

## 150 kHz HIGH PASS FILTER

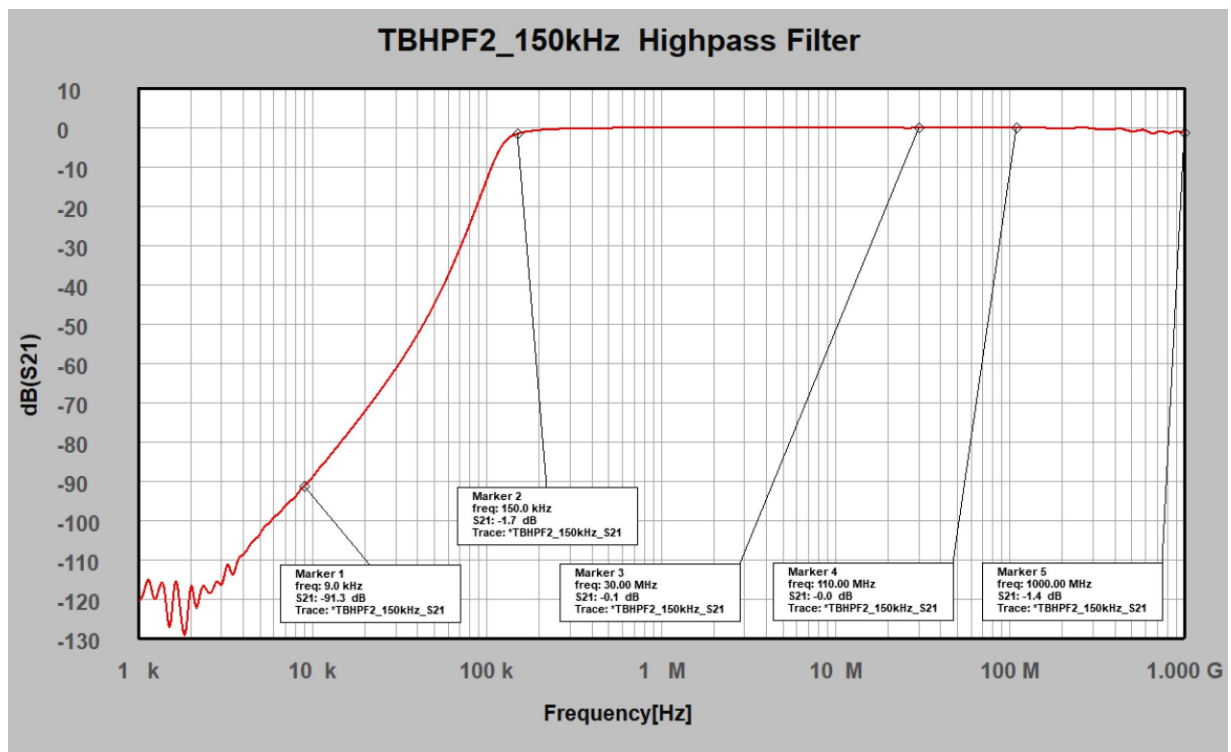
### 1 Technical Data

High Pass Filter, symmetric, reflective, 50 Ohm  
3dB bandwidth: 135 kHz – 1 GHz  
S11, 150 kHz – 110 MHz: < -17 dB  
Topology: 5<sup>th</sup> order Chebyshev  
Filter capacitor voltage rating: 250V  
Filter inductor saturation current: 1.5 A  
Maximum input power at frequencies 300 kHz – 1 GHz: 10W  
Connectors: N-Male / N-Female  
Dimensions: 26 x 26 x 97 mm  
Weight: ca. 110g



