

## TBL5016-3 50 $\mu$ H AC-LISN

The TBL5016-3 is a Line Impedance Stabilization Network for the measurement of conducted emissions 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 465V/270V 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 TBLM2 LISN Mate 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 LISN is equipped with 32A CEE sockets. The single phase EUT 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  $\Omega$  || (50  $\mu$ H + 5  $\Omega$ )
- Artificial hand: 220 pF + 511  $\Omega$
- Switchable PE: 50  $\Omega$  || 50  $\mu$ H
- 250 $\mu$ H pre-filter
- Separate RF outputs for each line and neutral
- Air core inductors
- Line voltage: max 465V/270V / 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  $\Omega$  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

# TBL5016-3 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 emission test equipment is set up correctly and that the necessary earth connections are reliably bonded to avoid the risk of lethal electric shocks. The LISN 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 through an isolation transformer.

Always use the LISN together with the supplied 9 kHz high pass and/or an attenuator 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 EUT after measurements to avoid unnecessary dissipation.

# TBL5016-3 50 $\mu$ H 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 a shielded chamber, a measurement receiver that complies with the requirements of CISPR 16, a 50 $\mu$ H LISN and a suitable table for the measurement setup. Follow the setup specified in the relevant standards to achieve optimum accuracy and repeatability.

Pre-compliance measurements target to give a very close approximation of the EMC performance of the Equipment 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 are affordable and can achieve good accuracy.

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 EUT (Equipment 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  $\parallel$  50 $\mu$ H + 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:

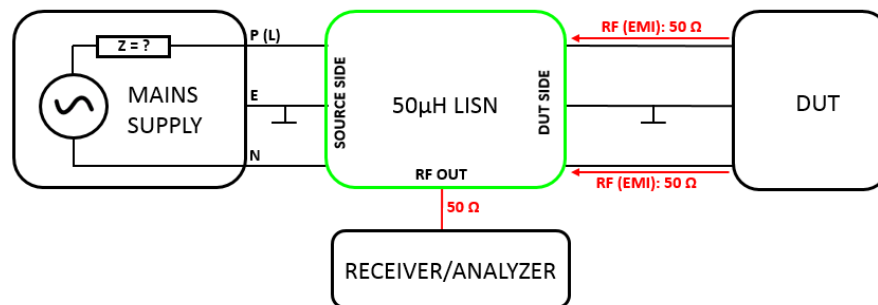


Figure 1 – Basic AC LISN set up: impedance levels

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

## TBL5016-3 50 $\mu$ H 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 an EUT supplied in Y-configuration, three separate measurements in case of EUTs supplied in Delta-configuration, or two separate measurements in case of single phase supplied EUTs. 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 TBLM2 LISN mate in order to split the output signal into its common mode and differential mode components. Note that CM/DM measurements can only be done between two lines. A complete CM/DM measurement requires twelve individual measurements. CM and DM between L1-L2, L1-L3, L2-L3, L1-N, L2-N and L3-N.

The TBL5032-3 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.

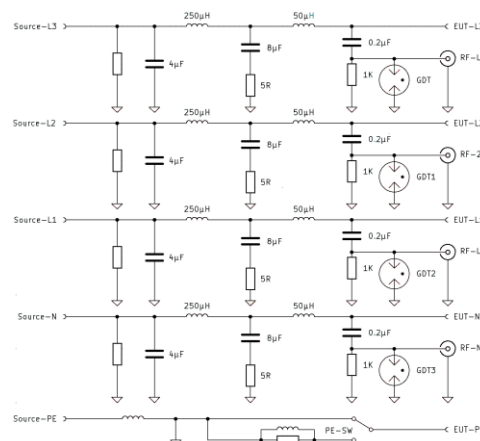


Figure 2 – 3-phase LISN, simplified schematic

**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.

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### 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 EUT shall be isolated and elevated from the ground plane. The spectrum analyzer shall measure the conducted emissions on all lines and neutral.

The value of the parallel combination of the capacitors is 12 $\mu$ F 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 **isolation 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.

