

TBL5032-3 50 μ H AC-LISN

The TBL5032-3 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 32A. Conducted noise can be measured on each phase and on the neutral conductor. The TBL5032-3 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 TBL5032-3 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.



TBL5032-3, variant with Schuko connector (CEE 7/3) socket

Features

- Frequency range: 9 kHz to 30 MHz
- Impedance: 50 Ω || (50 μ H + 5 Ω)
- Artificial hand: 220 pF + 511 Ω
- Switchable PE: 50 Ω || 50 μ H
- 250 μ H 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: 32A @ 23°C each
- 3-phase DUT socket: CEE / IEC60309, 3L+N+PE, 32A, female
- Single phase DUT socket: country specific
- Power connector: CEE / IEC60309, 3L+N+PE, 32A, 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

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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 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 TBL5032-3.

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.

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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 $50\ \Omega \parallel 50\ \mu\text{H} + 5\ \Omega$ 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:

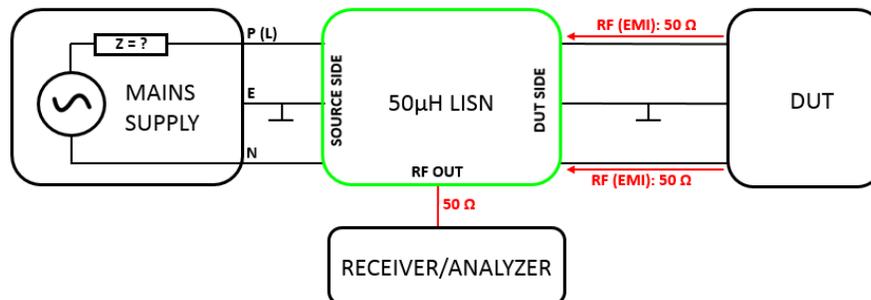


Figure 1 – Basic AC LISN set up: impedance levels

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.

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1.3 RF output

The TBL5032-3 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 TBL5032-3 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 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 TBL5032-3 AC LISN. It consists of four identical LISN paths.

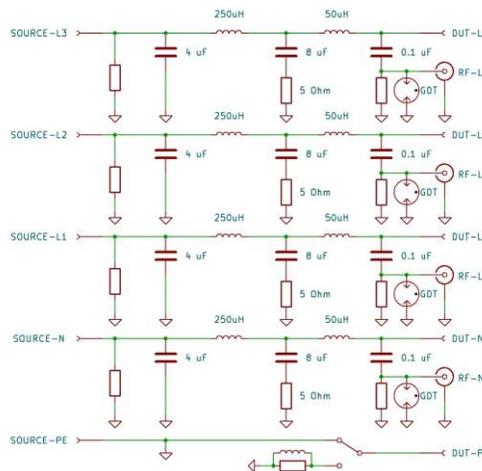


Figure 2 – 3-phase LISN, simplified schematic

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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2 TBL5032-3 specifications

2.1 Conformity

The TBL5032-3 is compliant with CISPR 16-1-2.

In line with the CISPR 16-1-2 standard compliant design and setup specification, the TBL5032-3 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 TBL5032-3. The TBL5032-3 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 μ H pre-filter
- Air core inductors
- Line voltage: max. 540V/260V, 50 – 60 Hz
- Max. current: 32A @ 23°C for each phase and neutral
- 3-phase DUT socket: CEE / IEC60309, 3L+N+PE, 32A, female
- Single phase DUT socket: country specific, note country specific DUT socket limits (see chapter 4)
- Power connector: CEE / IEC60309, 3L+N+PE, 32A, 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: 22 kg, length: 520mm, width: 470 mm, height: 180 mm

2.4 Supply voltage

The TBL5032-3 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.