### 2 Frequency response

Typical data, 50 Ohm system



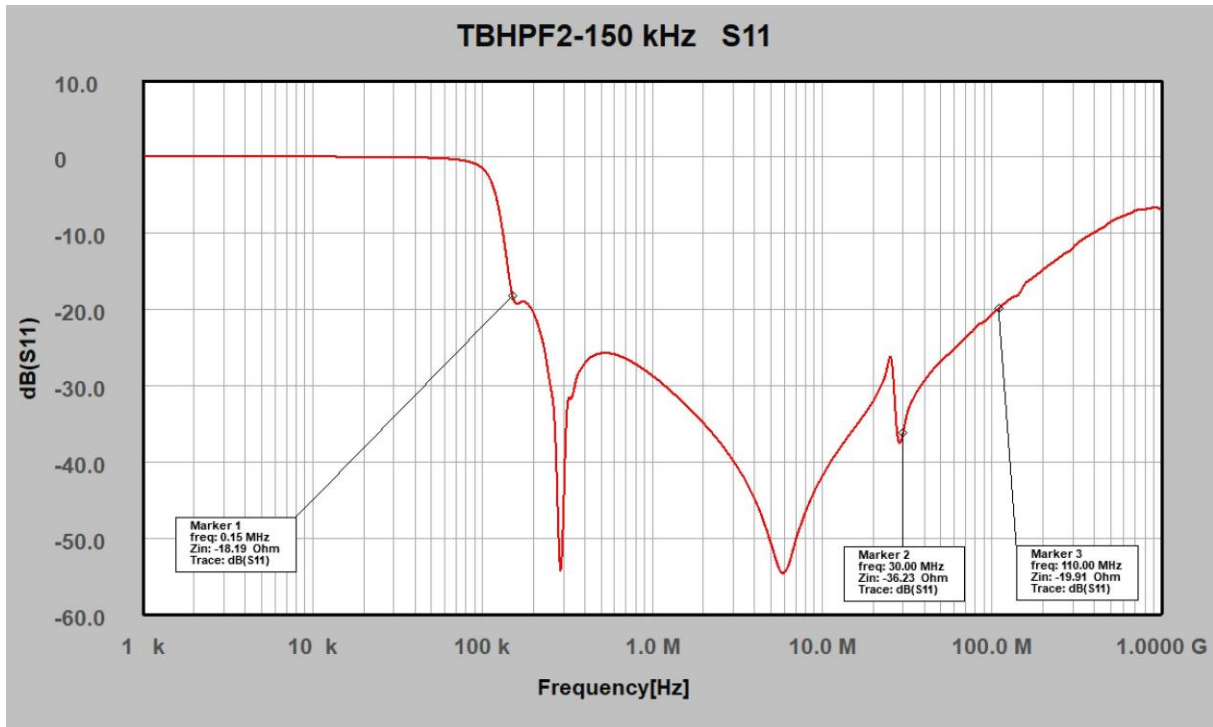
TBHPF2-150kHz: Insertion loss, 1 kHz to 1 GHz, typical data

# 150 kHz HIGH PASS FILTER

| Frequency [kHz] | Attenuation [dB] | Frequency [MHz] | Attenuation [dB] |
|-----------------|------------------|-----------------|------------------|
| < 1             | < -100           | 0.25            | -0,54            |
| 9               | -91,29           | 0.5             | -0,27            |
| 10              | -89,17           | 0.75            | -0,18            |
| 20              | -72,34           | 1               | -0,13            |
| 30              | -61,53           | 5               | -0,03            |
| 40              | -52,83           | 10              | -0,03            |
| 50              | -45,03           | 50              | -0,06            |
| 60              | -37,75           | 100             | -0,02            |
| 70              | -30,92           | 200             | -0,38            |
| 80              | -24,59           | 300             | -0,42            |
| 90              | -18,70           | 400             | -0,52            |
| 100             | -13,32           | 500             | -1,12            |
| 110             | -8,70            | 600             | -0,88            |
| 120             | -5,30            | 700             | -1,30            |
| 130             | -3,28            | 800             | -1,56            |
| 140             | -2,25            | 900             | -1,19            |
| 150             | -1,73            | 1000            | -1,38            |

