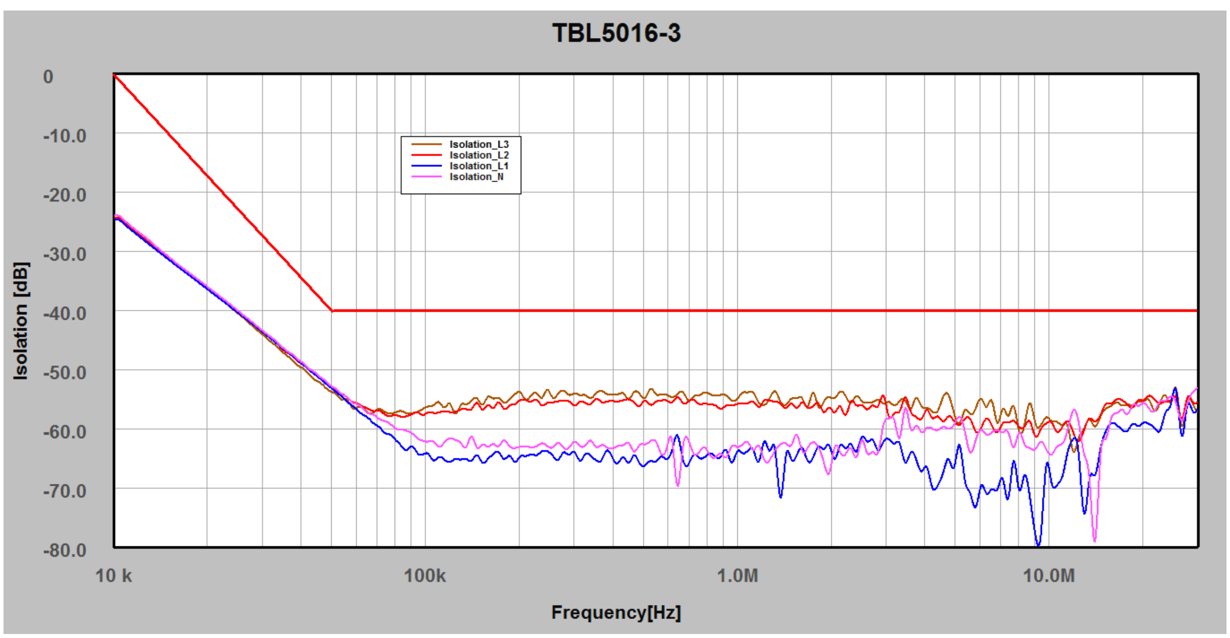


Figure 92: LISN Isolation, Source to RF out, limit line according CISPR 16-1-2

The isolation is measured between the mains (source) connector and RF port, with the DUT port terminated with 50 Ohm.

TBL5016-3 50µH AC-LISN

2.12 Thermal characteristics

Avoid touching the housing, when operating the LISN at maximum current over extended time. Typical conducted noise measurements take less than 10 minutes per line. Turn off the DUT after measurements to avoid unnecessary dissipation.