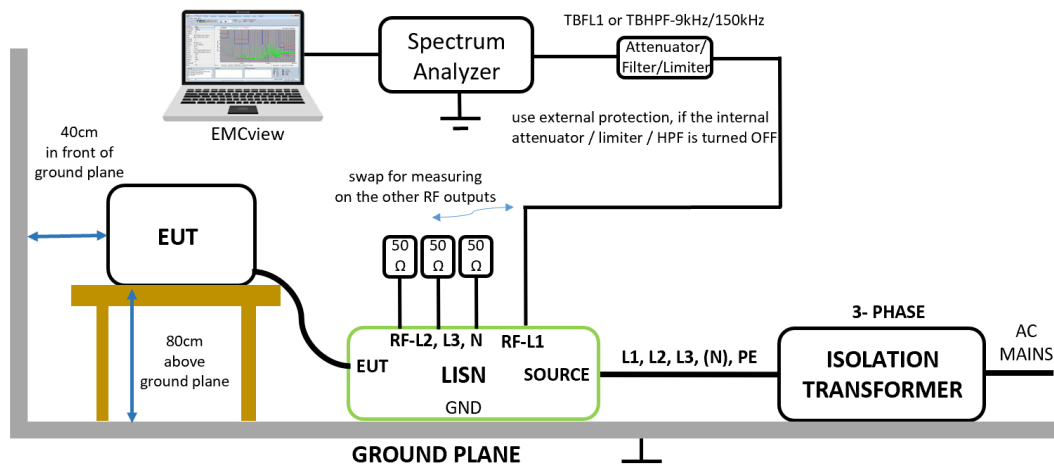


Figure 3 – Conducted emission measurement setup (informative only)

**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 10 cm each side.

A standard compliant setup uses a shielded chamber, with the LISN at the floor (ground plane) and the EUT on an 80 cm high wooden table and positioned 40 cm in front of the wall (ground plane).

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## 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.

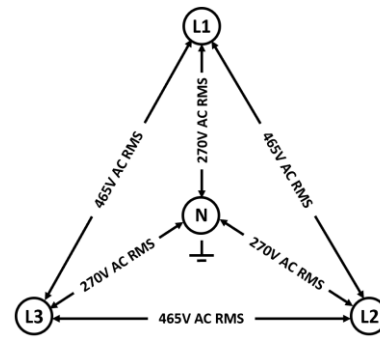
In order to prevent the danger of lethal electric shock, the operator is responsible for ensuring protective measures in line with IEC 60364-4-41 and IEC 60364-5-54 and to follow all safety related information of this manual.

### 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:  $50\ \Omega \parallel (50\ \mu\text{H} + 5\ \Omega)$
- Artificial hand:  $220\ \text{pF} + 511\ \Omega$
- Switchable PE:  $50\ \Omega \parallel 50\ \mu\text{H}$
- 250 $\mu$ H pre-filter
- Air core inductors
- Line voltage: max. 465V/270V, 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:  $50\ \Omega$  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 465V/270V, 50Hz/60Hz. It is also suitable for DC operation.

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### 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) PE switch to connect DUT earth either directly to case earth, or via 50 $\mu$ H || 50 Ohm (simulates extension cable/cable drum)
- 9) Single phase DUT socket, country specific
- 10) Power On indicator

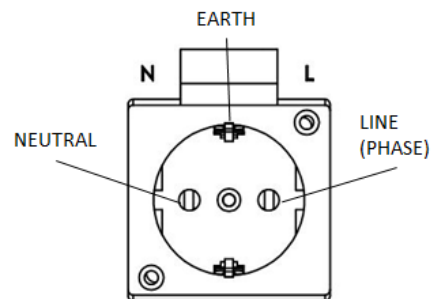


Figure 5 – DUT socket, pin assignment with reference to the rear power connector  
For the pin-assignment of the three phase socket, refer to the graphics on the front panel



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### 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.

### 2.7 Coaxial calibration adapter set

Tekbox offers coaxial adapters as optional accessories for calibration purpose, sanity checks with comb generators, etc.