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2.5 Front Panel

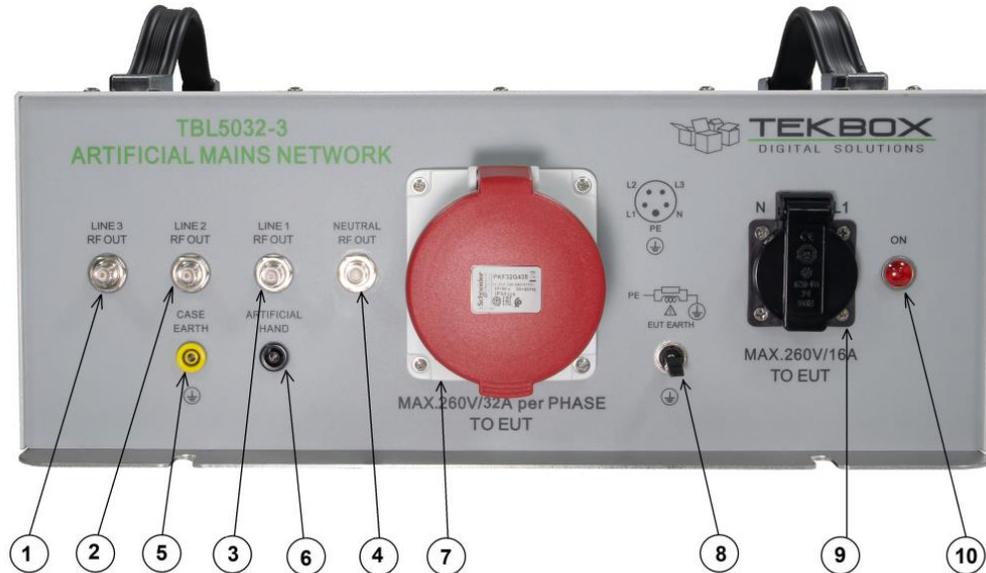


Figure 4 – Front panel layout

- 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, 32A, female
- 8) Protective Earth switch to connect DUT earth either directly to case earth, or via 50 μ H || 50 Ohm country specific
- 9) Single phase DUT socket,
- 10) Power On indicator

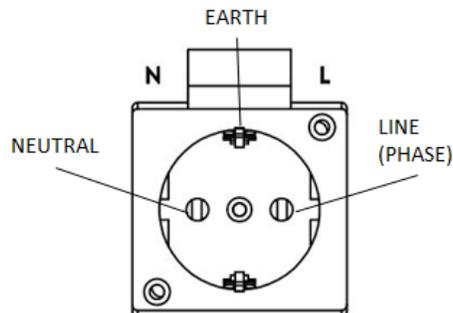


Figure 5 – DUT socket, pin assignment with reference to the rear power connector
For the pin-assignment of the three phase socket, refer to the graphics on the front panel

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2.6 Rear Panel

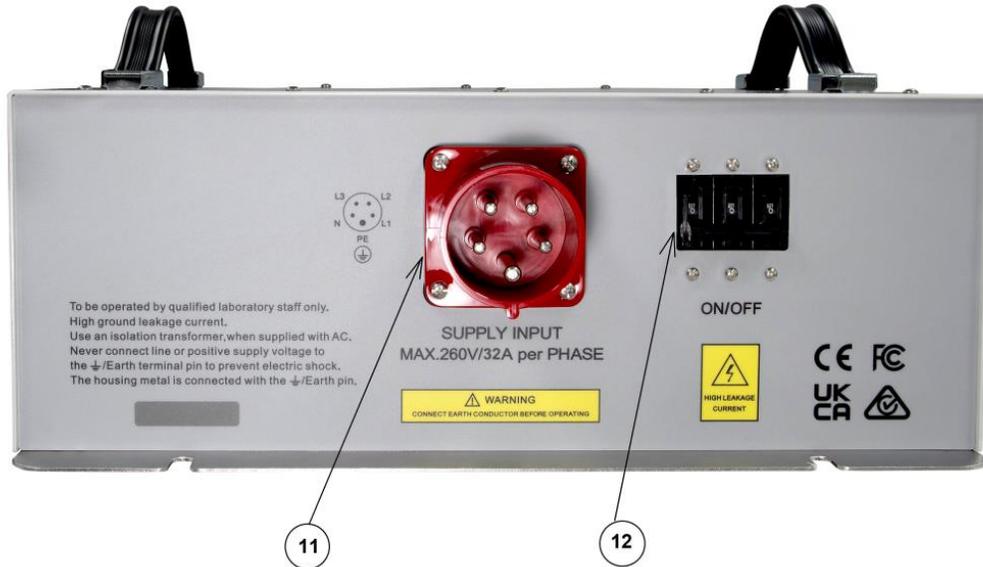


Figure 6 – Rear panel layout

- 11) Three phase power (source) socket, IEC60309, 3L+N+PE, 32A, male
- 12) Power switch