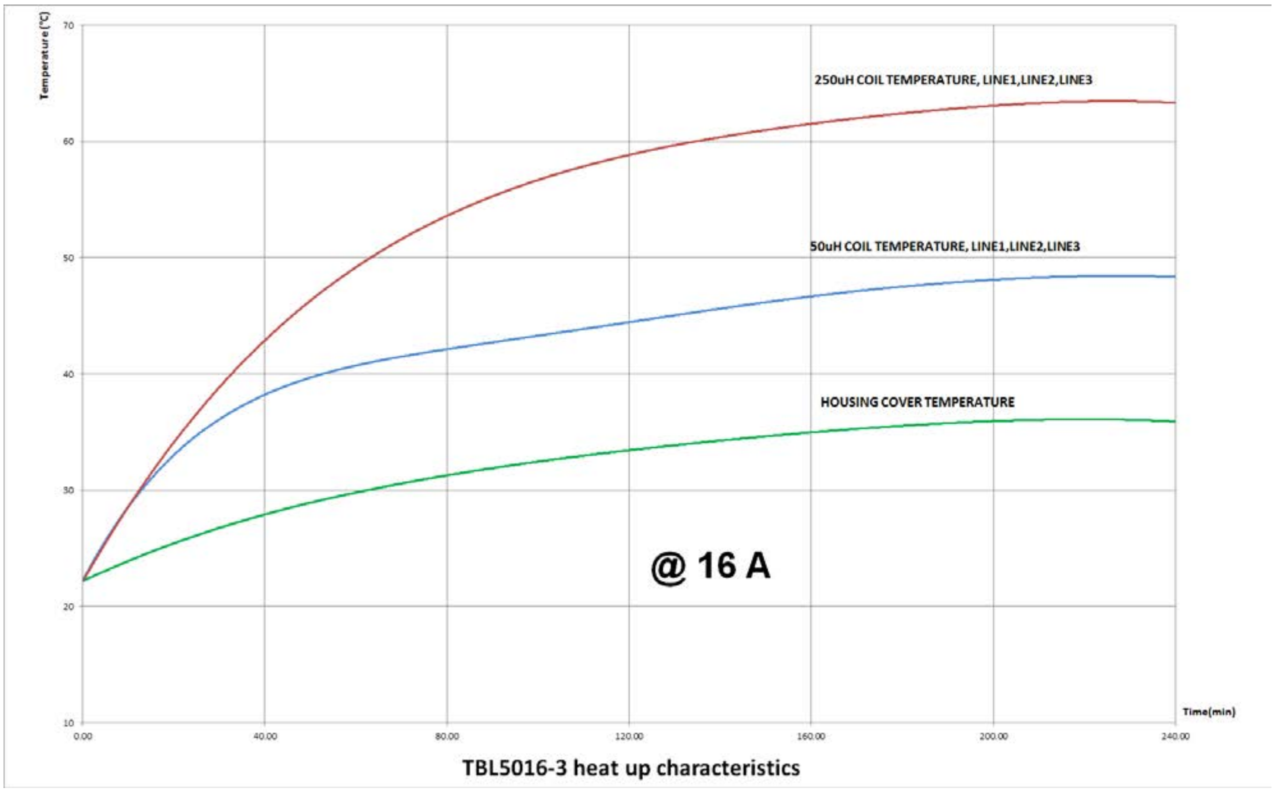


Figure 103: Coil and housing temperature at 16 A DUT current @ 22 °C ambient temperature

2.13 Spectrum analyzer / emi receiver RF input protection

The TBL5016-3 offers only limited protection to prevent surges appearing at the input of the measurement receiver or analyzer.

All lines and neutral are equipped with a 275V varistor to ground. All four RF paths are protected by a 50V gas discharge tube.

In order to suppress residual 50Hz AC from the RF output, the supplied external TBHPF1-9kHz high pass filter always has to be connected to the RF input of the connected spectrum analyzer / EMI-receiver, unless external attenuators or an external combined attenuator / filter / limiter such as the TBFL1 is used.

Find more details in the TBHPF1-9kHz datasheet that can be downloaded from our website.

Additional protection using a combined attenuator/ highpass filter / limiter at the spectrum analyzer RF input is recommended.

Tekbox offers a range of suitable attenuators and a combined attenuator / filter / limiter.

TBL5016-3 50µH AC-LISN

2.14 Artificial hand

When performing conducted noise measurements with devices which are held in hand, the artificial hand network mimics the influence of the human hand. Examples for such devices are power tools, hair driers, kitchen tools and similar equipment.

Insulated housing sections that are touched by the hand when operating the equipment are covered with metal foil and connected to the artificial hand jack.