Figure 7 – TBLA-3P-16A coaxial adapter set

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### 2.8 Impedance

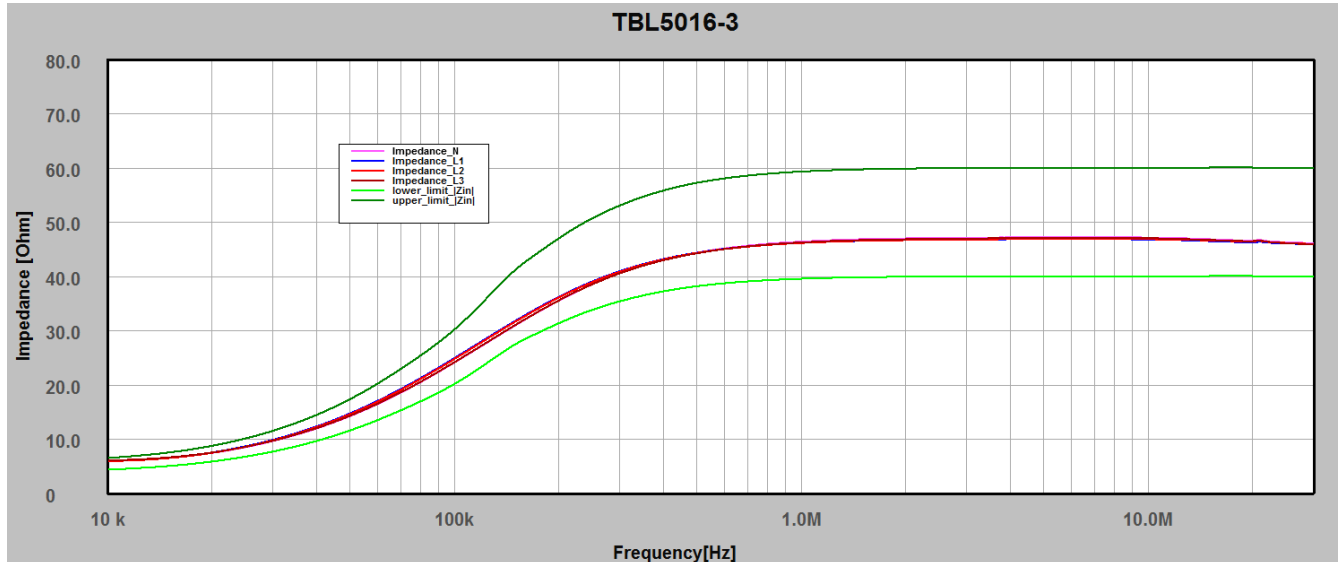


Figure 8 – Impedance vs. frequency at DUT terminals, limit lines according CISPR 16-1-2\*

\*) BNC connectors terminated with 50 Ohm

### 2.9 Phase

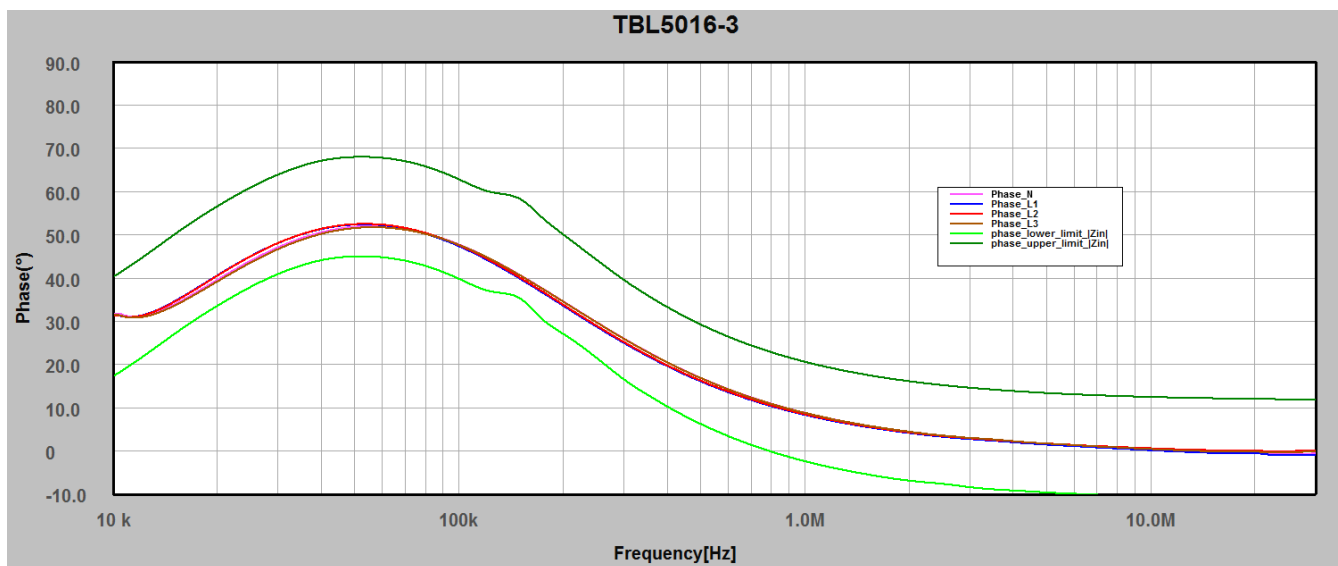


Figure 9 – Phase angle vs. frequency at DUT terminals, limit lines according CISPR 16-1-2\*

\*) BNC connectors terminated with 50 Ohm.