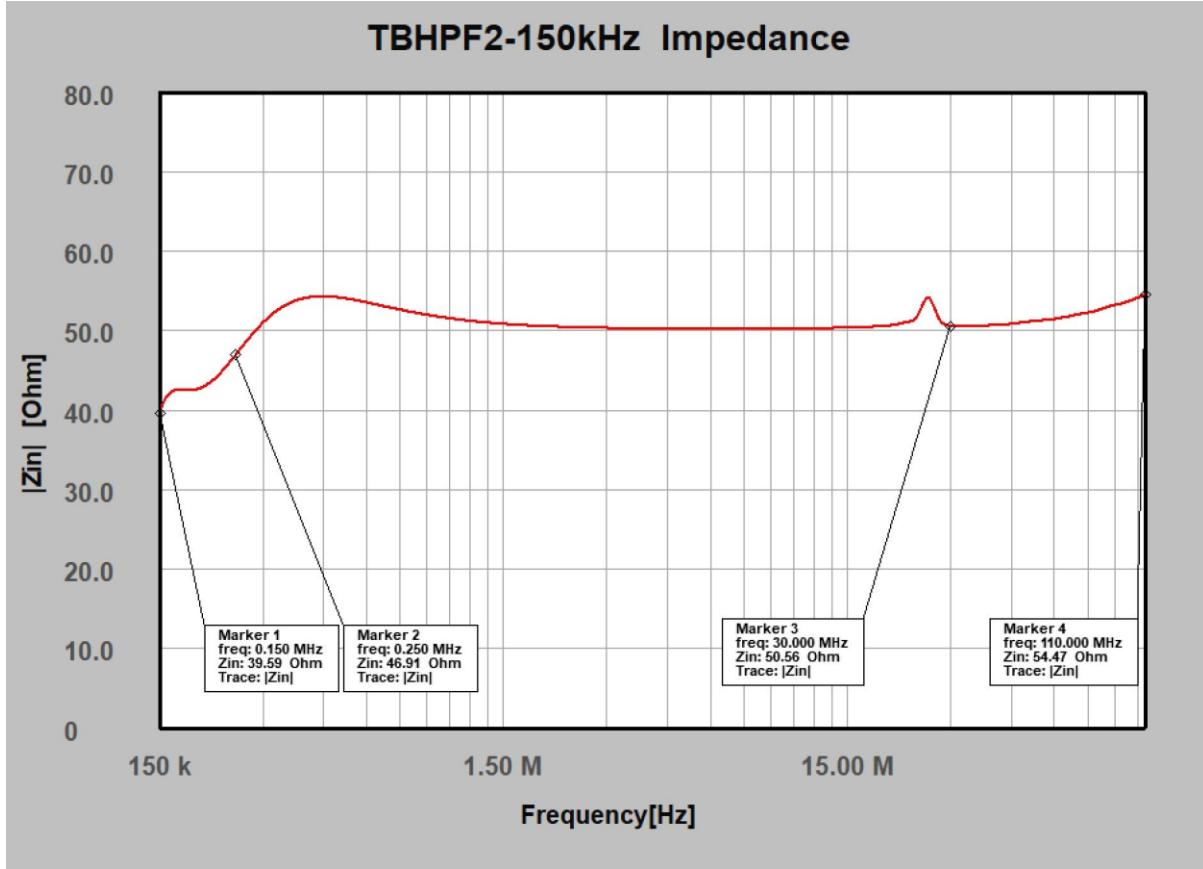
TBHPF2-150kHz: Insertion loss, 9 kHz to 1 GHz, typical data