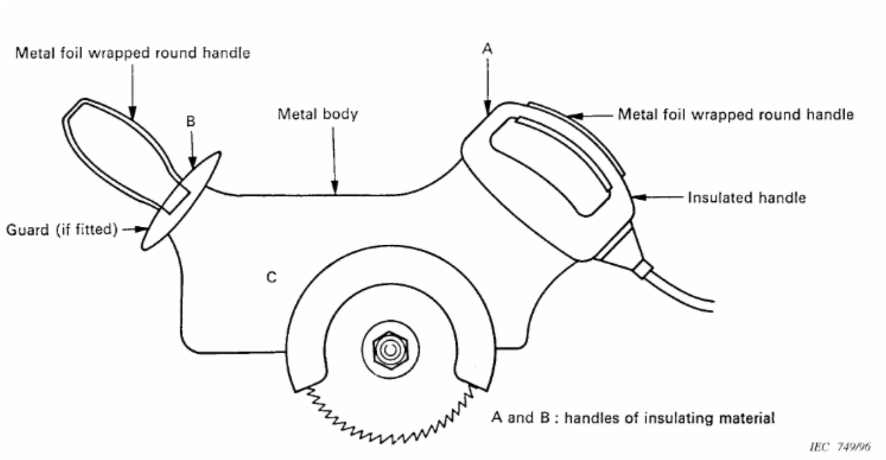


Figure 114 – Example from CISPR 16, portable electric saw with artificial hand

3 Operation checklist

- Setup the isolation transformer, TBL5016-3 , DUT and spectrum analyzer according to Figure 3.
- Before powering the isolation transformer, measure the connectivity between each equipment chassis and ground plane.
- Ensure that the supply cable of the isolation transformer, the supply cable of the LISN, the supply cable of the spectrum analyzer and if applicable the supply cable of the DUT contain a ground conductor.
- Ensure, that the RF cable is not yet connected
- Ensure that the Protective Earth switch is set to direct ground position
- Ensure that the 9 kHz high pass filter or a Limiter/Attenuator is attached to the RF input of the analyzer.
- Ensure that the power switch of the TBL5016-3 is in “OFF” position.
- Ensure that the DUT power switch is in “OFF” position.
- Power on the isolation transformer
- Power on the spectrum analyzer, set frequency, bandwidth, amplitude etc.
- Power on the TBL5016-3
- Power on the DUT

TBL5016-3 50µH AC-LISN

- Connect the RF cable to carry out the conducted noise measurements. If the conducted noise is not exceeding the analyzer input limits, remove the Limiter/Attenuator for better sensitivity and in order to avoid potential intermodulation. However, never use the analyzer without the 9 kHz HPF
- After finishing the measurement, proceed in reverse order. Take special care to disconnect the RF cable before powering off the DUT.