## TBL5016-3 50 $\mu$ H AC-LISN

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

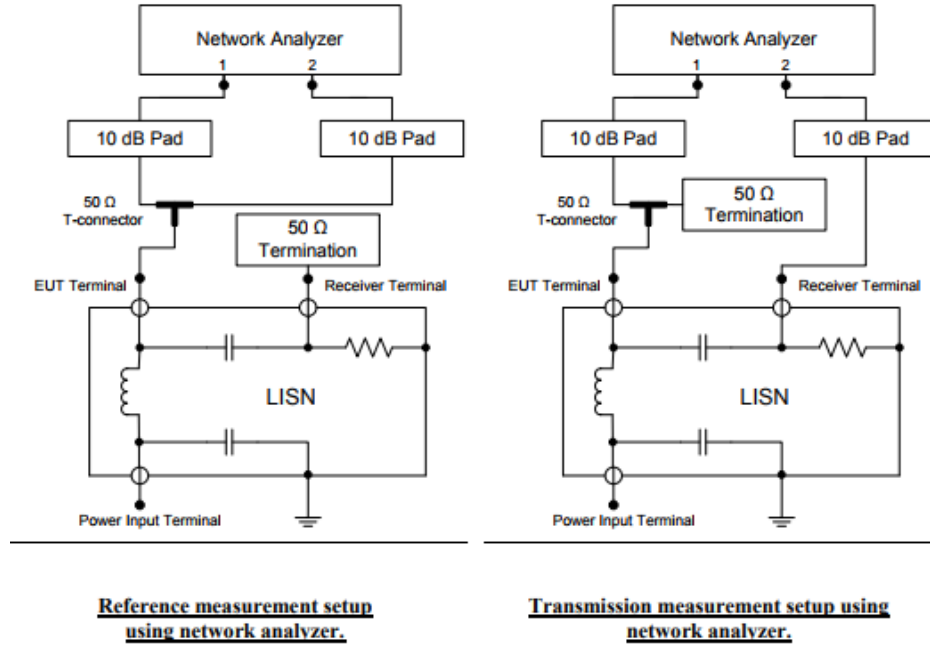


Figure 10– Calibration set up according to CISPR 16-1-2 Annex A.8.