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

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2.7 Impedance

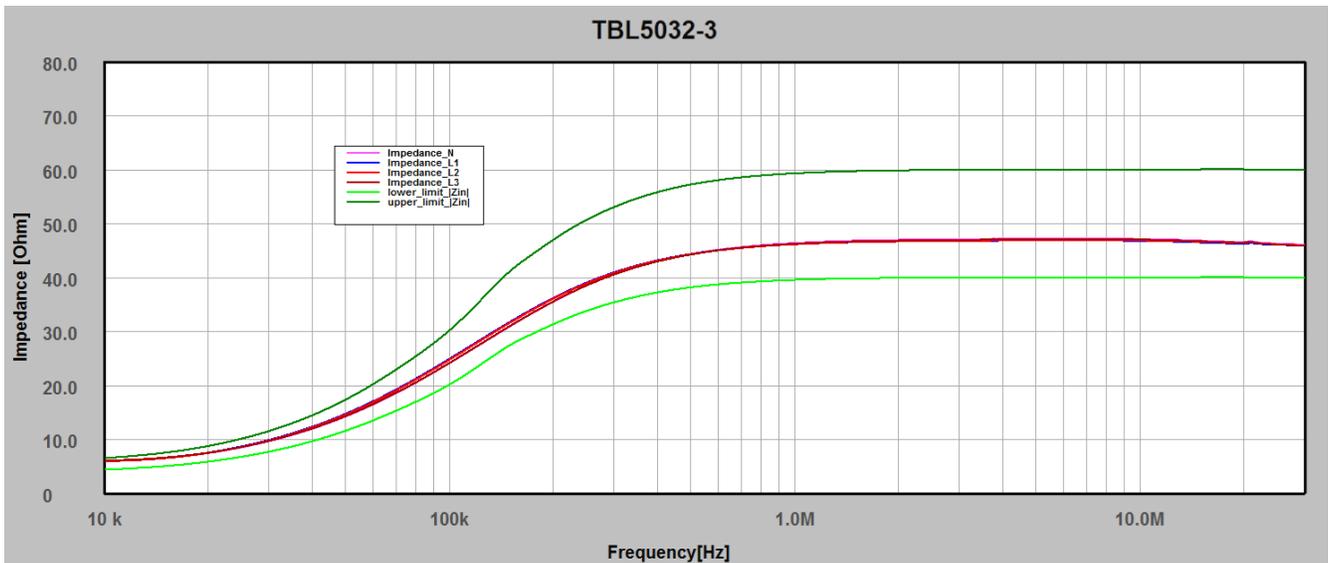


Figure 7 – Impedance vs. frequency at DUT terminals, limit lines according CISPR 16-1-2*