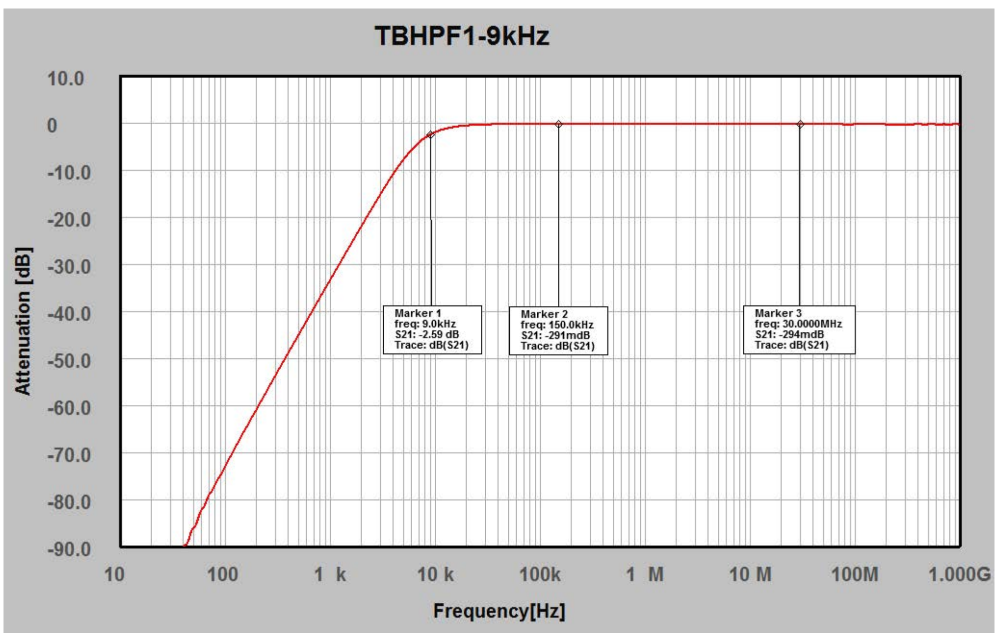
4 TBHPF1-9kHz high pass filter

4.1 Technical Data

High Pass Filter, reflective, 50 Ohm
3dB bandwidth: 9 kHz – 3 GHz
Maximum input voltage: 100V; 250V for < 5 sec.
Maximum permitted input current at frequencies < 9kHz and open output: 160 mA
Maximum input power at frequencies 20 kHz – 1 GHz: 10W
Resistive dampening to prevent pulses with high rise time cause excessive ringing.
Connectors: N-Male / N-Female
Dimensions: 26 x 26 x 82 mm
Weight: ca. 100g

4.2 Frequency response

Typical data, 50 Ohm system



TBHPF1-9kHz: Attenuation 10 Hz to 1 GHz, typical data

TBL5016-3 50µH AC-LISN

Attenuation table, 50 Ohm system:

Frequency [Hz]	Attenuation [dB]	Frequency [Hz]	Attenuation [dB]
30	97.13	13000	1.15
40	89.93	14000	1.02
50	85.91	15000	0.91
100	73.25	20000	0.61
250	57.30	25000	0.49
500	45.27	50000	0.33
750	38.20	100000	0.29
1000	33.20	250000	0.27
2500	17.59	500000	0.27
5000	7.31	1000000	0.27
6000	5.29	10000000	0.27
7000	3.92	30000000	0.28
8000	2.99	100000000	0.41
9000	2.35	250000000	0.53
10000	1.90	500000000	0.39
11000	1.57	750000000	0.43
12000	1.33	1000000000	0.46

TBHPF1-9kHz: Attenuation 10 Hz to 1 GHz, typical data

Voltage attenuation table, 1 MΩ load impedance:

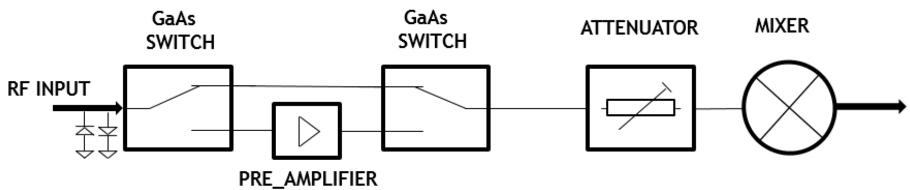
Frequency [Hz]	Vout/Vin [dB]	Frequency [Hz]	Vout/Vin [dB]
30	>60	7000	1.92
40	>60	8000	0.43
50	>60	9000	0.085
100	>60	10000	0.25
250	>60	20000	0.47
500	58.6	25000	0.56
750	53.9	50000	0.42
1000	48.4	100000	0.17
2500	20.1	250000	0.083
5000	9.93	500000	0.042
6000	6.11	1000000	0.034

TBL5016-3 50µH AC-LISN

4.3 Application

Analyzer RF frontend limitations:

Whenever working with spectrum analyzers, be aware that excessive input power, voltage transients or ESD can damage the RF-frontend. Spectrum analyzers typically have a maximum CW input rating in the range of +20 dBm to +30 dBm. Unlike oscilloscopes, spectrum analyzer inputs are not protected or only vaguely protected. A simplified RF frontend looks as below:



The diodes at the input typically serve as ESD protection diodes. In order to fully protect the input with a limiter, shunt diodes would need to be combined with a series resistor to limit forward current in case of excessive input signal. Consequently, a classic current limiting resistor solution cannot be implemented, as it would increase the input impedance of the analyzer.