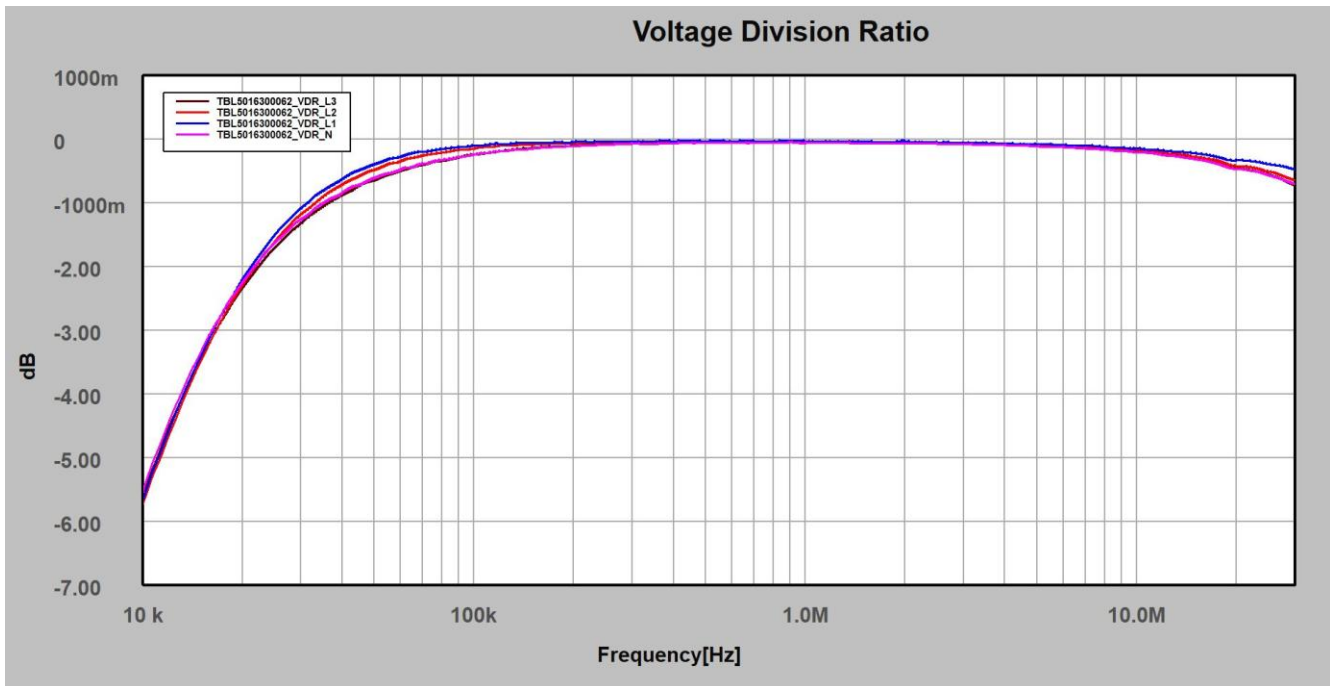


Figure 11– Voltage Division Ratio versus frequency

## TBL5016-3 50 $\mu$ H AC-LISN

Frequency [Mz]	Voltage Division Ratio L3 [dB]	Voltage Division Ratio L2 [dB]	Voltage Division Ratio L1 [dB]	Voltage Division Ratio NEUTRAL [dB]
0.009	-6.25	-6.42	-6.35	-6.23
0.01	-5.58	-5.75	-5.69	-5.54
0.015	-3.45	-3.48	-3.41	-3.34
0.02	-2.34	-2.30	-2.21	-2.26
0.025	-1.72	-1.62	-1.52	-1.64
0.05	-0.65	-0.49	-0.40	-0.62
0.075	-0.37	-0.24	-0.18	-0.36
0.1	-0.24	-0.15	-0.10	-0.25
0.125	-0.18	-0.10	-0.08	-0.19
0.15	-0.14	-0.09	-0.06	-0.15
0.175	-0.11	-0.07	-0.05	-0.13
0.2	-0.11	-0.07	-0.05	-0.12
0.3	-0.07	-0.05	-0.03	-0.07
0.4	-0.05	-0.04	-0.03	-0.07
0.5	-0.05	-0.04	-0.04	-0.06
0.6	-0.04	-0.04	-0.04	-0.06
0.7	-0.04	-0.03	-0.03	-0.06
0.8	-0.04	-0.04	-0.04	-0.06
0.9	-0.04	-0.04	-0.03	-0.05
1	-0.05	-0.05	-0.03	-0.06
2	-0.05	-0.05	-0.03	-0.07
3	-0.06	-0.07	-0.06	-0.08
4	-0.08	-0.08	-0.07	-0.10
5	-0.09	-0.09	-0.08	-0.12
6	-0.11	-0.11	-0.10	-0.13
7	-0.13	-0.13	-0.11	-0.15
8	-0.14	-0.14	-0.13	-0.17
9	-0.17	-0.16	-0.14	-0.19
10	-0.18	-0.17	-0.15	-0.21
11	-0.21	-0.20	-0.17	-0.22
12	-0.22	-0.21	-0.18	-0.25
13	-0.25	-0.24	-0.20	-0.27
14	-0.27	-0.25	-0.21	-0.30
15	-0.29	-0.28	-0.23	-0.32
16	-0.33	-0.30	-0.25	-0.34
17	-0.36	-0.32	-0.27	-0.38
18	-0.40	-0.36	-0.30	-0.42
19	-0.44	-0.41	-0.33	-0.46
20	-0.45	-0.43	-0.34	-0.47
21	-0.47	-0.43	-0.34	-0.48
22	-0.49	-0.44	-0.35	-0.50
23	-0.51	-0.46	-0.36	-0.51
24	-0.54	-0.49	-0.38	-0.54
25	-0.56	-0.51	-0.40	-0.57
26	-0.59	-0.53	-0.41	-0.60
27	-0.62	-0.57	-0.42	-0.62
28	-0.66	-0.60	-0.44	-0.66
29	-0.70	-0.63	-0.46	-0.69
30	-0.73	-0.65	-0.48	-0.71