*) 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

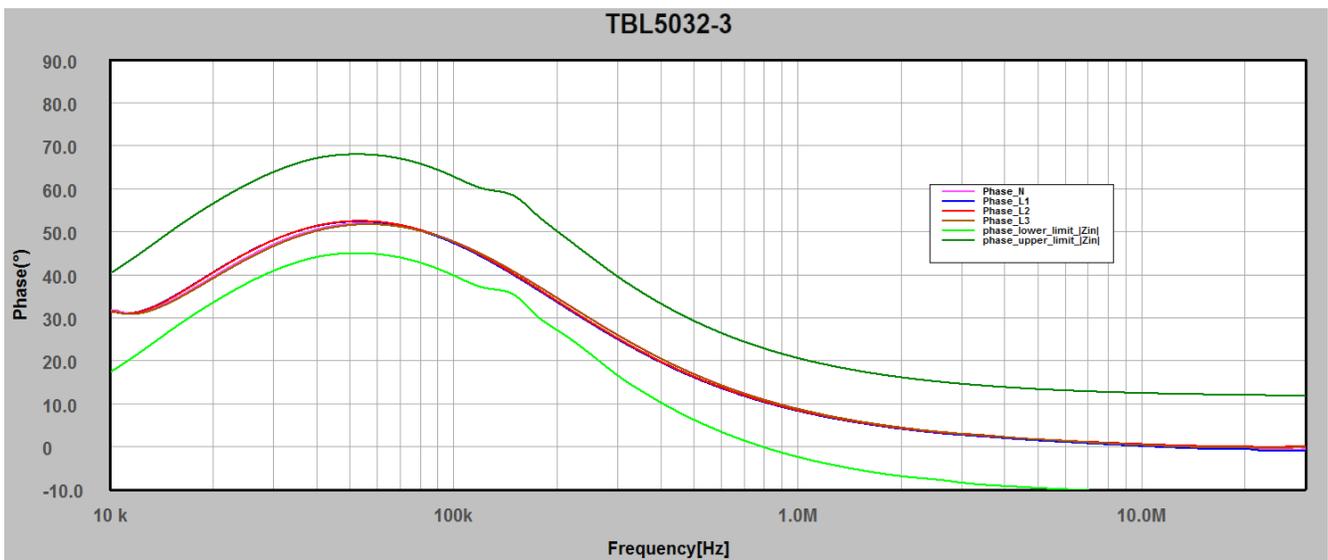


Figure 8 – Phase angle vs. frequency at DUT terminals, limit lines according CISPR 16-1-2*

*) 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

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2.9 Frequency response, S21 from DUT port to RF port