### 3 S11, Impedance



TBHPF2-150kHz: S11 (=S22), 1 kHz to 1 GHz, typical data

## 150 kHz HIGH PASS FILTER



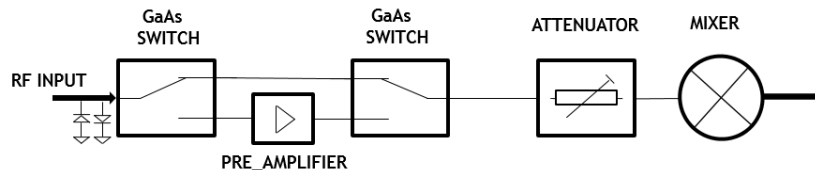
TBHPF2-150kHz: Impedance, 1 kHz to 1 GHz, typical data

### 4 Applications

- General purpose filter
- Spectrum analyzer / measurement receiver RF input protection

#### Analyzer RF frontend limitations:

Whenever working with spectrum analyzers, be aware that excessive input power, voltage transients or ESD can destroy 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:



## 150 kHz HIGH PASS FILTER

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 of an “honest” data sheet of a typical GaAs switch:

### HMC221B

#### ABSOLUTE MAXIMUM RATINGS

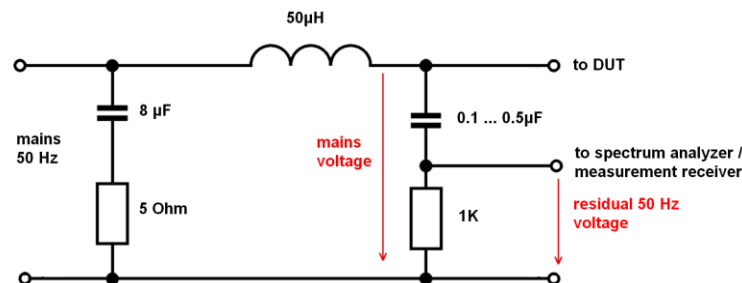
Table 2.

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

## 150 kHz HIGH PASS FILTER

Some LISN may need to use a higher value, in order to meet the impedance specifications at lower frequencies. Assuming a  $0.5\mu\text{F}$  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, they often go 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 analyzer into saturation may be a very high amplitude and low frequency sub-harmonic.

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 EUT 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 EUT 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 150kHz HPF is built using inductors with ferrite cores, which may be subject to saturation in case of excessive noise levels in the stop band below 150 kHz. This may happen with high power phase control devices, for example. In case of doubts, use an external attenuator in front

## 150 kHz HIGH PASS FILTER

of the HPF to prevent non-linear distortion.

### Guidelines when performing conducted emission measurements with a LISN:

- 1) Leave the RF output of the LISN unconnected
- 2) Connect the EUT to the LISN
- 3) Connect the LISN to the isolation transformer
- 4) Power on the EUT
- 5) Check the RF output of the LISN using a scope and / or the analyzer with an external 20 dB attenuator and 9kHz (150kHz) low pass filter or combined attenuator/filter/limiter
- 6) Connect the RF cable from LISN output to the spectrum analyzer input
- 7) Carry out the conducted noise scan
- 8) Disconnect the RF cable
- 9) Power off the EUT

**NOTE:** The purpose of having the analyzer disconnected during power cycling (ON/OFF) the EUT is to avoid voltage transients due to back EMF, especially of highly inductive loads such as motors or switched-mode power supplies. These signals can easily be large and fast enough to cause permanent damage to the sensitive RF front end of the analyzer.

In cases where the EUT produces sub harmonics, place a 9 kHz or 150 kHz high pass filter at the RF input of the spectrum analyzer. Alternatively, the Tekbox TBFL1 transient limiter not only contains a combined attenuator/limiter, but also a 9 kHz high pass filter.

## 5 Ordering Information

| Part Number   | Description                        |
|---------------|------------------------------------|
| TBHPF2-150kHz | High Pass Filter, N-female, N-male |

## 6 History

| Version | Date       | Author     | Changes                  |
|---------|------------|------------|--------------------------|
| V1.0    | 30.12.2024 | Mayerhofer | Creation of the document |
|         |            |            |                          |

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