Table 1– TBL5016-3 LISN voltage division ratio, typical calibration data\*

\*) individual data are supplied with each LISN

## TBL5016-3 50 $\mu$ H AC-LISN

### 2.11 Isolation

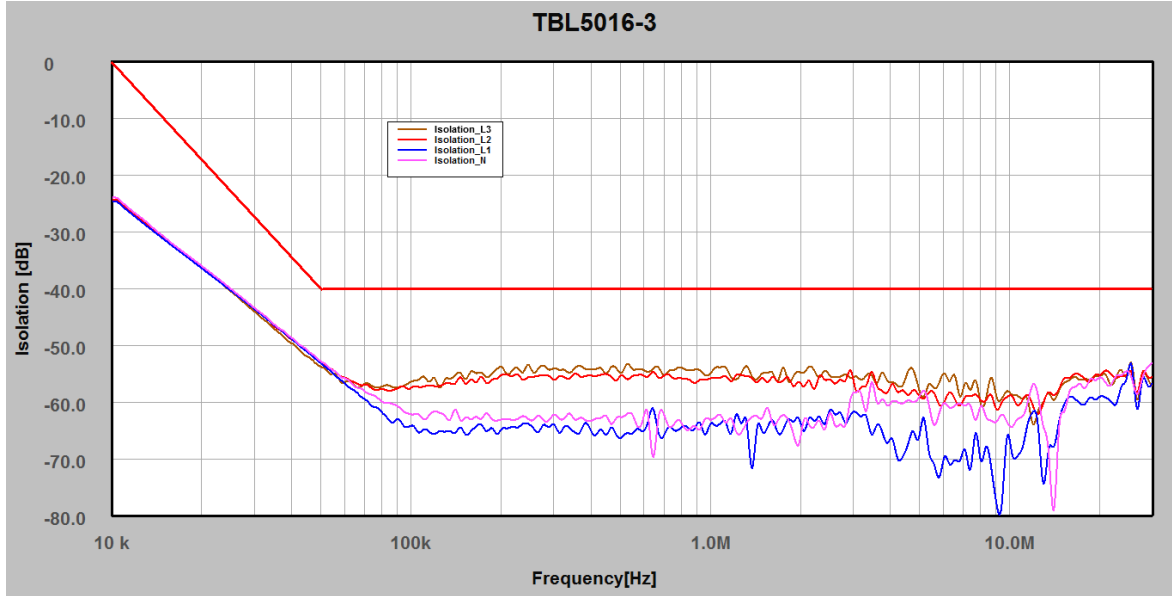


Figure 12: LISN Isolation, Source to RF out, limit line according CISPR 16-1-2

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

### 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.

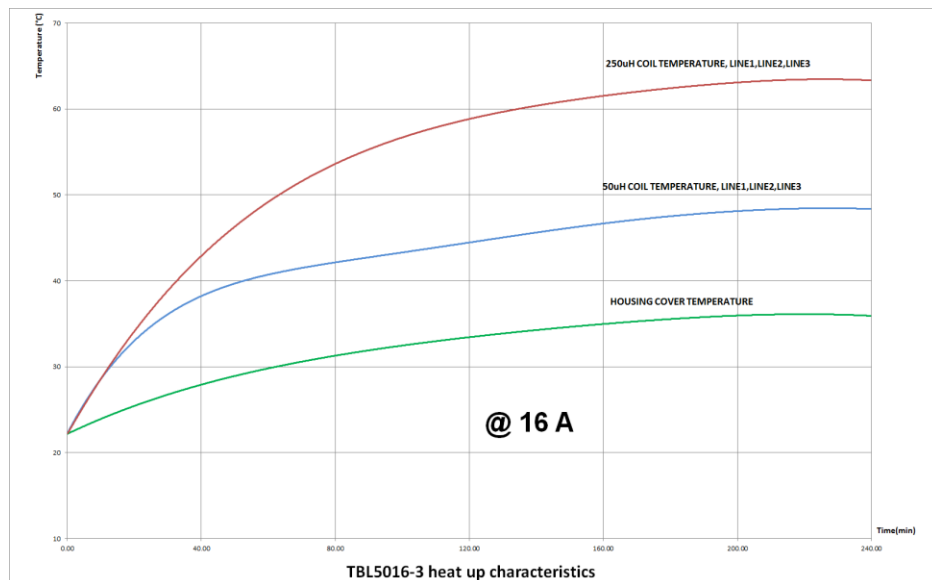


Figure 13: Coil and housing temperature at 16 A DUT current @ 22 °C ambient temperature

## TBL5016-3 50 $\mu$ H AC-LISN

### 3 Spectrum analyzer / emi receiver RF input protection

The TBL5016-3 offers no suppression of residual 50Hz AC, transients and excessive noise amplitudes.

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. A combination of a 10 dB attenuator followed by the highpass filter at the LISNs RF output is highly recommended.

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. Also note that the 9kHz HPF is built using inductors with ferrite cores, which are subject to saturation at excessive noise levels in the stop band below 9 kHz. In case of doubts, use an external attenuator in front of the HPF to prevent non-linear distortion.

Tekbox offers a range of suitable attenuators and a combined attenuator / filter / limiter, model TBFL1.