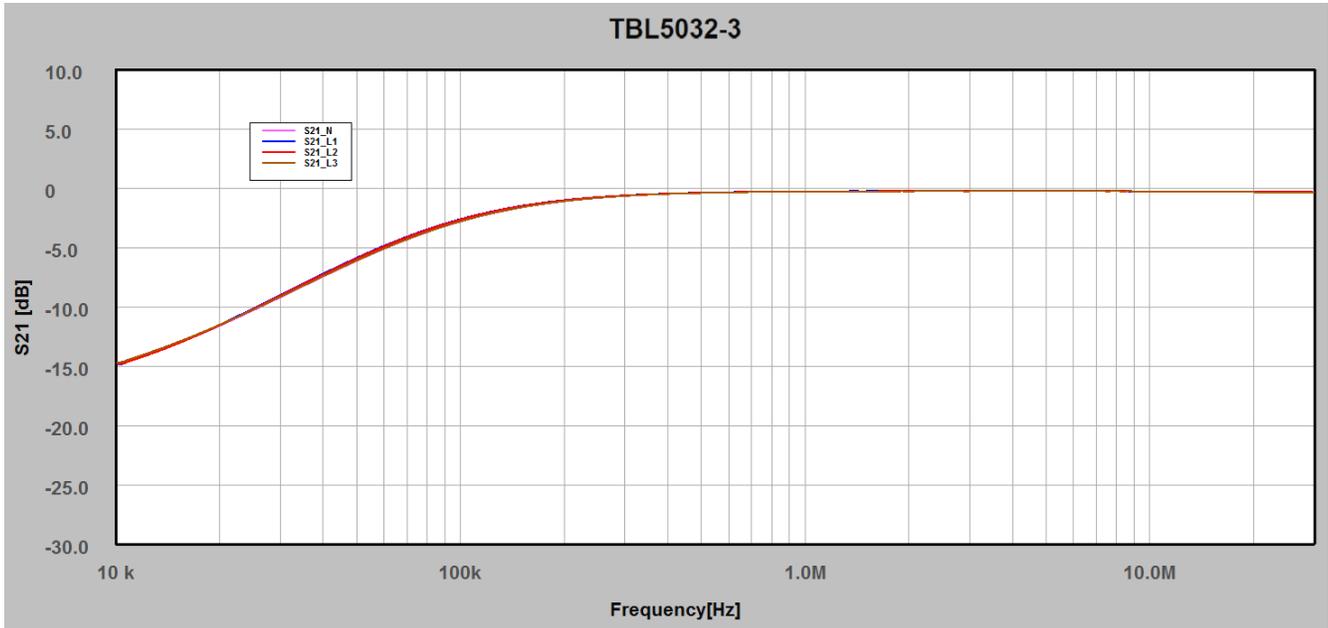


Figure 9 – Frequency response, S21, DUT terminals to BNC connector

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

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

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

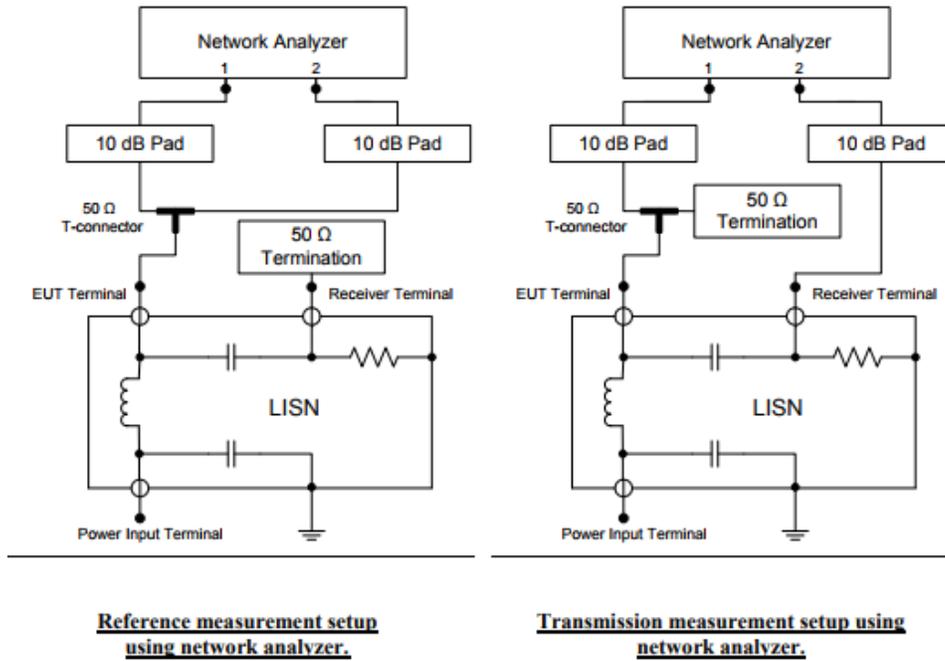


Figure 70 – Calibration set up according to CISPR 16-1-2 Annex A.8.