A limiter could be implemented by combining it with an attenuator, however this would degrade the sensitivity of the analyzer and limit its use.

The first weak link of the input chain is the RF switch. Typical EMI spectrum analyzers use integrated GaAs switches. GaAs switches are inherently weak at low frequencies. Many GaAs switches are not even specified with respect to maximum input power at low frequencies, down to 9 kHz.

Below is an example data sheet of a typical GaAs switch:

HMC221B

ABSOLUTE MAXIMUM RATINGS

Table 2.

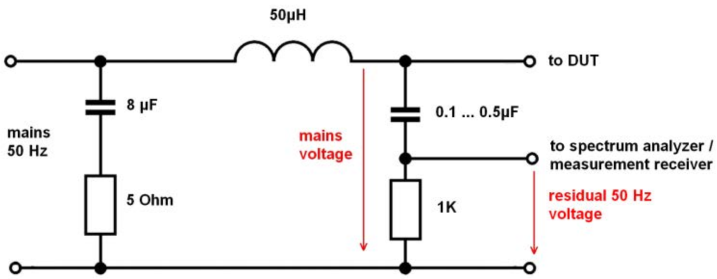
Parameter	Rating
Control Voltage Range (A and B)	−0.2 V dc to 12 V dc
RF Input Power Level (CW Peak, V_{CTL} = 0 V/5 V)	0.36 W
10 kHz to 10 MHz	8 dBm
10 MHz to 20 MHz	10 dBm
20 MHz to 30 MHz	11 dBm
30 MHz to 250 MHz	14 dBm
250 MHz to 3.0 GHz	31 dBm
Hot Switching RF Input Power Level (CW Peak, V_{CTL} = 0 V/5 V)	
10 kHz to 250 MHz	6 dBm
250 MHz to 3.0 GHz	20 dBm

The maximum RF input power ratings versus frequency clearly show the degradation at low frequencies.

TBL5016-3 50µH AC-LISN

Residual 50 Hz voltage at the RF output of LISN:

The picture below shows the basic circuit diagram of an AC LISN:



The full AC mains voltage is present at the DUT terminals of the LISN. The RF coupling capacitor and the 1K resistor form a voltage divider, which determines the amplitude of the 50 Hz voltage at the RF connector.

Considering a 0.1µF capacitor, which has an impedance of 32K at 50 Hz. Together with the 1K resistor, the resulting 50 Hz voltage at the RF terminal of the LISN is approximately 6.6V in the absence of any load. Assuming a 50 Ohm load in parallel to the 1K resistor, the residual 50 Hz voltage would become negligible.

Some LISN may need to use a higher value, in order to meet the impedance specifications at lower frequencies. Assuming a 0.5µF capacitor, the residual 50 Hz voltage at the RF terminal of the LISN would be as high as 31V. This still would become reduced to a negligible value, if a 50 Ohm load in parallel to the 1K resistor is present.

However, it is unlikely that a low cost analyzer has an input impedance of 50 Ohm at 50 Hz. Typically the input impedance is not specified for frequencies below 9 kHz. Furthermore, as already mentioned, low cost analyzers use GaAs switches at the RF input, which are inherently vulnerable at low frequencies.

Consequently, placing a 9 kHz high pass filters, or 150 kHz high pass filters at the RF input of a spectrum analyzer or measurement receiver will offer good protection against residual 50 Hz voltage. Due to its very low insertion loss in the pass band, it will not reduce the dynamic range of the measurement.

Sub-harmonics of switched mode regulators:

When carrying out conducted noise tests of switched-mode power supplies, the highest spurious levels occur at relatively low frequencies. Sub-harmonics are even more critical. These are typically at frequencies significantly below 100 kHz and unless they produce audible noise due to magnetostriction of the power inductors, they often go completely unnoticed, as most tests start at 9 kHz or 150 kHz. You may carry out a conducted noise test and wonder, why the analyzer beeps and displays an ADC overflow warning, despite all spurious being well below limits. What drives the attenuator into saturation may be a very high amplitude sub-harmonic at e.g. 6 kHz.