### 4 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.

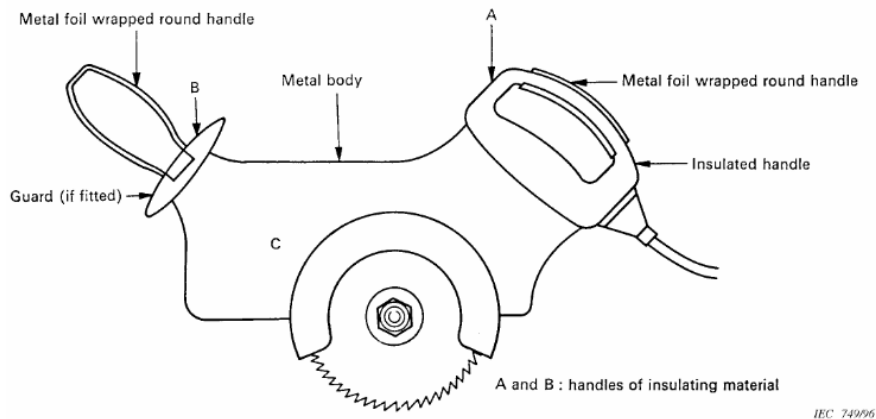


Figure 12 – Example from CISPR 16, portable electric saw with artificial hand

## TBL5016-3 50 $\mu$ H AC-LISN

### 5 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
- 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.

### 6 TBHPF1-9kHz-B high pass filter

#### 6.1 Technical Data

High Pass Filter, symmetric, reflective, 50 Ohm  
3dB bandwidth: 9 kHz – 1 GHz  
S11, 9 kHz – 110 MHz: < -12 dB  
Topology: 5<sup>th</sup> order Chebyshev  
Filter capacitor voltage rating: 100V  
Filter inductor saturation current: 0.7 A  
Maximum input power at frequencies 9 kHz – 1 GHz: 10W  
Connectors: N-Male / N-Female  
Dimensions: 26 x 26 x 82 mm  
Weight: ca. 100g



## TBL5016-3 50 $\mu$ H AC-LISN

### 6.2 HPF Frequency response

Typical data, 50 Ohm system

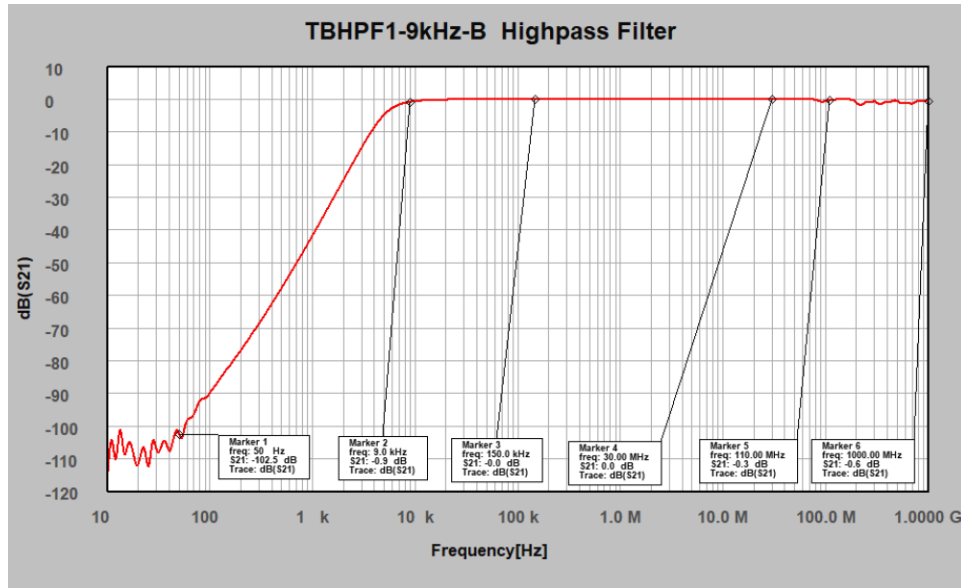


Figure 15 - TBHPF1-9kHz, attenuation 10 Hz to 1 GHz, typical data

Attenuation table, 50 Ohm system:

Frequency [kHz]	Attenuation [dB]	Frequency [MHz]	Attenuation [dB]
< 0.1	-0,03	0,1	-0,03
0,1	-89,88	0,5	-0,01
0,2	-76,96	1	0,00
0,3	-68,82	5	0,01
0,4	-62,72	10	0,01
0,5	-57,84	25	0,03
0,6	-53,74	30	0,03
0,7	-50,21	50	0,03
0,8	-47,11	75	-0,14
0,9	-44,34	100	-0,69
1	-41,83	200	-1,11
2	-24,87	300	-0,78
3	-15,02	400	-0,85
4	-8,68	500	-0,69
5	-4,84	600	-1,32
7,5	-1,41	700	-1,46
9	-0,86	800	-0,61
10	-0,67	1000	-0,58