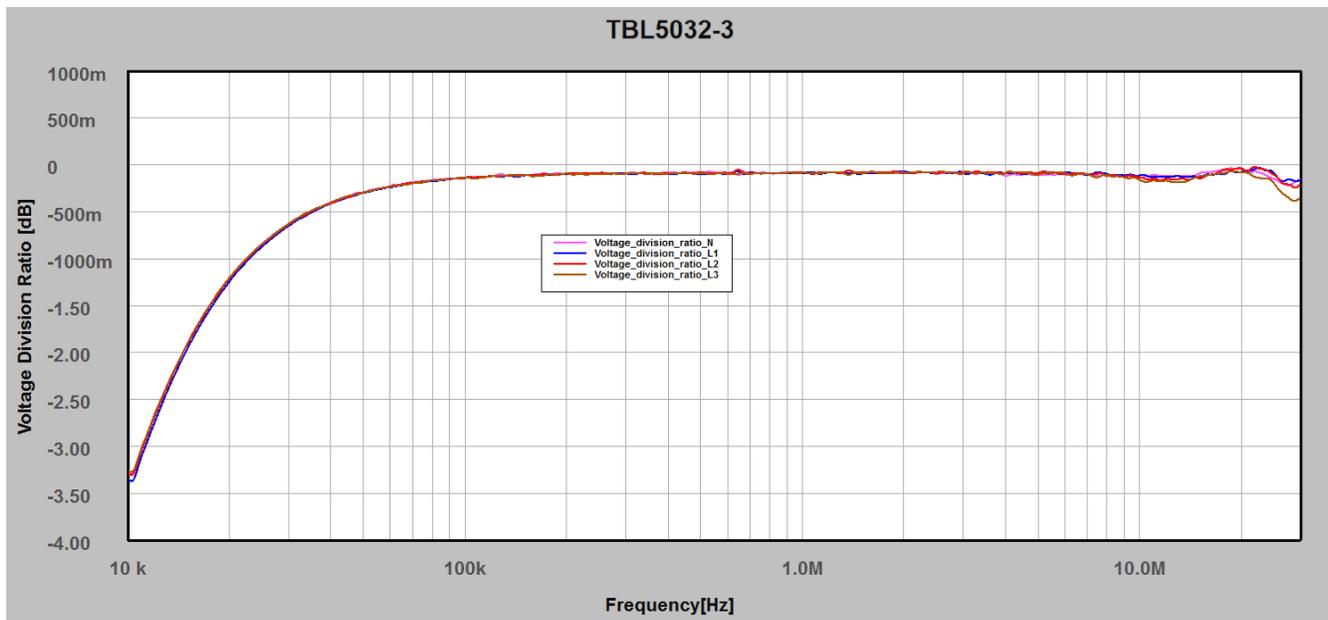


Figure 81 – Voltage Division Ratio versus frequency

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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, TBL5032-3 LISN voltage division ratio, typical calibration data*

*) measured from DUT terminals on the PCB to BNC

2.11 Isolation

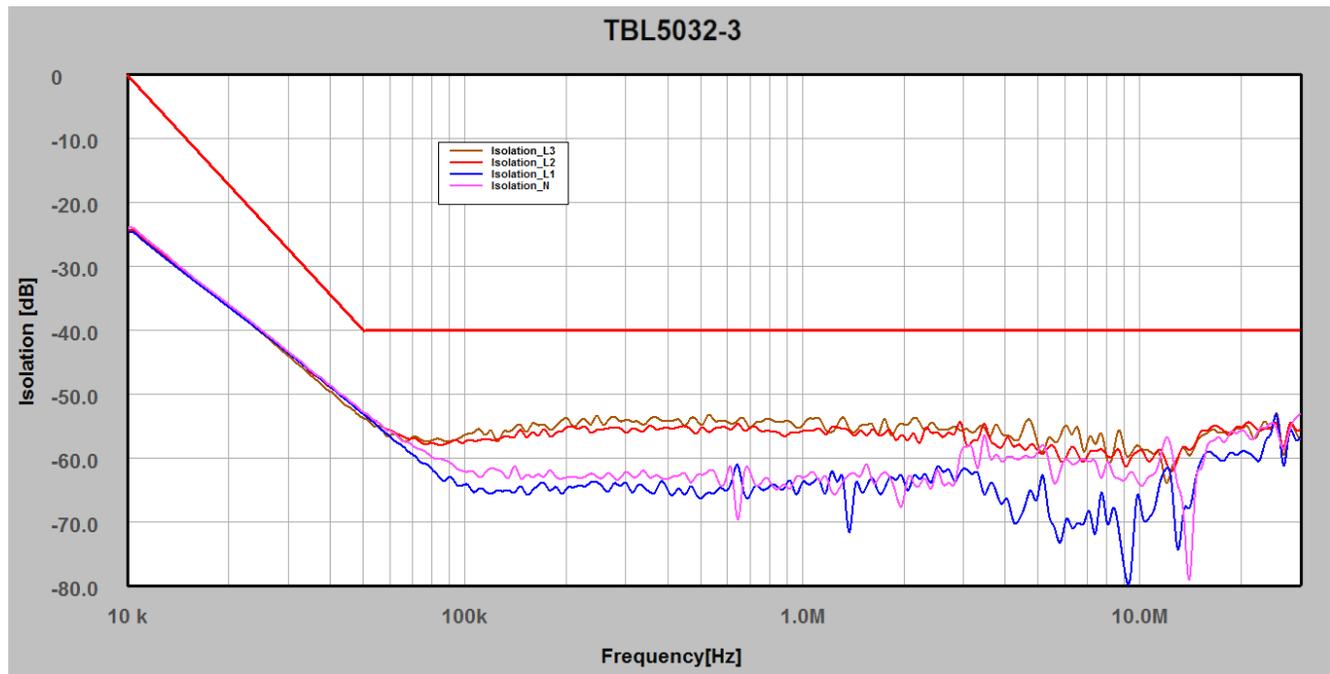


Figure 92: LISN Isolation, Source to RF out, limit line according CISPR 16-1-2

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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.