In case that you notice that your signals are in the range of 20 dB lower than what they actually are, disaster already happened. The first GaAs switch is already damaged. In most cases, it fails with a short on the RF path and protects the following components, but in extreme cases, the damage will reach as far as the first mixer.

In order to prevent such things happen, you always should start investigating any new DUT using external attenuators, high pass filters or a combined attenuator/filter/limiter. With an external 20 dB attenuator or limiter attached to the analyzer input, have a look at the spectrum at very low frequencies and ensure that there are no signals with critically high amplitude.

Alternatively, you can first connect an oscilloscope to the LISN RF output and check the DUT emissions in the time domain. In order to establish the same impedance level as with a connected spectrum analyzer, terminate the oscilloscope input with a 50 Ohm feed through or switch the input to 50 Ohm, if the scope offers this feature.

TBL5016-3 50µH AC-LISN

5 Ordering Information

Part Number	Description
TBL5016-3 -EU	50µH LISN with Schuko socket (CE7/3, 16A), 100 cm coaxial cable BNC-male / N-male/RG223, 3 pieces BNC 50 Ohm termination, TBHPF1-9kHz high pass filter
TBL5016-3 -US	50µH LISN with US socket (NEMA 5-15, grounded, type B, 15A), 100 cm coaxial cable BNC-male / N-male/RG223, 3 pieces BNC 50 Ohm termination, TBHPF1-9kHz high pass filter
TBL5016-3 -AU	50µH LISN with Australian socket (AS/NZS 3112:201, 15A), 100 cm coaxial cable BNC-male / N-male/RG223, 3 pieces BNC 50 Ohm termination, TBHPF1-9kHz high pass filter
TBL5016-3 -UK	50µH LISN with English socket (BS1363, 13A), 100 cm coaxial cable BNC-male / N-male/RG223, 3 pieces BNC 50 Ohm termination, TBHPF1-9kHz high pass filter
TBL5016-3 -xx	Any other socket requirements upon customer request will have 2-3 weeks lead time
TBPC- IEC60309-3m TBPC- IEC60309-5m TBPC- IEC60309-10m	3-phase mains power cable, 16A, 3m, 5m or 10m length, CEE / IEC60309, 3L+N+PE, 16A, male, CEE / IEC60309, 3L+N+PE, 16A, female
TBCON-IEC60309-SPEU	1-phase mains power cable, 16A, 1.5 m length, CEE / IEC60309, Schuko
TBCON-IEC60309-SPUK	1-phase mains power cable, 13A, 1.5 m length, CEE / IEC60309, UK connector
TBCON-IEC60309-SPUS	1-phase mains power cable, 15A, 1.5 m length, CEE / IEC60309, US connector
TBCON-IEC60309-SPAU	1-phase mains power cable, 15A, 1.5 m length, CEE / IEC60309, AU connector
TBCON-CEE-M	CEE / IEC60309, 3L+N+PE, 16A, male cable connector
TBCON-CEE-F	CEE / IEC60309, 3L+N+PE, 16A, female cable connector

Table 3– Ordering Information

Note the maximum current limitations of country specific DUT sockets. If you want to make full use of the 16A maximum current rating at the single phase output, order a TBL5016-3-EU plus a re-wirable Schuko plug which can be used to make a 16A extension cable for the DUT. Alternatively we can supply Schuko to C13 or C19 cables.

6 History

Version	Date	Author	Changes
V1.0	3.2.2022	Mayerhofer	Creation of the document
V1.1	3.2.2022	Mayerhofer	Ordering Information updated
V1.2	28.2.2022	Mayerhofer	Safety Information updated
V1.3	10.4.2022	Mayerhofer	Chapters 4, 5 updated
V1.4	29.11.2022	Mayerhofer	New housing

Table 4– History