Table 2– TBHPF1-150kHz-B: Insertion loss, 9 kHz to 1 GHz, typical data



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## 6.3 HPF Impedance

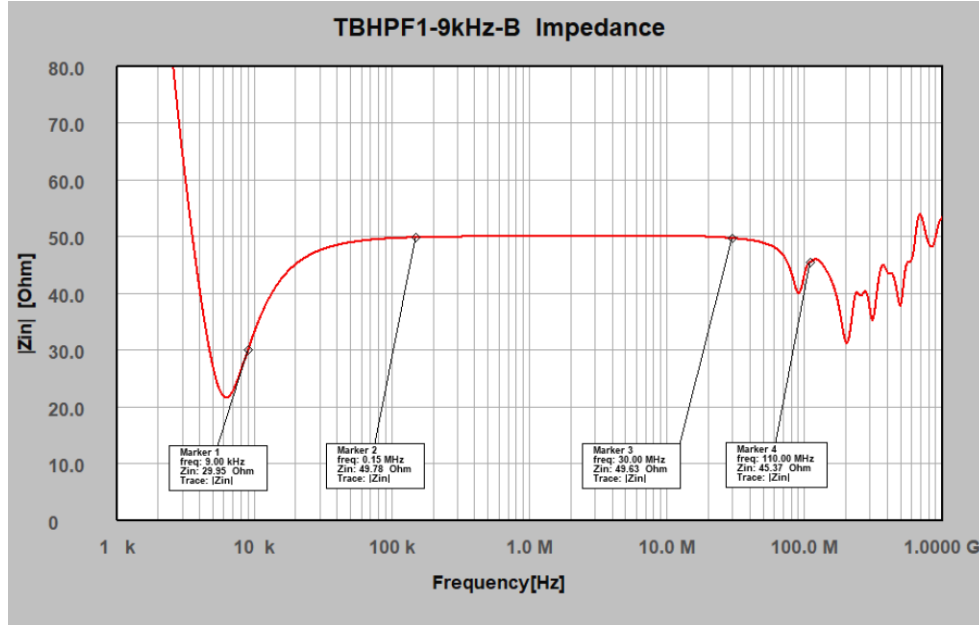
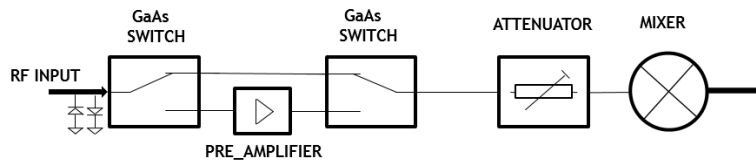


Figure 16 - TBHPF1-9kHz-B, impedance, 1 kHz to 1 GHz, typical data

## 6.4 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.

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

### HMC221B

### ABSOLUTE MAXIMUM RATINGS

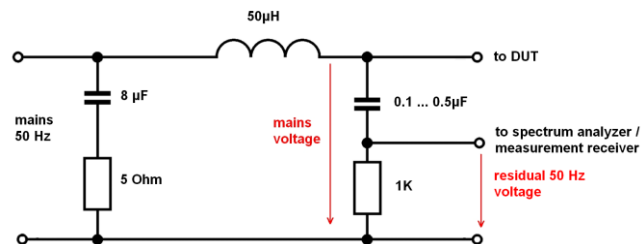
Table 2.

Parameter	Rating
Control Voltage Range (A and B)	–0.2 V dc to 12 V dc
RF Input Power Level (CW Peak, $V_{CTL} = 0\text{ V}/5\text{ V}$ )	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, $V_{CTL} = 0\text{ V}/5\text{ V}$ )	
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.

### 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 EUT 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 0.1 $\mu$ F 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 0.5 $\mu$ F 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.

## TBL5016-3 50μH AC-LISN

### 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.

### Saturation:

Note that the 9kHz HPF is built using inductors with ferrite cores, which are subject to saturation at excessive noise levels in the stop band below 9 kHz. In case of doubts, use an external attenuator in front of the HPF to prevent non-linear distortion.

## 7 Ordering Information

Part Number	Description
TBL5016-3 -EU	50μH LISN with Schuko socket (CE7/3, <b>16A</b> ), 100 cm coaxial cable BNC-male / N-male/RG223, 3 pieces BNC 50 Ohm termination, TBHPF1-9kHz-B high pass filter
TBL5016-3 -US	50μH LISN with US socket (NEMA 5-15, grounded, type B, <b>15A</b> ), 100 cm coaxial cable BNC-male / N-male/RG223, 3 pieces BNC 50 Ohm termination, TBHPF1-9kHz-B high pass filter
TBL5016-3 -AU	50μH LISN with Australian socket (AS/NZS 3112:201, <b>15A</b> ), 100 cm coaxial cable BNC-male / N-male/RG223, 3 pieces BNC 50 Ohm termination, TBHPF1-9kHz-B high pass filter
TBL5016-3 -UK	50μH LISN with English socket (BS1363, <b>13A</b> ), 100 cm coaxial cable BNC-male / N-male/RG223, 3 pieces BNC 50 Ohm termination, TBHPF1-9kHz-B 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

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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
TBLA-3P-16A	Coaxial adapter set

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.

## 8 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
V1.5	5.11.2024	Mayerhofer	Updated chapter 2, 3, 6, 7
V1.6	10.11.2025	Mayerhofer	Updated specifications after removal of the internal MOVs and introducing a new high pass filter revision

Table 4– History