At currents above 25A on each line simultaneously, limit measurement time to 20 minutes and allow the unit to cool down before carrying out further measurements.



Figure 103: Coil and housing temperature at 32 A DUT current @ 22 °C ambient temperature

2.13 Spectrum analyzer / emi receiver RF input protection

The TBL5032-3 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.

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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.

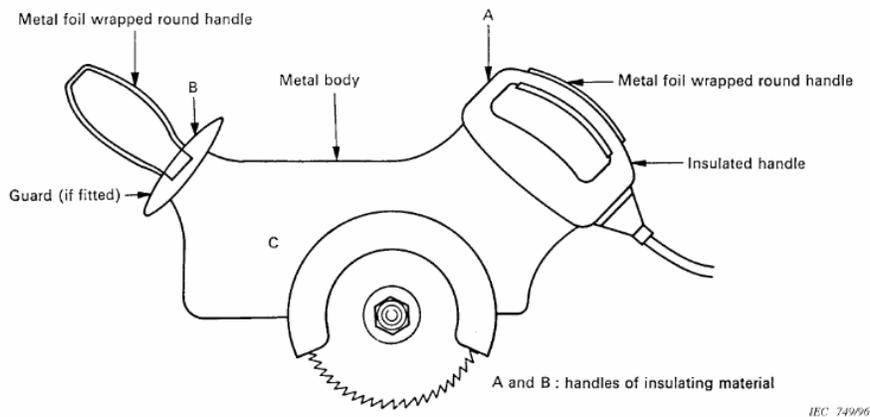


Figure 114 – Example from CISPR 16, portable electric saw with artificial hand

3 Operation checklist

- Setup the isolation transformer, TBL5032-3, 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 TBL5032-3 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 TBL5032-3
- Power on the DUT

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- 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

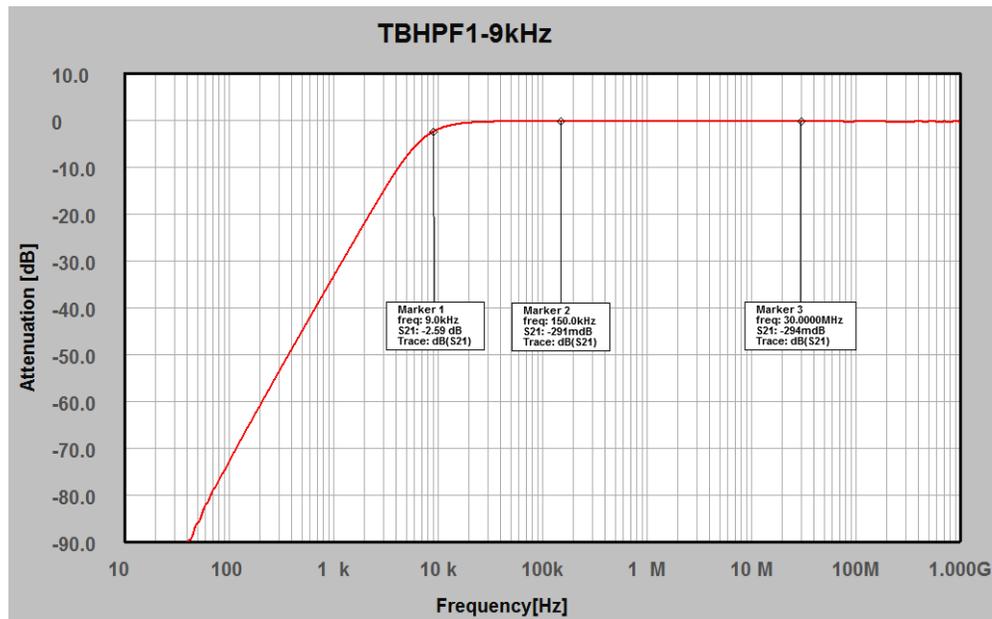
Dimensions: 26 x 26 x 82 mm

Weight: ca. 100g



4.2 Frequency response

Typical data, 50 Ohm system



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

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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 M Ω load impedance:

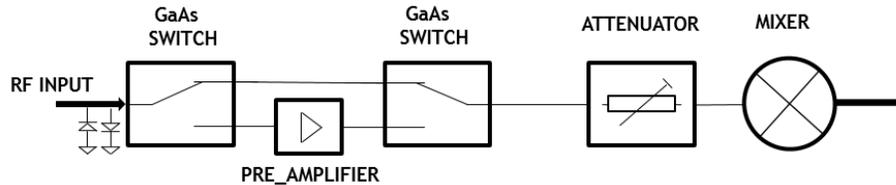
Frequency [Hz]	Vout/Vin [dB]	Frequency [Hz]	Vout/Vin [dB]
30	>60	7000	1.92
40	>60	8000	0.43
50	>60	9000	0.085
100	>60	10000	0.25
250	>60	20000	0.47
500	58.6	25000	0.56
750	53.9	50000	0.42
1000	48.4	100000	0.17
2500	20.1	250000	0.083
5000	9.93	500000	0.042
6000	6.11	1000000	0.034

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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.

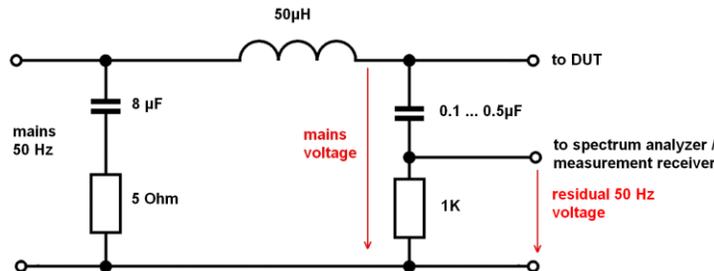
Parameter	Rating
Control Voltage Range (A and B)	-0.2 V dc to 12 V dc
RF Input Power Level (CW Peak, $V_{CTL} = 0\text{ V}/5\text{ V}$)	0.36 W
10 kHz to 10 MHz	8 dBm
10 MHz to 20 MHz	10 dBm
20 MHz to 30 MHz	11 dBm
30 MHz to 250 MHz	14 dBm
250 MHz to 3.0 GHz	31 dBm
Hot Switching RF Input Power Level (CW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

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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 0.1 μ 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 μ 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.

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.

TBL5032-3 50μH AC-LISN

5 Ordering Information

Part Number	Description
TBL5032-3 -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
TBL5032-3 -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
TBL5032-3 -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
TBL5032-3 -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
TBL5032-3 -xx	Any other socket requirements upon customer request will have 2-3 weeks lead time
TBPC- IEC60309-32-3m TBPC- IEC60309-32-5m TBPC- IEC60309-32-10m	3-phase mains power cable, 32A, 3m, 5m or 10m length, CEE / IEC60309, 3L+N+PE, 32A, male, CEE / IEC60309, 3L+N+PE, 32A, 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-32	CEE / IEC60309, 3L+N+PE, 32A, male cable connector
TBCON-CEE-F-32	CEE / IEC60309, 3L+N+PE, 32A, female cable connector

Table 3– Ordering Information

Note the maximum current limitations of country specific single phase DUT sockets. The single phase DUT sockets, depending on the country specific variant have a maximum current rating of 16A or less. Refer to the specifications of the country specific socket variants in table 3.

6 History

Version	Date	Author	Changes
V1.0	29.11.2022	Mayerhofer	Creation of the document
V1.1	6.12.2022	Mayerhofer	Chapter 2, correction

Table 4– History